INTERNATIONAL COFFEE ORGANIZATION

COFFEE DEVELOPMENT REPORT 2022-23

BEYOND COFFEE

Towards a Circular Coffee Economy

A flagship publication of the International Coffee Organization

INTERNATIONAL COFFEE ORGANIZATION

COFFEE DEVELOPMENT REPORT 2022-23

BEYOND COFFEE

Towards a Circular Coffee Economy

A flagship publication of the International Coffee Organization

This fourth edition of the ICO Coffee Development Report was drafted thanks to an extensive and unique participatory process that engaged many partners, consultants, experts and practitioners from academia, international organizations and private sector entities, coordinated through the International Trade Centre (ITC) Coffee Guide Network and its Circular Economy Working Group. It was produced in partnership with ITC and its Alliances for Action (A4A) programme, the Politecnico di Torino (PoliTO), the Lavazza Foundation and the Center for Circular Economy in Coffee (C4CEC).

International Trade Centre

Politecnico di Torino

CENTER FOR CIRCULAR ECONOMY IN COFFEE

LAVAZZA FOUNDATION

THE INTERNATIONAL COFFEE ORGANIZATION

Mission

The International Coffee Organization's (ICO) mission is to strengthen the global coffee sector and promote its sustainable expansion in a market-based environment for the betterment of all participants in the coffee sector.

Scope of Work

The ICO, established in 1963, operates under an international treaty, the International Coffee Agreement (ICA 2007). It is the only intergovernmental organization for coffee, bringing together the governments of exporting/producing and importing/consuming countries to tackle the challenges facing the global coffee sector through international cooperation.

It provides a unique forum for dialogue and cooperation among governments, the private sector, development partners, civil society and all coffee farmers and stakeholders to tackle the challenges and nurture the opportunities of the global coffee sector.

The ICO collects and compiles independent official statistics on coffee production, trade and consumption, supports the development and funding of technical cooperation projects and public-private partnerships, and also promotes sustainability and coffee consumption. It facilitates the contribution of coffee to achieving the Sustainable Development Goals (SDGs) by increasing the resilience of local communities and coffee farmers, in particular smallholders, enabling them to benefit from coffee production and trade, which can help eradicate poverty and achieve a living income for coffee-producing families. ICO Members include 75 countries representing 94% of global coffee production and 64% of world consumption.

CONTENTS

LIST OF FIGURES

LIST OF BOXES

LIST OF TABLES

ACKNOWLEDGEMENTS

The Coffee Development Report (CDR) 2022-23 was prepared by an extended team led by Vanúsia Nogueira, Executive Director of the International Coffee Organization (ICO) and guided by Gerardo Patacconi, Head of Operations, who overviewed and contributed to all stages of the report. Ariana Ocampo Cruz, Junior Economist, played an instrumental role in consolidating and reviewing its content.

The International Trade Centre (ITC), through its Alliances for Action (A4A) programme, co-led the production of this report and facilitated contributions from the ITC Coffee Guide Network Circular Economy Working Group, a global group of 62 individuals from 36 countries representing 44 coffee stakeholder organizations – including MSMEs and institutions from coffee growing countries (see ANNEX A1 list of members).

Alessandro Campanella (Researcher and Assistant Lecturer, Sys - Systemic Design Lab, Politecnico di Torino), Dario Toso (Product Sustainability and Circular Economy Manager, Lavazza, and Co-Coordinator, C4CEC), and Katherine Oglietti (Coffee Guide Network Coordinator, ITC, and Co-Coordinator, C4CEC) led the research and content creation for the report through a participatory and collaborative process. Sarah Charles (Communications Consultant, ITC) was the chief editor of the report, and oversaw its strategic design and production. Hernan Manson (Head Inclusive Agribusiness Systems) designed and oversaw the strategy and methodology behind the co-creation and evidence-based partnership process and Giulia Macola (Alliances for Action Programme Advisor) oversaw ITC contributions for the report. Camila Gadotti (Graphic Designer, ITC) created all original graphics and layout.

The ICO extends its sincere thanks and deepest appreciation to these contributors. Their outstanding commitment, dedication, and expertise were essential to the realization of this document.

This report builds on the ITC paper "Making a Case for a Circular Economy in the Coffee Sector: Insights from the multi-stakeholders working group on circular economy in coffee" (ITC, 2024), offering deeper technical and policy analyses of circular economy in the context of the coffee market.

Policy recommendations were led by Arthur Kay, Honorary Associate Professor and Entrepreneur in Residence at UCL's Institute for Global Prosperity, whose work was supported by Dr Rebecca Clube, Dr Berill Takacs of UCL, Independent Researcher Jasmine Kaur, and Prof Raimund Bleischwitz of the Leibniz Centre, as well as the ICO, ITC, and its Circular Economy Working Group Members.

The ICO also acknowledges the valuable contributions from Dock No, Statistical Coordinator, and Alexander Rocos, Statistics Associate, who prepared Part III Section D and contributed to the scientific work on defining coffee-specific biomass and waste parameters. Additionally, appreciation goes to Veronica Ottelli, ICO Secretariat and External Relations Officer, Adriel Tiongson, who provided support with editing the report, and to Chris Eccleston (The Clockwork Creative), who partially contributed to the graphical design of the report.

We extend our gratitude to everyone who contributed to this report, including those whose names may not appear here, as well as the families and friends who supported us in this endeavour.

The ICO team was highly motivated to work on this CDR, hoping it will empower all coffee stakeholders and the development community to seize opportunities for achieving sustainability and resilience in the coffee sector through circular and regenerative solutions. These solutions could drive substantial sector upgrades and resilience by combating climate threats, safeguarding natural resources and the environment, transforming waste into new products, implementing cost-effective circular and regenerative agricultural practices, reducing inputs, transaction costs, and environmental footprints, improving energy efficiency, and even producing alternative energy. Ultimately, by making the coffee economy circular, the sector can create new jobs, generate income opportunities, and reduce living income gaps.

We believe that everyone involved in the coffee supply chain, from farmers to consumers, has both an opportunity and a moral obligation to move towards circular, regenerative, and restorative coffee production, processing, consumption, and disposal. We sincerely hope that all participants in the coffee global value chain (C-GVC) will be inspired by this report and work alongside business, technical, and development partners to drive the transition from a linear to a circular coffee economy.

All coffee stakeholders can now benefit from the recently established Center for Circular Economy in Coffee (C4CEC), a unique pre-competitive platform designed to put circular economy into practice. The Center facilitates the piloting of innovations, advances research, and serves as a hub for collecting and sharing best practices, solutions, case studies, and practical information on applying circular economy concepts throughout the coffee value chain – from farming to consumption and disposal. We encourage all coffee stakeholders to join this platform and work towards a resilient, inclusive, and sustainable coffee sector.

PARTNERS

The main partners of this report include the International Coffee Organization (ICO), the International Trade Centre (ITC), the Center for Circular Economy in Coffee (C4CEC), Fondazione Giuseppe e Pericle Lavazza Onlus, and Politecnico di Torino. The report benefits from the contributions and insights of global coffee sector stakeholders through the ITC Coffee Guide Network Circular Economy Working Group.

International Trade Centre

The International Trade Centre (ITC) is the joint agency of the World Trade Organization and the United Nations. ITC is the only development agency fully dedicated to supporting the internationalization of micro, small and medium-sized enterprises (MSMEs). Its Alliances for Action programme leverages partnerships for sustainable food systems by cultivating ethical, climate-smart, and sustainable agricultural value chains aimed at achieving resilience and growth for farmers and MSMEs. The Circular Economy Working Group, coordinated by ITC as part of the Coffee Guide Network, is a global, multi-stakeholder group formed through a unique collaborative effort to pool knowledge and experience for the fourth edition of ITC's Coffee Guide, widely regarded as the industry reference for coffee knowledge. The Coffee Guide is freely available in English, French, Spanish, Portuguese, and, most recently, Amharic.

Politecnico di Torino

Founded in 1906, **Politecnico di Torino** is internationally recognized as one of Europe's leading universities for engineering and architecture studies. The university is a centre of excellence for education and research in engineering, architecture, design, and planning, working closely with the socio-economic system. As a comprehensive research university, Politecnico integrates education and research to create synergies that address the needs of the economy, the local community, and its students. Sys - Systemic Design Lab, part of Politecnico di Torino's Department of Architecture and Design, develops methods and tools of Systemic Design aimed at environmental, social, and economic sustainability. By collaborating with public and private stakeholders both locally and internationally, the lab applies the systemic approach in three main areas: sustainable products, industrial innovation, and territorial enhancement.

Lavazza Foundation

Established in 2004, the **Fondazione Giuseppe e Pericle Lavazza Onlus** promotes and implements economic, social, and environmental sustainability projects for coffee-producing communities worldwide. The foundation supports the autonomy of local communities by emphasizing the value of female workers, involving younger generations, encouraging good agricultural practices to improve crop yields and coffee quality, and promoting the use of technological tools to counter the effects of climate change. Since its inception, the non-profit has organized more than 50 projects across more than 20 countries and three continents in partnership with more than 60 public and private partners.

CENTER FOR CIRCULAR ECONOMY IN COFFEE

The Center for Circular Economy in Coffee (C4CEC) is a pre-competitive initiative established to accelerate the transition from linear to circular practices in the coffee sector. Established in Turin, Italy, as a non-profit organization, the Center was officially launched in September 2023 during the ICO 5th World Coffee Conference in Bangalore, India, and is supported by a global network of members. The Center serves as a platform to put circular economy into practice by piloting innovations, advancing research, and sharing best practices. Its web platform offers case studies, research, and practical information on applying circular economy principles across the coffee value chain, from farming to consumption and disposal.

ABBREVIATIONS

ACEF	Africa Circular Economy Facility
ACRAM	Robusta Coffee Agency of Africa and Madagascar
AFCA	African Fine Coffees Association
APR	Association of Plastic Recyclers
C4CEC	Center for Circular Economy in Coffee
CDR	Coffee Development Report
CFCG	Cradle-to-Grave Carbon Footprint
CGLF	CEOs and Global Leaders Forum
CIAT	International Centre for Tropical Agriculture
CIC	Coffee Industry Corporation
CICC	Interprofessional Cocoa and Coffee Council
C-GVC	Coffee Global Value Chain
CLAC	The Latin American and Caribbean Network of Fair Trade Small Producers and Workers
CNC	Conselho Nacional do Café
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
COSA	Committee on Sustainability Assessment
CPC	Coffee-Producing Country
CPPTF	Coffee Public-Private Task Force
CSA	Climate Smart Agriculture
D4ACE	Designing for a Circular Economy
ECF	European Coffee Federation
EU	European Union
EMF	Ellen MacArthur Foundation
FAO	Food and Agriculture Organization
GHG	Greenhouse Gas
HDPE	High-Density Polyethylene
ICC	International Coffee Council
ICD	International Coffee Day
I-CIP	ICO Composite Indicator Price
ICO	International Coffee Organization
IDH	The Sustainable Trade Initiative
IMF	International Monetary Fund
ITC	International Trade Centre
IWCA	International Women's Coffee Alliance
LCA	Life Cycle Assessment
LI	Living Income
LIFFE	London International Financial Futures and Options Exchange
LPI	Living and Prosperous Income
MSME	Micro, Small and Medium-Sized Enterprises
NGO	Non-Governmental Organization
NYBOT	New York Board of Trade
OECD	Organisation for Economic Cooperation and Development
OP2B	One Planet Business for Biodiversity
PVC	Polyvinyl Chloride
SCA	Specialty Coffee Association
SCTA	Swiss Coffee Trade Association
SSU	Single-Serve Unit
UCL	University College London
UN	United Nations
UN SDGs	United Nations Sustainable Development Goals
UNIDO	United Nations Industrial Development Organization
US EPA	United States Environmental Protection Agency
VOCs	Volatile Organic Compounds
WPC	Wood Plastic Composite

FOREWORD

A transformative shift is brewing in the coffee sector – one that embraces the principles of the circular economy in a way that works for all and leaves no one behind.

This concept has been at the forefront of the International Coffee Organization's (ICO) efforts throughout 2022-23, culminating in the celebration of International Coffee Day on 1 October 2022. This global event was a call to action for all stakeholders to reimagine coffee sector waste as a valuable resource. By repurposing waste into new products and alternative energy sources, we can unlock significant income possibilities and job opportunities while simultaneously lowering production costs.

The 5th World Coffee Conference, held in Bangalore, India, in September 2023 further amplified this message with its theme: "Sustainability through Circular Economy and Regenerative Agriculture." This gathering brought together hundreds of experts and practitioners from diverse sectors – coffee farmers, industry leaders, government representatives, academics, and development partners – for a collaborative exploration of innovative solutions.

Pivotal contributions from the International Trade Centre (ITC), the ITC Coffee Guide Network's Circular Economy Working Group, and the Center for Circular Economy in Coffee (C4CEC) have laid the groundwork for the 4th edition of the Coffee Development Report (CDR), titled "Beyond Coffee: Towards a Circular Coffee Economy." This report builds on the insights from the ITC paper, "Making a Case for a Circular Economy in the Coffee Sector" (2024), and The Coffee Guide, 4th Edition (2021). I am proud to present this report, the culmination of over two years of dedicated research and collaboration.

Remarkably, the coffee industry generates over 40 million tonnes of biomass annually. This is an underutilized resource brimming with potential for sustainable exploitation and waste reduction. We aim to challenge the outdated perception that coffee producers gain value solely from the coffee bean itself. The true wealth of coffee lies beyond the three billion cups consumed daily; by enhancing resource efficiency through a circular economy approach, we can cultivate new products, create jobs, combat climate change, and protect our environment.

Our shared responsibility for the planet transcends borders, extending from global leaders to local communities. I firmly believe that everyone in the coffee sector – coffee farmers, workers, industry stakeholders, and consumers – can play a crucial role in driving the shift towards a more sustainable and resilient industry. By embracing circular economy principles and implementing cost-effective, regenerative solutions, we can align coffee production with Climate Smart Agriculture (CSA) strategies, fostering meaningful change. The traditional linear model – characterized by inputs, transformation, outputs, consumption, and disposal – is becoming increasingly outdated and costly. Real progress in the coffee sector necessitates sustainable solutions that span the entire value chain.

The CDR 2022-23 introduces several impactful circular solutions in the coffee sector, proving that they are both accessible and economically viable. With the right policies and commitment from all stakeholders, these solutions can be scaled up, promoting sustainability, resilience, and prosperity for coffee farmers and everyone involved in the coffee journey, from production to consumption. This report aspires to demonstrate that the future of the coffee industry is not just a distant vision; it is within our grasp. By rethinking our supply chains in circular terms and fostering collaboration among the ICO and our partners, we can implement systemic and technological innovations across the entire value chain – not merely in isolated farms or cafes, but throughout the whole industry.

This report is designed to provide in-depth knowledge on the potential of circular economy in the coffee sector and to ignite action among coffee stakeholders, policymakers, international development agencies, NGOs, and bilateral and multilateral institutions. By leveraging circularity to address the challenges facing our sector, we can collectively shape the coffee industry we envision and lay a foundation for future generations to thrive. Transitioning to a circular coffee economy and adopting regenerative agricultural practices is not merely an innovative strategy; it is essential for increasing income while minimizing environmental impact, complementing traditional methods aimed at enhancing productivity.

I want to express my heartfelt gratitude to the ICO team and our external collaborators who have poured their efforts into this report over the past two years. Special thanks to Hernan Manson from ITC, Mario Cerutti of Lavazza and its Foundation, and Gerardo Patacconi from the ICO, whose leadership, technical knowledge and mobilization of partnerships and resources have been instrumental in bringing this vision to life. Together, let us cultivate a sustainable future for coffee.

Vanúsia Nogueira
Executive Director
The International Coffee Organization

PART I
OVERVIEW

0.1 Objectives and structure of the report

This fourth edition of the Coffee Development Report (CDR), the flagship publication of the International Coffee Organization (ICO), explores the untapped potential of coffee cherries and beans beyond traditional brewing.

By transforming the substantial biomass and waste generated throughout the coffee value chain – from production to consumption – this report demonstrates how new products, energy, jobs, and income can be created. This approach not only addresses climate change but also enhances the sustainability and resilience of the entire coffee sector.

The report was developed through a participatory process co-led by the ICO and the International Trade Centre (ITC), integrating insights from a diverse group of global coffee sector experts and practitioners. It draws on existing research, case studies, and expert presentations from international conferences. The report includes findings from the C4CEC Working Group, a multi-stakeholder group representing 44 coffee organizations across 36 countries, including MSMEs, coffee farmers, value chain operators and institutions from coffee-producing regions, the ICO, Politecnico di Torino, Lavazza Foundation, and the Center for Circular Economy in Coffee (C4CEC). This collaboration has resulted in a new definition of the circular economy for the coffee sector.

This report offers a unique analysis of circular and regenerative opportunities within the Coffee Global Value Chain (C-GVC), including unprecedented global data estimates on coffee by-products.

Contributions from the C4CEC, Politecnico di Torino, Lavazza Foundation, the Circular Economy Working Group, ICO, ITC and other key partners from University College London (UCL) were crucial in identifying sector-wide challenges and formulating actionable policy recommendations. These recommendations provide a clear path for governments, industry stakeholders, development partners, and consumers to transition the coffee sector from a linear to a circular economy, fostering a more sustainable and thriving future.

Report structure:

- **Part I:** Provides a comprehensive overview of the report, highlighting the main findings, opportunities, challenges, and policy recommendations for advancing a circular economy in the coffee sector.
- **Part II Section A:** Establishes the foundation for a circular economy and regenerative agriculture within the C-GVC. It explores the broader concept of circular economy, its application in agribusiness, and introduces a new definition tailored to the coffee sector, serving as a mission statement for transforming the sector.
- **Part II Section B:** Reviews the waste and biomass generated throughout the C-GVC, offering unprecedented data estimates and examining the current environmental and social impacts. It includes technical insights into the composition of coffee by-products and showcases case studies of circular and regenerative practices that add value to these materials.
- **Part II Section C:** Outlines the key challenges in implementing circular economy practices in the coffee sector. This section provides a comprehensive set of policy recommendations with specific actions for various stakeholders to support and accelerate the transition towards a circular economy, addressing sustainability challenges, creating new income and job opportunities, improving soil and plant health, and combating climate change.
- **Part III Section D:** Presents ICO statistics for the 2022-23 coffee year, analysing key market trends, market fundamentals, and their impact on the sector.

This report aims to engage readers in understanding the transformative potential of circular economy principles in the coffee sector and to inspire actionable change for a sustainable future.

0.2 Main findings

This report identifies key insights and actionable strategies for integrating circular economy principles into the coffee sector. The following sections delve into the implications of a circular economy for the coffee industry, build a case for transforming the Coffee Global Value Chain, and explore opportunities to enhance sustainability and circularity in both cultivation, post-harvest processing, transportation, and consumption. These findings provide a roadmap for fostering a more resilient and sustainable coffee sector.

0.2.1 A circular economy can help address urgent and systemic issues in the coffee sector

As climate challenges intensify, the sustainability of coffee production faces significant threats. Coffee, particularly the Arabica variety, thrives in cool tropical climates at high elevations, but these conditions are increasingly at risk due to environmental changes.

To address these challenges, coffee cultivation must undergo a significant transformation.

Moving production to higher altitudes encroaches on forested ecosystems, exacerbating environmental damage and becoming unsustainable under new regulatory frameworks. The sector requires investments in regenerative practices, climate-resistant varieties, and farm redesigns to enable efficient irrigation and mechanization.

The 2023 United Nations Climate Change Conference (COP28) emphasized the need to cut global greenhouse gas (GHG) emissions by 43% by 2030 to limit warming to 1.5°C (relative to 2019). The coffee sector, also with its impacts on emissions, biodiversity, water use, and eutrophication, must align with these goals.

Economically, coffee is a globally consumed beverage and a critical commodity, providing jobs and income in over 50 coffee-producing countries as well as in the entire value chain. However, smallholder farmers are those most affected by growing risks from climate change, resource competition, declining soil fertility, and economic pressures. Price volatility and an unbalanced value distribution further challenge their ability to achieve a living and prosperous income (LPI).

To navigate these environmental and economic challenges, the coffee sector must adopt transformative strategies that improve farmer livelihoods and promote sustainability. The circular economy, focused on reducing waste, enhancing resource efficiency, and regenerating natural systems, offers a promising path forward.

From linear to circular

Traditional linear economic models – based on a "take, make, waste" approach – are unsustainable, leading to resource depletion and environmental degradation. The circular economy, rooted in concepts like biomimicry, industrial ecology, and cradle-to-cradle design, offers an alternative. It creates a closed-loop system where waste is minimized, and the value of products and materials is retained within the economy for as long as possible. This model is increasingly applied across sectors, including agribusiness, to promote sustainability and resource efficiency.

The Circularity Gap Report 2024 reveals that only 7.2% of the global economy is circular, showing a decline in the reuse and recycling of materials. The report identifies the global food system as a major contributor to greenhouse gas emissions, land use, freshwater withdrawal, and phosphorus emissions. For biomass to be renewable and sustainable, carbon, nitrogen, and phosphorus must be reintegrated into the soil, consistent with circular economy principles (Circle Economy, 2024).

In the coffee sector, the waste generated at every stage of the value chain can be re-purposed into valuable resources. By adopting circular economy principles, the industry can reduce its environmental impact, unlock new economic opportunities, and foster job creation – especially in vulnerable coffee farming communities, youth, and small processors.

Countries around the world are embracing circular economy policies. The **European Union**, through its Circular Economy Action Plan, integrates circular practices into its 2050 climate neutrality goals. **Brazil**, leading the G20 in 2024, has prioritized circular economy in its presidency, and has launched a national strategy to transition to circular and sustainable practices. **India** is also setting ambitious circularity targets, focusing on renewable energy and rural empowerment. **Africa'**s efforts are bolstered by the Africa Circular Economy Facility (ACEF), aiding countries (Ethiopia, Cameroon, Chad, Ghana and Uganda) in developing circular roadmaps. **Indonesia** is advancing a National Circular Economy Roadmap.

> "By 2025, circular business models could generate about USD 1 trillion per year in materials cost savings."
>
> World Economic Forum and Ellen MacArthur Foundation (2014).

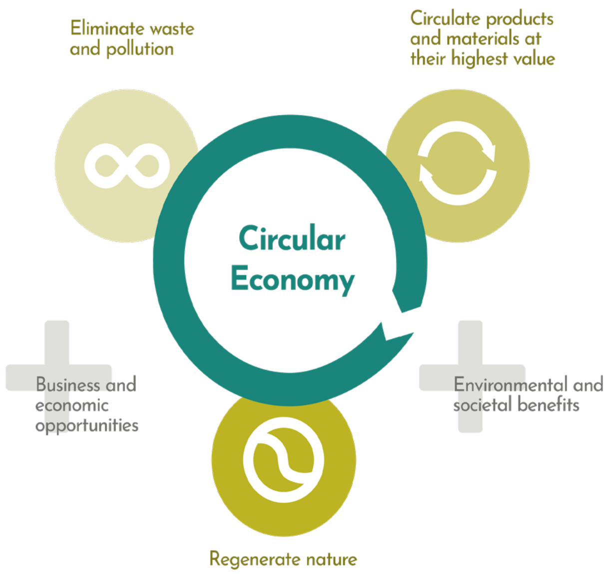
> "A circular economy model for the coffee sector designs, balances, and implements regenerative practices, resource efficiency, and waste reduction while giving value to process outputs, achieving environmental, social and economic sustainability. Driven by a systemic and holistic approach, it draws inspiration from the dynamics of natural systems to regenerate, maintain, and create shared value for all stakeholders, across different contexts and within the entire coffee value circle."
>
> ITC Coffee Guide Network, Circular Economy Working Group (2024).

At the **G7 Summit in 2024**, under Italy's presidency, a **multi-stakeholder programme for the circularity and sustainability of global coffee value chains** was launched including the decision to explore the establishment of a global public-private fund to enhance sustainability and fighting climate change.

Definition of circular economy in the coffee sector

This report adopts the definition of a circular economy for coffee developed by the Circular Economy Working Group within the ITC Coffee Guide Network, in collaboration with the ICO. It emphasizes a holistic and systemic approach to transforming the coffee sector – not just reducing negative impacts but actively regenerating and creating new value. This approach can empower communities, enhance cultural practices, and turn by-products into valuable resources, extending the life cycle of products and ensuring they stay in circulation rather than becoming waste.

FIGURE 0.1
Principles for circular economy in coffee

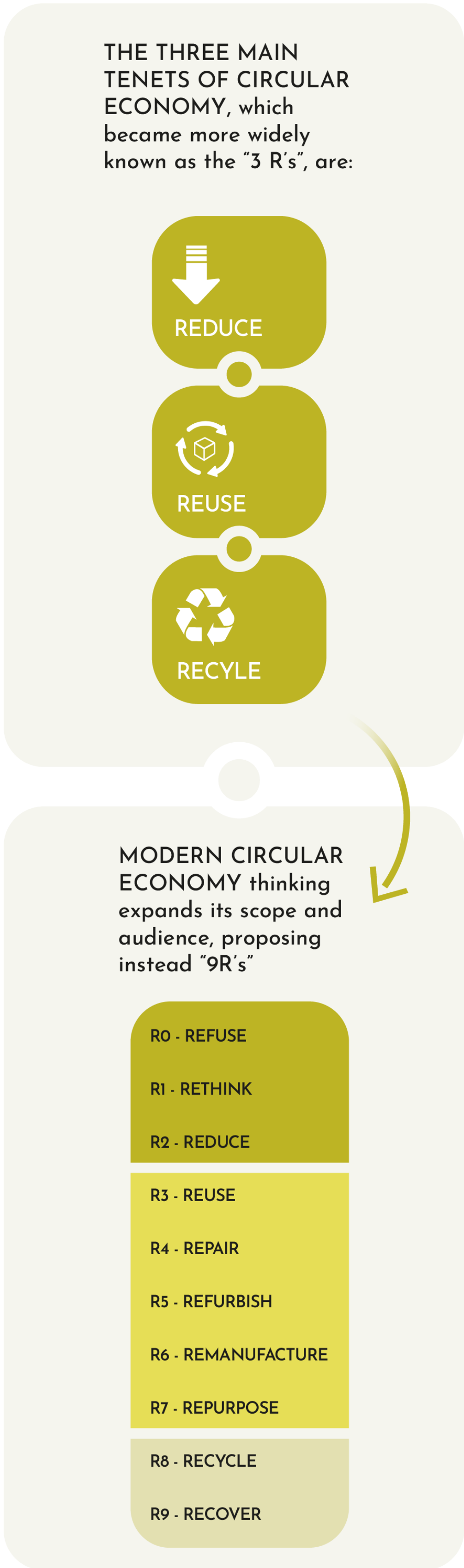


Source: ITC, *Making a Case for Circular Economy in Coffee: Insights from the multi-stakeholders working group on circular economy in coffee (2024).*
Note: Adapted from Ellen MacArthur Foundation.

Principles for circular economy in coffee

Modern circular economy thinking expands the traditional 3 R's – Reduce, Reuse, Recycle – into 9 R's.

FIGURE 0.2
From the "3R's" to the "9R's"



Note: Adapted from Kirchherr et al (2017).

BOX O.1

What is regenerative agriculture?

Regeneration is the process that allows cells, tissues, or organisms to recover from damage, essential for ecosystem conservation (National Institute of General Medical Sciences, 2024). Sustainability relies on nature's ability to regenerate (Illy and Vineis, 2024), especially in the face of climate change, which demands more resilient agricultural systems.

Regenerative agriculture is a systemic land-use approach aiming to regenerate and strengthen natural, social, and economic systems rather than merely reducing or minimizing damages. It provides a framework for practices that align with natural processes to create sustainable and resilient agricultural systems. By improving soil fertility through organic matter, it reduces the need for chemical fertilizers and decreases farmers' reliance on volatile markets.

According to One Planet Business for Biodiversity (OP2B), regenerative agriculture enhances soil health, biodiversity, climate, water resources, and farming livelihoods. It promotes carbon sequestration, reduces greenhouse gas emissions, and boosts farming efficiency.

"Regenerative agriculture is a holistic, outcome-based farming approach that generates agricultural products while measurably having net-positive impacts on soil health, biodiversity, climate, water resources and farming livelihoods at the farm and landscape levels. It aims to simultaneously promote above and belowground carbon sequestration, reduce greenhouse gas (GHG) emissions, protect and enhance biodiversity in and around farms, improve water retention in soil, reduce pesticide risk, improve nutrient-use efficiency and improve farming livelihoods"

- One Planet Business for Biodiversity (OP2B) working definition of regenerative agriculture.

In coffee production, regenerative agriculture draws on consolidated knowledge of organic farming, permaculture, climate-smart agriculture, holistic farm management, agroecology, and traditional indigenous farming practices. These methods can improve coffee quality, increase productivity, and strengthen farmers' livelihoods.

A key aspect of regenerative agriculture is diversification, such as increasing biodiversity with cover crops and integrating livestock farming for manure and additional income. This approach aligns with the circular economy by promoting sustainable production while enhancing natural resources.

Regenerative practices go beyond reducing negative impacts – they actively restore ecosystems, communities, and the broader coffee system. For example, in Brazil, the coffee leaf miner pest, which causes significant crop losses, can be managed through resistant cultivars, biological control, and cover crops (Dantas et al., 2021).

The goals of regenerative agriculture in coffee are to protect and restore soil fertility, optimize nutrient management, and improve land productivity, all while sustaining ecosystem services and consolidating farmers' livelihoods. These practices can ensure sustainable coffee production for future generations, meeting demand, providing stable incomes, and mitigating climate change impacts.

Note: Co-written by the Regenerative Society Foundation (RSF) and the Circular Economy Working Group (2024).

A circular transformation in the C-GVC could greatly benefit emerging coffee-producing economies. By adopting circular economy principles, the sector can drive innovation, reduce its environmental footprint, improve resource efficiency, and create new income and job opportunities, particularly for vulnerable coffee farming communities.

Coffee sector stakeholders can work together to overcome challenges like limited access to funding, technical innovation, and infrastructure in these economies. With the right support, smallholder farmers, who are especially vulnerable to environmental changes, can lead and benefit from a circular and regenerative transformation, helping to restore environmental balance.

Successfully implementing a circular economy requires commitment from all stakeholders across the value chain. This shift redefines value creation from scarcity to abundance, fostering a more equitable and sustainable coffee industry. Viewing by-products as valuable resources rather than waste can lead to new, innovative products, diversify offerings, and rebalance value chain dynamics.

O.2.2 We must shift from a coffee global value chain to a coffee global circle

Coffee is one of the most widely consumed beverages globally and a key internationally traded commodity. Its complex value chain involves production, processing, trade, roasting, distribution, and consumption, with distinct stakeholders at each step. Coffee is primarily grown in tropical and subtropical highlands across more than 50 countries, covering around 11 million hectares.

The coffee industry is a significant source of employment and income in both producing and consuming countries. Most coffee is exported as green beans, which are roasted, packed, and sold in consuming nations through various channels, including supermarkets, coffee shops, and online platforms.

However, the social impact of the coffee industry, particularly in terms of value distribution, is profound. Many smallholder farmers and workers face challenging living conditions and income instability. Addressing these social issues is as crucial as mitigating the environmental impacts.

Historically integrated into diverse ecosystems, coffee farming has shifted towards intensive practices due to rising demand. This has led to environmental degradation – soil erosion, loss of fertility and biodiversity, and increased greenhouse gas emissions – making ecosystems more vulnerable to pests, diseases, and climate change. Thus, "greening" the coffee value chain is essential to improving its efficiency, resilience, and sustainability.

The coffee production process generates significant biomass at every stage, from harvest to final consumption. This biomass, instead of becoming environmental waste, can be reduced, reused, or upcycled into valuable products through circular and regenerative agricultural practices. The entire coffee plant, including the cherry's skin, pulp, mucilage, husk, silverskin, and spent grounds, contains unique compounds suitable for various industrial applications.

Innovative entrepreneurs and researchers are finding ways to repurpose these by-products, creating new products and materials that support local economies and generate new income streams. For instance, coffee husks and pulp can be used as organic fertilizers, compost, biochar, or as inputs for bioplastics and biofuels. Spent coffee grounds are being upcycled into cosmetics, dietary supplements, and building materials, contributing to a circular economy that minimizes waste and adds value at every stage.

Integrating regenerative agriculture, agroforestry, and other sustainable practices can further enhance biodiversity, improve soil health, reduce the need for agrochemicals, and lower the carbon footprint of coffee farming, while supporting the quality and resilience of coffee trees.

Did you know that every part of the coffee plant – from the cherry's skin to spent grounds – holds compounds for industrial innovation?

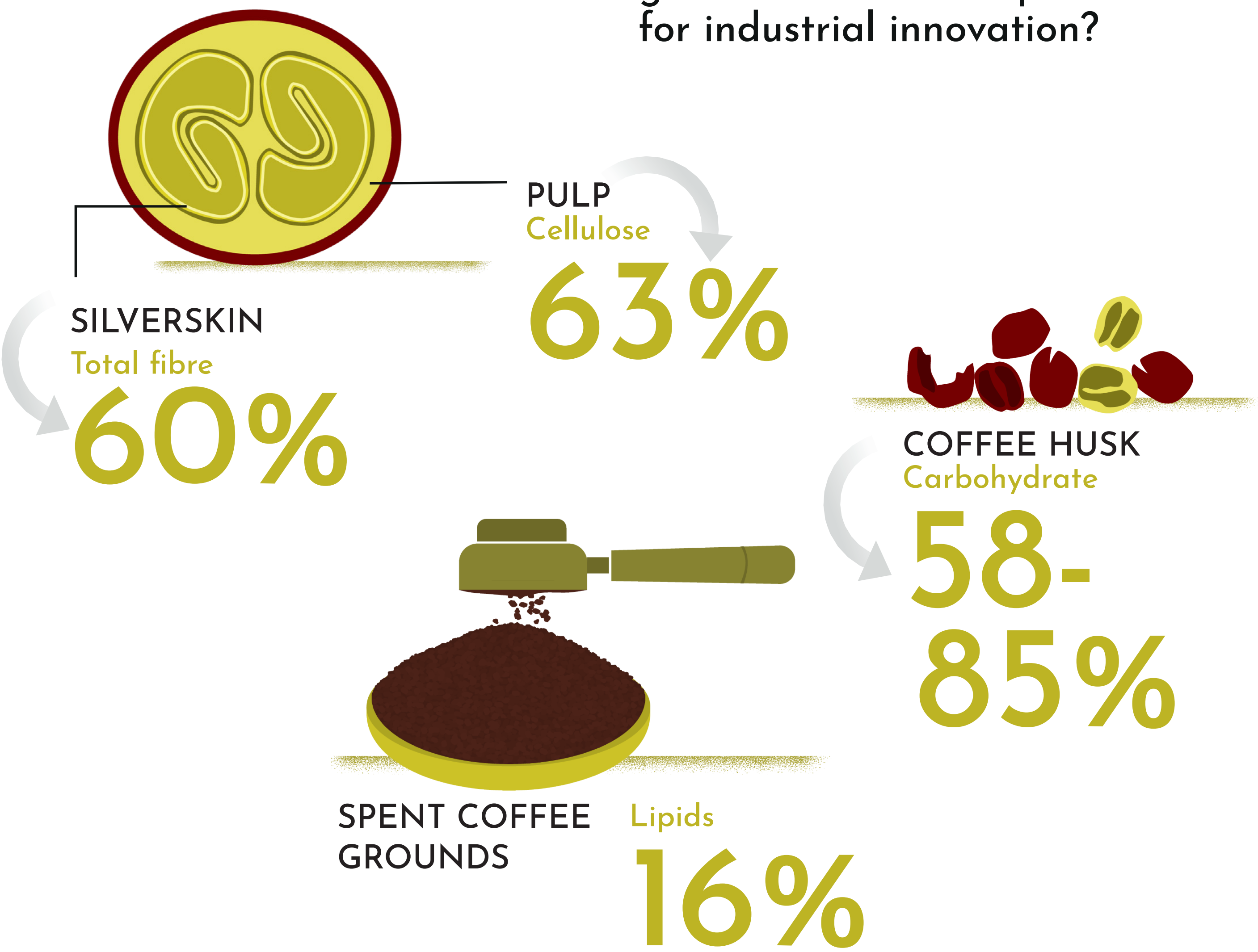


FIGURE 0.3
Coffee by-products and their chemical compounds

CHEMICAL COMPOUNDS OF BY-PRODUCTS	HUSK	PULP	SILVERSKIN	SPENT COFFEE GROUNDS
ASH	5.4% - 6.2%	7.3%	7.34% - 10.5%	0.47%
CAFFEINE	1%	1.5%	0.6% - 1.1%	0.02%
CARBOHYDRATE	58% - 85%	21% - 32%	0.2% - 6.3%	
CELLULOSE	43%	63%	17.8%	8.6%
CHLOROGENIC ACID	2.5%	2.4%	3%	2.3%
FAT	0.5%	2% - 7%	2.2%	2.3%
HEMICELLULOSE	7%	2.3%	13.1%	36.7%
LIGNIN	9%	14.3% - 17.5%	1%	0.05%
LIPIDS	0.5% - 3%	2%-7%	3%	16%
MINERALS	3% - 7%	9%	8%	0.8%-3.5%
MOISTURE	13% - 15%	82.4%	5% - 7%	74.7%
PROTEIN	8% - 11%	5%-15%	20%	10.3%
TANNINS	5%	3%	0.02%	0.02%
TOTAL FIBRE	24% - 30.8%	60.5%	60%	43%
TOTAL PECTIC SUBSTANCES	1.6%	6.5%	0.02%	0.01%

Source: C4CEC (2024).
Note: Based on data from Mendes dos Santos, É., Malvezzi de Macedo, L., Lacalendola Tundisi, L., Ataide, J. A., Camargo, G. A., Alves, R. C., Oliveira, M. B. P. P., & Mazzola, P. G. (2021). Coffee by-products in topical formulations: A review. Trends in Food Science & Technology, 111, 280-291. https://doi.org/10.1016/j.tifs.2021.02.064

Inspired by ecosystems, where waste does not exist, adopting a circular and regenerative mindset can address major constraints in the global coffee sector.

TABLE 0.1
Opportunities for the coffee sector

CONSTRAINTS

ENVIRONMENTAL DEGRADATION
Climate change, deforestation, and soil degradation are major challenges that threaten the sustainability of coffee production. The move to higher altitudes for coffee cultivation is encroaching on forested ecosystems, further exacerbating environmental damage. These are no longer feasible under the emerging new regulatory framework.

ECONOMIC INEQUITIES
Small coffee farmers, who are the majority in the sector, often struggle with price fluctuations, low incomes, increasing inputs and transaction costs, and inequitable distribution of value along the supply chain. This economic vulnerability is compounded by the lack of negotiating power these farmers have over market prices.

SUSTAINABILITY PRESSURES
Coffee producers face growing demands from consumers, buyers, and regulators to enhance sustainability, improve productivity, and maintain high-quality standards. Meeting these demands requires significant investment and adaptation, which can be challenging for small-scale farmers and for the entire C-GCV.

RESOURCE MANAGEMENT
The coffee sector generates significant waste at every stage of the value chain, contributing to pollution and resource depletion. Efficiently managing and reducing this waste is a key challenge for implementing circular economy principles.

OPPORTUNITIES

CIRCULAR SOLUTIONS TO HELP CLOSE THE LIVING INCOME GAP
Most coffee family farmers cannot reach a living income, i.e. selling their produce cannot cover input and labour costs and access to basic services such as health, housing, and education. While intercropping is among the solutions to diversify income, circular and regenerative solutions can increase income and reduce input costs, thereby reducing the living income gap.

RESOURCE EFFICIENCY AND WASTE REDUCTION
By adopting circular economy principles, the coffee sector can improve resource efficiency and reduce waste. This includes optimizing every stage of the coffee life cycle, from cultivation to consumption, and finding new uses for by-products.

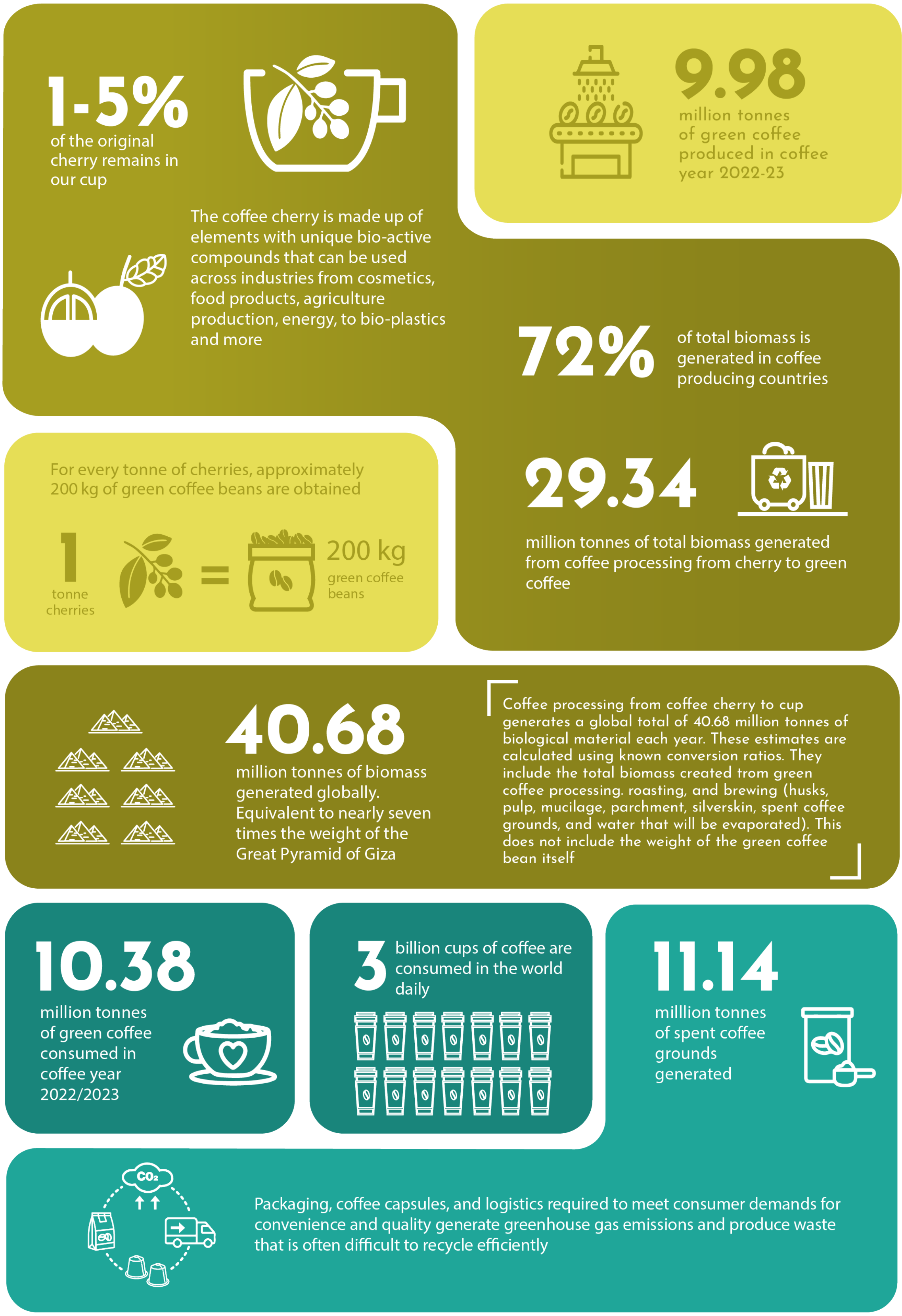
REGENERATION AND VALUE CREATION
The circular economy model goes beyond minimizing negative impacts by focusing on regeneration and value creation. This can lead to new business models, innovative products, and additional income streams for coffee producers.

SUSTAINABILITY AND LIVELIHOOD IMPROVEMENT
A circular economy in the coffee sector promotes environmental, economic, and social sustainability. This includes reducing the use of non-renewable resources, improving ecosystem health, and enhancing the quality of life for coffee-producing communities

SYSTEMIC AND HOLISTIC APPROACHES
Adopting a systemic and holistic approach allows for a more comprehensive understanding of the coffee sector as a complex network of stakeholders and processes. This approach can help address sustainability challenges more effectively and ensure that changes in one part of the system do not lead to unintended consequences elsewhere.

FIGURE 0.4

Global biomass generated through coffee transformation, coffee year 2022-2023



Note: With contributions from ITC Coffee Guide Network Circular Economy Working Group and C4CEC (2024).
NB (1): These calculations are made using ICO production and consumption statistics from coffee year 2022/2023. Known conversion rates from Oliveira, et al. (2021) are applied. See Annex A.2 for detailed calculations.
NB (2): These calculations include the total biomass created from green coffee processing, roasting, and brewing: husks, pulp, mucilage, parchment, silverskin, and spent coffee grounds. It includes moisture weight (30% of total) that will be evaporated but does not include the weight of green coffee bean itself or material from coffee pruning. Although these calculations are approximations and do not account for differences in coffee varieties, production efficiencies, or natural variances, they provide a useful estimation of the volume of waste generated throughout the coffee production process. This highlights the potential for revaluing what is often considered waste, transforming it into new products or energy sources.

The global sum of by-products generated through coffee processing, roasting, and consumption is 40.68 million tonnes/year – 86% of the volume of harvested cherries.

In coffee year 2022/23, production reached approximately 165.5 million (60-kg) bags (Part D), translating to 47.29 million tonnes of coffee cherries and 9.93 million tonnes of green coffee.

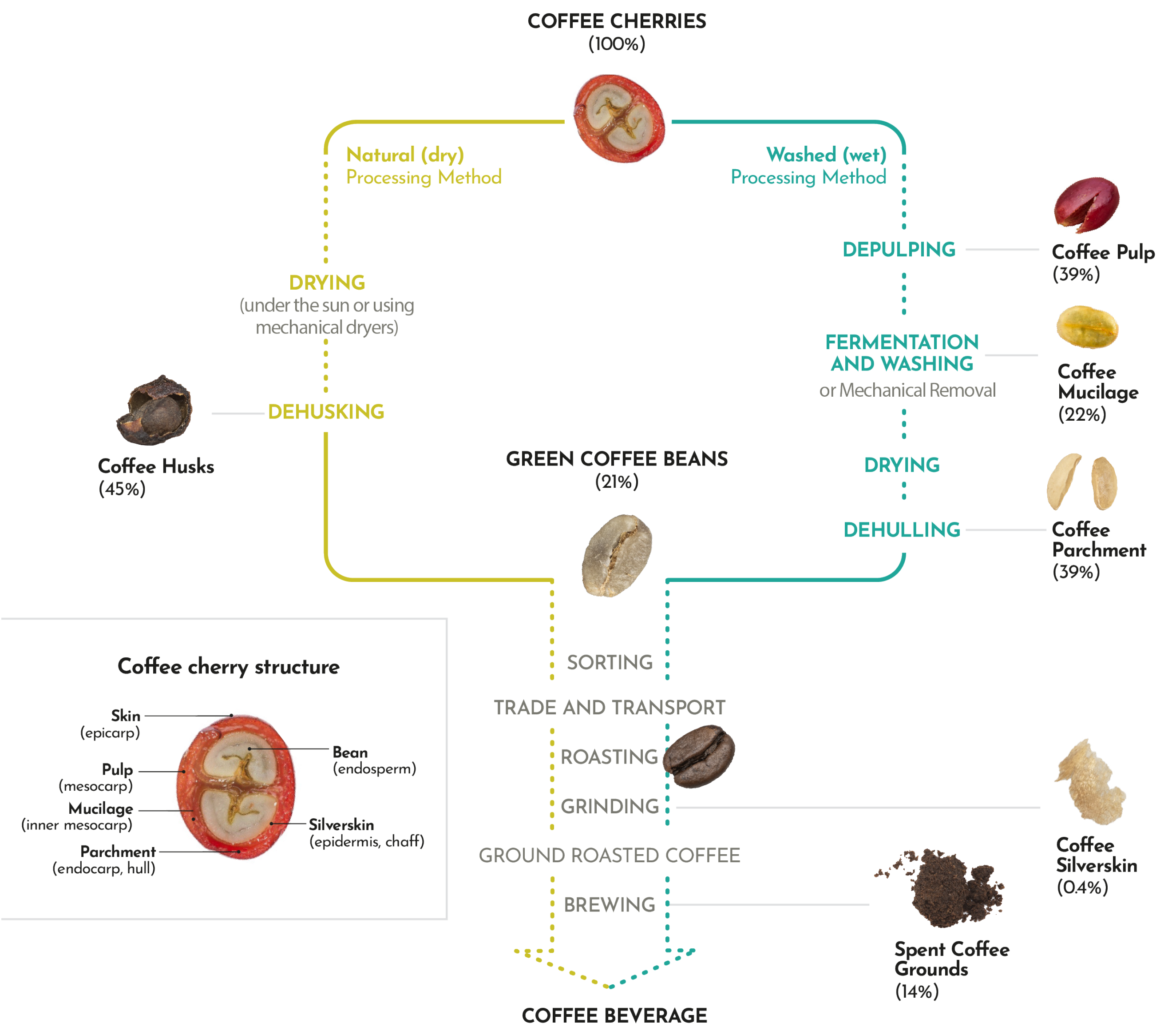
Coffee processed using the natural methods (an estimated 32.63 million tonnes of coffee cherries or 31% of total production) produced approximately 14.68 million tonnes of coffee husks, and 6.92 million tonnes of green coffee.

