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Waste Management in the Circular Economy. The Case of Romania.

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Abstract. Applying the principles of sustainable development in Romania involves a new approach to ecological waste using basic concepts of circular economy to weigh accurately the proposed projects in this area taking into account existing environmental resources and zero waste objectives. The paper is focused on: quantitative and qualitative measures of waste prevention in Romania, the changing status of the waste by selling it as product, the mechanisms for paying for treatment and / or disposal which discourage waste generation and the use of financial resources obtained from secondary raw materials for the efficiency of waste management.

1. Introduction

According to Executive Director of the European Environment Agency, Hans Bruyninck"circular economy concept has advanced in European policy decision as a positive perspectives, based on solutions for achieving economic development while respecting environmental limits". Romanian European Environment Agency is ready to support the transition towards a circular economy through analyses and evaluations.

Unlike traditional perspective of linear economy, circular economy is trying to respect environmental limits by increasing distribution of renewable or recycled resources and reducing the consumption of raw materials and energy. Thus, both the emissions and resources wasting will be reduced. Also, concepts such as eco design, distribution, reuse, repair, recycling of products and materials will play an important role in maintaining the use and value of products, components and materials. It is essential to move to a circular economy in order to meet the resource efficiency agenda established under the Europe 2020 strategy for smart, sustainable and inclusive growth [1]. It can get higher performance and sustainable efficient use of resources, which can bring major economic benefits. In the industrial sector, is already recognizes that improving resource productivity is a strong business case. It is estimated that improving resource efficiency along the value chain could reduce material needs with 17% -24% by 2030 [2] and a better use of resources should be a general potential saving of 630 billion per year for European industry [3] .

2. Waste generation

Waste generation is highly dependent on local consumer habits, the type of buildings, general living conditions and the type of industry and commerce. For example, in areas with individual fireplaces with wood, coal or coke, waste is considerably more and denser in winter compared to buildings with central heating. In rural areas, the amount of waste collected per capita is lower than in urban areas due to in-situ composting. In some societies waste are very wet in the autumn time and has a high content of organic matter due to conservation of vegetables. This can be problematic for waste incineration installations which may need additional fuel. Homes, with a relatively low income, produce less waste but more organic than homes with a relatively high income. The single measurement of waste generation there is made by weighing platforms from the landfill, recycling stations and treatment facilities with quality recording of waste type and transport origin. Based on these statistics, there are recorded quarterly/ or seasonal waste variations and can do prognosis.

2.1. Waste classification

In terms of nature and places of production, waste is classified as follows:
1. Household waste - waste from the household sector or other similar sectors (including hazardous waste they contain) and can be taken by our current pre-collection systems or villages collection systems;
2. Street waste - specific waste of public traffic routes, from the daily activity of the population, city green spaces, animals, deposition of solids in the atmosphere;
3. Similar waste with municipal waste - waste from small or large industry, commerce, public and administration sectors, which presents similar composition and properties to household waste and can be collected, transported, processed and stored with them;
4. Bulky waste - solid waste from different sources, which due to its size, cannot be taken with the usual pre-collection or collection systems, but requires a differentiated treatment.
5. Construction waste - waste from demolition of industrial and civil constructions;
6. Hazardous waste - toxic, flammable, explosive, infectious waste or otherwise, which after was introduced into the environment, can harm plants, animals or humans;
7. Agricultural waste - waste from agricultural and livestock units (manure, animal waste from slaughterhouses and meat industry);
8. Industrial waste - waste from technological processes;
9. Hospital waste - waste from the hospitals activities and health units which are incinerated in crematoria;
Depending on specific local conditions, could be other types of waste that requires special attention, for example, marine ballast (polluted with oil / chemicals) and mining waste.

2.2. The main objectives of solid waste management

The main objectives of solid waste management are: protect public health; protect the environment; maintaining cleanliness in public for these places to be aesthetically acceptable; conservation of natural resources through waste reduction policies and recycling. All these objectives are achieved through a good collection and waste safe treatment, a proper waste storage and disposal. By my opinion integrated waste management is vital for the community, for the following reasons:
1. The deposits capacity decreases continuously -Location and construction of new deposits is a difficult and expensive process.
*2.*Many waste materials are rare natural sources, imposing their recovery, decreasing the environmental impact and increasing humans' life quality.
*3.*The materials found in waste volume may be an opportunity to start a business.
*4.*A system that does not rely on one alternative is more flexible to economical, technological and legislative changes.
*5.*The investors or creditors favour capital projects that are part of a carefully eco -designed strategy.
Local authorities are in an advantageous position in assessing the proposals for a new facility, when they have the chance to thoroughly examine the entire system. Pollutant emissions from industry are very rich and very diverse. In very vast area, some principles are advanced only to reduce emissions of pollutants that need to be adapted for each industrial branch separately.

