International Labour Organization

Circular economy, trade and employment

Circular economy, trade and employment

International Labour Office • Geneva

ISBN: 9789220429945 (web PDF)
DOI: https://doi.org/10.54394/VSAU1377

Cover photo: “Recycling” by International Labour Organization ILO, CC BY-NC-ND 4.0

▶ Foreword

This report has been prepared by the Investment, Sectoral Strategies and Transitions Team of the Employment in Investments (EMPINVEST) branch of the ILO. It is in line with its mandate of promoting employment creation as outlined in Convention 122, with a focus on supporting the transition to formal employment for informal workers (Recommendation 204) in the context of a just transition to a green economy.

The growing urgency to address climate change, biodiversity loss, and resource scarcity has placed the circular economy (CE) at the centre of global sustainability debates. While CE policies are often focused on domestic material reuse and waste reduction, international trade plays a critical – yet under-explored – role in the transition to circularity. At the same time, the employment implications of CE trade remain insufficiently understood, particularly across different regions, sectors, and income groups. This report addresses this gap by providing the first systematic global estimate of the number, type, and distribution of jobs embedded in circular economy exports – both directly and indirectly – through global supply chains.

In this study, CE goods are defined as traded products that are recyclable, reusable, refurbished, or made from secondary raw materials, based on the convergence of frameworks from UNECE, Eurostat, ISO and other international institutions. A novel harmonisation method is applied to extract 159 CE goods from the Harmonized System (HS) 2022 classification at the 6-digit level. The concept of CE employment includes both direct and indirect jobs generated through upstream linkages in other sectors.

This research finds that trade in CE goods still plays a relatively marginal role in the global economy, but with a growing trend, and is concentrated in high-income countries. Employment linked to these exports is mostly generated in low- and middle-income countries. The leading CE-exporting sectors by value are basic metals (50 per cent), food and beverages (23 per cent), and paper products (12 per cent).

CE exports support 5.96 million jobs worldwide, of which 27 per cent are direct and 73 per cent are indirect, dominated by middle-income countries. Direct CE jobs are concentrated in food processing in developing economies and in basic metals in developed economies. Indirect jobs are driven by agriculture and wholesale trade. Globally, 58 per cent of CE jobs are informal, and 83 per cent are unskilled. Female and youth employment are relatively low. Labour intensity per unit of CE export is higher in developing countries due to lower productivity and more manual work.

This study presents the first comprehensive estimate of employment embedded in CE trade, showing that even a marginal share of trade can generate significant labour impacts—especially in informal, low-skilled, and upstream sectors. However, the analysis also highlights major challenges. CE employment is disproportionately informal and lacks quality standards. In addition, many countries remain excluded from circular trade due to structural, technological, or statistical constraints.

To address these issues and improve the accuracy and policy relevance of future analyses, the report recommends expanding employment datasets to allow deeper disaggregation by product, region and sector -especially in low-income economies.

Employment creation in the circular economy is highly sensitive to technological choices. Labour-intensive systems tend to generate more jobs but often under poorer working conditions. The ILO, through its Employment-Intensive Investment Programme (EIIP), and its well-tested inclusive approaches can ensure a just transition. The employment-intensive approach promotes decent jobs and skill development—and is key to aligning circular economy goals (SDG 12 on responsible consumption and production) with decent work (SDG 8). In this regard, trade could support the international integration of CE value chains, promoting scale, efficiency and labour formalisation.

Mito Tsukamoto
Chief
Employment and Investment Branch ILO

Acknowledgements

This report was prepared by the EMPINVEST Branch of the ILO, under the overall responsibility of Mito Tsukamoto, Chief of the branch, and more specifically by the Investment, Sectoral Strategies and Transitions (IST) Team under the technical leadership of Christoph Ernst, Lead of IST. The research coordinator was Carlos Adrián Romeri, in close collaboration with Gabriel Nicolas Michelena, María Priscila Ramos and Laura Pacin, all from the MESi research team[1] of the University of Buenos Aires and Christoph Ernst from the ILO. A big thanks for technical feedback goes to ILO staff, in particular Casper Edmonds from the Sectors Department and Arianna Rossi from the Priority Action Programme on Decent Work Outcomes in Supply Chains, the Trade and Environment Division of the WTO, various EU DG (ENV, EMPL, ECFIN, GROW, RTD, Clima, JRC Sevilla) and the Circle Economy Foundation. We are very grateful to Nina Cleary for administrative support, but also regarding edition and design of this report in close collaboration with Montserrat Romero Aversa from the MESi team.

[1] Modelos Económicos de Simulación area from the Instituto Interdisciplinario de Economía Política (IIEP, UBA-CONICET).

Contents

Executive summary

Motivation

The growing urgency to address climate change, biodiversity loss, and resource scarcity has put the circular economy (CE) at the forefront of global sustainability discussions. While CE policies are often focused on domestic material reuse and waste reduction, international trade plays a crucial yet overlooked role in advancing—or hindering the transition toward circularity. At the same time, the employment implications of CE trade remain poorly understood, particularly across different regions, sectors, and income groups. This report seeks to address that gap by offering the first systematic global estimate of the number, nature, and distribution of jobs linked to CE exports, both directly and indirectly through global supply chains.

Definitions and scope

In this study, CE goods are defined as traded products that are recyclable, reusable, refurbished, or made from secondary raw materials, based on the convergence of frameworks from the United Nations Economic Commission for Europe (UNECE), Eurostat, ISO, and other international institutions. A novel harmonisation method is applied to identify 159 CE goods within the Harmonized System (HS 2022) classification at the 6-digit level. The concept of CE employment includes both direct jobs (in recycling, reuse, and remanufacturing) and indirect jobs generated through upstream linkages across other sectors.

Methodological approach

The analysis combines trade, employment, and input–output (IO) data using the following steps:

1. Compilation of a CE goods list: identifying CE products using HS 6-digit codes, based on keyword matching and expert validation.
2. Data harmonisation: collecting and aligning trade data (UN COMTRADE), employment statistics (ILOSTAT), and input–output tables (OECD ICIO and GTAP-CE).
3. Direct job estimation: calculating employment-to-output ratios by sector and applying them to CE exports.
4. Indirect job estimation: using a multi-regional input–output (MRIO) model to trace upstream employment effects.
5. Job characterisation: profiling CE-related jobs by formality, gender, age, and skill level, and identifying sector-country employment hotspots.

Results

Trade patterns:

- CE goods account for only 0.52 per cent of global trade by volume and 1.29 per cent by value, highlighting their limited role in the global economy.
- CE trade is concentrated in high-income countries such as the EU, United States, and Japan, however, the employment linked to these exports is largely generated in low- and middle-income countries.
- The leading CE-exporting sectors by value are: basic metals (50 per cent); food and beverages (23 per cent); and paper products (12 per cent).

Employment:

- CE exports support an estimated 5.96 million jobs worldwide, with 27 per cent classified as direct and 73 per cent as indirect.
- Middle-income countries, such as Brazil, India, China, and Indonesia, account for the majority of CE-related jobs, especially in agriculture and food sectors.
- Direct CE jobs are concentrated in food processing (in developing regions) and basic metals (in developed regions), while indirect jobs are largely driven by agriculture and wholesale trade.
- Globally, 58 per cent of CE jobs are informal, and 83 per cent are considered unskilled.
- Female workers hold approximately 1.47 million CE jobs but are underrepresented in indirect employment.
- Youth employment remains low; CE jobs predominantly benefit adult male workers.
- Labour intensity per unit of CE export is higher in developing countries due to lower productivity and greater reliance on manual work.

Conclusions

This study presents the first comprehensive estimate of employment linked to CE trade, demonstrating that even a small share of global trade can have significant labour impacts—especially in informal, low-skilled, and upstream sectors.

However, the analysis also uncovers major challenges:

- CE-related employment is disproportionately informal and lacks quality standards.
- Many countries remain excluded from circular trade due to structural, technological, or data limitations for its accounting.

To address these gaps and improve the accuracy and policy relevance of future analyses, the report recommends expanding employment datasets to allow deeper disaggregation by product, region, and sector—especially in low-income economies.

1. Introduction

Despite its significant macroeconomic and external instability, global GDP has nearly quadrupled over the past 60 years, growing at an average annual rate of approximately 3.5 per cent (World Bank 2023). This sustained growth has led to increased demand for material goods, intensifying pressure on non-renewable resources and the environment.

According to the United Nations Environment Programme (UNEP 2021), the extraction and processing of materials account for 50 per cent of global greenhouse gas (GHG) emissions and 90 per cent of biodiversity loss and water stress, highlighting the urgent need to rethink resource use through circular economy (CE) approaches.

Krausmann et al. (2017) highlight that global economic growth remains closely linked to intensive material usage. While some developed economies have shown signs of decoupling, this has been partly offset by rising material consumption in several developing countries, although their per capita resource use remains significantly lower.

Globalization is one of the key drivers behind the rising use of materials. This has resulted in the fragmentation of productive activities and a growing demand for goods and services (Hummels et al. 2001). The value of global merchandise exports has increased significantly since 1948, with exports representing an average of 29 per cent of global gross domestic product (GDP) in 2016 (Wiedmann and Lenzen 2018).

However, the globalization of trade often shifts the environmental and social impacts of production away from the country of consumption to one or more countries. For example, the energy use, pollution, and employment effects associated with producing a single food product may be distributed across several countries involved in its supply chain.

Economic growth has also led to a sharp increase in municipal and industrial solid waste. This has exacerbated the negative externalities associated with production and consumption processes, including pollution and associated health and social risks. Under the Paris Agreement, countries have committed to reducing waste generation and supporting recycling industries, with the goal of advancing more sustainable economic development.

These national commitments align with the Sustainable Development Goals (SDGs), particularly SDG 12, which aims to ensure sustainable consumption and production patterns, and the employment dimension of SDG 8, which promotes decent work and economic growth. This aligns with recent international commitments: in its Resolution 5/11, the United Nations Environment Assembly (UNEA) explicitly recognizes the CE as a key strategy for achieving sustainable consumption and production, while also addressing climate change, biodiversity loss, and pollution (Environment 2022). Achieving these objectives requires significant progress in developing CE models. As highlighted by Dantas et al. (2020), the CE plays a critical role in tackling waste and other sustainability challenges. Although there is no universally accepted definition, the CE generally refers to principles aimed at closing and slowing the flow of natural resources into consumption systems beyond their capacity to regenerate (Bocken et al. 2016; Ghisellini et al. 2016).

The ultimate goal of CE initiatives is to decouple economic growth from the intensive use of material resources. Numerous studies, such as (Wiebe et al. 2019), suggest that transitioning to a CE can facilitate sustainable economic development by reducing material consumption and the transition could have a positive impact on both the economy and employment (Horbach et al. 2015; ILO 2018).

The **objective** of this report is to better understand the importance of the CE in international trade and the impact of circular trade on production and employment. In addition, a special focus will be given to the characterization of CE jobs in terms of decent conditions (formality) and inclusion (female, skills and youth employment).

In today's global economy, where international and regional value chains are deeply interconnected, strong links exist between international trade and the CE. A robust methodology is therefore needed to identify these connections and assess their indirect impacts. This study aims to quantify how much employment is supported by the international trade of CE goods. To achieve this, it is necessary to capture the complex interdependence between sectors and across borders that characterizes global supply chains. A multi-regional input–output (MRIO) model, including both primary and secondary production technologies in key sectors such as paper, plastics, iron, and other metals, is used to estimate the employment generated by the trade in CE goods. This approach allows the model to account for varying intensities of labour use based on the type of recycled inputs utilized.

This research draws on a range of data sources. The modelling approach applies input–output (IO) techniques based on the latest GTAP Circular Economy Social Accounting Matrix (SAM), ILO employment data, and WITS/COMTRADE trade data (2022/23). This numerical research will be complemented by a more qualitative analysis of selected employment dimensions, primarily through desk-based research. For this work, it is necessary to consolidate a harmonized list of CE-related products, drawing on existing literature and the Harmonized System (HS) 2022 for traded products, with the aim of capturing waste and recycled products in greater detail.

This study is structured into seven sections. Following this introduction, the second section presents the background of the topic, focusing on the relationship between CE, trade (including green trade), and job creation, based on current literature. The third section reviews existing studies on CE applications using input–output and computable general equilibrium (CGE) models. The fourth section presents the methodological approach applied in this study, along with the datasets to be collected and processed in line with definitions of CE trade coverages, CE activities, and jobs position accounting. The fifth section presents and analyses CE trade results, while the sixth section presents the associated results on CE employment worldwide. Finally, in the seventh section, the most important results are summarized and concluded.

2. Background

2.1. Circular economy: definitions

Despite its potential, e-waste management systems remain highly uneven across countries. Industrialized economies rely on capital-intensive, mechanized recycling, whereas low- and middle-income countries depend on labour-intensive, informal practices (ILO 2019). This divide creates asymmetries in environmental impacts, employment structures, and international trade flows, with concerns about environmental dumping where weaker regulatory systems prevail (Schluep et al. 2012; Magalini et al. 2014; UNCTAD 2024).

Among the various proposals addressing the current global challenges of climate change and resource supply risk, the paradigm of the CE has recently gained significant attention. The CE is a new and inclusive economic paradigm that aims to minimize pollution and waste, extend product lifecycles and enable broad sharing of physical and natural assets (UNECE 2023).

The concept of the CE is often framed as a transformative model that offers economic, environmental, and social benefits (Clube 2022). This notion aligns with the idea of resource decoupling—reducing material inputs per unit of output—which has become central to global sustainability strategies (UNEP 2011). However, most scholars in the field of CE have primarily associated it with environmental and economic sustainability. The predominant focus has been on aspects such as reducing environmental impact and fostering economic growth. A limited number of scholars advocate for a broader understanding of CE that encompasses sustainable development across all three dimensions: social, economic, and ecological sustainability (Ghisellini et al. 2016; Kirchherr et al. 2017).

