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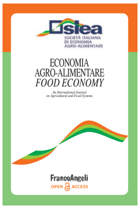

The Circular Economy in the Agri-food system: A Performance Measurement of European Countries

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Abstract

Agriculture and the agri-food industry are central to fostering economic growth and the Sustainable Development Goals' targets. However, to meet the world's future development, it is necessary to make the agri-food system more resource-efficient. The transition towards the circular economy (CE) paradigm is commonly seen as a promising strategy to overcome the critical issues affecting the sector. However, different theoretical and practical problems still need to be solved. Specifically, the CE performance measurement of specific sectors or national systems is crucial as it helps to identify and correct any deviation from the vision set out for achieving the sustainable development objectives. This article aims to contribute to CE research, focusing on European agriculture and the agri-food sector. Drawing on the EE-MRIO database EXIOBASE v3.7, this paper estimates the level of circularity in the European Union countries and the role of agriculture and agri-food in determining circularity. Results showed that circularity in the EU is low and significant differences between countries exist. Agriculture contributes to 80.5% of the entire amount of recycled materials in Europe. Vice versa, the contribution provided by the agri-food sector is limited to 1%. Some policy implications derive from this study.

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Introduction

Following the industrial revolution, the world economy has grown through the "extraction-production-consumption-disposal" model, based on easily denied assumptions (European Environment Agency, 2016), such as the abundance of available resources and economic convenience of their procurement. However, it is a common opinion that this linear "take-make-waste" model is not sustainable in the long term, requiring an urgent evolution to remedy the massive, negative impacts of humanity on society and the environment (Brandão *et al.*, 2020; Edgeman, 2020).

The circular economy (CE) stands in stark contrast to the linear model as it concerns an economy capable of reconstituting and regenerating itself, using renewable energy, and minimising waste due to the design of products that can be subsequently repaired, recycled and finally reused. In this perspective, CE is an approach to sustainable development that is gaining ever more attention among academics, politicians, and people in business (Ghisellini *et al.*, 2016; Golebiewski *et al.*, 2019; Kirchherr *et al.*, 2017; Korhonen, Honkasalo *et al.*, 2018; Xue *et al.*, 2010; Yuan *et al.*, 2006). Although CE studies are still in their initial phase and there are numerous fields to be explored yet (Korhonen, Nuur *et al.*, 2018), several scholars agree that it is "an idea and an ideal" (Gregson *et al.*, 2015, p. 218) to redirect the path of economic development and enable cyclical thinking towards the creation of a zero-waste economy (Homrich *et al.*, 2018; Zwier *et al.*, 2015).

The CE has been defined as an "umbrella concept" (Homrich *et al.*, 2018) under which there are various definitions that address the issue from different perspectives (Borrello *et al.*, 2020; Korhonen, Nuur *et al.*, 2018), although numerous are the authors (e.g. Blomsma & Brennan, 2017; Haas *et al.*, 2015; Haupt *et al.*, 2017; Hobson, 2016; Moreau *et al.*, 2017; Naustdalslid, 2014; Niero *et al.*, 2017; Singh & Ordoñez, 2016) who have relied on the definition provided by the Ellen MacArthur Foundation: "a CE is regenerative by design and aims to gradually decouple growth from the consumption of finite resources".

The CE consists of a continuous positive development cycle that preserves and enhances the natural capital, optimises the yields of the resources, and minimises system risks by managing finite stocks and renewable flows. According to the European Commission (2008), the CE is based on four principles (4R) – Reducing, Reusing, Recycling and Renewing –, which implies the review of all stages of production - that must comply with the fundamental criteria of eco-design, modularity and versatility, use of renewable energies, eco-systemic approach and recovery of materials (Ellen MacArthur Foundation, 2021) – and the supply chain involved in the production cycle.

However, it must be underlined that CE is first an economic strategy. In this sense, CE suggests innovative ways to switch from the current predominantly linear consumption system towards a material savings and resources regeneration system to achieve economic sustainability. With a specific reference to agriculture and the agri-food industry, it is pivotal to ensure the transition of this sector toward the CE paradigm to foster and achieve global development (De Pascale *et al.*, 2021).

Those key sectors for human wellness will face significant scenario changes and are called to solve issues such as resource scarcity, food loss and waste generation. The FAO (2019) estimated that in 2019, along the world's supply chain, was generated approximately 1.3 billion tons annually of waste with a cost of more than 1000 billion dollars per year. However, the agriculture and agri-food problems do not exhaust themselves in the mismanagement of resources and processes, that is, food production dependence on fossil fuel, non-renewable mineral resources, the exhaustion of groundwater reserves and excessive soil loss (Muscio & Sisto, 2020). Just think about how consumers' unsustainable consumption patterns is a major accomplice of agriculture in terms of its pressure on the environment and influence on climate change (Esposito *et al.*, 2020; Taghikhah *et al.*, 2019).

In this scenario, CE is seen as a possible and promising strategy to overcome the critical issues that affect those sectors (Esposito *et al.*, 2020; Hamam *et al.*, 2021), making the entire agri-food system more resource-efficient, with positive food security implications (Jurgilevich *et al.*, 2016; Muscio & Sisto, 2020). In effect, numerous are the expected benefits, that is, use a minimal amount of external inputs, reduce negative discharges to the environment, close nutrient loops, increase farming efficiency, improve the nexus into the food supply chain and among productivity sectors, increase competitiveness, stimulate innovation, boost economic growth (European Parliament, 2015; Ward, 2017). However, these benefits can be overshadowed by some critical issues that affect not only the agriculture and the agri-food sectors, such as theoretical (i.e., too multiple definitions), political and practical, also in terms of design, logistic, scale (i.e. processes, industrial site, business dimension, regions and economics) (Corvellec *et al.*, 2021; Muscio & Sisto, 2020; Walmsley *et al.*, 2019), and measurement (Circle Economy, 2021).

Especially the latter requires particular attention since the relevance of the CE into the actual economic strategies. Borrowing the phrase attributed to Peter Drucker, "if it cannot be measured, it cannot be managed", the CE performance measurement of specific sectors or national economies is crucial. Firstly because it is the first step in moving toward a circular food production system, a process that requires proper tools for effective measurement to support robust decision-making (Velasco-Muñoz *et al.*, 2021). Secondly, because of it helps to identify and correct any deviation from the vision set out for achieving several SDGs of the 2030 Agenda for sustainable development. In effect, the CE is seen as an engine of sustainability that improves traditional sustainability approaches based on eco-efficiency to reach a greener economy by promoting more appropriate, eco-friendly resource use and innovative business models (Hamam *et al.*, 2021). According to Xue *et al.* (2010, p. 1298) the CE "is the outcome of over a decade's efforts to practice Sustainable Development by the international economies and is the detailed approach towards Sustainable Development". In this vein, the current European Commission's target to close material loops and change the European economy towards a circular economy reveals the key role played by CE in reaching SD goals (European Commission, 2015; Geissdoerfer *et al.*, 2017). Moreover, CE contributes directly to several SDGs, such as SDG6, SDG7, SDG 8, SDG12, SDG15 (Schroeder *et al.*, 2019).

