DEVELOPMENT OF THE CIRCULAR ECONOMY WITHIN DEVELOPING REGIONS: A COMPARATIVE ANALYSIS OF ADVANTAGES AND OPPORTUNITIES FOR WASTE VALORIZATION

Ferronato N.[1], Rada E.C.[1/2/3], Gorritty M[4], Cioca L.I.[3/5], Ragazzi M.[2], Torretta V.[1]

[1] Department of Theoretical and Applied Sciences, University of Insubria, via G.B. Vico, 46, Varese 21100, Italy ;
[2] Department of Civil, Environmental and Mechanical Engineering, University of Trento, via Mesiano, 77, 38123, Trento, Italy ;
[3] Department of Industrial Engineering and Management, Faculty of Engineering, Lucian Blaga University of Sibiu, Sibiu, Romania
[4] Department of Chemical Engineering, Major University of S. Andrés, Calle 30, Cota Cota, La Paz, Bolivia
[5] Academy of Romanian Scientists, Bucharest 010071, Romania

Presenting author email: nferronato@uninsubria.it

Abstract

The introduction of new sustainable systems in solid waste management (SWM) is still a challenge for local authorities in developing countries. Romania is the emerging country analyzed in this paper where Circular Economy (CE) is becoming a future objective due to economic aids and strength regulations which the European Union (EU) established for the nations forming parts the alliance. As a comparison, Bolivia is reported as case study, in order to evaluate main differences founded for developing a reverse logistic system in a no-EU country. Moreover, a theoretical CE model, which can be applicable for a developing country, is developed within the study in order to compare which opportunities can spread for the countries presented. Despite the economic level, Romania and Bolivia are both facing with many management issues although in different amounts. On one hand it is visible how Romania cannot achieve the European goals for 2020 due to poor improvements and the need of important changes in public recycling behavior; on the other hand, EU recommendations are of utmost importance for starting a CE approach, which is more difficult for developing countries where economic sustainability and regulations systems are still lacking. As a result, the comparison suggests how external supports led to implement the principles of the CE within a developing region. The model of CE proposed is recommended in order to develop a new form of safe employment encouraging the activities that are still in action (i.e. informal sector) although with significant management efforts.

Keywords: Circular economy, developing countries, recycling behavior, solid waste management, European framework

1. Introduction

The treatment option mostly used worldwide for treating municipal solid waste (MSW) continue to be the landfill which, in developing area, means illegal and not controlled open dump sites [1,2]. If public policies do not engage in recycling resources and managing waste, we can expect that the reserves of many resources will soon become scarce [3]. For that purpose, one suitable solution can be the shift from a linear to a circular economy (CE) which will preserve the environment, increase products value and generate new economic growth. The introduction of this concept is intensifying in developed countries [4] while developing countries are still suffering inappropriate solid waste management (SWM) due to the lack of economic funds, public awareness and political will [5]. Anyhow, improving overall eco-efficiency is always the primary element of the economic system while resource productivity, material recycling and the amount of waste to final disposal represent three core indicators of sustainability in material flow systems which are not always considered [6].

As stated by Stahel [7], a CE system would turn goods that are at the end of their service life into resources for others. The degree of circularity of the global economy is measured as the share of actually recycled materials in total processed resources and the perfectly circular system will be introduced when longevity of goods equals limitlessness [9]. For instance, biomass can be always considered in a cyclical flow owing to the fact that all biomass waste products can be re-entered the biosphere [8]. However, a not well implemented selective collection (SC) does not allow the application of a such natural close loop cycle. Anyhow, a successful implementation of CE policy requires efforts at three levels: micro-level, meso-level and macro-level, where the complexity of practices increase when the scale level rise [10,11]. At micro level, factories and agricultural products producers are required to adopt cleaner production and eco-design although there are no comprehensive frameworks supporting every company business model in designing a circular model [11]; at meso-level the practices include developing eco-industrial parks and an eco-agricultural system; finally, at macro-level more complex and extensive co-operative networks between industries from every sectors should be introduced.

Many developing countries worldwide are trying to perform CE principles. For instance, in China, with a Gross National Income (GNI) equal to 7,930 USD, the CE policy has been chosen as a core dimension for the national sustainable development policy introducing the “Cleaner Production Promotion Law” which improved resource utilization efficiency and natural environment protection [6]. In Serbia (GNI equal to 5,540 USD) was committed a zero waste strategy where organic MSW fraction, which is the major one detectable in MSW, is considered an extremely rich resource [12]. In India (GNI equal to 1,600 USD) the Government has introduced the “Clean India Mission”, although with many difficulties [1]. So, many developing countries are adopting the principle of the CE although with no effective changes since are mostly pilots projects with many management issues for future implementations [13-17].

The aim of this work is to present opportunities for introducing the CE in developing regions with low-middle and upper-middle income levels and where recycling systems are not still developed. The comparison between an EU country and another no-EU allow understanding which are the main issues where policy makers have to act in both

cases. Considerations about this comparison give an indication of which concerns are presented in a developing country where regulations and laws are not still adopted and how future guidelines should be deal for the development in environmental, social and economic subjects. CE improvement is finally suggested as opportunity of economic development although some internal actions are required and global aids are recommended.

