Profundo
Research & advice

Disposable Paper-based Food Packaging

The false solution to the packaging waste crisis

12th September 2023

Environmental Paper Network

fern
MAKING EUROPE WORK FOR PEOPLE & FORESTS

EEB
European Environmental Bureau

ZERO WASTE EUROPE

RETHINK PLASTIC

About this report

This report has been commissioned by the Rethink Plastic Alliance, Zero Waste Europe, the European Environmental Bureau, Fern, and the Environmental Paper Network.

About Profundo

With profound research and advice, Profundo aims to make a practical contribution to a sustainable world and social justice. Quality comes first, aiming at the needs of our clients. Thematically we focus on commodity chains, the financial sector and corporate social responsibility. More information on Profundo can be found at www.profundo.nl.

Authorship

This report was researched and written by Manon Stravens, with contributions of Barbara Kuepper. Correct citation of this document: Stravens, M. (2023, July 28), *Disposable Paper-based Packaging for Food. The false solution to the packaging waste crisis,* Amsterdam, The Netherlands: Profundo.

Acknowledgements

The author would like to thank Igor Karlovits (Pulp and Paper Institute, Ljubljana), Justin Boucher (Food Packaging Forum Foundation), Evelyn Schönheit (Forum Ökologie & Papier), Emmanuel Katrakis and Julia Blees (EuRIC).

Disclaimer

Contents

List of figures

List of tables

Executive summary

Paper and board are the fastest growing packaging material group in Europe. Reduced demand for paper from other sectors, such as graphic and sanitary paper, have been offset by rapid growth in packaging, partly driven by emerging trends including e-commerce and food delivery.

Paper-based packaging remains the largest source of packaging waste in the European Union (41.1%). Totalling 32.7 million tonnes in 2020, paper-based waste is higher than the total of the two next largest materials combined - plastic (19.4%) and glass (19.1%).[1]

Paper-based materials are increasingly being used to package food and beverages. The food and beverage industry represents two-thirds of the total packaging market in Europe. Globally, paper- and paperboard-based packaging account for approximately 37% of food packaging demand.[2]

As a reaction to the environmental and socio-economic impacts associated with plastics - paper-based packaging is increasingly marketed as a sustainable alternative. Evidence shows however that paper-based substitutes present many new as well as similar challenges, furthermore paper is nearly always combined with plastics and chemical coatings.

Paper-based packaging in the food and beverage sector presents multiple challenges throughout its lifecycle, including the impact of the pulp and packaging industries on climate change, biodiversity loss, water stress and deforestation; the challenge of managing growing levels of paper waste (often contaminated by food and grease) including in on-the-go settings; the difficulty in recycling paper-based composites which integrate plastics and other materials; and the extensive use of hazardous chemicals - many of which may migrate into food and end up in our bodies - by the paper packaging industry.

Around 90% of paper pulp is made from wood [3]**, and paper production is responsible for about 35% of all clear-felled trees** [4] **- every year 3 billion trees are cut down globally for paper-based packaging.**[5]

---

1 Eurostat (2023, March 23), "Packaging waste statistics", online: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Packaging_waste_statistics#Waste_generation_by_packaging_material, viewed in June 2023.

2 Peters, R. et all (2019, March), "Review of analytical approaches for the identification of non-intentionally added substances in paper and board food contact materials ", Trends in Food Science & Technology. Volume 85, March 2019, Pages 44-54. Trends in Food Science & Technology Review.

3 Bandara, R., G.M. Indunil (2022, July 1), "Food packaging from recycled papers: chemical, physical, optical properties and heavy metal migration", Heliyon 8 (2022), p. 1.

4 Bandara, R., G.M. Indunil (2022, July 1), "Food packaging from recycled papers: chemical, physical, optical properties and heavy metal migration", Heliyon 8 (2022), p. 1.

5 The Grocer (2023, July 3), "Is paper really better for the Earth than plastic?", online: https://www.thegrocer.co.uk/sustainability-and-environment/is-paper-packaging-really-more-sustainable-than-plastic/680773.article, viewed in July 2023.

The country providing the most paper and pulp to the EU is Brazil - providing more to Europe than the region's biggest producers - Sweden and Finland.[6] In the last two decades Brazil has tripled its pulp production, now covering an area of 7.2 million hectares (twice the surface of Belgium). Eucalyptus and pine plantations in Brazil are exacerbating water scarcity, forest fires and biodiversity loss.[7]

Within Europe, Finnish forests have become a net emitter of carbon dioxide due to overlogging [8] and 76% of Finnish forest habitats are classified as threatened.[9] The capacity of Swedish forests to capture CO2 has been reduced by 5 million tonnes as result of over exploitation.[10] Lichen has decreased by 70% since 1950 threatening biodiversity and the livelihood of indigenous reindeer herders.[11]

The pulp and paper industry is the world's third largest consumer of water - the production of just one A4 sheet of paper requires around 10 litres of water.[12] The industry is also the world's fifth largest consumer of energy [13], and the International Energy Agency (IEA) states that the pulp and paper industry is not on track to reach its climate goals, being responsible for about 190 million tonnes of CO_2 emissions in 2021.[14]

Overall, little more than half of the paper and board produced use recovered fibre. The remainder are made of virgin fibres.[15] In theory, paper and cardboard can be recycled around eight times but on average European paper fibres are only recycled 3.5 times.[16] Recycling processes cannot cope

---

6 UN Comtrade (2023), "EU pulp imports (including intra-European trade)", viewed in May 2023.

7 Environmental Paper Network (2022, December), Scorching the earth. Pulp and paper expansion in Três Lagoas, Brazil. Summary Report, # Conflict Plantations 4, p. 3;

Centro de Agricultura Alternativa Vicente Nica (2022, July 19), Environmental Safeguards. An analysis of the impacts of eucalyptus monoculture on waters and rural communities. Summary, p. 1.

8 Environmental Paper Network (2023, April), Unwrapping a disaster. The human cost of overpackaging, p. 11-12.

9 Greenpeace (2022, November), Products of Nordic forest destruction end up on EU supermarket shelves, p. 4.

10 Greenpeace (2022, November), Products of Nordic forest destruction end up on EU supermarket shelves, p. 3.

11 Greenpeace (2022, November), Products of Nordic forest destruction end up on EU supermarket shelves, p. 3.

12 Beck-O'Brien, M., V. Egenolf, S. Winter, J. Zahnen, N. Griesshammer, N. (2022). Everything from wood – The resource of the future or the next crisis? How footprints, benchmarks and targets can support a balanced bioeconomy transition. WWF Germany, p. 77.

13 International Energy Agency (2022, September.), "Pulp and Paper. Tracking Report, September 2022", online: https://www.iea.org/reports/pulp-and-paper, viewed in April 2023.

14 International Energy Agency (2022, September.), "Pulp and Paper. Tracking Report, September 2022", online: https://www.iea.org/reports/pulp-and-paper, viewed in April 2023.

15 Confederation of European Paper Industries (2022), Key Statistics 2021, European Pulp & Paper Industry, p. 6.

16 European Paper Recycling Council (2022, September 5), Monitoring Report 2021, European Declaration on Paper Recycling 2021-2030, p. 2.

with more than 3-10% non-pulpable (or non-paper) materials.[17] For food and beverage packaging, the level and quality of recycling is inhibited by coatings and composites, which hamper recycling processes. One study showed that in 74% of tested samples, plastics were more recyclable than paper composite alternatives.[18]

While corrugated cardboard often contains high levels of recycled content, most food packaging uses virgin fibre due to food safety or technical requirements.[19] Paper-based food contact materials and cartons are nearly always made from virgin fibres. In on-the-go settings, paper-based packaging is rarely separately collected so unlikely to ever be recycled.[20]

Paper continues to be the second largest waste stream shipped to non-EU countries after ferrous metals. **12.4% of paper collected for recycling in the EU (representing 4.4 million tonnes) is exported, the bulk of which goes to Asia (primarily India, Indonesia and Turkey).**[21]

Chemicals are widely used throughout the production of paper-based packaging. Out of the 608 substances of concern found in food packaging, 256 (42%) are used in paper and board packaging materials.[22] These are chemicals known to, among others, be persistent, cause cancer and disturb the human reproductive and hormonal system. Importantly, many toxic chemicals may migrate from food packaging and thus become a significant source of contamination in food and eventually the consumer's body. **Analysis of paper-based take-away packaging and tableware in Europe showed that 32 out of 42 tested items had been deliberately treated with PFAS chemicals - including many labelled as biodegradable or compostable.**[23] European legislation addressing chemical safety for food contact materials needs a thorough revision and lacks specific rules and requirements for paper packaging.

---

[17] European Commission (2022, November 30), Commission Staff Working Document. Impact Assessment Report. Accompanying the document Proposal for a Regulation of the European Parliament and the Council on packaging and packaging waste, amending Regulation (EU) 2019/1020, and repealing Directive 94/62/EC, pp. 217;

The Grocer (2023, July 3), "Is paper really better for the Earth than plastic?", online: https://www.thegrocer.co.uk/sustainability-and-environment/is-paper-packaging-really-more-sustainable-than-plastic/680773.article, viewed in July 2023.