At the same time, research on agriculture and agri-food sustainability transitions toward the CE paradigm is still poor, especially concerning the measurement of circularity into the system (Hamam *et al.*, 2021; Muscio & Sisto, 2020).

This article aims to contribute to CE research, addressing the recent calls for research in CE in the agri-food sector (Hamam *et al.*, 2021). Specifically, the study focuses on the European context, which is among the world's leading producers and net exporters of agri-food products (European Commission, 2021b). Moreover, already from 2014, the concept of CE has become a strategic key to the development of the EU (see EU/COM/2014/0398 final) and to make it cleaner and more competitive (European Commission, 2021a). By the new Circular Economy Action Plan adopted in 2020, the EU reaffirmed the importance of the change towards the circular economy, also for the agricultural and agro-food sectors, highlighting how the food value chain is accountable for significant resources and environmental pressure. However, the EU economy is still largely linear, and the agricultural sector is a major user of natural resources (European Environment Agency, 2017, 2020; Muscio & Sisto, 2020).

Despite previous research at the macro level and few previous studies focused on some agri-food chains, such as pasta (Principato *et al.*, 2019) and tomato (Boccia *et al.*, 2019), as far we know, there are no studies that currently measure the circularity of the agricultural and agro-industrial sector of individual European countries.

Therefore, this paper aims to fill this literature gap by answering the following research question: "What is the level of circularity of the agricultural and agri-food sector of the European countries?". In particular, drawing on Aguilar-Hernandez *et al.* (2019) research and Environmentally extended multiregional input-output (EE-MRIO) database EXIOBASE v3.7, this paper intends to measure the circularity of European countries and the role of agriculture and agri-food in determining their circularity.

The paper is organised as follows: Section 2 presents the methodology employed. Section 3 presents the results. The final Section presents discussions and conclusions and outlines the implications for practitioners, academics, and policymakers and makes recommendations for future research.

1. Background

The performance measures are pivotal for guiding and reviewing CE policies (Ekins *et al.*, 2019), as the look forward indicators provide guidance, and backwards ones give feedback and review performance. Moreover, indicators importance arises from the fact that their choice is a critical determinant of the behaviour of a system (Meadows, 1998). Recently, some authors (i.e. De Pascale *et al.*, 2021; Saidani *et al.*, 2019) have provided an overview of the CE indices, classifying them into three levels, micro, meso and macro. Nevertheless, the attempts to globally assess the current circularity of the system are thin, perhaps due to the great challenge required and several data limitations (Ekins *et al.*, 2019). Grounded in Material Flow Accounting, Haas *et al.* (2015) estimate the global economy circularity as the "share of actually recycled materials in total processed materials". Mayer *et al.* (2019) based their study on previous contributions (Haas *et al.*, 2015; Nuss *et al.*, 2017) and used the material flow approach to investigate the degree of circularity of the EU.

An important contribution to this direction has been provided by the Circle Economy (Circle Economy, 2021) approach aimed to estimate the degree of circularity of the global economy. The first document – the Circularity Gap Report – was published in January 2018, and the assessment of circularity was based on the Material Flow Accounting. The reports published every year "provide high-level insights into the global metabolism and key levers for transitioning to circularity" (Circle Economy, 2021), and measure the circularity as 'cycled materials' as a share of the total resources entering the economy. The Circularity Gap Report (Circle Economy, 2021) revealed that at present, our world is only 8.6% circular, leaving a massive Circularity Gap. This report relies on the EE-MRIO database EXIOBASE v3.7.

The Environmentally Extended Input-Output Analysis is a particularly useful framework that fits with the economic outlook used in CE and allows considering diverse measures for improving circularity, that is residual waste management, loop-closing in supply chains, product life extension and resource efficiency (Aguilar-Hernandez *et al.*, 2018; Walmsley *et al.*, 2019). In particular, according to Harris *et al.* (2021), EXIOBASE is the dominant database in the CE literature and has been used to assess the generation and recovery of waste, depletion of stocks and the circularity gap. Moreover, although previous authors have raised some problems regarding the completeness of EXIOBASE (Tisserant *et al.*, 2017), the reliability of the entire database is not affected, and MRIO analysis was demonstrated to be capable of quantifying global and regional flows of material and estimating the quantity of it that is recycled (Aguilar-Hernandez *et al.*, 2019). Relying on the EE-MRIO database EXIOBASE v3.7, other authors used the same database to analyse the mitigation of environmental impact related to food consumption in Denmark (Osei-Owusu *et al.*, 2022) or to test the implementation of the strategies of the product lifetime extension and resource efficiency (Donati *et al.*, 2020). In the same vein, Aguilar-Hernandez *et al.* (2019) first have estimated and compared the material circularity gap of more nations (43 nations and 5 global regions in 2011) in a consistent framework. They quantify the Circularity Gap (CG), a measure of the waste materials that are theoretically available for circularity resulting from "the generated waste, plus old materials removed from stocks and durable products disposed of (i.e. stock depletion), minus recovered waste". In other terms, for the circularity gap calculation, they proposed the use of a metric that considers how much of the unrecovered waste can be turned into the economy as products or materials. Their approach differs from previous studies since they made an explicit mathematical distinction between the added materials to stocks and the ones dispersed in the environment as dissipative emissions or other combustion residues, allowing to determine the actual fraction of waste that is circular in a given period. From the GC, the authors drew up two other indicators, the Circularity index (CI) and the Circularity gap index (CGI).

Based on these considerations, the Aguilar-Hernandez *et al.* (2019) framework is suitable for our research purpose.

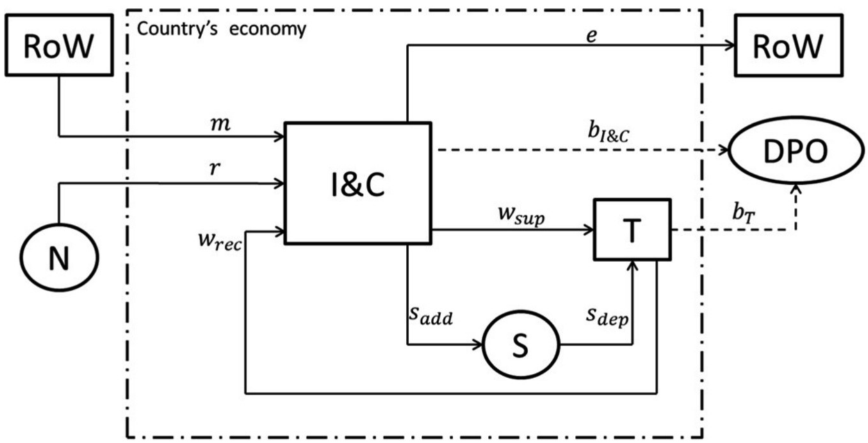
2. Materials and methods

Building upon the work of Aguilar-Hernandez *et al.* (2019), Figure 1 shows the system's boundaries of national material flow inputs, outputs and stocks according to the data contained in EXIOBASE.