2. Material and Methods

This work moved from a research in Bolivia where local SWM has been investigated and from few years of experience in solid waste treatment in Romania. This analysis would study the correlation between two different context where reverse logistic (RL) and take back programs are not still implemented with particular attention to evaluate which can be the opportunity for a developing region to be inserted within the EU organization. For that purpose, a theoretical CE model is developed within this dissertation, which can be applicable for a developing country. Direct surveys, interviews of local stakeholders, the international collaboration between universities and a literature survey allow implementing the considerations presented within the next sections. The main literature data obtained, useful to introduce Bolivia current state, are only provided by the study made by the Catalan international cooperation agency which, in 2010, wrote a manual about SWM systems in Bolivia [18], while Romanian studies are more in numbers and allow an integrated study although without many current data. The realities suggested are offered like SWM example of developing region where further improvements are required.

2.1. The study areas

2.1.1. Romania, the EU developing region

Romania has a population of 21,584,365 inhabitants, with about 44.8% who live in rural areas, with a population density of 90.5 inhabitants per km^2 and a GNI of 9,500 US$ [19]. It is situated in the south-eastern part of Europe in the crossing point of the main European communication axes: west-south east and north-south east. From the administration point of view Romania is divided in 41 counties, including 266 cities and towns and 2,689 villages, contained in 8 regions. Romania's entire development in the last decade is characterized and influenced by the process of transition from the old economic and social system to a new one, that started after 1989, from a mostly self-centered economy to an economy integrated in the EU and world structures. Indeed, in 2007 Romania entered to EU, and now it follows regulations and laws of the Union.

2.1.2. Bolivia, the example of low-middle income developing country

Bolivia is classified by the World Bank [19] as a low-middle income country (GNI of 3,000 US$) with a population of about 10,500,000 inhabitants. It is located in the center of the South America continent with no access to the sea. With a land extension of 1,098,581 km^2 and a population density of about 9.5 inhabitants per km^2, Bolivia is divided in nine department with 112 province and 327 municipalities. The capital city is Sucre, while the center of the Government is La Paz. However, at national level, Bolivia presented three levels of government: The central government, the autonomous departmental government and autonomous municipal government, which are active is regulation and management controls at each different level.

2.2. *The European framework in SWM*

The European Union (EU) is among the regions taking the lead with respect to policies of sustainable development and sustainable resource use, but it is also a major consumer of resources and producer of emissions. Indeed, in 2005, the EU accounted for 7.5% of the global population, and used 12.4% of the globally extracted materials, although the aggregate recycling rate was at 12.6%, roughly twice as high as the global average [8].

In a sustainable SWM perspective, The European Commission adopted an ambitious CE Package, which stimulates Europe's transition towards a CE in order to boost a sustainable economic growth. The legislative proposal on waste sets clear targets for the reduction of waste and establishes a long-term path for waste management and recycling [20]. Moreover, EU developed a new process of environmental improvement which includes the principle of sustainable innovation: the Horizon 2020. Horizon 2020 is the biggest EU research program ever with nearly €80 billion of funding available over 7 years (2014 to 2020). Main targets are reported in Table 1.

Table 1 EU and Horizon 2020 targets [20]

Common EU targets in SWM for 2030	**Horizon 2020**
i) A ban on landfilling the separately collected waste;	i) 75% of the 20-64 year-olds to be employed
ii) Simplified and improved definitions methods for recycling rates throughout the EU;	ii) 3% of the EU's GDP to be invested in Research and Development
iii) Actual measures to promote re-use and stimulate industrial symbiosis – turning one industry's by-product into another industry's raw material;	iii) Greenhouse gas emissions 20% (or even 30%, if the conditions are right) lower than 1990, 20% of energy from renewables, 20% increase in energy efficiency
iv) Economic incentives for producers to put greener products on the market and support recovery and recycling schemes (for packaging, batteries, WEEE, vehicles).	iv) Reducing the rates of early school leaving below 10%, at least 40% of 30-34–year-olds completing third level education
v) Promotion of economic instruments to discourage landfilling;	v) At least 20 million fewer people in or at risk of poverty
vi) Recycling 75% of packaging waste	
vii) Reduce landfill to maximum of 10% of MSW	
viii) Recycling 65% of MSW	

EU introduced a large number of directive in order to improve waste management activities in compliance with Horizon 2020 and the improvement of such CE policies. The most important are the Directive 2008/98/EC on waste, which forces the improvement of waste management activities, with a view to protecting human health and promoting a more CE, and the Directive 1999/31/EC on the landfill of waste which makes progress in the implementation of the raw materials recovery by reducing landfilling of waste. According to the Environmental European Agency [21], latest available trends show that recycling rates for both MSW and packaging waste have increased substantially: recycling rates for MSW increased by 13% between 2004 and 2014, and recycling rates for packaging waste by 10% between 2005 and 2013. In 2014, 43% of the MSW generated in the EU-27 and Norway was recycled, while in 2013, 65% of packaging waste generated was recovered. However, large differences in recycling rates between European countries prevail; in 2014, the rates ranged from 64% in Germany to 1% in Serbia. In six countries, recycling rates were equal or higher than 50%, while five countries recycled less than 20%. In 2014, 24 countries recycled 55% or more packaging waste and overall recycling rates ranged from 81% in Belgium to 41% in Malta. These differences indicate a large potential for improvement [21]. The policies implemented by EU are in accordance also with the Sustainable Development Goals (SDGs) which have many relations with SWM, most notably in Goal 12 (ensure sustainable consumption and production patterns) and Goal 3 (ensure healthy lives and promote well-being for all at all ages) [22]. These Goals aims to achieve, by 2020, the environmentally sound management of chemicals and all wastes throughout their life cycle and significantly reduce their release to air, water and soil, while, by 2030, reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution, in a CE perspective.

