ECO-INNOVATION PROMOTING THE CIRCULAR ECONOMY IN ROMANIA

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Abstract: *The development of eco-innovation parks in our country may be a key to regional as well as national sustainable development, due to their special features and opportunities for industrial synergy. Implementing a circular and green economy is also a current important challenge to a systemic transformation agenda in the European Union. Therefore, a main objective of this paper is to analyse from the viewpoint of the circular economy principles (closing-the-loop in the resource management) the strategic role of eco innovation parks as a community of manufacturing and service enterprises seeking enhanced environmental and economic performance through collaboration in managing environmental and resource issues including energy, water, and materials. In this respect we analyse both the conceptual and practical importance of eco-innovation for the circular economy and point out the character of the industrial ecosystem, as a regional metabolism in fostering both eco-innovation and industrial synergy of the SMEs and organisations involved. The case studies and conclusions recommend the urge to identify, design and plan industrial ecosystems within an eco-innovation park as an important way promoting circular economy on regional, microeconomic and sectoral scale in Romania.*

Keywords: *sustainable development; circular economy; resource efficiency; eco-innovation park; industrial symbiosis*

JEL Classification: *O44; O47; Q32*

1. Introduction

In this paper we have resumed our research in the fields of sustainable economic growth, resource-efficiency and eco-innovation, by adopting a new research objective: grounding and analysing the concepts, principles and implementation issues of the circular economy. The secondary objective of this paper is a deeper analysis of the eco-

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innovation and eco-innovation park' potential to play a decisive and major role in the transition to a green economy in Romania, by implementing industrial symbiosis as a high form of circular economy.

This reinforces the strategic role developing eco-innovation parks as industrial ecosystems for the manufacturing and service enterprises and the local authorities seeking enhanced environmental and economic performance through closer collaboration in managing environmental and resource issues.

We detail some of the characteristics and relationships for the green economic growth, focusing on the concepts of circular economy, eco-innovation, eco-industrial parks, resource efficiency industrial synergy. Special attention is given to the concept of circular economy, as one of the revolutionary paradigms of sustainable economic development and a priority of the EU policy agenda.

Based on our previous research outcomes which have proved a direct, positive correlation between the number of existing eco-innovation parks EInvP and the national level of resource productivity (as a macroeconomic indicator of the resource-efficiency) in European countries included in the analysed sample (Frone Simona, 2015), a deeper analysis emphasizing especially the synergic features of the eco-innovation parks (EInvP) in re-cycling and re-using the resources, so closing-the-loop as desired in the circular economy.

The methodological approach will be based on literature review, mostly on some European Commission documents, ourn recently published theoretical and empirical research findings to be reanalysed and developed from a new viewpoint, and on a case study. In the case studies we give examples of good practice, with the first circular economy workspace and with the ecosystem of industrial symbiosis in Suceava, which, according to our conceptual framework, may be considered an eco-innovation park.

The theoretical and empirical outcomes of previous research, the current analysis and synthesis, the data analysis in tables and graphs or figures and the evidence from the case study referring to the enhanced resource-recovery and other significant environmental and socio-economic performances within the ECOREG eco-innovation park support the research objectives of the paper.

2. Conceptual research framework

2.1. General background concepts

Sustainable development now involves carrying out a green economic growth. This new paradigm is due to the fact that, as stated in the strategic documents for economic

development (EC COM(2011) 571 final), sources of minerals, metals and energy, as well as stocks of fish, timber, water, fertile soils, clean air, biomass, biodiversity are all under pressure, as is the stability of the climate system.

If we carry on using resources at the current rate, by 2050 we need, on aggregate, the equivalent of more than two planets to sustain us, and the aspirations for a better quality of life will not be achieved. To avoid this unsustainable outlook, resource-efficient economy is strongly required, close to ideal concepts like a 'green economy' or a 'circular economy' (Frone Simona, Frone D.F., 2015) for promoting a systemic transformation in the way resources flow through the economy and society, as we shall further analyse in detail.

This approach leads to the need of a deeper analysis and understanding of the eco-innovation, eco-innovation parks and industrial ecosystems, as some important concepts related to the complex changes paradigm required by the green economy (Frone Simona, 2015). The green economic growth presents an alternative to the conventional economic paradigm of resource exploitation and is built around a theory of growth that integrates concepts such as the sustainable use of natural resources, including greater energy and resource efficiency and improved natural capital as drivers of growth.

The general methodological approach (Table 1) is based on literature review and mostly on some own recently published theoretical and empirical research findings, to be reconsidered and developed from a new viewpoint.

Table 1 - General background concepts of the present research

Concept	Definition or characteristics
Sustainable development	"Development that meets the needs of the present without compromising the ability of future generations to meet their own needs."— from the World Commission on Environment and Development's (the Brundtland Commission) report, Our Common Future (Oxford: Oxford University Press, 1987)
Eco-efficiency (Resource-efficiency)	Eco-efficiency may be acknowledged as a more general expression of the concept of resource efficiency , minimizing the resources used in producing a unit of output ,and resource productivity ,the efficiency of economic activities in generating added value from the use of resources. Eco-efficiency is achieved through the delivery of "competitively priced goods and services that satisfy human needs and bring quality of life while progressively reducing environmental impacts of goods and resource intensity throughout the entire life-cycle to a level at least in line with the Earth's estimated carrying capacity"(WBCSD).
Resource productivity	Resource productivity is defined as the ratio of GDP to domestic material consumption. Domestic material consumption measures the total amount of material directly used by an economy, such as biomass products, metal ores,

Concept	Definition or characteristics
	fossil fuels, non-metallic minerals, petroleum resources etc. and is equal to domestic material extraction plus imports minus exports.
Industrial ecology (IE)	Industrial ecology explores the assumption that the industrial system can be seen as an ecosystem. Industrial systems, just as natural ecosystems, can be described as a particular distribution of materials, energy, and information flows. Furthermore, the entire industrial system relies on resources and services provided by the biosphere, from which it cannot be dissociated. Industrial ecology suggests using the design of natural ecosystems to guide the redesign of industrial systems and offers opportunities and solutions to turn industrial parks into eco-industrial parks.
Circular economy	In a circular economy, the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimised. It is an essential contribution to the EU's efforts to develop a sustainable, low carbon, resource efficient and competitive economy, ultimately the green economy (COM/2015/0614 final).
Green economy	In a green economy the growth in income and employment is driven by public and private investments that reduce carbon emissions and pollution, enhance energy and resource efficiency, and prevent the loss of biodiversity and ecosystem services. The UNEP working definition of a green economy: an economy that results in improved human wellbeing and social equity, while significantly reducing environmental risks and ecological scarcities. In its simplest expression, a green economy can be thought of as one which is low carbon, resource efficient and socially inclusive (UNEP, 2011).

Source: Own synthesis mainly based on references.

As we see in Table 1, the green economy requires step changes in resource efficiency, investment in clean technologies, new alternative products, services and materials, and the ability to obtain value from the unavoidable waste (UNEP, 2012).