A key challenge in analysing the relationship between trade and the CE lies in determining which goods can be legitimately classified as CE goods. The literature presents a range of approaches, from broad conceptual frameworks to specific trade-oriented classifications. Early academic contributions have typically defined circularity in terms of function. van Loon et al. (2021) argue that truly circular products are those that combine reuse-based strategies with circular-oriented design or business models, rather than simply relying on end-of-life treatment. Similarly, Potting et al. (2017) emphasize high-quality reuse and material recovery, calling for a distinction between goods that merely participate in recycling and those designed for durability, reparability, and disassembly. Eberhardt et al. (2019), in a sector-specific study, highlight that goods such as prefabricated construction components can only be considered circular if designed for disassembly and reuse. Urbinati et al. (2017) complement this perspective by linking circularity to business models, identifying product-service systems and reverse logistics as key enablers of genuinely circular goods.

At a more operational level, organizations such as UNEP and OECD have begun to translate these principles into product categories relevant for trade. For example, Kalmykova et al. (2018) propose a mapping of circular strategies by product type, with a focus on tight loops, such as remanufacturing and modular design, that preserve higher economic and material value. However, as highlighted in trade policy discussions (Bellmann and Sell 2021) there is no internationally agreed list of CE goods, and many product categories are "circular" only depending on context or end-use. The lack of differentiation between new, used, refurbished, or recycled goods in current trade classifications further complicates the issue.

Recent policy-oriented efforts have sought to bridge this gap by moving toward trade-relevant classifications, including proposals to adjust the Harmonized System (HS) to better capture CE flows. Bellmann and Sell (2021) draw on the OECD and the World Trade Organization (WTO) discussions around the Environmental Goods Agreement (EGA), which provide early lists of goods used in environmental services, that significantly overlap with CE functions—such as recycling machinery, composting units, and drip irrigation systems. These authors recommend the use of HS "ex-outs" at the 8- or 10 -digit level, or certification of end-use, to identify waste and secondary materials that qualify as circular in practice. The Eurostat methodology on circular trade also applies HS codes to measure exports and imports of recyclable materials such as paper, plastics, metals and textiles. Finally, the World Customs Organization (WCO 2023) environmental goods list includes items such as prepared enzymes, ion exchangers, recycled paper, biofuels from waste oils, and batteries and scrap metal, all identified under specific HS codes (e.g., HS 3826.00, 3914.00, 4707.90, 8549.13).

In short, while the consensus on which goods qualify as “circular” continues to evolve, a growing body of literature and policy instruments is converging toward a functional and trade-operational approach. This perspective prioritizes recyclable, reusable, remanufacturable, and resource-efficient goods, and uses HS codes to facilitate their identification and monitoring in international trade data.

Critics argue that current interpretations of CE fail to deliver the promised results, particularly regarding the social dimension of sustainability (Clube 2022). This observation is reinforced by the findings of Kirchherr et al. (2017), who conducted an extensive analysis of 114 definitions of the CE. Their findings revealed that only 18-20 per cent of these definitions explicitly incorporated considerations of social equity. However, a recent study indicates a positive trend, with sustainable development being mentioned in 27–31 per cent of the definitions—a threefold increase. Specifically, the inclusion of social equity and related themes has risen from 19 per cent in 2017 to 24–27 per cent in 2022. These newer definitions highlight aspects such as human health, well-being, just transitions, and the concept of a circular society (Kirchherr et al. 2023).

These evolving interpretations of the CE have important implications for how it intersects with global trade dynamics and labour markets. These two dimensions are explored in the following subsections.

2.2. Circular economy and trade

The CE often operates within national borders, focusing on activities like recycling, eco-design, and product service systems. However, in a global economy interconnected through international and regional value chains, there are strong links between international trade and the CE, as trade-related policies can facilitate the CE transition (IISD 2021). WTO has prioritized the role of trade and trade policies in contributing to a CE in its members’ discussions in the Trade and Environmental Sustainability Structured Discussions (TESSD), an initiative launched in 2020 to intensify work on trade and environmental sustainability. In the 2021 TESSD Ministerial Statement, composed by 78 members, agreed to explore opportunities for voluntary actions and partnerships to ensure that trade and trade policies are supportive of and contribute to achieving a more resource-efficient CE (WTO 2024). UNECE is also pooling efforts to harness the potential of trade and economic cooperation for the circular transition. This follows Member States’ decisions at the 69th Commission session on “Circular economy and the sustainable use of natural resources” and continues through the implementation of decisions of 70th Commission Session on "Digital and Green Transformations for Sustainable Development" (UNECE 2023).

The intersection of CE with international trade occurs through two principal flows: trade within supply chains and trade of end-of-life products. Supply chain trade involves the import of raw materials and intermediate goods for production, supported by services such as eco-design, product-service system and recycling processes, while end-of-life trade includes the export of waste, scrap, secondary raw materials, and second-hand goods. For example, South Africa's plastics trade demonstrates significant engagement within the CE, particularly through feedstock exports. In 2021, the country's total plastics trade was valued at over $9.6 billion, with imports accounting for two-thirds of this amount. In addition to goods, the CE also impacts the trade in services, particularly in maintenance, repair, and product-service systems, creating new opportunities in services trade (Yamaguchi 2021).

Notably, non-hidden flows under HS code 39- covering “plastics and articles thereof”, accounted for 46 per cent of this trade, with imports valued at US$2.9 billion and exports valued at US$2.9 billion and exports at US$1.5 billion, respectively. Despite being a net importer of plastic products, South Africa recorded a trade surplus in the feedstock category, where exports exceeded imports. These feedstock exports, comprising materials such as additives, were primarily destined for developed regions, including the European Union, North America (the United States), and Asia (Singapore). This indicates South Africa's role in supplying materials—potentially containing recycled content—for further manufacturing in global markets. Additionally, exports of primary forms such as polypropylene and finished products dominated exports, mainly to Southern African countries and Nigeria, with some exports reaching beyond the continent. This trade pattern highlights South Africa's active participation in the CE through the export of plastic feedstock and products (World Economic Forum 2020).

Recent studies (Velis and Cook 2021; Schröder et al. 2018) emphasize that CE transitions differ significantly between industrialized and developing countries, raising important questions about global asymmetries and context-specific pathways. In high-income contexts, CE is often driven by advanced technology and formal systems. In contrast, CE in the global South tends to rely on informal labour, limited infrastructure, and second-hand imports. For instance, used vehicles and electronics - while affordable - often shift the burden of end-of-life management to developing countries, raising concerns about environmental dumping (Velis and Cook 2021). As Schröder et al. (2018) emphasize, simply transferring CE models from the North overlooks structural constraints in the South, including financing gaps, weak regulation, and health risks.

2.3. Circular economy and employment

The challenges regarding the employment impact of the circular economy can be outlined as follows. First, there is limited research on how employment benefits and drawbacks are distributed across different regions worldwide. Second, there is a lack of comprehensive analysis of the skill sets required in a circular economy and of whether workers will be willing and prepared to engage in these roles.

Few studies have estimated the effects of global circular trade on employment. One study found that increased recycling of materials such as plastics, glass, and metals could lead to job creation in the Americas and the EU, but to employment declines in Asia, the Pacific, and Africa (ILO 2018).

Wiebe et al. (2019) found that the adoption of CE (compared with a Business-As-Usual) shows positive, but small, impact on employment. Their findings show a shift in job positions from resource extracting sectors to the service sector, creating greater opportunities for high-skilled and female workers. Donati et al. (2020) predicted a decline of 5.3 per cent in the EU, with significant job losses globally. These projections are primarily based on assumptions about extended product lifetimes. There is a need for more detailed assessments of the global employment effects of the EU's transition to a circular economy, particularly in low- and middle-income countries. Further discussion is also needed on the CE's contribution to social sustainability (Repp et al. 2021).

With respect to the skill set required in a CE, the European Commission (2020) states that the positive impact on job creation in the CE depends on workers acquiring the necessary skills for the green transition. Ensuring an adequate labour force for both skilled "enabling" CE jobs (e.g. design, digitalization roles) and manual "core" CE occupations (e.g. waste management, maintenance, rental services) is a challenge in developed regions (Clube 2022). In addition, there is limited research into whether individuals are interested in these vocations, raising questions about the uptake and appeal of CE jobs compared to those in the linear economy (Clube 2022).

3. State of the art

Several studies have assessed the potential impacts of CE interventions using input–output models, particularly environmentally extended input–output analysis (EEIOA). For example, Donati et al. (2020) and Wiebe et al. (2019) use models based on the Exiobase database to simulate future CE scenarios. Donati et al. (2020) project that increased circularity in Europe could significantly reduce raw material extraction and land use by 2030. Wiebe et al. (2019) find that CE policies can lower metal extraction and resource consumption, while generating employment gains that benefit skilled and female workers, although with some losses for unskilled labour.

The International Labor Organization (ILO 2018) also applies a multi-regional input–output (MRIO) model using Exiobase and ILOSTAT data to estimate employment effects of CE policy adoption. The analysis suggests that recycling, reuse, and product lifespan extension policies could generate around six million new jobs worldwide. A complementary review by Aguilar-Hernandez et al. (2018) highlights both the usefulness and limitations of EEIOA approaches, noting particular challenges in modelling waste flows due to the reliance on monetary rather than physical data.

Other contributions have focused on improving the integration between monetary and physical flows. Bruckner et al. (2019) developed the FABIO model, which links global biomass flows with national accounts, offering a valuable alternative to purely monetary IO models. Similarly, Romero et al. (2024) constructed a hybrid model that combines financial transactions with physical waste streams to evaluate circularity in Argentina's production systems, employment patterns and institutional arrangements.

A different strand of the literature uses computable general equilibrium (CGE) models to evaluate CE policies at a macro level. Chepeliev et al. (2022) expand the GTAP database to include primary and secondary production technologies and simulate the effects of European Green Deal policies using the Envisage-CE model. In parallel, the Organisation for Economic Co-operation and Development (OECD 2022) further enhances the GTAP framework by incorporating a more detailed representation of plastics and other material flows throughout their life cycle, including waste management processes and environmental leakages. These additions are used to support simulations within the OECD's ENV-Linkages model (Chateau et al. 2014). This model has been widely applied: for example, Chateau and Mavroeidi (2020) analysed global economic and environmental effects of CE measures, finding that resource-exporting countries may experience net job losses, while Bibas et al. (2021) use an adapted version of ENV-Linkages to assess the fiscal impact of promoting secondary materials.

Additionally, Freire-González et al. (2022) employ a dynamic CGE framework to assess the impact of landfill and incineration taxes in Spain, finding that such measures can encourage recycling and reuse. Bartelings et al. (2021), meanwhile, propose an extension of the global MAGNET model to incorporate waste management systems.

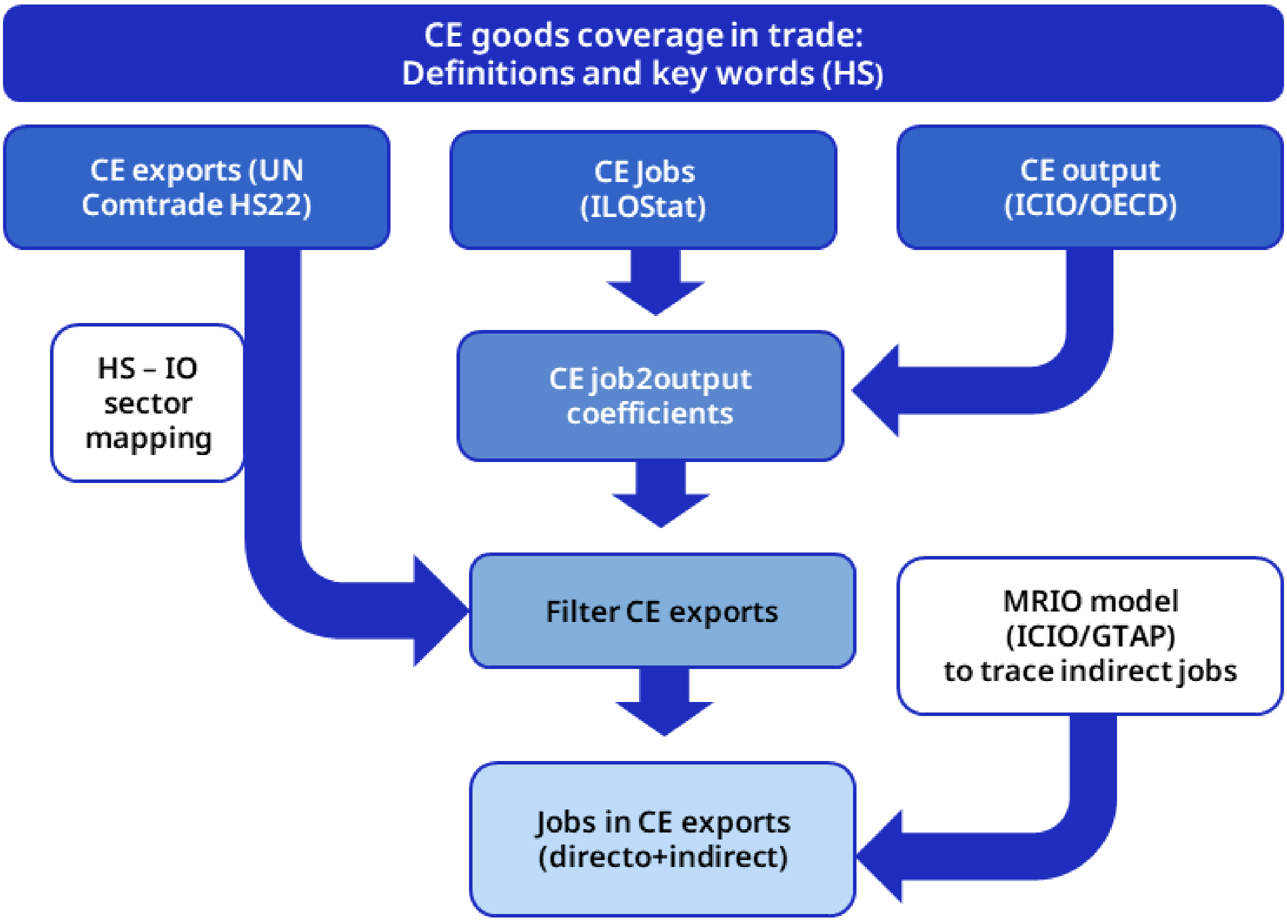
Finally, some research has applied dynamic IO models to developing economies. Groothuis (2019) estimated the impact of CE fiscal policies in Bangladesh by 2025, although detailed results are not reported in this summary.