2.3. The CE model

Many barriers are still existing for the development of the CE within a developing country, particularly due to low financial sustainability, presence of informal activities and the lack of technological facilities developed within the region [2, 23]. For these reasons rise the need to develop a model that can be affordable for these regions where many MSW management issues are common, although it cannot be equivalent for every region due to social, environmental, financial and political differences. The theoretical model suggested in this study is an example of sustainable management of MSW and it is introduced in order to present a suitable solution for the MSW mismanagement considering treatment and collection systems that are commonly existing in a developing region. Such model is simply depicted in Fig. 1 and intended to highlight recirculation and treatment possibilities for material through technical facilities and social behavior. Solid waste material considered are municipal, with attention to recyclable waste and refuse waste with high organic content, and other urban waste such as tires, sanitary waste, used batteries and WEEE. SC is not considered at first as too expensive to be applied in region with low GNI (<10,000 USD). For that purpose, informal sector inclusion is suggested. Moreover, other precautions are recommended which can be appropriate in a low-income region. All such considerations are divided in three groups, each supported by three different actors: informal sector, public management and public-private partnership.

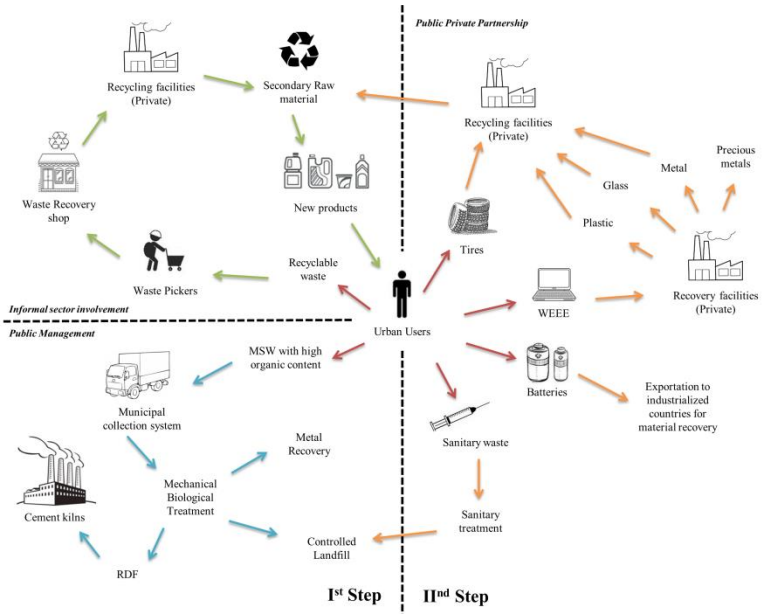

Fig. 1 Theoretical CE model applicable for developing countries

The first issue is the formalization of the waste pickers. The informal trade implemented at municipal level is commonly an issue since the municipal perception of those who work in the informal waste sector is often negative and in some instances the relationship is hostile [24]. However, the informal sector provides the major source of recycling and save money through reducing the quantities of waste collected for MSW treatment and disposal [24]. So, become of utmost importance the introduction of a CE which comprehend the presence of informal waste pickers. Taking into

account global examples, scavengers work commonly within final disposal sites or picking waste from road bins, street containers, and riverbanks [25, 26]. However they are responsible of a large part of recycling activities, starting a RL system without the contribution of public financing. Efforts should be focused on supporting those countries in developing the strategies which incorporate waste pickers into the formal waste management process [27].

So, the first step of the model is the formalization of these workers, giving duties and rights which can support the work. Public awareness should be improved by the introduction of advertisings and sensitivity campaigns in order to introduce the 'ecological operators' (name that should be given to waste pickers) into the collection system. The municipality could guarantee sanitary assistance for free and retirement at the end of their job career. Such aid should be assured without the demand of taxes, as this represent a real barrier for the operators which are not encouraged to enter within the formal system. This device introduces also a reliable information system about the amounts of recyclable materials which commonly face with miscalculations since the waste picker is not encouraged to give the real amounts. The solution is provided by the introduction of the 'zero tax' principle within the recycling chain. At the same time, the ecological operator must to accept to be formalized within a waste recovery shop and to work within a limited district area, recollecting the waste user by user. In this manner, every picker will be known by the citizens of each county. For that purpose, municipal control and monitoring system is essential and stranded costs for the waste recyclable material must to be ensured by the public organization, in order to guarantee the same business for each shop and operator. Finally, every worker must wear personal protection equipment, the first time provided by the municipality after the sign in into the recycling shops, in order to encourage the start of the process.

The system can be economically sustainable also for households, the private sector and the municipality: main advantages and disadvantages are reported in Table 2. Households can access to a curbside collection systems without economic efforts and such SC guarantees clean streets and neighborhoods. In order to boost the population to apply such methods, a municipal competition system can be introduced. For instance, the most 'green district' , that is the one that recycle the most per inhabitant, receive an economic discount in the sanitary charges or a public acknowledgment. The private sector is also involved since more recyclable materials entered in the system without any financial improvement while the public sector reduces the costs of transports and final disposal since the costs are commonly applied per ton of waste collected: so the effort adopted to improve the informal sector is paid by the economic save enhancing environmental sustainability and public consensus.