Cherries processed through washed/semi-washed methods (69%) generate 14.66 million tonnes of material (including coffee skin, pulp, mucilage, and parchment, and moisture content). These by-products condense to 6.80 million tonnes, approximately 46% of the cherry's original weight once dried.

In total, the various coffee processing methods from cherry to green coffee for export produced 29.34 million tonnes of biological material, which represents approximately 62% of the weight of the harvested coffee cherries in the 2022-23 coffee year. Global coffee consumption for the 2022-23 coffee year reached 173.0 million bags, equivalent to 10.38 million tonnes of green coffee (Part D).

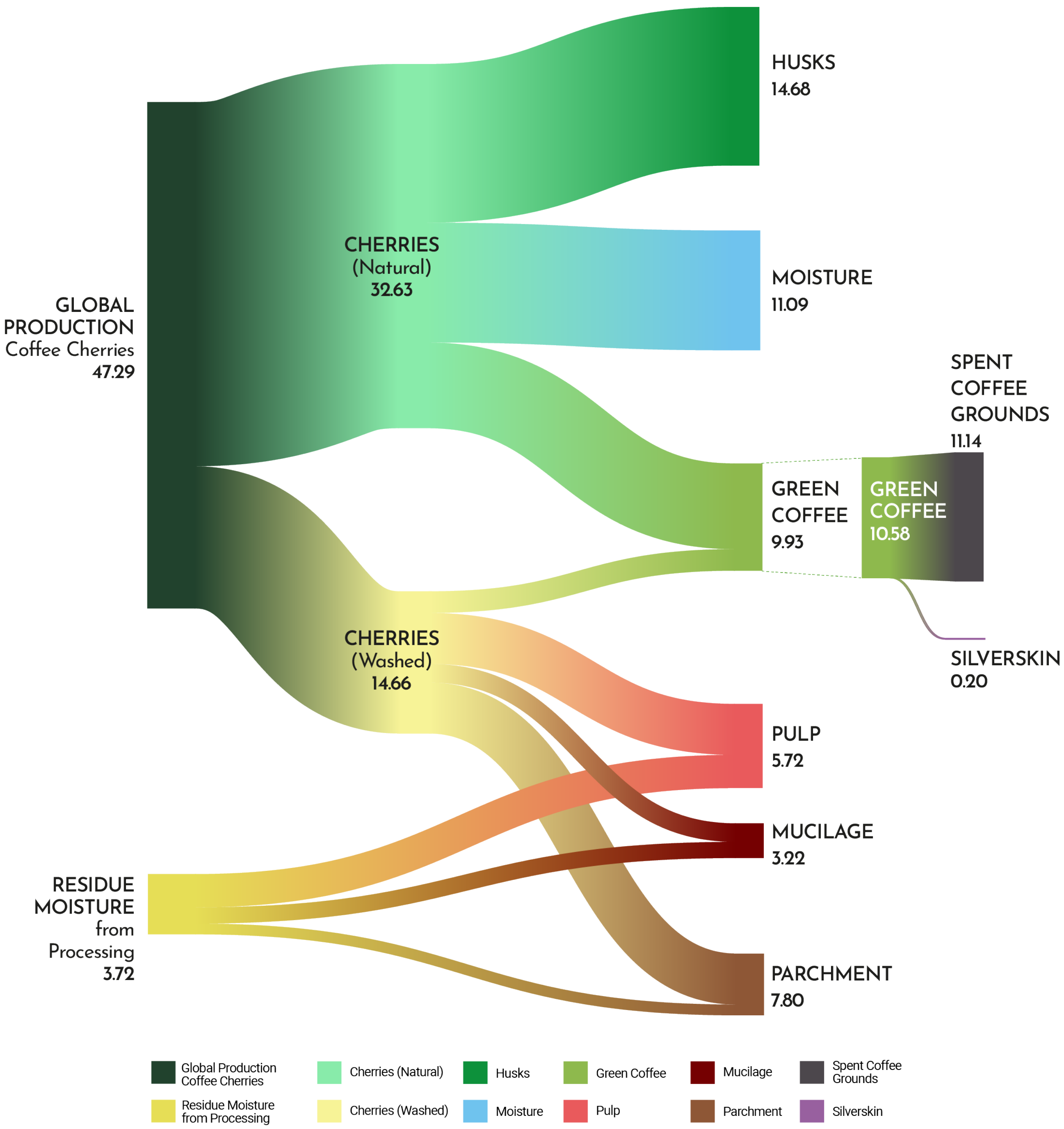
From this consumption figure, the roasting processes produced 0.20 million tonnes of coffee silverskin, accounting for 0.4% of the weight of the cherry and 1.7% of the green coffee bean. Additionally, spent coffee grounds after brewing totalled 11.14 million tonnes, which includes 61% moisture content, converting to approximately 6.92 million tonnes of dry material. By transforming this biomass into valuable products, the coffee sector can significantly reduce its environmental impact and create a more sustainable, resilient global coffee circle.

FIGURE O.5
Coffee cherry structure and by-products from coffee processing



Note: Adapted from Oliveira, et al. (2021).
NB: Schematic representation of the coffee cherry structure and coffee processing-derived by-products. The percentages refer to the amount of each by-product obtained from fresh coffee cherries.

FIGURE 0.6
Biomass flow - coffee year 2022-23



Note: With contributions from ITC Coffee Guide Network Circular Economy Working Group and C4CEC (2024).
NB: Unit in million tonnes. These calculations are made using ICO production and consumption statistics from coffee year 2022-23. Known conversion rates from Oliveira, et al. (2021) are applied. See Annex A.2 for detailed calculations.

The environmental impact of coffee cultivation is considerable and varies depending on farming practices and location. **Studies suggest that coffee cultivation and processing contribute to between 40% and 70% of the carbon emissions in the coffee lifecycle.** For instance, the carbon footprint of producing 1 kg of fresh coffee cherries ranges from 0.26 to 0.67 kg CO_2e in conventional systems and from 0.12 to 0.52 kg CO_2e in organic systems, with the primary emissions source being the use of nitrogen inputs (Nopenen et al, 2012).

The environmental burden extends beyond carbon emissions. Coffee production practices can consume substantial amounts of water and fertilizers, and the poor management of these inputs can lead to water scarcity, soil contamination, and biodiversity loss.

The average water footprint of a 125-milliliter cup of coffee is 132 litres from production to consumption (Water Footprint Network, n.d.), highlighting the resource-intensive nature of coffee production. Monoculture practices and deforestation further exacerbate these issues, making sustainable farming practices critical for the sector's overall sustainability.

0.2.3 Coffee cultivation and post-harvest processing can be enhanced through circular practices

There are numerous opportunities to improve the environmental and social sustainability of coffee cultivation by applying circular economy principles.

Coffee cultivation

Regenerative agriculture, aligned with circular economy principles, offers a holistic approach to making coffee production more sustainable. It focuses on regenerating soil health, enhancing biodiversity, and reducing the need for chemical inputs. By returning organic matter such as coffee pulp and husks to the soil, these practices contribute to healthier ecosystems and more sustainable food systems. Regenerative agriculture also helps diversify farmers' incomes, improves food security, and increases climate resilience, reducing the carbon footprint of coffee farming.

Intercropping – growing coffee alongside other plants, has a lower carbon footprint and higher carbon stocks than monocultures. Integrating trees and other plants into coffee farms supports biodiversity, improves soil fertility, and provides additional income for farmers. For example, coffee grown in polycultures has a carbon footprint of 6.2 to 7.3 kg CO_2e per kg of parchment coffee, compared to 9.0 to 10.8 kg CO_2e in monocultures.

Incentives like premiums and carbon insetting – investing in greenhouse gas reduction within a company's supply chain – can support sustainable coffee production. Carbon credit mechanisms that reward farmers for carbon sequestration through regenerative practices are additional strategies.

Post-harvest processing

Post-harvest coffee processing is critical to coffee quality and waste management. Two main methods dominate: washed (wet) and natural (dry) processing, each with distinct environmental and intrinsic quality impacts.

Washed (wet) processing is a resource-intensive method used to prepare coffee beans. The process starts with pulping, where the outer skin of the coffee cherries is mechanically removed. The beans, still coated with sticky mucilage, are then placed in fermentation tanks. Natural enzymes and microbes break down the mucilage during fermentation. After fermentation, the beans are thoroughly washed to remove any remaining mucilage, ensuring a clean flavour profile. This water-intensive process typically involves placing the beans in long troughs and repeatedly flushing them with water while stirring.

After washing, the beans are dried either in the sun or using mechanical dryers. The last step is hulling, which removes the parchment layer covering the beans, revealing the green coffee beans. These beans are then sorted and bagged for storage until they are ready for roasting.

While popular, washed processing has significant environmental implications due to its high-water usage and wastewater generation. On average, 15 to 20 litres of water are required to process each kg of coffee beans. The wastewater produced is highly acidic and contains a high concentration of organic matter, which can contaminate local water systems if not properly treated.

Washed coffee processing generates a significant amount of by-products – such as coffee pulp, mucilage, parchment, and wastewater – that together account for about 80% of the coffee cherry's mass. Coffee pulp, in particular, is rich in carbohydrates, proteins, minerals, and bioactive compounds like tannins and caffeine. However, these bioactive compounds require further research to assess their safety and toxicity. The organic content of coffee pulp makes it an excellent source for nutrient-rich fertilizer and a cost-effective addition to animal feed, supporting sustainable agriculture. Known as *cascara,* coffee pulp also has potential in various other applications.

Mucilage, the sticky substance clinging to the beans after pulping, is composed of 39% pectic substances and antioxidants. Unlike coffee pulp, it lacks bioactive compounds, making it a safer by-product for various applications, such as pectin production.

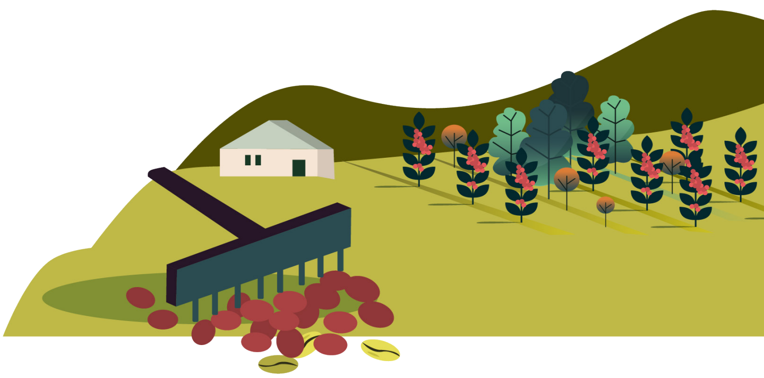
Coffee parchment, the fibrous material remaining after hulling, primarily consists of cellulose and lignin, with potential uses in bioenergy production and other industrial applications. The by-products of washed coffee processing present many opportunities for sustainable practices and economic benefits.

Natural (dry) processing is one of the oldest and most traditional techniques, particularly suited to regions with scarce water. Harvested coffee cherries are first sorted to remove defective or overripe cherries. Once sorted, the cherries are dried using either sun-drying or mechanical dryers. This drying process is crucial as it reduces the cherries' moisture content from approximately 60-65% to about 10-12%, which is necessary for safe storage and further processing. During drying, pit is important to ensure uniform drying to prevent mould or undesirable fermentation.

Traditionally, drying occurs on large patios or raised beds, where cherries are spread in thin layers to ensure even exposure to sun and air. Depending on weather conditions, this process can take several days to a few weeks. Some producers use mechanical drying methods to prevent contamination risks of improper drying and to speed up the process.

The next phase, hulling, involves removing the dried outer layers of the cherry – skin, pulp, and parchment – to reveal the green coffee beans. This step is typically done using mechanical hullers, which carefully remove the husk without damaging the beans.

Coffee husks, consisting of the dried skin, pulp, and parchment layers, make up about 45% of the coffee cherry. Disposing of



these husks can be challenging, especially in high production areas. Common disposal methods include landfilling, open burning, and composting. Open burning is particularly harmful as it releases pollutants like greenhouse gases and particulate matter, contributing to climate change and air pollution. Some regions have implemented regulations to reduce or ban open burning due to its negative environmental and health impacts.

However, coffee husks are increasingly recognized for their potential beyond waste disposal. Like coffee pulp, husks can be used as *cascara* or as nutrient-rich soil amendments, mulch, or compost. Their high lignocellulosic content also makes them suitable for biofuel production through processes like pyrolysis, as well as for various industrial applications, including the production of composite materials for construction, biodegradable packaging, and as a biosorbent to filter contaminants from water.

Additionally, many elements of the coffee farm, such as leaves and branches from pruning, cover crops, and fruit trees, can be integrated regeneratively and developed into value-added products. This promotes a circular economy in the coffee sector, reducing waste and creating new economic opportunities for coffee-producing communities.

TABLE 0.2
Opportunities to integrate circularity in coffee production and post-harvest processes

C-GVC stage and by-product	By-product characteristics and properties	Circular practice examples
Regenerative agricultural practices	Organic materials Locally available inputs Carbon sequestration Soil improvements Water retention	Regenerative agriculture practices • Promoting the well-being of animals, humans, and environment • Cover crops • Crop rotation • Animal husbandry • Composting • Mulching • Carbon insetting • Conservation of wild forest land
Intercropping and agroforestry: Shade trees Wood production Fruit Vegetables Honey	Creates shade for coffee Multipurpose woods Nutrition and income sources	• Shade crops and canopies • Intercropping bamboo • Intercropping fruit trees • Intercropping fruit and vegetables • Beekeeping • Carbon insetting
Coffee tree pruning: branches and leaves	Hardwood Organic material Leaves: caffeine, polyphenols, antioxidants Renewable and plentiful Local material	• Furniture (hardwood) • Coffee prunings for on-farm lumber (drying beds, posts) • Compost additive • Mulch • Biochar • Beverages and extracts from coffee leaves
Coffee drying	GHG emissions Materials used for drying beds or polyethylene tunnels	• Solar drying beds utilizing natural materials found near farm • Reuse of materials; i.e. polyethylene tunnels • Use biochar or biobricks as fuel • Renewable and bio-based energy sources

C-GVC stage and by-product	By-product characteristics and properties	Circular practice examples
Natural (dry) post-harvest processing: Dried coffee husks (coffee cherry skin, pulp, and husk)	Fruity or floral aroma with sweet berry flavour High in fibre (cellulose) Nutrients including proteins, lipids, and minerals Residual nutrients including carbon, phosphorus, potassium, and nitrogen	• *Cascara* products for human consumption • Compost additive • Soil amendment • Spread on coffee farms as a mulch and slow compost • Biochar and biobricks • Biochar for soil amendment • Biosorbent for wastewater treatment and caffeine removal • Polymer composite • Biogas
Washed (wet) post-harvest processing: Coffee pulp (coffee cherry skin and pulp)	Nutritionally dense Sweet smell and taste Bioactive compounds such as tannins, caffeine, and melanonids Pectin, moisture Residual nutrients including phosphorus, potassium, and nitrogen	• *Cascara* products for human consumption (fruit infusion, *Qishr* sweet tea in Ethiopia, distilled alcohol, ready to drink beverages) • Gluten-free flour alternative • Animal feed • Substrate for mushroom cultivation • Compost and fertilizer • Paper product ingredient (cellulose) • Dyes
Post-harvest washed (wet) post-harvest processing: Wastewater (Honey water)	Organic matter Toxic chemicals including tannins, phenolics, and alkaloids Depletion of oxygen levels in water	• Aerobic and anaerobic lagoons • Constructed wetlands • Vetiver grass cultivation • Membrane bioreactors • Composting and biofertilizers with treated wastewater • Water recycling after treatment • Rainwater capture
Post-harvest Washed (wet) post-harvest processing: Coffee mucilage	Sweet and sticky High in pectin High in antioxidants	• Human consumption as beverage or baked good ingredient • Organic fertilizer sprays • Natural food preservative
Milling (washed processed coffee): Coffee parchment	Fibrous material Lignin and cellulose	• Biofuels • Biochar component • Bio brick or cement component • Polymer composite • Paper, textiles, biodegradable packing materials • Biobricks (building material) • Compost ingredient • Mulch • Soil amendment

Note: Table informed by ITC, *The Coffee Guide, 4th Edition* (2021); ITC Coffee Guide Network Circular Economy Working Group (2023); and C4CEC (2024).

0.2.4 We can enhance the coffee transportation and trade with sustainability and circularity

The coffee industry is under increasing pressure to enhance the sustainability and circularity of the materials used in the trade and transport of green coffee beans. A key challenge is balancing the use of environmentally friendly packaging materials, such as jute and biodegradable sacks, with the need to protect coffee quality from moisture and odours. This requires innovative, chemical-free materials that ensure both sustainability and product integrity during storing, drying, and transportation.

Logistics and shipping

Logistics and shipping are also critical in reducing the environmental impact of coffee production, especially regarding greenhouse gas emissions from transportation. Strategies such as efficient warehousing, consolidation, and reducing the number of operational warehouses can improve efficiency and lower the carbon footprint. Adopting multi-modal transport – combining road, rail, and sea – can further enhance fuel efficiency and reduce pollution.

While coffee producers and exporters often reuse sacks for collecting coffee cherries and parchment, reusing those materials after export is challenging due to the difficulties in consolidating and shipping them back to coffee-producing countries.

Packaging and circularity

The coffee industry is increasingly focusing on designing recyclable and sustainable packaging to reduce resource extraction and waste.

Flexible packaging, which provides strong barriers against oxygen and moisture, is widely used but presents significant recycling challenges due to its multilayer composition. Current recycling infrastructure is often too inadequate to handle these materials effectively, resulting in low recycling rates. To address this, industry stakeholders are developing recyclable packaging solutions that align with circular economy principles.

In a circular economy, designing packaging to eliminate waste is crucial. Coffee packaging must be designed with its end-of-life use in mind, prioritizing the reuse and recycling of materials. This approach not only minimizes waste but also ensures that packaging can be effectively reintegrated into the production cycle. Recyclable packaging solutions made from polyolefins, such as polyethylene and polypropylene, are being developed to enhance the recyclability of flexible packaging. However, achieving widespread recyclability requires substantial investment in recycling infrastructure and consumer education on proper disposal practices.

Reuse models are being explored as alternatives to single-use packaging. However, in the coffee industry, maintaining product freshness remains challenging with reusable packaging options. To address this, packaging decisions should be informed by scientific analyses, such as life cycle assessments (LCAs), to ensure they support sustainability goals without compromising Zproduct quality.

TABLE 0.3
Opportunities to integrate circularity in transportation and trade

C-GVC stage and by-product	By-product characteristics and properties	Circular practice examples
Trade and transport: Packing materials	Biodegradable natural fibres (jute) Plastic "big bags" Polyethylene hermetic liners for jute bags Container liners Shrink wrap Pallets Plastic sample bags	• Jute bags • Recycling or reuse of plastic hermetic liners • Compostable sample bags
Trade and transport: Ocean freight Ground transportation Airline travel	GHG emissions	• Consolidated shipments • Multi-modal transport (road, rail, and sea) • Limit on corporate travel • Carbon insetting and carbon credits • Renewable energy and biofuels
Warehousing	GHG emissions Large, climate-controlled facilities	• Consolidated warehouses • Decreasing number of warehouses used

C-GVC stage and by-product	By-product characteristics and properties	Circular practice examples
Consumer packaging	Plastics Aluminium Bio-based materials with polymers Recycled materials Single-serve units (SSU) are often a blend of aluminium and plastic and combine with organic waste, limiting material separation for recycling and composting	• Single-serve capsule materials allowing for recycling • Coffee pod return scheme with major brands • Designing for reuse • Designing for recycling with mono-material packaging • Design for compostability • End-of-life product recyclability • Reduced and post-consumer recycled materials use

Note: Table informed by ITC, *The Coffee Guide, 4th Edition* (2021); ITC Coffee Guide Network Circular Economy Working Group (2023); and C4CEC (2024).

0.2.5 Coffee roasting and consumption require circular principles

Coffee consumption significantly impacts the global economy, with approximately 3 billion cups consumed daily. However, this large scale of consumption generates substantial waste, contributing to environmental challenges at various stages of coffee production and disposal. Waste from coffee consumption, particularly spent coffee grounds and single-use coffee capsules, underscores the need for sustainable end-of-life management strategies.

Coffee roasting

Coffee roasting, a critical step in developing coffee's flavour and aroma, is energy intensive. The environmental impact of roasting varies based on whether the energy source is renewable, electric, or fossil-based. Roasting emits carbon dioxide, volatile organic compounds (VOCs), organic acids, and by-products from natural gas combustion. Since most roasters are powered by natural gas, they produce carbon monoxide (CO) and carbon dioxide (CO_2), contributing to air pollution and posing health risks to workers and the nearby communities.

Roasting also generates a by-product called silverskin, or chaff. Proper management of silverskin is crucial, as its accumulation poses disposal and safety challenges due to its flammability. Some roasting facilities incinerate silverskin, which can increase air pollution.

Silverskin is a thin, papery layer between the coffee cherry and the green bean that tends to fragment during handling. Rich in bioactive compounds, including antioxidants, fibre, and lipids, silverskin has potential application in various industries. Its high cellulose content gives it fibrous and brittle characteristics, while its nutritional profile includes proteins, lipids, antioxidants, fibre, and essential minerals like potassium and magnesium. Studies have shown that silverskin contains phenolic compounds and flavonoids, known for their anti-inflammatory and anti-aging properties, making it valuable for multiple sectors.

Coffee consumption

The coffee we drink represents only a small fraction of the material produced throughout the coffee value chain – only 1-5% of the original mass of the coffee cherry ends up in our cup.

Widespread coffee consumption generates approximately 11.4 million tonnes of spent coffee grounds annually, matching the amount of ground coffee used for brewing. Different brewing methods have varying environmental impacts. Drip brewing, a common method, produces significant waste from both the coffee grounds and paper filters, which often end up in landfills instead of being composted or recycled. Espresso generates substantial waste in the form of spent coffee grounds. Coffee capsules, while efficient and increasingly popular, pose a significant environmental challenge due to which make recycling difficult.

Most spent coffee grounds are disposed of in landfills, where they decompose anaerobically, releasing methane – a potent greenhouse gas that contributes to climate change. This underscores the need for better waste management solutions.

However, spent coffee grounds hold significant potential for value addition. Rich in organic compounds and nutrients, they can be repurposed for various applications, including organic soil amendments, biochar production, biocosmetics, textiles, foods, and skincare products. Their high carbon and nitrogen content make them a valuable source of organic matter for agriculture, as they contain fibre, proteins, lipids, small amounts of caffeine, and bioactive compounds with antioxidant properties. Several innovative uses have transformed spent coffee grounds from waste into valuable resources.

The disposal of coffee capsules, despite their convenience, contributes to the problem of non-biodegradable waste. Their composite material structure makes recycling difficult, particularly in regions lacking the necessary infrastructure. As a result, many capsules end up in landfills, exacerbating environmental concerns.

Efforts are underway to address these issues, including the development of dedicated collection systems, recycling facilities, and compostable or recyclable capsules. However, these efforts are complicated by the varying recycling systems across different countries, where some regions lack the infrastructure needed to process these materials effectively. The fragmented nature of recycling and waste management systems poses significant barriers to the widespread adoption of standardized and effective solutions.

1-5%

of the original cherry remains in our cup

TABLE 0.4
Opportunities to integrate circularity in roasting and consumption

C-GVC stage and by-product	By-product characteristics and properties	Circular practice examples
Roasting: Silverskin (chaff)	Contains high value cellulose, hemicellulose, lignin, lipids, and some phenolic compounds	• Cosmetics • Nutraceuticals • Paper production • Agriculture fertilizers • Vegan leather fibre • Biopolymer additive
Coffee brewing: Spent coffee grounds (remain after brewing)	Rich in organic matter including carbon and nitrogen Fibre Residual caffeine Nutrients including protein and lipids Polyphenol Bioactive compounds with antioxidant properties	• Coffee flour for human consumption (baked goods) • Oil extracts for skincare products • Extracts for nutraceuticals and functional foods • Substrate for mushroom cultivation • Organic fertilizers or compost additive • Vermiculture • Biofuels • Feedstock component • Biobrick component • Biosorbents to remove dyes, oils, and metal ions from aqueous solutions • Paper products material component including coffee cups • Fabric and textile component • Natural dyes
Coffee shops: Single-serve coffee cups	Often lined with polyethylene plastic that is difficult to recycle	• Reusable coffee mugs • Integrated reuse programmes • Recycling with in-store recycling facilities • Industrial compostable cups

Note: Table informed by ITC, *The Coffee Guide, 4th Edition* (2021); ITC Coffee Guide Network Circular Economy Working Group (2023); and C4CEC (2024).

0.3 Policy and actions are required for a sustainable, inclusive, and circular coffee sector

The need for transformation in the coffee sector is clear, as are the sustainable opportunities that mainstreaming circular economy practices can provide. However, like any significant system change, this transformation comes with challenges.

To drive effective and actionable systemic change, starting with a realistic baseline assessment is essential. This report presents findings from a sector-wide survey conducted specifically for this purpose, identifying key challenges and offering recommendations for implementing and mainstreaming a circular economy throughout the coffee sector.

0.3.1 A global survey to gauge the industry's stance on circular economy

The global coffee sector stakeholder survey, conducted by the ITC Coffee Guide Network's Circular Economy Working Group, in partnership with the ICO, assessed the sector's understanding and perception of a circular economy. Using a participatory approach, the survey gathered perspectives from 322 producers, roasters, micro, small and medium-sized enterprise representatives, exporters, corporates, consumer facing companies and institutions. It helped assess the sector's assumptions and challenges in implementing a circular economy.

The survey confirmed a strong interest in and openness to a circular economy within the coffee sector. It revealed that the most common circular practices currently include the reuse of coffee by-products, waste reduction and recycling, and efficient use of resources and energy. However, the survey also highlighted the need for greater awareness and deeper understanding of the circular economy model, as well as the necessity for increased investment, sector cooperation and equitable distribution of knowledge, technical capacity, investment, and infrastructure across the coffee value chain.

FIGURE 0.7
Global sector survey findings

GAPS AND OPPORTUNITIES

- With an average response of 4.3 on a scale of one to five, survey respondents indicated broad consensus that a **circular economy is a model capable of improving environmental, social, and economic sustainability in the coffee sector**
- In stark contrast, **only 37% of respondents declared they implement some form of circular practice** within their activities
- **72% of respondents indicated they have limited to moderate knowledge** about circular economy in practice

MAIN IDENTIFIED CHALLENGES

- **Lack of knowledge**
- **Financial constraints** and limited access to funding
- **Low levels or coordination** between research centres and private sector organizations
- **Balancing economic viability** with broader circular economy goals
- **Lack of standardized guidelines** and best practices to implement a circular economy
- **Inadequate regulatory frameworks**
- **Low consumer awareness** and associated reluctance to pay means that potential is considerably reduced

International Trade Centre

The global survey received 322 responses that represent:

- **64** Countries
- **8** Value chain segments
- **24%** Coffee farmers
- **23%** Coffee support organizations
- **24%** Coffee traders and mills
- **20%** Consumer-facing brands & roasters
- **7%** Government authorities
- **2%** Other coffee industry

Note: Figure adapted from ITC, *Making a Case for a Circular Economy in the Coffee Sector: Insights from the multi-stakeholders working group on circular economy in coffee*, p.6 (2024).
NB: The Circular Economy Working Group co-created and distributed the survey in English, Portuguese, French, and Spanish in 2023. The ITC Coffee Guide Network distributed the global survey widely among its global network. Members of the network shared the survey with their own outreach networks in order to include a diverse set of perspectives, including: ITC, the ICO, Specialty Coffee Association (SCA), Lavazza Group and Foundation, The Latin American and Caribbean Network of Fair Trade Small Producers and Workers (CLAC), International Women's Coffee Alliance (IWCA), European Coffee Federation (ECF), Swiss Coffee Trade Association (SCTA) and SCTA Next Gen, Fair Trade International, Coffee Board of India, and Conselho Nacional do Café (CNC). It is important to note that the survey results do not represent a statistically significant sample of the global coffee sector. As such, it does not aim to provide a comprehensive state of the sector. Instead, it serves as a starting point for deeper reflection and more detailed research, encouraging discussion around its key topics.

0.3.2 Challenges remain in the implementation of a circular coffee economy

Transforming the coffee sector through circular economy practices presents both challenges and opportunities. Effective change requires addressing key obstacles, which are summarized below.

- **Coordination and knowledge sharing:** There is limited coordination among research centres, R&D initiatives, local solutions, farmers, and industry stakeholders across the C-GVC. Knowledge about circular economy practices is often isolated and fragmented, hindering the implementation of innovative models. Better coordination, standardized guidelines, and practical best practices are needed to develop and scale pilot projects. Additionally, there is a risk of undervaluing traditional indigenous knowledge in favour of new solutions from startups.

- **Inconsistent policies and regulations:** The policies and regulations governing coffee by-products and circular economy practices are often fragmented and inconsistent. Differences in regulations related to food safety, labelling, and import/export codes complicate global trade and tracking, making it challenging for MSMEs to navigate.

- **Funding and R&D:** Significant funding is needed to innovate and scale circular economy practices, posing high risks and costs for MSMEs and producers. The cost of developing new products from coffee by-products, such as biochar or coffee mucilage concentrate, is often prohibitive, especially at an industrial level. More efficient R&D investment is required to reduce costs and improve scalability.

- **Financial access and equity:** While there are opportunities, access remains limited for MSMEs and farmers in developing countries. Bridging the gap between small-scale innovators and financial support is crucial, as many good ideas are hindered by a lack of funding.

- **Logistics and matchmaking:** Efficient logistics for collecting and processing coffee by-products are lacking. Standards for collection and storage are underdeveloped, and better coordination is needed between collectors and product makers. Mismatches in product demand and availability, along with the high risk and cost of new product development, also create barriers to market entry.

- **Market fragmentation and transparency:** The market for coffee by-products is fragmented and lacks transparency in pricing and quality. The absence of standard practices for quality, collection, and packaging makes it difficult for farmers and producers to navigate and capitalize on niche markets.

- **Market development:** Developing new markets for upcycled coffee by-products requires establishing new B2B relationships and networks outside the coffee industry. Many producers lack the connections and knowledge to access these new supply chains, hindering market development.

- **Consumer awareness:** Low consumer awareness and understanding of circular economy benefits limit the market for upcycled products. Educating consumers and shifting mindsets is essential to increasing acceptance and demand for these products.

- **Value distribution:** The benefits of circular economy practices are not always equitably distributed. While circular initiatives should ideally support all stages of the coffee value chain, compensation for raw materials and efforts in collection and distribution is often insufficient. The economic impact needs to be recognized and appreciated across the entire value chain, including by farmers who may not fully realize the benefits of circular practices.

Addressing these challenges requires improving coordination, standardizing regulations, securing funding, and developing transparent markets to effectively integrate circular economy practices into the coffee sector.

0.3.3 Strategic and overarching recommendations

To address the challenges and seize the opportunities for a more sustainable, resilient, and prosperous future, the coffee sector must transition to a circular economy. This shift will strengthen the C-GVC and enhance its resilience in the coming decades. By improving the way coffee is produced, processed, and consumed, we can create a future where the C-GVC thrives in harmony with the planet.

The following policy recommendations serve as a roadmap for stakeholders dedicated to making this vision a reality. These recommendations are intended for all those engaged in the coffee sector, including governments, private sector entities (from farmers to retailers), NGOs, and development partners worldwide. They recognize the vast amounts of waste generated by the coffee sector and the potential to reduce and repurpose this waste through circular economy practices, creating new economic opportunities, especially for farmers and small businesses in coffee-producing countries. The shift from a linear to a circular economy aligns with several UN Sustainable Development Goals (SDGs), promoting sustainable consumption and production, economic growth, and climate action.

Recommendations are organized by C-GVC stages, outlining specific actions, impacted stakeholders, and expected outcomes. These include:

RECOMMENDATIONS

- **Stage identification**: Pinpointing where in the value chain the recommendation applies
- **Policy recommendation:** Detailed guidance on implementing circular practices
- **Stakeholder impact:** Identifying affected groups and organizations
- **Impact assessment:** Evaluating social, environmental, and economic effects, and alignment with SDGs
- **Strategy and implementation:** Providing actionable steps for effective execution

Guiding principles

The transformation should adhere to **principles such as circulating materials at their highest value, regenerating natural systems, and fostering local innovation.** These principles advocate for collaborative, open-source solutions and emphasize the importance of local actions in achieving global impacts. By integrating these strategies, the coffee sector can move towards a more sustainable, resilient, and economically beneficial future.

These recommendations build on the insights from the joint paper by ITC, C4CEC, and the ICO: "Making a Case for a Circular Economy in the Coffee Sector: Insights from the multi-stakeholders working group on circular economy in coffee" (ITC, 2024) and are intended to guide stakeholders in turning this vision into reality. They are integrated at both global and C-GVC-specific levels, identifying the actors in the C-GVC that should lead their implementation.

FIGURE 0.8
Overview of strategic and overarching policy recommendations

- Establish best practices and shine a light on good examples
- Set metrics and measure progress
- Undertake pre-competitive research and development for industry (processor) waste streams
- Collaborate with adjacent industries
- Develop economic incentives and promotion programmes
- Establish partnerships and pre-competitive collaboration
- Adopt waste reduction approaches
- Create a market for coffee by-products
- Establish standards and certifications
- Build education and awareness-raising
- Lay out regulatory frameworks and advocacy
- Catalyse investment

0.3.4 Specific policy recommendations for transforming the coffee sector through circular economy

The strategic recommendations provide a comprehensive framework for establishing a circular economy in the coffee sector. These foundations emphasize the importance of coordination, impact investment, and innovation, as well as the adoption of sustainable practices across all stages of the coffee value chain. By creating an environment that supports collaboration, research, and knowledge sharing, and by developing robust regulatory frameworks, financial incentives, and market mechanisms, the coffee sector can transition to a more sustainable and resilient model.

To achieve this transformation, it is crucial for all coffee stakeholders – farmers, industry players, government agencies, NGOs, and research institutions – as well as financial institutions, investors, and development partners to join forces. By embracing circular economy principles and scaling up existing solutions or developing new ones, the coffee sector can enhance its economic viability, environmental sustainability, and social equity. This collective effort will not only benefit the coffee industry but also contribute to broader global sustainability goals. Now is the time to act and drive meaningful change towards a more sustainable future for coffee.

TABLE 0.5

Overview of specific policy recommendations

FARMING AND PRODUCTION Recommendations	PROCESSING Recommendations	PACKAGING AND TRANSPORT Recommendations	CONSUMPTION Recommendations	POST CONSUMPTION Recommendations
Regenerative agriculture and agroforestry	Create value from waste and by-products	Circular economy in packaging	Responsible consumption	Resource recovery and waste management
Commercialization and use of coffee by-products	Coffee processing	Alignment of packaging choice with local waste policies	Certifications and standards	Revalorization of waste
Create market linkages for coffee by-products	Coffee wastewater	Transparent pricing structures	Resource efficiency in coffee shops	Promotion of R&D in valorization of coffee by-products
Circular economy and regenerative agriculture to close living income gaps	Technological solutions for emission control	Implementation of sustainable product-service systems		Promotion of R&D in packaging
Multi-stakeholder research collaborations for regenerative agriculture and by-product development in producing countries	Incentives for processors to move from countries of consumption to countries of production			
Diversification of income streams	Diversification of income streams			
Farmer-focused education initiatives	Farmer-focused education initiatives			

BOX 0.2

The Center for Circular Economy in Coffee (C4CEC)

CENTER FOR CIRCULAR ECONOMY IN COFFEE

This report emphasizes the need for pre-competitive collaboration, a practical research hub with mechanisms linking research with C-GVC actors, and actionable education to implement circular economy practices.

The Center for Circular Economy in Coffee (C4CEC) is a global pre-competitive initiative designed to foster and advance circular economy principles within the coffee sector. Established in Turin, Italy, as a nonprofit organization, the Center was officially launched in September 2023 during the ICO 5th World Coffee Conference in Bangalore, India. The Center serves as a platform to put circular economy into practice by piloting innovations, advancing research, and sharing best practices. Its web platform offers case studies, research, and practical information on applying circular economy principles across the coffee value chain, from farming to consumption and disposal.

With a pre-competitive, transparent, and science-based approach, the C4CEC expands its knowledge base through its scientific board and the ITC Coffee Guide Network Circular Economy Working Group. The Center is open to all stakeholders in the coffee sector:

- **Coffee farmers and producer organizations:** Access resources to learn, develop, and pilot circular innovations, enhancing business resilience, sustainability, and profitability
- **Coffee sector companies:** Improve and implement circular initiatives with support from a scientific network and connections to a global network of like-minded organizations
- **Public sector and academia:** Collaborate, share knowledge, propose new initiatives, and conduct research through a global multi-stakeholder network

The Center has more than 35 member organizations globally and counts on the support of its founding strategic partners.

LAVAZZA FOUNDATION · Politecnico di Torino · Università di Scienze Gastronomiche di Pollenzo · INTERNATIONAL COFFEE ORGANIZATION · International Trade Centre · UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

0.3.5 Conclusion

The coffee industry faces both challenges and opportunities from farm to cup. By embracing circular economy principles – such as waste reduction, regenerative agriculture, innovative value addition, and responsible consumption – the sector can enhance sustainability and social equity. Practices like agroforestry and carbon insetting not only reduce environmental impact but also create new income opportunities for farmers. Sustainable processing methods, including transforming waste into valuable by-products, adopting circular packaging, and optimizing logistics, can lower environmental impact while supporting profitability. Together, these efforts propel the coffee industry towards a more sustainable, responsible, and climate-conscious future.

Business success and sustainability are two sides of the same coin; when integrated effectively, they can mutually reinforce each other. A sustainable coffee industry is only achievable if circular practices align with the needs and incentives of MSMEs and farmers. Broad adoption of these practices along the C-GVC will occur when there are clear benefits and support systems tailored to their requirements. Finance and investment are critical enablers, providing the resources needed to innovate, scale, and implement circular models that drive both economic and environmental benefits across the value chain.

PART II
SECTION A Making a case for a circular economy

The circular economy offers a transformative model for extending material life cycles, eliminating waste, and regenerating nature, with significant benefits for the agribusiness and coffee sectors.

Key Findings

- **The concept of the circular economy does not have a single origin** but has evolved from various schools of thought, including biomimicry, industrial ecology, cradle-to-cradle design, the blue economy, and bioeconomy theories.
- **The circular economy is a production and consumption model designed to extend the life cycle of materials** by keeping them in circulation rather than allowing them to become waste. Its core principles are eliminating waste and pollution, circulating products and materials at their highest value, and regenerating nature.
- **In the agri-business sector, the circular model applies through two distinct cycles:**
  I. **The Technical Cycle,** which focuses on maintaining, returning, renewing, and reusing agri-processing technologies to enhance agricultural efficiency, minimize waste, and reduce costs;
  II. **The Biological Cycle,** which seeks to recover value from system waste by reusing food, utilizing by-products and food waste, and recycling nutrients.
- **In the coffee sector, a circular economy integrates regenerative practices, resource efficiency, and waste reduction while valuing process outputs** to achieve environmental, social, and economic sustainability. Inspired by natural systems, this model aims to regenerate, sustain, and create shared value for all stakeholders throughout the coffee value chain.
- **The global food system is responsible for a quarter of GHG emissions**, 44% of global land use, 61% of freshwater withdrawal, and 90% of phosphorus emissions to soil.
- **Key benefits of a circular economy in the coffee sector** include increased resource efficiency, sustainable management of biological waste, climate change mitigation and adaptation, job creation and income opportunities, reduced packaging waste, long-term soil health improvements, and healthier ecosystems and water systems.
- **Many countries are developing and implementing circular economy strategies and policies** that can also apply to the coffee sector.
- **The G7 Summit in June 2024, under Italy's presidency, launched a multi-stakeholder programme** to advance policy, investment, research, innovation, and partnerships for the circularity and sustainability of global coffee value chains, including exploring the feasibility of establishing a global public-private fund on coffee to support smallholders and family farmers.

A.1 Circular economy as an urgent measure

As we enter the "era of global boiling," as described by UN Secretary-General António Guterres, discussions about the future of coffee production are intensifying worldwide. Coffee, especially the prized Arabica varieties, thrives in cool, tropical climates. However, rising temperatures are forcing production regions to move uphill into cooler, often steeper, and less stable lands with shallower soils. These new areas are typically the remnants of once larger forest ecosystems. The effects of climate change and other environmental impacts are significantly reducing the amount of suitable land for coffee cultivation.

In December 2023, the United Nations Climate Change Conference (COP28) emphasized that to limit global warming to 1.5°C and maintain a safe operating space for humanity, global GHG emissions must be reduced by 43% by 2030.[1] The global stocktake of agreements calls for tripling renewable energy capacity, phasing out fossil fuels, and setting a "new quantified collective goal on climate finance" in 2024, with a focus on meeting the needs of developing countries. Beyond GHG emissions, the coffee sector also impacts biodiversity, water use, and eutrophication.

The coffee industry faces significant economic challenges. Price fluctuations make it difficult for smallholder farmers to predict production costs and secure a living income. The value added across the supply chain is unevenly distributed, with smallholder farmers often struggling to earn a decent livelihood (BASIC, 2024). Older generations have few alternatives to coffee farming, while younger generations are rapidly leaving the sector due to the lack of a stable future (ICO, 2021).

Additionally, coffee farmers and producing countries face increasing pressure from consumers, buyers, and regulators

1 Relative to 2019. See United Nations Framework Convention on Climate Change (UNFCCC) (2023). COP28 Agreement Signals "Beginning of the End" of the Fossil Fuel Era. https://unfccc.int/news/cop28-agreement-signals-beginning-of-the-end-of-the-fossil-fuel-era

to achieve higher levels of sustainability, productivity, quality, and output (ICO, 2004). To meet these demands, the coffee sector must prioritize the livelihoods of farmers in all policies and strategies and develop adaptive approaches to address environmental impacts and manage rising production and transaction costs. Adopting a "living income" provides a crucial metric for evaluating the success of sustainability efforts within the global coffee value chain (C-GVC). This approach, along with circular and regenerative solutions, is essential for ensuring prosperity for all coffee farmers and workers.

The Circularity Gap Report 2024 states that the global economy is only 7.2% circular to date, meaning that the amount of reused or recycled materials used by the global economy is declining year-on-year, driven by rising material extraction and use, while consumption continues to accelerate. The report indicates that the global food system contributes to 25% of greenhouse gas emissions, accounts for 44% of global land use, 61% of freshwater withdrawals, and 90% of phosphorus emissions into soil. For biomass use to be considered renewable, sustainable, and truly circular, carbon, nitrogen, and phosphorus need to be effectively reintegrated into the soil (Circle Economy, 2024).

The global food system is responsible for a quarter of GHG emissions, 44% of global land use, 61% of freshwater withdrawal, and 90% of phosphorus emissions to soil.

An analysis of the coffee sector's resource efficiency, as presented in this report, underscores the need for more sustainable business and production models. Effective implementation should focus on developing new coffee varieties and agricultural practices, intercropping, and increasing income opportunities through environmental services, while also promoting the large-scale adoption of a circular economy. This approach can help secure a sustainable future for the entire coffee sector, creating new opportunities for global well-being and sustainable growth.

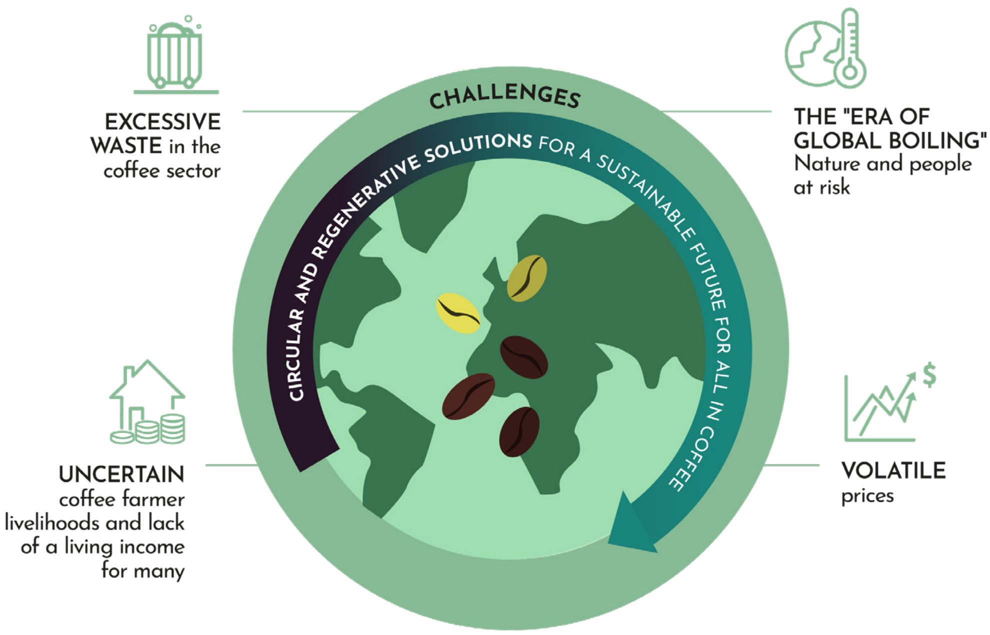
Circular economy principles are increasingly being applied across various sectors and industries to reduce waste, improve resource efficiency, and promote sustainability, addressing climate-related challenges and future supply-demand gaps. Key sectors and industries that have engaged in the transition from a linear to a circular economy include manufacturing sectors, such as:

- Electronics, electrical equipment, and car manufacturers, characterized by a strong emphasis on product (re)design and after-consumption recyclability and waste management;
- The textiles, apparel, and furniture industries are shifting towards developing and using sustainable materials, along with implementing systems to recycle fabrics, textiles, and furniture;
- The recycling and waste management, packaging, retail, and construction sectors, and the mining and extractive industries, which are also progressing towards circularity – either adding value to waste or eliminating it entirely to achieve resource and cost efficiency and save or generate energy.

The agri-business sector is increasingly focusing on circular solutions that promote sustainable, regenerative, and restorative agriculture. These efforts aim to reduce food waste and environmental impacts through improved supply chain management and to use waste to create new materials (known as "feedstocks") and products. This approach is particularly evident in the coffee sector.

This report demonstrates that by adopting circular economy principles along the C-GVC, the sector can reduce its environmental footprint, increase resource efficiency, and develop more sustainable business models. These models not only generate new products and value-added processes but also create significant income and job opportunities, especially for vulnerable coffee farming communities.

FIGURE A.1
Making a case for a circular economy



A.2 From linear to circular

The traditional production model in supply chain economics is linear, often described as a "take, make, waste" approach. Natural resources are used to manufacture products, which are typically discarded at the end of their life cycle. For the past 50 years, global consumption of natural resources has exceeded planetary boundaries, a trend expected to worsen without significant intervention.

BOX A.1
A historical barrier to circularity

Today's "throw-away society" a term coined in 1955 as a critique of rising consumerism, tends to use items once only, with disposable packaging and consumer products that are not designed for reuse or lifetime use. Many companies still make it difficult, or even illegal, to mend their products.

In 1924 a cartel of big lightbulb manufacturers, including General Electric, Osram and Philips, agreed to keep lifetimes of their products to 1,000 hours or so, down from an average of 2,500 hours, in order to sell more of them, in a strategy called planned obsolescence (Krajewski, 2014).

The concept of the circular economy has evolved over decades and cannot be attributed to a single source or date. Key contributors in the literature include John Kyle, William McDonough, Michael Braungart, and Walter Stahel (Winans et al., 2017). Rachel Carson's seminal book Silent Spring may also have inspired the circular economy model. Various schools of thought, such as biomimicry, industrial ecology, and cradle-to-cradle design, have also influenced the movement.

Biomimicry, as defined by the Biomimicry Institute, is the practice of applying lessons from nature to create more sustainable technologies. The term was coined by Otto Schmitt in 1957 (Phil. Trans. R. Soc. A, 2009) but gained popularity through Janine Benyus's work in 1997. The costs and benefits of climate change were first addressed around 1991 by Bob Ayres, a founding figure in industrial ecology (van der Bergh, 2013). That same year, a pioneering study on the Economic Aspects of Global Warming was published, with contributions from William Cline, future Nobel laureate William Nordhaus, and David Pearce (McLaughlin, 2022).

