



# Comparing European countries' performances in the transition towards the Circular Economy

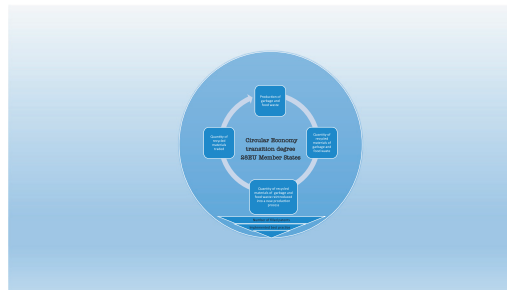
Alfonso Marino, Paolo Pariso \*

University of Campania "Luigi Vanvitelli" – Engineering Department, Via Roma 29, 81031 Aversa, CE, Italy

## HIGHLIGHTS

- Assesses the transition degree of the 28EU Member States towards the circular economy
- Comparing the CE state of art in Europe
- Measures the performances of the countries in the 3R activities for the transition towards the CE
- Evaluates the correlation between the GDP and the strategic elements identified by EU as barriers towards the transition.

## GRAPHICAL ABSTRACT



## ARTICLE INFO

### Article history:

Received 13 November 2019

Received in revised form 5 March 2020

Accepted 21 March 2020

Available online 21 April 2020

### Keywords:

Cross national comparative study

Circular Economy

Europe

Growth Domestic Product

3R actions

## ABSTRACT

The aim of the present research is to compare the performances of the 28 EU Member States in the period 2006–2016 in order to assess their progress towards the achievement of circular economy objectives. This study overviews the conceptual background, that informed the implemented measures so as to create an accumulation of knowledge which focuses on the one hand on “Reduction, Reuse, Recycling” actions, and on the other hand on the main impact areas of circular economy activities. Furthermore, the evaluation of these actions and their impacts were carried out correlating Growth Domestic Products in Purchasing Power Standards data with quantitative indicators: Produced Municipal Waste – PMW, Produced Food Waste – PFW, Municipal Waste Recycling rate – MWRr, Domestic Material Consumption – DMC, Production Material Reuse rate – PMRr, Market rate of Recyclable Raw Materials – MrRRM. These indicators allow assessing the degree of transition achieved by the member states in the implementation of circular economy. The analysis shows that different strategies were adopted by the 28 EU Member States and that only a few of these could be considered effective in meeting the challenges of the circular economy in European Union.

© 2020 Elsevier B.V. All rights reserved.

## 1. Introduction

Since the industrial revolution our industrial economy has been dominated by a “take make and dispose” pattern of production and

consumption in which products are made using raw materials, purchased, used and at the end of their life cycle is landfilled (Murray et al., 2017). This model has finally reached a point of no return, creating an imbalance between resource supply and goods demand. In fact, this model neglected nature's regeneration rate which cannot keep up with the resource consumption rate. This is one of the main problems of the linear model (Michellini et al., 2017). In fact, if current levels of

\* Corresponding author.

E-mail address: [paolo.pariso@unicampania.it](mailto:paolo.pariso@unicampania.it) (P. Pariso).

production and consumption continue at this rate and in this manner, it will not be possible to sustain development and preserve the planet for future generations (Stahel, 2016). The strategic need for an alternative model of growth emerged in terms of the debate about the circular economy (CE), described as an economy with closed material loops.

Over the last decade the CE, also due to the challenges posed by of the Circular Economy Action Plan, CE issues have attracted a great deal of attention. The efforts made by the Member States to shift their social and economic activities towards “circularity” have fostered changes in the business model and labor market, with new business models and new opportunities resulting from the implementation of the Reduction, Reused and Recycling (3Rs) actions able to create four million new jobs, to generate €147 billion in value added and promote €17.5 billion worth of investments (European Commission, 2015a). Furthermore, the recycling of municipal waste and the percentage of recycled material reuse (with respect to overall materials demand) increased during the last ten years. Despite this, the recycled materials do not even reach the 12% of the EU materials demand, and, a full circularity is applied to only 9% of the world economy, which indicates that there are still wide margins for improvement (European Commission, 2019d). This idea of CE considers it as a transformative economy redefining production and consumption patterns, inspired by ecosystems principles and restorative by design, which increases resilience, eliminates waste and creates shared value through an enhanced circulation of material and immaterial flows (Kirchherr et al., 2017). This concept highlights the key factors of the paradigm: resources efficiency, sustainable economic growth, environmental protection and social development. Following Hislop and Hill (2011, p. 2): “The circular economy represents a development strategy that maximizes resource efficiency and minimizes waste production, within the context of sustainable economic and social development”. With the reference to social-economic aspects, for Preston (2012, p. 1) “A circular economy is an approach that would transform the function of resources in the economy. Waste from factories would become a valuable input to another process—and products could be repaired, reused or upgraded instead of thrown away”. Despite the different emphases, perspectives and approaches these definitions evolve around the central idea that the CE is a 3R system with mainly environmental, economic and social impacts. Many studies analyzed the issues from a theoretical point of view. Kirchherr et al. (2017) elaborated a comparison analysis with 114 CE definitions, Ghisellini et al. (2016) performed an ample review on CE issues at micro, meso and macro level. More recently, Korhonen et al. (2018) analyzed the emergent literature from several fields to identify concepts and account for the complexity of the issues and the perspectives of different contributions. However, only a few authors focused on the operative application at macro level (Ghisellini et al., 2016) for an extended geographical area (i.e. Europe), and followed a quantitative approach as well. This paper intends to contribute in bridging this gap. Firstly, the relevant knowledge is gathered and organized so as to rank the 28EU member states according to their performances in terms of their transition towards the CE. In particular, the indicators, relating to environmental (Produced Municipal Waste, Produced Food Waste, Municipal waste recycling rate), economic (Domestic Material Consumption, Market rate of recyclable raw materials, Production Material Reuse rate), and socio-economic (Patents related to Circular Economy, Implemented Best Practices) variables, are used to assess outcomes and highlight good practices, so as to identify which of these are more likely to be conducive to a CE as envisioned by the EU. In order to assess the degree of transition towards the CE, we also evaluated GDP in PPS and the ratio of GDP/CEI correlating this information with the quantitative indicators. The performances of the 28EU Member State was analyzed in the period 2006–2016. The study was developed, firstly carrying out a performance analysis of each Member State in terms of the implementation of CE activities and the progress made towards the achievement of EU circular objectives. The accumulation of knowledge and application of quantitative indicators, should allow for the design of a CE achievement process.

The present analysis will be of interest for researchers, policy makers and government planners, who can acquire information for the development of CE strategies in long term plans.

The paper is organized as follow: sections two outlines a conceptual background on the CE will be developed. Moreover, Section 3 shows the state of art of the European context, Section 4 explains the elaborated methodology, and Section 5 displays the results and related discussion. Finally, Section 6 shows the conclusions of the paper.

## 2. Conceptual background

The literature and the EU directive and recommendations indicate that most of the issues concerning the CE transition evolve around waste, its production, its reuse and its disposal. In fact, the waste management is considered by European Commission (2019a) in overall 28EU Member States a strategic issue to address the transition from linear to circular economy. Liu et al. (2017) focused on the sustainable waste management under the concepts of the CE through “Reduce, Reuse and Recycle” (3R) rules. They underlined the need for an adequate legal framework and highlighted the importance of investing both in technologies for the efficient resource recycling and waste management infrastructures. Furthermore, Iacovidou et al. (2017b) presented an innovative approach “Complex Value Optimisation for Resource” (CVORR) that seeks to assess how complex value is created, destroyed and distributed in resource recovery from waste systems. In addition, in line with the Waste Framework Directive (European Parliament, 2018) the municipal waste is a complex bottleneck in waste management because even if it does not represent the main part of the total waste generated in the European Union (7–10% measured by weight), it is amongst the most complex ones to manage (Malinauskaitė et al., 2017). In particular, according to OECD (2016) the municipal waste is defined as the household waste and waste similar in nature and composition to household waste. Its mixed and dispersed nature typically makes it difficult to treat (European Parliament, 2017b). Amongst these kinds of wastes, food waste is potentially the largest un-tapped recyclable component of the municipal waste stream. Food waste according to Food and Agriculture Organizations of the United Nation (FAO, 2011) refers to the decrease in the quantity or quality of food resulting from decisions and actions by retailers, food service providers and consumers. It represents a growing problem in our society with almost 88 million tons of waste were generated every year. In particular, this implies that valuable and often scarce resources such as water, soil, and energy are being lost, and that climate change is being affected. At worldwide level, only 6.3% of food waste is diverted towards landfills and incinerators for composting. It represents 22% of discarded municipal waste (European Parliament, 2017b). In addition, as acknowledged by the Waste Framework Directive (European Parliament, 2018), sets a target of 50% of municipal waste to be recycled and prepared for reuse by 2020 in EU Member States. The Directive identifies the recycling actions (material recycling, composting and digestion) as a strategic drivers and strengths of the CE policy in Europe. Minelgaitė and Liobikienė (2019) focused on the importance of reducing, reusing, and recycling behaviors as effective tools for solving the waste problem in the European Union, and pointed out that the countries seeking to minimize waste generation should also pay more attention to the promotion of efficient consumption and production patterns. Despite their importance, these actions alone do not ensure the transition towards a total circularity. Winkler, 2011 (2011) reinforces this concept, identifying two structural barriers to the improvement the circularity in terms of product reuse. The first barrier is that a large part of the used materials is still accumulated as in-use stocks, and the second is that a large amount of unrecycled materials is sent to landfill. Reusing used materials as raw materials (second raw material) is another strategic cornerstone. Considering that the rates for some materials are already high, considerable improvements still seem possible (Iacovidou et al., 2017a; Horodytska et al., 2018; Hahladakis and Iacovidou,