In this paper, with the theoretical and empirical approaches employed there is argued more on the need to acknowledge and better understand the concept and aim of the circular economy (a feature of the green economy) designed to close the loop in product life cycles by keeping as many resources in the economy as possible, thereby reducing waste and promoting sustainability (EC Panorama, 2016).

2.2. The circular economy as a feature of the green economy and a strategic development principle in the European Union

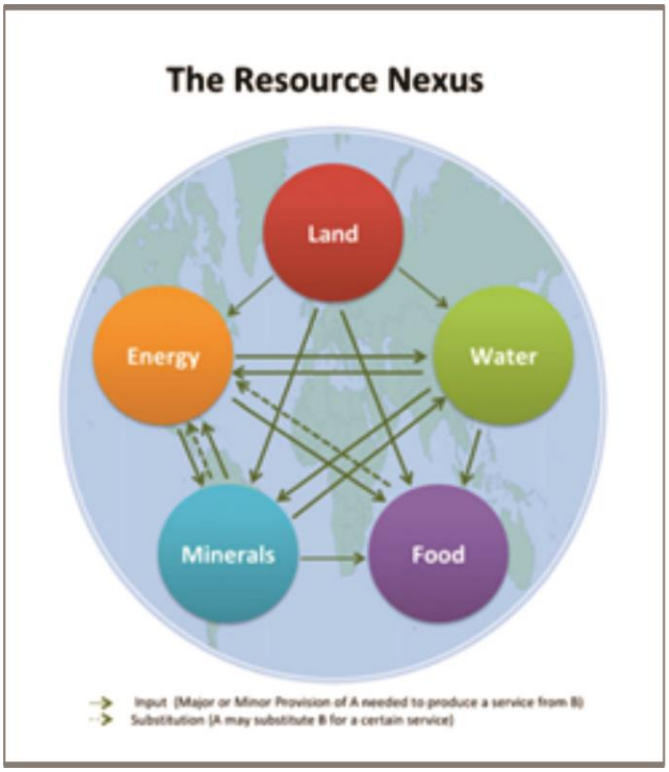
Green economy aims at sustainable management of environmental resources, based on the belief that our biosphere is a closed system with finite resources and a limited capacity of self-regulation and self-renewal.

As suggested in Frone D.F., Frone S., (2015) the global resource nexus model is very suggestive of a green (circular) economy model and especially of our topic, since the importance of the sustainable management of natural resources and of their increased resource-recovery and efficiency is better acknowledged.

To be followed and analysed carefully, the resource nexus (Blesichwitz R.*et al*., 2014) is a conceptual model that illustrates the interconnections between and among different resources (Figure 1); in other words, it visually displays that one resource (or more) is used as an input to produce another resource.

This is well suggested in Figure 1 since the legend specifies: a black continuous arrow from resource A to resource B shows that an amount of A is needed to produce a service from B; a black discontinuous arrow from resource A to resource B shows that A may substitute B for a certain service.

Figure 1: The global resource nexus model



Source: Figure 1 in (Blesichwitz R.et al., 2014).

By analysing the global resource nexus model (Figure 1) we notice some striking features and ideas:

- since all the environmental and natural resources of the planet are so interconnected and our economy relies on them, the sustainable development is required for the global survival and welfare, in the long run.
- there are some natural resources, such as water and land, which are really critical and may not be created and replaced by any others.
- only more efficient production processes and better environmental management systems may save water and other resources, and can significantly reduce pollution and waste.

The green economy is called to implement a more systemic and holistic socio-economic mechanism taking into consideration the sustainable management of the environmental and economic assets to preserve the ecosystem services and to ensure increased welfare of the planet.

According to an expert study (Szyja P., 2016), creating a green economy is aimed at achieving the following objectives: increase in energy and raw materials efficiency; reduction ingreenhouse gases (especially carbon dioxide); reduction of pollution resulting from production processes; increase in energy security; mobilizing the innovative potential; acquiring new competitive advantages.

As a feature of the green economy, circular economy the re-use of resources in products whose shelf life has come to an end or which have lost their usefulness to construct new objects, the same quality or even better. The circular economy model may be the ideal solution for relaunching sustainably the European economy which has faced problems in recent years (2008-2012).

The principles of a circular economy support ideas and mechanisms for increased competitiveness and economic growth in the European Union, by: creating new business and job opportunities; transforming and revamping the processes of consumption for better efficiency; the correct management of resources.

Therefore, the European Commission launched in December 2015 the ambitious **Closing the loop – An EU action plan for the circular economy (**COM/2015/0614 final) as a package of measures to develop the circular economy. It is believed that by stimulating sustainable activity in key sectors and new business opportunities, the plan will help to unlock the growth and jobs potential of the circular economy. Nevertheless, although the action plan focuses on “action at EU level with high added value”, implementing the circular economy will still require “long-term involvement at all levels, from Member States, regions and cities, to businesses and citizens”. Member States

(including Romania) are invited to play their full part in EU action, integrating and complementing it with national action.

The circular economy requires an innovative approach to production and consumption that offers the savvy entrepreneur significant opportunities (EC Panorama, 2016). As we further argue in the paper, we consider that the Eco-Innovation Parks and the industrial symbiosis within provide such an innovative approach to production and consumption which really increases the business, innovation and development opportunities for all the green-aware enterprises and authorities in an area or a region.

The EC action plan for the circular economy **(**COM/2015/0614 final) actually states that it is important to promote innovative industrial processes. For example, industrial symbiosis allows waste or by-products of one industry to become inputs for another. In revised proposals on waste, the Commission proposes elements to facilitate this practice, and will engage along with Member States to help ensure a common understanding of the rules on by-products."

Innovation will play a key part in the systemic change for the circular economy. In order to rethink our ways of producing and consuming, and transforing waste into high value-added products, we need new technologies, processes, services and business models shape the future of our economy and society.

The Horizon 2020 work programme 2016-2017 includes the initiative: "Industry 2020 in the circular economy", which will grant over €650 million for innovative demonstration projects that support the objectives of the circular economy and industrial competitiveness in the EU in a wide range of industrial and service activities, including process industries, manufacturing, and new business models.

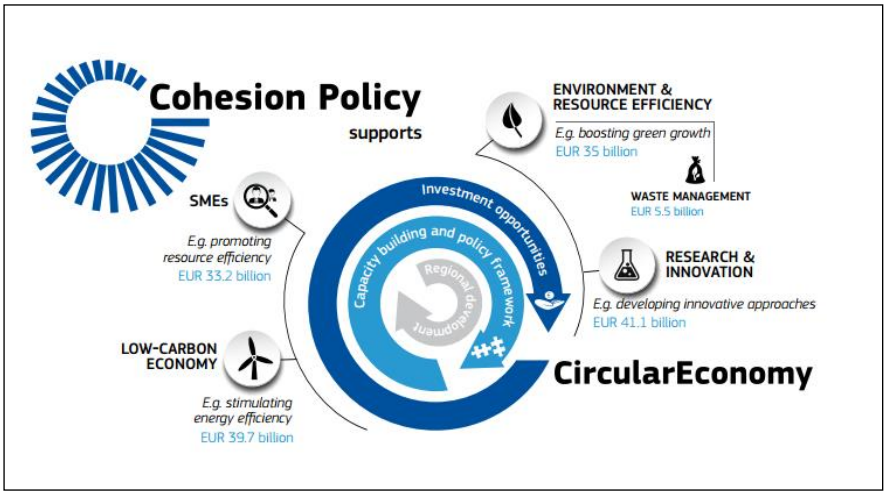
The EU Cohesion Policy funding can support its objectives, according to some important provisions of the Action Plan. The European Commission supports regions through, for example, the Smart Specialisation Platform which provides professional advice on the design and implementation of their research and innovation strategies for smart specialisation. The platform also helps facilitate interregional cooperation on issues related to innovation for the circular economy – and in specific areas like industrial modernisation (EC Panorama, 2016).