Gunter Pauli's "Blue Economy" approach,[2] which emerged later, advocates for zero-emission systems where waste is non-existent – every process output is used as input in other processes. The Blue Economy model seeks to shift society from scarcity to abundance by utilizing locally available resources in innovative ways (Pauli, 2010).These various schools of thought have collectively shaped the principles of today's circular economy.

In 2002, the "Cradle-to-Cradle" concept was popularized by Michael Braungart and Bill McDonough. This design philosophy categorizes all industrial and commercial materials as either technical or biological nutrients, aiming for products that positively impact the environment through effective design.

The concept of the bioeconomy has also evolved, focusing on using biological resources, processes, and principles to produce food, feed, bio-based products, and energy sustainably. The European Environment Agency suggests that the bioeconomy and circular economy have significant potential to partner towards sustainability, as the bioeconomy is inherently circular (De Schoenmakere et al., 2018).

The Ellen MacArthur Foundation (EMF) has been instrumental in promoting circular economy ideas across Europe and North America. Increasingly, countries in the Global North and South are incorporating circular economy principles into their environmental policies, advancing circularity on a global scale through extended cooperation across countries and industries.

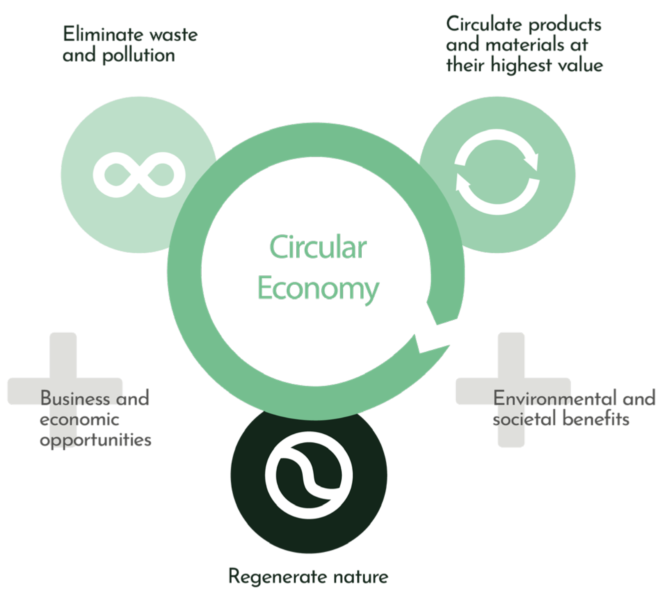
A.3 What is circular economy?

The circular economy is a production and consumption model that extends the life cycle of products by keeping them in circulation rather than allowing them to become waste. Its foundational principles are summarized as:

- **Eliminate waste and pollution**
- **Circulate products and materials at their highest value**
- **Regenerate nature**

From the inputs entering production to the final consumer, a circular flow of goods avoids pollution, prolongs material use, captures value from waste and regenerates organic flows.

FIGURE A.2
Principles for circular economy in coffee



Source: ITC, *Making a Case for Circular Economy in Coffee: Insights from the multi-stakeholders working group on circular economy in coffee (2024).*
Note: Adapted from Ellen MacArthur Foundation.

2 More recently the term "Blue Economy" has been associated with the concept of sustainable use of ocean resources.

A.4 Circular economy in agri-business

In 2022, agricultural land covered approximately 4.781 million hectares, accounting for more than one third of the Earth's land surface. Of this, 1.573 million hectares were cropland, with coffee cultivation representing 0.7% (FAO, 2024). The global food system is responsible for about one-third of GHG emissions, highlighting the agri-business industry's crucial role in addressing climate change and biodiversity loss. In this context, circular design for food can provide significant environmental and economic benefits.

For every dollar spent on food, society incurs two dollars in health, environmental, and economic costs, totalling USD $5.7 trillion annually. Half of these costs stem from current food production methods, which often rely on fossil fuels, chemical fertilizers, and unsustainable water use (EMF, n.d.). These practices have led to farmland degradation, biodiversity loss, and ecosystem damage.

A linear economic model also creates imbalances in the risk/reward equation. Smallholder farmers, the foundation of agricultural value chains, face increasing risks due to climate change, competition for natural resources, rising input costs, declining soil fertility, and an aging farming population.

Policymakers are beginning to support food system transformation. To facilitate the adoption of the circular economy, the United Nations Industrial Development Organization (UNIDO) has identified two distinct cycles within the circular model: technical and biological.

These principles align with the three foundational principles of the circular economy: eliminating waste and pollution, preserving value over time, and avoiding non-renewable resources. These principles apply to both biological and technical processes across all circular models.

BOX A.2
UNIDO's two cycles within the circular model

In the agri-business sector, these cycles can be described as follows:

1. **Technical Cycle:** involves maintaining, returning, renewing, and reusing agri-processing technologies to enhance agricultural efficiency while minimizing waste and reducing costs. Business models that focus on sharing capital-intensive machinery promote broader application and cost savings. This cycle also applies to non-natural packaging by prioritizing reuse and recycling.
2. **Biological Cycle:** recovers value from system waste by reusing food, utilizing by-products and food waste, and recycling nutrients. This waste becomes input for new products, supporting crop production, food processing, feed, energy, or other industries like cosmetics and pharmaceuticals. By closing input loops, discharges are minimized, resource demand is reduced, and efficiency is increased, fostering circularity in agri-business practices.

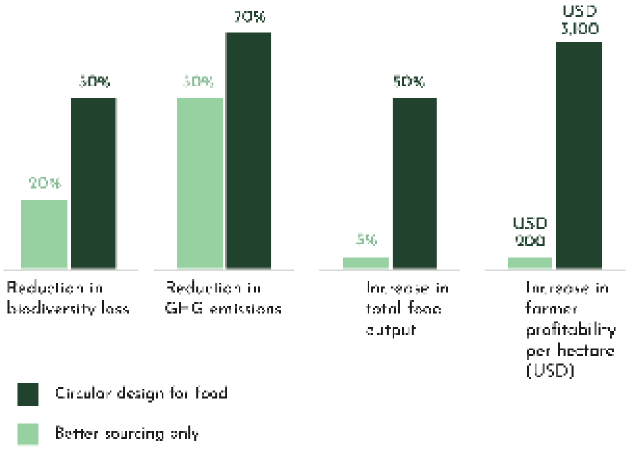
Source: UNIDO (2021).

The way food is designed directly impacts what is consumed and the ingredients grown. The EMF emphasizes circular design for food from product conceptualization through ingredient selection and packaging design. Applying these principles across all aspects of food design can maximize positive outcomes and help businesses meet their circular economy targets. A study by the EMF in the UK and EU found that adopting circular design yields greater benefits, such as reducing GHG emissions, minimizing biodiversity loss, and increasing food output, compared to merely improving sourcing practices.

A unique aspect of agri-business is potential to repurpose biomass as soil amendments, nutrients, compost, or energy, making regenerative agriculture a key component of the circular economy in this sector. With proper support, smallholder farmers – who are most vulnerable to environmental changes – can play a crucial role in restoring environmental balance.

The industrial scale of modern food systems also offers economies of scale for waste valorization and by-product (feedstock) development. Closing input loops minimizes waste, reduces resource demand, and increases efficiency, fostering circularity in agri-business. While reusing and recycling agricultural goods is not new, technological advancements have introduced more efficient techniques, expanding opportunities for value-added practices.

FIGURE A.3
Average benefit comparison between adopting circular design and only adopting better sourcing practices



Source: Graph adapted from Ellen MacArthur Foundation (2024).

A.5 Circular economy in the coffee sector

Coffee is one of the most widely consumed beverages globally, with around 3 billion cups consumed daily, and it is also one of the most significant internationally traded commodities. The sector provides jobs and income in over 50 coffee-growing countries and supports millions of people worldwide. However, like most agricultural commodities, it generates substantial waste at every stage of the value chain. By adopting circular economy principles and rethinking its supply chain, this waste could be transformed into valuable resources, reducing its contribution to global pollution and climate change.

For this report, we use the definition developed by the Circular Economy Working Group, part of the ITC Coffee Guide Network, in collaboration with the ICO and global experts and practitioners.

> "A Circular Economy model for the coffee sector designs, balances, and implements regenerative practices, resource efficiency, and waste reduction while giving value to process outputs, achieving environmental, social and economic sustainability. Driven by a systemic and holistic approach, it draws inspiration from the dynamics of natural systems to regenerate, maintain, and create shared value for all stakeholders, across different contexts and within the entire coffee value circle."
>
> ITC Coffee Guide Network, Circular Economy Working Group (2024).

This definition was crafted to reflect the perspectives of farmers, researchers, sector support organizations, and industry players. As the circular economy model gains traction within the coffee sector, this common definition aims to become a new reference point. Beyond defining the circular economy, it seeks to guide and inspire stakeholders in the coffee industry to pursue sector transformation in line with circular principles.

A circular economy for the coffee sector integrates key principles: waste reduction, resource efficiency, and sustainability. These principles are embodied in the definition of a circular economy for the coffee sector:

- **Engage efficiency in resource use and waste reduction:** This principle ensures that every stage of the coffee life cycle, from cultivation to consumption, is optimized for minimal resource use and maximum waste reduction. When waste is unavoidable, circular practices seek to repurpose it for the highest value. For example, by-products from coffee cherries can be transformed into raw materials for new products or processes, beyond just producing the final coffee beverage.

- **Regenerate, maintain, and create value:** Unlike conventional approaches that focus on reducing negative impacts, the proposed model emphasizes regeneration and value maintenance, aiming to create new value whenever possible. This value can manifest in the empowerment of communities, the preservation of culture and traditions, or the transformation of seemingly worthless assets through innovative technologies.

- **Aim for environmental, economic, and social sustainability:** A circular economy in the coffee sector promotes the well-being of coffee-producing communities, expanding economic opportunities for all stakeholders while conserving and regenerating natural resources. Environmentally, this means reducing the use of non-renewable resources, minimizing waste, and improving the health of ecosystems involved in coffee production. Socially, it aims to promote ethical work practices, enhance community quality of life, and ensure fair access to resources. Economically, the goal is to create long-term value, stimulate innovation, and provide equitable income distribution within the coffee value chain.

- **Employ a systemic, participatory, and holistic approach:** A systemic approach views the coffee sector as a whole rather than focusing on individual parts. It considers the sector as a complex network of stakeholders, material and value flows, and processes that span from the coffee cherry to the final product and beyond. This approach acknowledges that all systems are dynamic and interconnected, where changes in one part can have unintended consequences elsewhere. Understanding the coffee market as a system highlights the interdependence of all actors and activities, from production to consumption. It also recognizes the importance of indirect actors – those who don't directly buy or sell coffee but influence the market's structure, organization, and development.

  A holistic approach considers the coffee sector's complexity and the interconnectedness of its parts. Recognizing this complexity is crucial for addressing the sustainability challenges the sector faces. It also requires understanding timelines that extend beyond the short-term focus of business operations. Changing market systems demands awareness not only of core functions but also of supporting roles and key regulations that drive competitive and inclusive economies within the limits of our ecosystems.

- **Transition towards a value circle:** A circular approach to the coffee sector envisions a trade system rooted in cooperation, known as a value circle. This concept represents a shift in thinking that recognizes the unique contributions and needs of each stakeholder, balancing profit with environmental costs. Like a circle, this model must seek balance to remain intact, mirroring the principles of nature.

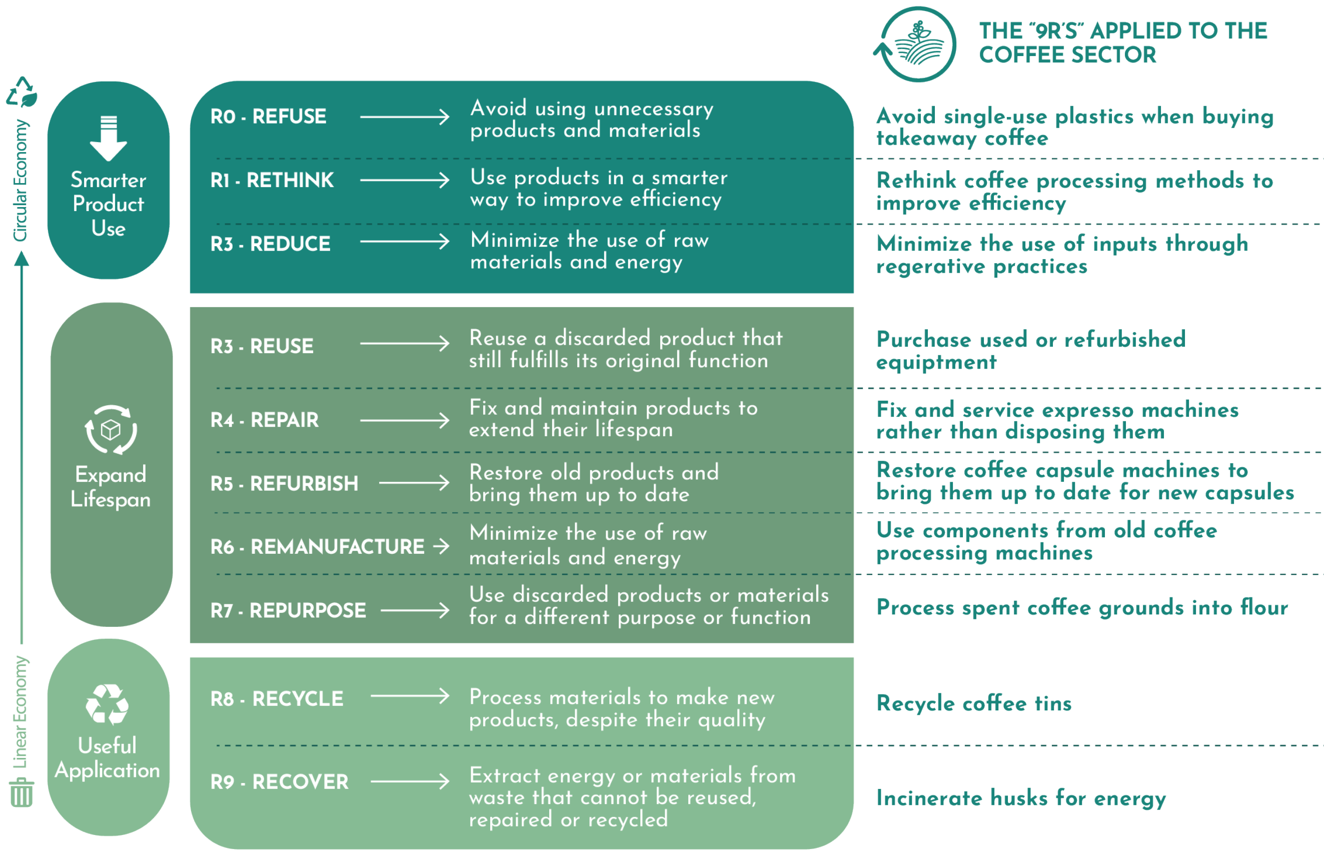
- **Ensure shared value for all:** The concept of shared value, defined as "creating economic value in a way that also creates value for society by addressing its needs and challenges" (Porter and Kramer, 2011), emphasizes the importance of generating benefits that serve all stakeholders proportionally. From this perspective, a circular economy can enhance the competitiveness of companies and coffee organizations while simultaneously improving economic and social conditions across the coffee sector, from producing regions to the global market.

A.6 Benefits of a circular economy

By 2025, circular business models could generate about USD 1 trillion per year in materials cost savings (World Economic Forum and Ellen MacArthur Foundation, 2014). A circular economy not only tackles environmental challenges but also drives innovation, creates new business practices, and generates income opportunities and jobs by utilizing agricultural waste, by-products, and co-products.

National economies, entrepreneurs, and employees can benefit

FIGURE A.4
The "9R's" applied to the coffee sector



Note: Adapted from Kirchherr et al (2017).

from the circular economy as they develop new businesses and jobs in resource recovery and remanufacturing. New technologies can convert food waste into organic fertilizers, biomaterials, medicines, and bioenergy.

These opportunities are particularly relevant for emerging economies with high food processing waste and underdeveloped infrastructure to manage it. On the technical side, business opportunities exist in agri-technology repair and maintenance, reuse and redistribution, refurbishment and remanufacturing, and recycling – leading to decent work, new businesses, and improved incomes.

The transition to a circular economy must be considered at the design stage to eliminate pollution and waste, preserve value over time, and avoid using non-renewable resources. Scaling existing solutions requires the commitment of all stakeholders across the value chain, with developing countries poised to lead this change.

The circular economy reframes value creation in a context of abundance rather than scarcity. Shifting the perspective from viewing by-products as waste to seeing them as resources opens opportunities for innovative, value-added products. This diversification can expand product offerings in new markets, particularly at the local level, and help rebalance long-standing power dynamics within value chains.

BOX A.3
Benefits of circular economy in the coffee sector

- Increased resource efficiency
- Sustainable management of biological waste from coffee processing
- Reduction of environmental footprint
- Climate change mitigation and adaptation
- Innovation and new market opportunities
- Reduction of packaging waste
- Long term improvements to soil health
- Healthier ecosystems and water systems
- Alignment with UN Social Development Goals

A.7 Circular economy policies and initiatives

Several European countries have launched circular economy initiatives. In March 2020, the European Commission adopted the new Circular Economy Action Plan (CEAP) as a key component of the European Green Deal, Europe's agenda for sustainable growth. The EU's transition to a circular economy aims to reduce pressure on natural resources, create sustainable growth and jobs, and achieve the EU's 2050 climate neutrality target while halting biodiversity loss. The action plan includes initiatives covering the entire life cycle of products. In 2023, the Commission updated its circular economy monitoring framework, adding new indicators for material footprint, resource productivity, and consumption footprint to better track material efficiency and EU consumption.

The upcoming European Union Circular Economy Resource Centre exemplifies the EU's commitment to advancing circularity globally, facilitating the transition to sustainable, climate-neutral societies. This centre aims to mobilize EU expertize, policies, standards, technologies, business models, and practices, promoting learning and exchange with partners across the Neighbourhood,[3] Asia, Africa, and Latin America.

In the Global South, numerous initiatives are underway. Brazil has placed a circular economy at the core of its 2024 G20 presidency, outlining a roadmap on waste management and circular practices. Brazil's National Strategy for Circular Economy (ENEC) aims to transition from a linear production model to a circular economy by promoting efficient use of natural resources, redesigning production chains, and encouraging nature regeneration.

The African Development Bank established the Africa Circular Economy Facility (ACEF) in 2022, the only trust fund dedicated to mainstreaming the circular economy as an inclusive green growth strategy in Africa. ACEF accelerates Africa's transition to a circular economy through three key areas: building institutional capacity, energizing the private sector, and advocating for the integration of circular economy principles into national policies. The facility has assisted countries such as Ethiopia, Cameroon, Uganda, Benin, and Chad in designing circular economy roadmaps and has supported 30 circular economy startups across Côte d'Ivoire, Rwanda, and Ghana. Additionally, it bolsters the African Circular Economy Alliance, a platform enabling African governments to integrate circular approaches into their economic development strategies.

India's approach to circularity and bioeconomy sets strict renewable energy targets, promotes biogas and other high-value products, and replaces fossil fuels in cooking, with a focus on empowering women and rural communities. Indonesia, following its Vision Indonesia 2045, is developing a National Circular Economy Roadmap, guided by the next National Medium Term Development Plan 2025–2029. Five sectors – wholesale and retail trade, textiles, construction, electronics, and food and beverage – have been identified as having the most potential for the country's circular transition.

On the policy front, the G7 Summit in June 2024, under Italy's presidency, included coffee in its Apulia G7 Leaders' Communiqué, supporting multi-stakeholder programmes to advance policy, investment, research, innovation, and partnerships for the circularity and sustainability of global coffee value chains. This includes exploring the feasibility of establishing a global public-private fund on coffee to support smallholders and family farmers.

This G7 decision builds on the Ministers of Climate, Energy, and Environment Communiqué, which announced a public-private partnership initiative for sustainable, resilient, circular, and regenerative coffee value chains. The upcoming G7 Ministerial meeting in October 2024 is expected to discuss this proposal in more detail.

FIGURE A.5
International standards on circular economy

Source: Adapted from International Organization for Standardization (2024). Circular economy – Vocabulary, principles and guidance for implementation (ISO Standard No. 59004:2024). https://www.iso.org/standard/80648.html

3 The **European Neighbourhood Policy (ENP)**, a specific EU policy framework that guides relationships with neighbouring countries in Eastern Europe, the Southern Mediterranean, and the Middle East.

Many other countries are also focusing on circularity, regenerative practices, and bioeconomy, but a comparative analysis is beyond the scope of this report.

In May of 2024, the International Organization for Standardization published three international standards designed to guide organizations in implementing circular economy principles. This set of standards officially defines the circular economy as an economic system that adopts a systemic approach to ensure a continuous, circular flow of resources. This definition highlights the importance of recovering, retaining, and even enhancing the value of resources, thereby fostering an economy that not only optimizes resource utilization but also aims to reduce environmental impacts, actively contributing to sustainable development. Moreover, this definition nurtured the proposed definition of a circular economy in the coffee sector adopted by the C4CEC.

The systemic approach emphasized in the definition of a circular economy suggests a holistic perspective on the interactions and relationships among various stakeholders and across different stages of the product life cycle or value chains. Through strategic planning and collaboration among businesses, governments, and consumers, it is possible to foster an economic environment that promotes innovation, social responsibility, and a shared commitment to sustainable practices, ultimately leading to a more equitable and sustainable future.

PART II
SECTION B
Breaking down sustainability across the coffee value chain

This section reveals the untapped potential of coffee by-products, highlights the environmental challenges of coffee production, and advocates for regenerative agriculture and circular packaging to boost sustainability and ecosystem health.

Key findings

- **86% of the coffee cherry** is typically discarded as agricultural waste or by-products.
- **Over 40.68 million tonnes of biomass** are generated by coffee processing annually.
- **72% of coffee's renewable, organic material is generated in coffee-growing countries**, representing 29.34 million tonnes of materials with underutilized productive and income-generating potential.
- **Coffee by-products include** the skin, pulp, mucilage, parchment, husk, silverskin, and spent coffee grounds – all these have unique compounds with value addition potential.
- **Research and innovation are yielding creative solutions** that give new value to coffee by-products and help diversify income sources and businesses while benefiting the environment.
- **Mismanagement of biological waste** contributes to water pollution, oxygen depletion, ecosystem damage, and greenhouse gas (GHG) emissions.
- **The excessive use of agri-chemicals in conventional agricultural** production can lead to soil erosion, loss of natural fertility and plant-available nutrients, and loss of natural pest and disease control capacity.
- **A key circular feature in agricultural production** is regenerative agriculture, which combined with local approaches for coffee processing, can add value for coffee-growing communities.
- **Regenerative agriculture and agroforestry in coffee cultivation** can improve the health and longevity of crops, people, and the ecosystem in the long term.
- **Circular packaging involves waste-efficient design** that minimizes raw material use as much as possible, with reuse and recycling promoted at end use.

B.1 Resource efficiency from bean to cup

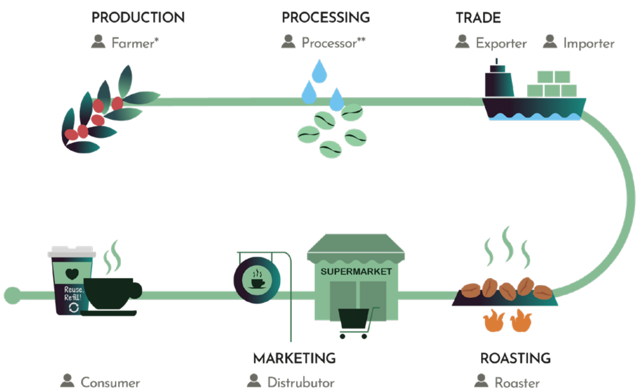
Coffee distinguishes itself from other commodities by its complex processing requirements, which prevent it from being simply packed for immediate sale or consumption, whether domestically or internationally. After harvest, various methods of primary processing are employed to remove the outer layers of skin and pulp from the coffee cherry, followed by drying the two beans contained within.

Once dried, the parchment, or outer skin of the bean, is mechanically removed. The beans are then sorted based on criteria like size and density. Further processing may be conducted to eliminate defective beans caused by insects or disease. At this stage, the coffee is ready for roasting and packaging, either as whole beans or ground coffee for sale to the final consumer.

Producers generally export little roasted coffee, with most coffee shipped as raw "green" beans to consuming countries. In these markets, the beans are roasted, packaged, marketed, and sold primarily through supermarkets, coffee shops, and increasingly through various e-commerce platforms.

The C-GVC comprises five main categories: production, processing, trade, roasting, and marketing, each representing key stakeholder roles within the value chain. Figure B.1 provides a more detailed view of the value chain, illustrating its complex roles and evolving dynamics (International Trade Centre, 2021).

FIGURE B.1
The coffee value chain, from producer to consumer

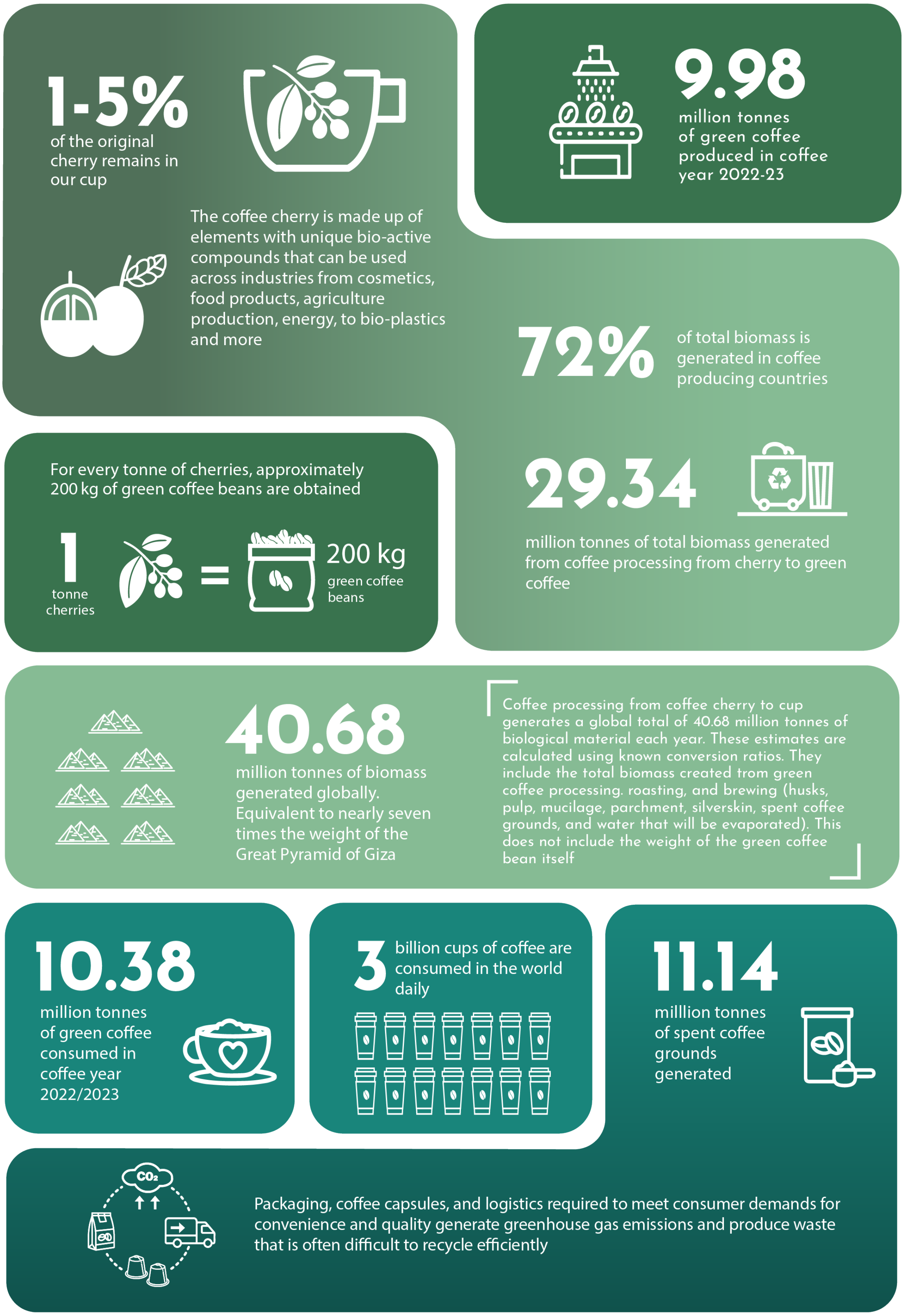


* **Producers include:** Small, medium-sized, large farms
** **Processors include:** Cooperatives, private and governmental structures

Source: International Trade Centre (2021). *The Coffee Guide, 4th Edition.*

FIGURE B.2

Global biomass generated through coffee processing, coffee year 2022-2023



Note: With contributions from ITC Coffee Guide Network Circular Economy Working Group and C4CEC (2024).
NB (1): These calculations are made using ICO production and consumption statistics from coffee year 2022/2023. Known conversion rates from Oliveira, et al. (2021) are applied. See Annex A.2 for detailed calculations.
NB (2): These calculations include the total biomass created from green coffee processing, roasting, and brewing: husks, pulp, mucilage, parchment, silverskin, and spent coffee grounds. It includes moisture weight (30% of total) that will be evaporated but does not include the weight of green coffee bean itself or material from coffee pruning. Although these calculations are approximations and do not account for differences in coffee varieties, production efficiencies, or natural variances, they provide a useful estimation of the volume of waste generated throughout the coffee production process. This highlights the potential for revaluing what is often considered waste, transforming it into new products or energy sources.

To gain a comprehensive understanding of the challenges and opportunities associated with coffee by-products, as well as to provide an approximate quantification of these by-products, data from the 2022/23 coffee year has been utilized. The authors of this report integrated this data with literature estimates on the percentages of each by-product generated during various processing stages (Oliveira et al, 2021) to produce new estimates for the main biological by-products generated through coffee processing, as detailed in Sections B.1.1 and B.1.2.

As indicated in Section D, the ICO figures show that approximately 165.5 million (60 kg) coffee bags were produced in coffee year 2022/2023, corresponding to approximately 47.29 million tonnes of coffee cherries and 9.93 million tonnes of green coffee, including both Robusta and Arabica. According to data from the ITC Data Aggregation Working Group, in coffee year 2021/2022, approximately 69% of the coffee produced was processed using the natural method, while the remaining 31% was processed using either a washed or semi-washed method (International Trade Centre and International Coffee Organization, 2023). Despite limitations regarding data precision, these figures offer a reasonably accurate depiction of coffee volumes.

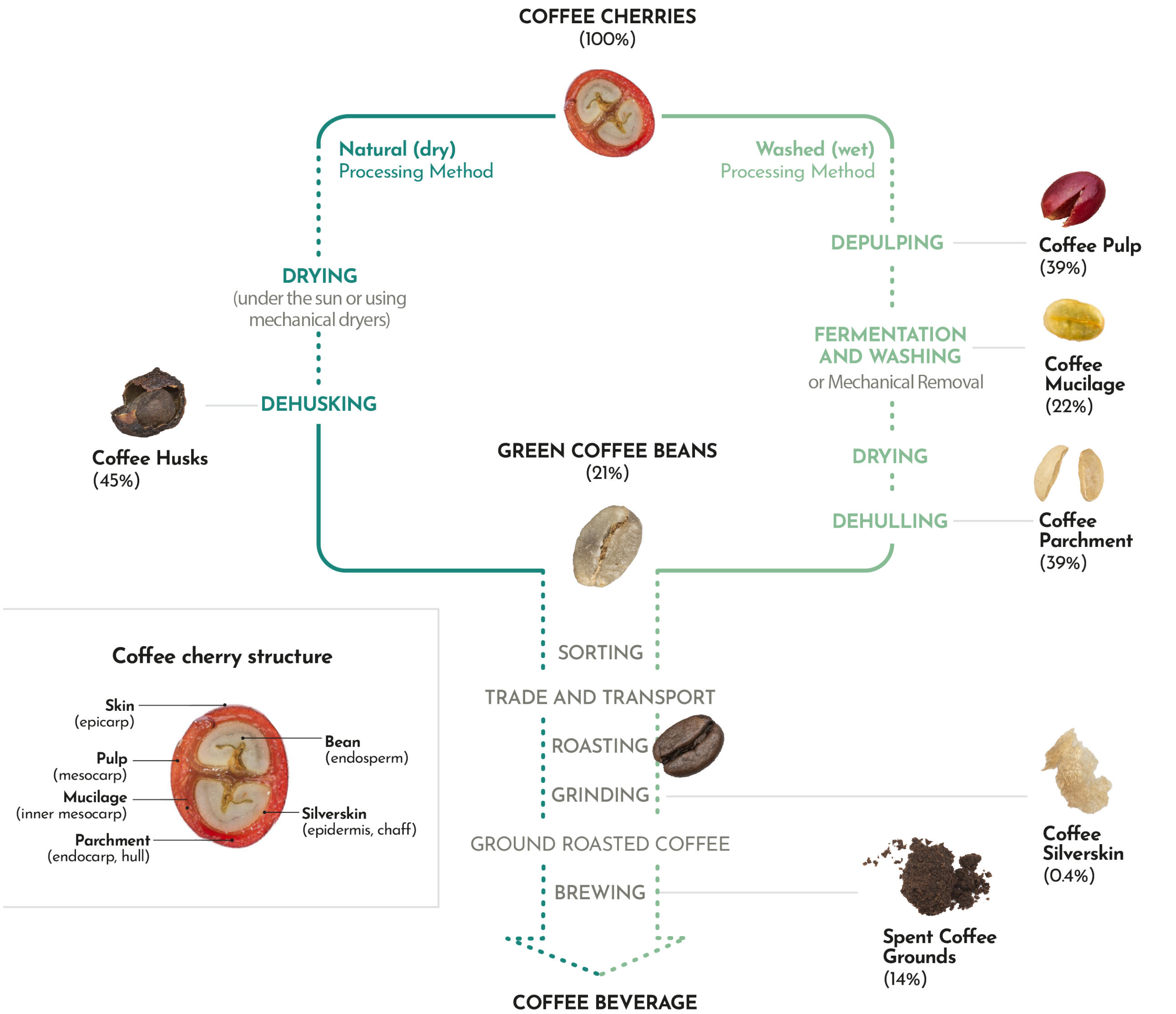
B.1.1 From cherry to green coffee

For coffee cherries processed using the natural method, approximately 32.63 million tonnes of cherries yield around 14.68 million tonnes of coffee husks (45%) and 6.92 million tonnes of green coffee (21%). The remaining weight (34%) corresponds to the moisture lost during the drying process.

In the washed processing method, each tonne of cherries processed generates a comparable volume of by-products, including coffee skin, pulp, mucilage, and parchment. This totals approximately 14.66 million tonnes of by-products. After removing moisture, these by-products amount to about 6.80 million tonnes of dry material, representing 46% of the original weight of the cherries. This figure closely aligns with the 45% conversion rate of coffee cherries to coffee husks observed in natural processing.

Overall, the various processing methods from cherry to green coffee for export produced approximately 29.34 million tonnes of biomass, which accounts for around 62% of the weight of the harvested coffee cherries in the 2022/2023 coffee year.

FIGURE B.3
Coffee cherry structure and by-products from coffee processing



Note: Adapted from Oliveira, et al. (2021).
NB: Schematic representation of the coffee cherry structure and coffee processing-derived by-products. The percentages refer to the amount of each by-product obtained from fresh coffee cherries.

B.1.2 From green coffee to consumption

Global coffee consumption for the 2022/2023 coffee year reached 173.0 million bags, equivalent to 10.38 million tonnes of green coffee, as analysed in Part D.

From this consumption, the roasting process yielded 0.20 million tonnes of coffee silverskin – equivalent to 0.4% of the cherry's weight and 1.7% of the green coffee bean. Additionally, brewing produced 11.14 million tonnes of spent coffee grounds (including 61% moisture), which translates to roughly 6.92 million tonnes of dry material.

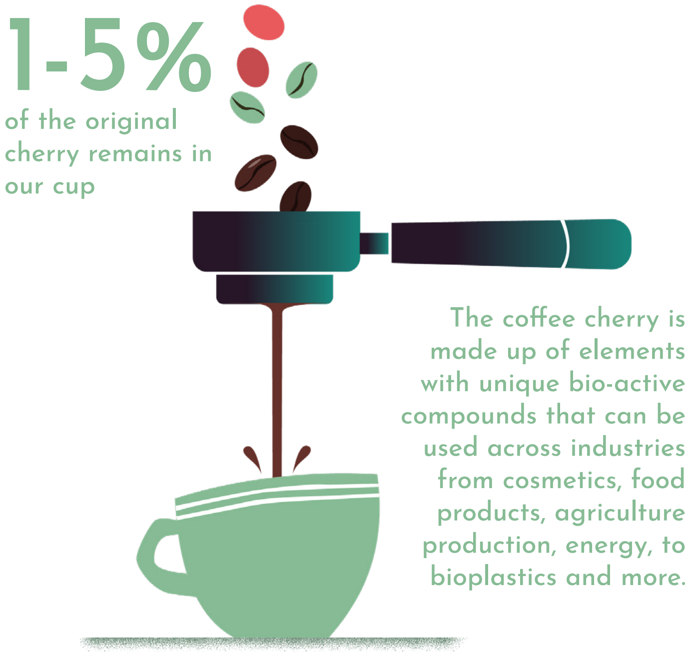
In total, over 86% of the coffee cherry's matter becomes by-product or waste, generating 40.68 million tonnes of biomass, excluding green coffee. This figure also excludes valuable biomass from coffee tree pruning, such as hardwood and leaves. When moisture is removed, the dry weight of these by-products reduces to 28.6 million tonnes, or 60% of the original biomass.

It is important to note the limitations of this calculation. The estimates do not account for the differing masses of Arabica and Robusta beans, variations in the efficiency of production processes, or natural and procedural differences that affect the weight of the products and their respective by-products. Nevertheless, these calculations provide a useful indication of the biomass generated and highlight the value of waste that often goes unnoticed throughout the journey from coffee farm to the final cup – and beyond.

B.1.3 Opportunities for transformation

The entire coffee plant offers valuable attributes that can be utilized across various industries and products. The coffee cherry, in its entirety – from the skin, pulp, mucilage, and parchment to the husk, silverskin and spent coffee grounds – contains unique compounds that can serve multiple purposes.

FIGURE B.4
Percentage of coffee cherry in the cup



Source: Mendes dos Santos et al., (2021).

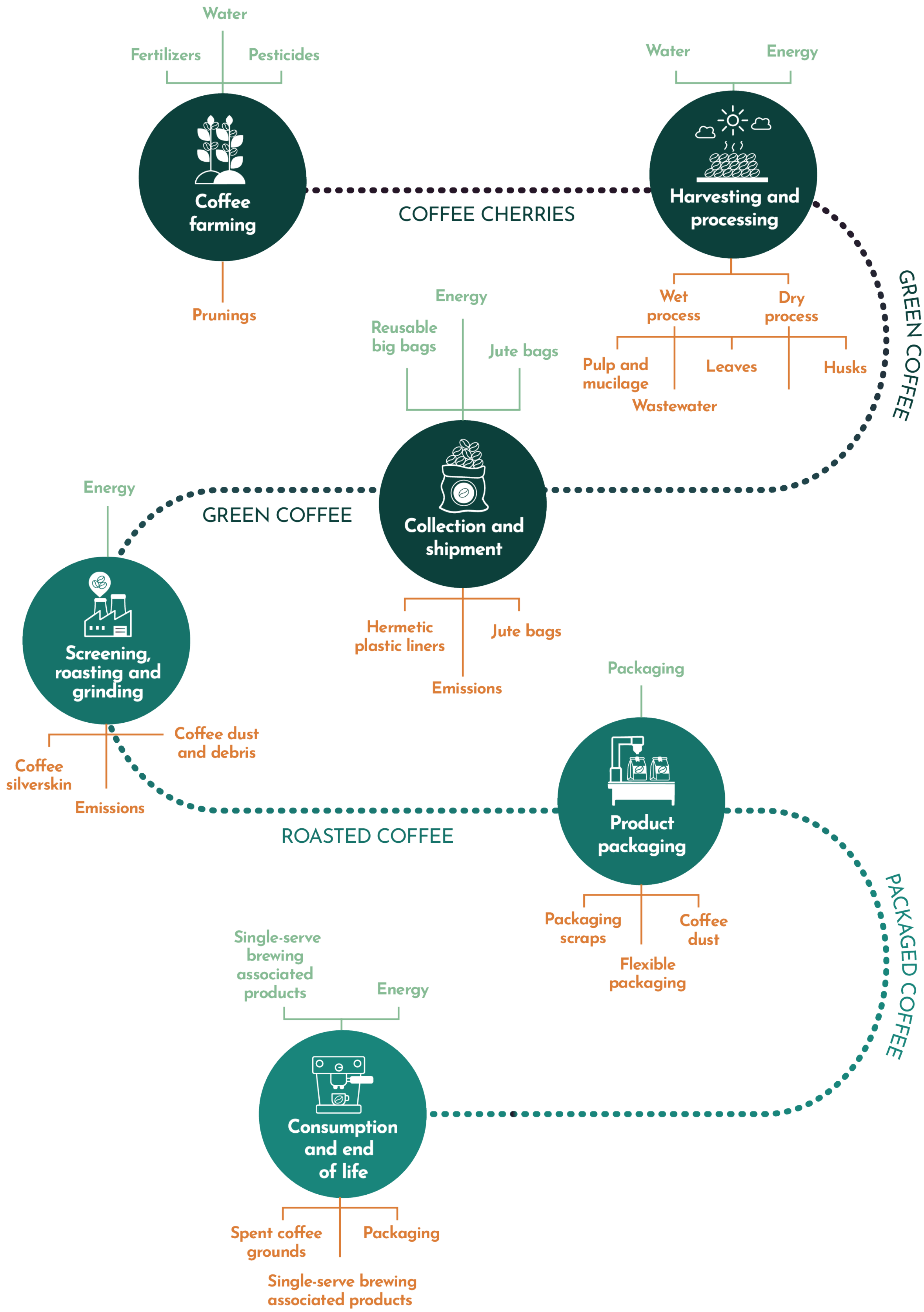
FIGURE B.5
Coffee by-products and their chemical compounds

CHEMICAL COMPOUNDS OF BY-PRODUCTS	HUSK	PULP	SILVERSKIN	SPENT COFFEE GROUNDS
ASH	5.4% - 6.2%	7.3%	7.34% - 10.5%	0.47%
CAFFEINE	1%	1.5%	0.6% - 1.1%	0.02%
CARBOHYDRATE	58% - 85%	21% - 32%	0.2%-6.3%	
CELLULOSE	43%	63%	17.8%	8.6%
CHLOROGENIC ACID	2.5%	2.4%	3%	2.3%
FAT	0.5%	2% - 7%	2.2%	2.3%
HEMICELLULOSE	7%	2.3%	13.1%	36.7%
LIGNIN	9%	14.3% - 17.5%	1%	0.05%
LIPIDS	0.5% - 3%	2%-7%	3%	16%
MINERALS	3% - 7%	9%	8%	0.8%-3.5%
MOISTURE	13% - 15%	82.4%	5% - 7%	74.7%
PROTEIN	8% - 11%	5%-15%	20%	10.3%
TANNINS	5%	3%	0.02%	0.02%
TOTAL FIBRE	24% - 30.8%	60.5%	60%	43%
TOTAL PECTIC SUBSTANCES	1.6%	6.5%	0.02%	0.01%

Source: C4CEC (2024).
Note: Based on data from Mendes dos et al. (2021).

Research and innovative entrepreneurs are actively exploring developing solutions to add new value to process outputs. These efforts contribute to the creation of new products and materials that, when properly designed and implemented, can foster local development and generate additional income sources.

FIGURE B.6
Opportunities to add value, reuse or reduce waste in a coffee value circle



Source: ITC, Making a Case for Circular Economy in Coffee: Insights from the multi-stakeholders working group on circular economy in coffee (2024).

The following section highlights some examples and case studies of circular practices and innovations that utilize coffee by-products. More examples of good practices throughout the coffee sector can be found at the C4CEC online platform:

https://www.circulareconomyincoffee.org/

B.2 Circularity in the Coffee Global Value Chain

This section highlights the concept of circularity within the C-GVC, emphasizing both the challenges and opportunities for integrating circular economy principles across the entire lifecycle of coffee production. From cultivation, where regenerative agricultural practices like agroforestry can help restore biodiversity and reduce environmental impacts, to post-harvest processing that generates significant by-products with potential for reuse, such as coffee pulp and mucilage, each stage offers avenues for improvement. Challenges like the high carbon footprint of trade and transport, especially in packaging and logistics, are offset by innovations in sustainable materials and methods. Roasting and packaging, while resource-intensive, present opportunities to adopt energy-efficient technologies and reduce waste through circular design. Finally, consumption and end-of-life management, particularly for packaging, underscore the need for recyclable, compostable solutions to minimize environmental damage. The following sections explore these stages in greater detail, beginning with farming and production practices.

B.2.1 Farming and production

Originally, coffee thrived naturally within diverse ecosystems, growing wild as a forest shrub or intercropped in the understory of multi-layered, shade-covered plots. This agroforestry system supported biodiversity and provided essential ecosystem services – regulating pests and diseases, maintaining soil health, and cycling water and nutrients. However, due to rising global demand, coffee cultivation has increasingly shifted towards intensive agricultural practices, moving away from these sustainable methods.

As global demand for coffee surged, the focus shifted to intensive production systems that prioritized high yields above all else.

While this approach has temporarily increased coffee stocks to meet growing demand, it has come at a significant environmental cost. The excessive use of chemical fertilizers, pesticides and herbicides in conventional agricultural practices has led to soil erosion, loss of natural fertility, and depletion of essential plant nutrients. These practices have also contributed to the deterioration of soil structure and water holding capacity, as well as reduced the biodiversity necessary for effective pest and disease control (Gliessman, S. R., n.d.).

Moreover, pesticide use carries a 45% chance of contaminating surface water and a 24% chance of contaminating groundwater (De Queiroz et al, 2018). Together, these factors have contributed to a sharp rise in GHG emissions and the overall carbon footprint of conventional coffee production. Additionally, nutrient runoff can lead to eutrophication, impacting both fresh water and marine ecosystems.

Coffee plants thrive in highland regions of tropical and subtropical climates and are farmed commercially on 12.5 million farms across more than 50 countries in Latin America, Africa, and Asia, covering over 10.6 million hectares worldwide (International Trade Centre, 2021). Integrating agroforestry and regenerative agriculture offers a substantial opportunity to create positive environmental impacts for the coffee sector overall.

B.2.2 The consequences of coffee cultivation

The environmental and social impacts of coffee cultivation can vary considerably by farm and location, depending on how farms are managed and how ecosystems are maintained. Coffee farming carries a considerable burden of potential environmental and social consequences due to the resources required for coffee cultivation, regardless of farm size (Bunn, C., Läderach, P., Ovalle Rivera, O., 2015). Currently, approximately 24% of the world's coffee area is managed under diverse shade, while 35% is under limited shade – a decrease of around 20% since the 1990s.

Various studies estimate that global coffee cultivation and processing account for approximately 40-70% of CO_2 emissions throughout the coffee lifecycle.

This figure varies depending on numerous factors, including growing practices, post-harvest processing, brewing techniques, and technology (Thoden van Velzen et al, 2023 and Quantis Environmental Consulting, 2023, n.d.) The carbon footprint for 1 kg of fresh coffee cherries ranges from 0.26 and 0.67 kg CO_2e for conventional systems, and from 0.12 and 0.52 kg CO_2e for organic systems. The primary driver of GHG emissions across all management systems is the use of organic and inorganic nitrogen inputs (Nopenen et al, 2012).

Research consistently shows that the cultivation and consumption stages account for the largest portion of environmental impacts within the C-GVC (Nab and Maslin, 2020).

For instance, Brommer et al. (2011) estimated the GHG emissions associated with preparing 2,000 cups of coffee (keep 125 ml together) typically consumed annually in German households. The agriculture phase accounted for 55.4% of total GHG emissions, followed by the consumer and post-consumer phases (36%), coffee roasting, packaging, and distribution (6.6%), and overseas transportation (1.9%) (Brommer et al., 2011).

A recent study (Cibelli et al., 2024) estimates the carbon footprint of coffee consumption, identifying the green coffee production phase as the primary hotspot, accounting for 59% to 70% of the cradle-to-grave carbon footprint.

The use phase represents a secondary hotspot, contributing to 12.5% to 18.2% of emissions (Cibelli et al., 2024). Additionally, PCF Pilotprojekt Deutschland (2008) estimated that 55% of coffee production's carbon footprint comes from cultivation and on-farm processing, 30% from consumption, and the remaining 15% from transport, processing, and waste disposal (PCF Pilotprojekt Deutschland, 2008).