In the material flow diagram, the solid boxes depict the socio-economic processes, and the solid circles represent the material stocks. The formers consider the intermediate activities and final demand (I&C), the waste treatment sectors (T), and the rest of the world economy (RoW).

The second are the stock of natural resources (N), the material in-use stocks (S), and the stock of nature from domestic processed outputs (DPO). The lines constitute the flows. The solid ones consider the imports (m), domestic resource extraction (r), recovered or secondary materials (w_{rec}), exports (e), waste generation or supply (w_{sup}), additions to stocks (s_{add}), and stock depletion (s_{dep}).

Figure 1 - System definition of national material flow inputs, outputs and stocks, own elaboration based



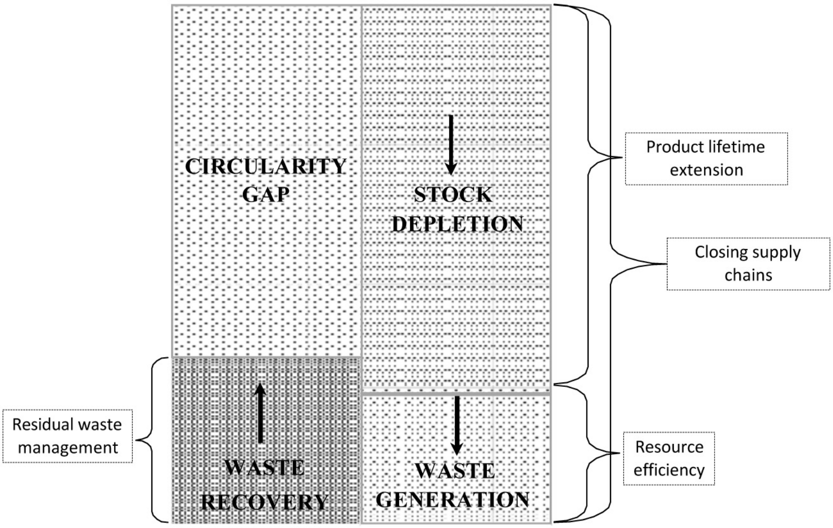
Source: Aguilar-Hernandez *et al.* (2019).

The dashed ones pose the flow of dissipative emissions and other combustion and biomass residues caused by intermediate activities and final demand ($b_{I\&C}$) and waste treatment (bT). According to the authors, as the analysis looks at a system boundary for the global economy, the imports (*m*) exports (*e*) are not considered, as well as the RoW sectors, that, due to physical trade balance to other regions, does not occur in this context. The Circularity Gap (CG) refers to all waste generated ruled out the recovery waste, which means the amount of waste not used in a circular way. In other terms, it is the difference between the entire volume of waste and the quota re-used or re-cycled.

It arises from three main outflows linked to the waste material: w_{sup}, s_{dep}, and w_{rec}. The CG can be expressed as follow:

$$CG = w_{sup} + s_{dep} - w_{rec} \quad (1)$$

Figure 2 - A circularity gap reduction through four intervention types



Source: Aguilar-Hernandez *et al.* (2019).

Figure 2 indicates the kinds of viable intervention (signalled by the white square with dots line border) to reduce the circularity gap by acting on stock depletion, material recovery, and waste generation, depicted in squares 1, 3 and 4. The up arrow indicates an increase in material flow, while the down arrow shows a decrease or delay in waste flow.

The Circularity Index (CI) for a specific country takes into account the import (*m*) – imports to EU and non-EU countries were considered for all 27 countries present in the study, as required by the CI formula, whereas the exports are not considered as not required by CI calculate – and domestic resource extraction (r), which together indicate the domestic material input of I&C.

In other words, this index shows the proportion of material that, after being introduced into the economy, is destined for reuse, and can be expressed as:

$$CI = \frac{W_{rec}}{r + m} \times 100 \qquad (2)$$

In the same vein, the country Circularity Gap Index (CGI), which reports how much material, compared to that potentially reused, is not addressed to recycling, can be calculated as

$$CGI = \frac{CG}{w_{sup} + s_{dep}} \times 100 \quad (3)$$

and it indicates the weight of all waste generated ruled out the recovery waste with respect to the total weight produced. The level of circularity is, therefore, inversely proportional to the CGI (the circularity increases with the decrease of CGI).

Data to estimate the circularity in the entire economic system (European Union and its single countries) and the role of agriculture and agri-food in determining circularity were delivered from the input-output tables shown by the EXIOBASE database. It arises from three EU-funded projects, CREEA, EXIOPOL and DESIRE, and includes data on global production recipes and demand by households, firms and government for different products and services.

EXIOBASE database is a global environmentally extended monetary and hybrid multi- regional supply and use/input-output table (MR SUT/MR IOT) for 164/200 industries/products, 44 countries (28 EU countries, 16 non-UE countries and five rest of world regions), and 2000-2011 years (Merciai & Schmidt, 2018). It uses different units measure: physical mass (e.g., tonnes for tangible goods and waste), joule (for energy and electricity flows) and currency/economic value (for services).

This study uses version 3.3.17 of hybrid EXIOBASE's data sources, which includes national reports, the Food and Agriculture Organization (FAO, 2021), International Energy Agency (IEA), Eurostat, International Fertilizers Association (IFA) and Ecoinvent databases.

The algorithm of EXIOBASE multi-regional hybrid supply and use tables is divided into general and sectorial modules. The latter is "a self-standing block that delivers results to the general part" (Merciai & Schmidt, 2018, p. 519), such as the agriculture module, which aims to determine the mass balance for all the agricultural activities. Figure 3 represents the input-output table of the EXIOBASE agriculture module.

Concerning the crop activities, in the EXIOBASE, the input comprises the carbon dioxide, minerals, and nutrients from chemical fertilisers and manure, while the outputs (i.e., the productions of activities) include the harvested crops, emissions, manure excreted and the use of crop residues. Regarding the livestock activities, the inputs include oxygen for animal respiration, marketable and non-marketable feed, and grass, while the outputs involve the animal growth, emissions, and manure excreted.