Cohesion Policy funds are directed towards a growing number of programmes supporting the circular economy, including support for reuse and repair, improved production processes, product design and SMEs (Figure 2):

- for Research and Innovation projects, the funding will be the most important, amounting to 41.1 billion Euro;

- for Environment and Resource efficiency programmes, the funding is up to 35 billion Euro;
- for the dedicated SME projects, the funding is up to 33.2 billion Euro;
- for developing the Low Carbon economy, the Cohesion funding is up to 39.7 billion Euro.

Figure 2. Mechanisms and policies of the EU Cohesion policy promoting the circular economy



Source: EC Panorama Autumn 2016/No.58, pg.18

The Commission will assist Member States, regions and local authorities in strengthening their circular economy approach in this context through targeted outreach (COM/2015/0614 final).

2.3. The role of eco-innovation for developing and implementing a green (circular) economy

In a green economy, all the economic organizations and stakeholders must develop the ways and vectors that will assure more efficient production processes and more performant environmental management systems. These developments are called to significantly reduce pollution and waste, to save water and other critical natural resources and ecosystem services.

In this respect, technological innovation could become the cornerstone of minimizing pollution and, at the same time, the key to global sustainable economic development [Constantinescu A., Frone S., 2014). Moreover, when looking for a balance between aspirations towards sustainability and locally existing possibilities to implement it, other important concepts have resulted: eco-innovation, eco-innovation parks, industrial synergy.

Eco-innovation is a principle that combines economic growth, employment and sustainable development in an integrated manner as required by the Lisbon Strategy.

This economic growth can create green gains for society provided a long-term vision regarding issues of resource conservation and of the environment and strong support from both the public authorities and citizens.

Eco-innovation is indeed a pillar of the green economy, having a double valence, both for ecological and economic accounting: a way to improve the protection of the environment; a way to increase the efficiency of resource use, contributing indirectly to increasing economic competitiveness.

Also stated by Frone D.F., Frone S., (2015) resource-efficiency is a main paradigm behind the green and circular economy system that optimizes the flow of goods and services to get the most out of raw materials and cut waste to the absolute minimum.

In previous papers we focused on the theoretical and methodological features of eco-innovation as a driver of sustainable economic development (Constantinescu Andreea, Frone Simona, 2014), and also on eco-innovation parks (EInvP) as vectors of transition to a green economy.

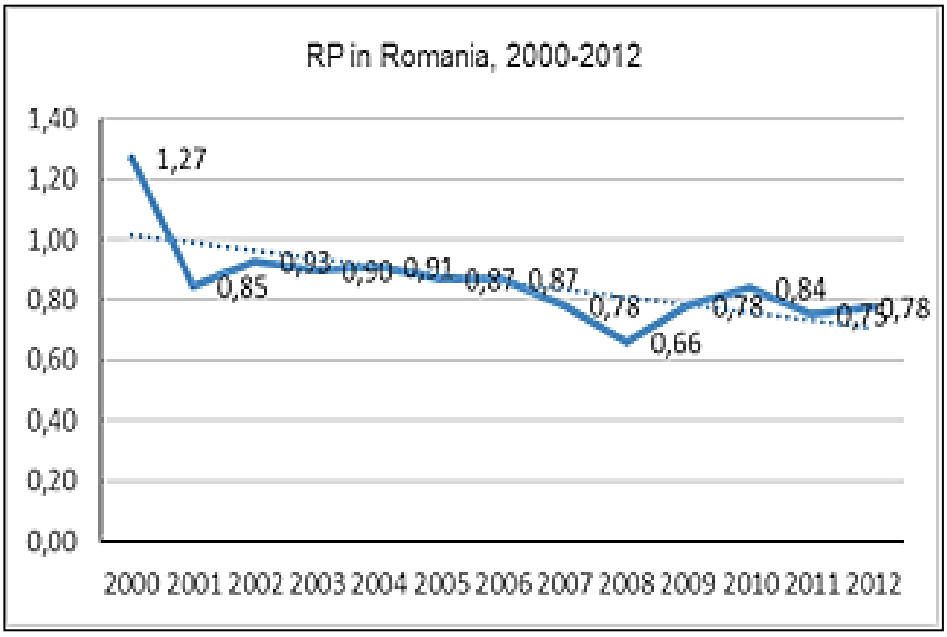
Here we would like to analyse the role of the eco-industrial and eco-innovation parks as regional metabolisms and industrial ecosystems, developed by grouping several SME-s in a certain area in order to let them share some technological eco-innovation facilities, as well as to put them in a relation of industrial synergy, leading to waste recovery and recycling as a resource, eventually improving the resource efficiency and productivity on the microeconomic as well as the sectoral and regional scale.

The concern for improved resource efficiency is crucial since the issue of low resource productivity (RP) in Romania is striking, as we showed in previous research papers. We notice (Figure 3) that over the period 2000-2012, the evolution in Romania of the resource productivity RP indicator development was quite significant and the overall trend is undoubtedly downward.

For the entire period considered (2000-2012), the overall resource productivity (RP) in Romania remained low, and even decreased more (with 38, 6% in 2012 as compared to 2002, see Figure 3). Since this downward RP trend in Romania was registered

simultaneously with an upward trend of the RP in the EU27, in 2000-2012, the resource productivity gap in Romania compared to the EU average has increased, missing the 2013 objective of the National Sustainable Development Strategy (Frone S., Frone D.F., 2015).

Figure 3 - Resource productivity (RP) evolution and trend in Romania, 2000-2012 (Thousand lei/t, 2005 prices)



Source: Own computations in Frone S., Frone D.F., (2015).

In the strategic efforts for a sustainable development, the motto "to achieve more quality goods and services with less consumption of natural and social resources" has become a common goal for many companies and the technological solutions adopted (Zaman G., 2014). Therefore, as a reaction to the latest economic as well as environmental challenges, some specific concepts have been developed and implemented in the last 20 years, especially in advanced economies such as the western EU.

Industrial areas are still underpinning economic development in many countries and can provide leadership in the area of environmental performance and resource efficiency by eco-innovation in the introduction of better environmental practices, because of their

provision of common infrastructure, their links with government institutions or by influencing the local suppliers due to their position in the global supply chain.

So it is important to acknowledge (see Table 2) the characteristics and the importance of the new concepts developed for the regional (spatial) dimension of the green economy.