It is important to note the wide range of findings across these studies, which can be attributed to several key factors. Variations in farm size, coffee varieties, and whether farms employ conventional, organic, or regenerative practices significantly influence outcomes. Furthermore, the cultivation location, traditional processing methods, beverage volumes (ranging from 40-237 ml), and packaging choices (e.g., pods, capsules, or various materials) all play a role. The brewing method used by consumers and the energy efficiency of the appliances also significantly affect the environmental impact during the use phase. Methodologies for measuring carbon sequestration can vary considerably, particularly in tropical systems, which influences assessments of net carbon emissions versus carbon sequestration.

Coffee production and processing require substantial amounts of water for irrigation and processing, as well as fertilizers to boost crop yields and pesticides to protect plants from diseases, especially on large-scale farms.

On average, the water footprint for a 125-millilitre cup of coffee is 132 litres (Water Footprint Network, n.d.). Effective management of these inputs, coupled with sustainable agricultural practices, could significantly mitigate negative impacts on local ecosystems, such as water scarcity, soil contamination, land degradation, deforestation, and biodiversity loss. Overall, the coffee value chain contributes to climate change, as coffee is a nitrogen-intensive plant with a long and complex production process that requires energy-intensive preparation for consumption (Birkenberg el al., 2021; Kilian et al., 2013). Sustainable farming practices are critical for ensuring the long-term sustainability of the sector.

Moreover, coffee production faces significant challenges related to unequal value distribution, which often fails to ensure a decent living income for famers and secure adequate living conditions for coffee producers and workers.

BOX B.1
A living income for coffee farmers

A primary challenge for coffee farmers, especially smallholders in most coffee-producing countries, is the difficulty in earning enough from coffee farming to secure a living income. A living income is defined as the earnings required by a household to ensure a decent standard of living for all members, covering essential needs such as adequate housing, education, nutritious food, clean water, healthcare, and provision for emergencies and savings –after farm costs are accounted for (Anker and Anker, 2017).

When farmers fail to earn a living income, other challenges in coffee-producing regions are often exacerbated.

Insufficient income means farmers are unable to invest properly in their farms, adopt environmentally sustainable agricultural practices, or pay fair wages to workers for essential tasks. Addressing the living income gap is therefore a critical first step in resolving broader social and environmental issues in coffee-growing communities. This is why governments in consuming countries are prioritizing the issue through legislation and declarations, while governments in producing countries are initiating national-level efforts and participating in global initiatives like the ICO's Coffee Public-Private Task Force (CPPTF).

For the ICO CPPTF, achieving a living income is seen as the first step towards long-term prosperity. By 2030, the goal is for at least half of the 42 coffee-producing countries that are ICO Members to implement initiatives aimed at closing the living income gap and fostering prosperity in coffee regions.

As part of its efforts, the ICO and its public and private partners have conducted living income benchmark studies in nine countries and have supported initiatives to better understand the cost of production and actual income levels in several of these regions. More importantly, the ICO has successfully brought together key stakeholders in at least two countries to launch initiatives aimed at closing these income gaps as part of their national coffee strategies. In 2024/25, the ICO and its CPPTF partners will focus on building a stronger case, securing necessary resources, and scaling up their approach to achieve their 2030 goal.

B.2.3 Opportunities for circularity in coffee cultivation

Coffee can be cultivated in ways that that yield positive environmental and social impacts, particularly in regions that adopt regenerative agriculture, organic practices, and agroforestry strategies. These approaches enhance the health, longevity, and productivity of coffee trees while benefiting the wider ecosystem. They promote long-term soil health, reducing the need for synthetic and organic fertilizers through practices such as cover cropping, organic fertilization, mulching of pruning residues, establishing shade canopies to enhance biodiversity, and integrating of post-harvest processing by-products into natural compost, mulch, biochar, foliar fertilizers, and biofertilizers.

Regenerative agriculture, aligned with circular economy principles, offers a holistic approach to making coffee production more sustainable. It focuses on regenerating soil health, enhancing biodiversity, protecting water sources, reducing the need for chemical inputs, and improving farming livelihoods. A key aspect of regenerative agriculture is diversification, such as increasing biodiversity with cover crops and integrating livestock farming for manure and additional income (One Planet Business for Biodiversity (OP2B), n.d.). By returning organic matter such as coffee pulp and husks to the soil, these practices contribute to healthier ecosystems and more sustainable food systems. Its holistic approach also helps diversify farmers' incomes, improves food security, and increases climate resilience, reducing the carbon footprint of coffee farming.

BOX B.2

OP2B working definition of regenerative agriculture

"Regenerative agriculture is a holistic, outcome-based farming approach that generates agricultural products while measurably having net-positive impacts on soil health, biodiversity, climate, water resources and farming livelihoods at the farm and landscape levels. It aims to simultaneously promote above and belowground carbon sequestration, reduce greenhouse gas (GHG) emissions, protect and enhance biodiversity in and around farms, improve water retention in soil, reduce pesticide risk, improve nutrient-use efficiency and improve farming livelihoods."

- One Planet Business for Biodiversity (OP2B)

As a result, regenerative agriculture offers the potential to diversify income streams and crop varieties, while simultaneously enhancing food security, soil quality, biodiversity, and climate resilience. Organic matter from coffee cherry processing, pruning, and cover crops plays a crucial role in fertilizing coffee plants, particularly when integrated with other sustainable farming practices. This holistic approach reduces the reliance on chemical inputs, promotes carbon insetting, and improves both soil health and tree vitality over time.

Regenerative practices in coffee go beyond reducing negative impacts – they actively restore ecosystems, communities, and the broader coffee system.

In practice, regenerative agriculture for coffee includes mulching, intercropping and cover crops, promoting plant diversity, integrating livestock farming, and implementing integrated weed and pest management (Pulleman, Rahn, and Valle, 2023). Vermiculture, which utilizes coffee pulp, husks, and spent coffee grounds, effectively converts coffee by-products into high-value compost. Farmers participating in a vermiculture project in Ethiopia reported that this solid biofertilizer not only maintains soil fertility but also increases the water retention and outperforms commercial synthetic fertilizers and traditional compost (Pulleman, Rahn, and Valle, 2023). In Brazil, the coffee leaf miner pest, which causes significant crop losses, can be managed through resistant cultivars, biological control, and cover crops (Dantas et al., 2021).

To facilitate the broader adoption of regenerative practices, it is essential to promote and financially incentivize coffee farmers through shared-value approaches, encouraging sustainable farming practices on a larger scale.

This is especially important as it addresses the urgent need to invest in rejuvenating old, low-yield coffee plantations by adopting new climate-resistant varieties and sustainable agricultural practices.

The Interprofessional Council of Cocoa and Coffee (CICC) in Cameroon is working to optimize coffee processing and refine harvesting techniques to enhance both the quality and efficiency of its Robusta coffee production. To support this effort, ITC's "ACP Business-Friendly" programme is facilitating a technical exchange between Robusta coffee value chain stakeholders from India and Cameroon, including the Central Coffee Research Institute of India (CCRI) and the coffee roaster BerryCo.

These initiatives embrace circular economy principles by utilizing tree pruning and shade trees for drying racks instead of plastic netting and treated wood. They also include testing anaerobic, natural, and honey processing methods to enhance quality while reducing water usage. Additionally, they are experimenting with *cascara* production and implementing traditional techniques, such as placing pits and clay pots in the ground to capture rainwater for plants, as practised in India (International Trade Centre, n.d.).

The methods and environment used in coffee farming significantly influence the carbon footprint. Polyculture practices – where coffee is grown alongside other plants that provide shade and facilitate beneficial nutrient exchanges – result in a lower average carbon footprint compared to monocultures. According to Van Rikxoort et al. (2014), the carbon footprint for polycultures ranges from 6.2-7.3 kg of CO_2 equivalent per kg of parchment coffee, while for monocultures, it is around 9.0-10.8 kg of CO_2 equivalent. Traditional polycultures also store significantly more carbon in vegetation, with an average of 42.5 Mg per hectare compared to just 10.5 Mg for unshaded monocultures.

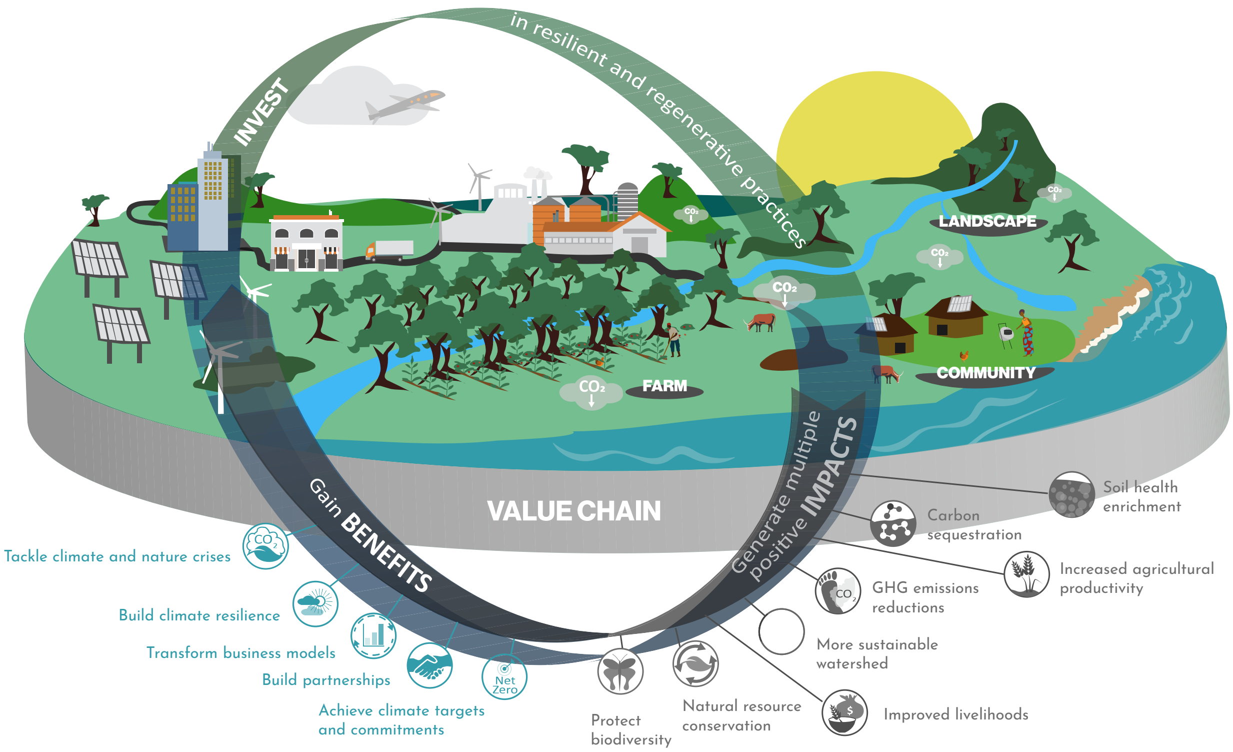
Reducing GHG emissions from agriculture and land use is crucial for the coffee sector's collective response to climate change. There remains considerable potential for agriculture and land use to not only cut GHG emissions but also serve as "sinks" that capture and store excess atmospheric carbon dioxide (CO_2) (International Trade Centre, 2021). To unlock this potential, developing shared value mechanisms that fairly reward farmers for regenerative practices is essential.

One effective strategy is carbon insetting, which involves investing in GHG emissions reduction and carbon storage within a company's own supply chain. This can be achieved by supporting farmers and communities in adopting regenerative agricultural and agroforestry practices.[4] Companies and nonprofits are piloting mechanisms to accurately record and reward the carbon storage achieved by producers within their supply chains. However, it is important to know that carbon insets may not fully recognize the value of ongoing stewardship under best practices, as they primarily account for changes in landscapes rather than the continuous improvements made by farmers.

ACORN Rabobank provides a direct marketplace for carbon removal units generated through the agroforestry practices of smallholder farmers, leveraging remote sensing technology. The philosophy behind ACORN is to compensate farmers for the climate-smart practices they adopt and to facilitate their transition to agroforestry. Its partnership model prioritizes carbon insetting, ensuring that the benefits and incentives

4 International Platform for Insetting. https://www.insettingplatform.com/insetting-explained/

FIGURE B.7
What is insetting?



Source: International Platform for Insetting (IPI).
N.B: The IPI is a business-led organization which advocates for climate action at the source of global value chains.

remain within the coffee value chain. As of August 2024, the ACORN model has generated over 30,000 Carbon Removal Units (CRUs) resulting in 7.9 million euros in carbon credits, with 80% of this value flowing directly to farmers (Rabobank, n.d.).

A pilot project funded by the Inter-American Development Bank used the Cool Farm Tool to assess the carbon footprint of 370 farms across six organic smallholder producer organizations in Honduras, Peru, and Guatemala. According to Cooperative Coffees, the commercial partner in this initiative, the results showed that the majority of the sampled coffee farms operated either carbon negative (55%) or carbon neutral (20%), with a median carbon footprint of -0.6 kg of carbon dioxide equivalent (CO_2e) per kg of coffee green bean equivalent (GBE). Cooperative Coffees provided carbon-based payments to cooperatives at a rate of $66 per tonne sequestered, resulting in total payments of $160,000 (Cool Farm Tool Impact Report, 2023).

Key insights from Cooperative Coffees indicate that regenerative organic agriculture can enable coffee production to be carbon neutral or even carbon negative, though often at a higher cost. Additionally, a narrow focus on emissions reductions overlooks the broader ecosystem benefits. The Greenhouse Gas Protocol standards identified that the primary determinant of carbon outcomes was whether trees had been planted or removed in the past 20 years, regardless of illegal logging by previous owners or the implementation of agroforestry practices (Root Capital, 2023). As a result, Cooperative Coffees has shifted its emphasis from simply achieving carbon neutrality to what it calls “regenerative trade,” a model that rewards producer partners for their long-term regenerative efforts and encourages investments that go beyond carbon metrics alone (Cooperative Coffees, n.d.).

B.2.4 Post-harvest processing

The post-harvest stage is a crucial part of the coffee production process, as it significantly influences both the final quality of the coffee and its environmental impact. This section explores various coffee processing methods, with an emphasis on circularity within the value chain. By examining traditional methods like natural and washed processing alongside innovative hybrids like honey processing, this section underscores how geography, climate, and resource availability critically influence post-harvest techniques. These methods have profound implications for the environment, influencing factors such as water usage, waste generation, and energy consumption. As we delve into each method and its broader impacts, the following subsections will examine the specific processes, environmental considerations, and opportunities for valorizing by-products to create more sustainable and efficient production systems.

B.2.4.1 Coffee processing and related methods

The next stage in coffee production is post-harvest coffee processing, which primarily utilizes two methods determined by the geographic and climatic conditions of the coffee’s country of origin: natural processing and washed processing.

Post-harvest processing methods vary based on factors such as water availability, climate conditions, and the desired cup quality profile. The chosen method can significantly impact the environment and is influenced by geographic location, traditional practices, market demand, and target market segment. Washed processing is typically employed in regions with abundant

BOX B.3

COMSA: Regenerative agriculture on coffee farms

CASE STUDY

COMSA: Regenerative agriculture on coffee farms

Partner(s):
Cafe Orgánico Marcala, S.A. (COMSA)

Country:
Honduras

Year launched:
2013

Coffee value chain area:
Farm and production

Industry/sector:
Coffee production

Technology readiness level:
Implemented action, tested solution

Input:
Fruit and shade trees; cover crops; coffee processing residues (coffee pulp) and plant and fruit material residues on farm (leaves, coconut husks, fruit residues, other composting material); cultured native microorganisms; minerals extracted from local rocks

Output:
Organic compost, microbiological activity in the soil, improved soil composition, biodiversity, fruit and beans from agroforestry and cover crops, hardwood trees, organic and high-quality coffee

Description: COMSA, a small producer organization in Honduras, implements an intensive regenerative farming system designed to strengthen the natural immune defenses of its members' fields. Finca Fortaleza, COMSA's farmer-focused centre for experimentation and innovation, prioritizes the sustainable use of local natural resources. This site also hosts El Diplomado Organic, a week-long farmer training programme that combines theory with hands-on learning and visits to farms where these practices have already been successfully applied. The training emphasizes key techniques such as enhancing organic matter in soils, improving compost with locally produced beneficial bacteria and fungi, applying liquid compost as a biofoliar to treat coffee leaves, and utilizing mulching and cover crops to maintain soil health and moisture. COMSA also cultures native microorganisms and incorporates minerals from local rocks to further enrich soil quality.

Motive: COMSA seeks to address the pressing challenges of farm profitability and climate change adaptation faced by smallholder farmers. Viewing coffee production from a holistic perspective, COMSA recognizes that coffee trees in degraded soils or monocultures are highly vulnerable to climate shocks, such as erratic weather and disease outbreaks. Many smallholder farmers in the region struggle with limited financial resources, food scarcity, and low incomes. Through organic regenerative agriculture and agroforestry, COMSA aims to restore ecological balance while promoting the well-being of coffee producers and their families.

Challenges and lessons learned: During the coffee leaf rust crisis that impacted Central America, many organic farms within COMSA's network remained unaffected by the fungus. This success was attributed to the restoration of beneficial microorganisms and healthier soils, which enabled coffee plants to resist both disease and drought.

Economic impacts: Improved soil health has reduced the need for costly agricultural inputs, lowering expenses for farmers. Additionally, it has supported long-term profitability by enabling the production of high-quality organic coffee and creating income diversification opportunities with other agricultural products. Through a pilot project with Cooperative Coffees, COMSA secured $36,751 in carbon-based premiums for their environmental contributions.

Environmental impacts: Adopting regenerative practices has not only improved soil quality but also enhanced climate resilience, resource efficiency, and nutrient cycling. COMSA also provides a waste management system for the municipality, including recycling and biofuel production.

Social impacts: Regenerative agriculture has improved public and community health in the regions where COMSA operates. The COMSA International School offers practical, multilingual education to local children, following innovative educational models such as Glenn Doman, Waldorf, and Montessori.

Cultural, educational and awareness impacts: COMSA's approach has fostered the adoption of sustainable and innovative agricultural practices in rural Honduran communities and beyond. This model has sparked a shift towards regenerative thinking, promoting innovation, creativity, research, and on-farm experimentation. It has strengthened rural networks, built leadership and technical capacities, and created new employment opportunities for members.

water sources and is favoured for producing high-quality, bright coffees. This method is especially common in Latin American countries like Colombia and Mexico, as well as in some African nations such as Ethiopia and Kenya.

In contrast, natural processing is preferred in water-scarce regions. This technique, prevalent in countries like Brazil, Ethiopia, and Yemen, involves drying the entire coffee cherry in the sun. It is valued for its ability to produce coffee with a fuller body and complex, fruity flavours.

In addition to natural and washed methods, there are hybrid processes that combine elements of both, resulting in unique flavour profiles and addressing some of the drawbacks associated with traditional techniques. One notable hybrid process is honey processing, where the coffee cherries are pulped to remove the outer skin while retaining varying amounts of mucilage before drying. This method is particularly popular in Costa Rica, El Salvador, and some innovative farms from around the world. Honey processing is valued for its ability to produce coffee with distinct sweetness, complexity, and balanced acidity (International Trade Centre, 2021).

B.2.4.2 A breakdown of the "washed" processing method

Washed processing methods are used to remove the outer layers that protect the coffee beans inside the coffee cherries. This method involves several distinct stages to ensure the beans are thoroughly cleaned and prepared for drying.

The first stage is pulping, where coffee cherries are mechanically pressed to eliminate the outer skin and pulp. This is accomplished using a pulping machine that utilizes flowing water to facilitate the removal of the cherry's outer layer. The cherries pass through rotating drums or screens, where mechanical action, combined with water, strips away the skin and most of the fruit pulp, exposing the beans inside.

Once pulping is complete, the beans – still covered in a sticky layer called mucilage – are placed in fermentation tanks filled with water. In these tanks, natural enzymes and microbes break down the mucilage. This fermentation process can last anywhere from 12 to 48 hours, depending on factors such as temperature, altitude, and desired flavour profile. During fermentation, the beans must be regularly stirred to ensure even fermentation and prevent the growth of unwanted microorganisms.

After fermentation, the beans are thoroughly washed with clean water to remove any residual mucilage. This step is essential for ensuring the beans are clean and reducing the risk of off-flavours developing during the drying phase.

Following washing, the beans, now covered only by a thin layer known as parchment, are spread out to dry. Drying can be achieved through various methods. In sun drying, the beans are placed on large patios or raised drying beds and turned regularly to ensure even drying, which can take several days to weeks. In regions with unpredictable weather, mechanical dryers are used to expedite the drying process. The goal is to reduce the moisture content of the beans to around 10-12%, the ideal level for safe storage and further processing.

Once the beans have reached the desired moisture level, they undergo hulling. Hulling machines remove the parchment layer, revealing the green coffee beans inside. The beans are then further cleaned and sorted to eliminate any remaining impurities or defective beans. After hulling, the beans may go through a final drying phase to ensure uniform moisture content. Finally, the green coffee beans are bagged and stored in a cool, dry place until they are ready to be roasted (International Trade Centre, 2021).

B.2.4.3 Wider impacts of the washed processing method

Washed coffee processing has a significant environmental impact due to the large volume of wastewater it generates. This wastewater is highly acidic and contains a high concentration of organic matter and suspended solids, posing a risk of contaminating water systems if not properly treated.

BOX B.4
Water usage of washed coffee

Washed coffee processing consumes approximately 15 to 20 litres of water for every kg of coffee beans processed (Ijanu et al., 2020).

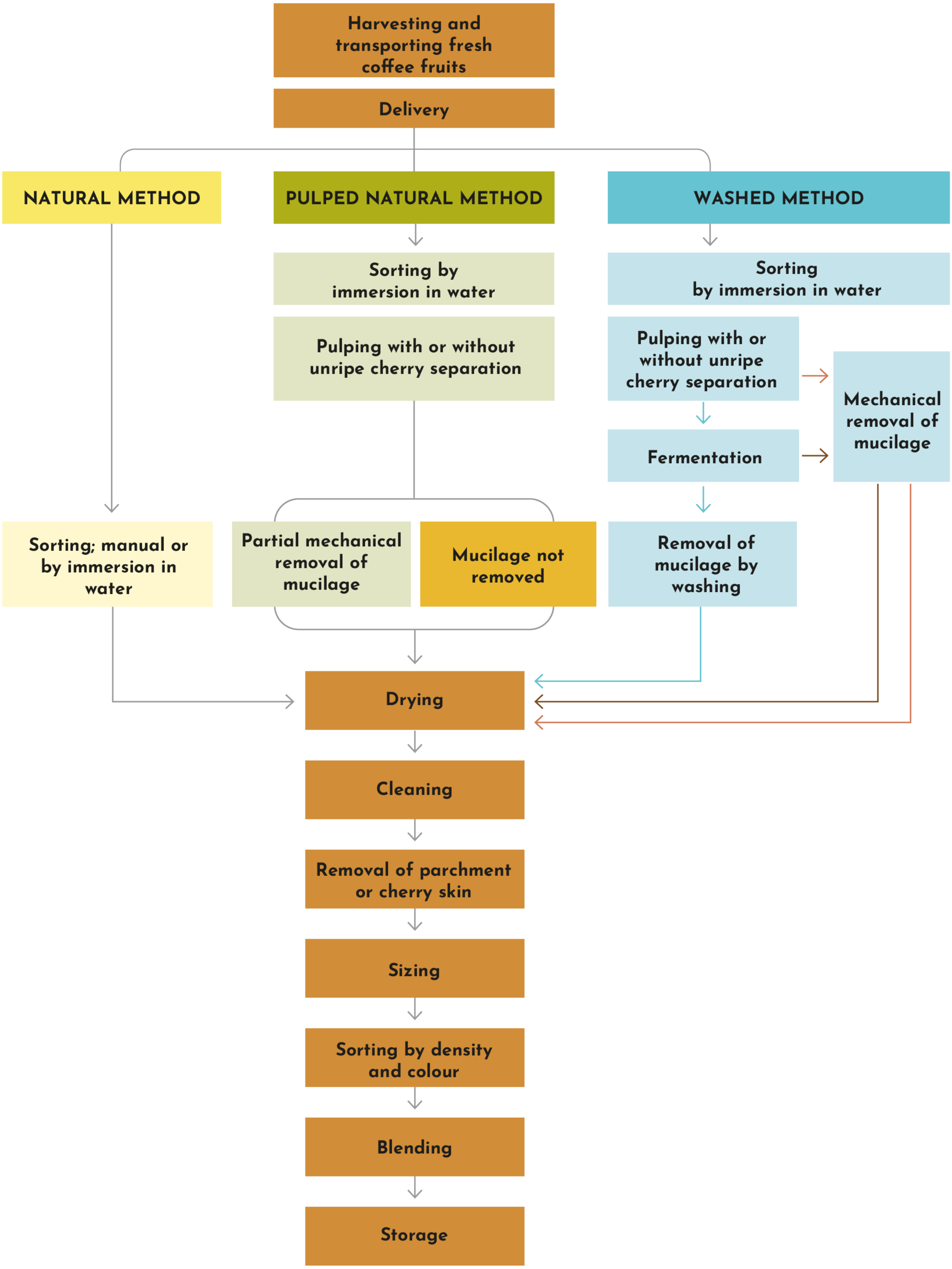
The environmental impact of washed coffee processing goes beyond high water consumption. Mismanagement of wastewater can lead to severe ecological threats. Untreated wastewater poses a significant environmental challenge, as it can pollute water sources and damage ecosystems. This wastewater often contains toxic chemicals such as tannins, phenolics, and alkaloids, which inhibit biological degradation and disrupt aquatic ecosystems, harm wildlife, and reduce biodiversity. The high biological and chemical oxygen demand from decomposing organic matter in the wastewater can deplete oxygen levels in water bodies, potentially endangering aquatic organisms (Rattan et al., 2015). Modern de-pulping equipment, such as de-mucilagers, mechanically separates the mucilage, which can generate significant water savings by eliminating the need for the fermentation step.

To address these environmental challenges, it is crucial to implement effective wastewater treatment solutions. These measures can help reduce the harmful impact of washed processing on local water systems and surrounding ecosystems. Adopting sustainable practices and innovations in wastewater management is essential to ensure the long-term viability of coffee production while protecting the environment.

B.2.4.4 The washed processing method's by-products and waste

During the washed coffee processing method, approximately 80% of the original coffee cherry's mass is converted into by-products, including coffee pulp, mucilage, and parchment.

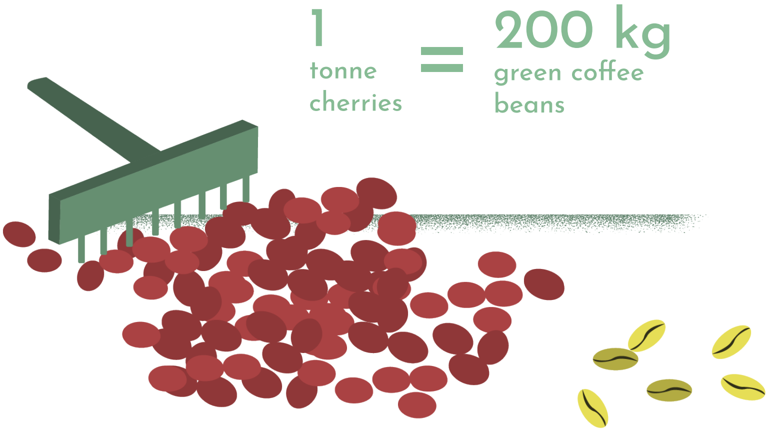
FIGURE B.8
An overview of coffee processing



Source: : International Trade Centre (2021). *The Coffee Guide, 4th Edition.*

FIGURE B.9

Every tonne of cherries obtains approximately 200 kg of green coffee beans



Note: Adapted from International Trade Centre (2024).

Coffee pulp, which includes both the skin (epicarp) and the pulp between the skin and the seed (mesocarp) of the coffee cherry, makes up about 39-43% of the coffee cherry's total weight (Oliveira et al., 2021; Bressani, 1978). This by-product is rich in carbohydrates, accounting for 21 to 32% of its composition. It also contains 6.5% total pectic substances, 12.4% reducing sugars, and 2% non-reducing sugars. The protein content varies between 5 and 15%, minerals make up 9%, and fats range from 2 to 7%. Additionally, coffee pulp is abundant in bioactive compounds, including 3% tannins, 2.4% chlorogenic acids, 1.6% caffeic acid, and 1.5% caffeine, which contribute to its nutritional and biochemical profile,making it a valuable material for a variety of product applications and worthy of additional studies (Mendes dos Santos et al., 2021).

Physically, coffee pulp has a soft, fibrous texture and can range in colour from green to brown. While no studies have provided specific data on the toxicity of coffee pulp, its composition – particularly the presence of bioactive compounds like caffeine and tannins, along with potential mycotoxin contamination and microbial deterioration – raises safety concerns. This highlights the need for further research to ensure the safe handling and potential consumption of this by-product (Klingel et al., 2020).

FIGURE B.10

Chemical compounds of coffee pulp (wet processing method)

CHEMICAL COMPOUNDS OF BY-PRODUCTS	PULP
ASH	7.3%
CAFFEINE	1.5%
CARBOHYDRATE	21% - 32%
CELLULOSE	63%
CHLOROGENIC ACID	2.4%
FAT	2% - 7%
HEMICELLULOSE	2.3%
LIGNIN	14.3% - 17.5%
LIPIDS	2%-7%
MINERALS	9%
PROTEIN	5%-15%
TANNINS	3%
TOTAL FIBRE	60.5%
TOTAL PECTIC SUBSTANCES	6.5%

Source: Mendes dos Santos et al., 2021

FIGURE B.11

Chemical compounds of coffee mucilage and parchment (washed processing method)

CHEMICAL COMPOUNDS OF BY-PRODUCTS	MUCILAGE
ASH	0.7%
CAFFEINE	
CARBOHYDRATE	45.8%
CELLULOSE	17%
CHLOROGENIC ACID	
FAT	0.7%
HEMICELLULOSE	
LIGNIN	
LIPIDS	0.12%
MINERALS	
PROTEIN	8.9%
TANNINS	3%
TOTAL FIBRE	0.9%
TOTAL PECTIC SUBSTANCES	39%

CHEMICAL COMPOUNDS OF BY-PRODUCTS	PARCHMENT
ASH	0.5% - 1%
CAFFEINE	0.1%
CARBOHYDRATE	0.45%
CELLULOSE	
CHLOROGENIC ACID	
FAT	
HEMICELLULOSE	
LIGNIN	
LIPIDS	0.6%
MINERALS	
PROTEIN	0.4%
TANNINS	
TOTAL FIBRE	89% - 91%
TOTAL PECTIC SUBSTANCES	

Note: Adapted from Iriondo-DeHond et al. (2020) and Elías, L.G. (1979).

Coffee mucilage is a viscous and sticky substance (inner mesocarp) that adheres to the coffee beans after pulping. From 100 kg of coffee cherries, approximately 22 kg of this by-product, including its moisture content, are produced (Iriondo-DeHond et al., 2020). This layer, typically 0.5–2 mm thick, is a colloidal liquid system and a lyophilic hydrogel. Mucilage is composed of up to 39% pectic substances, mainly in the form of reducing sugars, which are essential for microbial activity during the fermentation process. It also contains 84.2% water, 8.9% protein, 4.1% sugar, 0.91% pectic acid, and 0.7% ash. Notably, it includes enzymes that degrade pectin but does not contain tannins or caffeine (Elías, L.G., 1979). Coffee mucilage does not contain the bioactive compounds found in coffee pulp, such as tannins, caffeine, and melanoids (Iriondo-DeHond et al., 2020). Studies suggest that mucilage can promote the growth of beneficial microorganisms, which can ultimately influence and enhance the flavour profile of the resulting coffee (Cruz et al., 2019).

Coffee parchment is the brown, fibrous material (endocarp) that results from the hulling of dried coffee beans after the removal of the cherry pulp and mucilage. Although sometimes referred to as the husk, it is distinct from the coffee husks produced during natural processing, as discussed in this report. Coffee parchment makes up about 39% of the coffee cherry (including moisture) or 35% when dried (Oliveira et al., 2021). Primarily composed of cellulose and lignin (89-91%), it has a low moisture content, ranging from 10 to 15%. The gross chemical composition of coffee parchment has been compared to that of corncobs and cottonseed hulls (Bressani, R., 1978).

B.2.4.5 Circular opportunities for washed process by-products

Effectively managing by-products from the washed coffee processing method offers significant opportunities for sustainability and economic gain. By separating the solid components from the liquid ones, the potential of coffee pulp can be unlocked through various value-addition practices. While coffee pulp is often discarded or used to produce compost and biofertilizers from fermented organic residues, these practices represent just a fraction of its potential uses. Exploring innovative ways to repurpose coffee pulp could lead to new sustainable products and revenue streams, enhancing both environmental and economic outcomes.

Wastewater or honey water management

Various advanced systems are used to treat wastewater, each designed to address specific contaminants and operational needs. Common methods include constructed wetlands, which effectively remove organic matter and nutrients, and membrane bioreactors, known for their high-efficiency contaminant removal. Aerobic and anaerobic lagoons are also employed to manage coffee wastewater. The treated water can be repurposed as a nutrient-rich biofertilizer, reducing the reliance on chemical fertilizers, and supporting sustainable agricultural practices.

Vetiver grass (Vetiveria zizanioides) offers a circular approach to mitigating the environmental impact of honey water, a by-product of coffee processing. Vetiver's robust root system naturally filters out contaminants like nitrogen, phosphorus, and heavy metals, significantly reducing wastewater toxicity before release into the environment (Chen, Y., Shen, Z. G., & Li, X. D., 2004). The grass can also be harvested for erosion control, handicrafts, or as a raw material for thatch, maximizing its utility in agricultural systems. In Peru, cooperatives such as La Flor del Café and Valle Verde in Amazonas, as well as CENFROCAFE in Cajamarca, have successfully implemented constructed wetlands with vetiver grass, leading to substantial reductions in pollutants and improved water quality.

Coffee pulp

Coffee pulp is rich in organic matter, making it a promising by-product for biogas production through anaerobic digestion. This process breaks down coffee pulp in the absence of oxygen to produce biogas, which can be used for electricity and heat generation. The by-product of this process, known as digestate, is a nutrient-rich material that can be used as a fertilizer. Utilizing coffee pulp for biogas production has shown significant potential in various regions, allowing coffee producers to reduce reliance on external energy sources and minimize waste. The digestate also provides valuable agricultural input, supporting local farming and contributing to a circular economy.

However, this model has limitations. A project in Peru exploring the use of coffee pulp for biochar and biogas found it unsuitable for biogas production due to the presence of potentially harmful biocides and the limited availability of pulp during the harvest period. Additionally, biogas production requires significant investment (RePiC, 2020).

Coffee pulp can be incorporated into animal feed formulations, offering a sustainable and cost-effective alternative to traditional feed ingredients. Research has shown that coffee pulp can replace up to 20% of traditional feed for livestock such as cows (Pedraza et al., 2012), pigs, and rabbits, reducing feed costs while still providing a nutritious diet. This integration of coffee pulp not only addresses waste management challenges but also supports more sustainable agricultural practices. However, scepticism remains in the feed industry, and connections between coffee and feed industries remain limited. Research has also explored the use of coffee pulp in aquaculture (Ulloa Rojas, J., 2002).

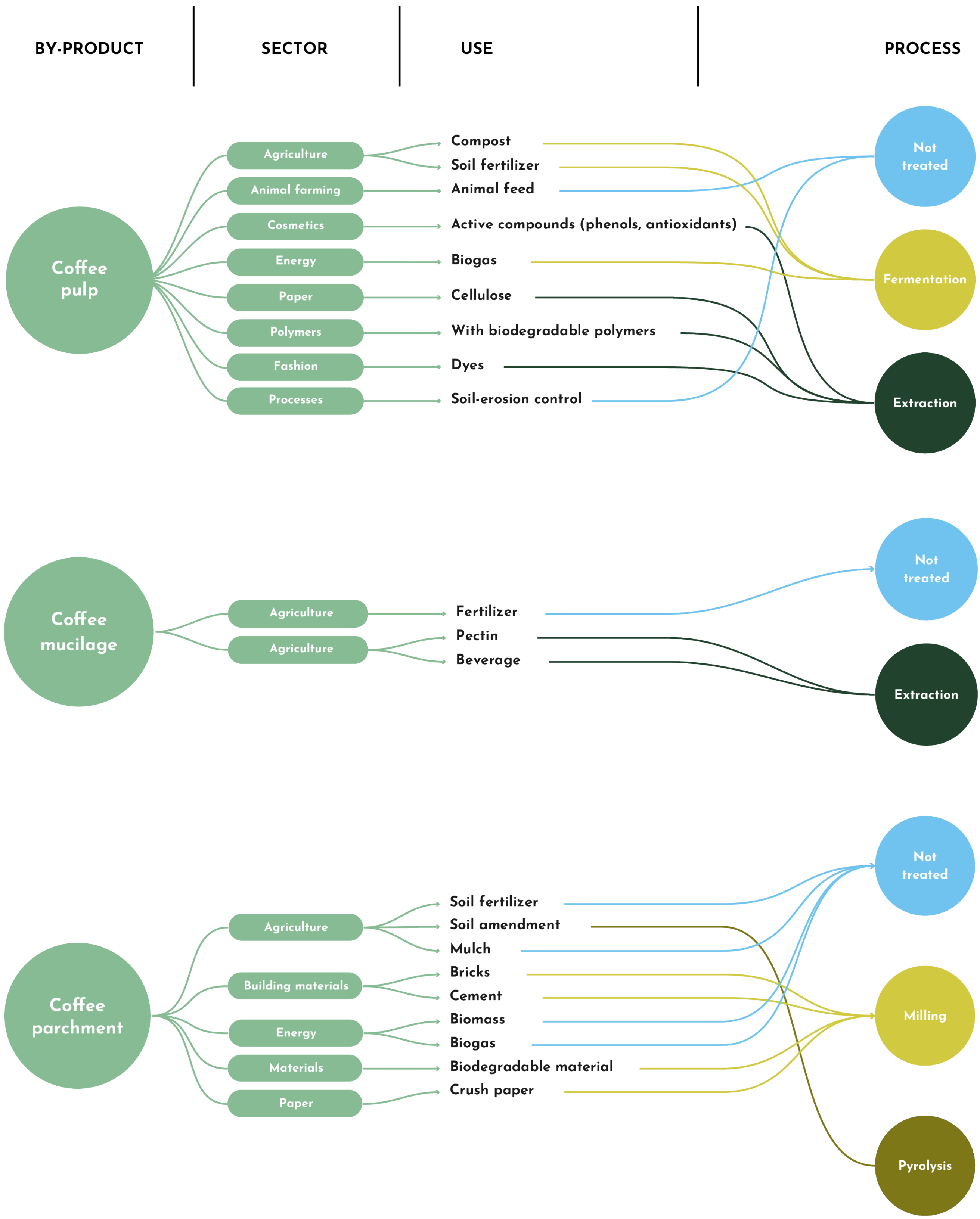
Another use for coffee pulp is as a substrate for cultivating mushrooms. Its high organic content makes it an ideal growing medium for fungi such as such as oyster and shiitake mushrooms (Murthy and Madhava Naidu, 2012). Using coffee pulp in mushroom cultivation offers a sustainable waste management solution while offering additional nutrients and potential income opportunities for farmers. However, this application faces challenges, including the limited consumption of specialty mushrooms in many coffee-producing regions, the perishable nature of fresh mushrooms, and the niche market for these products.

Coffee cherry mucilage is a rich source of pectic substances that can potentially be processed into pectins. However, traditional washing methods pose challenges in recovering these substances, as they are often washed away with large volumes of water during the pulping and washing stages and are subjected to advanced fermentation. To effectively harness these pectic substances, it is crucial to either recycle the water used in the process or use coffee pulp as the raw material (Bressani, 1978). The use of de-mucilagers allows for the separate collection of mechanically removed mucilage.

Mucilage concentrate has been explored for various applications, such as beverages, organic foliar fertilizer sprays and natural preservatives. For instance, Good Vodka, an American distillery, uses mucilage concentrate from Colombia (The Zero Waste Coffee Project, 2023). Another practical use of coffee mucilage is in the ready-to-drink beverage market. NAOX, a beverage rich in antioxidants, is produced from coffee mucilage concentrate.

This innovation was developed in Colombia through a collaboration between Nautucafe (The Zero Waste Coffee Project, 2023) and SANAM. An example of successful industrial-

FIGURE B.12
Value-addition uses for washed coffee process by-products



Source: ITC Coffee Guide Network's Circular Economy Working Group and Center for Circular Economy in Coffee, 2024.

scale production is seen with CoopeAgri, a small producer organization in Costa Rica. Through a joint venture named Agri-SANAM, CoopeAgri produces coffee mucilage concentrate on an agro-industrial scale. It is bottled and sold as NAOX in Costa Rica, available in retailers like WalMart, and is also exported to international markets for various uses. This initiative aims to maximize the use of the coffee cherry and enhance economic opportunities for farmers by integrating circular economy practices into their operations.

Coffee parchment is well-suited for bioenergy production. It can be utilized as biomass for energy generation through combustion or converted into biochar or biogas via pyrolysis or anaerobic digestion. A common use of parchment is as fuel for mechanical parchment coffee dryers, providing a renewable energy source while reducing waste. However, this approach poses sustainability challenges related to combustion emissions, which need careful management to minimize environmental impact.

In agriculture, coffee parchment can be composted to create organic fertilizer, enriching soil with essential nutrients and enhancing fertility. It can also be used as mulch, aiding in water retention, weed suppression, and soil temperature regulation, thereby improving crop yields. Converting coffee parchment into biochar serves as a soil amendment, reducing the need for fertilizers, improving soil properties over time, and aiding carbon sequestration, which helps mitigate climate change by capturing and storing carbon.

The fibrous nature of coffee parchment makes it suitable for producing paper and biodegradable packaging materials, which are increasingly in demand as sustainable alternatives to conventional products. In the construction industry, coffee parchment can be incorporated into building materials like bricks or cement to enhance properties such as insulation.

Research is ongoing to explore coffee parchment's use in building materials. For instance, incorporating parchment into bricks aims to enhance their porosity, improving thermal insulation (Sanchez-Zuiga et al., 2019). This innovation supports more sustainable and energy-efficient construction practices by leveraging the natural benefits of a by-product. An example is Woodpeckers WPC (wood plastic composite) panels developed in Colombia, designed for rural construction. These panels, made from parchment and recycled polymers, offer cost-effective and sustainable building solutions for low-income populations.

Coffee parchment is also being used in combination with polymers to create composite materials, taking advantage of its natural lignocellulosic properties to enhance mechanical strength, thermal insulation, and durability. However, challenges include variability in parchment quality and composition, which can affect the final product's performance. Additionally, integrating parchment with non-recyclable polymers raises issues related to biodegradability and disposal, potentially undermining the environmental benefits of these composites.

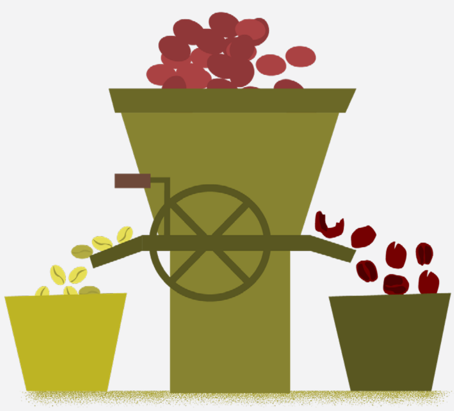
Huskee is a brand that exemplifies innovative use of coffee parchment, offering reusable coffee cups made from a mix of coffee parchment and polymers. The brand's "HuskeeSwap" model promotes reuse in cafes, universities, and offices to reduce single-use cups. Huskee also offers a recycling programme to ensure the proper disposal and recycling of their products, creating new products from recycled Huskee cups.

BOX B.5
What is *cascara*?

Cascara, which means "skin" or "husk" in Spanish, refers to the dried coffee cherry skin and pulp. It also broadly encompasses the coffee husk from natural coffee processing, including the skin, pulp, and parchment. *Cascara* can be used as a fruit infusion, with *Quishr, or Hashara* – a sweet tea made from coffee skin – originating in Ethiopia and still enjoyed in the region. The distinctive sweet red fruit and molasses flavour of cascara has driven its growing popularity as a refreshing beverage. This increasing demand requires new regulatory and marketing efforts to introduce and establish *cascara* in different markets (International Trade Centre, 2021).

Some companies have innovatively used cherry pulp to create "coffee flour," a gluten-free alternative to grain-based flours. Other initiatives include transforming "honey water" into a sweet syrup, often called "coffee honey." Coffee Cherry & Co. produces a nutritious, gluten-free flour from dried *cascara*, sourced with operations in Hawaii, Nicaragua, Guatemala, Mexico, and Vietnam. This product provides environmental benefits, economic opportunities for farmers, and helps address dietary deficiencies (The Index Project, n.d.).

Coffee pulp or *cascara* can also be used in both non-alcoholic and alcoholic beverage production. Dried *cascara* is now widely available for making infusions and teas, thanks to the novel food recognition process that has opened international markets, including Europe. *Cascara* can also be turned into syrups that add a unique, fruity depth to desserts, ice cream, pancakes, and cocktails. By processing and fermenting coffee pulp, manufacturers can create unique beverages such as coffee pulp-based refreshing drinks and low-alcohol beverages (Rathinavelu and Graziosi, 2005). This innovative use of coffee pulp not only reduces waste but also introduces novel products to the market, offering both environmental and commercial benefits.



B.2.4.6 A breakdown of the "natural" processing method

In the natural coffee processing method, the post-harvest workflow begins with an initial sorting phase to remove defective cherries, ensuring that only high-quality cherries move on to subsequent processing stages.

The selected coffee cherries are then dried to a residual moisture level of around 10%. This can be done using either solar or mechanical drying methods. In solar drying, cherries are spread in a thin, uniform layer on surfaces like drying patios, raised beds, or polytunnels.

Natural sunlight and air circulation reduce the cherries' moisture content, with regular turning and raking to ensure even drying and prevent mould growth or fermentation, which could affect quality and flavour.

BOX B.6
COMSA: Regenerative agriculture on coffee farms

CASE STUDY

NAOX:
Coffee honey concentrate

Partner(s):
COOPEAGRI, Agri-SANAM
Country:
Costa Rica
Year launched:
2019
Coffee value chain area:
Post-harvest processing
Industry/sector:
Food and beverages; agricultural inputs; cosmetics

Technology readiness level:
Proof of concept, ready for market
Input:
Coffee mucilage
Output:
Mucilage concentrate as an ingredient for multiple applications

Description: Mucilage, the sticky layer found in coffee cherries, is separated from the pulp during the washed processing of coffee. This mucilage is then extracted and heated to produce a sweet, antioxidant-rich concentrate suitable for human consumption. The versatile concentrate is used in a variety of products, including granola bars, fruit bites, spreads, sauces, nutraceutical supplements, energy gels, beverages, confectionery items, dairy products, ice cream, and baked goods. Additionally, the concentrate has proven effective as a bio-stimulant foliar fertilizer for both conventional and organic farming, and it also serves as a natural food preservative. Through a joint venture between COOPEAGRI and SANAM in Colombia, the product is marketed under the name NAOX, a ready-to-drink beverage sold in major retailers such as Walmart in Costa Rica.

Motive: COOPEAGRI, a cooperative with over 60 years of experience in coffee, sugarcane, and agro-industrial products, is committed to tackling the challenges of climate change, including environmental degradation and reduced crop yields. By adopting circular economy practices, the cooperative aims to maximize the use of coffee cherries and minimize waste.

Challenges and lessons learned: Extracting mucilage through a hermetic process was highly complex. The development of the foliar fertilizer required three years of research, testing, and refinement. As pioneers in this field, COOPEAGRI also faced significant challenges in positioning NAOX in the market, particularly in finding supply chain partners willing to invest in the product's success.

Economic impacts: The commercialization of this value-added product has created economic benefits for coffee producers through profit-sharing mechanisms. Additionally, cooperative members receive the biofoliar fertilizer at a discounted rate, leading to improved coffee yields and enhanced crop quality.

Environmental impacts: The production plant treats and recycles rainwater, ensuring that all wastewater is processed to meet national environmental regulations. This sustainable water management supports the cooperative's broader environmental goals.

Social impacts: Consumers benefit from the nutritional value and health advantages of the product, contributing to overall well-being.

Cultural, educational and awareness impacts: The cooperative has established demonstration plots to showcase the effectiveness of organic farming practices, allowing members to see firsthand the benefits of using the bio-stimulant fertilizer. These efforts have helped raise awareness and promote sustainable agricultural practices within the community.

Mechanical drying is particularly popular in regions prone to erratic weather, such as unpredictable rains. This method uses specialized equipment to control temperature and airflow, significantly reducing drying time from weeks (as with sun drying) to just hours or days. Mechanical drying helps maintain consistent quality and minimizes the risk of contamination from adverse weather conditions.