[18] Gesellschaft für Verpackungsmarktforschung (2021, May), Substitution von Kunststoffverpackungen durch papierbasierte Verbunde, IK Industrievereinigung Kunststoffverpackungen e.V., p. 27-50.

[19] Food Packaging Forum Foundation (n.d.), "Food packaging materials and recycling. Fact sheets.", online: https://www.foodpackagingforum.org/packaging-fact-sheets, viewed in June 2023.

[20] European Commission (2022, November 30), Commission Staff Working Document. Impact Assessment Report. Accompanying the document Proposal for a Regulation of the European Parliament and the Council on packaging and packaging waste, amending Regulation (EU) 2019/1020, and repealing Directive 94/62/EC, pp. 216.

[21] Eurostat (2022, May 25), "What are the main destinations of EU export of waste?", online: https://ec.europa.eu/eurostat/en/web/products-eurostat-news/-/ddn-20220525-1, viewed in June 2023.

[22] Ksenia J. Groh, B. Geueke, O. Martin, M. Maffini, and J. Muncke (2021), "Overview of intentionally used food contact chemicals and their hazards", Environment International. Volume 150, May 2021, 106225, p. 6.

[23] Straková, J., Schneider, J., Cingotti, N. et al. (2021). "Throwaway Packaging, Forever Chemicals: European wide survey of PFAS in disposable food packaging and tableware". 54p (https://chemtrust.org/wp-content/uploads/PFASreport_FCM_May2021.pdf)

In the ongoing negotiations of the EU Packaging and Packaging Waste Regulation, the realities of disposable paper-based food packaging should not be ignored. Marketing single-use paper-based products as sustainable alternatives to plastics is misleading citizens and policy makers. Legislators must seize the opportunity to curb the growing levels of packaging waste driven by overreliance on throwaway applications.

To effectively prevent waste, the EU must adopt effective rules to address the uncontrolled growth of single use packaging, no matter the material it is made of. In particular, to lessen pressure impact on forests, climate, biodiversity, water use and human health globally, it must champion a dramatic reduction of paper-based packaging.

It also must curb the widespread use of composite packaging materials and the waste they create as well as support transparency and restrictions of the harmful chemicals they so often contain.

Abbreviations

BPA	Bisphenol A
BPS	Bisphenol S
Cepi	Confederation of European Paper Industries
CSS	EU Chemicals Strategy for Sustainability
CMR	Carcinogenic, Mutagenic, or Toxic to Reproduction
DBP	Dibutyl phthalate
DEHP	Di(2-ethylhexyl) phthalate
DiBP	Diisobutyl phthalate
EC	European Commission
ECF	Elemental Chlorine Free
EDCs	Endocrine-Disrupting Chemicals
EPRC	European Paper Recycling Council
EU	European Union
EuRIC	European Recycling Industries' Confederation
FCA	Food Contact Articles
FCC	Food Contact Chemicals
FCCdb	Food Contact Chemicals Database
FCCoC	Food Contact Chemicals of Concern
FCM	Food Contact Materials
FDA	Food and Drug Administration
ECHA	European Chemicals Agency
EFSA	European Food Safety Authority
ENVH	Environmental Hazards
GHS	Globally Harmonized System of Classification and Labelling of Chemicals
HH	Health Hazards
IAS	Intentionally Added Substances
IEA	International Energy Agency
kWh	Kilowatt hour
kt	Kiloton
NGO	Non-Governmental Organisation
NIAS	Non-Intentionally Added Substances
OECD	Organisation for Economic Co-operation and Development
PAA	Polyacetic acid
PBT	Persistent, Bioaccumulative and Toxic
PFAS	Per- and polyfluoroalkyl substances
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctane sulfonic acid
PfR	Paper for Recycling
PPI	Pulp and Paper Industry
PPWR	EU Packaging and Packaging Waste Regulation
SIN	Substitute It Now
STOT	Specific Target Organ Toxicity

TDI	Tolerable Daily Intake
TWI	Tolerable Weekly Intake
US	United States
vPvB	very Persistent and very Bioaccumulative

Introduction

This study was commissioned by an NGO coalition in the context of the revision of the EU Packaging and Packaging Waste Regulation (PPWR). The coalition includes Rethink Plastic Alliance, Zero Waste Europe, the European Environmental Bureau, Fern, and the Environmental Paper Network.

In recent years, the detrimental impacts of plastics on the environment and human health have been receiving growing attention. Meanwhile, the growing popularity of paper as a substitute for plastics also raises sustainability concerns due to the enormous amounts of wood, water and chemicals used in the paper packaging sector. The use of recycled paper and effective waste management for food and beverage packaging remains limited. Therefore, packaging sustainability issues are not solved by simply replacing single-use plastic with an alternative fibre-based disposable material such as paper.

Paper- and paperboard-based packaging are among the most important packaging formats for food products like beverages, bakery products and fast food, accounting for approximately 37% of global food packaging material demand.[24] Due to its image of being more environmentally friendly compared to plastics, the bans on single-use plastics items such as straws, and the continuous rise in retail deliveries, demand for paper-based packaging is projected to continue growing in the coming years.[25] This report provides more insights into the environmental and health impacts of the sector.

Chapter 1 describes the study scope and methodology, chapter 2 provides an overview of the pulp and paper and packaging production and consumption trends in the European Union. Chapter 3 looks at the pulp, paper and packaging waste streams and their handling. Moreover, it discusses the recyclability of paper-based packaging and the related limitations. Chapter 4 maps the chemicals used and the potential risks for human health and the environment. Chapter 5 profiles the respective environmental and socio-economic impacts of pulp and paper in five selected countries. Chapter 6 summarises the main conclusions of the study and provides policy recommendations.

---

24 Peters, R. et all (2019, March), "Review of analytical approaches for the identification of non-intentionally added substances in paper and board food contact materials ", Trends in Food Science & Technology. Volume 85, March 2019, Pages 44-54. Trends in Food Science & Technology Review.

25 The Grocer (2023, July 3), "Is paper really better for the Earth than plastic?", online: https://www.thegrocer.co.uk/sustainability-and-environment/is-paper-packaging-really-more-sustainable-than-plastic/680773.article, viewed in July 2023.

1

Research scope and methodology

This chapter briefly outlines the approach applied for this study on paper-based food and beverage packaging. Moreover, it explains the data limitations encountered and their implications.

1.1 Desk research

The desk research phase involved a comprehensive literature review of the paper packaging industry and the paper-making process. Information was gathered on key processes to produce pulp and paper and in particular the manufacturing of food and beverage packaging in Europe, as well as on production, consumption, trade, and recycling on the use of chemicals and, finally, on the environmental and social impacts of the paper sector.

Information was obtained from various primary and secondary sources, including studies, trade and production data, as well as industry sources. To address data gaps, Profundo conducted interviews with different sector experts. Interviews were conducted with Igor Karlovits (Pulp and Paper Institute, Ljubljana), Justin Boucher (Food Packaging Forum Foundation), Evelyn Schönheit (Forum Ökologie & Papier), Emmanuel Katrakis, and Julia Blees (EuRIC). Additional information was requested by email to a variety of experts, including scientists, representatives of the industry, and non-governmental organisations (NGOs).

1.2 Methodological considerations

1.2.1 Paper and board grades for food and beverage packaging

To find specific data on production, consumption and trade for food and beverage packaging market segment, it was necessary to extract information from the relevant paper grades used by the pulp and paper industry.

A basic classification of the most important paper grades in the international market can be made, based on the one used by the European pulp and paper industry companies and organisations, with the main division being:

- Printing and writing papers
- Paperboards
- Tissue
- Specialty papers

Each group is divided into subgroups, with particular end uses, raw material composition, and manufacturing technologies.

Paperboard for packaging is generally divided into case materials (existing of liners and corrugating mediums), carton board, wrappings and other packaging materials. Each of these categories are again divided into various subgrades.