The formalization of the informal sector should be supported by a pre-treatment system before landfill, since the organic matter grow in percentage within the waste inflow into the landfill as well as the inorganic exploitable matter decrease. Commonly MSW is sent to open dump sites which are dangerous for the environment. Moreover, environmental reclamation is really too expensive and it is not affordable for a low-income country, worsening contamination extent. For that purpose, a mechanical biological treatment (MBT) can be implemented before the final disposal site. It can guarantee putrescible waste stabilization and refuse derived fuel (RDF) production, converting waste-to-energy as fuel, since waste is deprived of non-combustible materials and moisture, addressing the issue of energy demand and SWM in a CE perspective. Such highly-energetic material is exploitable in industrial factories i.e. cement kilns, as used in other developing areas [1]. In this manner, other economic revenues are guaranteed and the final disposal site can be managed in a more sustainable framework as bio-gas production and leachate releases are reduced [28]. Moreover, disposal site useful life is improved, enhancing environmental protection. As a result, MBT can be adopted since it is a cost effective treatment and it improves the environmental condition in emergency circumstances. Nevertheless, the model here suggested foresee the implementation of a controlled landfill, monitored and gated, so that no illegal activities can be improved within the area and a control flux system can be adopted. The application of this step should be provided by the public management system.

Table 2. Advantages and disadvantages for each stakeholder involved within the CE model.

Waste Pickers	Municipality	Private sector	Households
	Advantages		
• Sanitary assistance	• Improvement of public sensitivity in SWM practices	• Enhancing recycling activities	• Curbside collection for free
• Organization and public acceptation	• Reliable information about recycling activities	• New markets introduced within the area	• Upgrading of street cleanness
• Retirement guaranteed	• Sustainable management of Landfills		
	• Recycling rate improvement		
	Disadvantages		
• Introduction of a regulation within the daily collection activity	• Long time is necessary in order to introduce a visible change	• Competition with new recycling companies	• Efforts required to change the usual MSW delivering
• Change in habits	• New policies should be introduced		
• Collection areas limited	• Preliminary investments required		

The second phase of the CE model included the implementation of a more efficient SC applied by the citizens, which cannot consider the informal sector since materials as tires, sanitary waste, waste electric and electronic equipment (WEEE) and batteries are generally not exploitable directly since economic revenues are not available in short terms and the treatment is unsafe. No specification are provided in the model as many technologies are available for treating these typologies of waste. However, WEEE and tires recovery is suggested, sanitary waste need to be treated for healthy precautions while batteries could be exported to developed countries which just adopted the recovery

of the waste materials. Therefore, public economic efforts should be introduced in this step, which could be apply after the improvement and implementation of the vision of the first phase, since public behavior started to accept a CE system with consciousness and perseverance in material selection. A public-private-partnership (PPP) can be applied since collection, treatment and exploitation strategies required an important effort that can be overcome only by the cooperation between public organization of private financing and know how.

The same model can be adopted for private companies and offices which produce high amounts of waste that can be collected by the informal sector. However, public facilities like schools, nurseries and universities could sell the recyclable waste directly to the shops like parallel public campaign in order to involve students and higher educational institute to develop a CE plan; furthermore, the income derived from the activity can be used for improving the public structure or to introduce other sensitivity activities or buy new bins and objects useful to improve the recycling rate, even made by recyclable materials. Moreover, organic waste from agriculture, markets and green areas can be deviated to a SC system which is implemented periodically for introducing composting facilities.

3. Results

3.1. Romania: current and future perspective in SWM

The first National waste management strategy in Romania was developed in 2003, and published in early 2004, following the transposition of EU legislation in the field of SWM and according with the provision of the governmental ordinance, approved in 2001. In Romania, regulation for managing MSW is in its early stages and the accession to the EU in 2007 has put the Romanian SWM under the regulative influence of the European Directives presented in section 2.2. [29]. The Ministry of the Environment introduced a new regulation system after 2008 which took into consideration thematic about waste prevention and recycling, among others [30]. Future projects were connected with the construction of new landfills with the obligation to close-up the existing landfill with sorting and recycling stations for MSW, WEEE and used oils.

In Romania, the organization of collection and treatment of MSW is under the responsibility of the local public administration [29, 31]. In 2002 has been estimated that waste production overcome 8,800,000 tons per year and 251 landfills for MSW were functioning, out of which 15 complying landfills, 236 non-complying landfills. Apart from landfills in urban area, in Romania there were 2,686 dump sites in rural areas, equal to the number of villages, the most having the surface of 1 ha [32]. In 2012, 238 existing MSW landfills still were not in compliance with EU regulation and should be closed by 2013, at the same time 65 compliant landfills/transfer stations should be constructed, 50 of which with an average capacity of up to 100,000 tons $year^{-1}$ and another 15 landfills with an average capacity of up to 50,000 tons $year^{-1}$ [29]. In some regions, uncontrolled waste disposal take place in the form of illegal dumping, which means risk to human health and the environment [33]. Indeed, not all the rural areas have organized services for waste management and in some places the transportation of waste to dumping sites is made individually by each generator [32]. In 2008, the vulnerability of urban areas to uncontrolled waste disposal were high, as an average of 30% of Romanian urban population lacks sanitation services [34]. However, it has registered visible progress over the last years at country level: while in urban areas the situation has clearly improved (90% of the population have access to sanitary services), the same indicator for rural settlements do not achieve the 60%. In 2011, Romanian MSW generation indicator were between 0.78 and 1.03 kg inh^{-1} d^{-1} in urban areas, although the estimation of waste quantities generated or disposed still suffer a high percentage of miscalculation [33]. A recent study confirms the generation rate of urban areas (0.9 kg inh^{-1} d^{-1}), providing also the quantities per inhabitants in rural areas, which are 0.4 kg inh^{-1} d^{-1} [31]. Generally, poor data are available and the involvement of the informal sector within the collection of recyclable material is not monitored. The participation of the informal sector is still very significant (~40,000 people), caused mainly by low level of living. Direct trade of recyclables is the main source of income for the significant portion of poor citizens, who pick recyclable materials from bins and open dumps. In addition, second hand market is prominent in the field of furniture and building materials. Environmental awareness and public willingness to participate in SC is still at low level, although it is increasing through general environmental campaigns and educational activities [35].