4. Methodological Approach

The methodological framework relies on the tradition of multisectoral and multiregional models, which have long been used to study the economic interdependencies between sectors and countries. A multiregional, multisectoral input–output (IO) approach is applied (Timmer et al. 2015) to estimate the employment – both direct and indirect – embedded in CE exports.

A simplified step-by-step explanation of the calculation of jobs - both direct and indirect - into CE exports is presented in figure 1.

▶ **Figure 1: Step-by-step methodological approach for jobs embedded in CE exports**



Source: Own elaboration.

The first step defines the scope of CE trade at the HS 6 level (see table A1 in the appendix), based on established CE definitions and keyword classifications. In the second step, three datasets—UN Comtrade (HS2022), ILOSTAT and the OECD ICIO—are harmonized and integrated to compute CE employment-to-output coefficients. These coefficients are then applied to CE exports linked to relevant CE sectors, allowing for the estimation of direct employment. In the third step, input–output (IO) techniques are used to calculate the indirect employment generated through CE exports. Together, these steps provide a comprehensive assessment of both direct and indirect jobs embedded in CE exports, as analysed in this report, along with selected CE employment characteristics in terms of formality, youth, skills and gender.

The next subsection outlines the direct calculation stage, in which the coverage of CE-related sectors and goods is defined, relevant products at the HS 6 level are identified, and these are matched with employment and output data. This step establishes the statistical foundation for measuring CE exports and their immediate labour content.

The following subsection presents the indirect estimation, which expands the analysis using a multiregional input–output model. This allows us to trace the wider employment impacts of CE trade by capturing the international production linkages and intersectoral flows embedded in global supply chains.

4.1. Direct calculation

4.1.1. Employment data

The ILO collects household survey datasets compiled by national statistical offices in 161 countries. These raw data are then systematically processed to produce harmonized indicators in accordance with international statistical standards. The ILOSTAT database complies with a wide range of detailed and internationally comparable labour statistics, which form the basis for published reports.

For this analysis, all employment-related parameters are sourced from a satellite account containing employment data from ILOSTAT. The parameters used include the working-age population actively employed, defined as individuals engaged in any activity for at least one hour to produce goods or services in exchange for pay or profit, even if temporarily absent from work (International Conference of Labour Statisticians 2013).

The labour data included breakdowns by age group, gender, skill level and employment formality status. Within the data parameters, informal employment referred to jobs that, whether in practice or by law, were not subject to national labour legislation, income taxation, or social protection, and did not provide entitlement to benefits such as paid leave (International Conference of Labour Statisticians 2013). Skill levels are divided into two groups: skilled and unskilled workers. The skill level associated with an occupation reflects the complexity and scope of job tasks, assessed by examining occupational requirements or educational attainment. Skilled occupations include roles such as managers, professionals and technicians, which require advanced education, specialized training, or substantial experience. Unskilled occupations involve routine tasks that demand less formal education or training and include clerical support workers, service and sales workers, and those in elementary occupations. Workers between the ages of 15 and 29 were classified as youth while those aged 30 and over were categorized as adults.

4.1.2. International trade flows data

To estimate the international flow of CE goods, including their countries of origin and destination, bilateral import data from 2022 to 2023 were sourced from the United Nations International Trade Statistics Database (UN Comtrade). This dataset provided detailed information on bilateral export (Free on Board - FOB) and import (Cost, Insurance, Freight - CIF) values and quantities at the Harmonized System (HS) six-digit-level for approximately 178 countries.

Trade flows valued using CIF and FOB methods often showed discrepancies ranging from 5 to 20 per cent, with data accuracy varying across countries. Those discrepancies may stem from variations in how goods are classified by exporting and importing countries. Since imports were generally recorded with greater precision due to their link to tariff revenues, this report used CIF bilateral trade data for its analysis.

4.1.3. Circular Economy goods

The World Customs Organization (WCO) is actively addressing the challenges associated with transitioning to a CE. A key obstacle is the accurate tracking and quantification of circular trade flows, as current trade data, particularly those based on the Harmonized System (HS), do not adequately distinguish between products made from recycled versus virgin materials, or between new and used goods. To improve this, the WCO is exploring strategic enhancements to the HS classification system to better capture CE-related trade flows. However, significant difficulties exist, including the lack of globally accepted standards and methods for verifying the recycled content or the intended use of goods at borders.

The following is a concise summary of the types of CE-related products currently measured, although imperfectly using HS codes in international trade statistics. International trade data captures CE-related goods primarily in the following groups (Batlles-delaFuente et al. 2022; de Lange 2024; Yamaguchi 2021):

1. **Waste and scrap:**

- Mainly metallic scrap (iron, steel, aluminium, copper, gold), paper, and plastic waste.
- Metals represent the largest traded category, with high economic potential and increasing domestic recycling trends, particularly in major economies such as China.

2. **Secondary raw materials and used goods**:

- Includes recyclable construction materials, rubber and tyres, textiles, plastics, paper and cardboard, precious metals, ferrous metals (iron, steel), and non-ferrous metals (copper, aluminium, nickel).

3. **Second-hand goods, refurbished, and remanufactured products:**

- Tracking is limited to specific items such as retreaded tyres, worn clothing, and second-hand construction materials due to inadequate HS coding differentiation.
- The lack of clear coding creates challenges to distinguish these products from waste or new goods.

In addition to the CE definitions and those CE products groups in the HS2022, we implemented a procedure to isolate CE products at the 6-digit level of the HS classification.

$$\boldsymbol{\mathcal{H}} = \{(\boldsymbol{c_i}, \boldsymbol{d_i})\}_{\boldsymbol{i=1}}^{\boldsymbol{N}} \tag{1}$$

Let be the universe of all HS2022 items where $(code(c_i \in \{000000, \ldots, 999999\}), description(d_i))$, we extract $(\mathcal{H}_\mathrm{C} \subset \mathcal{H})$ such that each (d_i) references at least one CE activity. More precisely, we will look for keywords referred in the CE framework of those institutions that define the CE.

Thus, from the six reference frameworks (ADEME, EUROSTAT, CJM, UNECE, SEEA, ISO 59004) we choose a set of keywords K.

$$\boldsymbol{K} = \{\boldsymbol{k_j}: \boldsymbol{j} = \boldsymbol{1}, \ldots, \boldsymbol{m}\}, \textbf{ with } \boldsymbol{k_j} \in \{\boldsymbol{repair}, \boldsymbol{recycl}, \boldsymbol{remediat}, \ldots\} \tag{2}$$

Each stem k_j captures variant forms, e.g. $(repair \to repair, repairs, repaired, \ldots)$ and all of them are considered in the searching, normalising the description in a lower case format for description of the HS2022 products, that is for each (c_i, d_i), set $d_i \leftarrow lowercase(d_i)$.

To filter by pattern match, we define an indicator I_i that could take values 0 or 1 depending on the description of the HS2022 product contains a keyword that refers to CE, as follows:

$$\boldsymbol{I_i} = \begin{cases} \boldsymbol{1}, & \boldsymbol{if\ str\_detect(d_i, P) = TRUE} \\ \boldsymbol{0}, & \boldsymbol{otherwise} \end{cases} \tag{3}$$

Then, we retain those HS2022 products at the 6-digit level if that indicator is equal to 1, that means it refers to a CE-related good in trade, as follows:

$$\boldsymbol{\mathcal{H}_\mathrm{C}} = \{(\boldsymbol{c_i}, \boldsymbol{d_i}) \in \boldsymbol{\mathcal{H}}: \boldsymbol{I_i} = \boldsymbol{1}\} \tag{4}$$

Finally, we implement a human audit mechanism for each $\mathcal{H}_\mathrm{C}$ isolated in the previous process. This is important to remove false positives and to add any edge-case products missed by string matching.

The final list of CE-related goods under the HS2022 classification comprises 159 items. These span a wide range of HS chapters, covering products from vegetal and animal waste and pellets to machinery, pumps, and some parts (see Table A1 in the appendix).

While the previous steps allow us to measure CE exports and their direct labour content, a broader analysis of economic interdependencies across countries and sectors requires the use of multiregional input–output models, as presented in the next subsection.

4.2. Indirect estimation

4.2.1. Multi-regional input–output (MRIO) matrix

The multiregional input–output (MRIO) model captures the complexity of global supply chains by estimating both direct and indirect employment effects. To operationalize this framework, we draw on the GTAP-CE and ICIO databases. The Global Trade Analysis Project (GTAP) has recently developed a dedicated CE dataset, enhancing its database to explicitly include primary and secondary production technologies, particularly in the metals and plastics sectors. This updated GTAP-CE dataset clearly differentiates between traditional (primary) production methods and circular (secondary or recycled) production technologies, thereby enabling more accurate analysis of CE trade flows and policies. The dataset is designed to feed into Computable General Equilibrium (CGE) or input–output models—such as Envisage-CE and ENV-Linkages—to simulate the economic, labour, and environmental implications of adopting CE practices.

▶ **Table 1: Correspondence between CE sectors and GTAP sectors**

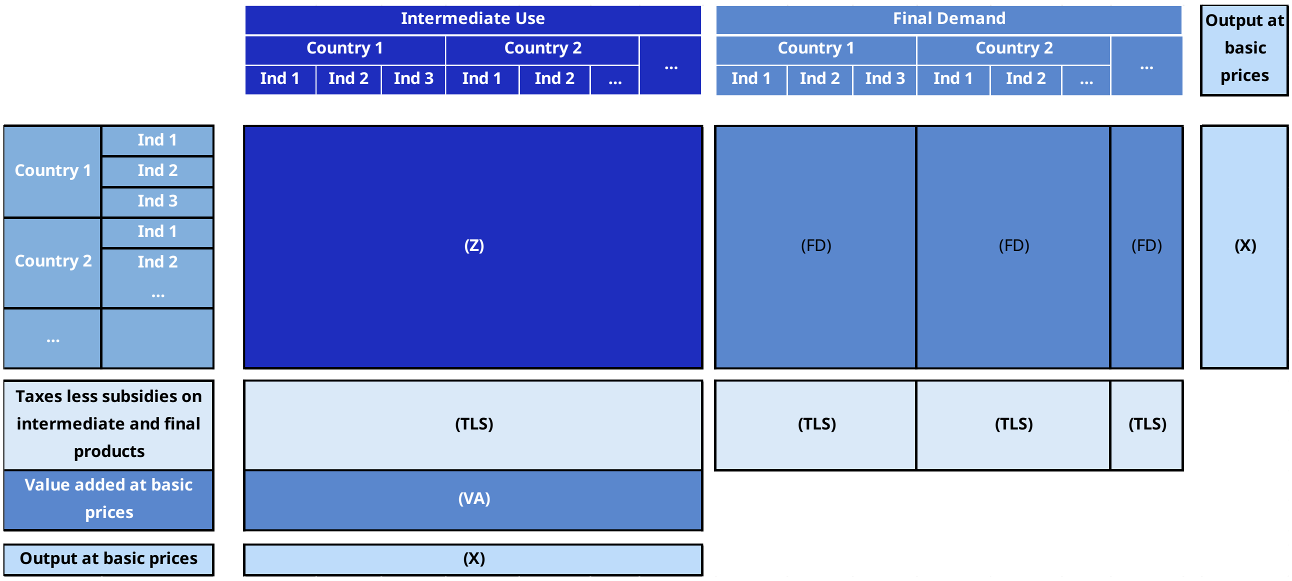
No.	New sector	Sector description	GTAP sector code	Description
1	nmm	Non-metallic minerals mining	oxt	Other extraction
2	mio	Mining of iron ores		
3	mao	Mining of aluminium ores		
4	mco	Mining of copper ores		
5	moo	Mining of other ores		
6	rbr	Rubber products	rpp	Rubber and plastic products
7	plp	Plastic products – primary		
8	pls	Plastic products – secondary		
9	plr	Recycling – plastics		
10	isp	Iron and steel – primary	i_s	Ferrous metals
11	iss	Iron and steel – secondary		
12	ris	Recycling – iron and steel		
13	isc	Iron and steel casting		
14	app	Aluminium – primary	nfm	Non-ferrous metals
15	aps	Aluminium – secondary		
16	ral	Recycling – aluminium		
17	cpp	Copper – primary		
18	cps	Copper – secondary		
19	rcp	Recycling – copper		
20	mpp	Other metals – primary		
21	mps	Other metals – secondary		
22	rom	Recycling – other metals		
23	nfc	Non-ferrous metals casting		

Source: Own elaboration based on GTAP website.

We use the inter-country input–output (ICIO) matrix of the OECD with 2019 as the base year. The matrix synthesizes data on 45 economic activities across 76 individual countries, along with an additional region representing the rest of the world (RoW). The IO table is a representation of the economy's monetary transactions between productive and institutional sectors. It captures the sectoral composition of the GDP components - such as household consumption, government expenditure, investment, exports, and imports - as well as the sectoral composition of taxes and value-added components such as wages and profits. Although the ICIO/OECD matrix does not cover all countries in the world, it accounts for 94 per cent of total exports, output and value added. When matched with ILOSTAT datasets, it allows coverage of about 84 per cent of global employment.

In the MRIO version (see figure 2), the intermediate transactions matrix, Z, contains the purchases and sales of inputs between sectors within the same country, but also includes external sales and purchases to and from third destinations.

▶ Figure 2: Structure of the multi-regional input–output matrix OECD



Source: Own elaboration.