Once the cherries reach the desired dryness, they undergo hulling, where the dried outer layers – known as coffee husks, including the skin, dehydrated fruit pulp, mucilage, and parchment – are mechanically removed. This process reveals the green coffee beans, which are then further cleaned and sorted to remove any remaining debris or defective beans, in line with market specifications (International Trade Centre, 2021).

B.2.4.7 Wider impacts of the natural processing method

Coffee husks are the main by-product of the natural coffee processing method, making up 45% of the coffee cherry (Oliveira et al., 2021). Managing the disposal of coffee husks poses significant challenges, especially in regions with high coffee production. Common disposal methods include landfilling, open burning, and composting. In some high-production areas, coffee husks and other agricultural residues are burnt to manage the large volumes of waste. However, open burning is particularly problematic. It depletes soil organic matter, reducing soil fertility and crop yields, and releases harmful pollutants like particulate matter, carbon monoxide, volatile organic compounds, and toxic chemicals. These emissions contribute to climate change, air pollution, smog, and health risks, including harm to farmers and their families (Tamilselvan et al., 2024; UNECE, 2022).

As a result, some countries and regional institutions are considering guidelines or regulations to restrict open burning, aiming to mitigate its environmental and health impacts and prevent fire hazards and uncontrolled wildfires (ASEAN, 2023).

B.2.4.8 Natural processing method's by-products and waste

Coffee husks consist of the dried skin, pulp, mucilage, and parchment layers (epicarp, mesocarp, inner mesocarp, and endocarp) of the coffee cherry. These layers are separated from the beans during milling. Coffee husks from natural processing are also used as *cascara* since they include the coffee cherry skin. Chemically, coffee husks are rich in cellulose (43%), hemicellulose (7%), and lignin (9%), contributing to their high fibre content. They also contain various nutrients, including proteins (up to 11%), lipids (up to 3%), and essential minerals (3-7%) such as potassium and magnesium. Although in smaller quantities than in the beans, coffee husks also contain caffeine (1%) and antioxidants like chlorogenic acids (2.5%), which contribute to their unique properties and potential uses (Mendes dos Santos et al., 2021).

The aroma and flavour profile of coffee husks can vary depending on the coffee variety and the drying process. The aroma is often described as fruity or floral, while brewed *cascara* tea can have a mildly sweet flavour with notes of dried fruit, berries, and a slight tartness.

B.2.4.9 Circular opportunities for natural process by-products and waste

There is growing interest in valorizing coffee husks into various useful products, reducing waste, and promoting a circular economy in the coffee sector.

Beyond their use in food and beverages as *cascara*, coffee husks have several other applications. In agriculture, coffee husks are traditionally used as soil amendments or compost material, enhancing soil structure and fertility by increasing organic matter and improving water retention. Unlike coffee pulp solids, which release limited nutrients, raw coffee husks are rich in organic carbon, significantly enriching the soil. As mulch, husks offer benefits such as moisture retention, weed suppression, and soil temperature regulation, all contributing to healthier crops and reduced soil erosion (Bomfim et al., 2023). Coffee husks have also proven valuable as a substrate for mushroom cultivation (Dissasa, 2022).

Like coffee parchment, biochar derived from coffee husks through pyrolysis serves as an excellent soil amendment while also contributing to carbon sequestration. This process enhances soil fertility and structure while helping mitigate climate change by sequestering carbon. The high lignocellulosic content of coffee husks makes them suitable for biofuel production through pyrolysis, fermentation, and anaerobic co-digestion, supporting the shift to biomass energy (Tamilselvan et al., 2024).

Coffee husks offer a cost-effective, eco-friendly alternative to fossil fuels, reducing GHG emissions and addressing waste in the coffee industry. Fuel briquettes made from coffee husks, dried coffee pulp, or parchment, such as those produced by the Dilla Briquette Factory in Ethiopia (The Zero Waste Coffee Project, 2023), provide a sustainable alternative to fossil fuels, using simple carbonization and pressing techniques. While converting coffee husks into biofuels and briquettes presents opportunities for local economic growth and energy sustainability, challenges include fluctuating husk availability and high processing costs (Flammini et al., 2020; Era of We, 2023).

In Vietnam and Peru, pilot projects[5] have implemented small-scale pyrolysis systems to add value to coffee waste by converting it into three main outputs: heat energy for mechanical coffee dryers, biochar as a soil amendment, and pyroligneous liquid (wood vinegar), which can be commercialized as a natural pesticide. These systems process 30-100 kg of dry material per hour, producing 10-30 kg of biochar per hour. The project also introduced thermal dryers that significantly reduce drying time, and the risk of mould compared to traditional sun drying. Pilot results showed positive environmental and economic impacts, including additional income from biochar sales, higher coffee yields, reduced climate risk, lower GHG emissions, less fertilizer runoff, reduced deforestation, and the creation of local markets for biochar (Biochar Vietnam, n.d.; RePiC, 2020).

Research has also highlighted innovative applications for coffee husks, such as their effectiveness as biosorbents in environmental applications, particularly in wastewater treatment. When converted into biochar with pyrolysis, these cellulose- and lignin-rich husks can effectively absorb pollutants

5 These pilot projects is carried out by partners United Nations Industrial Development Fund (UNIDO), State Secretariat for Economic Affairs (SECO), Sofies/dss+ (Switzerland), VNCPC, Ökozentrum/ Generation Carbon GmbH (Switzerland), and Husk (Spain) from 2020 to 2023. Technical resources for biochar are available at: https://biocharvietnam.org/portfolio/

like heavy metals, dyes, and pesticides due to their structure and chemical properties. This supports the use of coffee husks in a circular economy model for wastewater treatment, contributing to more sustainable practices within the coffee value chain in producing countries (Quyen et al., 2021; Castillo et al., 2021).

B.2.5 Trade and transport

Concerns about the sustainability and circularity of packaging materials used for storing raw coffee parchment and green beans are growing. Efforts to reintroduce jute bags for shipping green coffee beans are part of this discussion. However, these initiatives must balance the need to protect the quality and integrity of the product, particularly against water and odour, which are significant drivers of innovation. There is a need for organic, chemical-free procedures and materials for storing, drying, and transporting coffee and other agricultural commodities.

Improving warehousing efficiency and consolidating or reducing the number of operational warehouses can increase efficiency and reduce waste, contributing to a smaller carbon footprint. The transportation phase, particularly, generates significant GHG emissions (International Trade Centre, 2021).

Logistics and shipping partners play a crucial role in reducing the environmental impact of "food miles" (or "coffee miles"), which affect the sustainability of the coffee industry.

A life cycle assessment of the carbon footprint of Arabica coffee cultivated in Brazil and Vietnam compared traditional and sustainable cultivation methods. It found that sustainable coffee production can reduce the carbon footprint by 77% compared to conventional methods, mainly due to two factors: exporting coffee beans via cargo ship instead of air freight and reducing agro-chemical inputs. Specifically, CO_2 – equivalent emissions per kg of green coffee decrease from 72-73% of the total to about 6-11% when choosing sea transport (Nab and Maslin, 2020).

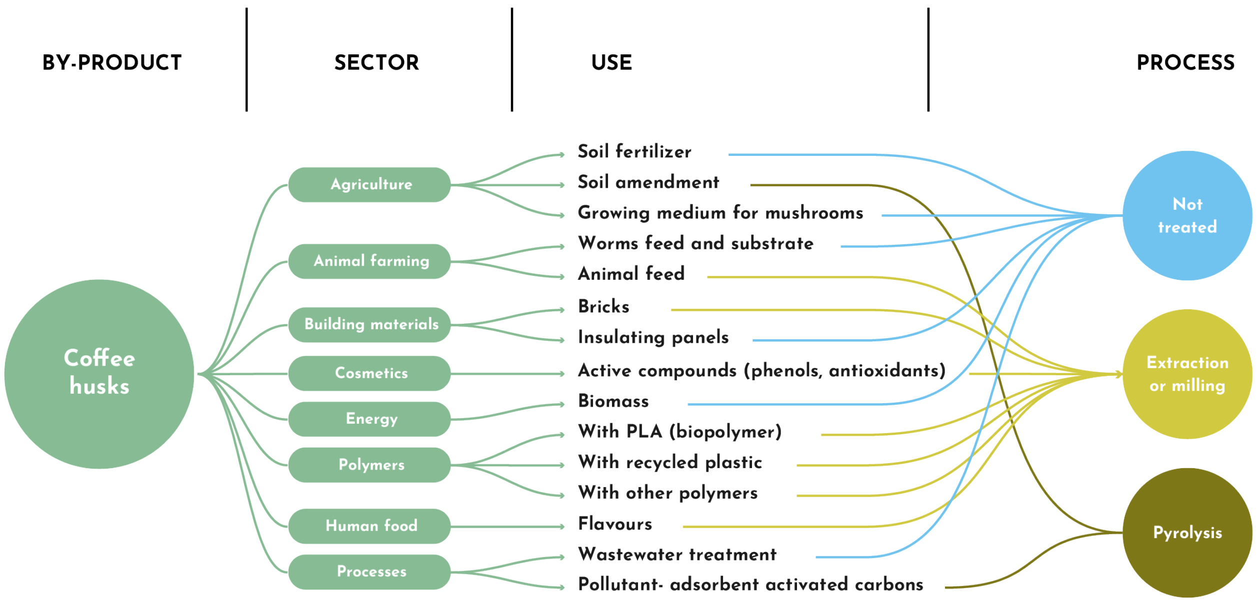
B.2.5.1 Enhancing circularity in transportation

Improved due diligence in supply chain assessments can help optimize logistical opportunities along the value chain. Multi-modal transport (combining road, rail, and sea) should be considered when it offers more fuel-efficient and less polluting alternatives to traditional routes and modes of transport (International Trade Centre, 2021). Although air freight for coffee is rare compared to cargo shipping, comprehensive global statistics on transportation emissions are needed, along with further exploration of ways to reduce emissions from shipping.

Coffee producers, mills, and exporters often reuse and recirculate bags for collecting cherries and parchment. The challenge lies in consolidating and transporting them back to producing countries.

Finally, promoting, developing, and incentivizing local and regional trade and value-addition at origin can help reduce the need for international shipments.

FIGURE B.13
Value-addition uses for natural coffee process by-products



Source: ITC Coffee Guide Network's Circular Economy Working Group and Center for Circular Economy in Coffee, 2024.

BOX B.7
NetZero: Biochar from biomass

CASE STUDY

NetZero: Biochar from biomass

Partner(s):
NetZero, COOCAFÉ
Country:
Brazil and Cameroon
Year launched:
2020
Coffee value chain area:
Post-harvest processing

Industry/sector:
Agri-business
Technology readiness level:
Implemented action
Input:
Coffee husk
Output:
Biochar

Description: Biochar is a type of charcoal produced from enriched coffee waste through a rapid process known as pyrolysis, which occurs inside a reactor with minimal oxygen in about 20 minutes. Unlike traditional charcoal, biochar is produced sustainably and can be made from any organic material, including kitchen scraps. NetZero, a company specializing in biochar, focuses on using coffee waste and offers their product at an affordable price for coffee growers, setting them apart from other producers.

Motive: In Brazil, coffee farmers traditionally burnt coffee husks to dispose of them, but this practice has been banned due to environmental concerns. Additionally, coffee husks had little impact as a fertilizer. This created a need to find a new, sustainable use for coffee husks, which led to the development of biochar as an alternative that could provide both environmental and economic benefits.

Challenges and lessons learned: A key challenge for NetZero is ensuring that biochar is sourced and sold locally to maintain feasibility and scalability. Another obstacle has been educating farmers in Brazil and Cameroon, many of whom were unaware of biochar's benefits, making market development difficult. Scaling up production has also been a challenge, as the necessary technology for large-scale biochar production was not readily available.

Economic impacts: Experimental production data from Colombia over a three-year period showed a significant increase in coffee yields – over 33% – which continued in subsequent years. This highlights the economic potential of biochar in improving agricultural productivity.

Environmental impacts: Biochar enhances soil health by providing a stable structure that retains water and nutrients. It acts as a carbon sponge that remains in the soil for more than a decade, improving soil quality over time. The increased nutrient retention reduces the need for chemical fertilizers, which in turn lowers CO_2 emissions, contributing to climate change mitigation.

Social impacts: NetZero's biochar initiative has created 120 direct jobs in biochar production. Additionally, the company subsidizes the cost of biochar for participating farmers, making it accessible and promoting its adoption in sustainable farming practices.

Cultural, educational and awareness impacts: NetZero has played a pioneering role in fostering collaboration between industry, research institutions, and coffee producers. This collaborative approach has driven innovation in product development and improvements in production processes, increasing awareness and education around sustainable agriculture.

B.2.6 Roasting and Packaging

B.2.6.1 A breakdown of roasting

Roasting is a critical phase that transforms green coffee beans into the final product, ready for consumption. This process involves heating the beans to change their chemical and physical properties, unlocking complex flavours and aromas that create different sensory profiles.

After reaching the desired roast level, the beans are rapidly cooled, usually through air cooling, to stop the roasting process. This rapid cooling is essential to prevent over-roasting, which can lead to the loss of desirable flavours and the development of unwanted burnt notes.

Once cooled, the beans undergo a rest period known as degassing, during which they release carbon dioxide. This step is important for achieving optimal flavour development before the beans are ground and brewed. Finally, the roasted coffee beans are packaged and sealed to preserve freshness and protect them from light, air, and moisture, which can degrade their flavours over time.

B.2.6.2 The wider impacts of roasting

The roasting phase of coffee production has significant environmental implications, primarily due to energy consumption and emissions. Roasting is energy-intensive, typically relying on gas or electricity, which contributes to the carbon footprint of coffee production through carbon dioxide emissions. The environmental impact varies depending on whether the energy source is renewable or fossil based.

Since most roasters are natural gas-fired, they produce carbon monoxide (CO) and carbon dioxide (CO_2), contributing to air pollution and posing potential health risks to workers and nearby communities.

Coffee roasting emits carbon dioxide, volatile organic compounds (VOCs), organic acids, and by-products from natural gas combustion.

The process also generates a by-product known as chaff or silverskin. Proper management of this flammable material is crucial, as its accumulation can pose disposal and safety challenges. Some facilities incinerate silverskin, which can increase air pollution, while others explore more sustainable practices, such as industrial composting. However, limited production quantities make it difficult to justify the adoption of advanced valorization processes, even for large roasteries.

Efforts to mitigate these environmental impacts include adopting more energy-efficient roasting technologies and using renewable energy sources. For example, Café William has started using a roaster powered by electricity from hydropower instead of natural gas. This roaster, with a capacity of 3.5 tonnes of green coffee per hour, is the world's first industrial-scale hydroelectric roaster (GCR Magazine, 2024). The company anticipates reducing CO_2 emissions by approximately 800 tonnes annually through various carbon reduction strategies (Food in Canada, 2024). As industry standards tighten, roasting plants are adapting by minimizing emissions and increasing efficiency through advanced equipment, which lowers energy consumption and emissions. Some companies are also implementing carbon offset programmes to further reduce their environmental impact.

N.B: This report does not cover the decaffeination process or instant coffee and its various methods due to limited research and time, as analysing these would require additional studies beyond the scope of this report.

B.2.6.3 Roasting by-products and waste

Silverskin is the thin, papery layer between the coffee cherry and the green bean, which tends to fragment into small flakes during handling. Its dimensions and morphology can vary depending on the coffee variety, but it consistently exhibits a fragile structure.

Chemically, silverskin is primarily composed of cellulose and hemicellulose, which make up about 30% of its total composition, contributing to its fibrous and brittle characteristics.

Nutritionally, silverskin contains up to 20% protein and up to 3% lipids. It also has essential minerals like potassium and magnesium, though in smaller amounts (about 8%) compared to the coffee bean. Caffeine is present in minimal amounts, ranging from 0.6% to 1.1%, reflecting its lower concentration relative to the beans. Additionally, silverskin contains antioxidants, including polyphenols and chlorogenic acids, though these are present in lower concentrations than in the coffee beans (Mendes dos Santos et al., 2021).

FIGURE B.14
Chemical compounds of silverskin (roasting)

CHEMICAL COMPOUNDS OF BY-PRODUCTS	SILVERSKIN
ASH	7.34% - 10.5%
CAFFEINE	0.6% - 1.1%
CARBOHYDRATE	0.25% - 6.35%
CELLULOSE	17.8%
CHLOROGENIC ACID	3%
FAT	2.2%
HEMICELLULOSE	13.1%
LIGNIN	1%
LIPIDS	3%
MINERALS	8%
PROTEIN	20%
TANNINS	60%
TOTAL FIBRE	60%
TOTAL PECTIC SUBSTANCES	0.02%

Note: Adapted from Mendes dos Santos et al. (2021).

B.2.6.4 Circular opportunities for roasting by-products and waste

Silverskin, a by-product of coffee processing, offers several practical applications beyond its traditional use in agriculture. Studies have highlighted its unique chemical and physical properties, presenting opportunities for valorization through lipid extraction, high-value molecule recovery, and as a source of cellulose. These attributes open possibilities for its use across various industries.

In agriculture, silverskin primarily serves as an organic fertilizer. Its high cellulose and hemicellulose content improves soil structure, enhances water retention, and stimulates microbial activity. When combined with coffee dust, another by-product rich in nitrogen, the nutrient profile becomes even more robust. Reground, an Australian initiative, collects coffee waste, including silverskin and spent coffee grounds, and redistributes it to local community gardens and home gardeners (Reground, n.d).

Silverskin's potential extends to other industries due to its bioactive compounds, including antioxidants, fibre, and lipids. It contains phenolic compounds and flavonoids, known for their anti-inflammatory and anti-aging properties. Lipids extracted from silverskin, similar to cocoa butter, are valuable in cosmetic formulations. The Italian company Intercos has optimized these molecules, particularly polyphenols and lipids, for use in skincare products (Intercos, 2024).

In the broader CirCo research project (Overturf et al., 2021), by-products from supercritical CO_2 extraction for cosmetics were repurposed in the paper-making industry. Favini, a paper mill, used cellulose-rich silverskin to replace 15% of virgin cellulose in its crush paper, aligning with sustainability goals by reducing waste and introducing innovative solutions like tree-free paper.

In materials science, silverskin's cellulose content presents opportunities for polymer production, crucial in developing biopolymers as alternatives to petroleum-based plastics. Researchers are exploring how silverskin-derived cellulose can be processed into films, fibres, and composites (Oliveira et al., 2021). Volkswagen has experimented with using silverskin as a filler in a PVC/polyurethane-based vegan leather alternative, providing an eco-friendly and cruelty-free option. Similarly, Danish furniture company Mater has created Matek™ material, combining silverskin, coffee husks, and plastic waste for use in office furniture (MaterUSA, n.d.). However, end-of-life management for these biopolymer products remains a challenge, requiring sustainable disposal or recycling methods.

Silverskin also has potential in the food industry due to its nutritional profile, which includes dietary fibre, protein, and antioxidants. It could be incorporated into products like cereal bars to enhance nutritional value, though its taste, texture, and safety must be carefully considered. As silverskin and its extracts are novel food products, regulatory approval would be required in markets such as the US and the EU.

Finally, some larger roasting companies, like J.J. Darboven in Germany (Tomblog, 2018) and CF Nielsen & BKI Foods in Denmark (CF Nielsen, n.d.), are pressing silverskin into pellets for use in biogas plants, providing a sustainable waste management solution.

B.2.6.5 Packaging

The main challenge for the coffee industry lies in developing packaging that incorporates renewable and recycled materials, minimizes quantities and weight, and promotes reuse, recycling, or composting at the end of its life. This challenge is especially complex with coffee capsules, which have seen rapid growth and pose significant waste management issues. An analysis by Tchibo (PCF Pilotprojekt Deutschland, 2008) estimates that packaging produces 0.13 kg of CO_2 per kg of green coffee, accounting for 1.8% of the total emissions for a cup of coffee (PCF Pilotprojekt Deutschland, 2008). Similarly, a life cycle assessment in Finland (Usva et al., 2020) found that packaging contributes to less than 2% of the total carbon footprint.

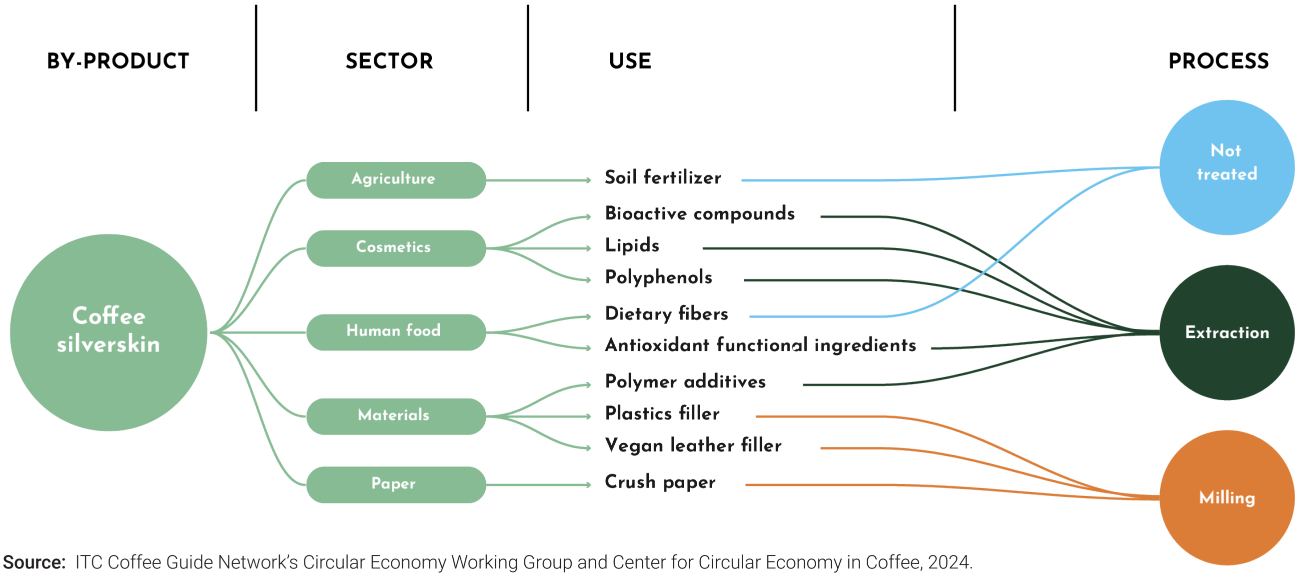
Roasted coffee, which is delicate and deteriorates when exposed to moisture, air, and light, requires high-barrier packaging to preserve its quality. The shelf life typically ranges from 12 to 24 months, depending on the packaging type and storage conditions.

Coffee roasters commonly use aluminium as a barrier layer in flexible packaging, cans, and capsules. Aluminium is often combined with plastic or paper for flexible coffee bags containing ground coffee or whole beans. While flexible packaging uses less material than metal cans or glass jars, it is difficult to recycle on a large scale.

Multilayer coffee packaging, which combines materials like polymers, paper, aluminium, and coatings, faces increasing pressure due to its complexity (Bauer et al., 2021). In the U.S., very few kerbside programmes accept this film and flexible material, and as a result, less than one percent of the nearly 4.8 million tonnes of this material generated annually is captured (Appel et al, 2024). However, as film and flexible material become more prevalent in products, investment in their recyclability has become crucial. In Europe, over 40% of the population lacks access to separate collection for flexible packaging (EMF, n.d.).

As regulators tighten their focus on reducing waste – with measures like the Packaging and Packaging Waste Regulation (PPWR), an ambitious EU regulation aimed at reducing packaging pollution and promoting a circular economy for

FIGURE B.15
Value-Addition Uses for Silverskin



Source: ITC Coffee Guide Network's Circular Economy Working Group and Center for Circular Economy in Coffee, 2024.

packaging, and the pending Extended Producer Responsibility (EPR) in the US – there is growing interest in compostable materials and reusable capsules.

In response, packaging producers and brand owners are increasingly focusing on designing recyclable, high-quality flexible packaging.

The packaging industry is working to improve recycling processes and enhance sustainable design to meet emerging legal requirements, such as mandatory recycling targets, and to advance the circular economy by closing the loop on materials and production cycles.

B.2.6.6 Opportunities for Circular Packaging

Circularity should be a key consideration in product and packaging design, ensuring that materials can be recovered and reused. For packaging, this approach builds on long-standing principles of minimizing resource extraction and reducing waste.

The sustainability of packaging is closely tied to the context in which it is used. Therefore, selecting the best eco-design strategies requires scientific analysis and measurable key

BOX B.8
Cir.Co: High-value compounds from silverskin

CASE STUDY

Cir.Co
High-value compounds from silverskin

Country:
Italy

Year launched:
2018 (ended in 2021)

Coffee value chain area:
Roasting and packaging

Industry/sector:
Cosmetics, nutraceuticals, paper production

Technology readiness level:
Tested solution

Partner(s):
ISTM-CNR - Istituto di Scienze e Tecnologie Molecolari, Università degli Studi di Milano, Dipartimento di Scienze e Politiche Ambientali, EURAC Research, Istituto per le Energie Rinnovabili, Intercos Group, Favini Srl and ILSA SpA.

Input:
Silverskin

Output:
High-value compounds such as cellulose, lignin, lipids, and some phenolic compounds

Description: The project aims to maximize the potential of coffee silverskin, a by-product of coffee roasting, by extracting valuable components such as cellulose, lignin, lipids, and phenolic compounds. These compounds have promising applications across various industries, including cosmetics, nutraceuticals, and paper production, all while reducing environmental impact. The initiative promotes cross-sector collaboration by involving multiple industrial sectors and research centres.

Motive: Although silverskin makes up a small fraction of the coffee bean, it has valuable physical and chemical properties. Traditionally, it has been used for low-value applications like agricultural fertilization, but this project seeks to explore higher-value uses and prevent it from being disposed of as waste.

Challenges and lessons learned: While the extraction of lipids and other valuable compounds from silverskin holds promise, the high extraction costs have limited its adoption for commercial purposes. Nonetheless, the project has generated valuable data on the quality and functional potential of silverskin extracts. Although not yet fully integrated into company operations, silverskin has been successfully incorporated into Favini's production of crush paper, which includes coffee grounds and other agricultural by-products.

Economic impacts: The revalorization of silverskin has unlocked new commercial opportunities, particularly in the paper production industry.

Environmental impacts: Research has demonstrated that silverskin extracts have potential for use in cosmetics with anti-aging and anti-pollution benefits. Additionally, the development of crush paper has replaced 15% of virgin cellulose with coffee by-products, reducing environmental impact.

Social impacts: The project has fostered new circular industrial collaboration models, connecting different sectors and creating new job opportunities, thus strengthening local economies.

Cultural, educational and awareness impacts: The initiative has raised awareness of the environmental and economic benefits of reusing coffee silverskin, promoting sustainability within the coffee industry and beyond.

performance indicators (KPIs). These strategies might focus on promoting reuse, material recycling, or compostability. Economic viability remains a key factor in packaging decisions for brands and providers.

BOX B.9
Packaging and Packaging Waste Regulation (PPWR)

The proposed Packaging and Packaging Waste Regulation (PPWR) from the European Union aims to prevent packaging waste, promote reuse, and enhance recycling and recovery methods. It sets out requirements that all packaging placed on the EU market must meet, with the goal of reducing waste disposal and fostering a more circular economy. As part of the European Green Deal and the new circular economy action plan, the European Commission proposed a revision of the PPWD in November 2022. The initiative's goal is to ensure that all packaging is reusable or recyclable in an economically viable way by 2030. It seeks to strengthen packaging requirements to ensure reuse and recycling, increase the use of recycled content, and improve enforceability. The measures also address over-packaging and aim to reduce packaging waste.

Source: European Parliament (2024).

BOX B.10
Strategies for circular packaging design

- To **avoid food waste**, packaging must be designed to preserve the product throughout its entire shelf life
- **Eliminate unnecessary packaging** and reduce the weight of materials used
- Packaging typically has a short lifespan, so it is essential to **minimize the environmental impact of the raw materials** used in its production
- Where feasible, and if it improves environmental performance over single-use options, **design packaging to be reusable**
- Focus on creating **mono-material packaging that can be recycled on a large scale**, avoiding components that hinder the recycling process
- When packaging cannot be emptied after use, **compostability is a smart option to valorize both the "bio-waste" and the packaging**

Packaging must fulfil several functions, including protecting contents, conveying product information, and facilitating transportation. It should also minimize environmental impact by closing the resource loop for extended use or reuse. Environmental performance must align with product protection, ensuring quality and hygiene throughout the product's life without compromising machinability, aesthetics, or usability.

Recent studies show that protecting contents is crucial for sustainable consumption while minimizing packaging material use. This supports the adoption of advanced, customized, and often combined material flexible packaging solutions (Ecoplus, BOKU, Denkstatt, OFI, 2020).

Recycling plays a crucial role in enabling packaging to contribute effectively to a circular economy, especially after waste prevention. Significant progress in this area is expected in the short to medium term. Recyclable packaging requires systems capable of industrial-scale recycling. However, the development and implementation of collection, sorting, and recycling technologies vary across countries and regions. The goal of recycling is to produce secondary materials that are safe and viable substitutes for "virgin materials," meeting the quality and safety standards required to replace primary raw materials in production processes.

In recent years, various design-for-recycling criteria have been developed to promote effective packaging design and avoid solutions that might inadvertently increase environmental impact. Examples include Recyclass guidelines, CEFLEX D4ACE, 4evergreen guidelines, and APR guidelines.

FIGURE B.16
Packaging, emissions and waste

Source: International Trade Centre (2024).

Significant efforts are currently focused on redesigning multilayer flexible packaging to improve recyclability within existing collection, sorting, and recycling systems. Recyclable film solutions based on polyolefins, such as polyethylene (PE) and polypropylene (PP), have been developed, as these materials have established recycling streams, at least for mixed polyolefin waste.

To achieve large-scale recyclability, it is essential not only to design packaging that is ready for recycling but also to guide consumers to properly dispose of packaging in the correct collection stream. This includes using specific labelling and avoiding misleading treatments, such as making plastic packaging look like paper. Environmental labelling guidelines have been developed to help consumers dispose of packaging correctly.

Flexible packaging generally generates less material loss throughout its lifecycle compared to alternative solutions and is increasingly fitting into a circular economy (Wellenreuther, 2019; 2016). The major benefits of multilayer packaging include efficiency, and a low carbon footprint compared to other packaging options (Marrone, M., and Tamarindo, S., 2018).

A comprehensive lifecycle analysis comparing different types of packaging shows that flexible packaging can be more environmentally friendly than steel or plastic containers, both in terms of carbon footprint and the amount of solid waste generated (Franklin Associates, 2008).

However, when it comes to coffee, reusable packaging presents challenges in maintaining freshness. Typically, reusable packaging is heavier than single-use alternatives to ensure durability and quality over multiple uses. This requires a minimum number of reuses to achieve environmental benefits. Consumer behaviour is crucial in realizing these benefits, so choices must be supported by scientific analysis, such as LCA assessments and material circularity indices, to determine the best packaging solution for each context.

In addition to end-of-life valorization, priority should be given to materials derived from renewable sources, provided they do not compete with the food supply chain, such as second or third-generation bio-based materials. Transitioning to a circular economy involves moving away from packaging made from finite resources. Increasing the use of recycled content reduces the need for raw materials.

Reusability is a key priority in a circular economy, aiming to reduce the resources used for single-use items. Where applicable, reuse models should be favoured over single-use packaging to minimize waste. While improving recycling is important, it alone cannot solve the packaging waste crisis. Reuse business models should be explored wherever feasible to reduce reliance on single-use packaging.

B.2.7 Consumption and end of life

Section B.2.7 focuses on the environmental impact and circular economy opportunities at the final stages of the coffee value chain. It examines how coffee is consumed, the waste generated during this process, and how end-of-life solutions for coffee by-products, such as spent grounds and coffee capsules, can be improved. With over 3 billion cups of coffee consumed daily, the section highlights how ingredients like dairy milk and the brewing method significantly influence coffee's carbon footprint. It also discusses the environmental challenges posed by disposable coffee capsules and cups, with varying regional capacities for recycling or composting. Additionally, B.2.7 explores the composition of spent coffee grounds, rich in organic material, which holds great potential for valorization in sectors like agriculture, energy, and cosmetics. The subsections delve deeper into the breakdown of consumption and end-of-life management, addressing the impacts of different brewing methods, the challenges of capsule disposal, and innovative approaches to upcycling coffee waste into valuable products.

B.2.7.1 A breakdown of consumption and end of life

The coffee we drink represents only a small fraction of the total material produced, processed, and transported to brew a cup. From every tonne of cherries, only about 200 kg of green coffee beans are obtained, and just a minimal portion of that ends up in our cup.

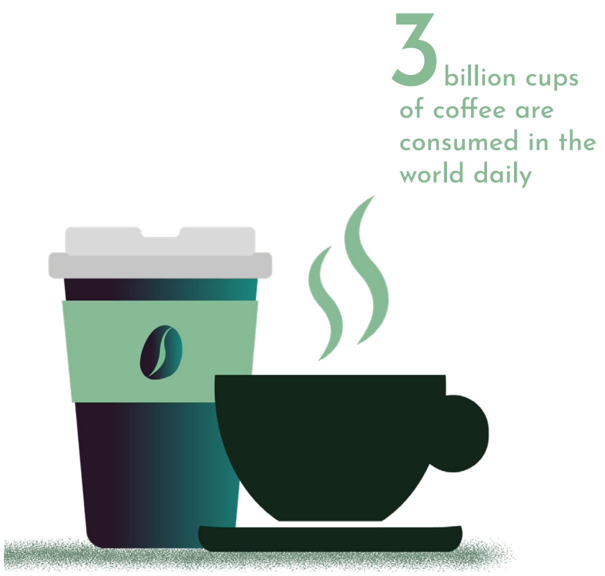
Around 3 billion cups of coffee are consumed daily worldwide (International Coffee Organization, 2021). The sustainability of ingredients frequently added to coffee, such as milk, should be carefully considered due to their significant environmental impacts. For example, dairy milk generates about three times more GHG emissions, uses 13 times more land, and consumes 22 times more freshwater than soy milk (Poore et al., 2018). A recent study found that replacing dairy milk and plastic cups with oat milk and oat cups can reduce coffee's carbon emissions by 70% (Zhao et al., 2024).

The method of brewing coffee influences both the characteristics of the final beverage and its environmental impact. Each method – whether drip brewing, espresso, or coffee capsules – employs different techniques that affect taste, experience, and the amount of waste produced.

Drip brewing, one of the most common methods globally, involves passing hot water through coffee grounds held in a paper filter. This process generates considerable waste, including used filters and spent coffee grounds.[6] For a 180 ml cup of drip coffee, about 10 grams of dry spent grounds are produced. These filters and grounds often end up in landfills rather than being composted or recycled.

Espresso, known for its rich and concentrated flavour, is made by forcing hot water through finely-ground coffee under pressure. While efficient at extracting strong flavours, it results in a higher amount of fine spent grounds per cup. An average Italian espresso, following a 1:3 coffee-to-water ratio, produces about 6-7 grams of spent grounds for a 20-25 ml cup (La Marzocco Home, 2014), though this can vary with brewing style.

FIGURE B.17
Global daily coffee consumption



6 https://athome.starbucks.com/brewing-guide/how-brew-drip-brewer

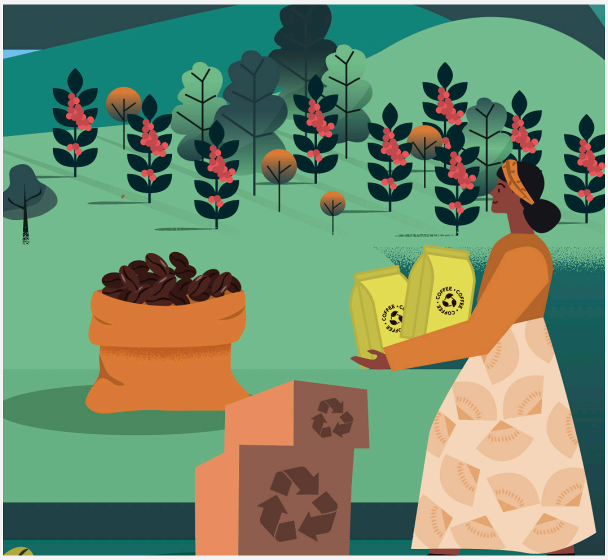
BOX B.11
Lavazza sustainable packaging roadmap

CASE STUDY

Lavazza
Sustainable Packaging Roadmap

Country:
Italy
Year launched:
2020
Coffee value chain area:
Roasting and packaging
Industry/sector:
Food and beverages
Technology readiness level:
Tested solution / On the market

Partner(s):
Lavazza Group with participation of research centres, laboratories, associations, and converters
Input:
More recyclable and low environmental impact material for packaging
Output:
Packaging with improved sustainability performances



Description: Lavazza's Sustainable Packaging Roadmap is a measurable path undertaken in 2020 to help reduce the Group's environmental footprint and make its entire packaging portfolio recyclable, reusable or compostable by 2025. Based on the Group's sustainable-by-design concept, the Roadmap is founded on the following indicators: i) reduction of CO_2eq emissions with the packaging emission category; ii) reduction of the ratio of the packaging weight to the product weight; iii) material circularity index iv) recyclability (ratio of recyclable to total packaging), consisting of 100% reusable, recyclable and compostable packaging.

Motive: Packaging is essential to maintain the quality, taste, and freshness of coffee and at the same time allows its safe storage, transport, and use. The utilization of non-renewable or non-recyclable materials has a significant impact on the environment in terms of both emissions and scarcity of resources. A sustainable packaging solution that meets consumer demands for quality and convenience while working within available consumer waste management services is needed.

Challenges and lessons learned: In 2023, through its activities, the roadmap enabled the Lavazza Group to make 76% of its product portfolio packaging recyclable. In detail, 77% of the packaging produced at the three main plants (Turin and Gattinara in Italy and Lavérune in France) – where 91% of the total production is concentrated – is recyclable.

Economic impacts: The Group has allocated a significant investment of approximately 25 million euros to convert 23 production lines.

Environmental impacts: Increase in the material circularity through recycling, reduction in the amount of material used in packaging, and reduction in CO_2eq emissions related to packaging material. Examples are the 18% reduction in the weight of the flexible packaging for the 1 kg beans format and the decrease in the weight of the tin packaging with a consequent 7% saving in CO_2eq emissions.

Social impacts: Strategy is focused on UN Sustainable Development Goals 12 – Responsible Consumption and Production and Goal 13 – Climate Action.

Cultural, educational and awareness impacts: The company has joined major European collaborative platforms (RecyClass and CEFLEX) developing new recyclability guidelines in the packaging sector.

Coffee capsules have recently become a popular alternative for brewing espresso-like beverages at home or in the office. In Europe, capsules account for 16% of the coffee consumed,[7] approximately 400,000 tonnes (Panhuyzen, S. and De Vries, F., 2023).

Single-use coffee capsules, containing pre-measured doses of coffee, are designed for specialized machines that ensure consistency and ease of use. The convenience and growing variety of flavours have made them popular. Due to their high extraction efficiency, capsules require less roasted and ground coffee to brew a cup compared to filter or espresso methods. This reduced coffee usage means that the GHG emissions of a single-serve unit (SSU) brewed cup are comparable to other brewing systems, while also minimizing coffee waste (Quantis Environmental Consulting, 2023).

7 https://www.osti.gov/servlets/purl/1649439

However, the single-serve coffee system faces criticism for its higher material usage compared to flexible packaging, leading to greater material waste. The main concern with capsules is the pollution they may cause during disposal, rather than their emissions impact.

Managing the end-of-life disposal of coffee capsules is a significant challenge, addressed through various strategies. These include dedicated collection systems, recycling facilities that separate the capsule body from the coffee, and compostable solutions that can be processed in industrial composting facilities.

There is no one-size-fits-all solution for recycling coffee capsules, as recycling systems vary significantly between countries, especially in waste collection, sorting, and recycling processes.

For instance, industrial compostability is not uniformly available or developed across regions. Some countries primarily use anaerobic treatment facilities, while others rely on aerobic treatment plants. Among these, some accept bioplastics (e.g., Italy), while others do not (e.g., Germany, Belgium). Similarly, aluminium and plastic recovery centres are often not yet equipped to handle the specific recycling needs of capsules.

In recent years, various initiatives in Europe have aimed to improve the recyclability and compostability of coffee capsules, such as Arecafe (Spain), Green Deal (Netherlands), Aluminum & Plastic Recovery Plan (Netherlands), Blue Bin (Belgium), recycling communication and Best in Class sorting technology (Germany), Alliance pour le Recyclage des Capsules en Aluminum (ARCA) and Alliance Recyclage Petits Plastiques (France), Podback (UK), and ReCap (Italy).

In addition to improving end-of-life management, there is a growing focus on using biobased or recycled materials to reduce reliance on virgin raw materials. New materials on the market aimed at replacing fossil-based sources include cellulosic materials, biopolymers like PLA (Polylactic Acid) and PHA (Polyhydroxyalkanoates), and recycled materials.

BOX B.12
Circular coffee capsule design critical elements

The circular design of a coffee capsule should consider several crucial aspects:

- Reduce the number of materials used without compromising the capsule's functionality.
- Choose materials with a reduced environmental impact, such as biobased or recycled materials.
- Create capsules that are easily recyclable or compostable, considering the specific recycling infrastructures available in different markets.

Analysing coffee consumption requires considering various contexts beyond the home, including cafes, coffee shops, and vending machines. In cafes, the practicality of serving beverages to-go often involves disposable cups, lids, and straws, which pose environmental concerns due to their single-use nature. Similarly, vending machines rely on disposable containers, contributing to the environmental impact of coffee consumption outside the home.

B.2.7.2 Impacts of consumption and end of life

The disposal and valorization of spent coffee grounds and associated waste materials remain critical environmental concerns. Most spent coffee grounds are still treated as waste, representing a significant missed opportunity for revalorization. When disposed of in landfills, these grounds contribute to GHG emissions, producing methane as they decompose anaerobically – a potent contributor to climate change.

The main barriers to valorizing spent coffee grounds are logistical and regulatory, including challenges in collection, management, and stabilization. Despite these hurdles, recent years have seen the emergence of several promising initiatives that suggest a future where used coffee grounds are increasingly viewed as a valuable resource rather than waste.

Regarding coffee capsules, their convenience comes with an environmental cost. Capsules, often made from plastic or aluminium, are not always recyclable due to variations in local facilities, regulations, and consumer disposal habits. This has raised concerns about their sustainability, as effective collection and processing schemes are challenging to establish.

B.2.7.3 Consumption and end of life by-products composition

Spent coffee grounds are the leftover coffee grounds after brewing, regardless of the method used. They are typically dark brown to black with a granular texture, though particle size and moisture content can vary depending on the brewing process and grind size.

Chemically, spent coffee grounds retain significant organic compounds and nutrients. They are rich in carbon (45-55%) and nitrogen (2-2.5%), making them a valuable source of organic matter. They contain around 40% total fibre, including cellulose (8%) and hemicellulose (36%). While much of the caffeine is extracted during brewing, spent grounds still contain small amounts (<0.5%). Additionally, they have notable levels of proteins (around 10%) and lipids (up to 16%), contributing to their nutrient profile. Spent coffee grounds also contain bioactive compounds, including chlorogenic acids (2.3%) with antioxidant properties (Mendes dos Santos et al., 2021).

B.2.7.4 Circular opportunities for consumption and end of life

Spent coffee grounds are the most extensively explored coffee by-product for valorization, largely due to their availability in large quantities and their rich organic content, oils, and bioactive compounds, which make them suitable for various circular

FIGURE B.18

Chemical compounds of spent coffee grounds (after coffee brewing)

CHEMICAL COMPOUNDS OF BY-PRODUCTS	SPENT COFFEE GROUNDS
ASH	0.47%
CAFFEINE	0.02%
CARBOHYDRATE	
CELLULOSE	8.6%
CHLOROGENIC ACID	2.3%
FAT	2.3%
HEMICELLULOSE	36.7%
LIGNIN	0.05%
LIPIDS	16%
MINERALS	0.8%-3.5%
MOISTURE	74.7%
PROTEIN	10.3%
TANNINS	0.02%
TOTAL FIBRE	43%
TOTAL PECTIC SUBSTANCES	0.01%

Note: Adapted from Mendes dos Santos et al. (2021).

economy opportunities. The concentration of spent coffee grounds in consuming countries likely drives more research and development funding compared to producing countries.

In agriculture, spent coffee grounds are valued as an organic fertilizer, rich in nitrogen, potassium, phosphorus, and micronutrients. Although caffeine levels are low, researchers continue to study potential negative effects on certain plant varieties, soil, and groundwater.

Additionally, converting spent coffee grounds into biochar through pyrolysis creates a stable, carbon-rich soil amendment with multiple benefits, reducing fertilizer use by about one-third, sequestering carbon, and decreasing nitrogen dioxide emissions from the soil.

Pyrolysis is a key focus in the recovery of coffee waste, with processed coffee grounds yielding three outputs: bio-oil, which requires upgrading for better performance; biogas, which has a lower calorific value than natural gas (14 MJ/Nm³ vs. 38 MJ/Nm³); and biochar, which can be used as a soil amendment or in other innovative applications (Matrapazi et al., 2020). For instance, activated carbon from coffee grounds has been successfully used in double-layer capacitors, showing good capacitance in high-rate charge-discharge cycles (Kikuchi et al., 2013). Additionally, CNR Nanotech has explored high-tech uses, such as incorporating coffee grounds into the production of accumulators and batteries.

In agriculture, spent coffee grounds have been utilized as a growing medium for mushrooms. This concept was researched by the Department of Architecture and Design at Politecnico di Torino in collaboration with Lavazza. Since 2007, they have developed a systemic solution to add value to spent coffee grounds (Barbero and Toso, 2009). After extracting lipids for pharmaceutical and cosmetic use, the grounds were used as a substrate for cultivating edible mushrooms (Pleurotus ostreatus), with the remaining substrate then used for vermicomposting.

In Egypt, Cupmena,[8] launched a project that repurposes spent coffee grounds as a substrate for specialty mushroom cultivation and organic fertilizers. These sought-after mushrooms are grown using coffee grounds, requiring effective collaboration with coffee chains for efficient collection and market development to sell the mushrooms as a sustainable product.

In vermiculture, worms thrive on spent coffee grounds, often enriched with other food and agricultural by-products. They convert these into nutrient-rich vermicompost, a high-quality fertilizer. The worms themselves can be processed into protein-rich flours for animal feed, as seen with Entocycle,[9] a UK-based company pioneering in this field.

Spent coffee grounds can also be used in animal diets. A study found that incorporating up to 10% of this by-product into the feed of dairy ewes improved both milk production and composition (De Otalora et al., 2020), without negatively affecting feeding behaviour or digestibility. Similar applications have been explored with other animals, particularly cows, with positive results, such as in a programme that repurposes spent coffee grounds in partnership with Starbucks locations in Japan.[10]

The cosmetics industry extracts valuable oils and bioactive compounds from spent coffee grounds, including polyphenols with antioxidant properties and caffeine, known for its skin-toning and anti-inflammatory effects. These extracts are used in skincare products for moisturizing, anti-aging, and protection. The natural texture of spent coffee grounds also makes them an excellent exfoliant in scrubs and soaps, offering a sustainable alternative to synthetic microbeads, which are harmful to the environment. Kaffe Bueno,[11] founded in 2016 by three Colombian entrepreneurs, exemplifies this approach by using green chemistry and biotechnology to transform coffee by-products into ingredients for cosmetics, nutraceuticals, and functional foods, including Kaffoil (an active oil) and Kaffibre (an exfoliating agent), with ongoing research into haircare and sunscreens.

In energy production, spent coffee grounds are a valuable biomass resource with a relatively high calorific value, suitable for combustion or gasification to produce heat and electricity. They can also be processed into bio-logs and pellets, offering a sustainable alternative to fossil fuels. In Joure, Netherlands, Jacobs Douwe Egberts partnered with Veolia to use spent coffee grounds as biofuel for its plant (Circular Economy Stakeholder Platform 2020), replacing natural gas to generate the steam needed for coffee production. This biomass boiler system reduces the plant's carbon footprint and exemplifies a closed-loop circular economy.