Table 2 - Concepts of spatial eco-innovation and green (circular) economy

Concept	Definition or characteristics
Eco-innovation	Eco-innovation is any form of innovation aiming at significant and demonstrable progress towards the goal of sustainable development, through reducing impacts on the environment or achieving a more efficient and responsible use of natural resources, including energy. Collaboration among project partners (private and academia) for research and development is an important element for eco-innovation.
Eco-industrial park	An eco-industrial park is a community of manufacturing and service businesses seeking enhanced environmental and economic performance through collaboration in managing environmental and resource issues including energy, water, and materials. By working together, the community of businesses seeks a collective benefit that is greater than the sum of the individual benefits each company would realize if it optimized its individual performance only (Lowe, 1997).
Industrial symbiosis	Industrial symbiosis (IS), as part of the industrial ecology research field, focuses on the flow of materials and energy from local and regional economies. Industrial symbiosis traditionally engages separate industries in a collective approach to a competitive advantage involving physical exchange of materials, energy, water, and/or by-products as well as services and infrastructures shared at the industrial park scale to reduce environmental impact and overall production cost (Mansard, 2011). The factors for industrial symbiosis are collaboration among actors and the synergistic possibilities offered by geographic proximity (Chertow, 2000).
Eco-innovation park (EInvP)	The term eco-innovation park is used to define both, eco-industrial parks and eco-innovative areas combining residential and industrial activities. Eco-innovation parks are optimized from an environmental point of view (e.g., piloting installations and processes that incorporate environmental technologies and services) and are open for continuous improvement (e.g., collaboration with institutions of research and development).
Industrial ecosystem	The broadest application of industrial ecology's analogical approach is to describe manufacturing complexes as "industrial ecosystems". This idea suggests a web of interaction among companies such that the residuals of one facility become feedstock for another. Industrial ecosystems aim to minimize inefficiencies and the amount of waste created by mimicking natural ecosystems in industrial systems.

Concept	Definition or characteristics
Regional metabolism	Within this concept, the assessment of ecosystem services can be integrated and based on the ecosystem approach and can form a unified framework of various insights dedicated to saving the environment. It opens the possibility of describing in detail the links between ecosystem services auditing and economic sectors they support. By binding the problem of the ecosystem services management to a regional metabolism functioning, we can choose the most appropriate strategy to adapt them to the conditions represented by a territory.

Source: Own synthesis mainly based on references.

According to a comprehensive dedicated study (ERA-NET ECO-INNOVERA, 2014) all these concepts, methodologies and procedures may be considered as eco-innovation when applied to an industrial or combined (*i.e*. urban and industrial) area.

Another paper concerned with the academic entrepreneurship and scientific innovation in the context of bio-economy strategy (Pipirigeanu M. *et al*., 2014) has stated that: "the current biodiversity loss is huge, increases every year, but many people are not aware of this at the moment. In general, structural changes to green business systems are not noticeable from one year to another (unless major environmental accidents and short term). Subsequently, eliminating disturbing factors, the natural environment can recover."

Therefore, eco-innovation designed for an entire area or regional metabolism would enable a systemic response to the sustainable development and green economic premises. Thus one of the most important concepts for the new paradigm of green economic growth and resource efficiency improvements is the industrial symbiosis (industrial ecology, industrial ecosystem) approach.

A recent outstanding study dedicated to the regional endogenous development in the case of Romania (Zaman G., Georgescu G. *et al*., 2015) outlined that an important part of the regional development programmes, in the post-crisis period should support the innovation and diversification of the local economies. This should be done especially by: boosting private investment in the fields of RDI, achievement of synergy among active RDI institutes at the regional level and the needs of local business communities, implementation of innovation activities in enterprises as well as stimulating the innovative activities and technology transfer from the universities or innovation centres towards the productive sector.

To link the premises for regional endogenous economic growth to the sustainable development and green economy trends and issues, we shall emphasize the role of

eco-innovation, as the particular type of innovation, in the regional green and circular economic development.

The collaborative patterns in industrial areas, also known as eco-industrial networks, industrial symbioses or industrial ecosystems, *are a type of eco-innovation applicable the scale of an eco-industrial park*.

Consequently, the eco-innovation parks (EInvP) are basically eco-industrial parks (EIP) which also embed research and development institutions pro-actively involved in technological innovation dedicated both to economic and environmental objectives, such as the increase in resource-efficiency (see the descriptions or definitions in Table 2).

In what follows we analyse more deeply the features of the EInvP as a regional metabolism and industrial ecosystem, implementing circular economy in a region.

3. Eco-innovation promoting the circular economy in Romania

3.1. Issues and trends of the eco-innovation in Romania

While the issue of poor or inefficient resource management was signalled in the previous edition, it is important to point out that the last EIO Country Profile report on Romania specifically raises the issues of barriers to and drivers of circular economy and eco-innovation in Romania.

According to the latest EIO Country Profile (EIO, 2015), Romania ranks 18th in the Eco-Innovation Scoreboard (Eco-IS), obtaining a score of 87.1. This indicates it is below the overall EU-28 average score 13%. However, it is encouraging that our country has advanced three positions since 2013, from of 21st to the current rank.

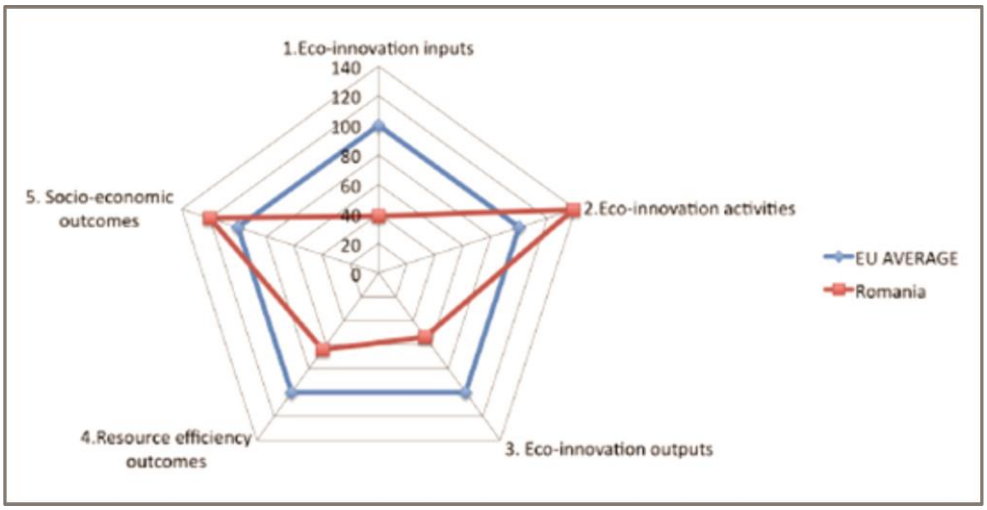
The best accomplishment is the fact that Romania ranks above the EU average in terms of eco-innovation activities, with an average score of 138 (38 points above the EU average score of 100). This is a positive improvement as against 2013, and the high score may be observed in Figure 4.