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3. Industrial Product Life Cycle Stages

Life cycle approach means considering the environmental impacts and resources used throughout the lifecycle of products (goods or services).

Approaching life cycle helps us to identify sensitive points and aspects of a product which can be improved as lower environmental impact, a reduced use of resources along the life cycle stages or compromises between different options on products. Sensitive issues can arise at any stage of the life cycle, from raw material extraction and conversion, and manufacturing and distribution, to customer use and / or consumption.

It ends with reuse, recycling, energy recovery and final disposal. The key objective of lifecycle based approach is to contribute to decisions or express any managerial transfer of responsibility. This means minimizing impacts on the environment in a life cycle stage or in a geographic region or a certain category of impacts, while helping to avoid environmental impacts increase elsewhere. For example, saving energy during the use phase of a product without simultaneously increase the amount of material required for its delivery and impacts associated with this supply.

At each stage of the life cycle there are raw materials consumed and chemicals are released as emissions. They contribute to different environmental impacts and issues like resource scarcity.

4. Measures to reduce waste, in order to achieve a circular economy in Romania

Circular economy approaches, exclude concept of waste and usually involve innovation along the value chain, rather than rely on solely solutions for the life cycle end of a product. For example, these approaches may include:

1. Reducing the amount of material required to provide a given service;
2. Extending the useful product life cycle (durability);
3. Reducing the use of energy and materials within production of use phases (efficiency);
4. Reducing the use of hazardous materials or difficult to recycle into new products and production processes (substitution);
5. The creation of markets for secondary raw materials, based on standards and public acquisitions (recycling);
6. Designing products that are easily maintained, repaired, refurbished, remanufactured or recycled (eco-design);
7. Development of services that consumers need to reduce waste (service maintenance / repair, etc.);
*8.*Stimulating and supporting the activities of waste reduction and quality separation, made by consumers;
9. Stimulating the separation and collection systems that minimize the costs of recycling and reuse;
*10.*Facilitating group activities to prevent the transformation in waste of industrial products (industrial symbiosis) and encouraging the expansion and consumers choice improvement. In this case the customer could use leasing and exchange of services as an alternative to holding of products. We need to protect consumers' interests (in terms of cost, protection, information, contract terms, issues related to insurance, etc.).

In order to show the relationship between industrial product lifecycle and industrial emissions, I have realized a matrix named "*Eco-friendly methods for reduction of industrial pollutant emissions– Industrial Product Life Cycle Stages Matrix"*table 1.

According with Luminiţa I. POPA and VasileN.POPA [4],the Industrial Product Life Cycle Stages are the follows: market needs; research and development; idea generation; opportunity identification and concept definition; research design and development; prototype &production; distribution and manufacturing; marketing; sales; maintenance &service; products feed-back; removal& disposal. As we can see in the matrix" research and development" and "research design and development "lifecycle stages have the highest score: 7.

Another two lifecycle stages ("prototype &production" and "distribution and manufacturing"), have a high score: 6. In this case, the industrial company managers have to take in consideration that these three metrics are very important, because they could affect the entire industrial product life cycle. Also another three metrics,"Eco-friendly production output" (score 10),'Eco-friendly operational life cycle" (score 10) and"Implementing TQM method" (score 8) are the most important ways to reduce the cost of green acquisitions.

Table 1. Eco-friendly methods for reduction of industrial pollutant emissions– Industrial Product Life Cycle Stages Matrix (Realized by the author) Source: [4].

No.	Industrial Product Life Cycle Stages	Eco-friendly methods for reduction of industrial pollutant emissions								
		Raw materials replacement	Industrial processes liquids recycling	Eco-friendly techno-logical process	Use closed techno-logical processes	Reduction of time required for techno-logical processes	Eco-friendly production output	Eco-friendly operational life cycle	**Total scores**	**Weighted score (%)**
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	Market needs	X	-	-	-	-	X	X	3	**6.66**
2	Research and development	X	X	X	X	X	X	X	7	**15.55**
3	Idea generation	-	-	X	X	X	X	X	5	**11.11**
4	Opportunity identification and concept definition	-	-	-	-	X	X	X	3	**6.66**
5	Research design and development	X	X	X	X	X	X	X	7	**15.55**
6	Prototype, production	X	X	X	X	X	X	-	6	**13.33**
7	Distribution and manufacturing	X	X	X	X	X	X	-	6	**13.33**
8	Marketing	-	-	-	-	-	X	X	2	**4.44**
9	Sales	-	-	-	-	-	X	X	2	**4.44**
10	Maintenance /service	-	-	-	-	-	X	X	2	**4.44**
11	Products feed-back	-	-	-	-	-	-	X	1	**2.22**
12	Removal& disposal and recycling	-	-	-	-	-	-	X	1	**2.22**
Total scores		5	4	5	5	6	10	10	45	**100**
Weighted score (%)		**11.11**	**8.88**	**11.11**	**11.11**	**13.33**	**22.22**	**22.22**	**100**	**100**