The use of this version of EXIOBASE required some adjustments for calculating the index variables. Since there were no extension accounts of waste supply/use and stock depletions, these flows were calculated using the

Figure 3 - The EXIOBASE Agriculture module schema

	CROPS	LIVESTOCKS
INPUT	– Carbon dioxide – Minerals – Nutrients from fertilisers and manure	– Oxygen from animal respiration – Market and non-market feed – Grass
OUTPUT	– Harvested crops * – Emissions – Manure excreted*** – Crop residues	– Animal growth** – Emissions – Manure excreted***

* Paddy rice, wheat, cereal grains nec, vegetables, fruit, nuts, oil seeds, sugar cane, sugar beet, plant-based fibers, crops nec.
** Cattle, Pigs, Poultry, Meat animals nec, Animal products nec, Raw milk, Wool, silk-worm cocoons, Fish and other fishing products, services incidental of fishing.
*** Conventional treatment, biogas treatment.
Source: Authors elaboration.

MR-SUT e MR-IOT. To identify the w_{sup}, both for the activities and the final demand, we considered 22 activities related to incineration, biogasification and land application, composting and land application, waste-water treatment, and landfill. The s_{dep} was estimated by the Gross fixed capital formation item presented in the final demand. The w_{rec} were identified considering 20 activities related to re-processing, recycling, biogasification and composting products. The r was represented by 18 activities related to wool and silk, forestry products, fishing activities and extraction of metals, fossil fuels, stone, sand, clay and other mining and quarrying products. The m are indicated by all material flows from other countries, except those related to waste recovery. The wsup and sdep were derived by MR-SUT. The wrec, r and m have been calculated from the MR-IOT (please see Appendix 1 for details on the list of items included in the variables of CI and CGI indexes).

Finally, two linear regression analyses across the 27 countries were applied to estimate if the general Circularity Index – that for its inherent nature represents the most relevant index in our study because provides a measure of the level of circularity – would depend on the domestic level of economy and on the economic weight of agriculture:

$$CI_i = \alpha + ß_1 \, GDP_i \tag{4}$$

$$CI_i = \alpha + ß_1 \, AEV_i \tag{5}$$

where CI_i is the Circularity Index by each *i*-country, α is a constant, ß is the coefficient related to the independent variables, GDP*i* is the pro-capita Gross Domestic Product by each *i*-country, AEV_i is the pro-capita Additional Economic Value of agriculture by each *i*-country.

The choice of applying two regressions was suggested by the need of prevent possible interdependency between the two variables. In this term, we would highlight not only the magnitude and the statistical significance of each variable, but also the degree of relation between each variable and the level of circularity (dependent variable).

Data on national GDP and AEV were extracted from the Eurostat database and represent annual average values with reference to the period 2011-2020.

3. Results

A preliminary analysis was carried out to offer a snapshot of what is occurring in the entire economic system of Europe. The findings on circularity in the whole economic system of Europe are shown in Table 1.

Firstly, the analysis shows that Europe is very far from the global average of the circular economy. Although it pains to say it – while using different versions of the database and methodological approaches – the fact is that Europe is only 4.1% circular, almost half of the already shallow global value of 8.6% (Circle Economy, 2021). However, it must be underlined that the different ways of calculation and versions of the database can affect magnitudes. Therefore, obtained results are not fully comparable with those shown in the Circularity Gap Report. Basically, the level of circularity related to the entire EU system is found to be low.

The best country is Ireland, equal to approximately three times the European average. Although at levels not comparable to this score, Denmark and France also show a good rate of circularity, placing themselves in second and third place, respectively.

However, 11 out of 27 countries re-employ less than 3% of material introduced into the economic system, with Malta, Bulgaria, and Greece representing the three worst countries, respectively.

Concerning the amount of materials that are not addressed to recycling compared to that potentially reused, Europe shows an average of 72.3%. Specifically, 24 out of 27 countries reveal a CGI above 50%, of which 13 are above 70%. Given the nature of these indexes, the country ranking by CGI reflects that by CI – in an inverted way – with only two countries (Denmark and Ireland) showing a score below 50%.

Finally, looking at the amount of waste not used circularly, European countries show an average of 27.5 million tonnes with sharp differences among them. The worst country is Bulgaria, followed by France and Germany, whereas the best one is Slovenia, followed by Croatia and Lithuania.

Table 1 - Analysis of the circularity degree of the entire European economic system

EU Country	**CI (%)**	**CGI (%)**	**CG (M tonnes)**
Austria	3.6	74.0	14.8
Belgium	4.4	61.0	12.4
Bulgaria	1.7	98.8	143.0
Croatia	3.3	65.4	2.0
Cyprus	2.2	98.5	23.8
Czech Republic	2.5	54.6	5.3
Denmark	8.3	42.1	5.0
Estonia	2.5	92.3	10.4
Finland	2.4	91.4	33.0
France	6.6	76.0	123.9
Germany	3.6	58.0	57.9
Greece	2.1	93.3	57.3
Hungary	6.0	85.0	23.9
Ireland	13.0	33.6	4.8
Italy	3.3	68.4	42.5
Latvia	5.0	83.5	4.9
Lithuania	5.6	62.3	2.9
Luxembourg	2.6	98.5	26.1
Malta	1.5	99.7	15.0
Netherlands	5.5	51.0	14.9
Poland	3.7	58.0	28.4
Portugal	2.6	64.8	7.2
Romania	5.0	54.7	10.3
Slovak Republic	2.2	78.0	5.7
Slovenia	5.1	55.5	1.5
Spain	5.0	62.9	37.0
Sweden	2.1	89.5	28.6
EU-27	4.1	72.3	27.5

To answer our research question, firstly, we analysed the circularity degree in the EU agricultural (Table 2) and the agri-food sectors (Table 3). Secondly, we measured the weight of latter compared to the circularity recorded in each country and estimated the weight of agriculture on agri-food (Table 4).