- Case materials or containerboard consist of papers and boards mainly used in the manufacturing of corrugated board. They are made from a combination of virgin and recovered fibres, depending on the end-use, and can be bleached, unbleached, or mottled. Corrugated board is made of a few layers of material and has broad applications in storing, shipping, and transporting goods (i.e., secondary and tertiary packaging).[26]
- Cartonboard can be coated or uncoated and is made from virgin and/or recycled fibres and has good folding properties and stiffness. It is mainly used in cartons for consumer products such as frozen, liquid, dry and fast-food packaging materials.[27] This means that this material comes in direct contact with food (e.g., pizza boxes, noodle boxes, soup cups). Cartonboard is also known as solid board, solid bleached board, solid unbleached board, folding box board, white lined chipboard, boxboard, or carrier board.
- Wrappings papers (for example to wrap sandwiches and burgers) are made from any combination of virgin or recovered fibres, bleached or unbleached. They may be subject to various finishing and/or marking processes. Wrappings include sack kraft, other wrapping krafts, sulphite wrapping, vegetable parchment (for example, to be put between pastries and meat slices), grease-proof papers, glassine, and other glazed transparent or translucent papers.
- Other paper and packaging products are for example moulded products used for egg and vegetable trays, or composite products made by sticking layers together with an adhesive. [28]

Paper-based packaging for the food and beverage sector comes in numerous shapes, sizes, and colours to cater to the specific requirements of the end users. Products vary from ice-cream cups and microwave popcorn bags, to baking paper, milk cartons, and fast-food containers such as pizza boxes and beverage cups, and new types are continuously emerging. Likewise, end-use properties are changing continuously due to ongoing quality competition.[29]

To determine the best proxy to extract production and trade data, an overview of current paper grades (i.e., those in use as of 2023), was requested to and provided by Cepi (the Confederation of European Paper Industries). Please refer to Table 6 in Appendix 1 for these grades. Cepi confirmed that the last four columns (case materials, carton board, wrapping, and all other paper and board) were the most relevant for the food packaging industry.

---

26 Geueke, B. (2016), "Paper and board food packaging", online: https://www.foodpackagingforum.org/food-packaging-health/food-packaging-materials/paper-and-board, Food packaging Forum, viewed in May 2023.

27 Geueke, B. (2016), "Paper and board food packaging", online: https://www.foodpackagingforum.org/food-packaging-health/food-packaging-materials/paper-and-board, Food packaging Forum, viewed in May 2023.

28 Confederation of European Paper Industries (2021, January), *Pulp and Paper Industry Definitions and Concepts*, p. 24-25. and Suhr, M. et all (2015), *Best Available Techniques (BAT). Reference Document for the Production of Pulp, Paper and Board. Industrial Emissions Directive 2010/75/EU (Integrated Pollution Prevention and Control)*, European Commission, JRC Science and Policy Reports, pp. 850-860.

29 TAPPI (n.d.), "Paper and Board Grades", online: https://imisrise.tappi.org/TAPPI/Products/02/FIN/0202FIN18.aspx, viewed in May 2023.

Based on this overview, Profundo could find the definitions of each grade in UN Comtrade and selected six grades in the pulp category deemed relevant for the production of food and beverage packaging (Table 7 in Appendix 1) as well as 43 paper and board grades (Table 8 in Appendix 1), as a proxy to extract production and trade data. This, however, does not mean that each code uniquely applies to food and/or beverages. It is not possible to further break down these numbers to quantify the actual role of food and beverage packaging. While it is an important segment, neither the statistics provided by Cepi nor official trade statistics provide this level of detail.

1.2.2 Statistics

An important data source for this study has been Cepi, the branch organisation of the European pulp and paper industry, together with statistics from Eurostat and UN Comtrade.

Cepi states it represents 91% of the European pulp and paper industry. Members include the national associations of Austria, Belgium, Czech Republic, Finland, France, Germany, Hungary, Italy, The Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, and United Kingdom. Profundo therefore considers Cepi statistics, provided in its annual Key Statistics report[30], as representative for the European sector. Hence, relevant Cepi data have been used in this report to describe the industry, including size, revenue, among other information. For readability purposes no explicit reference to Cepi statistics is made in the report, apart from the end notes in the reference list.

It should be noted that a detailed analysis of origins and trade flows is hampered by the fact that pulp-producing countries in the EU often also import from non-EU origins like Brazil and Uruguay. Large volumes of intra-European trade blur the actual origins and may lead to a certain level of double-counting.

1.2.3 Choice of countries

The choice of countries was done in close consultation with the alliance of NGOs who have commissioned this study. The production and supply data of pulp and paper and board partly informed the choice of countries. Other considerations that were taken into account, are the following:

- Brazil and Chile, among the top-3 suppliers to the European market along with Uruguay, were selected as key non-European exporting countries with pulp and paper production. Uruguay's pulp and paper mills are primarily linked to Finland, i.e. the Finnish forestry group UPM.
- Finland and Sweden were selected among the European countries as they are leading the top ten of producing and supplying countries of pulp for the paper industry to the European market. Sweden and Finland are also the second biggest suppliers of paper and board to the European market after Germany.
- Italy was selected as the third European country because it is among the top ten suppliers of paper and board to the European market, and it is Europe's second largest paper and board producer. However, limited information was found on this country, so it was decided to finally leave it out.

30 Confederation of European Paper Industries (2022), *Key Statistics 2021, European Pulp & Paper Industry*.

1.2.4 Overcoming general data shortcomings

This section clarifies data limitations by detailing some methodological challenges Profundo has encountered in the research process. A key challenge was the overall lack of independent and reliable public data on, for example, recycled content, the use of chemicals, as well as detailed data about the environmental footprint.

Whereas the European pulp and paper industry, represented by its branch organisation Cepi, provides comprehensive annual data about the industry performance and environmental footprint, independent data to verify and complement this information are generally absent. Moreover, the industry is not very transparent. This is observed in the following areas:

- The industry is not transparent about the use of chemicals and chemical additives and their potential health and environmental hazards. Some manufacturers even do not know themselves what chemicals exist in the materials they use, which is partly due to the complexity of the value chain;
- Little transparency exists on the exact recycling and recovery rate of paper and board. The industry does not provide figures about rejects by the paper industry, nor about the level of contamination of paper waste export to non-European countries;
- Whereas trade data show considerable intra-European trade of pulp and paper and board, the real origin is difficult to trace as European countries still import from risk countries such as Brazil, Uruguay, Belarus and Indonesia.

Furthermore, plastics have been receiving much more public and governmental attention in recent years, as a result of which much more scientific research has been conducted on the global flows and impacts of plastics than on paper.

2

Pulp, paper, and paper-based packaging trends in the EU

The EU consumption of paper-based packaging for food and beverages has increased rapidly over the years and is projected to continue growing in the coming decades. This chapter discusses key trends and drivers of the pulp, paper, and paper-based packaging industry in Europe.

2.1 Introduction

Packaging can be defined as *"products made of any materials of any nature to be used for the containment, protection, handling, delivery and presentation of goods, from raw materials to processed goods, from the producer to the user or the consumer"*.[31] Glass, paper and cardboard, metal, plastics, wood, cork, textile, or a combination of any of these materials (composite materials) among other materials are used for packaging. The diversity of packaging items is huge, ranging from cans, tubes and boxes to films and bags.[32]

The food and beverage industry, representing two-thirds of the total packaging market in Europe (in terms of market share value),[33] chooses the preferred packaging material, based on product requirements considering factors such as heat sealability, processability, printability, strength, barrier properties (water, oil, and gas barrier), cost-effectiveness, sustainability and legal requirements.[34]

---

31 Ragonnaud, G. (2023, March), *Revision of the Packaging and Packaging Waste Directive*, European Parliamentary Research Service (EPRS) Members' Research Service PE 745.707, p. 2.

32 Ragonnaud, G. (2023, March), *Revision of the Packaging and Packaging Waste Directive*, European Parliamentary Research Service (EPRS) Members' Research Service PE 745.707, p. 2.

33 Eunomia, et all (2020), *Effectiveness of the essential requirements for packaging and packaging waste and proposals for reinforcement. Final report and appendices*, European Commission, Directorate-General for Environment p. 8

34 Deshwal, G. N. Raju Panjagari, T. Alam (October 2019), "An overview of paper and paper based food packaging materials: health safety and environmental concerns", *Journal of Food Science and Technology*, 2019 Oct; 56(10): 4391–4403, p. 1.

Additionally, marketing, product presentation and consumer acceptance also play a central role, and are actually among the reasons for a gradual shift from plastic to paper-based packaging.[35]

Due to its environmentally friendly reputation and current regulatory pressure on single-use plastics, paper is an increasingly used alternative to plastic as a disposable packaging material in the food and beverage sector.[36] Paper and paperboard are used at primary level packaging, i.e. in direct contact with food products in single units, grouped packaging (secondary level) for storage and distribution, and transport packaging for distribution in bulk (tertiary).[37]

Key paper-based packaging materials range from pizza boxes to disposable beverage cups and include folding cartons, (multilayer) paper bags and sacks, beverage cups, food containers, cases, and corrugated boxes, as well as inserts and dividers. Corrugated boxes, mainly made of containerboard, are generally used for shipping heavy goods, due to their high strength. Containerboard is the most consumed paper type worldwide.[38]

For many food and beverage products, plain paper is insufficient as packaging because of poor barrier properties, low heat sealability and strength. Therefore, plastics, foils, as well as numerous chemicals and chemical additives are used during the papermaking process and in the final product, to improve its functional properties. As a result, some of these paper-based products are even classified as disposable plastic products.[39] Chemical treatments extend the applications range of paper and paperboard and make them also useable for fatty and liquid foods.[40]

Furthermore, paper and board are printed, dyed, glued, or labelled to provide nutritional details, health claims, instructions for use, expiry date and other information. This printed information is also an important source of chemicals in paper-based packaging. At the same time, the chemical composition of paper and board can differ and is even often unknown by the manufacturers. As a result, the safety of paper and board packaging is not well understood.[41]

Appendix 2 provides more insight in the pulp and paper making process and industry in Europe.