2019). In fact, by preferring the use of recycled materials to the raw materials, it is possible to influence the performance of companies both in relation with their production processes, by making them less energy-intensive and more resource efficient, and also to their market competitiveness. In fact, the 3Rs strategy is a manufacturing strategy which is also driven by market conditions (Brissaud and Zwolinski, 2017). According to the European Commission's Circular Economy package (European Commission, 2015b) the increase in secondary raw material use will open new markets, reduce costs of production, increase businesses competitiveness, encourage new product development, create jobs, promote innovation and thus stimulate economic growth. In order to assess the degree of transition towards CE, quantitative indicators can be useful (EASAC, 2016; Geng et al., 2012). However, they need to be correlated into well devised sets to account for their combined effects and the intricacies of the system's dynamics. Finally, data interpretation should be contextualized to evaluate impacts in each member state. In fact, Elia, et al. (2017) with reference to the methodologies and indicators used for an Environmental Agency report (EEA, 2013), pointed out that no single indicator, characteristic or methodology can prove to be adequate to in the interpretation of such a complex phenomenon. Moreover, Iacovidou et al. (2017b), in the context of the measurement of resource recovery from waste, showed that the proposed methods alone were not able to assess the retention of value in waste resources. The CE is a composite objective and therefore a single indicator does not explain the complexity of a whole transition process. Such a process needs to be investigated bearing in mind the impact of economic variables such as GDP in PPS in each country in order to understand their potential correlation with quantitative indicators (Awasthi et al., 2018). From our research perspective it is essential to outline the European context and analyze the performance of each Member State.

### 3. European context

In order to investigate CE awareness in the European context, it is necessary to understand how the countries are implementing and should implement actions to boost the transition towards the CE. Thirty five official reports were issued: European Commission (2015a, 2015b, 2016a, 2016b, 2016c, 2016d, 2017a, 2017b, 2017c, 2018a, 2018b, 2018c, 2018d, 2019a, 2019b, 2019c, 2019d), European Parliament (2017a, 2017b, 2018, 2019), European Environment Agency (2013, 2018), Eurostat (2017a, 2017b, 2019a, 2019b, 2019c), European Investment Bank (2017), European Circular Economy Stakeholder Platform (2018, 2019), European Economic Area (2019), OECD (2016, 2017), United Nation Environment (2019). Their common denominator was to accelerate the transition of European countries to the CE. We elaborated this information and devised a synoptic framework to outline the progress made so far and to identify possibilities and opportunities for improvement.

#### 3.1. Austria

Austria shows a high CE profile mainly focused on environmental innovation (i.e. "Green Tech" or "Clean Tech"). In fact, the country is oriented towards a growing improvement of municipal waste recycling and towards the promotion of initiatives supporting the transition (i.e. RepaNet). Despite this, an effective Austrian Circular Economy Strategy should include objectives aimed at reducing raw material use and waste production, because the country is amongst the highest waste producers. The country's National CE plan is focused on this topic and environmental concerns but neglects the economic opportunities that can be offered by the CE. Sustaining SMEs and taking advantage by the fact that the service sector represents 63% of national GDP in the transition towards the CE could be further strategic actions to implement.

#### 3.2. Belgium

Belgium devised a general framework supporting the CE. In fact, in this country many initiatives in improving the transition have been developed. Subsidies in support of reduction of landfill, incineration taxes aimed at minimizing household waste and waste amongst SMEs, investments in great infrastructure for separate collection, are only some actions that highlight the coordinated governmental actions in this direction. Despite this, Belgium still faces issues such as high operational costs of selective waste collection and low environmental taxation.

#### 3.3. Bulgaria

Bulgaria presents a weak position in the CE implementation. On the one hand the country has a low per capita waste production but on the other hand there are many difficulties in the waste reduction of SMEs and especially in the lack of funding available for enterprises. Efforts should be made to minimize the raw material use and waste production and to introduce tax incentives in support of new CE investments. The European Commission has recommended that all economic actors should foster 3R actions in their activities and safeguard prevention practices in waste management.

#### 3.4. Croatia

Croatia presents a profile with a low per capita waste production but shows criticalities in the recycling of municipal waste, in fact the country is at risk of not meeting the European recycling targets. The national CE plan is mainly focused on waste management and on sustainable tourism. The country should gear its efforts towards raising awareness of CE transition policies and promoting tax incentives. The European Commission has strongly recommended that both the private and the public sectors should implement 3R actions in their activities and ensure prevention practices in waste management to optimize recycling, incineration and landfill use.

#### 3.5. Cyprus

Cyprus is a country with below average in terms of per capita waste production. In fact, it is one of the greatest waste producers of the 28EU Member States. Its national CE plan is mainly focused on renewable energy (wind and solar). The country has greatly invested in latest framework program (2014–2020) in resource usage efficiency, and energy network infrastructures. Its particular geographical collocation does not allow for innovative investments by the multinationals and this is hindering the development in terms of technological innovation. Cyprus should enact 3R policies aimed at the reduction of material raw use, municipal waste and plastics production and at investing in research and innovation in order to boost the transition.

#### 3.6. Czech Republic

The Czech Republic has been quite active in pursuing the transition towards the CE with a good profile in the packaging waste recycling (amongst the EU28 member states). In addition, the country which received substantial EU funding, mainly concentrated on improving environmentally friendly innovative technologies and activating campaigns to raise the awareness of the population in the reduction of plastic use. In addition, the country is making efforts to deal with the issue of waste packaging. These include enacting proper legislation. Several initiatives have been undertaken such as the national Waste Management Plan 2015–2024 in which the CE has a leading role in the long term planning (Circular Czechia 2040). One of the main problems is given by the municipal waste management due to the presence of a great number of landfills. Furthermore, the country has been slow in the implementation of EU regulations on waste management and plastics. SMEs should be

supported with the introduction of tax incentives in CE activities. The European Commission has recommended that the public and private sector should improve 3R actions in their activities and ensure prevention practices in waste management.

### 3.7. Denmark

Denmark has been active in promoting the transition towards the CE since the beginning. The country has leader profile in household waste management and the reduction of landfills. At the same time, the country is one of the highest per capita producers of municipal waste and does not show a great capacity to minimize the waste produced by the SMEs. Many initiatives have been implemented such as the Danish Strategy for Circular Economy to boost the transition through the economic support to activities aimed at re-circulating materials and reducing the waste and enhancing the environmental innovation. The country should work harder at coordinating actions at the national level with actions at the local level in order to avoid different approaches at municipal level which do not penalize private companies that do not ensure the EU waste hierarchy. In addition, the transition could be facilitated by introducing tax incentives for repair services, re-circulation of goods and transactions with clearly defined social objectives.

### 3.8. Estonia

Estonia is a country with a great propension towards the transition, in fact the country produces little per capita waste and has promoted many actions aimed at reusing materials. It has a good system of deposit-refund for beverage packaging that allows to collect almost the entire quantity of this kind of waste. Additionally, several other measures have been developed in different contexts to boost the transition. In fact, it is the first country in which a University (TKK) established an institute for teaching specific skills to sustain the transition towards CE (Institute of Circular Economy and Technology). Furthermore, the country has been able to create effective national networks between all the stakeholders, private and public, involved in the CE system, in order to share information and promote constructive dialogues aimed at creating a national CE strategy (i.e. the Circular Economy Forum, the Estonian Association for Environmental Management, and the Ministry of Environmental Affairs). However, Estonia shows several criticalities in the transition policy with a low resource efficiency, a low ability of national SMEs in waste reduction practices, and an inefficient system of municipal waste and packaging recycling (3Rs).