5. European Union Resource efficient Scoreboard

The Resource Efficiency Scoreboard presents indicators covering themes and subthemes of the *Roadmap to a Resource Efficient Europe*. The scoreboard aims to monitor the implementation of the roadmap, to communicate the link between resources and economy and to engage stakeholders. Indicators are arranged in three groups – lead, dashboard and theme-specific indicators. For several indicators it is more meaningful to view the data at country level rather than at EU-28 level. The scoreboard by default presents the data for Belgium, the first country in the Member States list (sorted in protocol order). Data for the EU and other Member States were selected from the country list.

6. EU indicators: "Turning waste into a resource"

6.1. Waste excluding major mineral wastes

The indicator shows trends in waste generation, both EU-wide and for individual EU countries. It covers both non-hazardous and hazardous waste from: all sectors of the economy (production); households (consumption). It does not cover mineral wastes or soil. Over 90% of these come from the mining and construction sectors, which are subject to considerable fluctuation over time. Waste generation from which major mineral wastes are excluded *reflects general trends more accurately* than statistics on total waste generated. The indicator shows the amount of waste generated annually in the EU as a whole and in individual countries, expressed in kilos per inhabitant. It is based on data collected in the way stimulated by the Waste Statistics Regulation and is available for every second year as of reference year 2004 [5] (source: *http://ec.europa.eu/eurostat/web/waste/generation-of-waste-excluding-major-mineral-wastes*).

6.2. Landfill rate of waste excluding major mineral wastes

The indicator is defined as the volume of waste landfilled (directly or indirectly) in a country per year divided by the volume of the waste treated in the same year. Waste taken into account excludes major mineral wastes, dredging spoils and contaminated soils. This exclusion enhances comparability across countries, as mineral waste accounts for high quantities in some countries due to economic activities such as mining and construction. One exception, however, is that the indicator explicitly includes combustion wastes and solidified, stabilised and vitrified wastes, despite them being completely or partly mineral. The indicator is derived from the two-yearly reporting of the countries according to the Waste Statistics Regulation. It covers landfilling of hazardous (hz) and non-hazardous (nh) waste from all economic sectors and from households, including waste from waste treatment (secondary waste).[5](source: *http://ec.europa.eu/eurostat/cache/metadata/FR/t2020_rt110_esmsip.htm*).

6.3. Recycling rate of municipal waste

The recycling rate is the tonnage recycled from municipal waste divided by the total municipal waste arising. Recycling includes material recycling, composting and anaerobic digestion. Municipal waste consists to a large extent of waste generated by households, but may also include similar wastes generated by small businesses and public institutions and collected by the municipality; this latter part of municipal waste may vary from municipality to municipality and from country to country, depending on the local waste management system. For areas not covered by a municipal waste collection scheme the amount of waste generated is estimated.[5] (*http://ec.europa.eu/eurostat/cache/metadata/FR/t2020_rt120_esmsip.htm*).

6.4. Electrical and electronic equipment waste (WEEE)

WEEE poses on the one hand a risk to the environment (hazardous components), on the other hand it has a high potential for recycling to replace raw materials by secondary raw materials, such as precious metals and other highly valuable special materials. For the calculation of recycling rates it is crucial to know the volume of end-of-life electrical and electronic equipment. As this is for many devices and many countries difficult to deduct, the volume of put on the market during the previous 3 years (considered as easier to deduct) is considered as proxy for the volume of WEEE in the reference year (see statements in Article 7 of the WEEE-Directive 2012/19/EU). The collection rate is calculated as the collected volume of WEEE in the reference year, divided by the average sum of EEE put on the market in the three previous years. The 'recycling rate of e-waste' (this indicator) equals the 'total collection' in the present year divided by the average of the 'put on the market' of the three preceding years multiplied with the 'reuse and recycling rate' (of treatment facilities), considering that the total amount of collected e-waste is sent to treatment / recycling facilities.[5](*http://ec.europa.eu/eurostat/cache/metadata/FR/t2020_rt130_esmsip.htm*).