As reported in EIO 2015, in Romania, the positive results of eco-innovation activities are driven by a third indicator measuring the irms' interest in standardisation of their environmental management. According to the 466.3 companies per million inhabitants with an ISO 14001 certification in 2014, Romanian companies place a high importance on observing environmental management requirements.

Unfortunately, Romania's performance in achieving resource efficiency is stagnating, according to the latest data, as the economy remained on average 40% less resource efficient than the EU. As we notice f Figure 4, the highest contribution to the progress of

Romania's eco-innovation score is given only by some eco-innovation activities and the socio-economic outcomes.

Figure 4 - Components of the eco-innovation composite index for Romania, 2015



Source: Figure 2, page 4 in EIO 2015

Material (resource) productivity compares GDP generated relative to material consumption, measured in euros per kilogramme (EUR/kg), which amounted to 0.66 EUR/kg in 2013. The (EIO, 2015) report confirms some of our recent research outcomes (Frone S., Frone D.F., 2015) in showing that due to the increase in EU-level average material productivity, the gap is widening between the Romanian and the EU average (EU reached 1.93 EUR/kg average resource productivity in 2013).

There are also some other important features of the Romanian economy resource efficiency to be considered for eco-innovation in the transition to the green economy. According to the EIO 2015:

- the energy productivity, calculated as GDP relative to energy consumption and measured in euro per ton of oil equivalent (EUR/toe), is above EU average and has been rising, amounting to of 8.9 EUR/toe (108% of the EU average of 8.3 EUR/toe) in 2011. This evolution is due to the Romanian energy market, reaching a surplus production in 2014.

- the GHG emission intensity is somewhat higher in comparison to the EU average, amounting to 0.4 units of CO2-equivalent emissions generated per unit of GDP. The EU has a level of 0.35 CO2 - equivalent emissions per unit of GDP in 2013.

Due to more data available for Romania, the total score for socioeconomic outcome is now 20% above EU average performance (Figure 4). There are two indicators composing this sub-index which have improved due to the increased data availability and are not comparable to previous EIO reports: the employment in eco-industries is 4.26% of total employment in Romania in 2014, and this level places Romania at 68% above the EU average level of 2.53% of total employment in 2014; the eco-industries' revenue in Romania is also above EU average, at 2.99% of total revenue across sectors, as compared to the EU average turnover of eco-industries amounting to 2.2% of total turnover in 2012.

After reviewing these figures maybe more important are the identified trends in the selected circular economy and eco-innovation areas in Romania.

An important issue raised in EIO 2013 was that the Romanian SMEs were less likely to adopt measures to improve their resource efficiency in comparison to the EU average and had a low propensity to collaborate. These are important challenges for a systemic transformation agenda in the European Union such as the circular and green economy.

According to the most recent report EIO 2015 Romania's eco-innovation system can be broadly characterised in terms of push and pull factors acting in opposition. Indeed, there still is:

- a low level of investment in basic infrastructure and framework conditions for recycling, waste management and resource efficiency;
- low input into R&D from the public and private sectors.

The Green Business Index 2015, measuring the companies' environmental responsibility for 2014 (Green Revolution, 2015) provided a deeper analysis of the eco-innovative and environmental behaviour and approach of the Romanian enterprises. The main issues in the report include the following:

- Companies show weak environmental awareness and weak levels of transparency and communication on environmental issues. However, they increasingly make use of ecological product design, in spite of low uptake of environmental labelling.
- In terms of cost assessment, companies do not measure or do not want to declare the costs and benefits obtained through their environmental management practices.

- The surveyed companies do not monitor the resource use systematically, so they are not able to take measures to improve their environmental performance.
- A notable change is the increase in companies' use of renewable energy sources. Now 9.3% of the surveyed companies predominantly use renewable energy sources, while for 18.5% of the companies, less than 50% of their energy use comes from renewables.
- The majority of the surveyed companies (57%) do not use recycled resources as production materials at all, while for another 16.3%, recycled resources make up less than 2.5% of their production materials.
- A rising number of companies started implementing waste management policies: 83% in 2014, which is an increase of 15% compared to 2013. Although all of them also have a policy for minimising their waste production, but only 60% took actual measures. However, this trend is a promising one, towards more sustainable use of resources.

On the other hand, confirming the previous findings that eco-innovation activities are on the rise in Romania (EIO, 2013), there are islands of eco-innovation at the grass-root level that have gradually accumulated. They have the potential to reach the critical mass, and possibly have positive spill - over effects on further fields of economic activities in time.

While grass-root initiatives provide an indication of the economic potential and dynamism of the field, they generally need larger-scale investment and support to have a significant impact.

Nevertheless, after Romania's EU accession in 2007, the European Union Cohesion funding have been an important source of public investment in Romania, fostering some eco-innovation and green reforms. Some of the results of this funding are worth mentioning, according to the EIO 2015:

- The Competitiveness Sectoral OP 2007-2013 was an important funding source for eco-innovation and circular economy-related projects. For instance, the programme provided investments for 56 projects (either finalised or running in 2016) that use biomass, hydro-energy, solar, wind and biofuels as energy generating resources
- The Environment Sectoral OP 2007-2013 funded the majority of the environmental infrastructure investments. For example, by the end of 2015, it supported projects related to diminishing GHG emissions in the energy sector by investing €237 million in energy production from non-polluting sources; provided €2.2 billion to projects

related to modernising water and wastewater treatment facilities; and €500 million to projects in the waste management sector.

Indeed, as a conclusion to previous research, Romania's ability to provide efficient infrastructure and environmental services, both nationally and locally, is an important factor stimulating and supporting sustainable economic development. Therefore, besides providing water security for socio-economic development, the investments in environmental infrastructure funded and implemented within the Environment Sectoral OP 2007-2013 are much needed and expected in the national economy in view of complying with the EU Environmental Acquis.

However, a preliminary analysis shows, for instance, that due to significant challenges in analysing the correlation between water infrastructure and economic development and the peculiarities of the water supply and sanitation sector in Romania, the economic and environmental efficiency and sustainability of the Cohesion funded SOP Environment infrastructure investments has still to be further analysed and proved.

From the viewpoint of the green economy as a feature of sustainable development, we shall resume here the research on the importance of investment in environmental and business infrastructure, for fostering the regional scale eco-innovation able to provide for eco-innovation parks and industrial ecosystems eventually promoting a circular economy in Romania.

3.2. Industrial symbiosis in eco-innovation parks promoting a circular economy

Collaborative patterns in industrial areas, also known as eco-industrial networks, industrial symbioses or industrial ecosystems, are a type of eco-innovation applicable on the scale of an eco-industrial park, turning them into eco-innovation parks (EInvP).

The main conclusion of our approach in Frone Simona, (2015) was based on a regression model showing that in the 16 European countries of the analysed sample there is a positive correlation between the number of existing eco-innovation parks (EInvP) and the national level of resource productivity (as a macroeconomic indicator of the resource efficiency).

Based on the ERA-NET ECO-INNOVERA 2014 survey we have observed also the three main categories of benefits from eco-innovation parks, which are inter-connected, national, sectoral and local, public and private benefits:

I. The reduction of natural resource consumption and pollution, consisting in: the reduction of energy and material inputs on the plant and the park scale; increased

material productivity for economic players; reduction of waste and emissions to the environment on the plant and the park scale.