### 3.9. Finland

Finland is one of the European leaders in the CE transition. The country planned a strong national financing system to sustain the innovation in the CE (Finnish Innovation Fund Sitra), created a national program for the recycling of nutrients (RAKI), developed several projects for plastic reduction and CE (i.e. CIRCWASTE) and organized the World Circular Economy Forum conference. The latter was able to encourage the adoption of several best practices and to establish transition guidelines. The transition process has also been aided by the national community's general awareness of the opportunities that the CE could bring about for both traditional enterprises and new emerging businesses. At the same time, also the government has adopted some incentive tax in the recycling and reuse activities. Additional efforts should be made to enhance eco-innovation especially in the harmonization of its legislative framework with the European Parliament's criteria for sustainable forestry and the safeguard of biological cycle.

### 3.10. France

The country's CE transition yielded some improvements in the reduction of waste production and the increase of its recycling. The country published a national CE roadmap (2018) with effective objectives in support of the transition thanks to the collaboration between Ministry for an Ecological, the Inclusive Transition and Ministry for the Economy and Finance and the Institut National de l'Économie Circulaire (INEC). In addition, France planned an effective legal framework to encourage of 3R activities. It also imposed legal sanctions for non-compliance with the collection, recycling and packaging rules (i.e. plastic). It increased taxes on waste burials in landfills and reduced taxes on recycling operations. Further incentives have been granted for social enterprises that collect and sell used goods, through the exemption of the VAT. However, the SMEs require further support. A national program should be set up to encourage circular design training so as to reduce the use of raw materials and waste production and enhance reuse, repair and sharing practices.

### 3.11. Germany

Germany shows a very advanced profile in the transition towards the CE with a good management of municipal system of municipal waste recycling. The country carried out several well-coordinated CE initiatives with a good coordination at national level aimed at achieving resource efficiency and recycling targets. It promoted incentives for reuse and the design for recycling (i.e. fiscal incentives, favorable legislative framework). In order to encourage recycling actions, it introduced a new Packaging Act which includes a National Packaging Registry. The strengths of the German CE plan can be found in the strong national policy and the awareness and the receptivity of the population towards the sustainability issues. On the other hand, the country presents a very high per capita waste production that represents the main problem in this context.

### 3.12. Greece

The country's performance is particularly poor both in the private and in the public sector. The main weaknesses that can be identified in the 3R actions are mostly due to the difficulties in overcoming the barriers created by the linear economy and therefore the slow response in adopting the EU Commission's proposals. Efforts have been made to promote new legislation and to allocate funds for educational and organizational purposes. The aim of these measures was on the one hand, to enhance knowledge on CE and, on the other hand, to improve governance structures by establishing a specific operative organization with the task of supporting the transition. It is interesting to note that these recent efforts are in line with European Commission's suggestions but are clearly inadequate to promote a transition from linear to circular economy. The European Commission has strongly recommended that both the private and the public sectors should promote 3R actions in their activities and ensure prevention practices in waste management; implement the National Action Plan on Circular Economy; promote transparency laws and regulations; simplify administrative procedures; implement a Circular Procurement.

### 3.13. Hungary

The transition from linear to circular economy in this Member State has been slow and intermittent. Barriers include a lack of widespread resource-efficient and strategic thinking that could facilitate the transition. The barriers are present both in the public and the private sector. In the private sector, the SMEs and big companies are strongly anchored to a linear economy. In the agricultural and the public sector no effective plans or actions were implemented to support the transition. The European Commission underlined the importance of undertaking



actions: to implement a Hungarian Circular Economy Roadmap, to reduce raw materials use and waste production, to increase reuse, repair and sharing (3Rs), to protect the environment, and foster domestic economic growth.

### 3.14. Ireland

The Member State created a strong re-use and repair network and devised several government support programs. However, the effects have been more significant in the public than in the private sector. In fact, SMEs and big companies have not found a way to improve the efficiency of the 3R strategy. The European Commission underlines the importance of the implementation of a Green Deal Circular Procurement and the enhancement of an Irish Circular Economy Roadmap.

### 3.15. Italy

Italy's performance has been more positive in the private in terms of SMEs transition towards a CE. In the public sector the implementation of 3R strategy has been proven to be much more difficult at all levels of government. On several occasions the European Commission pointed out that the policy the policies enacted were not meeting the set objectives by established deadlines. The European Commission underlines the importance to implement a Green Deal Circular Procurement.

### 3.16. Latvia

Latvia's CE performance is quite poor, the main bottlenecks concern waste in terms of management. The primary main problems to separate non collection and sorting of materials and the creation of economic value. There is also little stakeholders' awareness of the need for the transition. European Commission recommendations are linked to the 3R strategy and its implementation. Particularly the suggestions concern the use of EU financing also to improve waste management infrastructure with common rules at national and local level. In addition, the application of Green Deal on Circular Procurement for both public and private sector, and include a free training program.

### 3.17. Lithuania

Lithuania has done well in private sector. SMEs and big companies implemented strategic actions linked to the end market and environmental concerns to support the transition. Instead, the experience of public sector is quite different. In this sector, much more is to be done. In this sector, a lack of policy measures to promote the transition and the low level of government involvement at national and local level, continues to hinder CE efforts. The European Commission recommendations concern the following actions: change investment cash flow in incineration capacity, introduce taxes on landfill; implement the EU regulations on waste management and plastics (3Rs) in the next two years. Furthermore, the EU Commission advised to apply for additional EU funds to set-up a national support program for public economic growth with focused activities that will support the creation of a CE hub.

### 3.18. Luxembourg

Luxembourg has done well in several areas concerning the CE, particularly in the private and the public sector. CE systemic actions were focused at the public level in communication with the stakeholders to foster better understanding of the transition from linear to circular economy. In terms of material and immaterial environmental development and domestic economic growth. The private sector in terms of SMEs and big companies has reached interesting outcomes linked to the 3R strategy. Nevertheless that, the European Commission recommendations suggested the following systemic actions: the launch of a Green Deal Circular Procurement for both the public and the private

sector, including a training program; the reduction of raw materials use and waste production; the creation of a public CE hub.

### 3.19. Malta

Malta's extremely slow progress, mainly due to multiple natural barriers such as: a strong dependence on external energy sources; lack of natural resources; delay in the innovation process in private sector. The European Commission recommendations advised to undertake the following systemic actions: implementation of the EU regulations on waste management and plastics (3Rs) in the next two years and the launch of a Green Deal on Circular Procurement for both the public and the private sector, and a free training program.

### 3.20. Netherlands

This Member State is at the forefront of the CE in Europe. The systemic actions and initiatives that it carried out consolidated its leadership role in the transition. The Netherlands created a multitude of roadmaps plans and formative strategies, both private and public sector, and involved all stakeholders in the transition. Despite that, the European Commission recommended the establishment of a long term budget for the CE to be sustained with domestic resources, the promotion of cross sectoral collaboration, and the creation of new circular value chains.

### 3.21. Poland

Poland is a Member State in which the CE concentration is low. The reasons can be found firstly, in the unresponsiveness of the public sector to the transition. In addition, the agricultural and manufacturing sectors show serious technological gaps. The European Commission's recommendations are linked to the following actions: implementation of the Polish CE roadmap, reduction of raw materials use and waste production (3Rs), resource optimization and the achievement of full circularity in the next ten years.

### 3.22. Portugal

Portugal has shown a strong awareness in public sector with circular agenda linked to the reduction and reuse of material that support the service delivery. It is interesting to note that the same agenda was also applied to immaterial resources such as software reuse in public administrations. Unfortunately, the strengths shown in the public sector are not found in the private sector. In the private sector, SMEs and big companies, are improved their performance but, many criticalities persist. The local waste recycling and material reuse practices are particularly inefficient in private sector. The 3R strategy in private sector is very weak. The European Commission, particularly recommended the following short term actions: the intensification of measures to protect the environment and the creation of a legislative framework to ensure compliance. These actions may be strategic to support the economic growth of local companies and facilitate the transition from linear to circular economy.

### 3.23. Romania

Romania is struggling to achieve better CE performance. This country is lagging behind the other Member States in both private and public sectors at the national and local level. This delay concerning both, in national and local level. Most measures were partial and uncoordinated. The improvements should be linked to the 3R approach, such as: the development of new products from reused or recycled materials and, reusable products. The specific recommendations of the EU Commission for the private and for the public sector include actions related to environment and the creation of a legislative framework.