7. Comparison of "Turning waste into a resource" indicator. Romania vs. European Union.

Using the indicator"*Recycling rate of e-waste*" (table 2) for Romania and EU, it is made an average of three (2010-2012) as following: Romania: 13,125; European Union: 31,433; it is chosen this period of time because there is after 2007, the year in which Romania has become full member of European Union.This relevant indicator shows that Romania is 2,4 times less efficient in the field of „Recycling rate of e-waste" than EU countries. Using the indicator *"Recycling rate of municipal waste"* (table 2) for Romania and EU, it is made an average of three years (2010-2013) as following: Romania: 13,125; European Union: 56,425; it is chosen this period of time because there is after 2007, the year in which Romania has become full member of European Union.This relevant indicator shows that Romania is 4.3 times less efficient in the field of „Recycling rate of municipal waste" than EU countries [5].

Table 2 *"Turning waste into a resource" indicator. Romania vs. European Union Comparison [5]. Romania/ European Union*

LEAD INDICATOR

THEMATIC INDICATORS

Transforming the economy

Turning waste into a resource

Indicators	*Romania/ European Union*	Measure-ment units	Reference Period								Source
			2000	2005	2010	2011	2012	2013	2014	2015	
Generation of waste excluding major mineral wastes	Romania	Kg/ capita	(:)	(:)	2050	(:)	2041	(:)	(:)	(:)	Eurostat
	EU	Kg/ capita	*(:)*	*(:)*	*4293*	*(:)*	*4999*	*(:)*	*(:)*	*(:)*	Eurostat
Landfill rate of waste excluding major mineral wastes	Romania	%	(:)	(:)	53	(:)	49	(:)	(:)	(:)	Eurostat
	EU	%	*(:)*	*(:)*	*9*	*(:)*	*8*	*(:)*	*(:)*	*(:)*	Eurostat
Recycling rate of municipal waste	Romania	%	0.00	01.80	12.80	11.70	14.80	13.20	(:)	(:)	Eurostat
	EU	%	48.40	53.80	57.70	57.40	55.70	54.90	55.10	(:)	Eurostat
Recycling rate of e-waste	Romania	%	(:)	(:)	12.0	10.3	14.5	(:)	(:)	(:)	Eurostat
	EU	%	(:)	(:)	30.4	31.9	32.0	31.7	(:)	(:)	Eurostat

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Source: Eurostat [5] (http://ec.europa.eu/eurostat/web/europe-2020-indicators/resource-efficient-europe)

8. Comparison of domestic material consumption indicator. Romania vs. European Union

Domestic Material Consumption (DMC) is based on the Economy-wide Material Flow Accounts (EW-MFA) [5]. Comparison of domestic material consumption indicator,"Romania vs. European Union"is shown in the table 3. The classification of materials used in EW-MFA and for which DMC is calculated is a Eurostat based system. EW-MFA includes the material categories:

*1.*Biomass and biomass products;
*2.*Metal ores and concentrates, raw and processed;
*3.*Non-metallic minerals, raw and processed;

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*4.*Petroleum resources, raw and processed;
*5.*Other products;
6.Waste imported for final treatment and disposal.

It is important to note that the term "consumption" as used in DMC denotes apparent consumption and not final consumption. DMC does not include upstream hidden flows related to imports and exports of raw materials and products. The indicator is a Resource Efficiency Indicator. It has been chosen as a lead indicator presented in the Resource Efficiency Scoreboard for the assessment of progress towards the objectives of the Europe 2020 flagship initiative on Resource Efficiency. The DMC is defined as the total amount of material directly used in an economy and equals direct material input (DMI) minus exports Domestic material consumption –is represented in “tonnes per capita”.
(Source: http://ec.europa.eu/eurostat/cache/metadata/DE/t2020_rl110_esmsip.htm)

Table 3 Comparison of domestic material consumption indicator. Romania vs. European Union [5]

Time geo	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Romania	:	:	:	:	13.685	14.463	11.251	9.940	10.820	8.700	7.684	12.372
EU (28 countries)	..	..	..	..	..	..	..	..	..	..	15.485 (s)	15.51 (s)

Table 3 Comparison of domestic material consumption indicator. Romania vs. European Union [5] (cont.)

Time geo	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Romania	12.069	13.255	14.265	15.705	17.020	20.557	26.843	21.262 (s)	19.748 (s)	22.325 (s)	21.845 (s)	22.056 (s)	21.327(ps)
EU (28 countries)	15.287	15.138 (s)	15.835 (s)	15.857 (s)	16.132 (s)	16.575 (s)	16.362 (s)	14.39 (s)	13.939 (s)	14.456 (s)	13.427 (s)	13.040 (s)	13.079 (ps)

Flags are codes added to the data and defining a specific characteristic:
p = provisional; s = Eurostat estimate (phased out)

Domestic material consumption indicator for Romania before has joined EU (table 4)
Time considered: 13 years before Romania has joined EU (from 1994 to 2006); Average: 161229/13 years = 12.402 tonnes per capita.