Spent coffee grounds are also being used in the development of biocomposites, where they serve as fillers combined with various polymers. While efforts to incorporate this by-product

8 https://cupmena.com

9 https://entocycle.com

10 https://www.thefuturescentre.org/signal/starbucks-japan-closes-loop-from-waste-coffee-grounds-to-milk/

11 https://www.kaffebueno.com

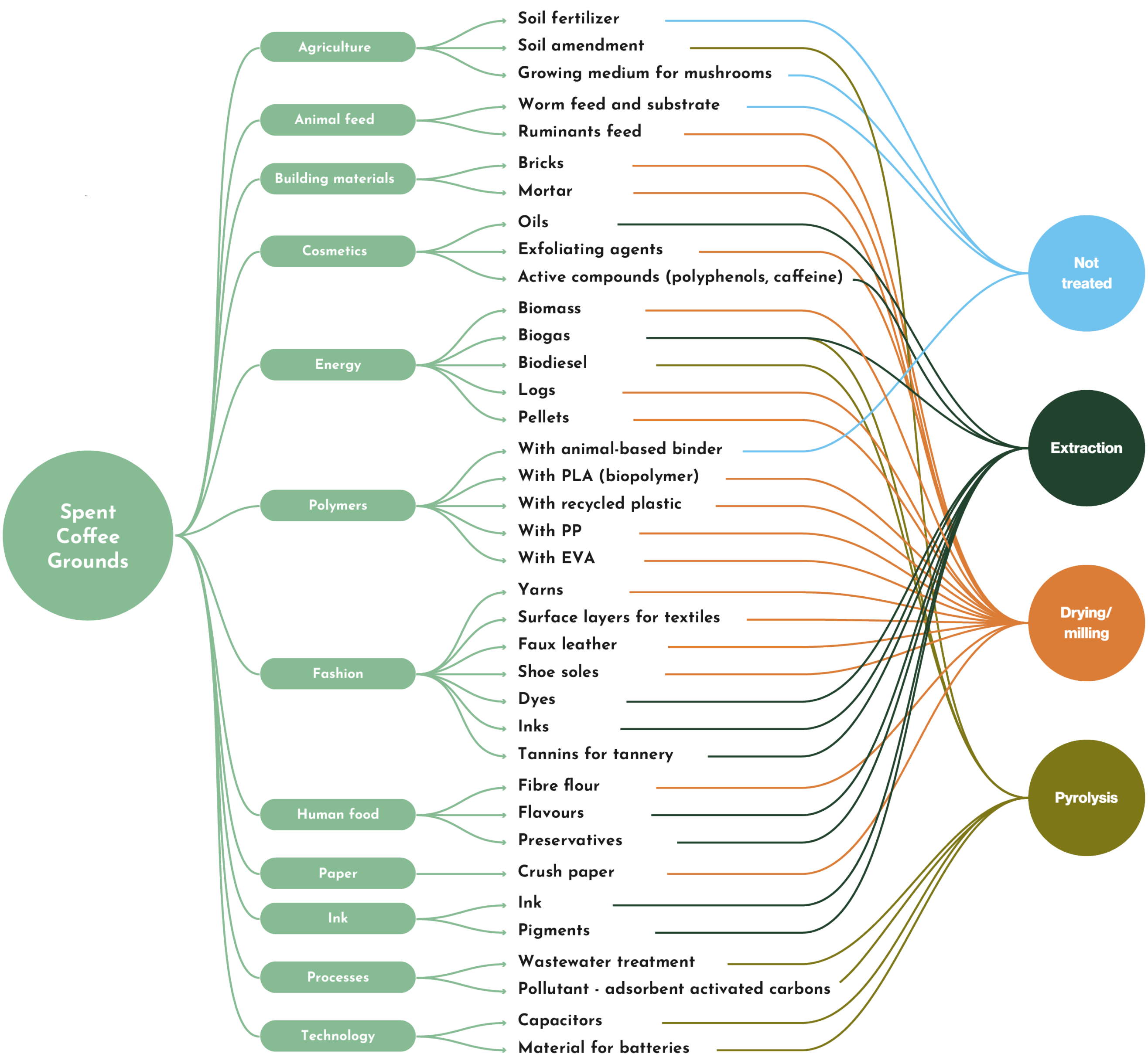
into polymers and biopolymers have been made, challenges remain in terms of recyclability, cost-effectiveness, and overall performance.

Coffeefrom, an Italian project by Il Giardinone Cooperativa Sociale in collaboration with Politecnico di Milano, developed an innovative biopolymer using spent coffee grounds (Coffeefrom, 2023). Their first industrial product is a coffee set – cup and saucer – made with a percentage of spent coffee grounds, certified for food use and featuring a refined design. The project also has a strong social foundation, as Il Giardinone integrates vulnerable individuals into production through its circular economy initiatives. Although the product is not compostable due to its thickness, Coffeefrom is exploring certifications and improved end-of-life options.

In the fashion industry, spent coffee grounds are increasingly being valorized, transformed into materials like yarn and fabrics with unique properties such as natural odor control, UV protection, and quick-drying capabilities – ideal for activewear and casual clothing. S.Café yarns, developed by Singtex in Taiwan, use a patented process to integrate micronized spent coffee grounds into polyester or nylon filaments (Singtex, n.d.). This innovative textile is versatile, suitable for products including t-shirts, socks, footwear linings, and bed sheets. Additionally, spent coffee grounds are used to produce natural dyes, offering an eco-friendly alternative to synthetic dyes and providing warm tones to fabrics.

In the food industry, a women-led startup from Denmark called Connecting Grounds has developed a product called Coffee Base, a versatile ingredient used in confectionery and snack products, replacing coffee aromas and artificial colourants while adding dietary fibre, protein, and caffeine. Coffee Base can also substitute all-purpose flour in gluten-free recipes,

FIGURE B.19
Value-addition uses for spent coffee grounds



Source: ITC Coffee Guide Network's Circular Economy Working Group and Center for Circular Economy in Coffee, 2024.

offering a sustainable and multifunctional solution for various culinary applications. It is made by drying spent coffee grounds, enabling cafes to locally produce sweets and baked goods. Similar initiatives have been undertaken by companies like RFine Biomass Solution (RFI Enbiomass, n.d.) and GroundUp Eco Ventures (Ground Up EV, n.d.), in Canada, and The Kawa Project in the US (The Kawa Project, n.d.).

In recent years, various extraction processes for producing food-grade oils and extracts have been evaluated. However, legislative barriers and market constraints have gradually reduced production.

Similar to using silverskin, coffee grounds can be integrated into paper production. Favini, a paper company, has tested and produced crush paper containing about 15% coffee grounds, reducing the need for virgin cellulose. Research at Politecnico di Torino also demonstrated the potential of using spent coffee grounds as an ingredient in ink production (Barbero and Fiore, 2015).

The issue of coffee capsules presents both logistical and complex challenges. In response, brand owners have played a pioneering role in launching comprehensive recycling initiatives for aluminium and plastic capsules.

For example, Nespresso facilitates the collection of used capsules through its boutiques and collection points at landfills. The collected aluminium is recycled and repurposed into high-value products such as bicycles, coffee machines, products like Victorinox Swiss knives and Caran D'Ache pens, as well as new Nespresso capsules. The residual coffee grounds from the capsules are composted and used as fertilizer.

A notable aspect of this initiative is the development of localized strategies tailored to specific countries. In Italy, this led to the creation of the "Alliance for the Recycling of Aluminum Capsules," which recently welcomed Illy as a partner, further expanding the programme's impact. In a fully circular approach, Nespresso purchases rice cultivated with compost derived from collected capsules and donates it to charity projects. This not only closes the recycling loop but also supports social causes, exemplifying corporate social responsibility and sustainable practices that address both environmental and community needs, while considering local contexts.[12]

Recently, various compostable capsules have been introduced, aiming to enhance sustainability by enabling waste collection where the biowaste stream accepts compostable capsules. This design simplifies disposal for consumers, allowing compostable capsules to be easily composted with organic waste without releasing harmful residues.

Disposable coffee cups, used in vending machines and for take-away coffee in shops, represent a significant waste stream, especially when they are not properly collected for recycling. Their widespread use contributes notably to waste production and challenges in urban solid waste management. Addressing this issue requires exploring sustainable alternatives to traditional disposable cups and promoting conscious consumption practices. This approach extends beyond just coffee consumption, aiming for more sustainable management of materials from daily habits.

This data highlights the potential of circular practices in the coffee sector, not just as strategies to add value to process outputs and reduce inputs but also as ways to generate positive impacts on the coffee system. These strategies include regenerating ecosystems where coffee is grown, easing the burden of agricultural and processing activities, supporting local economies and coffee farmers' incomes, and developing innovative products from what was previously considered waste.

The issues outlined here reveal an underexplored opportunity: systematically utilizing waste as materials for new products that benefit both society and the environment. Circular economy and regenerative agricultural practices offer a path to achieving sustainable system transformation.

12 https://www.nespresso.com/it/it/caffe-sostenibile

BOX B.13
Kaffe Bueno: Upcycling coffee by-products

CASE STUDY

Kaffe Bueno:
Upcycling coffee by-products

Partner(s):
Kaffe Bueno

Country:
Denmark

Year launched:
2016

Coffee value chain area:
Consumption and end of life

Industry/sector:
Personal care, human and animal nutrition, soil and crop health

Technology readiness level:
Implemented action

Input:
Coffee grounds

Output:
KAFFOIL, a lipophilic extract, KAFFIBRE, a coffee exfoliant, KAFFAGE an active biopolymer extract, KAFFAIR, an active ingredient for hair care

Description: Kaffe Bueno converts coffee by-products – such as coffee grounds – into active and multifunctional ingredients which can be applied in a wide range of products across several industries. From a lipophilic extract used in a body lotion, to a natural exfoliating ingredient used in a body scrub, this company is extracting the benefits of coffee beans for human health and wellbeing. Experiments were also conducted in the food sector to produce coffee flour and coffee extracts, which are used as preservatives or flavourings.

Motive: The coffee that ends up in the cup is about 15% to 20% of the ground coffee, the rest becomes spent coffee ground. To date, the industry has not adopted widespread applications for coffee by-products, which are instead treated as waste. However, coffee plants are a source of antioxidants, fatty acids, diterpene esters and proteins. Through bioscience and circularity, this company intends to upcycle coffee grounds into innovative ingredients to unlock the potential of coffee bioactive principles.

Challenges and lessons learned: The valorization of coffee grounds remains an open and promising field, as proven by the continually expanding range of extracts produced by the company. However, the use of ingredients derived from by-products by various industries still needs to demonstrate its full potential, as it requires a shift in entrepreneurial culture and business models. Moreover, significant investment and time is needed not only for research and development but also for overcoming regulatory hurdles.

Economic impacts: Revalorization of coffee by-product.

Environmental impacts: Transformation of by-products of the industrial coffee processing into ingredients for cosmetics, nutraceuticals, and functional foods.

Social impacts: Improved access to circular, healthy and functional ingredients.

Cultural, educational and awareness impacts: Enriched the supply of upcycled cosmetic products through circular practices.

BOX B.14

Nespresso's Da Chicco a Chicco: Coffee capsule recycling schemes

CASE STUDY

Nespresso's Da Chicco a Chicco:

Coffee capsule recycling schemes

Partner(s):
Nespresso

Country:
Italy

Year launched:
2011

Coffee value chain area:
Consumption and end of life

Industry/sector:
Food and beverages, agriculture

Technology readiness level:
Implemented action

Input:
Aluminium and organic waste from coffee capsules

Output:
Recycled aluminium, compost, rice

Description: The Italian name of the initiative *"Da chicco a chicco"* can be translated as "from (coffee) bean to (rice) grain". Capsule collection is carried out through Nespresso boutiques and selected landfills, then aluminium is recycled to build other valuable products (bikes, coffee machines, other Nespresso capsules) and coffee is turned into compost for rice fields in northern Italy. Finally, rice is bought back by Nespresso and donated to charity projects.

Motive: Coffee capsules pose a significant waste management challenge. Whether they are made of a single material or multiple materials, they are difficult to recycle due to the presence of used coffee grounds. This makes it often necessary to dispose of them in non-differentiated waste collection, resulting in the loss of opportunity to recycle the materials they are made of.

Challenges and lessons learned: The definition of capsule collection schemes clashes with the limitations and restrictions imposed by the Italian regulation, which significantly undermines the development of new strategies such as reverse logistics and home collection. The main alternative identified by the other competitors is the development of compostable capsules. Despite the creation of a national programme for the recovery of aluminium capsules (Alleanza per il riciclo delle capsule in alluminio), only one company (Illy) joined the initiative, which is still limited in terms of collection points and partners.

Economic impacts: Nespresso has allocated over 7 million euros to develop and implement its own capsule collection system.

Environmental impacts: Since its first day, the project has enabled the recovery of 8,000 tonnes of used capsules, over 480 tonnes of aluminium, and more than 4,950 tonnes of used coffee grounds.

Social impacts: The project contributes to national charities by donating the rice produced with the coffee grounds compost.

Cultural, educational and awareness impacts: The revalorization of coffee capsules into different outputs, which has proved the feasibility of their recycling.

PART II
SECTION C

Challenges and recommendations for a more circular coffee sector

The need for transformation in the coffee sector is evident, along with the sustainable opportunities offered by scaling circular economy practices. However, this shift presents challenges, and effective change requires a clear baseline. This section draws on a global survey by the ITC Coffee Guide Network Circular Economy Working Group, highlighting key challenges and recommendations for implementing and mainstreaming circular economy practices in the coffee sector.

Key findings

- **Strategic recommendations:** Collaboration across governments, NGOs, private sector, and coffee producers is essential for implementing circular economy practices. Over 40 million tonnes of coffee waste are generated annually, representing an untapped economic opportunity. Inclusive frameworks are needed to help small businesses and farmers adopt circular practices, supported by policy measures and transparent reporting.
- **Farming and production:** Regenerative practices like agroforestry and crop rotation can restore ecosystems and increase biodiversity. The use of coffee by-products (e.g. husks and cherry pulp) offers economic opportunities and environmental benefits. Financial support should help farmers adopt these practices, with living income benchmarks addressing income gaps for producers.
- **Processing:** Coffee processing generates large amounts of waste, with 95-99% of the coffee cherry becoming by-products. Governments and industry should support transforming this waste into valuable materials, while promoting energy efficiency and better wastewater management. Investments in R&D for by-product use and emissions reduction are critical.
- **Packaging and transport:** Industry should adopt compostable and recyclable packaging aligned with local waste management systems. Packaging should be designed with its end-of-life use in mind, prioritizing the reuse and recycling of materials. Circular business models can create economic value while reducing waste. Decarbonizing transport systems is also a priority.
- **Consumption**: Public campaigns should educate consumers on circular economy benefits. Certification schemes should highlight sustainable practices, ensuring economic rewards for those adopting them. Retailers should minimize energy, milk, and packaging waste to reduce environmental impacts.
- **Post-consumption:** Systems for collecting and recycling coffee by-products, including spent coffee grounds, must be developed to turn waste into biofuels, compost, and other value-added products. Local networks and regulations should support the collection and reuse of these by-products, fostering innovation in their use.

C.1 Challenges in implementing a circular economy across the coffee sector

The shift towards a circular economy in the coffee sector presents immense opportunities for sustainability, but also comes with significant challenges. To effectively implement circular economy practices, collaboration across the value chain, from research and development (R&D) centres to farmers and industry players, is critical. This section explores the core barriers that must be overcome, ranging from isolated actionable knowledge and fragmented policies to financial limitations and logistical hurdles. Each of the following subsections delves into these challenges and offers insights into how the coffee sector can move towards a more integrated and sustainable circular economy.

C.1.1 Actionable knowledge is isolated

More coordination is required between research centres, R&D, local solutions, farmers, and the industry throughout the C-GVC. While innovative models have been proven and tested, and much research exists on circular economy opportunities, it remains isolated and fragmented, hindering the practical and accessible implementation of circular economy. This underscores the need for a practical way to develop, implement, and scale pilot projects to apply circular economy technologies and processes in different contexts. Standardized guidelines, practical how-to best practices, and research must be consolidated and made accessible.

Training, piloting, and adapting circular economy practices in coffee-growing countries through the demonstration and dissemination of solutions to local cooperatives, coffee farmers' associations and programmes is important. A change of mindset is just as vital. Local indigenous knowledge of regenerative agricultural practices and the use of by-products are at risk of being forgotten or undervalued with the emergence of innovative and novel solutions coming from start-ups in consumer countries. Local knowledge and practices need to be understood, documented, shared, and uplifted for the effective and contextualized uptake of circular economy principles and processes.

C.1.2 Fragmented policies, regulations, and standards need adaptation and consensus

Technologies and products associated with a circular economy model are new, and the food safety requirements, labelling, and regulations for using a traditional food by-product as a new food ingredient are fragmented. Regulations and standards for import/export of new products can be either absent or too stringent. There are no specific or clear harmonized codes for the classification of coffee by-products as goods for import and export. Coffee husks, skins, and substitutes are included in the broad category for coffee, but none of them has its own clearly assigned code. This also makes it more challenging to track the amount of coffee by-products being traded globally. In the same way, novel food products that use coffee by-products may not have a clear harmonized code.

BOX C.1
Harmonized codes for coffee

09.01	Coffee, either roasted or decaffeinated; coffee husks and skins; coffee substitutes containing coffee in any proportion.
	Coffee, not roasted:
0901.11	Not decaffeinated
0901.12	Decaffeinated
	Coffee, roasted:
0901.21	Not decaffeinated
0901.22	Decaffeinated

Policies and regulations vary across countries and contexts, and food safety regulations and labelling requirements differ by country and region. In some contexts, regulations for exporting a coffee by-product are more strict or complicated than for exporting coffee. Whether new or existing legislations for coffee also apply to coffee by-products (e.g. dried coffee husks, cherry, or novel products made from these byproducts) remains under consideration. It is particularly challenging for MSMEs and coffee producers in developing countries to keep up with and adapt to a global and fragmented regulatory panorama. Inconsistent regulations across countries around the use of *cascara* as an ingredient, and new regulations forbidding the use or import of plastic in selected countries are some examples of this challenge.

For example, the distribution of coffee cherry mucilage fruit concentrate is restricted due to the stringent regulations and certifications required for export. The regulatory requirements for coffee fruit concentrate differ significantly from those for regular coffee, creating additional barriers for its broader market availability.

C.1.3 Early adopters of innovation, R&D, and industrialization of circular products and processes will run into high costs and risks

High risk and costs are inevitable when entering a market that is still in development, especially for small-sized enterprises, producers, and producer organizations. The feasibility and cost implication for new product development made with coffee by-products need to first be carefully assessed by entrepreneurs considering that market segment. Costs of production at scale are high – biochar and coffee mucilage concentrate are some examples – and while successful pilots and early technologies exist, they are not always cost-efficient at scale.

Product manufacturers, farmers, and farmer organizations take on considerable risk in devoting time, space, and resources to new operational processes. *Cascara* production, for example, requires extra operational costs and processes such as additional processing lines, equipment, and skills. There is no shortcut – a product that is easily contaminated requires learning through trial and error. Innovation requires the resources and capacity to take risks and experiment.

R&D in technology at industrial scale is required to reduce costs, increase efficiency, and ensure compliance with existing regulatory frameworks. International donor and development organization projects and investments that traditionally focus on capacity building through established and proven techniques could help by prioritizing innovation and pioneering new processes and technologies.

Overall, a lack of investment in public-private partnerships for collaborative research limits the potential for open-source or pre-competitive innovation.

C.1.4 There is limited access to finance sources for circular economy implementation

Opportunities for funding have remained few and far between to date. New models for linkages and funding mechanisms are being explored to reduce the gap in access to finance for MSMEs, farmers and producers from developing countries. In the Global South, circular economy is steadily climbing up governments' priority lists, but they need technical and financial support to navigate this transformation and to apply already-proven solutions. Connecting existing small-scale actors, individual farmers, producers, and MSMEs in the Global South with investment for innovations will be crucial. They often lack the information on how to apply for financial support for innovations, even if it is available, which substantially limits entrepreneurial efforts. Mobilizing financial resources and mechanisms to enable funding that promotes equitable access to technology could help bridge this gap.

C.1.5 Supply and demand may be mismatched

Logistical challenges exist in consolidating and distributing coffee by-products, often leading to mismatches between supply and demand. The collection, management, and stabilization of agricultural and food by-products, like used coffee grounds, can pose challenges for implementation. Efficiently gathering and transporting these by-products to entrepreneurs who can utilize them requires careful coordination to ensure sanitary conditions and timely delivery. It is also essential to consolidate and process these materials in a centralized location.

Currently, there is no established standard for collecting and storing coffee by-products. Coffee shops and cafes require standard operating procedures for the collection, preparation, and storage of used coffee grounds intended for collection, ensuring a quality process for food-grade products. Additionally, developing effective packaging and logistical solutions is essential. This process can be time-consuming and requires collaboration between the public sector and industry processors.

There may be a mismatch between the demand for a product, the best location for manufacturing, and the availability of by-products. To promote environmental sustainability, the movement of these by-products should be minimized. Developing local and regional markets for a new product can be difficult if there is not enough demand. If local markets are underdeveloped, it may be necessary to create new global supply chains and logistics, including international transport. However, this can have negative environmental impacts if not managed properly. Economies of scale are essential for achieving profitability, sharing knowledge, and building capacity within the industry (processors).

BOX C.2
Industrial symbiosis in the coffee sector (SISSI)

The SISSI (Information Tools to Support Industrial Symbiosis) project was developed by Area Science Park, an Italian national research centre, as a pilot initiative under the ARGO project (MIMIT, MUR, FVG Region) at the industrial port of Trieste, Italy.

Using a Decision Support System (DSS) that consolidates and georeferences data from multiple sources, SISSI maps the local industrial landscape, aiding consortium managers and policymakers in crafting strategic policies. This tool enabled numerous coffee companies in Trieste to identify waste streams from coffee processing that could be repurposed as inputs for other industries.

The initiative received backing from technical and legal authorities, as well as support from local and national coffee associations. SISSI exemplifies how industrial symbiosis can be achieved, integrating logistics at the industry level to create a network of users and producers of coffee by-products.

C.1.6 Niche and developing markets for coffee by-products are fragmented and lack transparency

There is a lack of transparency in the market for coffee by-products, including pricing and quality. Although new feedstocks for upcycled products are becoming available, there is no open marketplace. Some feedstocks are free, while others are sold as high-quality materials, but pricing varies widely among suppliers, buyers, and locations without any consistent standards. The market for such products is also still in its infancy, which means that standards for quality, collection methods, units of sale, or packaging are not yet in place.

The lack of established standards also creates a lack of opportunity for price discovery or competition and means there are no established logistics for packing and storing, nor regulatory frameworks for importing countries.

Farmers and producers lack important information about prices, best practices, logistics, and quality expectations. The concept of a circular economy is new and promising, but it requires a deep understanding and involves a steep learning curve. The significant costs, risks, and unique operational processes are not always reflected in the prices farmers receive. In Ethiopia, there is indigenous knowledge, such as that surrounding *cascara* tea, but this knowledge is often undervalued by potential buyers and markets.

C.1.7 A niche market development requires entering new, competitive supply chains

Most upcycled products are traded between industry processors (B2B) rather than directly between producers and consumers (B2C). Markets for upcycled products and coffee byproducts often exist outside the coffee industry. Sellers of coffee by-products, upcycled consumer products, and ingredients need to find new customers beyond the coffee sector. However, coffee industry actors may lack the connections and knowledge to access supply chains in other industries. This necessitates the development of new B2B relationships, industry expertise, and networks.

Coffee industry actors (processors) need more educational resources and trainings on how to sell coffee by-products, both within and outside the coffee sector. Most of the industry focuses solely on coffee as a beverage, and the fast pace of daily operations makes it challenging to dedicate time and resources to develop markets for new products. In producing countries, awareness and experimentation are required at the local level, particularly among smallholder farmers and cooperatives.

Many farmers and organizations lack awareness of new processes, and a business-as-usual mindset can make adaptation difficult. Additionally, legal and regulatory challenges may hinder the introduction of new processes and products.

For example, extracts and biorefined byproducts can be sold as ingredients in other sectors – biorefined oils from used coffee grounds can be used in cosmetics and nutraceuticals. Silverskin can serve as an ingredient in vegan leather for apparel and automotive applications, while *cascara* and refined pulp can be sold as food ingredients for energy and sports drinks. However, suitable product packaging may not be easily available.

Product testing and engagement in industries like food, renewable energy, or health and beauty can help gauge consumer expectations and reduce investment risks for entrepreneurs. But farmer organizations face significant restrictions, so it is crucial that they receive subsidies and support. Direct feedback from end users can also ground the process and provide motivation.

C.1.8 There is low consumer awareness of circular economy products

Upcycled and circular products remain a niche market, making investments by coffee producers and processors less viable. Low consumer awareness of the circular economy and the benefits of upcycled products lead to reluctance to pay, limiting the current market for these products. With so many certifications and sustainability concepts related to coffee, consumers may find the circular economy even more confusing.

The complexities, nuances, and sustainability challenges within the coffee global value chain are already difficult to explain to consumers. Communicating the holistic and multi-faceted benefits of circular economy in coffee is an added challenge. Products that require extensive explanation to sell or that are not pleasing to customer tastes will not last long in the market.

Consumer awareness and education are required to help shift the "take-make-waste" mindset and underscore that waste is avoidable in systems of production.

Linear Economy

To effectively reach consumers, processors must identify the messaging that aligns with local consumer preferences. Product-led and consumer preference-driven innovations will also be crucial for effective implementation.

C.1.9 The value is not always circular but should be

The market for circular upcycled products is currently niche, resulting in limited total value available for distribution. This lack of a market means there is also no transparent compensation for the raw materials, efforts, and transport costs associated with collection and distribution.

To address income gaps in the coffee global value chain, the added premiums and value from these products should flow back into the earlier stages of the chain. However, the economic impact of adopting circular economy practices must be evaluated on a case-by-case basis, considering pre-competitive data on costs and investments. Farmers need to assess the costs and benefits of these opportunities in their specific contexts.

A key challenge lies in the farmers' lack of awareness regarding how circular economy practices can positively impact their profits. Understanding varies – for consumers, the circular economy is seen as beneficial for the planet while, for producers, it can mean increased profits, new income streams, or cost savings.

The high costs of new innovations or processes at an agro-industrial scale also hinder progress, as not all technologies have achieved the efficiency of economies of scale. In some cases, subsidies or cost offsetting may be necessary.

Currently, circular economy practices at the production level are not recognized as environmental services that could yield coffee price premiums. To gain appreciation from buyers, the costs, time, and risks associated with implementing these practices must also be recognized by consumers.

Additionally, while carbon credits might be available for some practices, they can be claimed only by one actor within the value chain (such as the coffee producer, upcycled product manufacturer, or coffee roaster). This complicates the challenge of distributing the financial benefits generated by regenerative agriculture, biochar, renewable fuels, and other carbon offsetting practices.

C.2 How to transform the coffee sector through circular economy: policy recommendations

Below are policy recommendations organized by stages in the C-GVC. These recommendations are grounded in the recognition that fostering a circular economy within the C-GVC presents a significant and promising opportunity, driven by the following factors:

- **In the coffee industry, most waste is controlled by processors** and remains largely out of sight for consumers. The main consumer-facing elements of this waste are packaging materials—like containers, cups, and sleeves.
- **During processing, an astounding 95-99% of the coffee cherry becomes a by-product.** Although these by-products are valuable and versatile, they remain consistently undervalued, leaving a significant economic opportunity largely untapped.
- **Globally, the coffee value chain generates over 40 million tonnes of waste annually**, equal to the combined weight of every person in North America, or 365,000 blue whales.
- **Structurally, the coffee industry resembles an hourglass:** while tens of millions of people engage in farming and harvesting and millions more work in coffee shops, only a small group of processors control most of the trade, processing (including instant coffee and decaffeination), and retail. This concentration creates an imbalance across the value chain but also opens a unique window for impactful, large-scale change.

C.2.1 Why now?

Coffee is not only one of the most widely consumed beverages in the world but also one of the most significant internationally traded commodities. However, as outlined in this report, the coffee industry generates substantial amounts of by-products at every stage of the value chain. This waste s challenging for coffee value chain actors to manage, contributing to global pollution and climate change. Instead, it could be repurposed for productive uses.

The coffee sector provides jobs and income across more than 50 coffee-producing countries, impacting millions of people globally.

Farmers, who already face increasing risks due to environmental degradation and economic uncertainty, are particularly vulnerable to the adverse effects of excessive supply chain waste. However, this same waste can be redirected for new, productive purposes.

By adopting circular economy principles and regenerative practices, the industry can unlock opportunities for value addition and create new economic prospects by utilizing by-products that would otherwise become waste. This approach has the potential to foster job creation for young people and diversify income sources, enhancing resilience and growth, especially for farmers and MSMEs in producing countries.

To address these challenges and work towards a more prosperous and sustainable future, there is a significant opportunity to transition to a circular economy. This shift will strengthen the C-GVC and enhance its resilience in the decades to come. By improving how we produce, process, and consume coffee, we can cultivate a future where the C-GVC thrives in harmony with the planet. Transitioning to a circular economy will also contribute to achieving many of the United Nations Sustainable Development Goals (UN SDGs) (Opmeer and Van Eijk, 2020).

This section examines how the coffee global value chain (C-GVC) can transition from a linear to a circular economy. The authors outline key strategies and policy recommendations designed to facilitate this transformation. These recommendations are intended to serve as a roadmap for stakeholders dedicated to turning this vision into reality.

HOW TO READ THESE RECOMMENDATIONS

Recommendations are presented by C-GVC stages, outlining specific actions, impacted stakeholders, and expected outcomes. These include:

- **Stage Identification:** Pinpointing where in the value chain the recommendation applies
- **Policy Recommendation:** Offering detailed guidance on implementing circular practices
- **Stakeholder Impact:** Identifying affected groups and organizations
- **Impact Assessment:** Evaluating social, environmental, and economic effects, and alignment with SDGs
- **Strategy and Implementation:** Providing actionable steps for effective execution

C.2.2 The guiding principles behind the recommendations

The recommendations are based on ten guiding principles for the C-GVC. All organizations involved in the C-GVC can leverage these principles, alongside the broader document, to develop their circular strategies.

C.3 Strategic and overarching recommendations

Circular economy solutions must prioritize inclusivity, particularly for farmers and MSMEs. These key actors in the value chain often struggle to adopt circular practices due to constraints in resources, technical know-how, and access to markets and finance.

BOX C.3

Ten guiding principles for the coffee global value chain

1. **Circulate materials at their highest value**
2. **Regenerate natural systems**
3. **Design to eliminate waste and pollution**
4. **Uplift local approaches to generate local value**
5. **Embrace open-source solutions by sharing technologies and business models**
6. **Foster peer-to-peer learning**
7. **Recognize that local actions can have a global impact–"Think global, act local"**
8. **Focus on innovations that address the sector's most pressing challenges**
9. **Shift from a linear value chain to a circular value system that promotes shared economic value for all**
10. **Embrace progress over perfection**

Most importantly, enjoy the journey!

To ensure that circular economy benefits are widely accessible, supportive frameworks, tools, and policies should be developed through a participatory approach that enables coffee growers, producer organizations, and MSMEs in coffee growing countries to engage meaningfully and benefit from circular practices.

Inclusivity here fosters sustainable growth, diversifies income, and strengthens innovation and resilience across the economic ecosystem, respecting both nature and community while promoting economic empowerment.

In complex systems, traditional, linear problem-solving is insufficient. Addressing these challenges requires a circular, systemic approach that engages multiple issues in an interconnected way. No single solution or isolated actor can tackle these challenges alone. Instead, a collaborative approach allows diverse participants to take purpose-driven actions within the ecosystem, observe systemic changes, and adapt their next steps accordingly.

Table C.1 provides strategic and overarching recommendations for implementing a circular economy across the coffee global value chain, while tables C.2 to C.6 offer more detailed recommendations for each value chain segment.

FIGURE C.1

Key new approaches required to accelerate the transition from linear to circular

REGENERATIVE AGRICULTURE

Combined with local approaches for coffee processing, can make agricultural production circular and add value for coffee producer communities

COLLABORATION, COORDINATION, AND GLOBAL NETWORKS

Can help design and implement circular economy actions and effective cooperation between public and private sector actors to activate processes.

Source: International Trade Centre (2024).

TABLE C.1
Overarching recommendations for implementing a circular economy in the coffee sector

Policy	Stakeholders	Impact	Strategy
0.1 **Establish best practice and shine a light on good examples**	Governments and associations Plus: Farmers (producers), NGOs, industry (traders and processors), entrepreneurs, development partners, research and educational institutions, and consumers	Environmental and socio-economic benefits SDGs 2, 8, 12, 17	• Develop and share open-source databases featuring global best practices. For example, the Center for Circular Economy in Coffee (C4CEC) curates and shares replicable models for widespread impact. • Provide access to technologies, business models, step-by-step guides for farmers, specifications, datasets, and other practical resources, enabling others to adopt effective solutions. • Build local capacity by co-creating training packages with farmers, ensuring resources are accessible in various formats (e.g., videos, photos, and multilingual guides). • Highlight the potential of small, localized solutions by showcasing their innovation, scalability, and value to the broader community.
0.2 **Set metrics and measure progress**	Governments Plus: NGOs, associations, industry (processors, traders, retailers), research and educational institutions	Environmental and socio-economic benefits SDGs 12, 16, 17	• Establish and adopt standardized reporting metrics and key performance indicators (KPIs), integrating existing standards to enhance transparency and prevent greenwashing. This approach will align practices across the supply chain – from farm-level activities to mid-chain actors – and support clear consumer messaging. • Define collective metrics to track progress toward circular economy goals, including waste reduction, recycling rates, and resource efficiency. • Implement independent third-party verification for existing standards, and incorporate new metrics as needed. • Set achievable targets and maintain clear, evidence-backed communication. • Develop a circularity score for each organization to benchmark circular economy efforts. • Create a streamlined monitoring, evaluation, and reporting system to ensure accountability in implementing circular standards. Prioritize accurate reporting that avoids overburdening farmers while providing consumers with trustworthy information.
0.3 **Undertake pre-competitive research and development for industry (processor) waste streams**	Industry (traders and processors) Plus: Governments and development partners, NGOs, start-ups, entrepreneurs, MSMEs, research and educational institutions	Environmental and socio-economic benefits SDGs 12, 17	• Allocate dedicated budgets to Research and Development (R&D) to fuel innovation across the coffee value chain. • Conduct Life Cycle Assessments (LCAs) of coffee products and processes to pinpoint improvement areas and quantify the benefits of circular practices. • Support sustainable product-service design and prioritize R&D in by-product innovation at every stage. Invest in technologies that transform by-products and waste streams into valuable, clean ingredients for other industries. • Promote open-source innovation across the coffee global value chain (C-GVC). • Foster partnerships between academia, industry, and government to advance research on sustainable coffee production and effective waste management. • Create incentives for companies to integrate indigenous knowledge, ensuring that technological advancements are practical and applicable at the grassroots level. • Direct funding to coffee producers, producer organizations, local institutions, and NGOs to support farmer-driven innovation and local solutions.

Policy	Stakeholders	Impact	Strategy
0.4 **Collaborate with adjacent industries**	Governments and associations Plus: NGOs, industry (processors) and farmers (producers)	Economic and environmental benefits SDGs 9, 12, 17	• Identify strategic industries adjacent to the coffee sector and establish collaborative, cross-industry programmes. Industries such as cosmetics, chemicals, flavour and fragrance, and building materials present valuable opportunities for incorporating coffee by-products into their products and processes. • Engage these industries in circular innovation hubs and pre-competitive collaborations focused on developing circular economy solutions for the coffee sector. • Expand circular and regenerative agricultural practices to include adjacent crops, enhancing both environmental benefits and income generation for farmers.
0.5 **Develop economic incentives and promotion programmes**	Governments and industry, traders, and development partners Plus: NGOs, start-ups, MSMEs, research and educational institutions and consumers	Environmental and socio-economic benefits SDGs 9, 10, 12	• Promote policies that assign responsibility across the entire product lifecycle, from farming (upstream) to retail and consumer use (downstream). Encourage sustainable business models, take-back programmes, and recycling initiatives. Offer government incentives, such as tax breaks, grants, and subsidies, to support stakeholders in adopting circular economy and regenerative practices. • Develop and enhance reward models to compensate farmers, producer organizations, start-ups, and MSMEs engaged in regenerative agriculture and circular economy initiatives, especially in coffee-growing regions. • Integrate regenerative agriculture and circular economy practices into carbon insetting and compensation programmes across industry supply chains. • Evaluate carbon markets to ensure credible offsetting mechanisms, such as coffee land use offset by reforestation projects, effectively support environmental goals.
0.6 **Partnerships and pre-competitive collaboration**	All stakeholders including government, development partners, industry (processors/traders/retailers), start-ups and entrepreneurs, MSMEs, research and educational institutions, consumers and NGOs	Environmental, economic and social benefits SDG 17	• Foster public-private partnerships (PPPs) to scale circular economy initiatives by forming alliances with farmers, processors, retailers, NGOs, impact investors, and academic institutions. • Collaborate within existing pre-competitive networks, associations, and initiatives – locally and globally – to share best practices, foster innovation, and support collective research. Examples include the ICO Coffee Public-Private Task Force (CPPTF), ITC Coffee Guide Network, C4CEC, Global Coffee Platform (GCP), Sustainable Coffee Challenge (SCC), International Women's Coffee Alliance (IWCA), World Coffee Research (WCR), CGIAR, and the Swiss Sustainable Coffee Platform. • Partner with farmer organizations, regional associations, and producer-led movements in coffee-growing regions, such as CLAC-Fairtrade, Fairtrade International, and Solidaridad Network, to amplify farmer voices and support their innovations. • Publish regular reports on progress, initiatives, and challenges to ensure transparency and accountability. • Design multi-stakeholder collaborations with an inclusive, participatory approach, ensuring solutions are driven by and beneficial to coffee producers. Enable conditions that encourage new partnerships and innovations.

Policy	Stakeholders	Impact	Strategy
0.7 **Adopt waste reduction approaches**	Industry (processors) Plus: Farmers (producers), NGOs, research and educational institutions	Economic and environmental benefits SDGs 8, 9, 12, 13	• Launch initiatives that promote innovative approaches within the coffee industry, particularly among processors. For example, the UK's Time After Time Fund demonstrates how targeted funding can effectively support sustainable practices. • Facilitate collaboration across the coffee value chain – from producers and processors to retailers and consumers – to build a fully circular system (e.g., the SISSI model). • Utilize life cycle assessments (LCAs) to identify improvement areas and quantify the benefits of circular economy practices. • Enhance the value of by-products through product-service design and creative innovation, transforming waste into valuable resources.
0.8 **Create a market for coffee by-products**	Farmers (producers) and industry (processors) Plus: Start-ups, entrepreneurs, MSMEs, adjacent industries, research and educational institutions	Economic and environmental benefits SDGs 8, 12	• Support and strengthen Business-to-Business (B2B) networks that enable the effective reuse of waste and maximize the value of by-products. • Provide financial incentives for farmers, MSMEs, and industry stakeholders to aggregate and clean waste streams, making them suitable for reuse. • Invest in research and development of technologies that efficiently collect, sort, clean, and process waste into viable feedstock for new products. • Increase awareness among farmers, MSMEs, and processors about the economic and environmental benefits of repurposing waste streams into valuable ingredients and products.
0.9 **Standards and certifications**	Governments and NGOs Plus: Industry (traders and processors), farmers (producers), retailers, and consumers	Economic and environmental benefits SDGs 8, 12	• Encourage the adoption of international standards for circular economy practices in the coffee sector, such as those set by the International Organization for Standardization (ISO). • Support the use of harmonized codes under the World Customs Organization (WCO) Harmonized System (HS) to classify imports and exports accurately; these codes are updated every five years. • Develop certification programmes to recognize and reward circular practices in coffee production and distribution. • Identify circular economy and regenerative agriculture practices already covered by existing third-party sustainability certifications. Integrate these practices into both existing and new second-party verification schemes, such as the GCP Equivalence Mechanism, to reinforce sustainability commitments across the industry.

Policy	Stakeholders	Impact	Strategy
0.10 **Education and awareness**	Governments, development partners, and NGOs Plus: Farmers (producers), industry (traders and processors), research and educational institutions	Economic and environmental benefits SDG 12	• Implement educational campaigns to raise awareness among coffee value chain actors about the importance and economic opportunities of circular economy practices. • Offer training programmes for coffee farmers and retailers on sustainable practices and waste reduction strategies across the value chain. • Embed circular economy and regenerative agriculture training within existing coffee sector support initiatives. • Leverage pre-competitive platforms, local institutions, and regional coffee associations to disseminate knowledge on circular practices and their benefits. • Develop "Training of Trainers" programmes to empower local coffee support organizations, institutions, and associations, fostering local ownership and blending global insights with local expertise. • Promote ongoing learning by documenting and sharing lessons learned, fostering collaborative action among value chain actors beyond individual projects. • Create online learning modules with case studies for higher education students and professionals, supporting knowledge-building for future leaders in the coffee sector.
0.11 **Regulatory frameworks and advocacy**	Governments and development partners Plus: Farmers, industry, NGOs	Economic and environmental benefits SDGs 12, 17	• Engage in joint advocacy to shape policies that promote circular economy practices within the coffee industry. • Identify and address regulatory barriers that hinder the sale and trade of coffee by-products as raw materials, ingredients, or new products. • Propose legislation that incentivizes circular economy initiatives. • Introduce financial mechanisms (e.g., waste fees) to discourage unsustainable practices and support transformative changes. • Set ambitious sector-wide targets for waste reduction and resource efficiency. • Leverage policy windows to drive change; for example, recent volatility in oil prices presents an opportunity for governments to redirect funds toward regenerative practices. Such policies can enhance national self-reliance by using waste as nutrient inputs, reducing dependence on imported, fossil fuel-derived fertilizers.
0.12 **Catalyse investment**	Governments, development partners, NGOs, industry (traders processors), and networks Plus: Farmers	Economic and environmental benefits SDGs 8, 9, 17	• Develop and expand innovative financial mechanisms to support regenerative agriculture and circular business models. • Link MSMEs, producer organizations, and local institutions with finance, funding sources, and impact investors to drive innovation and circular practice adoption. • Showcase successful innovations and best practices from coffee-producing countries to attract investment. • Provide investment readiness training for MSMEs and producer organizations in coffee-producing regions. • Incorporate regenerative agriculture and circular economy practices into carbon insetting programmes, enabling supply chain investments in sustainable practices. • Subsidize the risks, opportunity costs, and operational investments needed to implement new products and processes. • Mitigate investment risks by offering tailored technical assistance, along with market and business development services.

C.3.1 Farming and production recommendations

These recommendations target the coffee farming and production stage and are aimed at achieving circularity in coffee farming by integrating sustainable practices such as regenerative agriculture, optimizing resource use, and enhancing the value of coffee by-products. Recommendations also focus on ensuring a living income for coffee farmers.

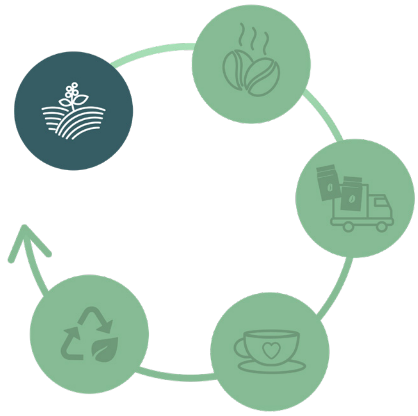


TABLE C.2
Farming and production recommendations

Policy	Stakeholders	Impact	Strategy
1.1 **Regenerative agriculture and agroforestry**	Governments and development partners Plus: Farmers (producers) and industry (traders and processors)	Primarily environmental but also socio-economic benefits SDGs 2, 13, 15	• Promote and support regenerative agriculture practices that restore soil health, enhance biodiversity, and build ecosystem resilience. • Encourage core regenerative methods, including no-till farming, cover cropping, crop rotation, agroforestry, integrated weed and pest management, and the use of enriched organic compost and natural fertilizers. • Develop and share detailed guidelines explaining the "what" and "why" of regenerative agriculture, along with practical tools to help farmers choose and adapt practices that align with their unique needs, goals, resources, and local conditions. • Adopt an inclusive, participatory approach to shape policies and legislative instruments that support regenerative agriculture while discouraging linear, extractive farming practices. • Offer financial incentives, including grants, subsidies, and interest-free or low-interest loans, to encourage widespread adoption of regenerative techniques.
1.2 **Commercialization and use of coffee by-products**	MSMEs and start-ups Plus: Development partners, farmers, industry (traders and processors), NGOs, and associations	Primarily environmental but also socio-economic benefits SDGs 2, 13, 15	• Encourage the use of coffee by-products at the farming stage (e.g., coffee husks) as organic fertilizer or soil amendments through financial incentives and technical support. • Simultaneously combine incentives with disincentivizing linear behaviours (e.g. increased levies on synthetic inputs), to create a mutually reinforcing approach. • Support coffee farmers, MSMEs, producer organizations, and local and regional institutions with market assessment, linkages, and training for coffee by-products. • Existing regional and local institutions support MSMEs and producer organizations with linkages to other sectors. Develop and share know-how for accessing supply chain partners in industries outside of the coffee industry.

Policy	Stakeholders	Impact	Strategy
1.3 **Market creation for coffee by-products**	Start-ups and farmers Plus: MSMEs, adjacent industries, and industry (processors)	Economic and environmental benefits SDGs 12, 8	• Encourage the repurposing of coffee by-products at the farm level (e.g., coffee husks, cherry skins, and leaves) as organic fertilizers, compost, mulch, and soil amendments, offering financial incentives and technical support to boost adoption. • Combine these incentives with measures that disincentivize linear practices, such as levies on synthetic inputs, creating a balanced, mutually reinforcing approach. • Support coffee farmers, MSMEs, producer organizations, and local and regional institutions through market assessments, linkages, and training for developing coffee by-products. • Empower regional and local institutions to connect MSMEs and producer organizations with supply chain partners outside the coffee sector, helping them access new markets. Explore both local and international opportunities for coffee by-products. • Facilitate market connections between producers and buyers through coordination with regional institutions. • Develop open-source technologies and business models to effectively utilize farming by-products (e.g., cherry skins, pulp, leaves, and branches) and establish milling processes that convert these materials into value-added products. • Establish milling processes to efficiently convert coffee by-products (e.g., cherry skins, husks, leaves, and stems) into high-value products. • Encourage the use of coffee by-products as organic fertilizers, compost, mulch, and soil amendments through financial incentives and technical support. Repurposing organic farming waste plays a vital role in fertilizing coffee plants and, combined with regenerative practices, can significantly reduce reliance on chemical inputs. • Customize approaches to align with local and regional contexts, considering farm size, specific farmer needs, production and processing methods, available facilities, and nearby crop ecosystems.
1.4 **Circular economy and regenerative agriculture to close living income gaps**	Governments, development partners, industry, NGOs, associations, and farmers	Primarily socio-economic but also environmental benefits SDGs 1, 5, 8, 17	• Develop a model to evaluate how circular and regenerative solutions reduce living income gaps in coffee-producing countries. • Commit to paying and transparently disclosing premiums to farmers adopting regenerative practices, strengthening industry transparency and sustainability. • Share information on the use of a living income framework to help ICO Members meet Roadmap commitments. • Collaborate with regional knowledge Hubs, such as the InterAfrican Coffee Organization (IACO), PROMECAFE, and the ASEAN Coffee Federation (ACF), to support ongoing localized research, monitoring, and evaluation of circular and regenerative contributions toward achieving living incomes. • Establish living income benchmarks across all ICO producing countries by 2030 and assess net income gaps. • By 2030, facilitate PPPs in at least 50% of coffee-producing countries to close income gaps, focusing on achieving living and prosperous income benchmarks. • Build on existing momentum from ICO Members, CPPTF, and the wider coffee sector to collaboratively address income disparities. • Provide farmers with economic incentives for adopting regenerative agriculture, agroforestry, and circular practices, including but not limited to carbon credit payments.

Policy	Stakeholders	Impact	Strategy
1.5 **Farmer-focused education initiatives**	Development partners, farmers and farmer organizations, associations, governments, and NGOs Plus: Industry and educational institutions	Social, economic and environmental benefits SDGs 1, 2, 4, 12, 13, 17	• Set up long-term education initiatives and support programmes to help farmers learn about and implement regenerative agriculture practices while safeguarding their future income. • Design and implement training initiatives to support farmers (producers) in proactively optimizing the economic, environmental, and social benefits of regenerative approaches. • Enhance and expand educational resources for farmers, focusing on regenerative agriculture and circular economy practices. Utilize materials from sources such as the Alliance of Biodiversity and CIAT, ITC Coffee Guide, C4CEC, World Coffee Research, Specialty Coffee Association, and the EU Circular Economy Action Plan, among others. • Build upon and integrate resources developed at local and regional institutions into global resources to further exchange of good practices between regions and countries. • Combine educational initiatives with longer-term approaches that include monitoring and feedback regarding training requirements. • Combine educational initiatives with upfront financial support to implement new know-how (e.g. supporting start-ups and transition costs).
1.6 **Diversification of income streams**	Farmers (producers), MSMEs, and start-ups Plus: Development partners, adjacent industries, governments, NGOs, and educational institutions	Socio-economic and environmental benefits SDGs 1, 2, 5	• Empower farmers with the skills and resources to maximize income streams and promote co-product strategies that create additional income streams e.g. through intercropping coffee with banana and other fruits and vegetables. • Promote entrepreneurial and development programmes, especially aimed at the "next generation" of farmers and entrepreneurs, to spark interest in new circular models and regenerative techniques. • Promote the synergic environmental, social and economic benefits of regenerative agriculture to ensure farmers (producers) are aware of all the benefits. • Focus NGO-led or micro-finance entrepreneurial programmes at marginalized societal segments (e.g. women, youth, etc.) to create additional co-benefits.
1.7 **Multistakeholder research collaborations for regenerative agriculture and by-product development in producing countries**	Industry (traders and processors) including farmers and farmer organizations (producers), associations, academic and scientific institutions, research organizations, development partners, and technology companies	Environmental benefits and added socio-economic benefits SDG 17	• Foster multistakeholder research collaborations to test and improve innovations in circular economy and regenerative agriculture throughout the different stages of coffee production, with a focus on economic viability. • Leverage existing networks, research focused entities, and local and regional institutions to bridge academic research with coffee sector and value chain actors. • Invest in transdisciplinary research programmes that integrate multiple fields (e.g., agriculture, environmental science, social policy, and innovation) and actively involve a diverse range of stakeholders, including researchers, private sector producers, NGOs, and companies beyond the coffee industry, such as tech firms. • Launch collaborative research projects and co-design pilot programmes that combine traditional methods with innovative approaches. • Offer incentives for companies to integrate indigenous knowledge into their operations, ensuring that technical advancements are grounded, practical, and effective at the grassroots level.