### 3.24. Slovakia

Despite the increasing efforts, Slovakia has achieved negligible transition results. The management of municipal waste is particularly inefficient also due to the delay in implementation of CE principles. In order to speed up the transition towards a CE, the European Commission recommended to launch a Green Deal Circular Procurement for both the public and the private sector, initiate a free training programs and ensure compliance with EU regulations on waste management and plastics, in the next two years. In this sense, lower per capita municipal waste production (3Rs) is a strategic objective that must be met, both, public and private sector. These outcomes are strategic in order to support the transition from linear to circular economy.

### 3.25. Slovenia

Slovenia has initiated numerous initiatives aimed at achieving circularity but many have been successful. This is mainly due to the lack of improvements in waste management and a production system that is still firmly anchored to the linear economy. The European Commission recommendations underlined the strategic importance to realize a Green Deal on Circular Procurement for both the public and the private sector, including a free training program. The EU Commission advised the reduction of raw materials use and of waste production. On the other hand, the country should make more efforts to foster secondary raw material use (3Rs), and to establish an appropriate materials accounting system so as to achieve the circularity objectives in ten years in compliance with EU recommendations.

### 3.26. Spain

Spain is doing relatively well in terms of CE both, in the private and public sector. Spain is making solid progress in the private sector with reference to the SMEs and big companies. The reuse process is advancing in terms of employment development and resources efficiency. Despite that, a few areas are in need of attention: the recycling of municipal waste which needs to be increased and the stakeholders should become more involved. In this framework, the recommendations of European Commission included the implementation of the new EU regulations on waste management and plastics in the next two years. In addition, the Spanish Circular Economy Roadmap should be enhanced and raw materials use and waste production should be reduced.

### 3.27. Sweden

In the Sweden there is an impressive implementation of CE. Many strategies have employed to realize the CE objectives. Particularly, in private sector, SMEs and big companies have adopted behaviors to quickly achieve the goals set by the national government and Europe. It is interesting to note that, this attitude it is not reflected in the public sector, in fact, specific objectives have been reached but a systemic change of public administration, at local and central level, is not yet come. Examples of good practices in private sector are the low VAT rate and income tax reduction for certain repairs. Following the European Commission recommendations, these actions could create a general ambition to change the logic from linear to circular.

### 3.28. United Kingdom

Although there is no national CE strategy in the United Kingdom (UK), several environmental protection plans have been implemented. Some of their objectives such the reduction of carbon emission and the minimization of waste that converge towards a CE. These objectives are actively pursued at regional level. Despite these local actions, there are not general ambitions at national level to reach the CE targets. The European Commission advised to launch a Green Deal Circular Procurement for both the public and the private sector, and to optimize the waste and plastics management systems by two years. (This analysis was carried out when the UK was yet one of the 28EU Member States.)

The comparison of the 35 official reports reveals that the 28 Member States show marked differences in the transition results achieved both in terms of the economic sector, private or public, that has driven the change and in terms of extent and degree of transition in each State. Criticalities that hinder the transition have emerged both at macroeconomic level in terms of national government choices and at microeconomic level connected to specific sectors and services. In the private sector most problems are connected to the difficulties experienced by the big companies and SMEs in complying with the mid-term objectives set by the EU which mostly concern reduction, re-use, and recycling activities of materials in all economic sectors. As to the public sector besides the above mentioned 3R problems, the main bottleneck concerns the achievement of the national transition objectives. This problem is addressed by EU recommendations that suggest an intensification of macroeconomic actions such as Roadmap, Green deal and Circular procurement implementation. These actions depend on:

- the wealth production capacity of each country (GDP);
- how of this wealth is correlated to purchasing trends (GDP in PPS);
- the quantity of GDP that is invested in CE, for example “patents”.

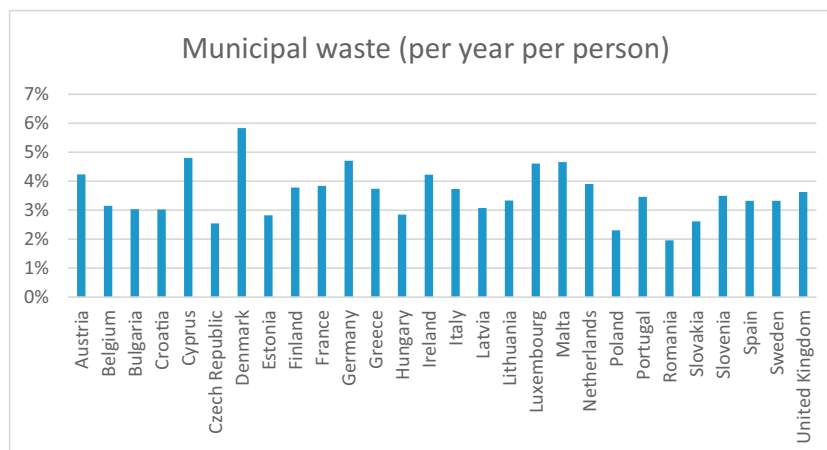


Fig. 1. Produced Municipal Waste (PMW).

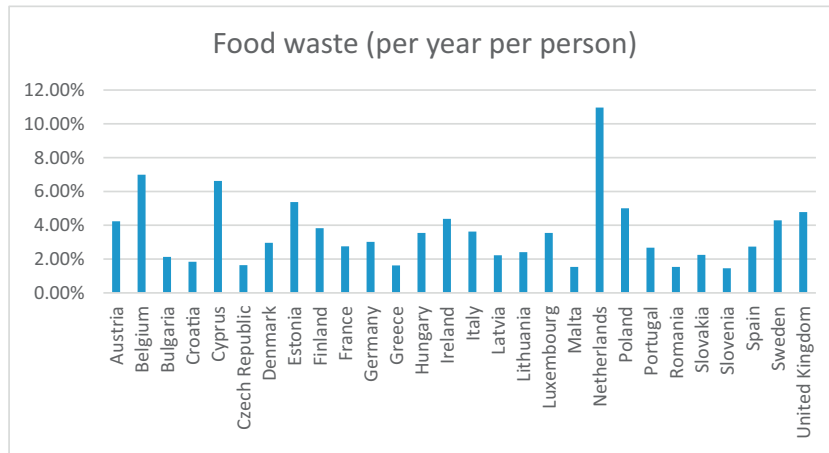


Fig. 2. Produced Food Waste (PFW).

For the transition at the microeconomic level (regional and local) the emphasis is on the strategic role of and the need for the enhancement of 3R activities which represent a bottleneck in 16 out of total of 28 member states i.e. the majority. Having gathered the qualitative data we set out to analyze how the performances of the 28 compare in terms of the criticalities and the weaknesses that we identified.

#### 4. Methodology

The assessment of these criticalities and weaknesses was carried out using six indicators (Figs. 1–6):

Produced Municipal Waste PMW (detected KG per year per person)

Produced Food Waste PFW (detected KG per year per person)

Municipal Waste Recycling rate MWRr (expressed in percentage).

Domestic material consumption DMC (detected KG per year per person)

Production Material Reuse rate PMRr (expressed in percentage)

Market rate of Recyclable Raw Materials MrRRM (expressed in percentage).

PMW displays the amount of waste produced by final consumers. This includes households waste and other kinds of waste similar in nature and composition to household waste. PFW shows the quantity of waste that derives from the food supply chain connected to all activities

that produce, process, distribute and consume food (Møller et al., 2014; European Parliament, 2018). MWRr detects how much of the waste produced by the final consumers is recycled and therefore contributes to the circularity of the process. Such an indicator yields useful information about the organizational quality of the waste management systems. According to the Economy-wide Material Flow Accounts (Eurostat, 2010), DMC is defined as the total amount of material directly used in an economy and equals direct material input (i.e. domestic extraction plus imports) minus exports. According to the Circular Material Reuse Rate methodology (Eurostat, 2018), the PMRr detects how much of the recovered material is reintroduced into the economy, and therefore supports the change towards the circularity. MrRRM, elaborated on International Trade in Goods Statistics (ITGS) published by Eurostat (2019e), measures the percentage of traded goods produced using recycled raw materials.