Final demand, on the other hand, represented by matrix **F**, comprises rows that reflect final purchases made by countries at the sectoral level and includes imports from other economies. In turn, this matrix includes columns detailing the components of domestic demand: private consumption, public consumption and investment. Finally, since one country's imports correspond to another's exports, external sales at the sectoral level, and by component, are represented in the final demand matrix, in the columns outside the main diagonal.

The MRIO model can be shown using the following subset of matrices and vectors, starting from the expenditure side:

$$x = \mathrm{Ze} + \mathrm{F} \qquad (5)$$

Where x is the vector of gross output values, **Z** is the matrix of intermediate uses, **e** is a row vector of ones, and **F** is the matrix of final demand.

After the algebraic steps of dividing and multiplying the elements of the matrix **Z** by the gross output, it is possible to reformulate Equation (5) such that:

$$\mathbf{x} = \mathbf{Ax} + \mathbf{F} \qquad (6)$$

where ***A*** is the input–output coefficient matrix describing the units of intermediate inputs needed to produce one unit of gross output.

Finally, by passing elements from one side of the equation to the other, the following expression is derived:

$$\mathbf{x} = (\mathbf{1} - \mathbf{A})^\wedge(-\mathbf{1})\ \mathbf{F} \tag{7}$$

The matrix $\mathrm{B} = (1 - \mathrm{A})^\wedge(-1)$ is the so-called Leontief matrix, or total requirements matrix. Each element of B represents the direct and indirect requirements of input *i* by activity *k*, in country *n*, from partner *m*.

To calculate how much employment is generated directly and indirectly by green exports, it is necessary to recover the diagonal matrix **θ**, whose elements contain the labour to output coefficients.

Finally, multiplying the matrix θ by **B** and the gross green exports matrix, **E**, yields the matrix **L**.

$$\mathbf{L} = \hat{\boldsymbol{\theta}}\mathbf{xBE} = \boldsymbol{\theta}\mathbf{BE} \tag{8}$$

Opening it:

$$\begin{pmatrix} L_{11} & \cdots & L_{1n} \\ \vdots & \ddots & \vdots \\ L_{k1} & \cdots & L_{kn} \end{pmatrix} = \begin{pmatrix} \theta_{11} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \theta_{kn} \end{pmatrix} \begin{pmatrix} 1 - a_{1,1} & \cdots & -a_{1,n} \\ \vdots & \ddots & \vdots \\ -a_{k,1} & \cdots & 1 - a_{k,n} \end{pmatrix}^{-1} \begin{pmatrix} E_{11} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & E_{k,n} \end{pmatrix}$$

5. Analysis of results: CE trade and its employment content

This section provides the main findings of the study. It begins by analysing international trade in CE-related goods (5.1), followed by an assessment of the employment embedded in these exports across regions and sectors (5.2).

5.1. CE-related international trade

Based on the previous list of CE-related products we calculate the volume and value of CE trade at the global level (table 2). As expected, trade remains dominated by non-CE goods, both in volume (99.47 per cent equivalent to 80.7 billion tonnes) and value (98.7 per cent or US$22.2 trillion). In contrast, CE goods—those aligned with principles of reducing waste to reuse and recycling material and products to enlarge their life cycle and efficiency—account for only 0.52 per cent of global trade volume (425.5 million tonnes) and 1.29 per cent of trade value (US$292.5 billion). This stark contrast highlights how marginal CE goods remain within international trade, despite growing environmental concerns and policy interest in circularity. The higher value share of CE goods relative to their volume suggests these products have on average higher unit value, possibly due to advanced processing, innovation, or limited supply on the international market. Overall, the data reveals the need for stronger global action and incentives to scale up circular trade flows.

▶ Table 2: 2022–23 average world CE & non-CE total exports – in volume (million tonnes) & value (billion US$)

	Volume		Value	
	Million tonnes	%	Billion USD	%
Non-Circular	80 723.74	99.47	22 213.13	98.70
Circular	425.50	0.52	292.48	1.29
Total	**81 149.24**	**100**	**22 505.61**	**100**

Source: Own elaboration.

By decomposing global exports by ISIC sector, we find that 50 per cent of CE exports by value and 26 per cent by volume originate from the Basic Metals sector (C24), primarily driven by trade in ferrous metals. This is followed by the food products, beverages, and tobacco sectors (C10–C12), which account for 23 per cent of CE export value and 33 per cent of volume, largely due to exports of vegetable oil residues and various fruit and vegetable products. The paper products and printing sectors (C17 & C18) also play a significant role, contributing 12 per cent of CE export value and 19 per cent of volume. Notably, exports from the latter sectors tend to have a lower unit value compared to basic metals, reflecting differences in value added intensity, market pricing, and material composition across CE-related goods. It is worth noting that rubber and plastic - low value recovered materials - do not rank among the top categories and are therefore not shown in the results tables. The top 10 ISIC sectors presented in table 3 account for 97 per cent of global CE exports (in value) but they represent only 40 per cent of non-CE exports, indicating a significant concentration of circular trade in a limited number of sectors. Thus, to advance the transition to a more circular global economy, there is a clear need to promote circularity within the sectors that currently make up the remaining 60 per cent of non-CE exports.

Within each of the main ISIC sectors presented in table 4, we observe that although the majority of exports are related to non-CE goods, several sectors—basic metals, food products, beverages and tobacco, paper products and printing, and wood and products of wood and cork—stand out for having CE goods represent more than 5 per cent of their total exports, both in value and volume. While CE trade remains a minority within each sector, these shares are not negligible, suggesting existing circular activity that can serve as a foundation for further expansion within these ISIC sectors.

▶ Table 3: Decomposition of the 2022-2023 Average World CE and Non-CE Exports across ISIC sectors – in volume (million tonnes) & value (billion USD)

ISIC	Description	Circular				Non-Circular			
		Volume		Value		Volume		Value	
		Million tonnes	*% of total*	Billion USD	*% of total*	Million tonnes	*% of total*	Billion USD	*% of total*
C24	Basic metals	110.34	*26%*	147.69	*50%*	510.23	*1%*	1 564.7	*7%*
C10–C12	Food products, beverages and tobacco	139.07	*33%*	67.28	*23%*	672.95	*1%*	1 227.03	*6%*
C17 & C18	Paper products and printing	80.5	*19%*	35.7	*12%*	167.6	*0%*	260.35	*1%*
C16	Wood and products of wood and cork	38.45	*9%*	8.06	*3%*	196.06	*0%*	147.81	*1%*
C20	Chemical and chemical products	17.52	*4%*	7.77	*3%*	954.55	*1%*	1.790.41	*8%*
C13 to C15	Textiles, textile products, leather and footwear	6.3	*1%*	6.16	*2%*	75.41	*0%*	989.2	*4%*
C21	Pharmaceuticals, medicinal chemical and botanical products	0.05	*0%*	5.72	*2%*	12.42	*0%*	903.6	*4%*
C23	Other non-metallic mineral products	7.2	*2%*	4.12	*1%*	338.19	*0%*	215.84	*1%*
A01 & C02	Agriculture, hunting, forestry	11.22	*3%*	4.02	*1%*	879.38	*1%*	637.56	*3%*
C27	Electrical equipment	1.86	*0%*	3.11	*1%*	5691.3	*7%*	1 111.54	*5%*
Others	Others	13	*3%*	2.84	*1%*	71 225.65	*88%*	13 365.09	*60%*
Total		**425.50**	***100%***	**292.48**	***100%***	**80.723.74**	***100%***	**22 213.13**	***100%***

Source: Own elaboration

We find that 50 per cent of CE exports by value and 26 per cent by volume originate from the basic metals sector (C24), primarily driven by trade in ferrous metals. This is followed by the food products, beverages, and tobacco sectors (C10–C12), which account for 23 per cent of CE export value and 33 per cent of volume, largely due to exports of vegetable oil residues and various fruit and vegetable products. The paper products and printing sectors (C17 & C18) also play a significant role, contributing 12 per cent of CE export value and 19 per cent of volume. Notably, exports from the latter sectors tend to have a lower unit value compared to basic metals, reflecting differences in value-added intensity, market pricing, and material composition across CE-related goods. It is worth noting that rubber and plastic - low value recovered materials - do not rank among the top categories and are therefore not shown in the results tables. The top 10 ISIC sectors presented in Table 3 account for 97 per cent of global CE exports (by value) but represent only 40 per cent of non-CE exports, indicating a significant concentration of circular trade in a limited number of sectors. To advance the transition to a more circular global economy, there is a clear need to promote circularity within the sectors that currently make up the remaining 60 per cent of non-CE exports.

Within each of the main ISIC sectors presented in Table 4, we observe that although the majority of exports are related to non-CE goods, several sectors basic metals, food products, beverages and tobacco, paper products and printing, and wood and products of wood and cork—stand out for having CE goods represent more than 5 per cent of their total exports, both in value and volume. While CE trade remains a minority within each sector, these shares are not negligible, suggesting existing circular activity that could serve as a foundation for further expansion within these ISIC sectors.

▶ Table 4: Decomposition of 2022-2023 Average World CE vs. Non-CE Exports within main ISIC sectors – in volume (million tonnes) & value (billion USD)

ISIC	Description	Volume (Million tonnes)			Value (Billion USD)		
		CE	Non-CE	Total	CE	Non-CE	Total
C24	Basic metals	*18%*	*82%*	**620.57**	*9%*	*91%*	**1712.4**
C10–C12	Food products. beverages and tobacco	*17%*	*83%*	**812.02**	*5%*	*95%*	**1294.32**
C17 & C18	Paper products and printing	*32%*	*68%*	**248.09**	*12%*	*88%*	**296.05**
C16	Wood and products of wood and cork	*16%*	*84%*	**234.51**	*5%*	*95%*	**155.87**
C20	Chemical and chemical products	*2%*	*98%*	**972.07**	*0%*	*100%*	**1 798.18**
C13–C15	Textiles. textile products. leather and footwear	*8%*	*92%*	**81.71**	*1%*	*99%*	**995.37**
C21	Pharmaceuticals. medicinal chemical and botanical products	*0%*	*100%*	**12.47**	*1%*	*99%*	**909.32**
C23	Other non-metallic mineral products	*2%*	*98%*	**345.38**	*2%*	*98%*	**219.96**
A01 & C02	Agriculture. hunting. forestry	*1%*	*99%*	**890.6**	*1%*	*99%*	**641.58**
C27	Electrical equipment	*0%*	*100%*	**5 693.16**	*0%*	*100%*	**1 114.66**
Others	Others	*0%*	*100%*	**71 238.66**	*0%*	*100%*	**13 367.92**
Total		*1%*	*99%*	**81 149.24**	*1%*	*99%*	**22 505.61**

Source: Own elaboration

When examining the regional origin of CE exports (Tables 5 and 6), we find that, as with total exports, high-income countries dominate the global market, accounting for more than twice the value and volume of CE exports compared to the rest of the world.

▶ Table 5: Regional Origin of 2022-2023 Average CE vs. Non-CE Exports – in volume (million tonnes) & value (billion USD)

Income level	Circular		Non-Circular		Total	
	Volume	Value	Volume	Value	Volume	Value
High-income countries	293.12	203.96	69 709.10	13 608.95	70 002.23	13 812.90
Low-income countries	1.51	0.94	117.83	66.87	119.34	67.8
Lower-middle-income countries	42.46	25.09	1 521.35	1 939.50	1 563.82	1 964.58
Upper-middle-income countries	87.66	62.14	9 353.02	6 517.50	9 440.68	6 579.63
Other non-classified countries	0.74	0.37	22.43	80.33	23.17	80.69
Total	**425.5**	**292.48**	**80 723.74**	**22 213.13**	**81 149.24**	**22 505.61**

Source: Own elaboration.

The European Union – notably Germany, Netherlands, France - leads in CE exports, followed by the United States, the United Kingdom, and Japan. However, upper-middle-income countries such as China, Brazil and Argentina, along with several lower-middle-income countries, also play a significant role. Together, these economies account for approximately one-third of global CE exports. This contribution is not negligible and highlights the growing involvement of emerging economies in circular trade flows.