C.3.2 Processing recommendations

These recommendations target the coffee processing stage and seek to enhance efficiency and sustainability in coffee processing by promoting innovative technologies, best practices, and the utilization and repurposing of waste and by-products generated during the coffee processing stage.

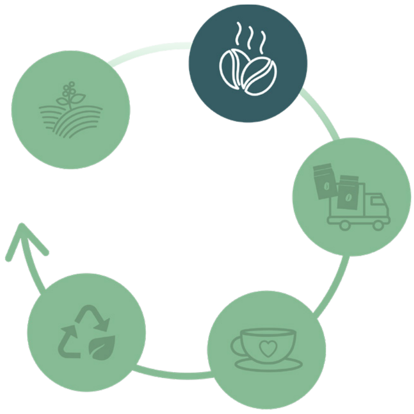


TABLE C.3
Processing recommendations

Policy	Stakeholders	Impact	Strategy
2.1 **Value creation from waste and by-products**	Farmers, entrepreneurs, and MSMEs Plus: Industry (traders and processors), adjacent industries, research institutions, start-ups, governments, and NGOs	Environmental benefits, and economic opportunities for start-ups and coffee processors via new markets for clean and aggregated feedstocks SDGs 12, 8	• Encourage the valorization of waste and by-products from coffee processing through targeted research, financial incentives, and technical support. Beyond producing fertilizers from fermented organic residues (see Section 1.3), explore and incentivize other high-value applications of processing by-products • Promote the use of processing waste as a valuable feedstock by implementing supportive policies from both government and industry stakeholders. • Engage local scientific and research institutions to provide essential training and technical support for effective project implementation. • Empower farmers to aggregate, clean, and add value to coffee by-products, such as cherries and husks, unlocking new economic opportunities at the production level.
2.2 **Coffee processing**	Governments, development partners, and industry (traders and processors) Plus: Research institutions and associations	Socio-economic and environmental benefits SDGs 1, 2, 5, 9, 12, 17	• Establish policies and incentives to promote R&D and innovation in coffee processing facilities (instant, roasted, and decaffeinated) to adopt energy-efficient and renewable energy technologies, reducing both production energy intensity and emissions. • Identify and pursue opportunities to decarbonize manufacturing processes and enhance sustainable disposal of processing waste. • Explore and support alternative uses for coffee grounds to reduce methane (CH_4) emissions from land spreading and decrease reliance on incineration.[13]
2.3 **Coffee wastewater**	Governments Plus: Development partners, farmers (producers), industry (traders and processors) and research institutions	Environmental benefits SDGs 6, 9, 12, 17	• Promote water-saving practices in coffee processing to significantly reduce wastewater volumes. • Adopt biological treatments for coffee processing wastewater to ensure that discharged effluents are safe for plants and surrounding ecosystems. • Establish and enforce strict regulatory standards for wastewater discharge to protect water quality and preserve local ecosystems. • Support research into innovative, eco-friendly solutions for wastewater reduction and safe effluent management.

13 Currently, used coffee grounds are incinerated to produce low-grade heat; however, this process is inconsistent, and the heat generated is insufficient for effective factory use, making it more of a waste disposal method aimed at enhancing green perceptions. Another alternative, "land spreading", is impractical in large quantities for farmers and leads to significant methane (CH_4) emissions. Additionally, anaerobic digesters are generally ineffective with used coffee grounds, limiting viable options for sustainable disposal and utilization.

Policy	Stakeholders	Impact	Strategy
2.4 **Technological solutions for emission control**	Governments Plus: Industry (processors)	Environmental and potential economic benefits from scaling-up innovative technological solutions SDGs 9, 12, 17	• Create a comprehensive guide detailing best practices and technological solutions for coffee processing, including catalytic emission cleaners, emission control systems, heat recirculation systems, gas abatement systems, flexible ventilation systems, and energy-efficient equipment. • Transition coffee processing operations to renewable electricity sources to significantly reduce GHG emissions. • Promote the adoption of sustainable technologies through targeted training workshops and tax incentives to encourage widespread implementation.
2.5 **Incentives for processors to move from countries of consumption to countries of production (origin)**	Governments and industry (traders and processors) Plus: Adjacent industries and development partners	Economic and social impacts SDGs 9, 12, 17	• Encourage the industry (processors) to invest in value addition at origin by establishing roasting plants and instant coffee manufacturing facilities within coffee-producing countries. • Develop skills and training programmes focused on value-added coffee processing and circular economy practices in producing regions, ensuring that local communities gain skilled job opportunities and achieve a living income.

C.3.3 Packaging and transport recommendations

These recommendations target the coffee packaging and transport stages and seek to develop sustainable packaging solutions, to implement transparent pricing that rewards circular and sustainable practices, and to decarbonize transport.

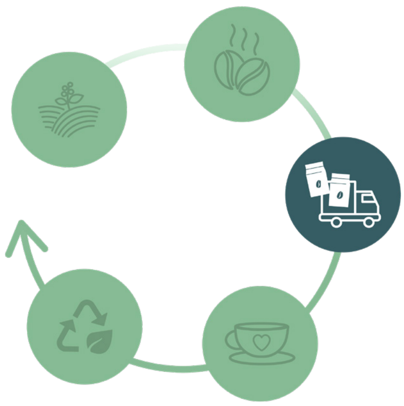


TABLE C.4
Packaging and transport recommendations

Policy	Stakeholders	Impact	Strategy
3.1 **Circular Economy in packaging**	Industry (processors), governments, and research institutions	Economic and environmental benefits SDGs 9, 12, 17	• Develop and implement innovative packaging solutions grounded in compostability, bio-based materials, and mono-material designs to facilitate the separation of biological and technical materials. • Mandate sustainable, recyclable, and biodegradable packaging throughout the coffee supply chain, promoting re-usable containers over single-use bags. • Support R&D for advanced packaging technologies that reduce waste and improve recyclability. • Encourage the adoption of Sustainable Product-Service Systems (SPSS), where processors retain ownership of packaging and products. This incentivizes design for durability, recyclability, and optimized performance, lowering costs, increasing profits, and enhancing environmental sustainability.

Policy	Stakeholders	Impact	Strategy
3.2 **Alignment of packaging choice with local waste policies**	Governments, industry (processors), packaging industry (traders and processors), coffee retailers and waste management industry (processors), and development partners	Primarily environmental benefits, but, if well-designed, can also yield economic advantages SDGs 9, 12, 17	• Ensure that all coffee packaging, including single-serve capsules, aligns with local waste management policies to maximize recyclability and minimize environmental impact. • Design and procure packaging solutions tailored to the waste management capabilities of the regions where they will be consumed and disposed of. For instance, using commercially compostable bioplastics is effective only if composting and recycling facilities are available locally. • Foster open dialogue with key stakeholders – including packaging processors, government agencies, and coffee retailers – to make informed, regionally appropriate packaging choices.
3.3 **Transparent pricing structures**	Governments, NGOs, and industry (processors), including wholesalers and roasters	Economic and environmental benefits SDGs 9, 12, 17	• Implement transparent pricing structures that incentivize circular and sustainable practices upstream. • Establish meaningful price differentials for suppliers who adopt circular economy practices, in line with best practices, to ensure fair, living incomes for all supply chain actors. • Reform internal structures that currently reward buyers for minimizing supplier costs; instead, prioritize circularity and efficient practices to foster green procurement and a fair, sustainable circular economy. • Leverage accessible digital technologies across the supply chain to enhance traceability, transparency, and management of social and environmental data, with support from NGOs and industry partners. • Align with downstream government policies in consumer countries (e.g., procurement policies, compliance standards, international commitments) to maximize impact and effectiveness.
3.4 **Implement sustainable product-service systems**	Industry (processors) Plus: Retailers, instant coffee manufacturers, manufacturers, farmers, governments, NGOs, and development partners	Economic and environmental benefits SDGs: 8, 9, 12, 13	• Adopt innovative business models that provide coffee as a service rather than just a product (e.g., "Coffee as a Service" or "CaaS"). • Sustainable Product-Service Systems (SPSS) could include delivering coffee in reusable containers with collection and refilling options, or leasing and buyback programmes for coffee equipment that include maintenance and end-of-life services to ensure recycling or refurbishment. • To support the widespread adoption of SPSS models, consider implementing: 1) supportive policies, such as tax incentives for MSMEs investing in SPSS, and 2) industry education campaigns that highlight the benefits of circular economy practices in the coffee sector.

C.3.4 Consumption recommendations

These recommendations target the consumption stage and seek to promote responsible consumption choices.

TABLE C.5
Consumption recommendations

Policy	Stakeholders	Impact	Strategy
4.1 **Responsible consumption**	Governments Plus: Consumers, governments (national and local), NGOs, industry (processors), and retailers	Environmental benefits SDGs 12, 17	• Design and implement national and local policies to promote sustainable consumer behaviour. • Introduce mandatory or voluntary eco-labelling to guide citizens towards environmentally conscious purchases. • Provide clear disposal instructions to encourage responsible consumer practices. • Test various information campaigns and pricing strategies in real-world settings (e.g., cafes) to shift consumer habits, such as offering discounts for reusable cups or surcharges for single-use cups. • Back these efforts with supportive policies. For instance, France has introduced bans on the most harmful single-use plastic coffee cups. • Develop partnerships to explore effective behavioural prompts, such as visual and verbal cues, to help consumers adopt more sustainable habits.
4.2 **Certifications and standards**	Governments and NGOs Plus: Industry (processors), farmers, consumers, and development partners	Environmental and socio-economic benefits SDGs 12, 17	• Develop consumer-focused certifications and standards to help circular organizations stand out. • Create voluntary standards, certifications, and codes of conduct with clear circular economy criteria and indicators. Encourage adoption to enhance transparency, accountability, quality control, and tracking across the supply chain. For instance, Starbucks has introduced "green store" certification, evaluated by an independent auditor, covering areas such as energy efficiency, water stewardship, renewable energy, sustainable materials, and waste reduction. • Use certification to inform consumers about the environmental impact of single-use capsules and ready-to-drink (RTD) coffee products. • Require that all environmental claims undergo verification by an advertising ombudsman to prevent greenwashing and ensure integrity.
4.3 **Resource efficiency in coffee shops**	Retailers Plus: Consumers and industry (processors)	Environmental and economic benefits SDGs 7, 12	• Optimize water temperature for coffee brewing, ideally between 85-95°C, just below boiling, for optimal flavour extraction. • Use energy-efficient appliances for heating water. • Refine frothing techniques to minimize milk waste and lower costs. • Optimize energy use by utilizing efficient, high-performance coffee machines. • Install renewable energy sources on-site or source renewable energy from a provider. • Switch from printed menus to digital displays such as QR codes and offer digital receipts to cut down on paper waste.

C.3.5 Post consumption recommendations

These recommendations target the post-consumption stage and seek to promote better management and revalorization of coffee waste, improved recycling efforts, and sustainable disposal practices.

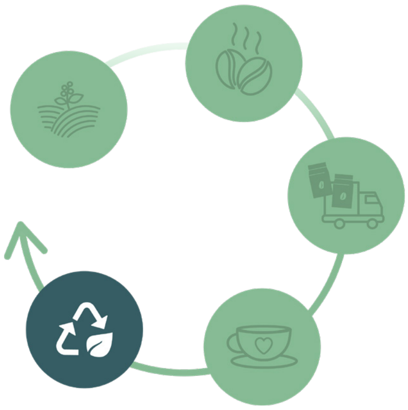


TABLE C.6
Post consumption recommendations

Policy	Stakeholders	Impact	Strategy
5.1 **Resource recovery and waste management**	Governments and development partners Plus: Waste management companies, industry (traders and processors, especially retailers and coffee shops), research organizations, and educational institutions	Environmental and economic benefits SDGs 12, 13	• Invest in systems for the efficient collection and recycling of coffee grounds and by-products utilizing reverse logistics as part of a Sustainable Product-Service System (SPSS). • Introduce regulations governing the collection, disposal, and reuse of used coffee grounds and other coffee by-products. • Encourage entrepreneurs, MSMEs, and industry stakeholders to create value-added products from coffee waste, such as biofuels, compost, and innovative materials. • Implement economic incentives, such as tax credits or grants, to motivate retailers and cafes to sort coffee waste at the source. Retail shops could receive exemptions from disposal fees for proper waste segregation and management. • Establish local monitoring and evaluation units to develop data collection methodologies and implement comprehensive tracking systems. Data-backed monitoring and regular feedback will enhance compliance and continuous improvement.
5.2 **Revalorization of waste**	Governments and development partners Plus: NGOs, community groups, and consumers	Environmental and social benefits SDGs 2, 3, 11, 12, 17	• Develop new pathways for local revalorization of coffee waste, such as used coffee grounds. • Establish local networks to manage the supply and demand for waste products from coffee shops and consumers, enabling local revalorization efforts. These exchanges can operate as for-profit ventures led by entrepreneurs or startups, or as non-monetary initiatives (e.g., through NGOs, community projects, or swapping schemes), maximizing social impact by creating opportunities for youth, women, and marginalized groups to engage in circular practices. • Seek support from local governments to strengthen these networks, backed by enabling national policies to ensure effective operations.

Policy	Stakeholders	Impact	Strategy
5.3 **Promote R&D in valorization of coffee by-products**	Governments and development partners Plus: Industry (processors) such as coffee shops and retailers, start-ups and entrepreneurs, and research and educational institutions	Environmental benefits and economic opportunities SDGs 12, 17	• Identify innovative uses for the 40 million tonnes of used coffee grounds generated annually by households, coffee shops, and the instant coffee industry. • Implement circular recycling programmes for coffee grounds and other by-products: coffee processors can collect grounds from their own facilities and participating coffee shops to repurpose into new products or services. • Aggregate and purify feedstocks to prepare them for various uses. • Promote collaboration among government, industry, and academia to conduct research and develop new applications for used coffee grounds. • Establish a dedicated research fund to explore efficient, location-specific repurposing solutions for coffee grounds, such as energy production, chemicals, absorbents, food ingredients, and construction materials. This valuable resource should be optimized rather than wasted. • Encourage and incentivize entrepreneurial ventures dedicated to innovatively repurposing coffee by-products.
5.4 **Promote R&D in packaging**	Governments Plus: Industry (processors), especially packaging manufacturers, and research and educational institutions	Environmental benefits, economic opportunities SDG 12	• Promote R&D initiatives aimed at reducing material use in packaging. • Make it the responsibility of processors to ensure that their packaging is easily recyclable on a wide scale. • Introduce innovative mechanisms, such as Extended Producer Responsibility (EPR) fees, to fund advancements in local sorting and recycling technologies. • Explore further opportunities to enhance recycling capabilities through ongoing R&D efforts. • Support reverse logistics and drive innovation in packaging design and chemical recycling technologies (especially for plastics) to optimize the potential for "coffee cup-to-coffee cup" recycling.

The strategic recommendations in Section C provide a comprehensive roadmap for embedding a circular economy within the coffee sector. This framework highlights the need for coordination, impact investment, and innovation, alongside the adoption of sustainable practices at every stage of the coffee value chain. By fostering collaboration, research, and knowledge sharing, and by establishing strong regulatory frameworks, financial incentives, and market mechanisms, the coffee sector can move towards a more sustainable and resilient model.

Achieving this transformation requires the active involvement of all coffee stakeholders – farmers, industry players, government agencies, NGOs, research institutions, financial institutions, investors, and development partners. By embracing circular economy principles and scaling up both existing and new solutions, the sector can enhance its economic viability, environmental sustainability, and social equity. This collective action will not only strengthen the coffee industry but also advance global sustainability goals.

PART III
SECTION D The coffee sector in numbers

Key findings

- International coffee prices refer to the ICO Composite Indicator Price (I-CIP). In the 2022/23 coffee year, prices opened at 190.18 US cents/lb, fluctuating between a season low of 145.54 US cents/lb on 11 January 2023 and a coffee year high of 194.92 US cents/lb on 5 October 2022.
- All coffee group indicators, except for Robustas, saw declines in 2022/23. Robustas rose by 5.1%, from 106.89 to 112.39 US cents/lb. In contrast, Colombian Milds underperformed significantly, dropping 25.2% from 289.38 to 216.50 US cents/lb. Other Milds and Brazilian Naturals also declined by 20.5% and 22.1%, settling at 209.83 and 174.03 US cents/lb, respectively, largely due to weakened exports. The high prices of Colombian and Other Milds prompted roasters to adjust blends, incorporating more Robustas to keep product costs competitive.
- The average annual volatility for the I-CIP was 8.8%, while New York futures showed 11.3% volatility. Brazilian Naturals displayed the highest volatility among the groups, reaching 11.7% during the 2022/23 coffee year.
- Global coffee exports dropped by 5.7% to 122.9 million 60-kg bags, reflecting a drawdown in stock levels, particularly in non-producing countries. The decline was broad-based, with the Americas, notably South America, experiencing the steepest fall at 11.0%.
- Green beans dominate global coffee exports, accounting for 90.1% (110.7 million bags) of total exports in 2022/23. The share of Arabica in green bean exports fell to 60.4% from 63.6% in 2021/22, primarily due to shifts in pricing and income dynamics.
- In coffee year 2022/23, global coffee production declined slightly by 0.04% to 165.5 million bags, with Asia and Oceania experiencing a 3.0% production drop, mainly from Vietnam due to adverse weather, resulting in a net loss of 1.5 million bags.
- That same coffee year, global consumption fell by 1.9% to 173.0 million bags, following a 3.8% expansion in 2021/22. The reduction in consumption was driven by high costs, decreasing disposable income, and a base effect after the sharp rise in 2021/22, which marked the largest expansion in over 20 years with an increase of 6.4 million bags—the biggest net gain since 1978/99.

D.1 Prices

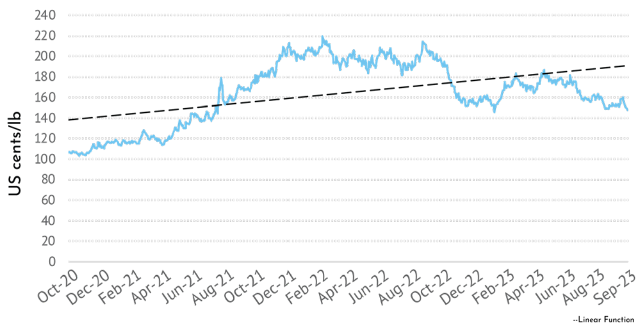
D.1.1 I-CIP Prices

The ICO Composite Indicator Price (I-CIP) is the benchmark for international coffee prices. In coffee year 2022/23, prices opened at 190.18 US cents/lb, fluctuating between a seasonal low of 145.54 US cents/lb on 11 January 2023 and a high of 194.92 US cents/lb on 5 October 2022.

The I-CIP averaged 165.39 US cents/lb in 2022/23, buoyed by a 4.9 million bag deficit that kept upward pressure on prices. While the I-CIP declined year-on-year by 16.4% from 197.90 US cents/lb, it remained well above the previous 10-year average of 130.63 US cents/lb. Over the coffee year, the I-CIP decreased by 14.2%, from 178.54 US cents/lb in October 2022 to 153.13 US cents/lb by September 2023.

The largest day-on-day increase occurred between 30 January and 31 January 2023, with the I-CIP rising by 4.5% as stock levels hit their lowest point in nearly 20 years, driving up short-term prices.

FIGURE D.1
ICO Composite Indicator Price (I-CIP) | October 2020 - September 2023



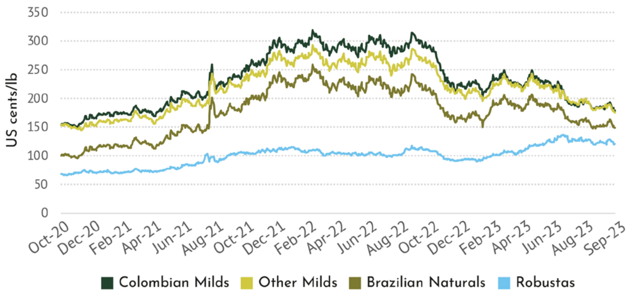
D.1.2 Growths

Prices for all coffee group indicators declined in coffee year 2022/23, except for Robustas, which rose by 5.1%, from 106.89 to 112.39 US cents/lb. Colombian Milds saw the largest drop, contracting by 25.2% from 289.38 to 216.50 US cents/lb.

Similarly, Other Milds and Brazilian Naturals fell by 20.5% and 22.1%, reaching 209.83 and 174.03 US cents/lb, respectively. This decline was mainly driven by reduced exports throughout 2022/23. Additionally, high prices for Colombian and Other Milds prompted roasters to reconsider their blends, incorporating more Robustas to keep final products competitively priced.

FIGURE D.2

ICO Group Indicator Prices | October 2020 - September 2023

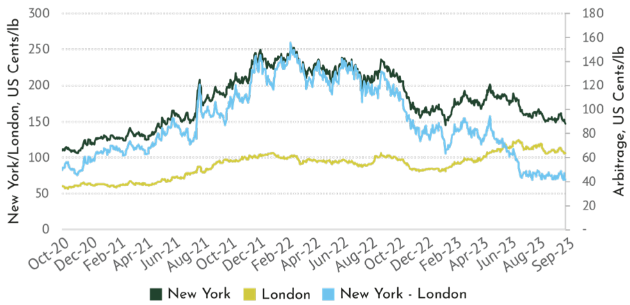


D.1.3 Price volatility in spot and futures coffee markets

In coffee year 2022/23, Arabica prices underwent a downward adjustment, likely correcting a prior overvaluation. Day-to-day, Arabica futures prices fluctuated between 145.03 and 212.28 US cents/lb. In the London futures market, the 2nd and 3rd positions averaged between 80.97 and 124.10 US cents/lb, with the lowest point on 16 November 2022 and a 28-year

FIGURE D.3

Average of 2nd and 3rd position of ICE Futures, US cents/lb



peak on 19 June 2023.

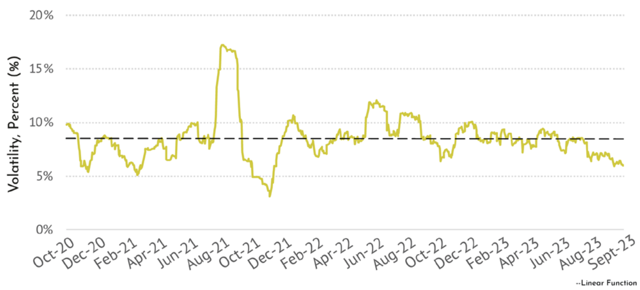
The I-CIP exhibited an average annual volatility of 8.8%, compared to 11.3% in the New York futures market. Among the coffee groups, Brazilian Naturals experienced the highest volatility, reaching 11.7% in coffee year 2022/23.

D.1.4 Arbitrage

Throughout coffee year 2022/23, the arbitrage between the London and New York futures markets narrowed steadily, decreasing from 99.56 US cents/lb in October 2022 to 44.41 US cents/lb by September 2023. On average, the arbitrage for the 2022/23 coffee year was 70.63 US cents/lb—a 44.2% decline from the previous year's average of 126.56 US cents/lb. Increased pressure on the Robusta futures market, driven by concerns over sustained high Arabica prices, contributed significantly to closing the gap between the two.

FIGURE D.4

Rolling 30-day volatility of the I-CIP | October 2020 - September 2023

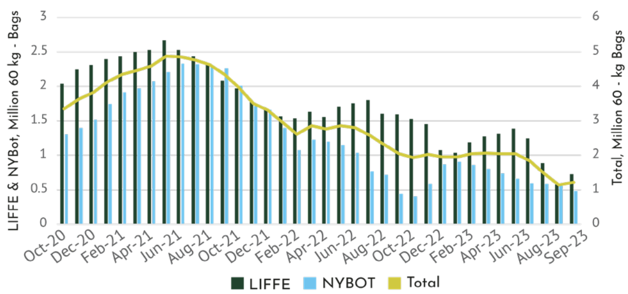


D.1.5 Certified Stocks

In October 2022, New York Board of Trade (NYBOT) certified Arabica stocks hit a low of 0.41 million 60-kg bags, the lowest point of the 2022/23 coffee year. Stocks gradually recovered to 0.91 million bags by January 2023, averaging 0.67 million bags over the year. In contrast, London International Financial Futures and Options Exchange (LIFFE) certified stocks remained more stable, averaging 1.14 million bags for the year and peaking at 1.52 million bags in October 2022.

FIGURE D.5

Certified stocks | October 2020 - September 2023



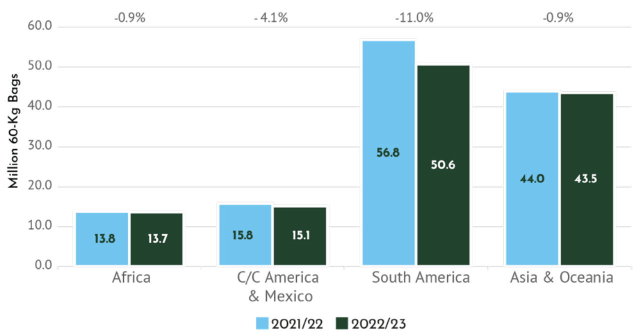
D.2 Exports

D.2.1 Exports of all forms of coffee – world and regions

In coffee year 2022/23, global exports of all forms of coffee declined by 5.7% to 122.9 million 60-kg bags, marking the largest downturn since a 9.5% fall in 1994/95. The global macroeconomic environment did little to bolster consumer confidence, with high inflation and rising interest rates across key advanced economies increasing the cost of living and reducing disposable income worldwide.

While these conditions likely contributed to a decline in coffee consumption and, consequently, green bean exports, much of the downturn's magnitude was due to a drawdown in stocks held in non-producing countries. Sustained high interest rates made stockholding increasingly uneconomical. Green bean stocks in Europe, Japan, and America dropped by 6.1 million bags in 2022/23—a 26.1% decrease compared to coffee year 2021/22.

FIGURE D.6
Exports of all forms of coffee - regions, millions of 60-kg bags



The downturn affected all regions, with the Americas experiencing the steepest decline, particularly South America, which saw an 11.0% drop in exports. This regional disparity partly reflected the global stock drawdown and the broader division within the coffee industry: Arabicas, dominant in the Americas, versus Robustas, more prevalent in other regions. Stocks of Arabica beans in Europe, Japan, and America fell by 3.1 million bags (36.2%), while Robusta stocks dropped by 2.3 million bags (43.8%) in coffee year 2022/23 compared to 2021/22. Consequently, South America's share of total exports decreased by 2.4 percentage points in 2022/23.

A closer look at export data reveals the following:

- Brazil was the main driver of the global and South American downturn, with a 7.9% decline and a net loss of 3.1 million bags in coffee year 2022/23. This decrease was still influenced by the frost in July 2021, which limited Brazil's supply for the export market.
- Colombia and Peru recorded the second and third largest net losses, with exports down by 12.0% and 36.7% respectively in 2022/23. Heavier-than-normal rainfall adversely impacted production in both countries, leading to reduced supplies for export and contributing to the declines from these two South American origins.
- Honduras and Uganda saw the largest net gains in total coffee exports, at 0.6 million and 0.3 million bags, respectively, in coffee year 2022/23. Despite Honduras' strong growth, exports remain below coffee year 2020/21 levels due to the lasting impacts of hurricanes Iota and Eta on its 2021/22 performance. Uganda, Africa's largest Robusta producer and exporter, managed to fill the gap left by Asia and Oceania, especially India, through a solid harvest and stock drawdown in the second half of the year, spurred by rising international Robusta prices.
- India drove the slight dip in Asia and Oceania's exports, down by 0.9 million bags in 2022/23. However, this was due to a base effect rather than underlying industry issues, as India's exports in 2021/22 had reached a record high of 7.2 million bags, surpassing the previous five-year average by 1.2 million bags.

FIGURE D.7
Exports of all forms of coffee - regions, percent share (%)

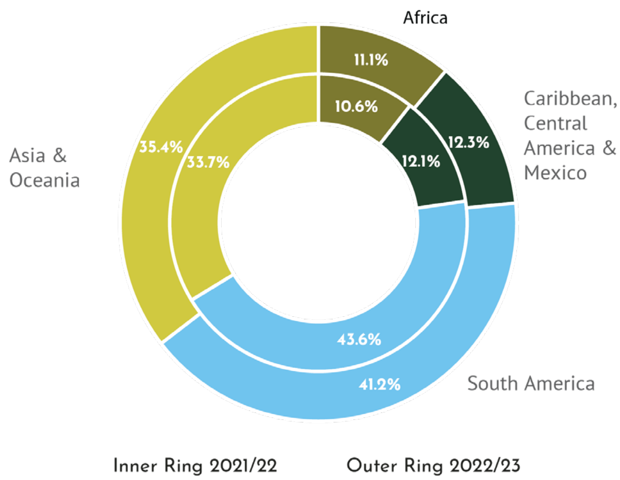


FIGURE D.8
Exports of all forms of coffee - top ten countries, '000 60-kg bags

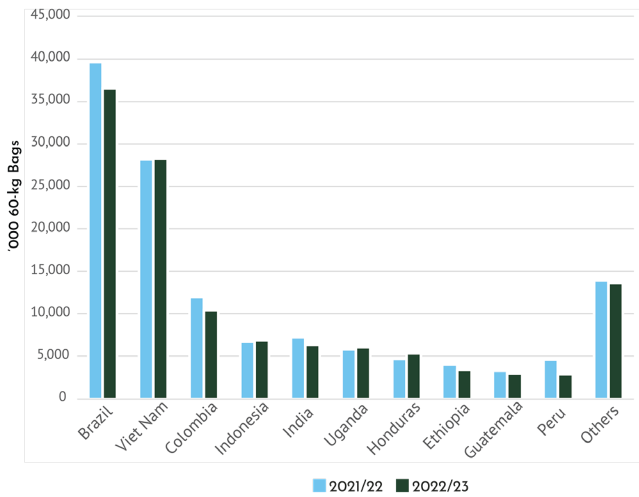
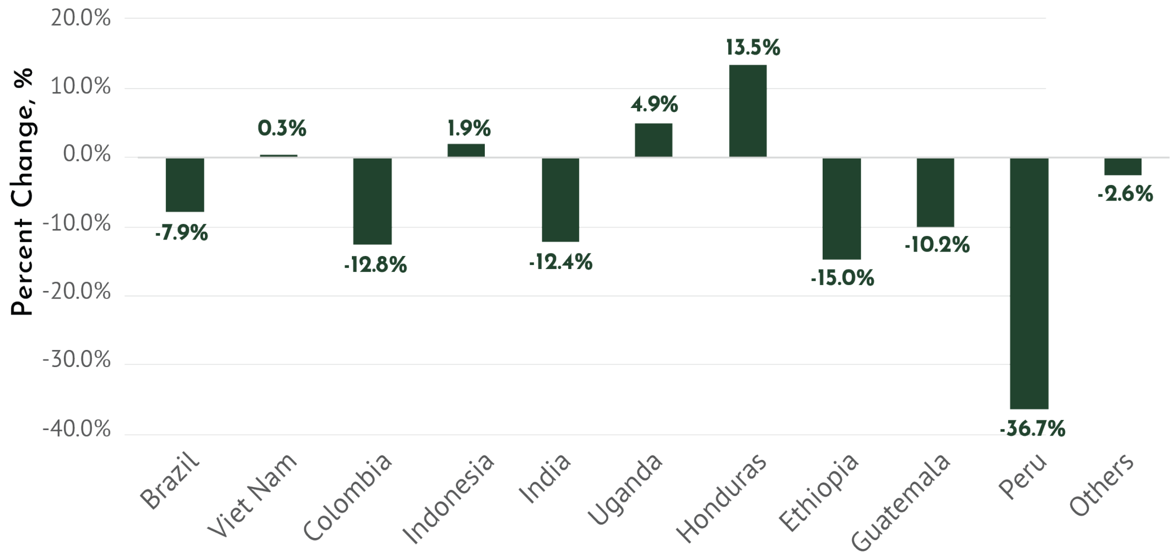


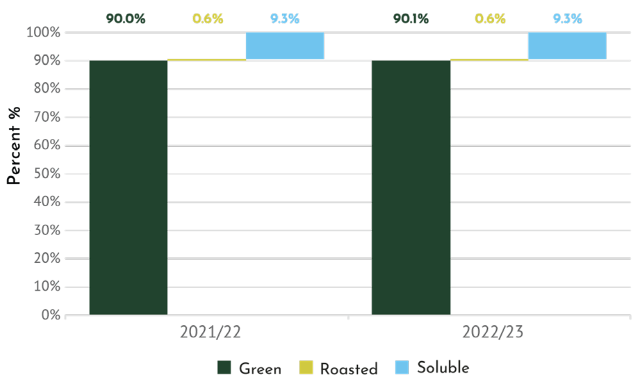
FIGURE D.9
Exports of all forms of coffee - top ten countries, growth rates (%)



D.2.2 Coffee exports by form

Green beans remain the dominant form of coffee exported worldwide, comprising 90.1% (110.7 million bags) of total coffee exports in coffee year 2022/23, a slight increase from the 90.0% share in 2021/22. Processed coffee (roasted and soluble) accounted for the remaining 9.9% (12.2 million bags) of exports.

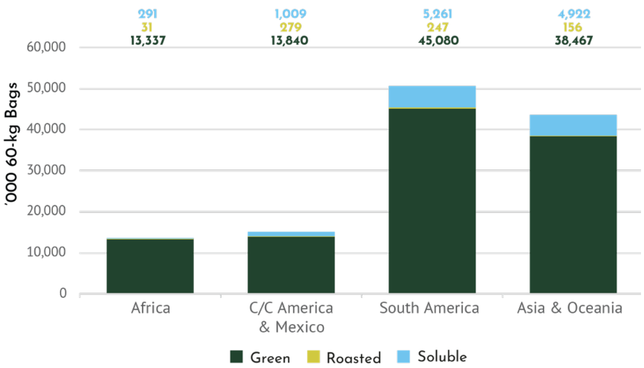
FIGURE D.10
Share of exports by forms of coffee - world, percent share of total (%)



*Rounding to 0.1 decimal point may result in the percentage not adding to 100%

Regionally, significant differences exist in the composition of coffee exports. The Asia and Pacific region is positioned further up the value chain compared to the world average and other regions, with processed coffee (roasted and soluble) accounting for 11.7% (5.1 million bags) of its exports. In contrast, Africa's share of processed coffee exports was just 2.4% (0.3 million bags).

FIGURE D.11
Exports of coffee by different forms - regions, '000 60-kg bags



D.2.3 Exports of Arabica and Robusta – green beans

Green bean exports of Arabicas totalled 74.6 million bags in coffee year 2022/23, a decline of 10.4%, while Robustas increased by 2.7% to 43.8 million bags. Consequently, the share of Arabicas in green bean exports dropped to 60.4% from 63.6% in 2021/22. This shift between Arabicas and Robustas was largely influenced by price and income substitutions. The Arabica-Robusta price differential had widened significantly in 2021/22 to 152.0 US cents/lb from 87.6 US cents/lb the previous year and remained relatively high at 90.4 US cents/lb in 2022/23. Global inflation peaked at 9.4% in 2021, while the benchmark interest rate across the EU, UK, and USA averaged 4.9% by the end of September 2023 – the highest since 5.8% in 2000 – reducing net disposable income worldwide.

Coffee year 2022/23 was the first time since coffee year 2012/13 that exports of the Colombian Milds had fallen below the 11.0 million bags mark. The exports of this group of coffee are primarily driven by Colombia, the main origin of this group, and there was weather-related disruption to its supply throughout most of coffee year 2022/23. For the year, Colombia's exports contracted 13.1%, decreasing to 9.42 million bags, the first time since coffee year 2013/14 the origin's exports had dropped below the 10.0 million bags level.

The Americas are predominantly Arabica producers, with the Arabicas' share of Caribbean/Central America and Mexico exports of green beans at 99.2%, while it was 93.6% for South America in coffee year 2022/23. This contrasted with Asia and Oceania, where the Arabicas' share was 11.5%. In the middle was Africa, with the share of the Arabicas at 48.9%.

FIGURE D.12
Green beans exports - groups, millions 60-kg bags

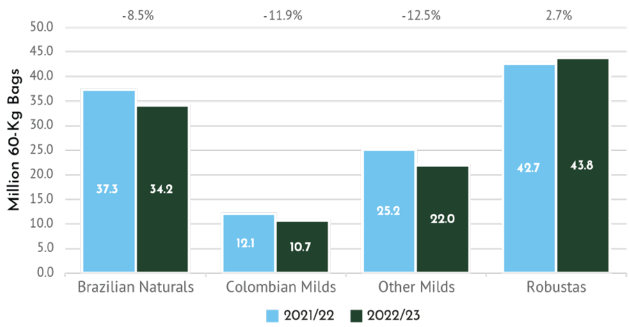
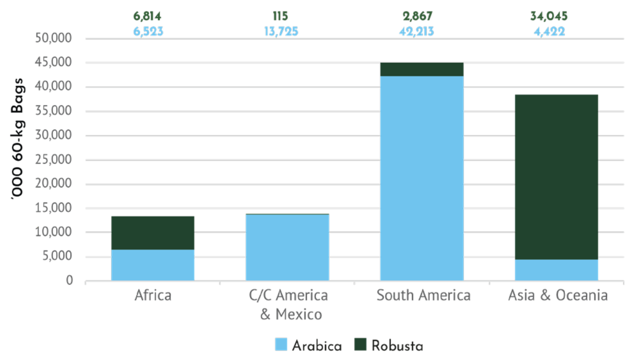


FIGURE D.13
Green beans Arabica/Robusta exports - regions, '000 60-kg bags



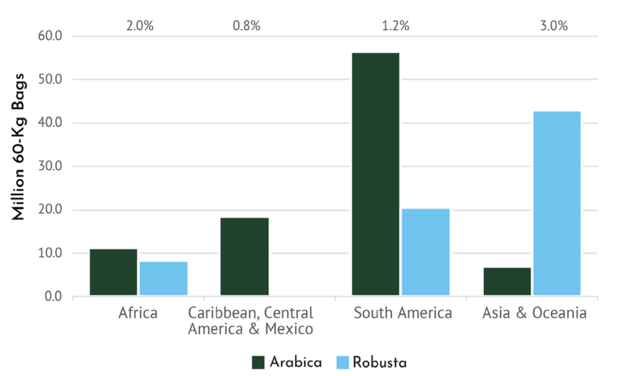
D.3 Production

D.3.1 Total coffee production – world and regions

In coffee year 2022/23, global coffee production fell slightly by 0.04% to 165.5 million bags. This decrease was primarily due to:

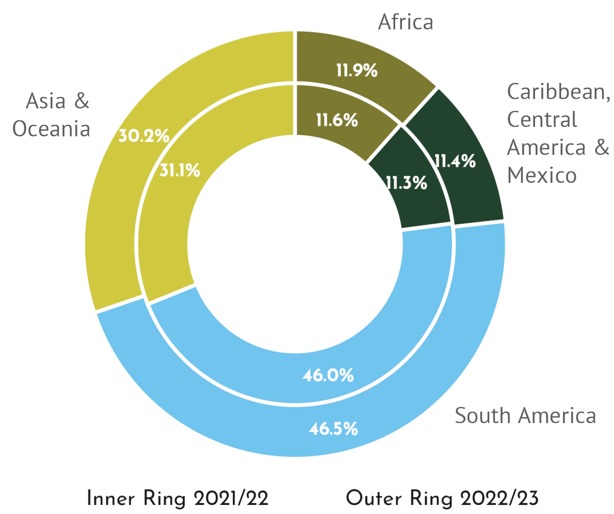
- Asia and Oceania, where production declined by 3.0%, resulting in a net loss of 1.5 million bags. This drop was largely attributed to adverse weather conditions affecting Vietnam, the region's main producer.
- The impact of Asia and Oceania's decline was nearly offset by gains in South America and Africa, with a combined net increase of 1.3 million bags. South America's 1.2% growth was mainly driven by Brazil's biennial production cycle, while Tanzania and Uganda were the primary contributors to Africa's increase.
- Production in Central America, Mexico, and the Caribbean rose by 0.8%, reaching 18.9 million bags.

FIGURE D.14
Production of coffee - regions, million 60-kg bags and growth rates (%)



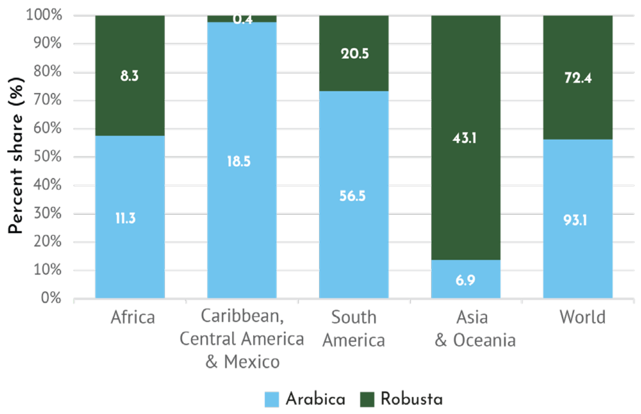
The consequences of the differing fortunes of the regions were that Asia and Oceania alone experienced its share of the world production fall in coffee year 2022/23 by 0.9 percentage point, decreased to 30.2%. However, Arabica holds the majority share of global coffee bean production and dominates in three of the four coffee-producing regions.

FIGURE D.15
Production of coffee - regions, percent share (%)



Arabica holds the majority share of global coffee bean production, as well as dominance in three of the four coffee-producing regions. In coffee year 2022/23, Arabica accounted for 56.3% of global output, marking a 0.5 percentage point increase over 2021/22. South America led Arabica production worldwide, with Arabica beans making up 73.3% of the region's total coffee output. Meanwhile, Asia and Oceania was the largest Robusta-producing region, with Robusta beans comprising 86.2% of its total production in 2022/23.

FIGURE D.16
Production of Arabica/Robusta share - regions, percent share (%), 2022/23



D.3.2 Total coffee production – countries

A closer look at the data reveals that individual origins largely mirrored the overall directional trends of their regions:

- Brazil was the largest positive contributor to global coffee production in 2022/23, with a net increase of 2.4 million bags. This gain was due to Brazil's "on-year" in its biennial production cycle, though the impact was softened by lingering effects of the July frost from 2021/22.
- In contrast, Vietnam was the primary negative contributor, with a net loss of 2.2 million bags. This decline resulted from prolonged rainfall in key coffee-growing provinces (Dak Lak, Gia Lai, and Kon Tum), reduced fertilizer use, and a shift to more profitable crops such as durian and pepper.
- Colombia registered the second largest decline, with a net loss of 1.1 million bags, as unfavourable weather conditions persisted throughout 2022/23. This led to a 9.1% drop in output, bringing production down to 10.7 million bags—the lowest since 2012 and marking Colombia's third consecutive year of negative growth.
- In the Caribbean, Central America, and Mexico region, Honduras saw the sharpest production increase, expanding by 10.7%, with a net gain of 0.5 million bags. This rebound is largely attributed to the biennial production effect following a 19.2% output decrease in 2021/22.
- In Africa, Uganda achieved the largest net gain, with output rising to 6.4 million bags, a 6.5% increase. This growth was driven by a strong harvest in the South-Western region and the maturation of new coffee varieties planted in 2019/20.

FIGURE D.17
Production of coffee - top ten countries, '000 60-kg bags

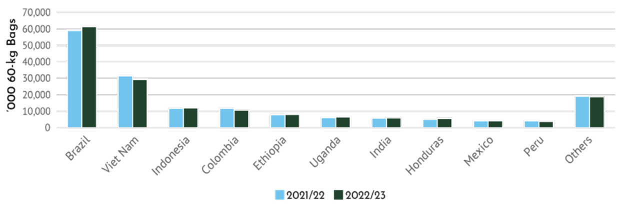
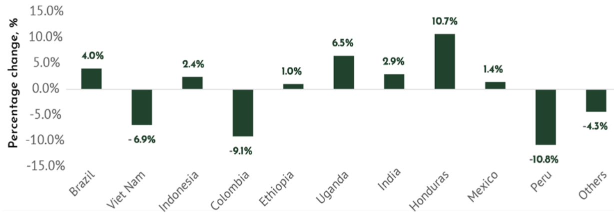


FIGURE D.18
Production of coffee - top ten countries, growth rates (%)



D.3.3 Arabica coffee production

In coffee year 2022/23, global Arabica production reached 93.1 million bags. Output increased across all regions except Asia andOceania, which experienced a decline of 3.4%. South America led with a production increase of 1.5%, the highest among regions, followed by Africa with a 1.0% rise. Consequently, Asia andOceania's share of total Arabica production dropped by 0.3 percentage points to 7.4% in 2022/23.

FIGURE D.19
Production of Arabica - regions, million 60-kg bags and growth rates (%)

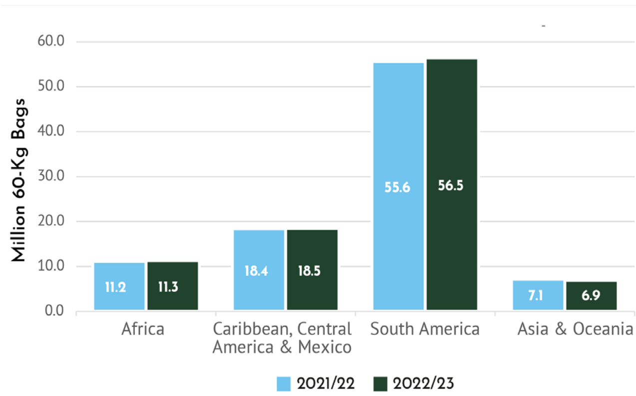
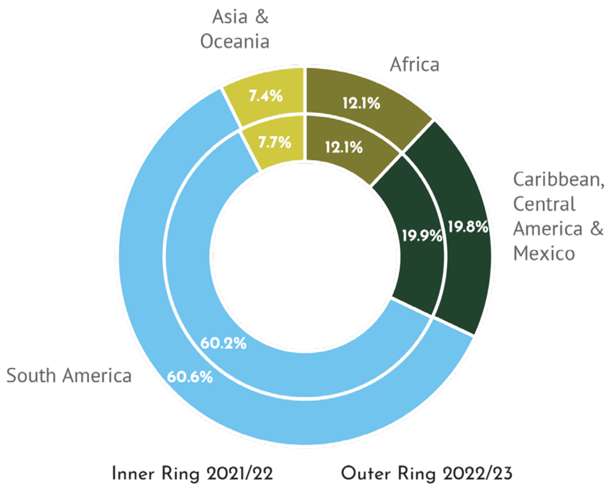


FIGURE D.20
Production of Arabica - regions, percent share (%)



A closer analysis of the data reveals the following:

- Brazil was the primary positive contributor to global Arabica production in coffee year 2022/23, with a net gain of 2.3 million bags. This increase was due to Brazil's "on-year" in its biennial production cycle, though the impact was somewhat subdued as the industry continued to feel the effects of the July 2021 frost.
- Colombia recorded the largest decline in global production, with a net loss of 1.1 million bags.
- Nicaragua's Arabica output fell by 8.1% in 2022/23, largely due to the biennial production effect. Similarly, Guatemala saw a 7.4% decline in Arabica production despite a significant expansion of coffee-growing areas, from 275,576 hectares in 2018 to 302,000 hectares by 2019, with this area reportedly maintained through 2022/23. Production was hindered by factors common to Central American neighbours, including high labour costs, labour shortages, and erratic weather.
- Peru's coffee production decreased by 7.1%, totalling 3.9 million bags in 2022/23, due to exceptionally heavy rainfall.