According with the Europe's 2020 strategy and CE Package, Romania should recycle 50% of its waste for 2020. However, in 2004 Romania recycled only the 3% [36] while, to date, the recycling rate of MSW is grown up to 13% [21]. So, recycling in Romania is not a well-developed practice since the rate did not achieve 6 kg per capita in 2010; Moreover, the waste collected and treated achieved only the 80%. No landfill taxes are required and current typical landfill gate fee do not surpass 10 € per ton [36]. Same consideration can be made for waste-to-energy facilities, which are not declared in 2015 as regard MSW. Incineration is considered to be too expensive for the Romanian waste management market except for medical, industrial and dangerous waste [37]. Even so, the plans for the integrated SWM system within the Bucuresti-Ilfov region includes the construction, in the coming years, of the first MSW incinerator in Romania [29]. The waste-to-energy more applied is co-incineration, which is well established since all cement kilns have invested in specific technologies and have been authorized for the co-incineration of a wide range of waste fractions. It has been estimated that the co-incineration capacity in Romania and the potential demand for RDF at the cement kilns is ten times higher than the currently available quantities [29, 38, 39].

As indicated by EU legislation, landfill targets for the diversion of biodegradable waste going to landfills, reported in Table 3, should be on the 50% of the total quantity of biodegradable waste generated in 1995, by 2013, whereas 65% of the total quantity of biodegradable waste generated in 1995, by 2016. In this topic, Romania has decided not to use

the derogation option for the 2016 target and new information about current situation are still expected [35]. Nevertheless, the most widely used alternative option in Romania is still landfill while in terms of material valorizations, like compost facilities and digestion installations, some initiatives have been observed since 2011, for approximately a total of 20,000 tons of waste per year treated [37].

Table 3 Targets set up for the Romanian SWM provided by EU [30]

Target year	Landfills	Reduction of biodegradable MSW to landfills*	Packaging waste	MSW recycling rate
2011		25%		
2013	i) Closure of 238 existing municipal landfills which are not in compliance with EU.		Recycling target level - 55%	
	ii) Construction of 65 municipal landfills in compliance with EU regulations (min. capacity of 100,000 t $year^{-1}$ at regional level).			
2015		50%		
2016	Reduction of the quantity of MSW disposed in 101 municipal landfill which are not in compliance with EU regulations.	65%		
2020				50%

*Compared with the quantities generated in 1995

In 2011 there were no landfill ban for MSW disposal as only landfill disposal of packaging waste materials were prohibited in accordance with EU regulation. Indeed, to date, good improvements were made for the recycling of plastic packaging waste, since the European goal has been surpassed, since the 56.8% is recycled [21] although data on packaging recycling were not available until the end of 2016 [40]. Such improvement can be introduced by EU and Government funds which developed waste management infrastructure in some rural areas by introducing SC points, building transfer stations equipped with waste sorting and composting facilities in line with EU directives [34]. Furthermore, according to EU regulations, Romania implements the principle of the Extended Producer Responsibility (EPR) in solid waste, in particular concerning tires disposal [41]. However, limited producer responsibility (applied for few waste streams) or equivalent systems in place are not able to cover the full costs of SC and recycling of main waste streams, while no incentive systems to favor prevention and participation to separate collection (Pay as you throw schemes) are in place [35]. The required budget that can be co-funded by the EU for the period 2014-2020 has been estimated in a recent study to 1,3 billion € [35]. Approximately 300 million € from EU funding were assigned in 2012 to improve MSW management in Romania, covering ten projects across ten counties. Applications for funding the remaining counties were in the preparation phase, with a total planned investment of 730 million € [29].

Anyhow, waste recycling is one of Romania's key priorities, striving to reach the average level of EU's countries with regard to the value of this indicator of sustainable development [42]. Also high educational institutes are including policies of SC, although only a few have functional one and the majority have no waste quantity monitoring system [43]. In Europe, six countries (Bulgaria, Croatia, Latvia, Lithuania, Slovakia and Romania) require an annual increase rate of between four and five percentage points. Such an increase rate has not been achieved by any of these European countries in the periods 2001–2010 or 2006–2010 [36]. Romania is one of the countries which received a derogation period for the fulfilment of the 2020 target of 50% recycling of MSW. However, Romania will not accomplish this target if progress continues at the current rate, therefore an exceptional yearly increase in the recycling rate is needed [29]. Including some of the recycled packaging waste from MSW sources will also increase the recycling rate: An exceptional effort from the regional and national Romanian authorities will be needed to increase the recycling level to 50% by 2020 but a similar effort will be required even with a five year derogation period to 2025. An important aspect which could lead to improved results is raising the level of awareness among citizens, who are not used to selectively collecting their waste, even though the infrastructure is already in place in some Romanian cities [29].