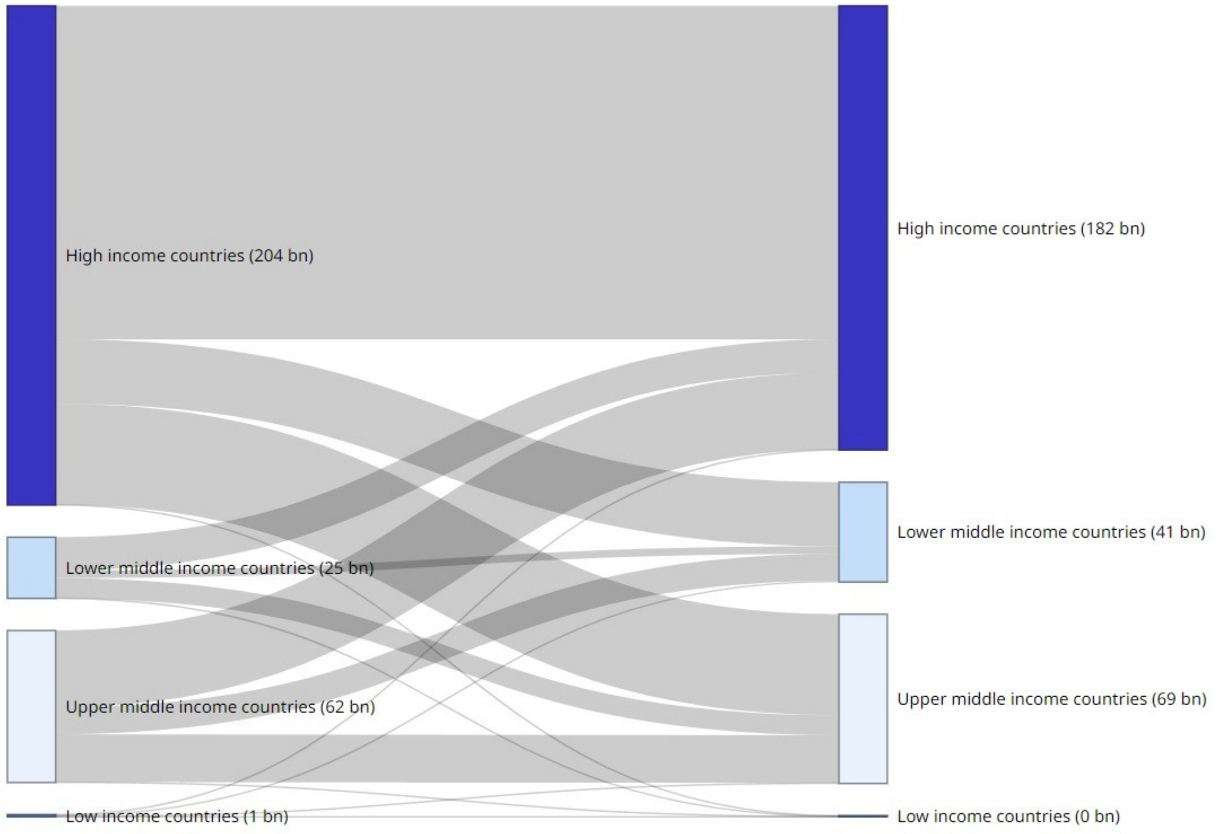
▶ Table 6: Country (CE top 10) Origin of 2022-2023 Average CE vs. Non-CE Exports – in volume (million tonnes) & value (billion USD)

	Circular		Non-Circular		Total	
	Volume	Value	Volume	Value	Volume	Value
United States of America	67.89	46.72	63 760.12	1 855.95	63 828.01	1 902.67
Germany	30.53	22.05	314.61	1 499.59	345.14	1 521.64
Brazil	20.37	12.02	656.31	332.34	676.68	344.35
United Kingdom	16.38	11.81	117.21	413.15	133.59	424.95
Netherlands	18.41	11.63	252.32	583.56	270.74	595.18
France	17.03	11.51	164.78	609.61	181.81	621.12
Argentina	20.09	11.08	70.74	69.12	90.83	80.2
Canada	19.92	10.89	562.27	603.03	582.19	613.92
Japan	10.44	8.27	111.92	759.56	122.37	767.83
China	7.06	8.19	6 280.23	3 141.81	6 287.29	3 150.00
Others	197.38	138.33	8 433.22	12 345.42	8 630.60	12 483.75
Total	**425.50**	**292.48**	**80 723.74**	**22 213.13**	**81 149.24**	**22 505.61**

Source: Own elaboration

As shown in figure 3, CE trade is mainly concentrated among high-income countries followed by exchanges between high-income countries with upper-middle-income countries and lower-middle-income countries. CE trade within upper-middle-income countries and lower-middle-income countries is limited, while participation in low-income countries is negligible.

▶ Figure 3: Sankey diagram of the CE exports between countries classified by their income per capita (left: origin & right: destination) in value (billion USD)



Source: Own elaboration

Regarding the destination of CE exports (Tables 7 and 8), the pattern remains largely concentrated in high-income countries. However, upper-middle-income and lower-middle-income countries play a relatively greater role as importers of CE goods compared to their share as exporters. This suggests a growing demand for circular inputs in these economies.

▶ Table 7: Regional Destination of 2022-2023 Average CE vs. Non-CE Exports – in volume (million tonnes) & value (billion USD)

Level	Circular		Non-Circular		Total	
	Volume	Value	Volume	Value	Volume	Value
High-income countries	251.95	181.79	6 310.35	15 361.15	6 562.31	15 542.94
Low-income countries	0.65	0.52	383.61	34.63	39.01	35.14
Lower-middle-income countries	74.11	40.81	1 548.44	1 803.78	1 622.55	1 844.59
Upper-middle-income countries	98.77	69.35	72 824.18	5 009.70	72 922.94	5 079.05
Other non-classified countries	0.03	0.01	2.41	3.88	2.44	3.89
Total	**425.50**	**292.48**	**80 723.74**	**22 213.13**	**81 149.24**	**22 505.61**

Source: Own elaboration

While the reuse of second-hand goods and recycled materials could offer cost-effective opportunities for low-income countries, limited infrastructure and technological capacity continue to constrain their ability to process and benefit fully from CE materials. Strengthening these capabilities will be essential to enhance the global inclusiveness of the circular economy.

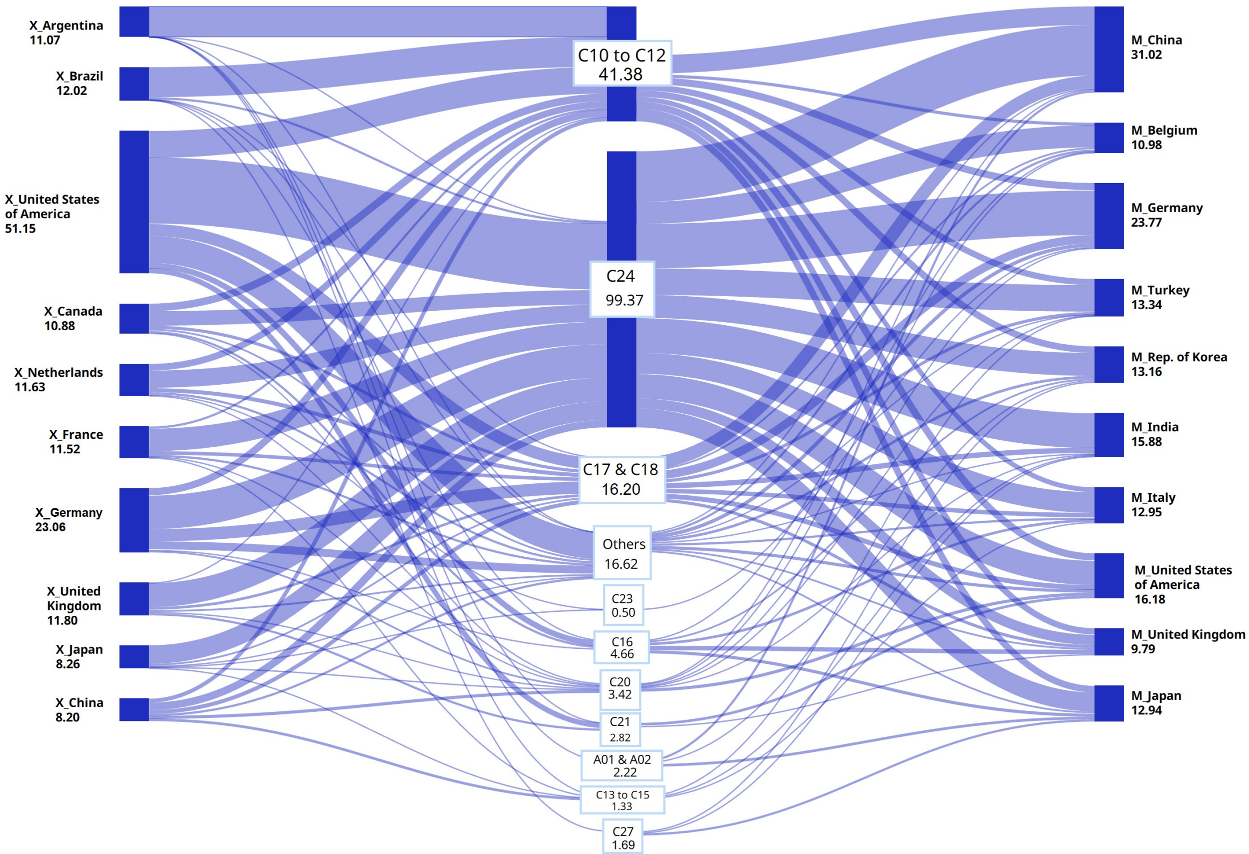
▶ Table 8: Countries (CE top 10) Destination of 2022-2023 Average CE vs. Non-CE Exports – in volume (million tonnes) & value (billion USD)

	Circular		Not circular		Total	
	Volume	Value	Volume	Value	Volume	Value
China	28.01	31.02	2 891.52	2 489.23	2 919.53	2 520.24
Germany	24.14	23.77	445.14	1 448.67	469.27	1 472.44
United States of America	17.6	16.18	993.88	3 253.88	1 011.48	3 270.06
India	23.14	15.88	785.59	682.48	808.73	698.36
Turkey	29.15	13.33	180.88	349.46	210.03	362.79
Rep. of Korea	20.22	13.16	540.1	669.36	560.31	682.52
Italy	16.57	12.95	288.48	647.08	305.05	660.03
Japan	15.19	12.94	664.38	812.1	679.57	825.03
Belgium	12.78	10.98	238.68	428.31	251.47	439.28
United Kingdom	14.36	9.8	250.07	763.8	264.43	773.59
Others	224.33	132.5	73 445.04	10 668.77	73 669.37	10 801.27
Total	**425.5**	**292.48**	**80 723.74**	**22 213.13**	**81 149.24**	**22 505.61**

Source: Own elaboration

The Sankey diagram (figure 4) links origin, destination and ISIC sectors associated with CE traded products. CE exports of basic metals come mainly from high-income countries such as the United States, Germany, United Kingdom, France and Japan, while food products, beverages and tobacco CE products (C10–C12) are mainly exported by Argentina, Brazil and the United States. In terms of destination, CE exports of basic metals go to both high-income countries – such as the United States, Germany and Belgium, but mainly to upper-middle-income countries (China, Turkey) and India, a lower-middle-income country. For other CE products linked to ISIC sectors, the origins and destinations are varied and do not follow a defined pattern.

▶ **Figure 4: Sankey diagram of CE exports by ISIC sectors**



Note: Description of each ISIC sectors related to CE are: C24: Basic metals; C10–C12: Food products, beverages and tobacco; C17 & C18: Paper products and printing; C16: Wood and products of wood and cork; C20: Chemical and chemical products; C13–C15: Textiles, textile products, leather and footwear; C21: Pharmaceuticals, medicinal chemical and botanical products; C23: Other non-metallic mineral products; A01 & C02: Agriculture, hunting, forestry; C27: Electrical equipment.

Source: Own elaboration (Sankey).

5.2. Employment

While CE exports represent 1.29 per cent of global exports, the employment embedded in these exports account for 1.15 per cent of all jobs generated by global exports—equivalent to approximately 5.96 million jobs (Table 9). Just one quarter of those CE export- related jobs are directly created in the production of CE goods, while the remainder are indirectly created through other sectors of activity along the chain (Table 10).

▶ **Table 9: Worldwide employment embedded in CE and Non-CE exports – in '000 jobs and % of the total**

	'000 jobs	%
Circular	5 960.79	1.15
Not circular	513 032.68	98.85
Total	**518 993.47**	**100.00**

Source: Own elaboration

Direct jobs embedded in CE exports are predominantly concentrated in the food products, beverages, and tobacco sectors (C10–C12), despite these sectors contributing less in terms of the value and volume of CE exports compared to basic metals (C24). While basic metals represent a larger share of CE export value, they generate significantly fewer jobs per unit exported due to their higher capital intensity. Notably, the agriculture, hunting, and forestry sectors (A01 and A02) account for nearly half of the total indirect employment associated with CE exports, underscoring their critical role in upstream job creation within CE-related value chains (Table 10).

▶ Table 10: Employment embedded in CE exports from main ISIC sectors – in direct, indirect and total '000 jobs

ISIC	Description	Direct	Indirect	Total
A01_02	Agriculture, hunting, forestry	84.96	1 981.74	2 066.70
G	Wholesale and retail trade; repair of motor vehicles	0	758.89	758.89
C10T12	Food products, beverages and tobacco	521.22	97.09	618.31
C24	Basic metals	422.75	84.19	506.94
C17_18	Paper products and printing	229.60	72.85	302.45
C13T15	Textiles, textile products, leather and footwear	142.91	66.97	209.88
H49	Land transport and transport via pipelines	0	188.22	188.22
C16	Wood and products of wood and cork	117.92	47.62	165.54
B07_08	Mining and quarrying, non-energy producing products	9.61	125.20	134.82
M	Professional, scientific and technical activities	0	108.94	108.94
Others	Others	98.21	801.89	900.10
Total		**1 627.18**	**4 333.60**	**5 960.79**

Source: Own elaboration

When examining direct job creation linked to CE exports across country groups classified by income level (Table 11), a notable pattern emerges: the direct employment coefficient is lower in high-income countries than in upper-middle- and lower-middle-income countries. This reflects underlying differences in technology and, consequently, in the labour-to-capital ratio of CE-exported products from each group.

With regard to indirect job creation associated with CE exports (Table 11), both upper-middle- and lower-middle-income countries also generate a higher number of indirect CE-related jobs than high-income countries. These differences can be attributed to variations in technology, workforce skills – particularly in services linked to CE sectors - and the nature of CE goods exported by high-income versus middle-income economies. Together, these influence the direct and indirect employment content of CE exports.

▶ Table 11: Employment embedded in CE exports from countries based on income per capita classification – in direct, indirect and total '000 jobs

Income level	Direct	Indirect	Total
High-income countries	555.60	740.29	1 295.89
Lower-middle-income countries	439.70	1 358.38	1 798.09
Upper-middle-income countries	490.93	1 404.33	1 895.26
Other non-classified countries	140.95	830.60	971.55
Total	**1 627.18**	**4 333.60**	**5 960.79**

Source: Own elaboration

The CE employment patterns described above are detailed in table 12. Upper-middle-income countries—such as Brazil, China, and Argentina—generate more than twice as many indirect jobs as direct jobs associated with CE exports. A similar pattern is observed for lower-middle-income countries, including India, Indonesia, and Viet Nam, where the total employment generated per dollar of CE exports is significantly higher than in high-income countries such as the United States and Germany.