II. Significant economic benefits, resulting from synergic mechanisms: resource efficiency generating additive revenue for economic actors, providing cost savings and reducing the market dependence of non-renewable and imported resources; participation in eco-innovation projects gives businesses a competitive edge on the growing green market; adaptability and flexibility to regulatory changes.

III. Sustainable regional development, since eco-innovation parks EInvP contribute to the strength of regional economies by fostering innovation and diversity on local and regional scales; eco-innovation strategies reduce the region dependence on non-renewable resources and thus increase its resilience to shortage in supply

In this section, the case-study analysis of the ECOREG (a pilot EInvP in the Suceava County) aims to provide evidence for the actual dimension and realization in these categories of green and complex environmental, economic and social benefits provided by the EInvP.

Also important from the view point of the current research is the key feature of the eco-innovation park in which material flow exchanges (or industrial symbioses) generally encompass other eco-criteria as well, in particular energy efficiency, waste and water management, so leading to an almost exponential growth in the local resource-efficiency, for all the clustered companies.

This inner mechanism of the EInvP closing-the-loop of resource use in a region deserves further attention due to the outstanding green economic growth impact and will be analysed and detailed. The role eco-industrial parks, namely eco-innovation parks EinvP, is not limited to their potential of increasing the resource efficiency but also to implementing and making the new modern synergic and circular business models work.

To foster eco-innovation in eco-industrial parks, several tools have been developed to store and analyse data on material and energy flows. Most focus on supporting the identification of potential networking and industrial symbiosis, few of them including functionalities for project management and technical assessment or integrating geographical information systems (Grant G.B. *et al*., 2010).

An “Industrial symbiosis engages diverse organisations in a network to foster eco-innovation and long-term culture change. Creating and sharing knowledge through the network yields mutually profitable transactions for new sourcing of required inputs and value-added destinations for non-product outputs, as well as improved business and technical processes”. (Lombardi D.R. & Laybourn P., 2012)

It is important for SMEs to be part of an EInvP (eco-innovation Park) and engage in such industrial symbiosis, since it provides a means to improve competitiveness and build resilient and sustainable economies. Eventually, industrial symbiosis helps businesses and organisations to operate in the same way as the natural eco-system where everything has a place and function, and nothing goes to waste. Whether working at company level, within a region or multiple regions, or at national level this eco-system based approach is considered.

Our research also recommends to study the EInvP as regional metabolisms, since as stated in Frone S., Constantinescu A., (2015) the ultimate purpose of the regional metabolism is eco-efficiency, which may indicate the quality of the entire process and on the other hand, represent a guarantee for the willingness of the business and community to restore the health of our habitats. Such regional metabolisms are inspired by of the new theory of Industrial Ecology (IE) designed to enable transformation of the traditional model of industrial activity into a more comprehensive model by which regional economies can be assembled in an industrial ecosystem composition, so the residues of some companies can be used as inputs for others. In addition, industrial ecosystems can be organized around product or material supply chains and/or in defined geographical areas.

A tendency toward planned and facilitated industrial symbioses is widely observed in industrialized and even in some emerging economies like India or China. Many private and government-led experiences are intending to facilitate inter-firm collaborations: in Switzerland, the strong political support fostered the establishment of a policy framework for material, water and energy exchanges within the city of Geneva; in the United Kingdom, the National Industrial Symbiosis Program (NISP) supports companies in diverting waste from landfills by facilitating of collaborations.

Since the National Industrial Symbiosis Programme (NISP) has become a world-known leader and consulting partner in creating and developing industrial eco-systems we should mention it first as European good practice of EU reference, serving as a model for other regional eco-innovation parks, such as the ECOREG in Romania (further analysed).

The NISP was developed in 2005 in the United Kingdom as an 'independent facilitator' to help businesses in various sectors and of various sizes come together to find uses for unwanted materials, aiming to divert significant waste loads from landfill and produce bottom line benefits for companies through reduced disposal costs and new commercial opportunities, by sharing assets, resources, logistics and expertise.

According to the (NISP_Factsheet, 2009), the National Industrial Symbiosis Programme is regionally based, facilitating material exchange over a given geographic area. The twelve UK regions have output targets and all results are externally verified.

Since the launch of NISP in 2005, the programme has: diverted more than 5.2 million tonnes of industrial waste from landfill; eliminated 357,000 tonnes of hazardous waste; prevented the use of 7.9 million tonnes of raw materials; prevented the use of 9.4 million tonnes of industrial water; delivered member cost savings of £131 million; generated £151 million in new sales for the members. This is actually a proof of the important dimension of the circular economy in the U.K. and it is probably still growing (NISP_Factsheet, 2009).

Hence, according to the expertise of the National Industrial Symbiosis Programme (nisp-ecoreg.ro), an efficient industrial metabolism cannot be achieved at the level of a single unit. By coupling two or more units, the material and energy flows become interconnected and various options for recycling matter and energy may emerge. Every surplus becomes a "resource" that the unit can recuse, sell or transfer to another production cycle, usually based on commercial agreements.

In practice using industrial symbiosis as an approach to commercial operations – using, recovering and redirecting resources for recuse – means resources remain in productive use in the economy for longer. This, in turn, creates business opportunities, reduces demands for the earth's resources, and provides a stepping-stone towards creating a circular green economy.

In the following we shall refer to some successful and pioneering circular economy enterprises or industrial eco-systems already working in Romania, as good practices and pilot projects to serve as example and to raise awareness for eco-innovation and circular economy.

For instance, in the EIO 2015 report, the first circular economy workspace in Romania is considered QUIB, a project developed with the help of the European Social Fund, promoting cradle-to-cradle design and circular economy production principles. All of the products developed here are made of recused materials without generating waste. Since opening in 2015, the centre has supported 100 makers to develop 125 products out of 430 tonnes of reused materials.

The services offered by the QUIB centre include support for product design and prototyping, access to a full range of equipment for wood, metal and textiles processing, and several advanced technical tools such as a 3D printer, a CNC router and laser printer. It also offers various creativeness and technical design classes.

According to the EIO 2015, there are several issues to be learned by analysing the main drivers and barriers for opening the QUIB space in the Brasov county:

- the drivers were environmental, as well as the range of economic opportunities that the circular economy offers;

- the barriers to developing the business further include the scarcity of Romanian suppliers of organic raw materials, so that the company had to import the raw materials from Germany or Italy, because businesses are hard to convince to give up materials they do not use.
- the workers are not accustomed to using as little material as possible, while the Romanian consumers place less value on the sustainability of products, but more on the design.

These issues open new directions of research to identify the actual needs and policies for educating and training the Romanian people for greener and sustainable production and consumption behaviour.

Fortunately, in our research interests, there is also a recent successful large pilot project of an eco-innovation park development as industrial ecosystem and a regional metabolism in Romania. As a case study, we shall analyse here the main features, objectives and outcome of this pilot Romanian EInvP named Application of Industrial Ecosystems Principles to Regional Development (ECOREG) in the Suceava County, according to the official reporting (nisp-ecoreg.ro).