Table 2 - Analysis of the European agricultural sector circularity degree

EU Country	CI (%)	CGI (%)	CG (M tonnes)
Austria	2.7	49.8	3.9
Belgium	3.4	36.4	3.5
Bulgaria	1.5	50.9	1.6
Croatia	2.9	48.3	0.9
Cyprus	2.1	51.0	0.4
Czech Republic	2.0	38.3	2.2
Denmark	7.0	15.2	1.0
Estonia	1.6	48.6	0.5
Finland	1.4	66.9	3.6
France	5.7	32.2	15.9
Germany	2.5	43.9	23.0
Greece	1.2	59.5	3.6
Hungary	4.6	34.3	1.7
Ireland	12.7	9.3	0.9
Italy	2.4	56.0	18.2
Latvia	4.2	37.5	0.5
Lithuania	5.3	29.2	0.7
Luxembourg	2.0	40.1	0.2
Malta	1.5	89.6	0.4
Netherlands	4.4	32.5	5.5
Poland	2.9	32.2	7.6
Portugal	2.2	44.4	2.6
Romania	4.1	41.1	4.9
Slovak Republic	1.7	54.7	1.5
Slovenia	4.1	36.4	0.5
Spain	3.8	33.7	8.5
Sweden	1.8	56.4	3.6
EU-27	3.4	43.3	4.4

Table 3 - Analysis of the European agri-food sector circularity degree

EU Country	CI (%)	CGI (%)	CG (M tonnes)
Austria	2.7	49.0	3.8
Belgium	3.5	34.8	3.3
Bulgaria	1.5	50.9	1.6
Croatia	3.0	47.6	0.9
Cyprus	2.1	50.9	0.4
Czech Republic	2.1	37.8	2.2
Denmark	7.0	14.9	1.0
Estonia	1.6	48.2	0.5
Finland	1.4	66.3	3.6
France	5.7	31.4	15.5
Germany	2.6	42.6	22.3
Greece	1.2	59.4	3.6
Hungary	4.7	32.9	1.6
Ireland	12.7	9.1	0.9
Italy	2.5	54.6	17.8
Latvia	4.2	37.2	0.5
Lithuania	5.4	28.7	0.7
Luxembourg	2.0	39.9	0.2
Malta	1.5	89.6	0.4
Netherlands	4.6	29.8	5.0
Poland	3.0	30.1	7.1
Portugal	2.2	44.2	2.6
Romania	4.1	41.0	4.9
Slovak Republic	1.7	54.3	1.5
Slovenia	4.1	36.2	0.5
Spain	3.9	31.8	8.0
Sweden	1.8	55.5	3.5
EU-27	3.4	42.6	4.2

Looking at the European agricultural sector, the results highlight the role of this sector in determining European circularity. In fact, on average European countries recycle 3.4% of the materials introduced into the economic system, equal to 80.5% of the entire amount of recycled materials in the EU. Also specifically in this sector, the most striking countries in this area are Ireland, Denmark, and France, whereas Greece, Finland and Malta represent the less virtuous.

Regarding materials that are potentially recyclable but have not been sent for recycling, the average value of the agricultural sector is equal to 43.3% (CGI). However, slightly more than half of these countries are below this average. The average CG of the agricultural sector is equal to 4.4 million tonnes. The surprising fact is that as many as 9 countries have a value of less than one million and 13 less than 2 million.

The amount of waste not used in a circular way by the 5 worst countries (Poland, Germany, Italy, France, Spain) is compressively bigger more than two times that of the other 22 countries.

The circularity analysis on the agri-food sector traces the agricultural sector data partially. Even in this case, the recycling percentage of materials introduced into the sector is 3.4%, and the most virtuous countries are Ireland, Denmark, and France.

Compared to that potentially reused, the average of material not addressed to recycling is slightly lower than that of the agriculture sector (CGI equal to 42.6%). Only Ireland reports a score of less than 10%.

Concerning the amount of waste not used in a circular way in the agri-food sector, European countries show an average of 4.2 million tonnes. One of the most noteworthy data is that the three worst countries (Germany, Italy and France) record together almost the same value (55.6 million tonnes) deriving from the sum of the other 24 countries (58.4 million tonnes).

The impact of the agricultural and agri-food sector on the CE in individual countries is showing the Table 4. It should be noted that the calculated scores mean how much a single economic sector contributes to the entire country's circularity and not the circularity solely inherent to that given sector. This occurs because the nature of the input-output matrix does not allow us to enucleate a single production sector as a closed system, as each sector is characterised by exchanges of materials with the rest of the economy. This means it is impossible to arrive at circularity measures referable to a single sector. Still, we can calculate the level of circularity in the entire economic system that derives from the processes of a given sector.

The findings showed that:

1. The agriculture contributes, on average, to determine 80.5% of the total circularity in the European countries. This percentage varies from 57.4% of Finland to 97.7% of Malta. It means that agriculture plays a predominant role in determining circularity in all EU countries.
2. Looking at the agri-food sector leaving out its upstream phases, it results that it affects circularity by about 1% (the difference between the agri-food and agriculture CIs). Indeed, the agriculture weights for about 99% on the agri-food index, highlighting how the weight of the other phases along the supply chain is little more than insignificant in promoting circularity processes.

Table 4 - Impact of agricultural and agri-food sector on the circularity of each country

EU Country	CI agricultural sector/ CI country (%)	CI agri-food sector/ CI country (%)	CI agricultural sector/ CI agri-food sector (%)
Austria	74.5	75.7	98.4
Belgium	76.9	78.8	97.5
Bulgaria	89.1	89.2	99.9
Croatia	88.3	89.5	98.7
Cyprus	97.5	97.7	99.8
Czech Republic	81.1	81.7	99.2
Denmark	84.0	84.3	99.6
Estonia	64.9	65.4	99.2
Finland	57.3	58.4	98.2
France	85.6	86.5	98.9
Germany	70.1	71.6	97.9
Greece	59.2	59.4	99.6
Hungary	77.0	78.7	97.9
Ireland	97.4	97.6	99.9
Italy	73.1	75.5	96.9
Latvia	84.7	85.0	99.6
Lithuania	95.3	95.9	99.4
Luxembourg	76.4	76.6	99.7
Malta	97.7	97.8	100.0
Netherlands	79.7	82.9	96.2
Poland	78.2	80.7	96.9
Portugal	84.9	85.2	99.6
Romania	82.2	82.3	99.9
Slovak Republic	79.4	80.1	99.2
Slovenia	80.6	80.8	99.7
Spain	76.7	78.8	97.3
Sweden	82.3	84.1	97.8
EU-27	80.5	81.5	98.8

However, we investigated to understand if and how much a possible improvement of the Gross Domestic Product and/or agricultural production value would affect national CI. Therefore, the general CI was separately regressed on two variables: the pro-capita Gross Domestic product, the pro-capita Additional Economic Value of Agriculture (AEV) according to the formulas (4) and (5).

The regression model was tested to estimate if the preferable model is with or without the constant term. As a testing procedure, we adopted the Generalised likelihood-ratio test, which allows us to evaluate a restricted model with respect to the adopted model. Findings suggest that the preferred model is without the α term.

Results of both regression analyses are reported in Tables 5 and 6.

Table 5 - Estimation of the linear regression model – Independent variable: GDP

Variables		**Coefficient**	**S.E.**	**z**	**p-value**	
Constant	α	–	–	–	–	
GDP	β_1	0.001	0.001	3.904	0.001	***
$R^2 = 0.641$						
		Test on regression				
LL value	*LL' value**	χ^2	*d.f.*	χ^2 *(0.95)*		
–60.8	–61.6	1.6	1	3.84	0.000	***

* Alternative model without the constant term.