3.2. SWM barriers in Bolivia

At national level, the SWM is charge of of the Deputy Minister of Potable water and Sanitation, by means of SWM direction agency, responsible of the introduction of new polices and development plans. It has been estimated that in 2010 the generation of solid waste achieved 1,677,650 tons per year, among which 85% were produced within urban areas, while the 15% in rural towns. The national production of MSW in urban areas was about 0.5 kg inh^{-1} $year^{-1}$ while in rural area was about 0.2 kg inh^{-1} $year^{-1}$. This represent an average although it has been confirmed by the field work and the interviews obtained by the stakeholders. Generally, within the cities, sanitation services are provided by municipal companies in four different forms: (1) direct management from the municipalities, (2) from an indirect office of the municipality, (3) and from decentralized companies which can be autonomous or engaged by the municipality. In 2010, 51% of the municipalities, which are mostly of little dimensions (2,000 inhabitants), were not provided by sanitations services. Within the cities where SWM is applied, only the 17% obtained urban charges, which allow the cover of the 40-60% of the total costs. As a result, this practice influence the financial sustainability of a municipality, which must introduce an important part of economic resources for the collection of MSW [18]. The service covered the 86% of the areas in capital cities, the 78% of bigger municipalities, the 63% of the minor municipalities and the 42% of the rural areas. It has been estimated that, at national level, only the 4.6% of MSW is recovered by the informal and formal sector and introduced within the recycling chain. Indeed the informal sector is widespread within the country, since it is a common practice for poor people or households which can achieve a financial sustainability by sending

recyclable materials to an informal sector that is growing in dimension. It has been estimated that around 10,000 people work like informal pickers. Considering that each pickers can collect more than 100 kg of exploitable waste per week, about 50,000 tons per years of recyclable materials are recovered by the informal sector.

An important role is made by the Non-Governmental Organizations (NGO) which work within the country at direct contact with the population, especially in rural areas. The efforts applied by these groups led to implementing new programs which aid the public governments to improve the informal sector and the recycling systems. For instance, Swisscontact, with the program '*Eco-vecindarios*' allows the implementation of 378 new jobs and the collection of 15,900 tons of recyclable waste in three years [44].The worst environmental issue come from sanitary landfill, which receive only the 45% of solid waste from formal collection systems in the whole country, since only the 8% of final disposal sites in Bolivia are sanitary landfills. It means that final disposal is mostly uncontrolled, without environmental monitoring, growing the threat of disease and pollution. Low financial sustainability, technical facilities and management plans do not encourage Bolivia policy makers to introduce new solutions in order to improve sanitation systems [18]. However, in 2015 the first national regulation were introduced by the National Government and some improvements are going to be introduced, mostly by the international cooperation and South America economic aids.

In 2011 was introduced the national program for SWM, where future strategies, projects and goals were introduced. For the end of 2015 the objectives were the reduction of the MSW generation index of about 1% in comparison of the 2010, improve the operation activity of the 15% of the final disposal sites, improve the service covering of the 5% at national level, involve the citizens in 15% of the Bolivian municipalities and at the same time improve the technical management within the 15% of the cities. This program is carry out by the national policy, however, international economic funds were introduced for an amount of about 62 million US$ [45]. To date there are not public information about the evolution of such indicators, and is difficult to estimate the current improvement applied within the country. Anyhow, SWM is still a difficult issue and in continue development; appropriate technologies could be introduced in order to improve the CE national framework since could be seen as a sustainable solution.

3.3. Bolivia and Romania: the comparison

Romania is an emerging region which take positive aids by EU for SWM improvement. European social funds and regulation limits enable the improvement of sanitary conditions although with not high efficiency. Indeed, the answer gave to the European efforts is slow because, since 2007, the recycling rate improved only by the 10% while 30% of national area is still not covered by sanitation systems. At the same time, good response are given by packaging waste recycling which overcome European goals.

Bolivia is a developing country with a low economic growth, where regulation systems are not efficient and the introduction of new technologies is still poor. However, lack of national recycling goals controlled by other international organization, do not stimulate the improvement of sanitation, even if by the support of NGOs. The Environmental Ministry and all departmental and municipal Governments are working to improve the current SWM situation, but with pilot projects and without the involvement of the population at big scale. Indeed the main practice which improves the recycling rate is the informal sector.

Many differences are detectable between Bolivia and Romania as expected. First of all the economic progress, as reported in Fig. 2, which imply the introduction of new facilities and the improvement of population wellness.

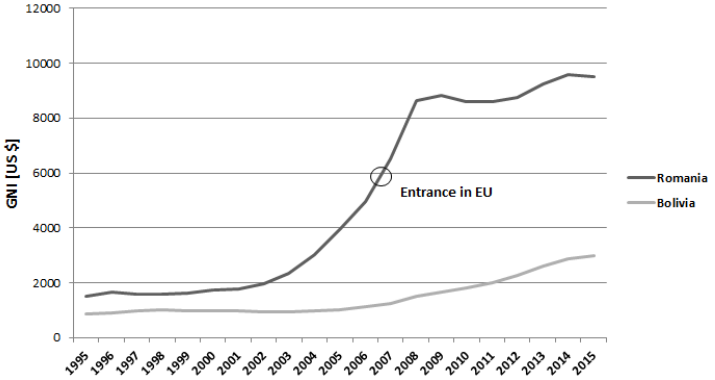

Fig. 2 Bolivia's and Romania's Gross National Income (GNI) trend [19]

Romanian economic development is based on the entrance in EU and on financial aids came from European private sectors which invested in the country since the lower outgoings in the production chain represent an opportunity for all big and small firms. As a result, also the recycling rate improved at the same time. Indeed, in 2004 the recycling rate was about the 3% while in 2014 achieved the 13%. Nevertheless, Romania is one of the EU countries which received many financial aids by the European bank and when the economic support will end, the local industry could suffer a crisis due to the lack of continuous investments. This consideration underlined the importance and the correlation between economic growth and recycling rates improvement within the EU, theory not valid worldwide. Indeed, many developing countries improved its financial sustainability, while the waste generation raise, without significant technological development [46]. This might be the example gave by Bolivia, where the economic improvement is not follow by an increased awareness on environmental behavior. As a result, CE and recycling chain in Bolivia is not well

developed yet and economic aids are still required. Other differences are evident concerning MSW average generation and waste collected sent to landfill, as described in Table 4.