---

35 The Grocer (2023, July 3), "Is paper really better for the Earth than plastic?", online: https://www.thegrocer.co.uk/sustainability-and-environment/is-paper-packaging-really-more-sustainable-than-plastic/680773.article, viewed in July 2023.

36 The Grocer (2023, July 3), "Is paper really better for the Earth than plastic?", online: https://www.thegrocer.co.uk/sustainability-and-environment/is-paper-packaging-really-more-sustainable-than-plastic/680773.article, viewed in July 2023.

37 Deshwal, G. N. Raju Panjagari, T. Alam (October 2019), "An overview of paper and paper based food packaging materials: health safety and environmental concerns", *Journal of Food Science and Technology*, 2019 Oct; 56(10): 4391–4403, p. 1.

38 Confederation of European Paper Industries (2022), *Key Statistics 2021, European Pulp & Paper Industry*, p. 6.

39 Official Journal of the European Union (2019, June 12), *Directive (EU) 2019/904 of the European Parliament and the Council of 5 June 2019 on the reduction of the impact of certain plastic products on the environment* (Text with EEA relevance), p. 4.

40 Food Packaging Forum Foundation(n.d.), *Paper & Board. Food Packaging*, p. 1-2.

41 Food Packaging Forum Foundation (n.d.), *Paper & Board. Food Packaging*, p. 1-2.

2.2 The EU pulp, paper and (paper) packaging industry and market

Europe plays an important role in the global pulp and paper industry, being the second largest pulp producer after North America and the third largest pulp consumer after North America and Asia in 2020. The EU is also a large producer and consumer of paper and board, the second largest after Asia.[42] In 2021, according to Cepi, the EU paper industry counted 679 companies. The industry reported a turnover of EUR 95 billion and an export rate of 22% of its paper and board production.[43]

Newsprint, writing and printing paper production see a continuous downturn, mainly due to digitalisation and in recent years the global pandemic had an impact too.[44] On the contrary, growing e-commerce and increasing demand for paper-based packaging for food and beverages record annual increases.[45]

Overall, production capacity, operation rate, and production for both pulp and paper and board has been decreasing somewhat since 2010. Also, the total consumption of both pulp and paper and board in Europe has seen a decline since that year (-7.9% for paper and board, and -8.2% for pulp).[46]

At the same time, turnover and investment in the industry have experienced significant growth with respectively more than 25% and 54% between 2010 and 2021.[47] Exports, especially of market pulp, saw a great increase over the ten years period (+123%), but also paper and paperboard exports have risen, though relatively little (+5%).[48]

Market projections foresee a further increase in paper production and consumption in the coming decades, as growth resulting from increasing demand for paper-based packaging (and sanitary paper products) will eventually outweigh the current decrease in printing papers.[49] Global paper and paperboard consumption is expected to nearly double between 2010 and 2050.[50]

---

42 Confederation of European Paper Industries (2022), *Key Statistics 2021, European Pulp & Paper Industry*, p. 10, 16.

43 Confederation of European Paper Industries (2022), *Key Statistics 2021, European Pulp & Paper Industry*, p. 3.

44 International Energy Agency (2022, September.), "Pulp and Paper. Tracking Report, September 2022", online: https://www.iea.org/reports/pulp-and-paper, viewed in April 2023.

45 Confederation of European Paper Industries (2022), *Key Statistics 2021, European Pulp & Paper Industry*, p. 15.

46 Confederation of European Paper Industries (2022), *Key Statistics 2021, European Pulp & Paper Industry*, p. 4.

47 Confederation of European Paper Industries (2022), *Key Statistics 2021, European Pulp & Paper Industry*, p. 4.

48 Confederation of European Paper Industries (2022), *Key Statistics 2021, European Pulp & Paper Industry*, p. 4.

49 International Energy Agency (2022, September.), "Pulp and Paper. Tracking Report, September 2022", online: https://www.iea.org/reports/pulp-and-paper, viewed in April 2023.

50 Beck-O'Brien, M., V. Egenolf, S. Winter, J. Zahnen, N. Griesshammer, N. (2022). *Everything from wood – The resource of the future or the next crisis? How footprints, benchmarks and targets can support a balanced bioeconomy transition,* WWF Germany, p. 74;

McKinsey & Company (2019, August 7), "Pulp, paper, and packaging in the next decade: Transformational change", online: https://www.mckinsey.com/industries/paper-forest-products-and-packaging/our-insights/pulp-paper-and-packaging-in-the-next-decade-transformational-change, viewed in July 2023.

2.2.1 Pulp

The EU's annual production of wood pulp reached 37.3 million tonnes per year in 2021,[51] representing around one fifth of the world's total pulp production of 178.7 million tonnes (2020).[52] In 2021, Europe counted 151 pulp mills with a production capacity of 43.4 million tonnes, operating at 86% of their capacity.[53]

In the period 2010 to 2021, total pulp production capacity declined by 1.8% to 43.4 million tonnes, while actual pulp production decreased by 3.6% to 37.3 million tonnes.[54]

Main pulp producers in the EU are Sweden, Finland, Portugal, Germany, and Austria, according to Eurostat (2021). The EU's largest direct supplier of pulp for food and beverage packaging is however Brazil (3.6 million tonnes, 20% of total trade of 17.6 million tonnes), followed by Sweden, Finland, Portugal, Uruguay and the USA, jointly representing almost 70% of total trade (Figure 1).[55] In total 6.8 million tonnes, or 39% of the pulp consumed in the EU comes from outside of Europe.

The category 'other' is 87% composed of other Western European countries, including Austria, France, Norway, Belgium, plus the Russian federation and East European countries including Slovakia, Czechia, and Estonia.

51 Confederation of European Paper Industries (2022), *Key Statistics 2021, European Pulp & Paper Industry*, p. 4.

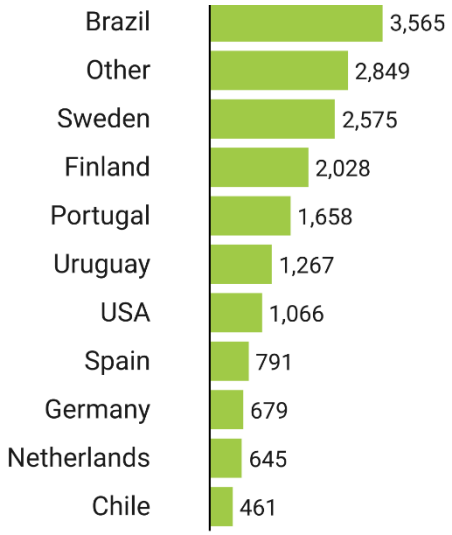
52 Confederation of European Paper Industries (2022), *Key Statistics 2021, European Pulp & Paper Industry*, p. 10.

53 Confederation of European Paper Industries (2022), *Key Statistics 2021, European Pulp & Paper Industry*, p. 4.

54 Confederation of European Paper Industries (2022), *Key Statistics 2021, European Pulp & Paper Industry*, p. 3.

55 UN Comtrade (2023), "EU pulp imports (including intra-European trade)", viewed in May 2023.

Figure 1 **Pulp for packaging suppliers to the EU market (1,000 tonnes, 2021)**



Source: UN Comtrade (2021).

In 2021, European pulp mills produced their pulp from 112.3 million tonnes of wood as well as a smaller, not further quantified volume of other fibres. While around 8.7 million tonnes of market pulp were imported, 5.7 million tonnes were exported to outside Europe. Main destination was Asia with a share of 82% in European market pulp exports.[56]

Of the total wood pulp produced in Europe, 77% is chemically obtained pulp (of which 94% sulphate pulp and 6% sulphite pulp). Only 23% is mechanical and semi-mechanical pulp.[57] Please refer to Appendix 2 for a detailed description of the pulp and papermaking process to understand these terms.

For the production of paper and board, three types of inputs were used: a net pulp volume of 40.3 million tonnes, a certain volume of pulp made of 'paper for recycling' by the industry [58] (50.7 million tonnes) and non-fibrous materials (11.4 million tonnes).[59]

---

56 Confederation of European Paper Industries (2022), *Key Statistics 2021, European Pulp & Paper Industry*, p. 4.

57 Confederation of European Paper Industries (2022), *Key Statistics 2021, European Pulp & Paper Industry*, p. 8.

58 The term 'Paper for Recycling' is a term used by Cepi and gives the impression that all the paper that is called like this, is used for recycling. However, it should be noted that 'paper for recycling' does not mean that all this paper is actually recycled. There is an unknown percentage of this collected paper that will end up as waste, not being recycled, or being exported. Chapter 3 explains more about paper waste management.