Table 4 Domestic material consumption indicator for Romania, before has joined EU (13 years time period)

Year	1994	1995	1996	1997	1998	1999	2000	2001
DMC (tonnes per capita t/c)	13.685	14.463	11.251	9.940	10.820	8.700	7.684	12.372
Year DMC (tonnes per capita t/c)	2002	2003	2004	2005	2006	-	-	-
	12.069	13.255	14.265	15.705	17.020	-	-	-

Domestic material consumption indicator for Romania after has joined EU (table 5)
Time considered: Eight years after Romania joined the EU (2007-2014)
Average: 175963/ 8 years = 21.995 tonnes per capita

Table 5 Domestic material consumption indicator for Romania after has joined EU

Year	2007	2008	2009	2010	2011	2012	2013	2014
DMC (tonnes per capita)	20.557	26.843	21.262 (s)	19.748 (s)	22.325 (s)	21.845 (s)	22.056 (s)	21.327 (ps)

After joining the EU, the domestic material consumption in Romania, has increased 1.77 times, compared with the previous period 1994-2006. That means that Romania has benefited from EU membership (reduced fees, transfer of know-how).

9. Domestic material consumption indicator for EU (28 countries) after Romania has joined EU (table 6)
Time considered: Eight years after Romania joined the EU (2007-2014)

EU Average: 102.189/ 8 years = 12.773 tonnes per capita at EU level (28 countries) ;
After joining the EU (2007-2014), the domestic material consumption in Romania, has increased 1.72 times, compared with EU average in the same period of time (8 years). That means that Romanian people has consumed as a consuming society, as is shown in the figure 1.

Table 6 Domestic material consumption indicator for EU (28 countries) after Romania has joined EU

Year	2007	2008	2009	2010	2011	2012	2013	2014
DMC (tonnes per capita)	16.575 (s)	16.362 (s)	14.390 (s)	13.939 (s)	14.456 (s)	13.427 (s)	13.040 (s)	13.079 (ps)

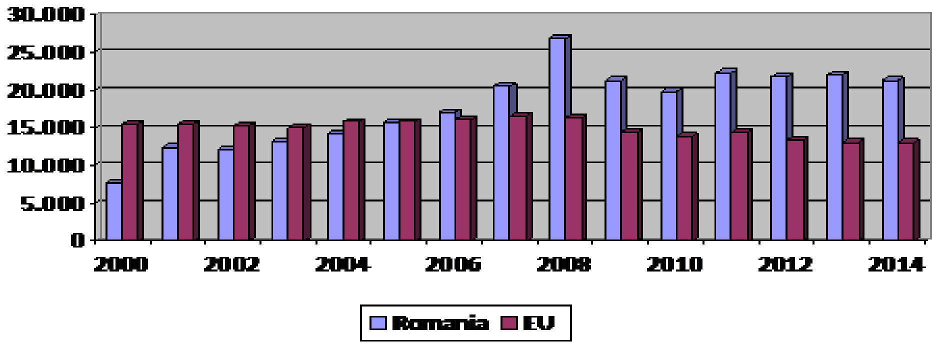

Figure 1. Domestic material consumption indicator. Romania vs. European Union Comparison

Source: **[5]** .
http://ec.europa.eu/eurostat/tgm/printTable.do?tab=table&plugin=1&language=en&pcode=t2020_rl110&printPreview=true.

10. Conclusions

The transition benefits towards a circular economy in Europe could be considerable by reducing environmental pressures reducing drastically Romanian economy dependence on imports which, if gradual increases, can become a source of national vulnerability.

Increasing global competition for natural resources has contributed to increased prices and volatility. Also circular economy strategies applied could have as effect of reducing costs and increased competitiveness of Romanian industry by net benefits which consist of job opportunities.
Creating a circular economy in Romania requires fundamental changes in the value chain, from product design and production processes to new models of circularity business and consumption patterns.

In this manner, recycling will turn waste into a resource, and product life extension facility will contribute to reducing natural resources consumption.

Some Romanian companies are already are experimenting new circularity business models such as those based on functions and services of collaborative consumption model specific for circular economy. For the future Romanian managers could take some measures for waste reduction: the changing status of the waste by selling it as product; the mechanisms for paying for treatment and / or disposal which discourage waste generation; the use of financial resources obtained from secondary raw materials for the efficiency of waste management.

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