▶ Table 12: Employment embedded in CE exports by a top 10 countries – in direct, indirect and total '000 jobs

Country	Direct	Indirect	Total
Brazil	97.61	417.27	514.88
India	89.41	415.97	505.38
Indonesia	99.95	301.82	401.77
Viet Nam	75.29	284.25	359.54
China	70.54	264.44	334.98
Argentina	84.88	218.24	303.11
United States of America	87.59	148.05	235.64
Germany	63.64	76.43	140.07
Peru	21.13	113.41	134.54
Rest of the world	937.15	2 093.72	3 030.88
Total	**1 627.18**	**4 333.60**	**5 960.79**

Source: Own elaboration

By cross-referencing countries and ISIC sectors where CE-related employment is generated -both directly and indirectly - distinct patterns emerge (Table 13).

In upper-middle-income countries such as Argentina, Brazil, China, and Peru, and in lower-middle-income countries, including India, Indonesia, and Viet Nam, direct CE export-related jobs are primarily concentrated in the food products, beverages, and tobacco sectors. In contrast, indirect employment is largely generated in more labour-intensive sectors, particularly agriculture, hunting, and forestry—especially in lower-middle-income economies.

In high-income countries such as Germany and the United States, the pattern differs: direct CE jobs are mainly found in the basic metals sector, while indirect employment is primarily concentrated in service sectors, notably wholesale and retail trade and the repair of motor vehicles.

▶ **Table 13: Employment embedded in CE exports by a top 10 countries and main ISIC sectors – in direct, indirect and total '000 jobs**

Country	ISIC	Description	Direct	Indirect	Total
Argentina	**C10T12**	**Food products, beverages and tobacco**	**83.15**	11.96	95.11
	A01_02	**Agriculture, hunting, forestry**	1.14	**86.23**	87.37
	G	Wholesale and retail trade; repair of motor vehicles	0	54.47	54.47
	Others	Others	0.59	46.08	46.68
	H49	Land transport and transport via pipelines	0	13.49	13.49
	M	Professional, scientific and technical activities	0	6.01	6.01
Brazil	**A01_02**	**Agriculture, hunting, forestry**	0.04	**165.89**	165.93
	Others	Others	12.00	92.07	104.06
	C10T12	**Food products, beverages and tobacco**	**85.58**	15.92	101.5
	G	Wholesale and retail trade; repair of motor vehicles	0	89.37	89.37
	H49	Land transport and transport via pipelines	0	29.08	29.08
	M	Professional, scientific and technical activities	0	24.94	24.94
China	**A01_02**	**Agriculture, hunting, forestry**	10.12	**144.2**	154.32
	Others	Others	18.56	58.18	76.74
	G	Wholesale and retail trade; repair of motor vehicles	0	33.98	33.98
	C17_18	Paper products and printing	17.95	8.44	26.39
	C13T15	Textiles, textile products, leather and footwear	10.13	12.60	22.74
	C24	Basic metals	13.78	7.03	20.82
Germany	Others	Others	10.38	43.84	54.22
	C24	**Basic metals**	**23.68**	6.62	30.30
	C17_18	Paper products and printing	19.97	4.22	24.19
	G	Wholesale and retail trade; repair of motor vehicles	0	13.84	13.84
	C10T12	Food products, beverages and tobacco	9.61	1.64	11.24
	N	Administrative and support services	0	6.28	6.28
India	**A01_02**	**Agriculture, hunting, forestry**	2.24	**315.55**	317.79
	Others	Others	12.10	42.81	54.91
	C10T12	**Food products, beverages and tobacco**	**45.14**	4.73	49.88
	G	Wholesale and retail trade; repair of motor vehicles	0	40.94	40.94
	C13T15	Textiles, textile products, leather and footwear	19.04	8.41	27.45
	C17_18	Paper products and printing	10.88	3.53	14.41

Country	ISIC	Description	Direct	Indirect	Total
Indonesia	**A01_02**	**Agriculture, hunting, forestry**	0.16	**155.98**	156.14
	Others	Others	27.33	43.49	70.82
	G	Wholesale and retail trade; repair of motor vehicles	0	55.36	55.36
	C10T12	**Food products, beverages and tobacco**	**38.10**	5.69	43.79
	B07_08	Mining and quarrying, non-energy producing products	0.08	40.89	40.97
	C24	Basic metals	34.27	0.41	34.68
Peru	**A01_02**	**Agriculture, hunting, forestry**	0.30	**78.33**	78.63
	C10T12	Food products, beverages and tobacco	19.93	2.23	22.16
	G	Wholesale and retail trade; repair of motor vehicles	0	18.70	18.70
	Others	Others	0.90	8.75	9.66
	H49	Land transport and transport via pipelines	0	3.40	3.40
	A03	Fishing and aquaculture	0	1.99	1.99
United States of America	Others	Others	30.50	86.22	116.71
	G	**Wholesale and retail trade; repair of motor vehicles**	0	**37.53**	37.53
	C24	**Basic metals**	**21.54**	6.22	27.76
	A01_02	Agriculture, hunting, forestry	6.46	12.15	18.61
	C13T15	Textiles, textile products, leather and footwear	16.79	1.78	18.57
	C17_18	Paper products and printing	12.30	4.16	16.46
Viet Nam	**A01_02**	**Agriculture, hunting, forestry**	1.54	**206.2**	207.74
	C16	**Wood and products of wood and cork**	**50.24**	18.54	68.77
	Others	Others	5.04	27.73	32.77
	G	Wholesale and retail trade; repair of motor vehicles	0	21.40	21.40
	C17_18	Paper products and printing	10.06	4.99	15.05
	C10T12	Food products, beverages and tobacco	8.41	5.40	13.81

Source: Own elaboration

To complete the characterization of employment embedded in CE exports, it is worth noting that these exports generate more informal jobs (3.45 million) than decent jobs (2.50 million) globally (Table 14). In high-income countries, CE export-related employment is predominantly formal, whereas in lower-middle-income countries, it is largely informal—highlighting the need for targeted formalization policies in these contexts.

Regarding the skill levels, only about one-fifth of the jobs created through CE exports are classified as skilled, while the majority are unskilled positions. These jobs primarily involve adult workers (aged 30 and older) and are mostly held by men, although women also account for a significant share - approximately 1.47 million CE-related jobs globally (Table 14).

▶ **Table 14: Employment embedded in CE exports by income level and labour group**

Income level	Formal	Informal	Skilled	Unskilled	Adult	Youth	Male	Female
High-income countries	1 091.81	202.20	435.46	859.93	1 186.99	108.88	780.52	404.59
Lower-middle-income countries	300.65	1 495.62	154.45	1 638.17	1 549.35	248.21	1 119.39	633.65
Upper-middle-income countries	933.32	959.52	311.28	1 583.00	1 649.81	245.40	866.61	432.30
Others non-classified countries	174.86	796.69	64.02	907.53	764.09	207.46	0	0
Total	**2 500.64**	**3 454.04**	**965.21**	**4 988.63**	**5 150.24**	**809.96**	**2 766.51**	**1 470.54**

Source: Own elaboration.

6. Conclusions

Although CE goods account for less than 1 per cent of global trade by volume and just under 2 per cent by value, they are estimated to support almost 6 million jobs - both directly and indirectly - worldwide. These jobs arise from direct activities such as recycling, repair, and reuse, as well as from indirect upstream services. Labour intensity is notably higher in low- and middle-income regions, particularly in East Asia & the Pacific (China, India, Indonesia, Viet Nam) and Latin America & the Caribbean (Brazil, Argentina, Peru), where CE exports support a larger share of regional employment compared to advanced economies. In less developed countries, primary sectors such as agriculture, food production and basic industries typically demand more labour per unit of output, reflecting lower productivity levels.

The sectoral composition of CE-related employment varies significantly across regions. In East Asia and the Pacific, direct and indirect jobs are concentrated in agro-residue processing. Similarly, in Latin America and the Caribbean, most direct CE employment is found in food production, while indirect jobs are primarily linked to agricultural residues. In contrast, direct CE jobs in the United States are concentrated in capital-intensive industries related to basic metals remelting and indirect jobs to services (sales and repair). The European Union – notably Germany, France and Belgium - and the United Kingdom show a comparable trend. China occupies an intermediate position, combining large-scale employment in both agro-residue processing and metal reprocessing.

At the same time, the analysis reveals important distributional challenges. CE trade disproportionately benefits adults, unskilled and informal workers, and there is a modest gender gap in indirect employment. These findings highlight the need for coherent policy frameworks - such as trade facilitation measures to reduce barriers to circular flows and targeted labour-market interventions to improve job quality.

Future research should build on this MRIO-based approach by incorporating dynamic computable general equilibrium (CGE) modelling to capture price and investment feedback, assess the effects of CE-specific policy interventions, and evaluate the long-term potential of circular trade to decouple economic growth from resource use while promoting inclusive, green employment.

References

Bartelings, Heleen, Monika Verma, Kirsten Boysen-Urban, and Monika Verma. 2021. *Waste Management and Circular Economy in a CGE Framework*. https://ageconsearch.umn.edu/record/333314.

Batlles-delaFuente, Ana, Emilio Abad-Segura, Mariana-Daniela González-Zamar, and Francisco Joaquín Cortés-García. 2022. "An Evolutionary Approach on the Framework of Circular Economy Applied to Agriculture." *Agronomy* 12 (3): 3. https://doi.org/10.3390/agronomy12030620.

Bellmann, Christophe, and Malena Sell. 2021. *Options to Incorporate Circular Economy Provisions in Regional Trade Agreements*. International Institute for Sustainable Development (IISD) Finnish Innovation Fund Sitra.

Bibas, R, Jean Chateau, and E Lanzi. 2021. *Policy Scenarios for a Transition to a More Resource Efficient and Circular Economy*. OECD Environment Working Papers No. 169. Vol. 169. OECD Environment Working Papers. https://doi.org/10.1787/c1f3c8d0-en.

Bocken, Nancy M. P., de Pauw, Ingrid, Bakker, Conny, and Bram and van der Grinten. 2016. "Product Design and Business Model Strategies for a Circular Economy." *Journal of Industrial and Production Engineering* 33 (5): 308–20. https://doi.org/10.1080/21681015.2016.1172124.

Bruckner, Martin, Richard Wood, Daniel Moran, et al. 2019. "FABIO—The Construction of the Food and Agriculture Biomass Input–Output Model." *Environmental Science & Technology* 53 (19): 11302–12. https://doi.org/10.1021/acs.est.9b03554.

Chateau, Dellink, and Lanzi. 2014. "An Overview of the OECD ENV-Linkages Model." OECD, June 10. https://www.oecd.org/en/publications/an-overview-of-the-oecd-env-linkages-model_5jz2qck2b2vd-en.html.

Chateau, Jean, and Eleonora Mavroeidi. 2020. "The Jobs Potential of a Transition towards a Resource Efficient and Circular Economy." OECD, August 27. https://www.oecd.org/en/publications/the-jobs-potential-of-a-transition-towards-a-resource-efficient-and-circular-economy_28e768df-en.html.

Chepeliev, Maksym, Angel Aguiar, Thomas Farole, Andrea Liverani, and Dominique van der Mensbrugghe. 2022. "EU Green Deal and Circular Economy Transition: Impacts and Interactions." *25th Annual Conference on Global Economic Analysis* GTAP Resource #6607: 2–35. https://ageconsearch.umn.edu/record/333431.

Clube, Rebecca. 2022. "Is Job Creation a Legitimate Social Benefit of the Circular Economy?" *Resources, Conservation and Recycling* 181 (June): 106220. https://doi.org/10.1016/j.resconrec.2022.106220.

Dantas, T. E. T, E. D. de Souza, I. R. Destro, G. Hammes, C. M. T. Rodríguez, and S. R. Soares. 2020. "How the Combination of Circular Economy and Industry 4.0 Can Contribute towards Achieving the Sustainable Development Goal." *Sustainable Production and Consumption*.

Donati, Franco, Glenn A. Aguilar-Hernandez, Carlos Pablo Sigüenza-Sánchez, Arjan de Koning, Arnold Tukker, and João F.D. Rodrigues. 2020. "Modeling the Circular Economy in Environmentally Extended Input-Output Tables: Methods, Software and Case Study." *Resources, Conservation & Recycling*.

Eberhardt, Leonora Charlotte Malabi, Harpa Birgisdottir, and Morten Birkved. 2019. "Potential of Circular Economy in Sustainable Buildings." *IOP Conference Series: Materials Science and Engineering* 471 (9): 092051. https://doi.org/10.1088/1757-899X/471/9/092051.

Environment, U. N. 2022. "UN Environment Assembly 5 (UNEA 5.2) Resolutions | UNEP - UN Environment Programme." September 20. https://www.unep.org/resources/resolutions-treaties-and-decisions/UN-Environment-Assembly-5-2.

European Commission. 2020. "Circular Economy Action Plan." https://environment.ec.europa.eu/strategy/circular-economy-action-plan_en.

Freire-González, Jaume, Veronica Martinez-Sanchez, and Ignasi Puig-Ventosa. 2022. "Tools for a Circular Economy: Assessing Waste Taxation in a CGE Multi-Pollutant Framework." *Waste Management* 139 (February): 50–59. https://doi.org/10.1016/j.wasman.2021.12.016.

Ghisellini, Patrizia, Catia Cialani, and Sergio Ulgiati. 2016. "A Review on Circular Economy: The Expected Transition to a Balanced Interplay of Environmental and Economic Systems." *Journal of Cleaner Production*, Towards Post Fossil Carbon Societies: Regenerative and Preventative Eco-Industrial Development, vol. 114 (February): 11–32. https://doi.org/10.1016/j.jclepro.2015.09.007.

Groothuis. 2019. *Tax as a Force for Good – Case Study Bangladesh | The Ex'tax Project*. September 17. https://ex-tax.com/bangladesh/.

Horbach, Jens, Klaus Rennings, and Katrin Sommerfeld. 2015. "Circular Economy and Employment." Paper presented at 3rd IZA workshop: labor market effects of environmental policies.

Hummels, David, Jun Ishii, and Kei-Mu Yi. 2001. "The Nature and Growth of Vertical Specialization in World Trade." *Journal of International Economics*, Trade and Wages, vol. 54 (1): 75–96. https://doi.org/10.1016/S0022-1996(00)00093-3.