Table 4 Comparison between Romania and Bolivia national SWM.

	Inhabitants	**GNI[g]**	**Waste production**		**Recycling rate**	**Waste collected and treated**	**Lack of sanitation service**	**Informal sector activities**
		[USD]	[kg inh^{-1}d^{-1}]	[t year^{-1}]	[%]	[%]	[%]	[tons year^{-1}]
Bolivia [18]	~10,000,000	3000	0.2-0.6	1,677,650	4.5	45	51	~50,000
Romania	~21,000,000	9500	0.78-1[a]	8,800,000[f]	13[b]	80[c]	30[d]	~40,000[e]

[a] [33] [b] [21] [c] [36] [d] [34] [e] [35] [f] [32] [g] [19]

Waste production in rural and urban areas range between 0.2-0.6 kg inh^{-1}d^{-1} in Bolivia whereas 0.78 kg inh^{-1}d^{-1} in Romania. These generation rates are respectively comparable with the values typical of low-middle income countries and upper-middle income countries. On the other hand, waste composition are mostly similar (Fig. 3) and comparable with ones of low-middle income countries [46]. Worrying is the level of the sanitation system provided for both countries. In Bolivia has been estimated that only the 51% of the municipalities is provided by a sanitation system, which recollect and send to landfill only the 45% of the MSW generated. The remain waste percentage is not collected, or is sent to open dumping sites, buried, burned or threw in water bodies. This data is date on 2010, however, the survey conducted in 2016 confirm this habit also in towns situated within the country side. Better is the situation within the metropolis which received the service, although not covering the whole urban area. This situation is improved in Romania, however many efforts should be applied as in 2012 still more than 2,000 open dump sites were introduced near urban area while the collection system was not provided for all the municipalities.

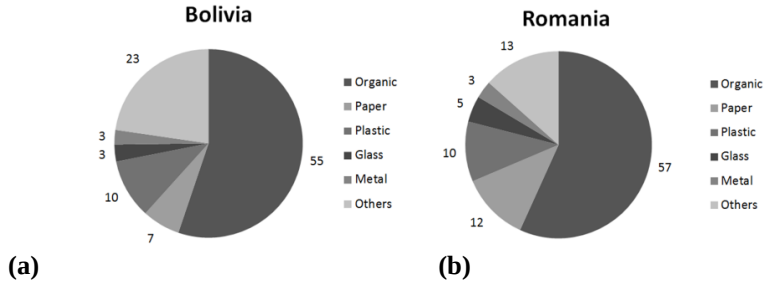

Fig. 3 Average solid waste fraction in (a) Bolivia [18] and (b)Romania [31]

In this framework, the informal sector has an important role for both countries as regard the recycling chain and the CE. Romania, despite the GNI achieved in the last years, is constantly supported by the work of the waste pickers, and the European Commission in 2011 estimated that about 40,000 tons of waste per year were introduced in the informal recycling chain. Mostly similar amounts were estimated also in Bolivia, although such quantities means about the 2-3% of the total recycling practices into the country. Therefore, the CE practice is mainly introduced by scavengers and waste pickers which operate constantly within the whole country. The informal activity, commonly applied in developing regions worldwide [47], is mostly introduced equally in Romania and Bolivia like opportunity of employment, although it is not recognized.

The considerations that were introduced in this section lack of recent and reliable information, especially for the case of Bolivia. However, global reflections can be made concerning the introduction of the CE within the case studies presented, highlighting pros and cons for a developing region inserts within the EU framework. Table 5 sum up such advantages for an upper-middle income like Romania. The main tool which commonly miss in a developing country is the introduction of reliable regulations which can support the development of recycling activities. Indeed, Bolivia main issue is the introduction of suitable rules for the application of RL systems including the informal sector and all the stakeholders involved. As a result, international hints, the implementation of sustainable goals and the support of experts can provide an effective aid for introducing the CE in developing regions. This consideration is applicable for the Romanian case study which, on one hand, has been attended during the process of developing by financial aids, technical knowledge, private investments and CE principles, unknown before the entrance in the union.

Table 5 Pros and cons for the entrance of a developing country into the EU in a SWM perspective

Pros	**Cons**
• Regulation system ready to be introduced	• Goals quite strengths for a developing region
• Economic aids and European fund	• Scarce indications for achieving the recycling rate required
• Reliable information sets required by EU	• Expensive penalties that should be paid in case of failure
• Obligatory introduction of CE principles	• Poor consideration of current SWM practices (informal sector)
• Technical support and open markets	

On the other hand, EU waste directives are challenging in developing and transition countries, as stated also by other authors [48], since the lack of know-how and improvement systems do not allow the implementation at short terms of

such principles. Indeed, citizens, municipal governments and private sector should implement EU regulations that are new for the area, hence not easy to implement and introduce. Moreover, expensive penalties should be pay in case of failure, which can imply a dangerous effect.