59 Confederation of European Paper Industries (2022), *Key Statistics 2021, European Pulp & Paper Industry*, p. 18.

2.2.2 Paper and board

In 2021, the production volume of paper and paperboard in Europe totalled 90.6 million tonnes, declining by 4.7% since 2010 (95.1 million tonnes). This volume represented around 23% of the global paper and board production (398.5 million tonnes in 2020).[60] With a production capacity of more than 100 million tonnes, the 735 European mills operated at approximately 90% of their capacity.[61]

Paper mill capacity increased by 13% from an average of 121,000 tonnes per mill in 2010 to 137,000 tonnes in 2021.[62] At the same time, the overall production capacity and production of paper and paperboard saw a decline of respectively 3% and 4.7% between 2010 and 2021.[63]

While these declines could suggest the industry is disappearing, this is not the case according to analysts. A 2019 Mc Kinsey report states that, due to the growing packaging industry, *"The paper and forest-products industry is not disappearing—far from it. It is changing, morphing, and developing. We would argue that the industry is going through the most substantial transformation it has seen in many decades."*[64]

In 2021, the six leading paper- and board-producing countries in Europe were Germany (26%), followed by Italy (11%), Sweden (10 %), Finland (10%), Spain (7%) and France (7%). These countries have been also the top producers in the past 10 years.[65]

Of the total paper and board production of around 90.6 million tonnes, around 20.1 million tonnes (22%) were exported. Domestic producers supplied 70.4 million tonnes to the EU market. In conjunction with imports of 4.8 million tonnes, this resulted in a total consumption of 75.2 million tonnes of paper and board in the EU (i.e., -7.9% since 2010).[66]

The biggest supplier of paper and board for packaging to the EU is Germany (6.6 million tonnes, 23% of total supply), followed by Sweden, Finland, Austria, Netherlands, France, Poland, and Italy, jointly responsible for 75% of total paper and board supply to the EU (Figure 2).

---

60 Confederation of European Paper Industries (2022), Key Statistics 2021, European Pulp & Paper Industry, p. 16.

61 Confederation of European Paper Industries (2022), *Key Statistics 2021, European Pulp & Paper Industry*, p. 4.

62 Confederation of European Paper Industries (2022), *Key Statistics 2021, European Pulp & Paper Industry*, p. 4.

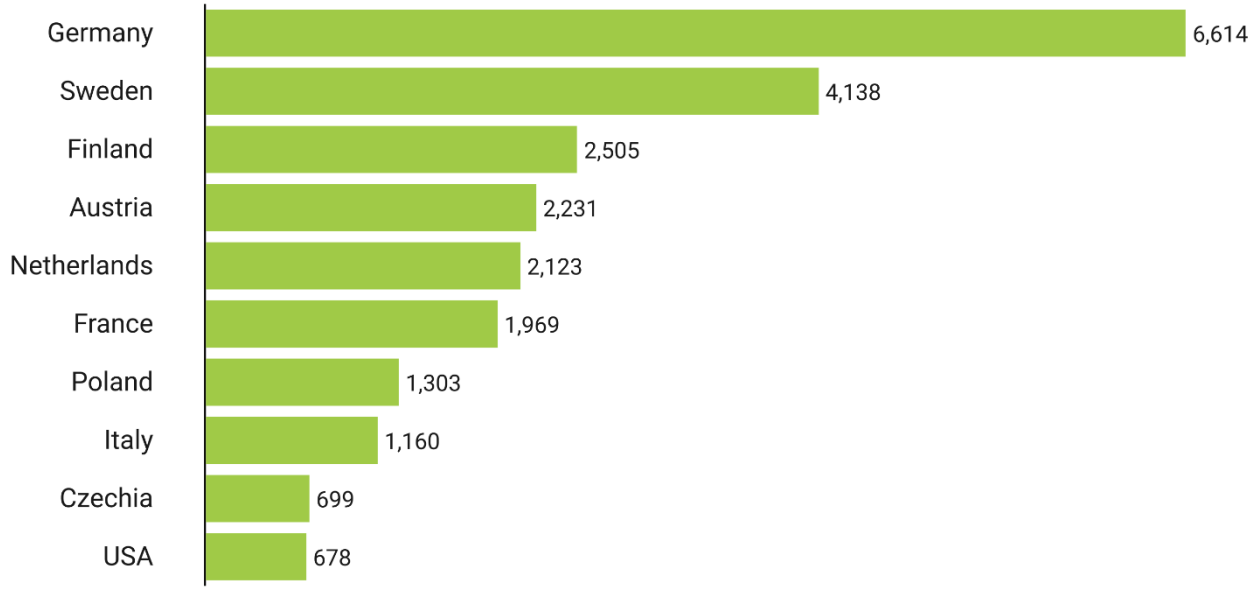
63 Confederation of European Paper Industries (2022), *Key Statistics 2021, European Pulp & Paper Industry*, p. 3.

64 McKinsey & Company (2019, August 7), "Pulp, paper, and packaging in the next decade: Transformational change", online: https://www.mckinsey.com/industries/paper-forest-products-and-packaging/our-insights/pulp-paper-and-packaging-in-the-next-decade-transformational-change, viewed in July 2023.

65 Eurostat (n.d.), "Total Paper and Paperboard Production, EU 27 + UK 2021", retrieved May 2023

66 Confederation of European Paper Industries (2022), *Key Statistics 2021, European Pulp & Paper Industry*, p. 3.

Figure 2 **Biggest suppliers of paper and board for packaging to the EU market (1,000 tonnes, 2021)**



Source: UN Comtrade (2021).

For the first time in several years, the consumption of all graphic papers increased in 2021 (by 2.7%, compared to 2020). This is explained by the industry as a recovery from the global pandemic, but nothing could be said about a future trend as industry analysts suggest that overall, graphic papers will continue facing a decline.

By contrast, the consumption of packaging paper and board increased by 8.5% year-on-year, while tissue papers saw a decline (-3%). Production of graphic paper increased with 5.6%, paper and board with 7.5%, and tissue paper a decrease of 2.2% in that period.[67]

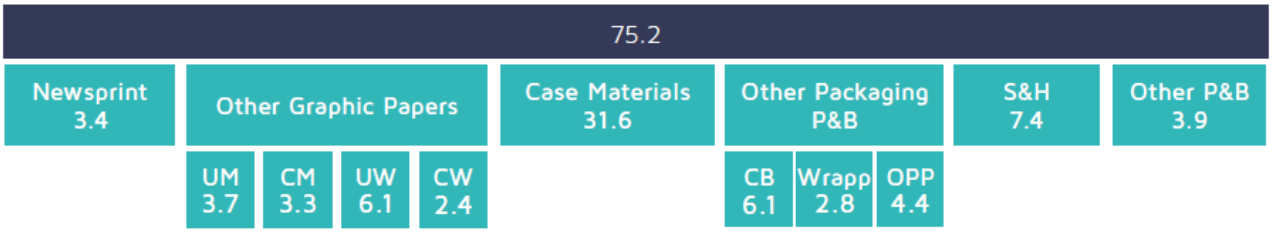
2.2.3 Paper-based packaging

The packaging industry is a significant economic activity in Europe and is characterised by high levels of cross border trade, with many producers selling packaging in multiple Member States across the EU. Cross-border movements of packaging as well as overall consumption of paper packaging have recently grown, driven by the rise in online sales of packaged goods. Packaging manufacturing generated a turnover of EUR 355 billion in 2018 in the EU. Packaging for e-commerce has an estimated global turnover of EUR 57 billion in 2022, increasing annually by 20% from 2017 till

67 Confederation of European Paper Industries (2022), *Key Statistics 2021, European Pulp & Paper Industry*, p. 13.

2021.[68] Paper and paperboards encompass approximately 37% of the global food packaging market demand.[69] Figure 3 shows the share of the different paper and board grades.

Figure 3 **Paper and board consumption grades in Europe (2021)**



Note: UM=Uncoated Mechanical, CM=Coated Mechanical, UW=Uncoated Woodfree, CW=Coated Woodfree, CB=Carton Board, W= Wrappings, OPP=Other Paper and Board for Packaging, S&H=Sanitary and Household. Source: Confederation of European Paper Industries (2022), *Key Statistics 2021, European Pulp & Paper Industry*, p. 6.

In 2021, of the more than 75 million tonnes of total paper consumption in the EU, 60% (44.9 million tonnes) was used for packaging. This volume consisted of 70% for case materials, carton board (14%), and wrappings (6.2%) being categorised under 'other packaging materials'. Packaging was followed by newsprint and other graphic papers taking a share of 25%, sanitary and household with 9.8%, and 5% of other paper products.[70] It is not possible to further break down these numbers to quantify the actual role of food and beverage packaging. While it is an important segment, neither the statistics provided by Cepi nor official trade statistics provide this level of detail.