IISD. 2021. "Options to Incorporate Circular Economy Provisions in Regional Trade Agreements." https://www.iisd.org/publications/circular-economy-regional-trade-agreements.

ILO. 2018. "World Employment and Social Outlook 2018: Greening with Jobs | International Labour Organization." May 14. https://www.ilo.org/publications/world-employment-and-social-outlook-2018-greening-jobs.

ILO. 2019. *Decent Work in the Management of Electrical and Electronic Waste (e-Waste)*. First edition 2019. Issues Paper for the Global Dialogue Forum on Decent Work in the Management of Electrical and Electronic Waste (E-Waste). Geneva. https://www.ilo.org/sites/default/files/wcmsp5/groups/public/%40ed_dialogue/%40sector/documents/publication/wcms_673662.pdf.

International Conference of Labour Statisticians. 2013. *Statistics of Work, Employment and Labour Underutilization: Report for Discussion at the 19th International Conference of Labour Statisticians (Geneva, 2-11 October 2013)*. With International Labour Organization Department of Statistics. International Conference of Labour Statisticians, Report II. ILO.

Kalmykova, Yuliya, Madumita Sadagopan, and Leonardo Rosado. 2018. "Circular Economy – From Review of Theories and Practices to Development of Implementation Tools." *Resources, Conservation and Recycling*, Sustainable Resource Management and the Circular Economy, vol. 135 (August): 190–201. https://doi.org/10.1016/j.resconrec.2017.10.034.

Kirchherr, Julian, Denise Reike, and Marko Hekkert. 2017. "Conceptualizing the Circular Economy: An Analysis of 114 Definitions." *Resources, Conservation and Recycling* 127 (December): 221–32. https://doi.org/10.1016/j.resconrec.2017.09.005.

Kirchherr, Julian, Nan-Hua Nadja Yang, Frederik Schulze-Spüntrup, Maarten J. Heerink, and Kris Hartley. 2023. "Conceptualizing the Circular Economy (Revisited): An Analysis of 221 Definitions." *Resources, Conservation and Recycling* 194 (July): 107001. https://doi.org/10.1016/j.resconrec.2023.107001.

Krausmann, Fridolin, Heinz Schandl, Nina Eisenmenger, Stefan Giljum, and Tim Jackson. 2017. “Material Flow Accounting: Measuring Global Material Use for Sustainable Development.” *Annual Review of Environment and Resources* 42 (Volume 42, 2017): 647–75. https://doi.org/10.1146/annurev-environ-102016-060726.

Lange, Deborah E. de. 2024. “Circular Economy International Trade: An Investigation of the Relationship between European Union Circularity and International Trade.” *Journal of Cleaner Production* 484 (December): 144350. https://doi.org/10.1016/j.jclepro.2024.144350.

Loon, Patricia van, Derek Diener, and Steve Harris. 2021. “Circular Products and Business Models and Environmental Impact Reductions: Current Knowledge and Knowledge Gaps.” *Journal of Cleaner Production* 288 (March): 125627. https://doi.org/10.1016/j.jclepro.2020.125627.

Magalini, Federico, Feng Wang, Jaco Huisman, et al. 2014. *Study on Collection Rates of Waste Electrical and Electronic Equipment (WEEE): Possible Measures to Be Initiated by the Commission as Required by Article 7(4), 7(5), 7(6) and 7(7) of Directive 2012/19/EU on Waste Electrical and Electronic Equipment (WEEE).* European Commission Study.

OECD. 2022. “Global Plastics Outlook.” OECD, June 21. https://www.oecd.org/en/publications/global-plastics-outlook_aa1edf33-en.html.

Potting, José, Marko Hekkert, Ernst Worrell, and Aldert Hanemaaijer. 2017. *CIRCULAR ECONOMY: MEASURING INNOVATION IN THE PRODUCT CHAIN*.

Repp, Lars, Marko Hekkert, and Julian Kirchherr. 2021. “Circular Economy-Induced Global Employment Shifts in Apparel Value Chains: Job Reduction in Apparel Production Activities, Job Growth in Reuse and Recycling Activities.” *Resources, Conservation and Recycling* 171 (August): 105621. https://doi.org/10.1016/j.resconrec.2021.105621.

Romero, Carlos A., Sofia Rojo Brizuela, and Gustavo Ferro. 2024. “Measuring the Effects of Increasing Circularity in the Economy Through Recycling.” *Circular Economy and Sustainability* 4 (1): 503–22. https://doi.org/10.1007/s43615-023-00299-6.

Schluep, Mathias, T. Terekhova, Andreas Manhart, Ervín Muller, D. Rochat, and Oladele Osibanjo. 2012. “Where Are WEEE in Africa?” *Electronics Goes Green 2012+, ECG 2012 - Joint International Conference and Exhibition, Proceedings*, January 1, 6.

Schröder, Patrick, Kartika Anggraeni, and Uwe Weber. 2018. “The Relevance of Circular Economy Practices to the Sustainable Development Goals.” *Journal of Industrial Ecology* 23 (February). https://doi.org/10.1111/jiec.12732.

Timmer, Marcel P., Erik Dietzenbacher, Bart Los, Robert Stehrer, and Gaaitzen J. de Vries. 2015. “An Illustrated User Guide to the World Input–Output Database: The Case of Global Automotive Production.” *Review of International Economics* 23 (3): 575–605. https://doi.org/10.1111/roie.12178.

UNCTAD. 2024. “Developing Pathways for Circular Economy: Enhancing Collaboration to Strengthen Global Circular Value Chains.” https://unctad.org/meeting/developing-pathways-circular-economy-enhancing-collaboration-strengthen-global-circular.

UNECE. 2023. “Harnessing Opportunities from the Circular and Green Economy: Compendium of Guidance Resources for Micro, Small and Medium-Sized Enterprise Development.” Circular Economy Transition Paper Series. https://unece.org/sites/default/files/2023-10/CE-TransitionPaperSeries_MSME-Compendium.pdf.

UNEP. 2011. “Decoupling Natural Resource Use and Environmental Impacts from Economic Growth.” United Nations Environmental Programme.

UNEP. 2021. “The Use of Natural Resources in the Economy: A Global Manual on Economy-Wide Material Flow Accounting. Nairobi, Kenya.” United Nations Environment Programme.

Urbinati, Andrea, Davide Chiaroni, and Vittorio Chiesa. 2017. “Towards a New Taxonomy of Circular Economy Business Models.” *Journal of Cleaner Production* 168 (December): 487–98. https://doi.org/10.1016/j.jclepro.2017.09.047.

Velis, Costas A., and Ed Cook. 2021. “Mismanagement of Plastic Waste through Open Burning with Emphasis on the Global South: A Systematic Review of Risks to Occupational and Public Health.” *Environmental Science & Technology* 55 (11): 7186–207. https://doi.org/10.1021/acs.est.0c08536.

WCO. 2023. “Transition to a Circular Economy and Implications for Customs Administration.” World Customs Organization.

Wiebe, Kirsten S., Marek Harsdorff, Guillermo Montt, Moana S. Simas, and Richard Wood. 2019. “Global Circular Economy Scenario in a Multiregional Input–Output Framework.” *Environmental Science & Technology* 53 (11): 6362–73. https://doi.org/10.1021/acs.est.9b01208.

Wiedmann, Thomas, and Manfred Lenzen. 2018. “Environmental and Social Footprints of International Trade.” *Nature Geoscience* 11 (5): 314–21. https://doi.org/10.1038/s41561-018-0113-9.

World Bank. 2023. “World Bank Open Data.” World Bank Open Data. https://data.worldbank.org.

World Economic Forum. 2020. “Plastics, the Circular Economy and Global Trade.” World Economic Forum. https://www.weforum.org/publications/plastics-the-circular-economy-and-global-trade/.

WTO. 2024. “Trade and Environmental Sustainability.” https://www.wto.org/english/tratop_e/tessd_e/tessd_e.htm.

Yamaguchi, Shunta. 2021. “International trade and circular Economy - Policy - ProQuest.” https://www.proquest.com/docview/2498625167?fromopenview=true&pq-origsite=gscholar&sourcetype=Working%20Papers.

▶ Appendix

▶ Table A1: CE goods list

HS 2022	Description
30910	pellets of fish
30990	pellets of crustaceans, molluscs and other invertebrates
50100	hair and waste of human hair
50290	hair and other brush making hair and waste of such bristles
50590	skins and other parts of birds
50690	bones and horn-cores and powder or waste
50710	ivory powder and waste
50790	tortoise-shell waste and powder
50800	coral powder and waste
110320	cereal pellets
110520	flakes, granules and pellets
121300	cereal straw and husks pressed or in the form of pellets
121410	lucerne (alfalfa) meal and pellets
121490	forage products pelletised or otherwise
180200	cocoa and other cocoa waste
230110	flours, meals and pellets; of meat or meat offal
230120	flours, meals and pellets of fish
230210	other residues of maize (corn)
230230	other residues of wheat
230240	other residues of cereals
230250	other residues of leguminous plants
230310	residues of starch manufacture and similar residues; whether or not in the form of pellets
230320	waste of sugar manufacture
230330	brewing or distilling dregs and waste
230400	oil-cake from the extraction of soya-bean oil
230500	oil-cake from the extraction of ground-nut oil
230610	oil-cake from the extraction of cotton seed oils
230620	oil-cake from the extraction of linseed oils
230630	oil-cake from the extraction of sunflower seed oils
230641	oil-cake of low erucic acid rape or colza seed oils
230649	oil-cake of rape seed oils
230650	oil-cake of coconut or copra seed oils
230660	oil-cake from the extraction of palm nuts or kernels oils
230690	oil-cake from the extraction of oils, n.e.c. in heading no. 2306
230800	vegetable materials and vegetable waste
251720	macadam of slag, dross or similar industrial waste
252530	mica; waste

HS 2022	Description
261900	other waste from the manufacture of iron or steel
262110	residues from the incineration of municipal waste
262190	slag and ash n.e.c. in chapter 26
271091	waste oils; of petroleum
271099	waste oils weight 70% or preparations of the same
280110	chlorine
290377	halogenated derivatives of acyclic hydrocarbons
290378	halogenated derivatives of acyclic hydrocarbons n.e.c. in item no. 2903.71 to 2903.76
300692	pharmaceutical goods; waste pharmaceuticals
382510	residual products of the chemical municipal waste
382530	residual products of the chemical clinical waste
382541	residual products of the chemical halogenated waste organic solvents
382549	residual products of the chemical waste organic solvents, other than halogenated
382550	wastes of metal pickling liquors, hydraulic fluids
382561	other wastes containing organic constituents
382569	other wastes except those containing organic constituents
391510	ethylene polymers; waste
391520	styrene polymers; waste
391530	vinyl chloride polymers; waste
391590	plastics n.e.c. in heading no. 3915; waste
400300	rubber; reclaimed rubber
400400	rubber; waste
400610	rubber; unvulcanised, camel-back strips
400690	rubber; unvulcanised, other than camel back strips
401211	retreaded tyres used on motor cars
401212	retreaded tyres used on motor buses
401213	retreaded tyres used on aircraft
401219	retreaded tyres; other
401700	rubber; ebonite and other hard rubber, including waste and scrap
411520	leather; parings and other waste
440131	wood waste and scrap, agglomerated in wood pellets
440132	wood waste and scrap, agglomerated in wood briquettes
440139	wood waste and scrap, agglomerated in logs or similar form
440141	wood waste and scrap, not agglomerated; sawdust
440149	wood waste and scrap, not agglomerated and not including sawdust
450190	cork; waste cork, crushed, granulated
470620	pulp; of fibres derived from recovered waste and scrap

HS 2022	Description
470710	waste and scrap, of unbleached kraft paper
470720	waste and scrap, paper or paperboard made mainly of bleached chemical pulp
470730	waste and scrap, paper or paperboard made mainly of mechanical pulp
470790	paper or paperboard; waste and scrap
500300	silk waste
500500	silk; yarn spun from silk waste, not put up for retail sale
50710	ivory powder and waste
50790	tortoise-shell waste and powder
50800	coral powder and waste
500600	silk yarn and yarn spun from silk waste; put up for retail sale, and silk-worm gut
500720	silk; woven fabrics, containing 85% or more of silk waste
510310	wool and hair; including yarn waste
510320	wool and hair; waste of wool
510330	wool and hair; waste of coarse animal hair
520210	cotton; yarn waste
520291	cotton; garnetted stock waste
520299	cotton; waste other than garnetted stock and yarn waste
530130	flax; tow and waste
530290	hemp, true hemp tow and waste
530390	jute and other textile bast fibres, tow and waste of these fibres
550510	fibres; waste of synthetic fibres
550520	fibres; waste of artificial fibres
630900	clothing; worn, and other worn articles
631010	rags; used or new, scrap twine, sorted
631090	rags; used or new, scrap twine, other than sorted
680800	panels, boards, tiles, blocks and the like; of vegetable fibre, of straw, shavings, chips, particles, sawdust or other waste, of wood, agglomerated with cement, plaster or other mineral binders
700100	glass; cullet and other waste and scrap of glass
711230	waste and scrap of precious metal
711291	waste and scrap of gold
711292	waste and scrap of platinum
711299	waste and scrap of, other than that of gold and platinum,
720410	ferrous waste and scrap; of cast iron
720421	ferrous waste and scrap; of stainless steel
720429	ferrous waste and scrap; of alloy steel
720430	ferrous waste and scrap; of tinned iron or steel
720441	ferrous waste and scrap; turnings, shavings, chips, milling waste
720449	ferrous waste and scrap; n.e.c. in heading no. 7204
720450	ferrous products; remelting scrap ingots