3.4. The implementation of the CE model

The model suggested in this dissertation is a simplification of the application of a CE system applicable within a developing country, taking into account specific issues which are not improved. It is a reference example in order to explain the current situation of the both countries considered.

The main activity suggested is the involvement of the informal sector within the sanitation systems. It is of utmost importance in particular for the Bolivian case study. Indeed, the recycling rate is mostly improved by waste pickers and scavengers, which, to date, have been introduced a shape of take back program within the country. In particular, the presence of recovery shops is commonly and are widely scattered within the main big cities. As a result, this practice can be introduced without many difficulties, except for public inclusion and waste pickers involvement, topic that should not be neglected. However, the secondary raw material produced by the informal recycling chain is currently sent mostly in other neighbor nations and are exploited locally by big companies only in low rates. In conclusion, the informal activity is just applied in both country, while the process of formalization is not well developed.

The main differences between Romania and Bolivia in the CE model suggested is the possibility for implementing a MBT plant before landfilling. Indeed, the exploitation of the organic fraction, in Romania, as indicated by the EU, should be implemented by the introduction of anaerobic digestion plants; moreover, incineration facilities can be introduced within the waste management chain reducing the waste inflow into the landfill, so reducing the needs to implement a MBT system. Anyhow, the method introduced in this model is suggested like short term solution for the municipalities that are not able to introduce expensive facilities, and, at the same time, because RDF can be immediately introduced within the cement kilns widespread in the area. Bolivia, instead, can be the reference example for introducing MBT treatment plants, since it is a low-cost methodology which can solve, like first step, environmental issues typical of a region with no controlled landfills and with the lack of monitoring. Of course, such method should be evaluate for each study area and urban dimension in order to be a cost effective method. However, the use of RDF and the exploitation of metals recovered by the system can be an appropriate option. Other approaches could be applied, such as the introduction of manual selection before landfilling. However, this methodology was not considered within the model in order to improve and boost the involvement of the informal sector in the curbside collection that is currently applied. In spite of which model, methodology or application will be applied, the common issue is the presence of open dump sites; as a result, the construction of controlled landfills is imperative and international aids are required for both cases.

Concerning the second step, the most important consideration, valid both for the Romanian and Bolivian case study, is that the progress of the CE can be introduced only by the recovery of all the material discarded by households. However, there are material more difficult to recover and many investment, most of all private, are required. Indeed a public-private partnership is essential in order to implement and introduce suitable recovery plants which can treat sanitary and hazardous materials, end of life batteries, tires and WEEE. Romania introduced a few practices in order to develop the second step of the model as introduced within the European regulation and by the CE principles. However, Bolivia still lack such practices, except for treating tires which are shredded in Amazonian areas for preventing dengue propagation during the rainy seasons.

4. **Conclusion**

The case study presented in this dissertation allow understanding opportunities and main difficulties for a developing region included in the EU for the introduction of a CE model. Moreover, the comparison with a developing region inserted in a different environmental and social framework gave the picture of the current advantages of the inclusion within a community where CE principles are applied. Despite the economic level, Romania and Bolivia are both facing with many management issues although in different amounts: Romania is an emerging region which takes positive aids by EU for improving the SWM while Bolivia is a developing country with a low economic growth, where regulation systems and the introduction of new technologies is still poor.

The development of a CE model in Romania requires national strategies, which includes means to sustain the adoption of necessary new consumption behaviors. Recycling options in Romania have started to emerge, but the financial crisis of 2008 has slowed down the trend, while positive changes could be seen since 2010, although the 2-3% of recycling rate, which today raised to 13%, is still very far from the desired scenario [37]:the European Commission set a target for recycling 50% of MSW by 2030. So, the situation in Romania cannot be described as encouraging, since Romania is one of the country with the lowest level of waste recycling in the EU-28. European social funds and regulation limits led to improving sanitary conditions although with low efficiency. Nevertheless, good responses are given by packaging waste recycling which overcome the European goal of 55% recycling rate although there is the tendency to adopt laws and regulations resulting from an acceptance of standards from high income countries that may not be financial sustainable. On one hand is visible how Romania cannot achieve EU goals for 2020 for poor improvement and behavior changes, on the other, EU recommendations are of utmost importance for starting a CE approach, which is more difficult for developing countries where financing sustainability and regulations systems are still lacking

One of the main problems in Bolivia is the lack of reliable data sets and the miss of continuous monitoring on sanitary burden and natural resources contamination. Moreover, literature about SWM is scarce, making more difficult to obtain an historical approximation of the experiences on environmental science and engineering. The informal sector is the main actor which improves the recycling rate while the lack of monitoring and data collection do not encourage the development of a CE. As a result, Bolivia need international aids in order to improve in short terms its SWM since future economic improvement could be of interest for international markets.

The CE model suggested in this paper can be a reliable and applicable solution for developing countries. However, financial sustainability, stakeholder inclusion and regulation development are required. The example reported are of interest as concerning one developing country with low economic aids and with unreliable regulation, and another inserted into the EU and with a great economic development. Clearly, the implementation of a CE system must take into account the specific needs of a country, however a general indication is important for starting to implement the principle of the CE for a sustainable development. This comparison would introduce such consideration, aiming to give a direction for RL improvements in developing countries, since the sustainable development pass through the international implementation of the CE principle, guarantying the preservation of natural resources and environmental conditions.

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