FIGURE D.21
Production of Arabica - top ten countries, '000 60-kg bags

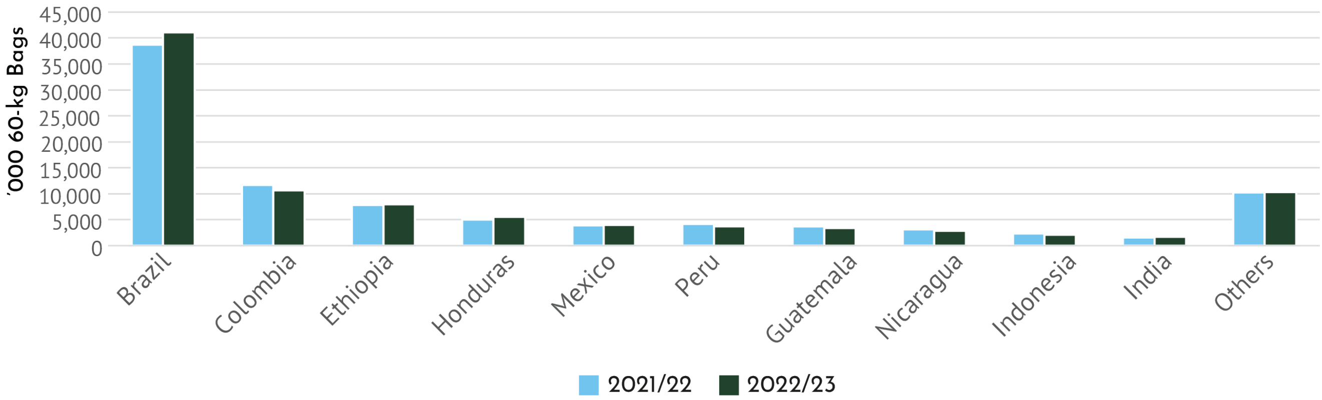
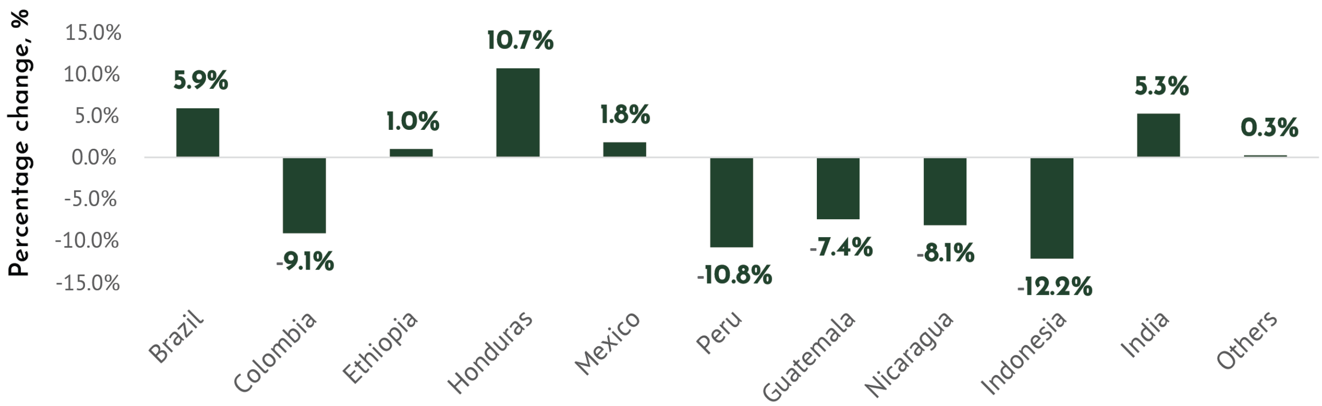


FIGURE D.22
Production of Arabica - top ten countries, growth rates (%)



D.3.4 Robusta coffee production

In coffee year 2022/23, global Robusta production totalled 72.4 million bags, representing a 1.1% decline. Asia and Oceania, the largest producer of Robusta, accounted for 60.6% of global output and was the primary driver of this reduction. Robusta production in the Caribbean, Central America, and Mexico increased by 33.2%, largely due to the first-time inclusion of Robusta output, estimated at 120,000 bags.

A closer analysis of the data reveals the following:

- Vietnam was the largest negative contributor to global Robusta production in coffee year 2022/23, with a net loss of 2.0 million bags. This decline was driven by prolonged rainfall in key producing provinces (Dak Lak, Gia Lai, and Kon Tum), reduced fertilizer use, and a shift to more profitable crops such as durian and pepper.

FIGURE D.23
Production of Robusta - regions, million 60-kg bags and growth rates (%)

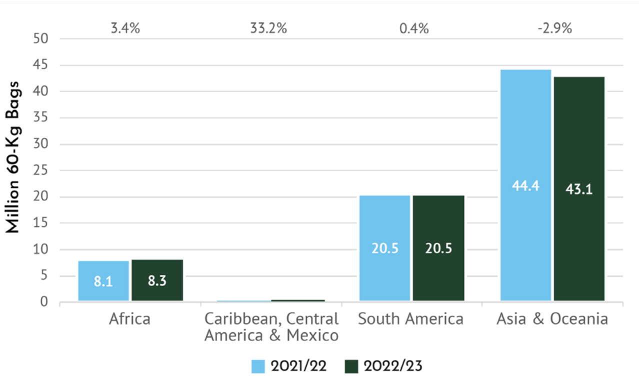
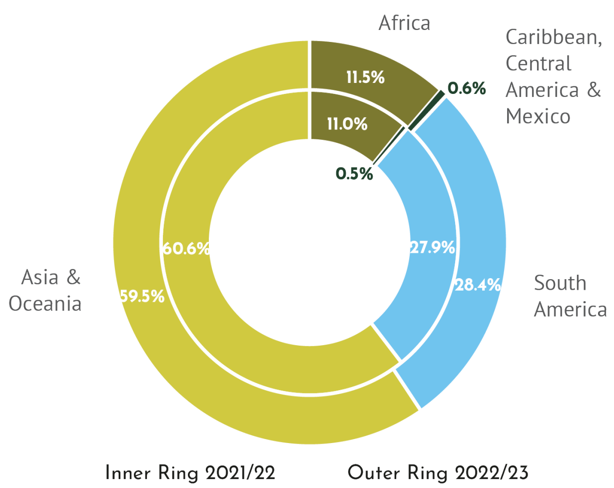


FIGURE D.24
Production of Robusta - regions, percent share (%)



- Indonesia saw a 6.0% increase in output in 2022/23, adding a net gain of 0.6 million bags. Despite heavy rainfall due to the La Niña weather phenomenon – which typically hinders production – this growth resulted from an expansion of coffee-growing areas.

- Côte d'Ivoire experienced a 20.5% decrease in production in coffee year 2022/23, with a net loss of 0.3 million bags. This reduction followed a period of strong growth in 2021/22 and was exacerbated by drought conditions in the country.

FIGURE D.25
Production of Robusta - top ten countries, '000 60-kg bags

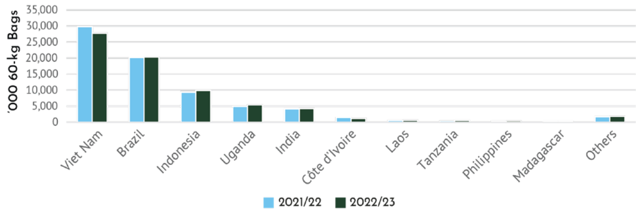
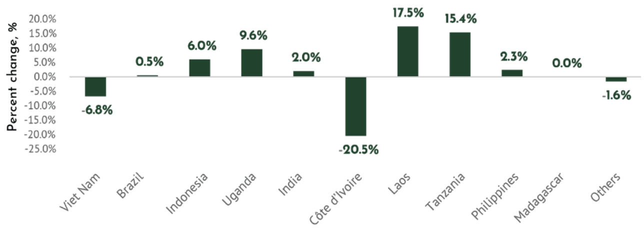


FIGURE D.26
Production of Robusta - top ten countries, growth rates (%)



D.4 Consumption

D.4.1 Total coffee consumption – world and regions

Global coffee consumption declined by 1.9% to 173.0 million bags in coffee year 2022/23, following a 3.8% expansion in 2021/22. The coffee industry continued to grapple with issues stemming from the COVID-19 pandemic, alongside new challenges posed by rising living costs and reduced disposable income.

In the first two years of COVID-19, global coffee consumption was significantly reduced, with an average growth rate of –0.4%, compared to a long-term average of 2.3% (1990–2018). This created a substantial pent-up demand, estimated at 10.2 million bags, which was released in 2021/22 as consumption rebounded by 3.8%, or 6.4 million bags—the sharpest rise since 2000/01 (4.6%) and 1978 (7.0 million bags).

Following this rebound, a modest positive growth was anticipated for 2022/23. However, high living costs and declining disposable incomes reversed this trend. In 2021, global inflation peaked at 8.7%, the highest since 1996, only marginally decreasing to 6.9% in 2022—the second highest in 27 years. Central banks responded with sustained monetary tightening, raising nominal interest rates from near zero at the end of 2021 to an average of 4.9% by September 2023 across the EU, UK, and USA. This was the highest average since 5.8% in 2000, placing consumers under dual pressures of high costs and reduced disposable income.

Regional consumption trends in 2022/23:

- North America saw the largest decline in consumption among all regions, down by 2.0 million bags, reducing its share of global consumption to 16.9%.
- Europe experienced a 3.8% decline in coffee consumption, with a net loss of 2.1 million bags, resulting in a 0.6 percentage point decrease in its global market share.
- South America posted the highest positive growth rate, with consumption increasing by 2.1% to 27.6 million bags.
- Asia and Pacific recorded the largest absolute increase, gaining 0.7 million bags and raising its share of global coffee consumption by 0.9 percentage points to 25.8%.

FIGURE D.27

Consumption of coffee - regions, million 60-kg bags

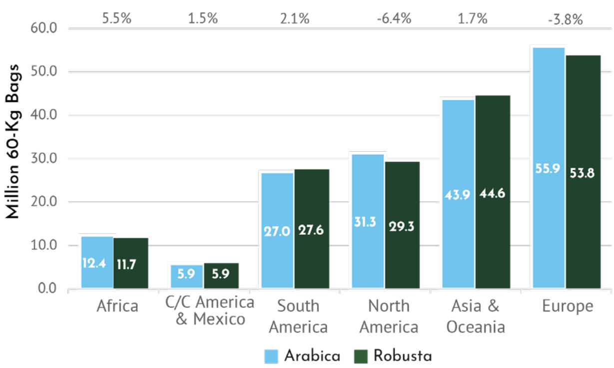
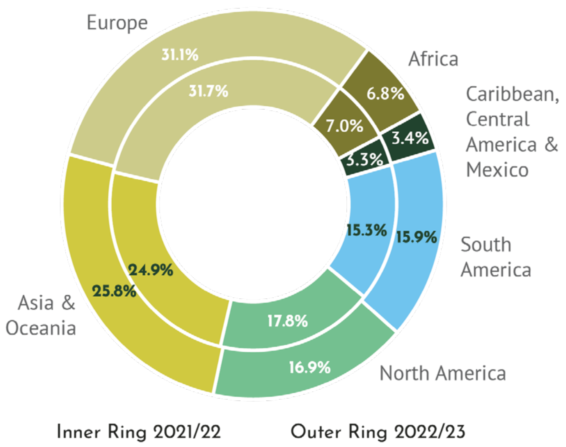


FIGURE D.28

Consumption of coffee - regions, percent share (%)



- Africa saw a 5.5% decrease in coffee consumption, falling to 11.7 million bags.
- Caribbean, Central America, and Mexico reported a 1.5% increase in consumption.

D.4.2 Coffee consumption – producing countries

Coffee consumption in producing countries grew by 1.5% in coffee year 2022/23, reaching 55.5 million bags. Among the top ten consumers:

- Brazil was the largest, with consumption rising by 0.3 million bags.
- India recorded the highest growth rate, expanding by 6.3% to 1.6 million bags, a net gain of 0.1 million bags.
- Mexico saw the lowest growth rate among the top consumers, with a 1.4% increase in consumption.

FIGURE D.29

Top ten consumption - producing countries, million 60-kg bags

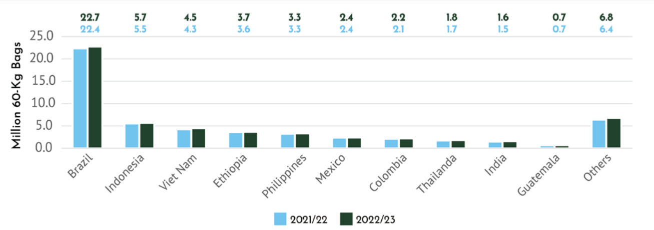
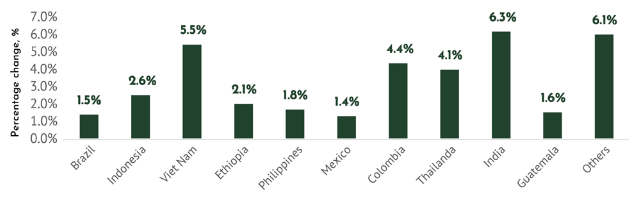


FIGURE D.30

Top ten consumption - producing countries, growth rates (%)



D.4.3 Coffee consumption – non-producing countries

In coffee year 2022/23, coffee consumption in non-producing countries declined by 4.0%, reducing to 117.5 million bags, a net loss of 4.9 million bags. Among the top ten consumers:

- Russia was one of only two top consumers to post positive growth, with consumption rising by 7.1% to 51 million bags, the highest growth rate among the group.
- Canada experienced the steepest decline, with consumption dropping by 9.5%, a net loss of 0.5 million bags.
- The United States recorded the largest absolute decline, with consumption down by 1.6 million bags.

FIGURE D.31
Top ten consumption - non producers, million 60-kg bags

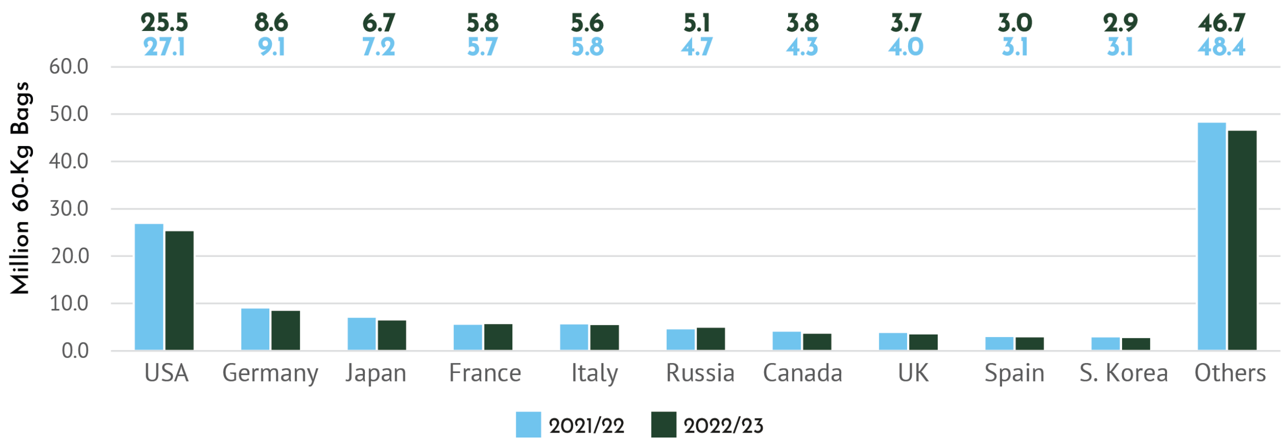
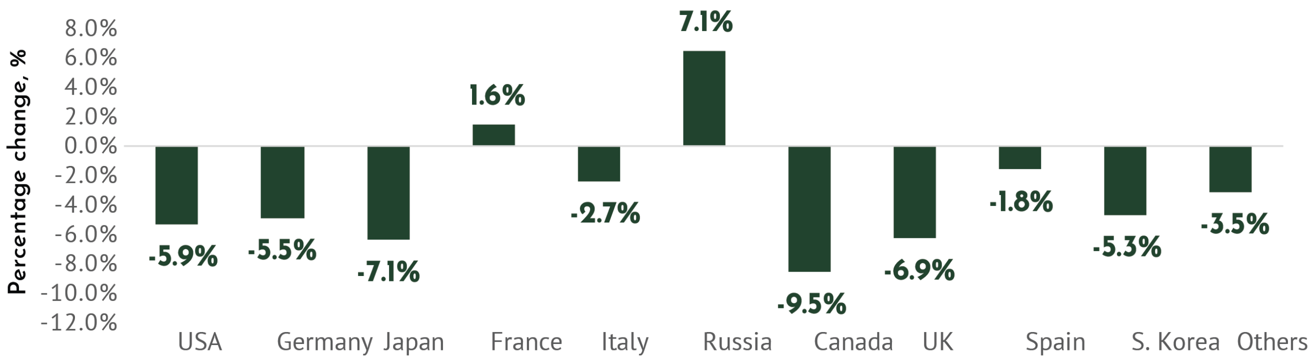


FIGURE D.32
Top ten consumption - non producers, growth rates (%)



ANNEXES

ANNEX A1

ITC Coffee Guide Network

The Circular Economy Working Group is coordinated by ITC as part of the Coffee Guide Network, a pre-competitive initiative within the Alliances for Action programme. The working group is facilitated in collaboration with Lavazza Foundation and Politecnico di Torino.

The working group's members represent 62 value chain and coffee sector actors in 36 countries globally who convene to co-create and share knowledge about the circular economy in the coffee sector. Through discussion, the goal is to understand the state of the circular economy in the coffee sector in practice, uncover challenges, gaps, and opportunities, and collaboratively generate knowledge related to the application of the circular economy concept throughout the coffee value chain.

ITC Coffee Guide Network Circular Economy Working Group members and reviewers of this report:

Kasahun Adelo Alato, PUR, Ethiopia
Emi-Beth Aku Quantson, Kawa Moka, Ghana
Ibrahim Al-Jubari, Brunel University London, United Kingdom
Shemina Amarsy, ITC, Switzerland
James Astuhuaman, Consultant, Peru
Walter Baethgen, Columbia University, USA
Devon Barker, Cafe Imports, USA
Ana Patricia Batalhone, ITC, Switzerland
Madhu Bopanna, Small Growers Symposium and Equinox, India
Martina Bozzola, Research Institute of Organic Agriculture FiBL, Switzerland
Alessandro Campanella, Sys – Systemic Design Lab - Politecnico di Torino), Italy
Emmeline Cardozo, Accenture, USA
Natalia Carr, Conselho Nacional Do Cafe (CNC) and Cooxupé, Brazil
Blanca Maria Castro, International Women's Coffee Alliance (IWCA), Guatemala
Mario Cerutti, Lavazza Group and Foundation, Italy
Sarah Charles, ITC, Greece
Frederic Couty, ITC, Switzerland
Safoura Dao, Togo
Stephany Dávila-Hermeling, ENCAFE, Guatemala
Mory Diawara, ITC, Gabon
Kathleen Draper, Ithaka Institute for Carbon Intelligence, USA
Rene Edde, Accenture, USA
Pedro de Figueiredo, Net Zero, Brazil
Monika Firl, Fairtrade International, Canada
Enselme Gouthon, Robusta Coffee Agency of Africa and Madagascar (ACRAM), Togo
Akanksha Gupta, Berry Co., India
Abdulrhman Halafawy, Cupmena, Egypt
Daniela Insignares, Coffee Kreis, Colombia
Hans Jurgen Langenbahn, Happy Goat Coffee and The Zero Waste Coffee Project, Canada
Henry Kamande, Rainforest Alliance, Kenya
Anne Kasong Yav, ITC, Switzerland
Peter Kettler, Consultant, USA
Changhee Kim,Xi'an Jiaotong-Liverpool University, China
Taye Kufa, Ethiopian Institute of Agricultural Research (EIAR), Ethiopia
Giulia Macola, ITC, Switzerland
Gustavo Magalhaes Paiva, ITC, Brazil
Malisa Mukanga, ITC, Uganda
Esther Makooma, SAWA World, Uganda
Hernan Manson, ITC, Switzerland
Giulia Marchetti, Connecting Grounds, Denmark
Omer Maledy, The Interprofessional Council of Cocoa and Coffee (CICC), Cameroon
João Mattos, The Latin American and Caribbean Network of Fair Trade Small Producers and Workers (CLAC), Brazil
Christophe Montagnon, RD2 Vision, France
Andrés Montenegro, Specialty Coffee Association (SCA), USA
Ismael Ndjewe, ACRAM, Gabon
Katherine Oglietti, ITC and C4CEC, USA
Alexis Pantziaros, Coffeeco, Greece
Gerardo Patacconi, ICO, United Kingdom
Mariano Ponce Fernández, Agrisanam, Costa Rica
Anja Rahn, Curious about Coffee Science, Canada
Pranita Rimal, UNIDO, Italy
Chiara Scaraggi, United Nations Industrial Development Organization (UNIDO), Italy
Niels Schulz, UNIDO, Austria
Denis Seudieu, ICO, Côte d'Ivoire
Mariamawit Solomon, Consultant, Ethiopia
Alison Streacker, African Fine Coffees Association (AFCA), Rwanda
Dario Toso, Lavazza and C4CEC, Italy, Working Group Facilitator
Marios Vlachogiannis, Coffeeco, Greece
Johnnie Voutsas, Coffeeco, Greece
David Lenny Waweru, Ruwawa Farm, Kenya
Melissa Wilson Becerril, Cooperative Coffees, Mexico
Chahan Yeretzian, Zurich University of Applied Sciences, Switzerland

We are grateful for the dedication, insights, and research contributed by the Circular Economy Working Group's valued members.

ANNEX A2

Global Biomass from Coffee Processing Calculations (coffee year 2022/2023)[1]

	Million 60 kg bags	Million tonnes	%
2022/23 world production	165.50	9.93	100.00%
Total natural (production)	114.20	6.85	69.00%
Total washed and semi washed (production)	51.31	3.08	31.00%
2022/23 world consumption	173	10.38	

Source: ICO and ITC Data Aggregation Working Group

		Million tonnes	%
Total cherries (2022/23 world production)		47.29	100.00%
Total cherries for natural (production)		32.63	69.00%
Total cherries for washed and semi washed (production)	.	14.66	31.00%
Total cherries (2022/23 world consumption)		49.43	

	Dry weight (million tonnes)	Wet weight (million tonnes)	%
Coffee husks	14.68	/	
Coffee pulp	1.09	5.72	
Coffee mucilage	0.52	3.22	
Coffee parchment	5.20	5.72	
Coffee green bean	10.38	/	
Coffee silverskin	0.20	/	
Spent coffee grounds	6.92	11.14	

Note: Coffee by-products from processing are calculated based on 2022/2023 world production figures. Coffee by-products from roasting are calculated based on 2022/2023 consumption figures.

1 These calculations are made using ICO production statistics from crop year 2022/2023. Known conversion rates from Oliveira et al. and calculations are applied. Source: Oliveira et al., 2021).

	Million tonnes	%
Total dry biomass from natural coffee processes	14.68	/
Total wet biomass from washed coffee processes	14.68	/
Total dry biomass from washed coffee processes	6.80	/
Total biomass from coffee processes	29.34	62.05%

Based on the typical state (dry or wet) of each process output as it is produced

	Million tonnes	%
Total dry biomass from roasting and consumption	7.12	15.05%
Total biomass from roasting and consumption	11.34	22.94%

	Million tonnes	%
Total dry biomass	28.60	60.49%
Total biomass	11.34	86.03%

Based on the state (dry or wet) of each process output as it is produced. Percentages shown as a total of the total world production of coffee cherries.

BIBLIOGRAPHY

Anker, R., & Anker, M. (2017). Living wages around the world: Manual for measurement. Cheltenham: Edward Elgar Publishing.

Appel, M., Francis, A., Payne, A., Tanimoto, A., & Mouw, S. (2024). State of recycling: The present and future of recycling in the U.S. The Recycling Partnership. https://recyclingpartnership.org/residential-recycling-report/

Association of Southeast Asian Nations. (2023). Strategy or guideline for crop burning reduction to support the implementation of the ASEAN carbon neutrality strategy. https://asean.org/wp-content/uploads/2023/10/16.-Strategy-or-Guideline-for-Crop-Burning-Reduction-to-Support-the-Implementation-of-the-ASEAN-Carbon-Neutrality-Strategy.pdf

Barbero, S., & Fiore, E. (2015). The flavours of coffee grounds: The coffee waste as accelerator of new local businesses. Annals of the Faculty of Engineering Hunedoara, XIII(1), 57-63. ISSN 1584-2665

Barbero, S., & Toso, D. (2009). Buone previsioni dai fondi di caffè. Ricerca applicata alla coltivazione dei funghi dai fondi di caffè. Time&Mind Press. ISBN 978-88-903392-6-4

Barlow, C., & Morgan, D. (2013). Polymer film packaging for food: An environmental assessment. Resources, Conservation & Recycling, 78, 74–80.

Bauer, A.-S., Tacker, M., Uysal-Unalan, I., Cruz, R.M.S., Varzakas, T., & Krauter, V. (2021). Recyclability and redesign challenges in multilayer flexible food packaging—a review. Foods, 10, 2702. https://doi.org/10.3390/foods10112702

Biochar Vietnam. (n.d.). Strengthening the business case of small scale pyrolysis in Vietnam. Biochar Vietnam. https://biocharvietnam.org/featured_item/strengthening-the-business-case-of-small-scale-pyrolysis-in-vietnam/

Birkenberg, A., Narjes, M. E., Weinmann, B., & Birner, R. (2021). The potential of carbon neutral labeling to engage coffee consumers in climate change mitigation. Journal of Cleaner Production, 278. https://doi.org/10.1016/j.jclepro.2020.123621 https://www.sciencedirect.com/science/article/pii/S0959652620336660

Bomfim, A. S. C., de Oliveira, D. M., Walling, E., Babin, A., Hersant, G., Vaneeckhaute, C. (2023). Spent coffee grounds characterization and reuse in composting and soil amendment. Waste, 1, 2–20. https://doi.org/10.3390/waste1010002

Bressani, R. (1978). Potential uses of coffee berry by-products. In J. E. Braham & R. Bressani (Eds.), Coffee pulp: Composition, technology, and utilization (pp. 17–24).

Bressani, R. (1978). The by-products of coffee berries. In J. E. Braham & R. Bressani (Eds.), Coffee Pulp. Composition, Technology, and Utilization (pp. 5–10).

Brommer, E., Stratmann, B., Quack, D. (2011). Environmental impacts of different methods of coffee preparation. Volume 35, Issue 2, Special Issue: Household Technology and Sustainability, March 2011.

Bunn, C., Läderach, P., Ovalle Rivera, O. (2015). A bitter cup: climate change profile of global production of Arabica and Robusta coffee. Climatic Change, 129, 89–101. https://doi.org/10.1007/s10584-014-1306-x

Bureau d'analyse sociétale d'intérêt collectif (BASIC). (2024). The grounds for sharing: A study of value distribution in the coffee industry. Global Coffee Platform, IDH, Solidaridad.

Castillo, N. E. T., Sierra, J. S. O., Oyervides-Munoz, M. A., Sosa-Hernández, J. E., Iqbal, H. M., Parra-Saldívar, R., Melchor-Martínez, E. M. (2021). Exploring the potential of coffee husk as caffeine bio-adsorbent – a mini-review. Case Studies in Chemical and Environmental Engineering, 3, 100070. https://doi.org/10.1016/j.cscee.2020.100070

CF Nielsen. (n.d.). Agricultural briquetting cases. CF Nielsen. https://cfnielsen.com/agricultural-briquetting/cases/

Chayer, J.-A., & Kicak, K. (2015). Quantis© LCA of single-serve coffee versus bulk coffee brewing Life Cycle Assessment of coffee consumption: comparison of single-serve coffee and bulk coffee brewing Final Report Prepared for: Prepared by: Quantis. https://lyonspc2019.files.wordpress.com/2019/03/pac0680-full-lca.pdf

Chen, Y., Shen, Z. G., & Li, X. D. (2004). The use of vetiver grass (Vetiveria zizanioides) in the phytoremediation of soils contaminated with heavy metals. Applied Geochemistry, 19(10), 1553-1565. https://doi.org/10.1016/j.apgeochem.2004.02.003

Cibelli, M., Cimini, A., Cerchiara, G., Moresi, M. (2021). Carbon footprint of different methods of coffee preparation. Sustainable Production and Consumption, 27, 1614-1625. ISSN 2352-5509

Circle Economy. (2024). The circularity gap report 2024. Amsterdam: Circle Economy. Retrieved from: CGRi https://www.circularity-gap.world/2024.

Circular Economy Stakeholder Platform. (2020). Veolia and JDE - turning spent coffee grounds into bio-fuel. https://circulareconomy.europa.eu/platform/en/good-practices/veolia-and-jde-turning-spent-coffee-grounds-bio-fuel

Coffeefrom (2023). Tutto comincia dai fondi di caffè. Coffeefrom. https://coffeefrom.it/

Cool Farm Tool Impact Report. (2023). https://coolfarm.org/wp-content/uploads/2024/02/Cool-Farm_Impact-Report-2023.pdf

Cooperative Coffees. (n.d.). Rethinking climate action: From emissions accountability to climate justice. Cooperative Coffees. https://coopcoffees.coop/rethinking-climate-action-from-emissions-accountability-to-climate-justice/

Cruz, R. C., Martins, R. A., de Oliveira, J. P., & de Oliveira, J. M. (2019). Impact of mucilage on fermentation and flavor profile of coffee. Journal of Agricultural and Food Chemistry, 67(15), 4235-4242. https://doi.org/10.1021/acs.jafc.9b00010

Cupmena. (2024). Cupmena.com. https://cupmena.com

Dantas, J., Motta, I. O., Vidal, L. A., Nascimento, E. F. M. B., Bilio, J., Pupe, J. M., Veiga, A., Carvalho, C., Lopes, R. B., Rocha, T. L., Silva, L. P., Pujol-Luz, J. R., & Albuquerque, É. V. S. (2021). A comprehensive review of the coffee leaf miner Leucoptera coffeella (Lepidoptera: Lyonetiidae)—A major pest for the coffee crop in Brazil and other neotropical countries. Insects, 12(12), 1130. https://doi.org/10.3390/insects12121130

De Otálora, X. D., Ruiz, R., Goiri, I., Rey, J., Atxaerandio, R., San Martin, D., Orive, M., Iñarra, B., Zufia, J., Urkiza, J. (2020). Valorization of spent coffee grounds as functional feed ingredient improves productive performance of Latxa dairy ewes. Animal Feed Science and Technology, 264, 114461. https://doi.org/10.1016/j.anifeedsci.2020.114461

De Queiroz, V. T., Azevedo, M. M., da Silva Quadros, I. P., Costa, A. V., do Amaral, A. A., Juvanhol, R. S., (2018). Environmental risk assessment for sustainable pesticide use in coffee production. Journal of Contaminant Hydrology, 219, 18-27.

De Schoenmakere, M., Hoogeveen, Y., Gillabel, J., et al. (2018). The circular economy and the Bioeconomy: Partners in Sustainability. European Environment Agency. https://doi.org/10.2800/02937

Dissasa, G. (2022). Cultivation of different oyster mushroom (Pleurotus species) on coffee waste and determination of their relative biological efficiency and pectinase enzyme production, Ethiopia. International Journal of Microbiology, 2022, 1–10. https://doi.org/10.1155/2022/5219939

Dixon, J. (2011). Packaging Materials 9: Multilayer Packaging for Food and Beverages. ILSI Europe Report Series. ILSI Europe Packaging Materials: Washington, DC, USA. Available online: https://ilsi.eu/publication/packaging-materials-9-multilayer-packaging-for-food-and-beverages/ (accessed on 17 February 2011).

Ecoplus, BOKU, Denkstatt, OFI. (2020). Lebensmittel-Verpackungen-Nachhaltigkeit: Ein Leitfaden für Verpackungshersteller, Handel, Politk & NGOs; Enstanden aus den Ergebnissen des Projektes “STOP waste–SAVE Food”. Wien, Austria. Available online: https://www.ecoplus.at/media/20682/leitfaden_stopwaste_de.pdf (accessed on 27 September 2021).

Elías, L.G. (1979). Chemical composition of coffee-berry by-products. In Coffee Pulp: Composition, Technology and Utilization (pp. 11–16). International Development Research Centre: Ottawa, ON, Canada. ISBN 0-88936-190-8.

Ellen MacArthur Foundation (EMF). (n.d.). Food and the circular economy: Deep dive. Ellen MacArthur Foundation. https://www.ellenmacarthurfoundation.org/food-and-the-circular-economy-deep-dive.

Entocycle, The Insect Technology Company. (n.d.). Entocycle | the Insect Technology Company. https://entocycle.com

Era of We. (2024). Tapping into the potential of coffee waste as a renewable energy source. Era of We. https://www.eraofwe.com/coffee-lab/en/articles/tapping-into-the-potential-of-coffee-waste-as-a-renewable-energy-source

Fairfood. (n.d.). Tracing our food, farm to fork | We believe fair food can exist. https://fairfood.org/en/

Flammini, A., Brundin, E., Grill, R., Zellweger, H. (2020). Supply chain uncertainties of small-scale coffee husk-biochar production for activated carbon in Vietnam. Sustainability, 12(19), 8069. https://doi.org/10.3390/su12198069

Food and Agriculture Organization (FAO). (2024). Land statistics 2001 - 2022; Global, regional and country trends. https://www.fao.org/statistics/highlights-archive/highlights-detail/Land-statistics-2001-2022.-global-regional-and-country-trends

Food in Canada. (2024). Café William opens new factory powered by 100 per cent electric industrial roaster. Food in Canada. https://www.foodincanada.com/food-business/cafe-william-opens-new-factory-powered-by-100-per-cent-electric-industrial-roaster-156644/

Franklin Associates. (2008). Retrieved at: https://www.americanchemistry.com/chemistry-in-america/chemistry-in-everyday-products/plastics

GCR Magazine. (2024). Café William on its mission to make the most sustainable coffee. GCR Magazine. https://www.gcrmag.com/cafe-william-on-its-mission-to-make-the-most-sustainable-coffee/

Gliessman, S. R. (n.d.). Agriculture modern. In Encyclopedia.com. Retrieved from https://www.encyclopedia.com/science/news-wires-white-papers-and-books/agriculture-modern

Ground Up EV. (n.d.). Home. Ground Up EV. Retrieved from https://www.groundupev.com/

How to Brew with a Drip Brewer, Starbucks. (n.d.). Athome.starbucks.com. https://athome.starbucks.com/brewing-guide/how-brew-drip-brewer

Ijanu, E. M., Kamaruddin, M. A., & Norashiddin, F. A. (2020). Coffee processing wastewater treatment: A critical review on current treatment technologies with a proposed alternative. Applied Water Science, 10(11), 1-15. https://doi.org/10.1007/s13201-019-1091-9

Illy, A., & Vineis, P. (2024). No sustainability without regeneration: A manifesto from an entrepreneurial viewpoint. Anthropological Sciences. https://doi.org/10.1007/s44177-024-00080-w

Insetting Explained. (n.d.). IPI. https://www.insettingplatform.com/insetting-explained/

Intercos. (2024). Intercos and Amarey announce partnership with Illycaffè. Intercos. https://www.intercos-investor.com/wp-content/uploads/2024/03/20240320_CS_IntercosAmareyIlly_vENG.pdf

International Coffee Organization. (2021). The future of coffee: Investing in youth for a resilient and sustainable coffee sector. Coffee Development Report. International Coffee Organization.

International Coffee Organization. (2024). Coffee Global Funding Mechanism, Sustainability and Resilience of the Coffee Global Value Chain: Towards a Coffee Investment Vehicle. London: International Coffee Organization.

International Trade Centre. (n.d.). ACP Business Friendly: Supporting value chains through inclusive policies. International Trade Centre. https://www.intracen.org/our-work/projects/acp-business-friendly-supporting-value-chains-through-inclusive-policies

International Trade Centre. (2021). The Coffee Guide, 4th Edition.

International Trade Centre. (2024). Making a Case for Circular Economy in Coffee: Insights from the multi-stakeholders working group on circular economy in coffee. https://intracen.org/file/240410circulareconomyinthecoffeesecto

International Trade Centre and International Coffee Organization. (2023). ITC Data Aggregation Working Group documents.

Iriondo-DeHond, A., Iriondo-DeHond, M., & del Castillo, M. D. (2020). Applications of compounds from coffee processing by-products. Biomolecules, 10, 1219. https://doi.org/10.3390/biom10091219

Kaffe Bueno. (2017). Kaffe Bueno. https://www.kaffebueno.com

Kikuchi, K., Yasue, T., Yamashita, R., Sakuragawa, S., Sudoh, M., & Itagaki, M. (2013). Double layer properties of spent coffee grounds-derived carbon activated with potassium hydroxide (KOH). Electrochemistry, 81(10), 828-832. https://doi.org/10.5796/electrochemistry.81.828

Kilian, B., Rivera, L., Soto, M., & Navichoc, D. (2013). Carbon footprint across the coffee supply chain: The case of Costa Rican coffee. Journal of Agricultural Science and Technology, 3, 151–175. http://www.davidpublisher.org/Public/uploads/Contribute/55d17d4c702dc.pdf

Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. Resources, Conservation and Recycling, 127, 221-232. https://doi.org/10.1016/j.resconrec.2017.09.005

Klingel, T., Kremer, J., Gottstein, V., Rajcic de Rezende, T., Schwarz, S., & Lachenmeier, D. (2020). A review of coffee by-products including leaf, flower, cherry, husk, silver skin and spent grounds as novel foods within the European Union. Foods, 9, 665.

Kooduvalli, K., Vaidya, U. K., & Ozcan, S. (2020). Life Cycle Assessment of Compostable Coffee Pods: A US University Based Case Study. Scientific Reports, 10(1). https://doi.org/10.1038/s41598-020-65058-1

Krajewski, M. (2014). The Great Lightbulb Conspiracy, EEE Spectrum. Available at: https://spectrum.ieee.org/the-great lightbulb-conspiracy. Accessed on 16 January 2024.

La Marzocco Home. (2014). Brew Ratios Around the World - La Marzocco Home. La Marzocco Home. https://home.lamarzoccousa.com/brew-ratios-around-world/#:~:text=While%20many%20specialty%20shops%20around

Marrone, M., & Tamarindo, S. (2018). Paving the sustainability journey: Flexible packaging between circular economy and resource efficiency. Journal of Applied Packaging Research, 10, 53–60.

Materusa. (n.d.). Matek. Materusa. https://materusa.com/pages/matek

Matrapazi, V. K., & Zabaniotou, A. (2020). Experimental and feasibility study of spent coffee grounds upscaling via pyrolysis towards proposing an eco-social innovation circular economy solution. Science of the Total Environment, 718, 137316. https://doi.org/10.1016/j.scitotenv.2020.137316

McLaughlin, E. (2022). How have economists thought about climate change? Economics Observatory. https://www.economicsobservatory.com/how-have-economists-thought-about-climate-change

Mendes dos Santos, É., Malvezzi de Macedo, L., Lacalendola Tundisi, L., Ataide, J. A., Camargo, G. A., Alves, R. C., Oliveira, M. B. P. P. (2021). Coffee by-products in topical formulations: A review. Trends in Food Science & Technology, 111, 280-291. https://doi.org/10.1016/j.tifs.2021.02.064

Nab, C., & Maslin, M. (2020). Life cycle assessment synthesis of the carbon footprint of Arabica coffee: Case study of Brazil and Vietnam conventional and sustainable coffee production and export to the United Kingdom. Geo: Geography and Environment, 7(2), e00096. https://rgs-ibg.onlinelibrary.wiley.com/doi/full/10.1002/geo2.96

National Institute of General Medical Sciences. (2024). Regeneration. National Institute of General Medical Sciences. https://www.nigms.nih.gov/education/fact-sheets/Pages/regeneration.aspx

Nespresso (n.d.). Da Chicco a Chicco | Caffè sostenibile Nespresso. https://www.nespresso.com/it/it/caffe-sostenibile

Noponen, M., Edwards-Jones, G., Haggar, J., Soto, G., Attarzadeh, N., & Healey, J. (2012). Greenhouse gas emissions in coffee grown with differing input levels under conventional and organic management. Agriculture, Ecosystems & Environment, 151, 6–15. https://doi.org/10.1016/j.agee.2012.01.019

Oliveira, G., Passos, C. P., Ferreira, P., Coimbra, M. A., & Gonçalves, I. (2021). Coffee By-Products and Their Suitability for Developing Active Food Packaging Materials. Foods, 10(3), 683. MDPI.

Opmeer, T., and Van Eijk, F. (2020). Circular Economy & SDGs: How circular economy practices help to achieve the Sustainable Development Goals. https://circulareconomy.europa.eu/platform/sites/default/files/3228_brochure_sdg_-_hch_cmyk_a4_portrait_-_0520-012.pdf.

Pauli, G. (2010). Blue economy: 10 years, 100 innovations, 100 million jobs. Paradigm Publications.

PCF Pilotprojekt Deutschland. (2008). Case study tchibo private kaffee: Rarity machare by tchibo GMBH.

Pedraza, B. P., Estrada, F. J. G., Martínez, C. A. R., Estrada, L. I., Rayas, A. A. A., Yong, A. G., Figueroa, M. M., Áviles, N. F., & Castelán, O. O. A. (2012). On-farm evaluation of the effect of coffee pulp supplementation on milk yield and dry matter intake of dairy cows grazing tropical grasses in central Mexico. Tropical Animal Health and Production, 44(2), 329-336.

Phil. Trans. R. Soc. A. (2009). 367, 1443–1444. https://doi.org/10.1098/rsta.2009.0026

Porter, M. E., & Kramer, M. R. (2011). Creating shared value. Harvard Business Review, 89(1-2), 62–77.

Pulleman, M. M., Rahn, E., & Valle, J. F. (2023). Regenerative agriculture for low-carbon and resilient coffee farms: A practical guidebook (Version 1.0). International Center for Tropical Agriculture (CIAT). https://hdl.handle.net/10568/131997

Quantis Environmental Consulting. (2023). Data calculated by Quantis Environmental Consulting.

Quyen, V. T. B., Pham, T. T. H., Kim, J., Thanh, D. N. H., Thang, P. Q., Van Le, Q., Jung, S., Kim, T. (2021). Biosorbent derived from coffee husk for efficient removal of toxic heavy metals from wastewater. Chemosphere, 284, 131312. https://doi.org/10.1016/j.chemosphere.2021.131312

Rabobank. (n.d.). Acorn. https://acorn.rabobank.com/en/

RePiC. (2020). Pulpa Pyro Peru: Clean generation of biochar and energy from coffee pulp [PDF file]. RePiC. https://www.repic.ch/wp-content/uploads/2020/07/Pulpa-Pyro-Peru-%E2%80%93Clean-generation-of-biochar-and-energy-from-coffee-pul.pdf

RFI Enbiomass. (n.d.). Home. RFI Enbiomass. Retrieved from https://www.rfinebiomass.com/

Root Capital. (2023). Coffee and climate: Navigating the future of coffee production [PDF file]. Root Capital. https://rootcapital.org/wp-content/uploads/2023/09/coffeeClimate_v3.pdf

Sanchez-Zuiga, J. V., Sanchez-Molina, J., Diaz-Fuentes, C. X. (2020). Improvements in the thermal behavior in the manufacture of the H10 block using coffee husks as an alternative industrial additive. Journal of Physics: Conference Series, 1645(1). https://doi.org/10.1088/1742-6596/1645/1/012013

Singtex. (n.d.). S.Café®. Singtex. https://www.singtex.com/fabric/s-cafe/

Tamilselvan, K., Sundarajan, S., Ramakrishna, S., Amirul, A. A. A. (2024). Sustainable valorization of coffee husk into value added product in the context of circular bioeconomy: Exploring potential biomass-based value webs. Food and Bioproducts Processing, 145, 187-202. https://doi.org/10.1016/j.fbp.2024.03.008

Toupin, D., Hatcher, A. C., Ghobadian, B., Najafi, G., & Schaefer, C. E. (2020). Energy efficient industrial technologies. Elsevier.

The Futures Centre (n.d.). Starbucks Japan closes loop from waste coffee grounds to milk. The Futures Centre. https://www.thefuturescentre.org/signal/starbucks-japan-closes-loop-from-waste-coffee-grounds-to-milk/

The Index Project. (n.d.). Nominee: Coffee Flour. The Index Project. https://theindexproject.org/award/nominees/1345

The Kawa Project. (n.d.). The Kawa Project. (n.d.). Home. The Kawa Project. Retrieved from https://www.thekawaproject.com

The Zero waste Coffee Project. (2023). Ethiopia: The Dilla briquette factory turning coffee by-products into energy. The Zero waste Coffee Project. https://www.thezerowastecoffeeproject.com/post/ethiopia-the-dilla-briquette-factory-turning-coffee-by-products-into-energy

The Zero waste Coffee Project. (2023). From pulper to bottle: Good vodka made from coffee mucilage. The Zero Waste Coffee Project. https://www.thezerowastecoffeeproject.com/post/from-pulper-to-bottle-good-vodka-made-from-coffee-mucilage

The Zero waste Coffee Project. (2023). Natucafe: Producer of an unusual product—coffee mucilage concentrate. The Zero waste Coffee Project. https://www.thezerowastecoffeeproject.com/post/natucafe-producer-of-an-unusual-product-coffee-mucilage-concentrate

Thoden van Velzen, E. U., Goyal, B., Barouta, D., Brouwer, M. T., & Smeding, I. W. (2023). Sustainability assessment of different types of coffee capsules (Report / Wageningen Food & Biobased Research; No. 2450). Wageningen Food & Biobased Research. https://doi.org/10.18174/641509

Tjerk Opmeer, Greek Van Eijk (2020). Circular Economy & SDGs How circular economy practices help to achieve the Sustainable Development Goals.

Tomblog. (2018). Tomblog. (17 September 2018). J.J. Darboven: Kaffeehäutchen als Energiequelle. Coffee News Tomblog. https://coffeenewstomblog.wordpress.com/2018/09/17/j-j-darboven-kaffeehaeutchen-als-energiequelle/

Organization (UNIDO). (2021). Circular economy for sustainable development: A guide for policymakers. https://www.unido.org/sites/default/files/files/2021-07/CE4ABD.pdf. https://unfccc.int/news/cop28-agreement-signals-beginning-of-the-end-of-the-fossil-fuel-era

Usva, K., Sinkko, T., Silvenius, F., Riipi, I., & Heusala, H. (2020). Carbon and water footprint of coffee consumed in Finland—life cycle assessment. The International Journal of Life Cycle Assessment, 25, 1976-1990.

Van den Bergh, J. C. J. M. (2013). Robert Ayres, Ecological Economics and industrial ecology. Environmental Innovation and Societal Transitions, 9, 1–7. https://doi.org/10.1016/j.eist.2013.09.008

Van Rikxoort, H., Schroth, G., Läderach, P., & Rodríguez-Sánchez, B. (2014). Carbon footprints and carbon stocks reveal climate-friendly coffee production. Agronomy for Sustainable Development, 34, 887-897. https://doi.org/10.1007/s13593-014-0223-8

Water Footprint Network. (n.d.). Product Gallery – Water Footprint Network. Water Footprint Network. https://www.waterfootprint.org/resources/interactive-tools/product-gallery/

Wellenreuther, F. (2016). Resource efficient packaging. IFEU (Institut für Energie- und Umweltforschung Heidelberg). https://www.flexpack-europe.org/files/FPE/sustainability/IFEU_Resource%20Efficient%20Packaging_summary_2016.pdf

Wellenreuther, F. (2019). Potential packaging waste prevention by the usage of flexible packaging and its consequences for the environment. IFEU (Institut für Energie- und Umweltforschung Heidelberg). https://www.flexpack-europe.org/files/FPE/sustainability/2020/FPE-ifeu_Study_Update_2019_Executive_Summary.pdf

Winans, K., et al. (2017). The history and current applications of the circular economy concept. Renewable and Sustainable Energy Reviews, 68, 825–833. https://doi.org/10.1016/j.rser.2016.09.123

World Economic Forum & Ellen MacArthur Foundation (2014). Towards the circular economy: Economic and business rationale for an accelerated transition. https://www3.weforum.org/docs/WEF_ENV_TowardsCircularEconomy_Report_2014.pdf

Zhao, S., Chan, K., Sheng, N., Song, Q. (2024). Reducing carbon footprint of typical coffee consumption from the whole lifecycle viewpoint. Environmental Impact Assessment Review, 106, 107476. https://www.sciencedirect.com/science/article/abs/pii/S0195925524000635

DISCLAIMER

This work is a product of the staff of the International Coffee Organization (ICO) with external contributions by partners and experts. The findings, interpretations, and conclusions expressed in this work do not necessarily reflect the views of the ICO, its International Coffee Council, nor the governments they represent. The ICO does not guarantee the accuracy of the data included in this work.

This document has been produced without formal ICO editing.

Nothing herein shall constitute or be considered to be a limitation upon or waiver of the privileges and immunities of the ICO, all of which are specifically reserved.

The mention of firm names or commercial products does not imply endorsement by the ICO.

INTERNATIONAL COFFEE ORGANIZATION

222 Gray's Inn Road
London
WC1X 8HB
United Kingdom
Tel: +44 (0)20 7612 0600
Email: info@ico.org
www.ico.org

COFFEE DEVELOPMENT REPORT 2022-23

ICO FR/01/23E
ISBN: 978-1-0369-0405-0