The main objective of the ECOREG Project was to test the application of industrial symbiosis (IS) principles in the area of the Suceava County (the focal area of the project), also allowing for regional symbiotic development with the neighbouring counties. This entails the reuse of resources and by-products used from one production cycle to another, thus creating mutually beneficial partnerships between companies in various sectors.

The environmental objectives were actually the most important: a reduction in raw material consumption, energy, utilities, by 2-5 % for all units through implementing innovative tools and instruments; reduction of waste generation and pollutant emissions by 5-20% for all units; the conversion of wastes/by-products into resources (secondary materials); significant reduction of environmental impact at the level of industrial units.

ECOREG is modelled on (the previously introduced) NISP, the world's only national industrial symbiosis programme (UK) which demonstrated that industrial symbiosis has the potential to significantly reduce industrial and commercial waste and comprehensively lessen the adverse environmental impacts of a business. The ECOREG project used actual business opportunity as a mechanism for encouraging resource efficiency and its holistic approach is actively dealing with all resources including water, energy, materials, logistics, assets and expertise.

ECOREG was implemented with financial support of the European Union through the LIFE+ Programme, in the period 1st February 2009 – 1st October 2011, in the area of the

Suceava County. The total project budget was of 880 700 Euro. ECOREG was funded by the European Commission through the LIFE+ programme as part the its package to help businesses to improve resource efficiency and reduce waste.

The most important feature of the ECOREG is **the industrial symbiosis as eco-innovation implemented on the regional scale.** It is supported by the numerous industrial synergies (more than 200) identified in the area, out of which 114 have been actually implemented (nisp-ecoreg.ro).

We analyse such an industrial synergy in the following case study, namely the one identified and implemented between:

a) SC RITMIC SRL**,** a SME based in Ilisesti, 18 km E from Suceava, dealing, among others, with collecting wooden waste (sawdust, chops, branches, etc.), conditioning it and selling it as bio-fuel (wooden briquettes) and

b) SC IASIMOLD SRL, another SME located near the Moldovita Commune, Suceava County, some 100 km W from Suceava, in a beautiful landscape. The company exploits wood and completes the first stages in processing timber, producing large quantities of sawdust and wooden waste, a heavily polluted material with no economic value.

The synergy created works like that: the sawdust and wooden debris produced by SC IASIMOLD SRL are collected by S.C. RITMIC SRL's trucks, transported and directed to the wooden debris processing unit of SC RITMIC SRL in Ilisesti. The sawdust and wooden debris are turned into briquettes and sold at a price of 400 RON/ton (95 Euros/ton) at the facility gate. It is worth noting that the same briquettes are sold in supermarkets at a price of 850 RON/ton (200 Euros/ton).

The ecological driver of the industrial symbiosis is the harmful environmental impact of the sawdust and wooden debris (Adding Value to Wooden Waste 1, 2009): "Disposed of on soil, saw dust modifies drastically the soil quality and composition, by changing the Carbon Nitrogen ration in soil. Bacteria that consume carbon from saw dust consumes also the Nitrogen (essential to plant metabolism) in soil, leaving less Nitrogen for plants. The impact upon water is similar, bacteria that consumes carbon in celluloses from sawdust, exhaust the oxygen in the water, suffocating fishes and other organisms."

The life cycle analysis of the final product should be done in order to certify the circular economy system created:

- Raw material for the briquettes comes from an insidious waste that currently pollutes the forests' outskirts and river valleys in the Suceava County as well as in other Romanian Counties. As wood is the main fuel for households in the Suceava area

(together with coal of rather low quality - lignite), the collateral benefit of using sawdust briquettes is sparing virgin resources (forests).

- The processing technology is environmentally friendly, uses biomass (wooden chips) as an energy source and the only waste produced is the (benign) carbon dioxide that comes from the biomass burnt. No additives (adhesives, binders) are used in the technology that could add some inorganic or organic load to the final product and increase its environmental impact;
- During their life time the briquettes do not cause any environmental hazard and their combustion produces benign carbon dioxide and small quantities of ash that can be used as fertilizer.

There are important economic, environmental and social benefits from this industrial synergy identified and exploited in the ECOREG EInvP of Suceava:

i. The economic benefits are significant, since SC RITMIC SRL obtains the raw material it needs at a bargain price (cost of transportation and of manipulation – uploading and downloading trucks - constitutes the major share in cost breakdown); SC LIAMOLD SRL gets rid of the wooden debris that occupies the production space;

ii. The environmental benefits from this industrial symbiosis are even more interesting, considering the saved virgin forests in the area, as well as the biomass energy potential and the avoided CO_2 emissions (Table 3):

Table 3 - Estimated environmental benefits from the industrial synergy SC IASIMOLD SRL - S.C. RITMIC SRL

Characteristics	Value	U.M.
Volume of biomass involved in synergy	380	m^3
Virgin forest resources saved	0.437	ha
Methane gas saved by the biomass produced	35625	m^3
Total harmful CO_2 emissions avoided	25.5892	tons
Persistent Organic Pollutants (POPs) emissions avoided	100.32	micrograms

*Source: Own selection and computation from ***Adding Value to Wooden Waste (5), ECOREG Project Case Study No 5, 2010.*

iii. The social benefits are also notable since the synergy keeps the present jobs in both organizations and contributes to their social role. For customers, the synergy adds important quantities of renewable biomass fuel to the market, at a convenient price, saving households money.

iv. Last but not least, the sustainability of this industrial synergy is high, since when the price of oil and gas increases, biomass becomes the alternative at hand. On the other hand, forest management in Romania does not fully comply with international and EU rules for sustainability, since large quantities of wood are cut illegally, jeopardizing the virgin forest natural heritage of Romania (Platon V. *et al*., 2016). In the coming years, the cost of raw wood could raise, once sustainable forest management policies are implemented, adding also to the costs of processing wood.

v. An important feature for our research is the replication potential of this industrial ecosystem synergy between these SMEs in the Suceava County, as well as in other regions of Romania. The project description mentions in (ECOREG Case Study #05 2010 that: "the synergy is a good and straightforward solution for improving the energy of small communities and limited geographic areas. It may be replicated in small communities across 28% area of Romania covered by forests."

The synergy presented and analysed above - between the SC IASIMOLD SRL and S.C. RITMIC SRL - is only one of the many industrial synergies working in the ECOREG project. However, ECOREG may be considered an actual eco-innovation park, since it is a spatial, regional application of eco-innovation with rich environmental, economic and social benefits to all the companies and organisations involved, as well as for the people and natural environment in that area of Suceava County.

In an overall outlook, the ECOREG project has led to the following main quantitative outcomes (nisp-ecoreg.ro):

1) over 200 economic and social units from various fields and industrial sectors have been included in a regional symbiotic network;

2) 568 resources flows and 200 synergies were identified;

3) 114 synergies, involving 13 waste categories were completed;

4) The quantity of waste involved in the synergies was of over 530.000 to, out of which: 30,000 t of construction and demolition waste; over 500,000 t wood waste; 232 t of animal and food waste; 25 t plastic waste; 20 t waste electrical and electronic equipment.