The European paper-based packaging market is expected to continue its steady growth in the coming years. This is partly driven by a rising demand for - perceived - environmentally friendly and recyclable packaging options.[71] As a result of this, there is an ongoing trend to substitute disposable plastic packaging with disposable paper composites, i.e., multimaterial packaging combining paper and board with plastic, aluminium, and other materials to improve functionalities for food and beverage packaging. Examples are multiple, including beverage cups, laminated paper-based meat packages, etc. Of the 500 million disposable beverage cups annually consumed worldwide, between

68 European Commission (2022, November 30), *Commission Staff Working Document. Impact Assessment Report. Accompanying the document Proposal for a Regulation of the European Parliament and the Council on packaging and packaging waste, amending Regulation (EU) 2019/1020, and repealing Directive 94/62/EC*, p. 5.

69 Peters, R. et all (2019, March), "Review of analytical approaches for the identification of non-intentionally added substances in paper and board food contact materials ", Trends in Food Science & Technology. Volume 85, March 2019, Pages 44-54. Trends in Food Science & Technology Review.

70 Confederation of European Paper Industries (2022), *Key Statistics 2021, European Pulp & Paper Industry*, p. 6.

71 Digital Journal (2023, February 15), "Europe Paper Packaging Market Trends, Size, Growth Factors and Analysis 2021-2026", online: www.digitaljournal.com/pr/news/europe-paper-packaging-market-trends-size-growth-factors-and-analysis-2021-2026#ixzz7xWy5VSvD, viewed in May 2023.

250 to 300 million are plastic-lined paper cups.[72] For more information on the waste generated from this, please refer to chapter three.

A 2021 study on paper-based food and beverage packaging in Germany noted that the German market for paper composites will grow by 31.6% by 2025, corresponding to an annual growth rate of 5.7%.[73] It is expected that this substitution trend will be the strongest for bags (for higher priced foods, such as coffee, baby and organic food), bowls, trays and wrappers (among others for meat, sausage, fish and dairy products), but also cups made of paper composites are considered viable alternatives to plastic packaging.

The study forecasted that by 2025, 60.9 kiloton (kt) of plastic packaging, most of it accounted for by food and beverages (45%) and service packaging (52%), will be substituted by paper-based composites. This is 3.8% of the relevant market volume. The study further states that an additional 40% of packaging material will be needed to pack the same amount of products and substitute the 60.9 kt of plastic packaging, amounting to 85.5 kt of paper composites.[74]

Although the German market does not necessarily represent other European markets, similar trends in paper-based food packaging can be expected in other European countries.

Another trend in the packaging universe is the growth of disposable on-the-go or take-away packaging. The use of this type of packaging has increased significantly over the past decades, especially in the rapidly growing food delivery and take-away sector.[75]

---

72 United Nations Environment Programme (2021), *Single-use beverage cups and their alternatives - Recommendations from Life Cycle Assessments*, p.14.

73 Gesellschaft für Verpackungsmarktforschung (2021, May), *Substitution von Kunststoffverpackungen durch papierbasierte Verbunde*, IK Industrievereinigung Kunststoffverpackungen e.V., p. 14-16.

74 Gesellschaft für Verpackungsmarktforschung (2021, May), *Substitution von Kunststoffverpackungen durch papierbasierte Verbunde*, IK Industrievereinigung Kunststoffverpackungen e.V., p. 14-16.

75 European Commission (2022, November 30), Commission Staff Working Document. *Impact Assessment Report. Accompanying the document Proposal for a Regulation of the European Parliament and the Council on packaging and packaging waste, amending Regulation (EU) 2019/1020, and repealing Directive 94/62/EC*, p. 10.

3

Waste management and recycling

Paper and cardboard represent the largest share of total packaging waste materials and is the second fastest growing waste stream. This chapter gives an overview of the main waste streams of the pulp and paper industry as well as of their management and disposal. The chapter also deals with the potential recyclability of paper-based packaging and the challenges of recycling such materials.

3.1 Pulp and paper waste streams

Already during the pulp and paper production process, various waste streams are generated (Table 1), that can be generally divided into two categories:

1. Pulp mill waste, including wood residues, lime mud, dregs, wastewater and chemicals depending on the type of raw material and method utilised;
2. Paper mill waste, including wood residues, fibres, staples, metals from ring binders, rubber bands, sand, glass, and sizing agents.

Table 1 provides a detailed, but non-exhaustive overview of the different waste streams, the estimated amounts generated, as well as the way these streams are dealt with. However, little is known about the exact percentages of landfilling, incineration, energy recovery, or other waste management practices.

Table 1 Waste streams during pulp and paper making

Process step	Type of waste generated	Amount	Destination
Wood harvesting	Branches and stumps	44 tonnes of branches generated per 100 tonnes of produced pulp (2016)[76]	Left in the forest for soil nutrition or used for power generation in the biomass boiler in the PPI.
Debarking	Bark	100–300 kg of bark is generated per tonne of dry pulp produced[77]	Left in the forest, incinerated, or used for

[76] Amândio, M.S.T., et all (2022, June 2), "Getting Value from Pulp and Paper Industry Wastes: On the Way to Sustainability and Circular Economy", *Energies 2022*, 15, 4105, p. 3.

[77] Amândio, M.S.T., et all (2022, June 2), "Getting Value from Pulp and Paper Industry Wastes: On the Way to Sustainability and Circular Economy", *Energies 2022*, 15, 4105, p. 4.

Process step	Type of waste generated	Amount	Destination
			energy or steam production in the PPI.
Chipping and screening	Sawdust and rejects from coarse and fine screening	Not found	Energy generation, manufacturing of fibre- and particle boards, pellets for fuel.
Pulping process	Cooking chemicals and dissolved organic compounds	Not found	Not found
Sulphite chemical pulping	Spent Sulfite Liquor (SSL), highly acidic	90 billion litres annually worldwide[78]	Evaporated for water recovery, followed by burning for energy production and chemicals recovery.
Sulphate chemical pulping	Black liquor (byproduct from the kraft process when digesting pulpwood into paper pulp removing lignin, and other extractives from the wood to free the cellulose fibres).	Est. 10 tonnes per tonne of pulp produced, i.e. annual global production of about 1.3 billion tonnes.[79]	Evaporated for water recovery, the concentrated stream is burned in a recovery boiler for energy production and cooking chemicals recovery.
	Inorganic wastes containing different minerals, including green liquor dregs, calcite mud, lime mud waste, and slacker grits.	Not found.	Dregs: for soil acidity, fertilizer and wastewater treatment; Grits and lime mud: replacement of calcareous raw materials in construction sector; Lime mud: soil remedial agent or fertilizer.
Paper making process	Wastewater, containing concentrations of organic	220-380 m3 per tonne of paper (2011).[81]	Reused in the PPI or released in the environment.

78 Amândio, M.S.T., et all (2022, June 2), "Getting Value from Pulp and Paper Industry Wastes: On the Way to Sustainability and Circular Economy", *Energies 2022*, 15, 4105, p. 6.

79 Amândio, M.S.T., et all (2022, June 2), "Getting Value from Pulp and Paper Industry Wastes: On the Way to Sustainability and Circular Economy", *Energies 2022*, 15, 4105, p. 6.

81 Badar, S. and I. Haq Farooqi (2011, September), "Pulp and Paper Industry—Manufacturing Process, Wastewater Generation and Treatment", online: https://www.researchgate.net/publication/226218540_Pulp_and_Paper_Industry-Manufacturing_Process_Wastewater_Generation_and_Treatment#:~:text=The%20pulp%20and%20paper%20industry%20consumes%20a%20lot%20of%20freshwater,)%20%5B114%2C%20115%5D, viewed in April 2023.

Process step	Type of waste generated	Amount	Destination
	and inorganic contaminants.[80]		
	Pulp and paper mill sludge (PPMS, after wastewater treatment).	Est. 40-50 kg of sludge (dry basis) generated per tonne of paper.[82]	Landfilling, composting, incineration, combustion; or used for energy recovery; integrated in bioplastics, cement, asphalt, etc.[83]
Recovered paper processing: deinking	Fines, coatings, fillers, ink residues and deinking additives; deinking sludges from recovered paper processing.	Not found.	Not found.
Common wastes	Non-industry specific waste streams (metal parts, electronic equipment, wires, felts, building waste, spill oil, packaging material, domestic waste, etc.).	Not found.	Not found.

Source: Amândio, M.S.T., et all (2022, June 2), "Getting value from pulp and paper industry wastes: On the way to sustainability and circular economy", *Energies 2022*, 15, 4105.

As Table 1 above shows, while the pulp and paper industry reuses some of its waste streams, such as wood and rejects, wastewater and sludge (including for energy recovery), unsustainable waste management practices are still very common in the EU. The incineration of biomass and other byproducts for energy recovery is considered unsustainable because it has low economic value and causes severe impacts on human health and the environment due to the risk of releasing organic pollutants. Also landfilling, combustion and composting of, for example, sludge, are unsustainable and unhealthy but still common practice.[84]

80 Ashraf, O. et all (2015), "Wastewater treatment in the pulp-and-paper industry: A review of treatment processes and the associated greenhouse gas emission", *Journal of Environmental Management*, pp. 1-2.