Source: Own elaboration

HS 2022	Description
740400	copper; waste and scrap
750300	nickel; waste and scrap
760200	aluminium; waste and scrap
780200	lead; waste and scrap
790200	zinc; waste and scrap
800200	tin; waste and scrap
810110	tungsten; articles thereof, including waste and scrap, powders
810197	tungsten; waste and scrap
810210	molybdenum; articles thereof, including waste and scrap, powders
810297	molybdenum; waste and scrap
810330	tantalum; waste and scrap
810420	magnesium; waste and scrap
810530	cobalt; waste and scrap
810610	bismuth;including waste and scrap
810690	bismuth; including articles n.e.c. in heading 8106, including waste and scrap
810830	titanium; waste and scrap
810931	zirconium; waste and scrap, containing less than 1 part hafnium
810939	zirconium; waste and scrap, containing not less than 1 part hafnium
811020	antimony; waste and scrap
811100	manganese; articles thereof, including waste and scrap
811213	beryllium; waste and scrap
811222	chromium; waste and scrap
811231	hafnium, waste and scrap
811241	rhenium, waste and scrap
811252	thallium; waste and scrap
811261	cadmium; waste and scrap
811292	gallium, germanium, indium, including waste and scrap, powders
811300	cermets; including waste and scrap
854911	waste and scrap of lead-acid accumulators
854912	waste and scrap; of primary cells, containing lead, cadmium or mercury
854913	waste and scrap; of primary cells, sorted not containing lead, cadmium or mercury
854914	waste and scrap; of primary cells, unsorted and not containing lead, cadmium or mercury
854919	waste and scrap; of primary cells, n.e.c. in item no 8549.1
854921	electrical and electronic waste and scrap
854929	waste and scrap; of a kind used principally for the recovery of precious metal
854931	electrical waste and scrap; electronic assemblies and printed circuit boards
854939	waste and scrap; electrical and electronic assemblies and printed circuit boards
854991	waste and scrap; n.e.c. in heading no 8549
854999	waste and scrap; n.e.c. in item no 8549.91

▶ Table A2: CE and Non-CE Exports by country and ISIC sector of origin – in volume (million tonnes) and value (billion US$$)

Country	ISIC	Description ISIC	Circular		Not circular		Total	
			Volume	Value	Volume	Value	Volume	Value
Argentina	C10T12	Food products, beverages and tobacco	19,92	10,95	11,06	19,64	30,98	30,59
	A01_02	Agriculture, hunting, forestry	0,11	0,05	42,27	17,68	42,38	17,73
	C21	Pharmaceuticals, medicinal chemical and botanical products	0	0,04	0,15	1,77	0,15	1,81
	C24	Basic metals	0	0,01	0,95	4,36	0,95	4,37
	Others	Others	0,04	0,01	16,21	24,95	16,25	24,96
	C13T15	Textiles, textile products, leather and footwear	0	0,01	0,1	0,73	0,1	0,74
Brazil	C10T12	Food products, beverages and tobacco	19,23	10,78	32,19	46,01	51,42	56,79
	C24	Basic metals	0,41	0,81	18,63	22,34	19,04	23,15
	C17_18	Paper products and printing	0,21	0,2	20,43	15,37	20,64	15,57
	C16	Wood and products of wood and cork	0,47	0,13	5,68	4,51	6,14	4,64
	C27	Electrical equipment	0,01	0,06	0,27	3,22	0,28	3,28
	Others	Others	0,04	0,04	579,11	240,89	579,15	240,93
Canada	C24	Basic metals	5,26	5,19	11,58	70,08	16,83	75,26
	C10T12	Food products, beverages and tobacco	5,98	2,65	14,02	39,26	20,01	41,92
	C17_18	Paper products and printing	2,46	1,17	13,99	15,1	16,45	16,27
	C16	Wood and products of wood and cork	3,35	0,78	17,82	15,66	21,17	16,45
	Others	Others	1,83	0,71	458,62	420,02	460,44	420,73
	C20	Chemical and chemical products	1,03	0,38	46,26	42,91	47,29	43,29
China	C24	Basic metals	0,55	2,71	67,96	114,85	68,51	117,56
	C17_18	Paper products and printing	1,32	1,49	10,88	30,18	12,2	31,67
	C10T12	Food products, beverages and tobacco	2,57	1,35	114,78	47,73	117,35	49,07
	C20	Chemical and chemical products	1,29	1,04	100,37	238,01	101,65	239,05
	C13T15	Textiles, textile products, leather and footwear	0,5	0,88	30,79	307,05	31,29	307,93
	Others	Others	0,83	0,73	5955,46	2403,99	5956,29	2404,72
France	C24	Basic metals	7,63	8,08	12,86	28,41	20,48	36,49
	C17_18	Paper products and printing	3,48	1,34	3,82	7,87	7,29	9,21
	C10T12	Food products, beverages and tobacco	2,04	0,77	29,69	63,92	31,74	64,69
	Others	Others	2,72	0,74	97,86	395,22	100,58	395,96
	C13T15	Textiles, textile products, leather and footwear	0,31	0,3	0,95	27,33	1,26	27,63
	C20	Chemical and chemical products	0,86	0,29	19,6	86,86	20,46	87,14

Country	ISIC	Descrption ISIC	Circular		Not circular		Total	
			Volume	Value	Volume	Value	Volume	Value
Germany	C24	Basic metals	10,14	12,09	28,57	81,91	38,71	94
	C17_18	Paper products and printing	7,81	4,46	10,97	24,24	18,78	28,69
	C10T12	Food products, beverages and tobacco	5,75	2,53	36,92	78,8	42,68	81,33
	Others	Others	3,13	1,9	169,21	1153,54	172,34	1155,43
	C20	Chemical and chemical products	1,29	0,63	54,8	150,65	56,1	151,28
	C16	Wood and products of wood and cork	2,39	0,44	14,13	10,46	16,53	10,9
Japan	C24	Basic metals	5,84	6,62	30	65,28	35,85	71,9
	C17_18	Paper products and printing	2,13	0,68	1,62	3,35	3,74	4,04
	Others	Others	1,94	0,33	51,97	597,62	53,92	597,95
	C20	Chemical and chemical products	0,25	0,28	20,56	79,12	20,82	79,4
	C23	Other non-metallic mineral products	0,05	0,21	7,42	7,79	7,47	8
	C13T15	Textiles, textile products, leather and footwear	0,22	0,14	0,35	6,4	0,57	6,55
Netherlands	C24	Basic metals	6,19	6,25	10,23	21,27	16,42	27,53
	C10T12	Food products, beverages and tobacco	4,9	2,33	30,76	73,02	35,66	75,35
	C17_18	Paper products and printing	4,06	1,49	3,22	6,33	7,28	7,82
	Others	Others	1,79	0,84	166,6	411,4	168,39	412,24
	C20	Chemical and chemical products	0,9	0,43	37,39	68,6	38,29	69,03
	C23	Other non-metallic mineral products	0,57	0,29	4,12	2,92	4,69	3,21
United Kingdom	C24	Basic metals	7,88	8,56	3,72	32,64	11,6	41,2
	C17_18	Paper products and printing	3,99	1,03	1,17	5,54	5,17	6,57
	C21	Pharmaceuticals, medicinal chemical and botanical products	0	0,84	0,2	23,97	0,2	24,81
	Others	Others	1,28	0,71	94,65	284,73	95,93	285,45
	C20	Chemical and chemical products	2,66	0,37	9,1	39,65	11,76	40,01
	C10T12	Food products, beverages and tobacco	0,56	0,29	8,37	26,62	8,93	26,91
United States of America	C24	Basic metals	15,78	23,83	11,52	73,09	27,3	96,91
	C10T12	Food products, beverages and tobacco	20,25	9,73	27,41	82,76	47,66	92,49
	Others	Others	8,33	4,87	63697,81	1566,32	63706,13	1571,19
	C17_18	Paper products and printing	14,47	4,34	15,32	27,05	29,79	31,4
	C16	Wood and products of wood and cork	9,05	2,01	7,52	6,23	16,57	8,23
	C21	Pharmaceuticals, medicinal chemical and botanical products	0,01	1,94	0,55	100,5	0,56	102,44

Source: Own elaboration

▶ Table A3: CE and Non-CE export by country of destination and ISIC related sectors – in volume (million tonnes) and value (billion US$)

Country	ISIC	Description	Circular		Not circular		Total	
			Volume	Value	Volume	Value	Volume	Value
Belgium	C24	Basic metals	4,77	7,88	9,32	17,62	14,09	25,51
	C10T12	Food products, beverages and tobacco	3,18	1,11	15,99	26,92	19,17	28,03
	Others	Others	1,4	0,74	178,33	327,77	179,74	328,51
	C17_18	Paper products and printing	1,63	0,69	2,59	4,7	4,22	5,39
	C20	Chemical and chemical products	0,43	0,3	27,34	48,61	27,77	48,9
	C16	Wood and products of wood and cork	1,37	0,26	5,11	2,68	6,48	2,94
China	C24	Basic metals	4,1	18,2	38,08	210,58	42,18	228,78
	C10T12	Food products, beverages and tobacco	10,84	6,67	47,69	102,57	58,53	109,24
	C17_18	Paper products and printing	11,19	4,59	32,75	27,95	43,93	32,54
	A01_02	Agriculture, hunting, forestry	1,54	0,78	207,98	127,41	209,52	128,19
	Others	Others	0,15	0,47	2441,61	1812,75	2441,75	1813,22
	C20	Chemical and chemical products	0,2	0,31	123,42	207,97	123,63	208,28
Germany	C24	Basic metals	5,71	16,09	29,5	82,79	35,21	98,88
	C17_18	Paper products and printing	7,43	3,04	12,53	19,5	19,96	22,54
	C10T12	Food products, beverages and tobacco	6,02	2,53	30,21	76,6	36,24	79,14
	Others	Others	3,31	1,21	320,99	1129,26	324,3	1130,48
	C20	Chemical and chemical products	0,89	0,54	41,67	126,63	42,56	127,16
	C23	Other non-metallic mineral products	0,78	0,36	10,23	13,89	11,02	14,25
India	C24	Basic metals	12,38	12,58	13,9	71,69	26,28	84,27
	C17_18	Paper products and printing	7,45	1,84	4,94	5,43	12,39	7,27
	C13T15	Textiles, textile products, leather and footwear	0,88	0,45	1,37	8,36	2,25	8,81
	Others	Others	0,96	0,42	693,28	493,03	694,24	493,45
	C27	Electrical equipment	0,31	0,34	0,96	18,54	1,27	18,88
	C20	Chemical and chemical products	1,17	0,25	71,13	85,43	72,3	85,68
Italy	C24	Basic metals	6,32	7,53	25,93	57,67	32,25	65,21
	C10T12	Food products, beverages and tobacco	3,53	1,71	16,39	43,49	19,92	45,2
	C17_18	Paper products and printing	2,17	1,56	7,42	9,53	9,59	11,09
	C16	Wood and products of wood and cork	3,35	0,96	7,06	5,84	10,41	6,8
	Others	Others	1,07	0,83	229,15	488,58	230,22	489,41
	C13T15	Textiles, textile products, leather and footwear	0,12	0,36	2,53	41,97	2,65	42,32

Country	ISIC	Description	Circular		Not circular		Total	
			Volume	Value	Volume	Value	Volume	Value
Japan	C24	Basic metals	0,52	6,88	10,31	34,28	10,83	41,16
	C10T12	Food products, beverages and tobacco	6,21	2,39	15,23	54,45	21,44	56,84
	C16	Wood and products of wood and cork	5,28	1,13	17,32	9,9	22,59	11,03
	A01_02	Agriculture, hunting, forestry	2,33	1,01	38,39	22,06	40,72	23,07
	C27	Electrical equipment	0,16	0,82	1,92	36,99	2,07	37,81
	Others	Others	0,7	0,71	581,21	654,41	581,91	655,12
Rep. of Korea	C24	Basic metals	5,64	8,25	19,07	35,41	24,71	43,66
	C10T12	Food products, beverages and tobacco	6,29	2,34	12,08	28,67	18,38	31,01
	Others	Others	2,58	0,93	480,45	558,77	483,02	559,69
	C16	Wood and products of wood and cork	4,04	0,68	4,39	2,36	8,43	3,04
	C27	Electrical equipment	0,51	0,53	1,33	32,37	1,83	32,9
	A01_02	Agriculture, hunting, forestry	1,15	0,43	22,79	11,79	23,94	12,22
Turkey	C24	Basic metals	20,12	9,53	22,66	59,27	42,79	68,8
	C10T12	Food products, beverages and tobacco	5,3	2,17	6,48	10,41	11,78	12,57
	C17_18	Paper products and printing	2,15	1,04	3,6	4,33	5,76	5,37
	C20	Chemical and chemical products	1,28	0,36	26,9	41,93	28,17	42,29
	C13T15	Textiles, textile products, leather and footwear	0,16	0,15	1,32	10,31	1,48	10,46
	Others	Others	0,14	0,09	119,91	223,22	120,06	223,31
United Kingdom	C24	Basic metals	0,44	3,71	6,74	72,29	7,18	75,99
	C10T12	Food products, beverages and tobacco	4,37	2,2	22,2	58,19	26,58	60,39
	C16	Wood and products of wood and cork	7,04	1,63	6,35	7,43	13,39	9,06
	C17_18	Paper products and printing	1,39	1,17	5,19	10,87	6,58	12,05
	Others	Others	1,12	0,6	209,21	584,25	210,33	584,85
	C21	Pharmaceuticals, medicinal chemical and botanical products	0	0,48	0,37	30,77	0,37	31,25
United States of America	C24	Basic metals	5,88	8,72	45,16	129,43	51,04	138,15
	C10T12	Food products, beverages and tobacco	4,71	2,58	53,75	162,24	58,46	164,82
	C17_18	Paper products and printing	2,34	1,73	16,91	30,9	19,24	32,63
	C20	Chemical and chemical products	1,64	1,09	69,22	166,6	70,86	167,69
	Others	Others	3,04	1,06	807,49	2572,29	810,53	2573,36
	C21	Pharmaceuticals, medicinal chemical and botanical products	0,01	1	1,34	192,41	1,34	193,41

Source: Own elaboration

ilo.org

International Labour Organization
Route des Morillons 4
1211 Geneva 22
Switzerland