Table 6 - Estimation of the linear regression model – Independent variable: AEV

Variables		**Coefficient**	**S.E.**	**z**	**p-value**	
Constant	α	–	–	–	–	
AEV	β_1	0.005	0.001	10.9	0.000	***
$R^2 = 0.908$						
		Test on regression				
LL value	*LL' value**	χ^2	*d.f.*	χ^2 *(0.95)*		
–48.3	–48.7	0.9	1	3.84	0.000	***

* Alternative model without the constant term.

Results suggest that Circularity Index is positively and significantly related to the per capita Gross Domestic Product even if the magnitude is shallow. The correlation between the two variables is not much high ($R^2 = 0.641$), but this analysis can depend on the differences in economic structure across regions (Aguilar-Hernandez *et al.*, 2019). The Circularity Index also results positively and significantly related to the per capita Additional Economic Value of agriculture. The magnitude of the coefficient is about five times higher than that estimated for the GDP, and the standard coefficient of determination is high (R^2 = 0.908). These findings imply that the elasticity of CI with respect to the only agricultural sector income is remarkably higher than the entire domestic income of each country.

4. Discussion and conclusions

The role played by agriculture and the food sector in the natural resources sustainable use and preservation is undisputed. The European Commission (2020) intends to make European food the global standard for sustainability (Corrado & Zumpano, 2021) and sees the food sector as one of the most strategic in guiding the transition to a circular economy (Chiaraluce, 2021; Rocchi *et al.*, 2021). To that end, it promotes the more efficient use of resources, that, in turn, contributes to economic growth, new market opportunities development and the mitigation of climate change.

Bearing in mind that CE principles can be deployed as a "toolbox" to attain several SDGs (Schroeder *et al.*, 2019) and Green Deal, the centrality of the agri-food sector, in Europe as in worldwide, emerges strongly, even in light of emergencies linked to the Covid-19 pandemic.

Given the above, and since the use of indicators is essential for monitoring the progress of sectors and countries towards a circular model (Poponi *et al.*, 2022), the purpose of this study was to estimate the circularity level of the agricultural and agri-food sector in European Union countries.

First, we examined the overall level of circularity of the 27 European countries, finding that the average of the countries differs from the values previously observed by Aguilar-Hernandez *et al.* (2019) and stands at a much lower level (–4.5 points of difference) than the world average of 8.6 % as it stands in the last Circularity Gap Report (Circle Economy, 2021). This is despite a series of ambitious CE policies adopted by the European Commission, e.g., its "Circular Economy Package" (launched in 2015 and subsequently updated in 2018).

By focusing on the agri-food sector, although circular agriculture is still a new concept (Mor *et al.*, 2021), the data clearly showed how relevant it is in pursuing the transition to an CE in the EU because the agriculture sector recycles 80% of the entire amount of recycled materials in Europe. However, there are major differences between countries. A significant finding is the scarce contribution of agri-food to the CE of countries. This data reflects the amount of food waste generated in Europe, estimated at 88 million tonnes, equal to about 20% of the total food produced (Eurostat, 2018; Stenmarck *et al.*, 2016). It is an absurd situation that odds with economic and ethical principles since it means to lose 143 billion euros, and 33 million Europeans cannot afford a quality meal every second day (Eurostat, 2018). Furthermore, the waste of food also depletes the environment of limited natural resources, clashed with SDG 12 aimed at ensuring the population's well-being by reducing the excessive consumption of natural resources, and SDG 2 that fosters the sustainability of food production systems and achievement of food security.

Further noteworthy results concern the relationships between CI and, by a hand, the additional value of the agricultural production and, by another hand, the GDP of each EU country: the first positive and significant, the second negative and significant. Therefore, increasing the domestic value of the agricultural production increases the circularity provided by the agriculture sector and the whole countries.

Therefore, it emerges that agriculture – given the state of technology nowadays and the nature of the inherent technical and economic processes – is the sector that contributes most to determining the level of CI in European countries – as confirmed by the incidence of the CI by agriculture on the global CI – and a possible increase of the additional value of agricultural production can affect CI more than can happen with a proportional improvement of the entire GDP. In other terms, an increase in the level of circularity of the EU economy passes primarily by the development of agriculture rather than by a general improvement of the performance of the entire economic system due to the relative high elasticity of this sector.

Basically, the marked ability of agriculture to be a leverage for fostering circularity would derive from the physiological propensity of the sector to resort to technical practices based on the regeneration of natural resources and the re-use of waste materials even within the same farms that generate waste. On the other hand, it should be emphasised that more than in other sectors, there is a widespread tendency on the part of farmers to use the resources at their disposal with caution – i.e., efficiently – and this predisposes, among other things, to naturally seek forms of management of crops or livestock that are partly based on the re-use of waste.

In the light of these considerations, some policy implications can derive in terms of quality and quantity improvement of agriculture.

Although not acting on resource circularity enhancing and agricultural quality side (thus keeping the technological frontier unchanged), policies aimed at increasing agricultural production will increase the agricultural circularity and country circularity. This would occur even without necessarily rethinking the agricultural model to be promoted in the direction of greater circularity given the natural propensity of agriculture to resort per se to practices already centred on the re-cycle of the used resources. Obviously, the eventual introduction of virtuous processes that increasingly apply the CE principles and better integration, in this sense, with the upstream and downstream sectors of agriculture can increase the sector's ability to affect the overall circularity of the economic system.

Furthermore, new practices and innovation based on the CE approach have proved economically feasible as they create additional income and paid employment by the local population, lead to social benefits such as better living conditions and new openings, and ecological benefits, such as better waste management, less natural contamination and fewer fossil fuel by-products (Mor *et al.*, 2021).

To summarise, since the elasticity of the agricultural sector is greater than that of all the entire economy, qualitative and quantitative interventions on the agricultural sector will generate a more than proportional return to the benefit of the circularity of all the EU countries.

The food sector, in contrast, requires policy expressly oriented to the quality side. Indeed, the scarce contribution that the sector today, without the primary phase, provides to the economic system in terms of circularity is very limited. This suggests that it would be not enough to improve the sector's performance if, at the same time, the processes and the farms' organisation are not rethought towards practices with a high rate of circularity. It implies that a remarkable effort needs to be made to promote innovations in different fields such as prevention of packaging waste, eco-design and end-of-life packaging management, food waste prevention and food surpluses management. This is one of the better ways to increase food quality and security, environmental sustainability, and the economic well-being of countries (Fiore *et al.*, 2019).

On the other hand, this paper presents some limits that can open up prospects for further studies.

First, findings are grounded in material flow accounting, but, as the CE is an economic strategy, future research can replicate our analysis on Monetary EXIOBASE.

Second, results are focused on the entire agriculture and food sector; future research can investigate differences among industries.