82 Amândio, M.S.T., et all (2022, June 2), "Getting Value from Pulp and Paper Industry Wastes: On the Way to Sustainability and Circular Economy", *Energies 2022*, 15, 4105, p. 7.

83 Amândio, M.S.T., et all (2022, June 2), "Getting Value from Pulp and Paper Industry Wastes: On the Way to Sustainability and Circular Economy", *Energies 2022*, 15, 4105, pp. 7-8.

84 Amândio, M.S.T., et all (2022, June 2), "Getting Value from Pulp and Paper Industry Wastes: On the Way to Sustainability and Circular Economy", *Energies 2022*, 15, 4105, p. 1,8.

To make matters worse, the use of high amounts of chemicals in the industry, including potentially hazardous substances, may be dangerous for the environment and human health and pose thus a threat to sustainable waste management practices in the sector (see Chapter 4).

3.2 Paper-based packaging waste

The total mass of packaging waste generated in the EU increased from 66 million tonnes in 2009 to 79 million tonnes in 2020 (+20%).[85] This is equivalent to an average of 177 kg per inhabitant in 2020 against 150 kg in 2009. There are, however, large differences between Member States. For example, Germany generated more than 225 kg per inhabitant in 2020, compared to 66 kg in Croatia.[86]

Paper and cardboard represented Europe's largest share of total packaging waste materials (41.1%), followed by plastic (19.4%), glass (19.1%), wood (15.2%) and metal (5.0%).[87] Both plastic (+27 %) and paper and cardboard (+25 %) are the two waste streams with highest growth since 2009. In municipal solid waste in Europe, the paper and board waste takes the second largest share with around 18%, second only to food waste (25%). Plastic waste stands third, amounting to 12%.[88]

Packaging waste is particularly relevant in the food sector. The informal eating out (IEO) sector alone generated about 1 million tons of packaging waste in 2021.[89]

Figure 4 shows the projections of the growth of packaging waste until 2040, including a 56% estimate for the increase of paper waste by 2040 compared to 2006.

85 European Commission (2022, November 30), *Commission Staff Working Document. Impact Assessment Report. Accompanying the document Proposal for a Regulation of the European Parliament and the Council on packaging and packaging waste, amending Regulation (EU) 2019/1020, and repealing Directive 94/62/EC*, p. 5.

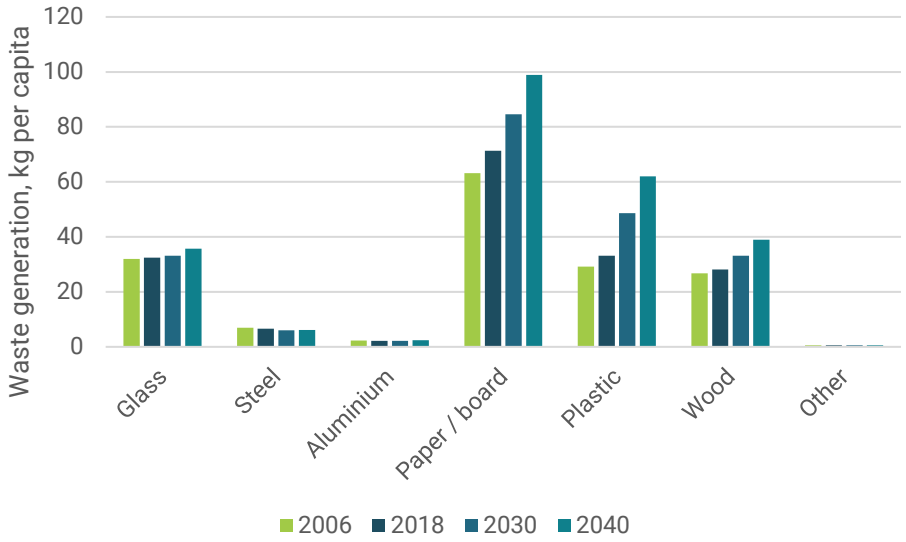
86 Eurostat (n.d.), online: https://ec.europa.eu/eurostat/databrowser/view/env_waspac/default/table?lang=en, retrieved in May 2023.

87 Eurostat (2023, March 23), "Packaging waste statistics", online: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Packaging_waste_statistics#Waste_generation_by_packaging_material, viewed in June 2023.

88 Trinomics (2020, March 6), *Emerging Challenges of Waste Management in Europe. Limits of Recycling. Final Report*, p. 18.

89 Kearny (2023), *No silver bullet Why the right mix of solutions will achieve circularity in Europe's informal eating out (IEO) sector*, p. 1.

Figure 4 **Projected growth of packaging waste in Europe**



Source: European Commission (2022, November 30), *Commission Staff Working Document. Impact Assessment Report. Accompanying the Document Proposal for a Regulation of the European Parliament and the Council on Packaging and Packaging waste, Amending Regulation (EU) 2019/1020, and Repealing Directive 94/62/EC*, p. 8.

The growth of packaging waste will also be driven by the increased use of paper composites, i.e., multilayer multimaterial packaging forms that combine paper with for example plastic and aluminium to reduce overall amounts of plastic used and thus plastic waste. However, recent research calculated that paper composites require 40% more material to pack the same amount of product.[90]

Table 2 provides the percentages for the different paper and board food and beverage packaging types present in waste streams. Corrugated board boxes and carton board account for the greatest tonnage of paper and board packaging.

[90] Gesellschaft für Verpackungsmarktforschung (2021, May), *Substitution von Kunststoffverpackungen durch papierbasierte Verbunde*, IK Industrievereinigung Kunststoffverpackungen e.V., p. 14-16.

Table 2 Share of (food and beverage) packaging type in waste streams in Europe

Type of paper and board	Type of packaging[91]	Weight (1,000 tonnes)	Share of waste (%)
Corrugated and other board boxes	Tertiary packaging	20,408	26.2%
Carton board e.g., cereal boxes	Primary packaging	6,144	7.9%
Corrugated, other board boxes (e-commerce)	Tertiary packaging	3,392	4.4%
Non-beverage liquid packaging board e.g. soups	Primary packaging	860	1.1%
Other paper / board	Primary packaging	649	0.83%
Beverage cartons	Primary packaging	363	0.11%
Total paper and board % of waste stream		**31,816**	**40.5%**

Source: European Commission (2022, November 30), *Commission Staff Working Document. Impact Assessment Report.* p. 349.

3.3 Recycling

Packaging is one of the main users of raw materials (40% of plastics and 50% of paper used in the EU is destined for packaging)[92], and as earlier mentioned an estimated 37% of the food packaging consists of paper and board. The recycling of paper into new paper or other paper-based products reduces the overall carbon footprint of paper-based packaging and can save trees, energy, and water. Hence, wood, forest, biomass, and other bio-based raw materials can be preserved or used for other purposes if needed, and according to the cascading use of biomass principle.

In 1994, EU legislation had set targets to increase recycling of paper and paperboard under the Directive on Packaging and Packaging Waste (94/62/EC) reflecting the importance of paper recycling. In the 2022 European Declaration on Paper Recycling 2021-2030, the signatories of the European paper industry set a target to reach a 76% paper recycling rate by 2030.[93] This section will however show that next to the advantages of recycling, there are important limitations too, particularly when it comes to food and beverage packaging.

91 Defined in the methodology (section 2.1).

92 European Commission (2022, November 30), *Proposal for a regulation of the European Parliament and of the Council on packaging and packaging waste, amending Regulation (EU) 2019/1020 and Directive (EU) 2019/904, and repealing Directive 94/62/EC*, p. 18.

93 European Paper Recycling Council (2022, June 21), *European Declaration on Paper recycling 2021-2030*, p. 2.

3.3.1 The footprint of recycling

Around 90% of the paper pulp is currently made of wood, and as such, paper production is responsible for about 35% of clear-felled trees.[94] Around 3 billion trees are used annually to meet global demand for paper packaging.[95]

It is difficult to provide exact values of CO_2 emissions, water and energy consumption across the pulp and paper industry as each mill and every type of paper has its own production standards. However there have been efforts to calculate resource efficiency when using recycled papers, suggesting that one tonne of newspaper recycling could save an estimated 1 tonne of wood, while printing or copying paper recycling could save more than 2 tonnes of wood per tonne of product. Recycled paper production consumes 50% less water and reduces air pollution by 74% compared to virgin paper production.[96]

Recycling also requires less energy because the production process is different from virgin paper production which requires energy to harvest wood, as well as for the pulping, refining, and drying.[97] According to European Recycling Industries Confederation (EuRIC), 4,000 kWh of energy is saved by recycling one tonne of paper, compared to virgin paper.[98]

However, recycled paper still has an environmental footprint. Large amounts of water and energy are needed to recycle paper and to make it suitable for new packaging products. According to the International Energy Agency (IEA) increased recycled pulp production will only reduce emissions if it can rely on renewable energy sources. *"[P]rimary pulp production relies largely on bioenergy that is available as a by-product from the wood used, while recycled production does not have by-product bioenergy readily available and so currently relies mostly on fossil fuels. Thus, switching to low emission fuels such as bioenergy and electricity for recycled pulp production will be important in parallel to increasing the total amount of recycled production."*[99]

---

94 Bandara, R., G.M. Indunil (2022, July 1), "Food packaging from recycled papers: chemical, physical, optical properties and heavy metal migration", *Heliyon 8* (2022), p. 1.