GDP per capita is expressed in Purchasing Power Standards (PPS) in which the volume index is correlated to the European Union average which is set as equal to 100. Values higher than 100 show that the country's level of GDP per capita is higher than the EU average and vice versa. PPS can be considered as a sort of common currency that eliminates the differences in price levels between countries therefore allows for meaningful volume comparisons of GDP between countries (World Bank, 2019). Circular Economy Investments (CEI) include the tangible goods with a useful life of more than one year, persons employed as a percentage of total employment and gross income from operating activities in the recycling, repair and reuse sector (Eurostat, 2019a, 2019b, 2019c, 2019d, 2019e). The data Eurostat on filled patents consist of innovative ideas related to recycling and secondary raw

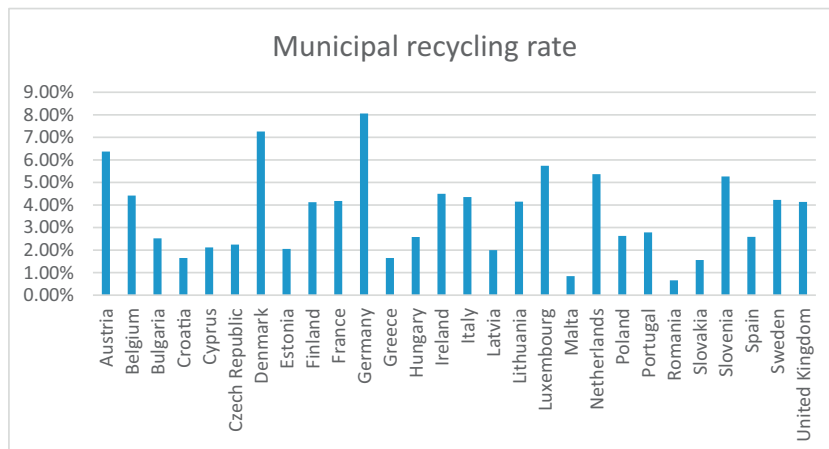


Fig. 3. Municipal Waste Recycling rate (MWRr).

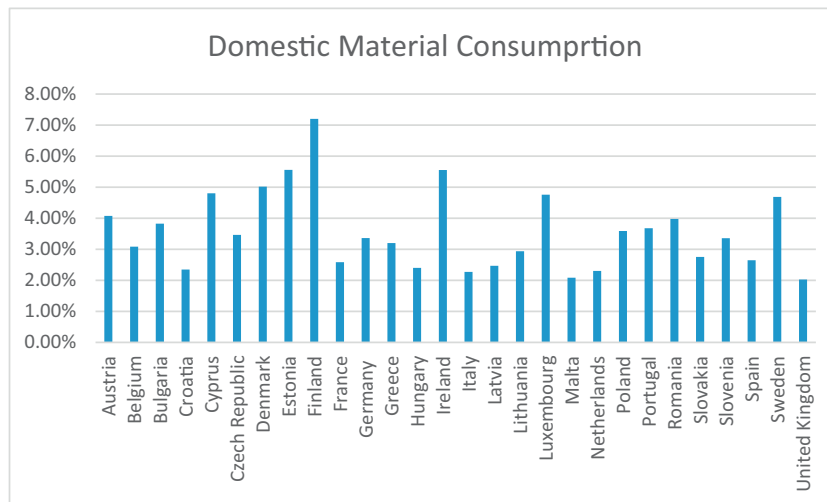


Fig. 4. Domestic Material Consumption (DMC).

materials and in particular technologies classified in the following codes in the Cooperative Patent Classification (CPC): solid waste management; reuse, recycling or recovery; wastewater treatment; potential or indirect contribution to greenhouse gas emissions mitigation. Implemented Best Practices (IBP) refer to successful “virtuous” activities implemented to meet CE objectives (Rizos et al., 2015). These quantitative indicators were obtained by integrating the data set, included in the Circular Economy indicator (Eurostat, 2019d), with the analyzed official reports. The data is referred to the decade 2006–2016 (Eurostat, 2019d) and European Parliament (2018), because before 2006 the official data available were incomplete and partial. This approach becomes fundamental in view of the sharing of such techniques or methods in the development of CE transition.

## 5. Results and discussion

Table 1 outlines that the average share of investment, for the period 2006–2016 and for all countries, is equal to 0,096%. Considering this average value, 16 countries, out of total of 28, are above the average and 12 are under such an average. The standard deviation with the reference to above average group ranges between a minimum value of 0,006%, displayed by Finland, and a maximum value of 0,059% of displayed by the Netherlands. The standard deviation of the under average group ranges between a minimum value of  $-0,004$  (Latvia) and a maximum value of  $-0,090$  (Czech Republic). Column four (Table 1) shows the average value of GDP per capita in PPS during the decade 2006–2016 and

that 12 countries exhibit values that are higher than the EU average. Results are reported in Table 1.

The 28 EU member states are ranked with respect to each quantitative indicators. The results are shown in Figs. 1–6.

Data suggest that there is a direct correlation between the values of PMW and the GDP per capita of the countries. In fact, those with higher GDP per capita averages show high values in PMW (Netherlands GDP 136 PMW 3,90%; Ireland GDP 148 PMW 4,23%; Austria GDP 130 PMW 4,23%; Finland GDP 116 PMW 3,78%; United Kingdom GDP 109 PMW 3,63%; Italy GDP 102 PMW 3,73%). This would entail that the countries' waste management systems is strictly correlated to waste production. The values of MWRr, reveal another correlation with GDP per capita of the countries. In fact, the upper-middle- and high-income countries recycle more waste (Netherlands GDP 136 MWRr 5,37%; Austria GDP 130 MWRr 6,37%; United Kingdom GDP 109 MWRr 4,14%; Italy GDP 102 MWRr 4,35%; France GDP 108 MWRr 4,18%; Sweden GDP 126 MWRr 4,23%; Belgium GDP 120 MWRr 4,42%; Denmark GDP 128 MWRr 7,26%; Germany GDP 123 MWRr 8,06%). These countries are endowed with a closed loop waste management system. In fact, they collect and recycle almost all types of waste (i.e. plastic, paper, cardboard, metal, and glass). The PFW confirms the above mentioned correlation (Netherlands GDP 136 PFW 10,96%; Belgium GDP 120 PFW 6,99%; United Kingdom GDP 109 PFW 4,78%; Ireland GDP 148 PFW 4,38%; Sweden GDP 126 PFW 4,30%; Austria GDP 130 PFW 4,24%, Finland GDP 116 PFW 3,83). However, it also shows that amongst the high quantity waste producers, there are different levels of income. This, in turn,

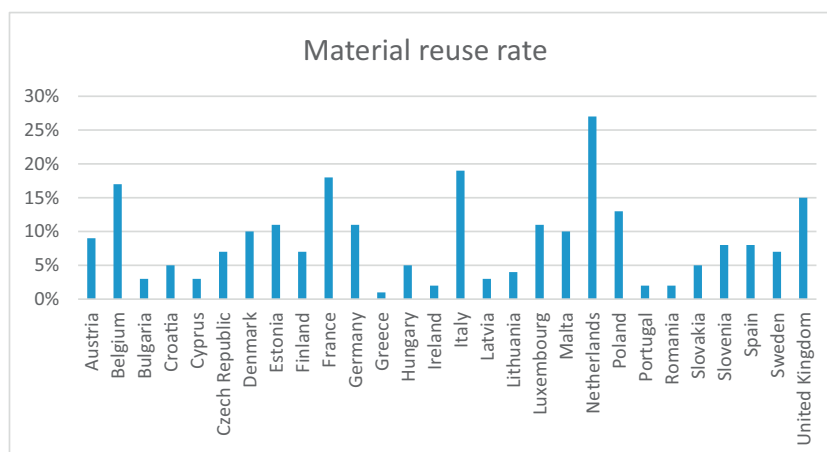


Fig. 5. Production Material Reuse rate (PMRr).