Third, according to Ellen MacArthur Foundation (2021) "A circular economy is one that is restorative and regenerative by design and aims to keep products, components, and materials at their highest utility and value at all times". Because the Aguilar-Hernandez *et al.* (2019) framework employed in this study considerers the mass of recycled waste but not "how much energy is required to restore the recovered material back to the desired material or product" (Cullen, 2017, p. 483), future research can investigate the material losses and energy inputs associated with recycling that can affect the environmental benefits deriving from the agribusiness transition toward a circularity paradigm.

Fourth, previous research highlighted the pivotal role of biomass in the circularity economy analysis (Allain *et al*., 2022; Erb & Gingrich, 2022; Paes *et al*., 2019). In the European Union (EU), the importance of biomass feedstocks has been boosted by policies that promote renewable energy and biobased products, and being a source of material goods and energy, biomass is of critical importance in a circular economy (Sherwood, 2020). Since changes in time of vegetation biomass per unit area (biomass density) is an essential climate variable that directly measures the sequestration or release of carbon between terrestrial ecosystems and the atmosphere (FAO, 2009), to realize the transformative potential of the circular economy unsustainable biomass production must be eliminated (Haas *et al*., 2020). Future research can investigate how such a variable affects the circularity of the agribusiness industry in the European countries. Finally, analyses on different versions of the EXIOBASE database can lead to results hardly comparable among scholars. The hope is that an increasingly accurate database will be available in the future, also to allow a more sophisticated computational procedure of circularity indicators.

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Appendix 1
List of items included in the variables of CI and CGI indexes

Waste Supply (considered both for Activities and Final demand sheets)
- Food waste for treatment: biogasification and land application
- Food waste for treatment: composting and land application
- Food waste for treatment: incineration
- Food waste for treatment: landfill
- Food waste for treatment: waste water treatment
- Inert/metal/hazardous waste for treatment: landfill
- Intert/metal waste for treatment: incineration
- Manure (biogas treatment)
- Manure (conventional treatment)
- Oil/hazardous waste for treatment: incineration
- Other waste for treatment: waste water treatment
- Paper and wood waste for treatment: composting and land application
- Paper for treatment: landfill
- Paper waste for treatment: biogasification and land application
- Paper waste for treatment: incineration
- Plastic waste for treatment: incineration
- Plastic waste for treatment: landfill
- Sewage sludge for treatment: biogasification and land application
- Textiles waste for treatment: incineration
- Textiles waste for treatment: landfill
- Wood waste for treatment: incineration
- Wood waste for treatment: landfill

Stock Depletion (derived from the voice "Gross fixed capital formation" from the Final Demand sheet)
- Air transport services (62)
- Aluminium and aluminium products
- Aluminium ores and concentrates
- Animal products nec
- Ash for treatment, Re-processing of ash into clinker
- Basic iron and steel and of ferro-alloys and first products thereof
- Beverages
- Biogas an other gases nec.
- Bottles for treatment, Recycling of bottles by direct reuse
- Bricks, tiles and construction products, in baked clay
- Cattle
- Cement, lime and plaster
- Ceramic goods
- Cereal grains nec
- Chemical and fertilizer minerals, salt and other mining and quarrying products nec
- Chemicals nec; additives and biofuels

- Coal, lignite and peat
- Coke oven products
- Collected and purified water, distribution services of water (41)
- Computer and related services (72)
- Construction work (45)
- Copper ores and concentrates
- Copper products
- Crops nec
- Crude petroleum and services related to crude oil extraction, excluding surveying
- Dairy products
- Distribution and trade services of electricity
- Distribution services of gaseous fuels through mains
- Education services (80)
- Electrical machinery and apparatus nec (31)
- Electricity by biomass and waste
- Electricity by coal
- Electricity by gas
- Electricity by Geothermal
- Electricity by hydro
- Electricity by nuclear
- Electricity by petroleum and other oil derivatives
- Electricity by solar photovoltaic
- Electricity by solar thermal
- Electricity by tide, wave, ocean
- Electricity by wind
- Electricity nec
- Extra-territorial organizations and bodies
- Fabricated metal products, except machinery and equipment (28)
- Financial intermediation services, except insurance and pension funding services (65)
- Fish and other fishing products; services incidental of fishing (05)
- Fish products
- Food products nec
- Food waste for treatment: biogasification and land application
- Food waste for treatment: composting and land application
- Food waste for treatment: incineration
- Food waste for treatment: landfill
- Food waste for treatment: waste water treatment
- Foundry work services
- Furniture; other manufactured goods nec (36)
- Glass and glass products
- Health and social work services (85)
- Hotel and restaurant services (55)
- Inert/metal/hazardous waste for treatment: landfill
- Inland water transportation services

- Insurance and pension funding services, except compulsory social security services (66)
- Intert/metal waste for treatment: incineration
- Iron ores
- Lead, zinc and tin and products thereof
- Lead, zinc and tin ores and concentrates
- Leather and leather products (19)
- Machinery and equipment nec (29)
- Manure (biogas treatment)
- Manure (conventional treatment)
- Meat animals nec
- Meat products nec
- Medical, precision and optical instruments, watches and clocks (33)
- Membership organisation services nec (91)
- Motor vehicles, trailers and semi-trailers (34)
- N-fertiliser
- Natural gas and services related to natural gas extraction, excluding surveying; includling liquid gas
- Nickel ores and concentrates
- Nuclear fuel
- Office machinery and computers (30)
- Oil seeds
- Oil/hazardous waste for treatment: incineration
- Other business services (74)
- Other Hydrocarbons
- Other land transportation services
- Other non-ferrous metal ores and concentrates
- Other non-ferrous metal products
- Other non-metallic mineral products
- Other services (93)
- Other transport equipment (35)
- Other waste for treatment: waste water treatment
- P- and other fertiliser
- Paddy rice
- Paper and paper products
- Paper and wood waste for treatment: composting and land application
- Paper for treatment: landfill
- Paper waste for treatment: biogasification and land application
- Paper waste for treatment: incineration
- Pigs
- Plant-based fibers
- Plastic waste for treatment: incineration
- Plastic waste for treatment: landfill
- Plastics, basic
- Post and telecommunication services (64)
- Poultry