5) A surface of over 2,500 ha of forest was preserved, following the replacement of wood raw materials with other types of wastes;

6) The reduction in GHG emissions by over 130,000 t of CO_2, following the replacement of virgin materials with alternative resources.

The economic impact of implementing the ECOREG industrial ecosystem in the Suceava region is given by: reducing production costs by processing waste (cheaper

than raw materials); reducing waste disposal costs by 20 to 30% on average per company (as shown in the synergy sheets for the finalised synergies); reducing the penalties for environmental non-compliance and other economic benefits through the sale of waste.

The social impact of implementing the ECOREG industrial ecosystem is featured mainly by the safeguarding of jobs in crisis conditions strongly felt in the pilot area. Some synergies also led to the creation of jobs, with direct positive impact on one of the poorest regions of Romania (N-E). There is also a redefining of the business strategy in order to develop a new organisational culture, suited to competitiveness in a European economy.

Despite numerous constraints and over a period of economic crisis (2009-2011), the implementation of the ECOREG project proved successful in setting up an Industrial Symbiosis network, in other words in implementing an eco-industrial park at the county level.

This pilot experiment must have led the ECOREG project coordinators (the European Commission, the Romanian Ministry of Environment, the Romanian Ministry of Economy) to „believe that the approach could be easily replicated in other regions of Romania before rolling out as a national programme, following the evolution of NISP in the UK" (LIFE07 ENV/RO/000690, 2011).

4. Conclusions and recommendations

For the circular economy, eco-innovation is based on centralizing knowledge about material and energy flows as an efficient tool to foster a transition from a linear industrial system to a closed-loop system mimicking biological ecosystems.

Although industrial ecology has emerged as a form of innovation required by the challenges posed by sustainable development, the principle of industrial symbiosis has been replicated and developed with much more dedication and interest during the recent global financial and economic crisis (2009-2012), its to the extraordinary potential to increase resource-efficiency and to many other related socio-economic benefits.

We strongly believe that the future implementation of industrial ecology models in eco-industrial parks will turn them into the EInvP needed for a resource-efficient, circular and green economy in the European Union and in Romania. In this respect, after having previously claimed that eco-innovation and eco-innovation parks are the vectors of transition to a green economy and their importance (Frone Simona, 2015), this paper there are analyses and highlights some of the objectives, features and principles of the

circular economy as they are implemented through industrial synergies in these very eco-innovation parks.

The eco-innovation and especially the regional eco-innovation of an industrial symbiosis will bring increased competitiveness and better management of resources over their life cycle, for all the economic entities and partnerships which are part of the industrial ecosystem.

However we have shown, by considering the recent reported trends and issues of the eco-innovation in Romania that there still is a lot to be done in order to catch-up in this field which is essential for sustainable development and systemic green economic restructuring.

It was only after Romania's accession to the European Union and with the Cohesion funding support, that adoption of the environmental acquis and of the know-how and good practice of the EU member states, as well as of the Strategy 2020 has enabled the implementation of ECOREG, a pilot project of industrial symbiosis in the Suceava County.

The objectives of the project correspond to the local, regional and national sustainable development requirements, since they are environmental, economic and social objectives. The pilot project ECOREG was drawn up for the assessment of the opportunity for a future industrial symbiosis programme on a national scale.

As the main case-study of circular economy, we have briefly analysed this Romanian project as a pilot eco-innovation park and a regional metabolism enabling the promotion of a circular economy system and a green growth in the N-E region. The official European web-site for the project description (http://ec.europa.eu/environment/life/project/Projects) has concluded that the ECOREG project „demonstrated major environmental benefits, as a result of developing a sustainable approach to waste and resource management. This will help Romania to recycle more of its waste, in line with EU policy. ECOREG recycled 530 000 to of waste, which would otherwise have gone to landfill, using less than €500 000 (€0.88/t)".

A recommendation for replicating the ECOREG in other regions and for the objective of increasing resource efficiency by industrial symbiosis is applying material flow analysis to planned activities for the identification of solutions to foster resource efficiency prior to the settlement of the EInvPs' tenants.

One of the lessons learnt on promoting regional eco-innovation in Romania from the ECOREG implementation was that technical and financial evidence was required in order to encourage businesses to apply the principles of Industrial Symbiosis. However, once the synergy concept had been accepted, businesses became active promoters for

its introduction in the North-East Region of Romania and helped to remove any doubts that might have existed about the benefits of becoming a member of the programme"(LIFE07 ENV/RO/000690, 2011).

Nevertheless, there will always be quite important challenges in implementing the industrial ecosystem as a regional eco-innovation, for turning business clusters into eco-industrial or eco-innovation parks. As stressed by Deutz P. and Gibbs D., (2008), "the distinctive features of EIPs as clusters include the need for physical exchanges, which can involve complex negotiations/technical arrangements pertaining to items which for potential symbiosis partners are low priority items. For many firms these may simply be items they wish to dispose of without incurring excessive costs or uncertain liabilities. Such factors significantly add to the challenges involved".

Since over 95% of the waste is landfilled in Romania, there still are high opportunities for developing the circular economy in Romania. As exemplified in the paper, some bottom-up civil society and private sector initiatives have indeed identified the existence of opportunities in this sector.

There are good trends in a survey of Romanian companies showing that many of them are improving their waste collection and resource efficiency policies. As based on our analysis, the wood sector of Romania has proved to be really suited for spatial industrial symbiosis, and a new direction of research is identifying other industrial sectors which may benefit from clustering in EInvP.

However, some research limitations of this paper mainly related to the methodology and the scope of research must be admitted:

- The eco-innovation composite score for Romania and the ECOREG case-study analysis are based on the official reporting, without own data collection and checking. Besides, due to the lack of other similar experiences of industrial ecosystems in other counties or regions of Romania, there was no possibility of national comparison or benchmarking.
- The scope of the research is quite limited since, for instance, the eco-innovation park and the industrial symbiosis are not grounded on detailed technical and financial evidence or on extended literature review.

Although limited to the case study and to only one industrial synergy analysis, the conclusions of this research paper reiterate our belief that planning, implementing and development of eco-industrial and eco-innovation parks are mostly needed in Romania, in view of a sustainable economic development and a path of green growth. But a pro-active policy, a coordinated approach and a public management are strongly required to

sustainably develop circular economy in Romania and reap its significant advantages (including preservation of the virgin forests).

The prospects, policies and strategic approaches to implement the green economy by fostering eco-innovation in developing eco-industrial (eco-innovation) parks in Romania will be the topic of future research.

A new direction of research will be demonstrating the importance of EInvPs for increasing the economic and ecological performance of regional or county economies, through the creation and application of cross-regional (cross-county) regression models to Romania, like that applied to the EU member states.

Although seemingly very difficult to implement, such industrial ecology projects, involving a national program of industrial symbiosis in Romania are eligible for generous support from the Social and Cohesion Funds (through programmes and mechanisms supporting implementation of circular economy, as described in section 2.2) and would contribute to a balanced, endogenous and sustainable development of all the counties and regions.

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