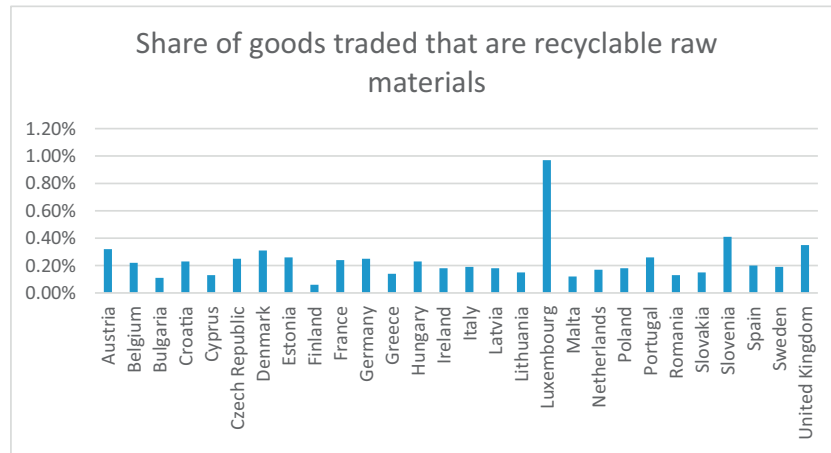


Fig. 6. Market rate of Recyclable Raw Materials (MrRRM).

indicates different pattern of consumption. In fact, amongst first ten food waste producers there are also three countries belonging to the lower - medium income group (Cyprus GDP 94 PFW 6,63%; Estonia GDP 73 PFW 5,37%; Poland GDP 65 PFW 5,01%), whereas countries belonging the higher income group are not included in the first ten food waste producers (Italy GDP 102 PFW, Luxembourg GDP 264 PFW 3,55%, Germany GDP 123 PFW 3,02%, Denmark GDP 128 PFW 2,96%, France GDP 108 PFW 2,76%). This is also confirmed by the different waste composition and the GDP per capita values correlation as reported by Eurostat (2019d). In fact, in line with the high-income countries generate in percentage less food waste (32% of total waste) but more dry waste which is easier to recycle (51% of total waste). By contrast the middle - and low-income countries generate more food waste which amounts to the 53% of total waste. This percentage varies according to the level of a country's economic development whereby less economically developed countries produce more food waste. The DMC shows exceptions to the material consumption patterns. In fact, despite material consumption should increase when the GDP per capita

of the countries increases, in the case of UK, Netherlands, France, Italy, and Belgium the opposite happens (United Kingdom GDP 109 DMC 9,72%, Netherlands GDP 136 DMC 11,06%, France GDP 108 DMC 12,41%, Italy GDP 102 DMC 10,00%, Belgium GDP 120 DMC 14,82%). This can be explained by considering that above mentioned countries optimized their production processes so as to use more second raw material as a consequence demand for raw materials. Another interesting feature is represented by 5 low GDP per capita countries (Czech Republic, Poland, Bulgaria, Romania, and Estonia). These countries are amongst the less industrialized in the EU and so enjoy grater margin of economic growth and receive more EU funds. Consequents consumption levels are more likely to grow (Czech Republic GDP 86 DMC 16,63%; Poland GDP 65 DMC 17,24%; Bulgaria GDP 46 DMC 18,37%; Romania GDP 54 DMC 19,10%; Estonia GDP 73 DMC 26,69%). Another interesting correlation can be identified between GDP per capita in PPS, PMRr and MrRRM. In fact, it can be observed that higher GDP per capita countries use and trade more products made from second raw materials (France GDP 108 PMRr 18% MrRRM 0,24%; UK GDP 109 PMRr 15% MrRRM

Table 1  
GDP per capita in PPS and ratio GDP/CEI.

Country name	Country code	Area	Average value 2006–2016 GDP per capita in PPS	Average annual GDP 2006–2016 ML€	Average CE investments 2006–2016 ML €	Ratio GDP/CEI
Austria	AUT	G1	130	€ 309.224	3,50 €	0,113%
Belgium	BEL	G1	120	€ 374.967	2,80 €	0,075%
Bulgaria	BGR	G4	46	€ 39.363	0,50 €	0,127%
Croatia	HRV	G4	61	€ 44.472	0,60 €	0,135%
Cyprus	CYP	G3	94	€ 18.307	0,10 €	0,055%
Czech Republic	CZE	G4	86	€ 155.469	0,10 €	0,006%
Denmark	DNK	G2	128	€ 249.636	2,30 €	0,092%
Estonia	EST	G4	73	€ 17.236	0,20 €	0,116%
Finland	FIN	G2	116	€ 195.310	2,00 €	0,102%
France	FRA	G3	108	€ 2.047.106	21,30 €	0,104%
Germany	DEU	G1	123	€ 2.715.249	28,70 €	0,106%
Greece	GRC	G3	79	€ 205.484	0,60 €	0,029%
Hungary	HUN	G4	66	€ 102.336	0,90 €	0,088%
Ireland	IRL	G2	148	€ 196.714	0,20 €	0,010%
Italy	ITA	G3	102	€ 1.613.556	17,80 €	0,110%
Latvia	LVA	G4	61	€ 21.655	0,20 €	0,092%
Lithuania	LTU	G4	69	€ 32.041	0,40 €	0,125%
Luxembourg	LUX	G1	264	€ 43.126	0,20 €	0,046%
Malta	MLT	G3	87	€ 7.244	0,10 €	0,138%
Netherland	NOR	G1	136	€ 335.596	5,20 €	0,155%
Poland	POL	G4	65	€ 368.814	4,70 €	0,127%
Portugal	PRT	G3	79	€ 175.088	1,40 €	0,080%
Romania	ROU	G4	54	€ 137.309	1,10 €	0,080%
Slovakia	SVK	G4	75	€ 70.165	0,60 €	0,086%
Slovenia	SVN	G4	85	€ 36.591	0,50 €	0,137%
Spain	ESP	G3	95	€ 1.065.259	11,00 €	0,103%
Sweden	SWE	G2	126	€ 393.094	4,10 €	0,104%
United Kingdom	GBR	G2	109	€ 2.107.470	31,00 €	0,147%

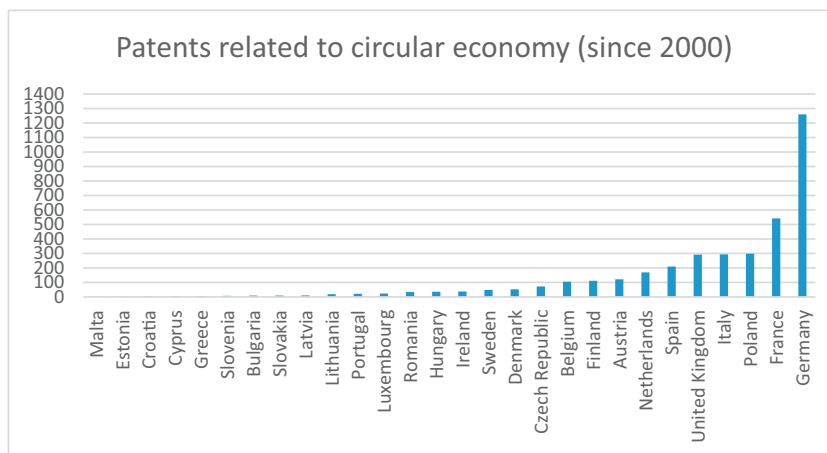


Fig. 7. Patents related to Circular Economy (PrCE).

0,35%; Luxembourg GDP 264 PMRr 11% MrRRM 0,97%; Germany GDP 123 PMRr 11% MrRRM 0,25; Denmark GDP 128 PMRr 10% MrRRM 0,31%; Austria GDP 130 PMRr 9% MrRRM 0,32%). The data confirm this trend with the presence of six out of total of twelve countries with the highest values of GDP per capita. An additional useful element for the assessment of the degree of transition is the analysis of GDP/CEI ratio with PrCE and IBP because it favors the comprehension of the operative transition level achieved by each country (Figs. 7 and 8).

The data analysis of this relation highlights a scenario which confirms the positive correlation trend between the higher GDP/CEI average countries and those with high performance in PrCE (Austria GDP/CEI PrCE 3,21% - IBP 3,75%, Finland GDP/CEI PrCE 2,92% - IBP 5,00%, France PrCE GDP/CEI 14,24% - IBP 8,75%, Germany GDP/CEI PrCE 33,11% - IBP 8,75%, Italy GDP/CEI PrCE 7,72% - IBP 15,42%, Netherlands GDP/CEI PrCE 4,44% - IBP 12,08%, Spain GDP/CEI PrCE 5,52% - IBP 12,08%, United Kingdom GDP/CEI PrCE 7,67% - IBP 5,00%). In this context, the data of PrCE are in line with the data of MWRr highlighting countries' profiles in which there are more investments in CE that result in a greater number of innovative technologies that may influence their recycling and reuse actions by activating CE processes. To confirm this trend, the data of IBP show that within best ten performers of this rate, there are six shared countries with PrCE (Italy, Netherlands Spain, Germany, France UK). This feature highlights the strong influence of the economic structures on countries' initiatives that result in best practices.

The analysis identifies areas 'profiles deeply different'. In fact, G1 and G2 represent the areas that drive, support and operate the transition towards the CE. In the G3 area only France and Italy show behaviors in line

with the main part of the G1 and G2 countries. The data highlight that the countries with a leader profile are all included amongst the countries with a higher GDP in PPS and GDP/CEI ratio average values, confirming a correlation between these economic elements with the transition degree of the countries towards the CE. The G4 area, with six countries out of total of eleven countries, shows a high degree of investment propensity, due to the strong commitment of the EU in terms of huge investments towards the EU incoming countries. Despite this, these countries do not reach significant transition outcomes in relation with the investments made. Finally, the G4 countries display a low level of PrCE and IBP by highlighting a difficulty in strategic investments.