- Precious metal ores and concentrates
- Precious metals
- Printed matter and recorded media (22)
- Private households with employed persons (95)
- Processed rice
- Products of forestry, logging and related services (02)
- Products of meat cattle
- Products of meat pigs
- Products of meat poultry
- products of Vegetable oils and fats
- Public administration and defence services; compulsory social security services (75)
- Pulp
- Radio, television and communication equipment and apparatus (32)
- Railway transportation services
- Raw milk
- Real estate services (70)
- Recreational, cultural and sporting services (92)
- Refined Petroleum
- Renting services of machinery and equipment without operator and of personal and household goods (71)
- Research and development services (73)
- Retail trade services, except of motor vehicles and motorcycles; repair services of personal and household goods (52)
- Retail trade services of motor fuel
- Rubber and plastic products (25)
- Sale, maintenance, repair of motor vehicles, motor vehicles parts, motorcycles, motor cycles parts and accessoiries
- Sand and clay
- Sea and coastal water transportation services
- Secondary aluminium for treatment, Re-processing of secondary aluminium into new aluminium
- Secondary construction material for treatment, Re-processing of secondary construction material into aggregates
- Secondary copper for treatment, Re-processing of secondary copper into new copper
- Secondary glass for treatment, Re-processing of secondary glass into new glass
- Secondary lead for treatment, Re-processing of secondary lead into new lead
- Secondary other non-ferrous metals for treatment, Re-processing of secondary other non-ferrous metals into new other non-ferrous metals
- Secondary paper for treatment, Re-processing of secondary paper into new pulp
- Secondary plastic for treatment, Re-processing of secondary plastic into new plastic
- Secondary preciuos metals for treatment, Re-processing of secondary preciuos metals into new preciuos metals
- Secondary raw materials

- Secondary steel for treatment, Re-processing of secondary steel into new steel
- Services auxiliary to financial intermediation (67)
- Sewage sludge for treatment: biogasification and land application
- Steam and hot water supply services
- Stone
- Sugar
- Sugar cane, sugar beet
- Supporting and auxiliary transport services; travel agency services (63)
- Textiles (17)
- Textiles waste for treatment: incineration
- Textiles waste for treatment: landfill
- Tobacco products (16)
- Transmission services of electricity
- Transportation services via pipelines
- Uranium and thorium ores (12)
- Vegetables, fruit, nuts
- Wearing apparel; furs (18)
- Wheat
- Wholesale trade and commission trade services, except of motor vehicles and motorcycles (51)
- Wood and products of wood and cork (except furniture); articles of straw and plaiting materials (20)
- Wood material for treatment, Re-processing of secondary wood material into new wood material
- Wood waste for treatment: incineration
- Wood waste for treatment: landfill
- Wool, silk-worm cocoons

Waste recovery
- Ash for treatment, Re-processing of ash into clinker
- Bottles for treatment, Recycling of bottles by direct reuse
- Food waste for treatment: biogasification and land application
- Food waste for treatment: composting and land application
- Manure (biogas treatment)
- Manure (conventional treatment)
- Paper and wood waste for treatment: composting and land application
- Paper waste for treatment: biogasification and land application
- Secondary aluminium for treatment, Re-processing of secondary aluminium into new aluminium
- Secondary construction material for treatment, Re-processing of secondary construction material into aggregates
- Secondary copper for treatment, Re-processing of secondary copper into new copper
- Secondary glass for treatment, Re-processing of secondary glass into new glass
- Secondary lead for treatment, Re-processing of secondary lead into new lead

- Secondary other non-ferrous metals for treatment, Re-processing of secondary other non-ferrous metals into new other non-ferrous metals
- Secondary paper for treatment, Re-processing of secondary paper into new pulp
- Secondary plastic for treatment, Re-processing of secondary plastic into new plastic
- Secondary preciuos metals for treatment, Re-processing of secondary preciuos metals into new preciuos metals
- Secondary steel for treatment, Re-processing of secondary steel into new steel
- Sewage sludge for treatment: biogasification and land application
- Wood material for treatment, Re-processing of secondary wood material into new wood material

Resource extraction
- Aluminium ores and concentrates
- Biogas an other gases nec.
- Chemical and fertilizer minerals, salt and other mining and quarrying products nec
- Coal, lignite and peat
- Copper ores and concentrates
- Crude petroleum and services related to crude oil extraction, excluding surveying
- Fish and other fishing products; services incidental of fishing (05)
- Iron ores
- Lead, zinc and tin ores and concentrates
- Natural gas and services related to natural gas extraction, excluding surveying; inclulding liquid gas
- Nickel ores and concentrates
- Other Hydrocarbons
- Other non-ferrous metal ores and concentrates
- Paddy rice
- Precious metal ores and concentrates
- Products of forestry, logging and related services (02)
- Sand and clay
- Stone
- Uranium and thorium ores (12)
- Wool, silk-worm cocoons

Imports
- Aluminium and aluminium products
- Aluminium ores and concentrates
- Animal products nec
- Basic iron and steel and of ferro-alloys and first products thereof
- Beverages
- Biogas an other gases nec
- Bricks, tiles and construction products, in baked clay
- Cattle
- Cement, lime and plaster

- Ceramic goods
- Cereal grains nec
- Chemical and fertilizer minerals, salt and other mining and quarrying products nec
- Chemicals nec; additives and biofuels
- Coal, lignite and peat
- Coke oven products
- Copper ores and concentrates
- Copper products
- Crops nec
- Crude petroleum and services related to crude oil extraction, excluding surveying
- Dairy products
- Electrical machinery and apparatus nec (31)
- Fabricated metal products, except machinery and equipment (28)
- Fish and other fishing products; services incidental of fishing (05)
- Fish products
- Food products nec
- Foundry work services
- Furniture; other manufactured goods nec (36)
- Glass and glass products
- Iron ores
- Lead, zinc and tin and products thereof
- Lead, zinc and tin ores and concentrates
- Leather and leather products (19)
- Machinery and equipment nec (29)
- Meat animals nec
- Meat products nec
- Medical, precision and optical instruments, watches and clocks (33)
- N-fertiliser
- Natural gas and services related to natural gas extraction, excluding surveying; inclulding liquid gas
- Nickel ores and concentrates
- Office machinery and computers (30)
- Oil seeds
- Other Hydrocarbons
- Other non-ferrous metal ores and concentrates
- Other non-ferrous metal products
- Other non-metallic mineral products
- P- and other fertiliser
- Paddy rice
- Paper and paper products
- Pigs
- Plant-based fibers
- Plastics, basic
- Poultry
- Precious metal ores and concentrates

- Precious metals
- Printed matter and recorded media (22)
- Processed rice
- Products of forestry, logging and related services (02)
- Products of meat cattle
- Products of meat pigs
- Products of meat poultry
- products of Vegetable oils and fats
- Pulp
- Radio, television and communication equipment and apparatus (32)
- Raw milk
- Refined Petroleum
- Rubber and plastic products (25)
- Sand and clay
- Stone
- Sugar
- Sugar cane, sugar beet
- Textiles (17)
- Tobacco products (16)
- Uranium and thorium ores (12)
- Vegetables, fruit, nuts
- Wearing apparel; furs (18)
- Wheat
- Wood and products of wood and cork (except furniture); articles of straw and plaiting materials (20)
- Wool, silk-worm cocoons

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