## 6. Conclusions

The paper presented a comparison analysis on the CE transition in the 28EU Member States. Starting from a conceptual background and operational overview, the study describes the state of art of the phenomenon. Moreover, six quantitative indicators (PWM, PFW, DMC, MWRr, PMRr, MrRRM) have been elaborated in order to investigate the transition degree of each country towards the CE. The analysis shows a heterogeneous transition with countries in which the presence of higher GDP in PPS and GDP/CEI ratio average values show a good capacity of recycling (MWRr) and reuse (PMRr; MrRRM). An interesting feature, by analyzing the European geographical areas, is represented by the fact that G1 and G2 areas are composed by leader countries in transition. These performances are highlighted also at operative level by the ranking in PrCE and IBP.



Fig. 8. Implemented Best Practices (IBP).

In conclusion, it can be observed that in order to reduce the gap within the 28 EU Member States, it is necessary to develop ambitious government actions to support the best possible transition in each country. This necessitates a strong economic structure, a willingness of the governments in term of policies, an entrepreneurial culture on the territory able to understand the economic opportunities behind this change, and a population awareness and receptivity able to see in this transition an opportunity to enhance its social context and wellbeing. The CE is an open question, and therefore in conclusion the output of discussion linked to research results, reject a stance whereby the transition must be seen as under constant development and re-interpretation.

### Declaration of competing interest

The authors of this manuscript certify that they have No affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

### References

- Awasthi, A.K., Cucchiella, F., D'Adamo, I., Li, J., Rosa, P., Terzi, S., ... Zeng, X., 2018. Modelling the correlations of e-waste quantity with economic increase. *Science of the Total Environment* 613, 46–53.
- Brissaud, D., Zwolinski, P., 2017. The scientific challenges for a sustainable consumption and production scenario: the circular reuse of materials for the upgrading and repurposing of components. *Procedia CIRP* 61, 663–666.
- EASAC, 2016. Indicators for a Circular Economy. European Academies' Science Advisory Council, Halle.
- EEA, 2013. Municipal waste management in Italy. <https://www.eea.europa.eu/publications/managing-municipal-solid-waste/italy-municipal-wastemanagement>.
- Elia, V., Gnoni, M. G., & Tornese, F., 2017. Measuring circular economy strategies through index methods: A critical analysis. *Journal of Cleaner Production* 142, 2741–2751.
- European Circular Economy Stakeholder Platform, 2018. Luxembourg's Climate Pact now also mainstreams circular economy in local policy. <https://circulareconomy.europa.eu/platform/en/good-practices/luxembourgs-climate-pact-now-also-mainstreams-circular-economy-local-policy>.
- European Circular Economy Stakeholder Platform (ECSPR), 2019. <http://cdlink2.eesc.europa.eu/m/1/76282871/p1-b19044be4818fc7c414b6d89b98905a6051293/1/13/3fd2b728-b1bf-4419-b7f9-540ad21ef56c>.
- European Commission, 2015a. Closing the Loop: An Action Plan for the Circular Economy. European Commission, Brussels [https://eur-lex.europa.eu/resource.html?uri=C2%BCcellar:8a8ef5e8-99a0-11e5-b3b7-01aa75ed71a1.0012.02/DOC\\_1&format=C2%BCPDF](https://eur-lex.europa.eu/resource.html?uri=C2%BCcellar:8a8ef5e8-99a0-11e5-b3b7-01aa75ed71a1.0012.02/DOC_1&format=C2%BCPDF), Accessed date: 10 February 2020.
- European Commission, 2015b. Towards a circular economy. [https://ec.europa.eu/commission/priorities/jobs-growth-and-investment/towards-circular-economy\\_en](https://ec.europa.eu/commission/priorities/jobs-growth-and-investment/towards-circular-economy_en).
- European Commission, 2016a. European Structural and Investment Funds: country factsheet – Cyprus, May 19, 2016. Retrieved on February 26, 2019. [https://ec.europa.eu/regional\\_policy/en/information/publications/factsheets/2016/european-structuraland-investment-funds-country-factsheet-cyprus](https://ec.europa.eu/regional_policy/en/information/publications/factsheets/2016/european-structuraland-investment-funds-country-factsheet-cyprus).
- European Commission, 2016b. European Structural and Investment Funds: Czech Republic fact sheet. May 19, 2016. Retrieved January 7, 2019, from. [https://ec.europa.eu/regional\\_policy/sources/policy/what/investment-policy/esif-countryfactsheet/esi\\_funds\\_country\\_factsheet\\_cz\\_en.pdf](https://ec.europa.eu/regional_policy/sources/policy/what/investment-policy/esif-countryfactsheet/esi_funds_country_factsheet_cz_en.pdf).
- European Commission, 2016c. European Structural and Investment Funds: Greece fact sheet, 2016, May 19. Retrieved January 8, 2019. [https://ec.europa.eu/regional\\_policy/en/information/publications/factsheets/2016/european-structuraland-investment-funds-country-factsheet-greece](https://ec.europa.eu/regional_policy/en/information/publications/factsheets/2016/european-structuraland-investment-funds-country-factsheet-greece).
- European Commission, 2016d. European Structural and Investment Funds: Country factsheet – Lithuania. [https://ec.europa.eu/regional\\_policy/en/information/publications/factsheets/2016/european-structuraland-investment-funds-country-factsheet-lithuania](https://ec.europa.eu/regional_policy/en/information/publications/factsheets/2016/european-structuraland-investment-funds-country-factsheet-lithuania).
- European Commission, 2017a. The EU Environmental Implementation Review. Country report – Czech Republic. Commission Staff Working Document SWD(2017) 37 final. Brussels, 3.2.2017. [http://ec.europa.eu/environment/eir/pdf/report\\_cz\\_en.pdf](http://ec.europa.eu/environment/eir/pdf/report_cz_en.pdf).
- European Commission, 2017b. Factsheet Greece, DG Environment. February 2017. [http://ec.europa.eu/environment/eir/index\\_en.htm](http://ec.europa.eu/environment/eir/index_en.htm).
- European Commission, 2017c. Investment boost in Romania: circular economy project under Juncker Plan, three agreements under SME Initiative. October 19, 2017. [https://ec.europa.eu/commission/news/investment-boost-romania-circular-economy-project-underjuncker-plan-three-agreements-under-sme-initiative-2017-oct-19\\_en](https://ec.europa.eu/commission/news/investment-boost-romania-circular-economy-project-underjuncker-plan-three-agreements-under-sme-initiative-2017-oct-19_en).
- European Commission, 2018a. Flash Eurobarometer 456, SMEs, resource efficiency and green markets, January 2018. Online. <http://ec.europa.eu/commfrontoffice/publicopin/index.cfm/ResultDoc/download/DocumentKy/81280>.
- European Commission, 2018b. 2018 European semester: country reports. Retrieved on February 26, 2019 from: [https://ec.europa.eu/info/publications/2018-european-semester-country-reports\\_en](https://ec.europa.eu/info/publications/2018-european-semester-country-reports_en).
- European Commission, 2018c. Challenges for the Islands in the era of the Circular Economy. International conference on Chania/Crete, 20–22 September 2018. <https://circle2018.eu>.
- European Commission, 2018d. EXTREMADURA 2030: strategy for green and circular economy. Retrieved from. <https://ec.europa.eu/growth/tools-databases/regional-innovation-monitor/policydocument/extremadura-2030-strategy-green-and-circular-economy-0>.
- European Commission, 2019a. Circular Economy, DG GROW. Retrieved on April 12 2019 from. [https://ec.europa.eu/growth/industry/sustainability/circular-economy\\_en](https://ec.europa.eu/growth/industry/sustainability/circular-economy_en).
- European Commission, 2019b. Second Environment Implementation Review (EIR). Retrieved from. [http://ec.europa.eu/environment/eir/country-reports/index2\\_en.htm](http://ec.europa.eu/environment/eir/country-reports/index2_en.htm).
- European Commission, 2019c. The Environmental Implementation Review 2019. Country report Greece. Retrieved on April 8 from. [http://ec.europa.eu/environment/eir/pdf/report\\_el\\_en.pdf](http://ec.europa.eu/environment/eir/pdf/report_el_en.pdf).
- European Commission, 2019d. Report from the commission to the European Parliament (2018), the council, the European economic and social committee and the committee of the regions on the implementation of the circular economy action plan COM(2019)190 final. <https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1551871195772&uri=CELEX:52019DC0190>.
- European Economic Area (EEA) Grants, 2019. Latvia EEA - Norway Grants. <https://eeagrants.org/latvia>.
- European Environment Agency, 2013. Municipal waste management in Denmark. Retrieved January 9, 2019, from. <https://www.eea.europa.eu/publications/managing-municipal-solid-waste/denmark-municipal-waste-management/view>.
- European Environment Agency, 2018. Resource productivity, graph created 23 August 2018. Retrieved on April 8. [https://www.eea.europa.eu/data-and-maps/daviz/resource-productivitygdp-dmc-5#tab-chart\\_1](https://www.eea.europa.eu/data-and-maps/daviz/resource-productivitygdp-dmc-5#tab-chart_1).
- European Investment Bank, 2017. Recycling and circular economy. Green Fibre International, Romania Retrieved from. <http://reports.eib.org/eib-operations-inside-the-eu-2017/recycling-andcircular-economy-green-ibre-international-romania>.
- European Parliament, 2017a. [http://www.europarl.europa.eu/resources/library/images/20170512PHT74421/20170512PHT74421\\_original.jpg](http://www.europarl.europa.eu/resources/library/images/20170512PHT74421/20170512PHT74421_original.jpg).
- European Parliament, 2017b. European Parliamentary Research Service, Towards a Circular Economy – Waste Management in EU.
- European Parliament, 2018. Waste management in the EU: infographic with facts and figures, 06-04-2018. [http://www.europarl.europa.eu/resources/library/images/20180328PHT00737/20180328PHT00737\\_original.jpg](http://www.europarl.europa.eu/resources/library/images/20180328PHT00737/20180328PHT00737_original.jpg).
- European Parliament, 2019. MEP VOTE.EU: vote result source. Statistics retrieved from. <http://www.mepvote.eu> and number of MEPs per country. <http://www.europarl.europa.eu/meps/en/home>.
- European Parliamentary Research Service, 2018. <http://www.europarl.europa.eu/thinktank/infographics/circulareconomy/public/index.html>.
- Eurostat, 2017a. Circular economy indicators. Retrieved January 7, 2019. <https://ec.europa.eu/eurostat/web/circular-economy/indicators/monitoring-framework>.
- Eurostat, 2017b. Waste generation by packaging material. Share of treatment of all packaging waste in 2016. Retrieved on February 26, 2019 from 114. [https://ec.europa.eu/eurostat/statisticsexplained/index.php/Packaging\\_waste\\_statistics#Recycling\\_and\\_recovery\\_rates](https://ec.europa.eu/eurostat/statisticsexplained/index.php/Packaging_waste_statistics#Recycling_and_recovery_rates).
- Eurostat, 2018. <https://ec.europa.eu/eurostat/documents/3859598/9407565/KS-FT-18-009-EN-N.pdf/b8efd42b-b1b8-41ea-aaa0-45e127ad2e3f>.
- Eurostat, 2019a. Renewable Energy Statistics.
- Eurostat, 2019b. 487 kg of municipal waste generated per person, January 29, 2019. <https://ec.europa.eu/eurostat/web/products-eurostat-news/-/DDN-20190123-1>.
- Eurostat, 2019c. Treatment of waste by waste category, hazardousness and waste management operations [env\_wasttr]. Last update: 19-02-2019. <https://ec.europa.eu/eurostat/web/waste/waste-generation-and-management/management/incineration>.
- Eurostat, 2019d. <https://ec.europa.eu/eurostat/web/circular-economy/indicators/main-tables>.
- Eurostat, 2019e. <https://ec.europa.eu/eurostat/web/international-trade-in-goods/data/database>.
- EW-MFA Eurostat, 2010. <https://ec.europa.eu/eurostat/documents/3217494/5723037/KS-32-10-283-EN.PDF/22a4889d-e6c9-4583-8d17-fb5104e7ec0>.
- Food and Agriculture Organizations of the United Nation FAO, 2011. Global Food Losses and Food Waste: Extent, Causes and Prevention.
- Geng, Y., Fu, J., Sarkis, J., Xue, B., 2012. Towards a national circular economy indicator system in China: an evaluation and critical analysis. *J. Clean. Prod.* 23 (1), 216–224.
- Ghisellini, P., Cialani, C., Ulgiati, S., 2016. A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems. *J. Clean. Prod.* 114, 11–32.
- Hahladakis, J.N., Iacovidou, E., 2019. An overview of the challenges and trade-offs in closing the loop of post-consumer plastic waste (PCPW): focus on recycling. *J. Hazard. Mater.* 380, 120887.
- Hisllop, H., Hill, J., 2011. Reinventing the Wheel: A Circular Economy for Resource Security. Green Alliance.
- Horodytska, O., Valdés, F.J., Fullana, A., 2018. Plastic flexible films waste management—a state of art review. *Waste Manag.* 77, 413–425.
- Iacovidou, E., Millward-Hopkins, J., Busch, J., Purnell, P., Velis, C.A., Hahladakis, J.N., Brown, A., 2017a. A pathway to circular economy: developing a conceptual framework for complex value assessment of resources recovered from waste. *J. Clean. Prod.* 168, 1279–1288.
- Iacovidou, E., Velis, C.A., Purnell, P., Zwirner, O., Brown, A., Hahladakis, J., ... Williams, P.T., 2017b. Metrics for optimising the multi-dimensional value of resources recovered

- from waste in a circular economy: A critical review. *Journal of Cleaner Production* 166, 910–938.
- Kirchherr, J., Reike, D., Hekkert, M., 2017. Conceptualizing the circular economy: an analysis of 114 definitions. *Resour. Conserv. Recycl.* 127, 221–232.
- Korhonen, J., Nuur, C., Feldmann, A., Birkie, S.E., 2018. Circular economy as an essentially contested concept. *J. Clean. Prod.* 175, 544–552.
- Liu, L., Liang, Y., Song, Q., Li, J., 2017. A review of waste prevention through 3R under the concept of circular economy in China. *J. Mater. Cycles Waste Manag.* 19 (4), 1314–1323.
- Malinauskaitė, J., Jouhara, H., Czajczyńska, D., Stanchev, P., Katsou, E., Rostkowsk, P., ... Anguilano, L., 2017. Municipal Waste Management and Waste-to-energy in the Context of a Circular Economy and Energy Recycling in Europe.
- Michellini, G., Moraes, R.N., Cunha, R.N., Costa, J.M.H., Ometto, A.R., 2017. From linear to circular economy: PSS, conducting the transition. *Procedia CIRP* 64 (2017), 2–6.
- Minelgaitė, A., Liobikienė, G., 2019. Waste problem in European Union and its influence on waste management behaviours. *Sci. Total Environ.* 667, 86–93.
- Møller, H., Hanssen, O.J., Svanes, E., Hartikainen, H., Silvennoinen, K., Gustavsson, J., Östergren, K., Schneider, F., Soethoudt, H., Canali, M., Politano, A., Gaiani, S., Redlingshöfer, B., Moates, G., Waldron, K., Stenmarck, Å., 2014. Standard approach on quantitative techniques to be used to estimate food waste levels. *FUSIONS Report*.
- Murray, A., Skene, K., Haynes, K., 2017. The circular economy: an interdisciplinary exploration of the concept and application in a global context. *J. Bus. Ethics* 140 (3), 369–380.
- OECD, 2016. Extended producer responsibility. Updated guidance for efficient waste management. <http://www.oecd.org/development/extended-producer-responsibility-9789264256385-en.htm>.
- OECD, 2017. Making the Slovak Republic a more resource efficient economy. Retrieved from. <http://www.oecd.org/environment/waste/Policy-Paper-Making-the-Slovak-Republic-a-more-resourceefficient-economy.pdf>.
- Preston, F., 2012. A global redesign? Shaping the circular economy. *Energy Environ. Resour. Gov.* 2, 1–20.
- Rizos, V., Behrens, A., Kafyke, T., Hirschnitz-Garbers, M., Ioannou, A., 2015. The Circular Economy: Barriers and Opportunities for SMEs, CEPS Working Group – Work n. 412.
- Stahel, W.R., 2016. The circular economy. *Nature* 531, 435–438, 23.
- UN Environment, 2019. Global resources outlook natural resources for the future we want. Retrieved on April 5, 2019 from. <http://www.resourcepanel.org/reports/global-resources-outlook>.
- Winkler, H., 2011. Closed-loop production systems—A sustainable supply chain approach. *CIRP Journal of Manufacturing Science and Technology* 4 (3), 243–246.
- World Bank Report, 2019. <https://olc.worldbank.org/content/circular-economy>.