95 The Grocer (2023, July 3), "Is paper really better for the Earth than plastic?", online: https://www.thegrocer.co.uk/sustainability-and-environment/is-paper-packaging-really-more-sustainable-than-plastic/680773.article, viewed in July 2023.

96 Bandara, R., G.M. Indunil (2022, July 1), "Food packaging from recycled papers: chemical, physical, optical properties and heavy metal migration", *Heliyon 8* (2022), p. 1.

97 Deshwal, G. N. Raju Panjagari, T. Alam (October 2019), "An overview of paper and paper based food packaging materials: health safety and environmental concerns", *Journal of Food Science and Technology*, 2019 Oct; 56(10): 4391–4403.

98 EuRIC (n.d.), "What we recycle. Paper", online: https://euric-aisbl.eu/what-we-recycle/paper, viewed in May 2023.

99 International Energy Agency (2022, September.), "Pulp and Paper. Tracking Report, September 2022", online: https://www.iea.org/reports/pulp-and-paper, viewed in April 2023.

In addition, other limited climate benefits of global pulp and paper recycling are that recycled pulp tends to be powered by fossil fuels and grid electricity, whereas chemical pulping of virgin timber is typically powered by burning by-products.[100]

3.3.2 Recyclability of paper and board packaging

In general, paper and board are said to have a high recycling potential, i.e., 96%[101], though this figure is 78% according to the European Paper Recycling Council due to *"non-collectable or non-recyclable paper products"*.[102]

In theory, paper and board fibres can be recycled up to eight times.[103] In reality, in 2021, European paper fibres were used 3.5 times on average, compared to a global average of 2.5 times.[104] Similar to plastics, paper cannot be recycled endlessly, as the process gradually shortens and weakens the fibres.[105]

Furthermore, the recycling of paper-based food and beverage packaging into new food and beverage packaging materials is very limited compared to, for example, glass and metal food packaging. Material properties and chemical safety remain high with glass and metal after repeated recycling cycles, which is not the case for paper and board.[106] A lot of the paper and board is downcycled into carton boxes, for example to be used to transport goods.[107] Moreover, as is the case for plastic, to recycle paper for food and beverage packaging, virgin materials need to be added and special measures are needed to guarantee functionality and safety.[108]

Furthermore, the exact recyclability of paper-based packaging products will be determined by the composition and the design, the levels of chemicals used, the level of contamination with food, the

---

100 Beck-O'Brien, M., V. Egenolf, S. Winter, J. Zahnen, N. Griesshammer, N. (2022), *Everything from wood – The resource of the future or the next crisis? How footprints, benchmarks and targets can support a balanced bioeconomy transition*, WWF Germany, p. 78.

101 Trinomics (2020, March 6), *Emerging Challenges of Waste Management in Europe. Limits of Recycling. Final Report*, p. 20.

102 European Paper Recycling Council (2022, September 5), *Monitoring Report 2021, European Declaration on Paper Recycling 2021-2030*, p. 8.

103 European Paper Recycling Council (2022, September 5), *Monitoring Report 2021, European Declaration on Paper Recycling 2021-2030*, p. 2.

104 European Paper Recycling Council (2022, September 5), *Monitoring Report 2021, European Declaration on Paper Recycling 2021-2030*, p. 2.

105 The Grocer (2023, July 3), "Is paper really better for the Earth than plastic?", online: https://www.thegrocer.co.uk/sustainability-and-environment/is-paper-packaging-really-more-sustainable-than-plastic/680773.article, viewed in July 2023.

106 Food Packaging Forum Foundation(n.d.), "Food packaging materials and recycling. Fact sheets.", online: https://www.foodpackagingforum.org/packaging-fact-sheets, viewed in June 2023.

107 Katrakis, E. and J. Blees (2023, May 11), *Interview with Manon Stravens of Profundo.*

108 Food Packaging Forum Foundation(n.d.), "Food packaging materials and recycling. Fact sheets.", online: https://www.foodpackagingforum.org/packaging-fact-sheets, viewed in June 2023.

way waste is collected and presented for reprocessing, as well as the innovation capacity of the recycling industry and market dynamics. In fact, the amount of packaging with design features that inhibits recycling has been increasing at a greater rate than total packaging waste generated in the last decade. Among those features are composite, or waxed materials, and materials with adhesives.[109]

- **Multimaterial paper-based packaging products**

Especially in the food sector, paper-based packaging has numerous applications, which is possible due to the combination of paper fibres with other materials such as plastics to increase water resistance for example.[110] Whereas these multilayer multimaterial food and beverage packaging are increasingly used in the food packaging sector in the search for alternatives for disposable plastic, the recyclability is even more limited as the materials are difficult to separate, potentially increasing the costs of reprocessing as this can be hampered by inks, adhesives, and paper coating agents. They may even pose a risk for recycling machinery or be detrimental to the quality of the finished secondary material.[111]

The separation into single materials and homogeneous waste streams is a prerequisite for high quality recycling and the production of new and safe food and beverage packaging materials. The most prominent example of this challenge are beverage cartons, which generally consist of about 75% paperboard, 20% plastics, and up to 5% of aluminium foil and that are difficult to separate.[112] The separation of plastic, metal, and fibres can be done to a certain extent in specialised plants with special equipment, of which there are only a few in the EU. Still, recycling in these plants remains very niche.[113]

Other specific food and beverage packaging that pose challenges for recycling are:

- Varnished paper products can partly break down into microplastic particles, which can pollute wastewater and which are often not trapped in wastewater treatment plants;
- Paper products with adhesives on tape/labels and in the binding of packaging can soften or plasticise in heat and form 'stickies' which could spoil the finished paper;
- The wax of waxed papers cannot be removed by usual mill cleaning systems and as such passes onto the finished product. Silicone, greaseproof and glassine papers cannot be pulped and pass into the mill waste stream; and

---

109 European Commission (2022, November 30), *Commission Staff Working Document. Impact Assessment Report. Accompanying the document Proposal for a Regulation of the European Parliament and the Council on packaging and packaging waste, amending Regulation (EU) 2019/1020, and repealing Directive 94/62/EC*, p. 237-244.

110 CEPI (2019, February 8), *Paper and Board Packaging Recyclability Guidelines*, p. 3.

111 European Commission (2022, November 30), *Commission Staff Working Document. Impact Assessment Report. Accompanying the document Proposal for a Regulation of the European Parliament and the Council on packaging and packaging waste, amending Regulation (EU) 2019/1020, and repealing Directive 94/62/EC*, p. 240, 244.

112 Food Packaging Forum Foundation (n.d.), *Factsheet multimaterial food packaging*, p. 1-2

113 European Commission (2022, November 30), *Commission Staff Working Document. Impact Assessment Report. Accompanying the document Proposal for a Regulation of the European Parliament and the Council on packaging and packaging waste, amending Regulation (EU) 2019/1020, and repealing Directive 94/62/EC*, p. 220.

- Yoghurt pots include a foil, a rigid plastic pot and a paper label, and are less likely to be collected by sorted streams.[114]

Another study, commissioned by the German IK Industry Association for Plastic Packaging e.V., made a comparison between 24 food packaging materials made of plastic compared to their paper composite alternatives. The report shows that in 75% of the cases, the recyclability of composite packaging is lower. For example, the composite to-go-cup has a 95% recyclability rate compared to a 100% rate of the plastic cup. A composite noodle pack has a 74% recycling rate compared to 100% of the plastic alternative. The cornflakes or muesli composite package only has a 30% recyclability rate.[115]

Multimaterial food packaging is often incinerated or sent to landfills. While there are efforts to ensure separate collection and sorting streams for fibre-based multimaterial packaging for recycling, they cannot be recycled efficiently at present. The paperboard fibres can be separated but cannot be used in new packaging with direct food contact.[116]

- **Chemicals contaminate recycled paper**

The countless numbers of chemicals added to paper and board to make it suitable for food and beverage packaging (please refer to Chapter 4) also negatively influence the recyclability of the material, as the recycled paper may be contaminated due to chemical migration. The migration level depends on, among others, the composition of recycled paper, the fat content in the food, or the type of recycling. The incorrect recycling of food packaging materials that consist of multiple layers, like beverage carton for the packaging of drinks, could contribute to an accumulation of non-intentionally added chemicals (NIAS) - often hazardous - into the packaging waste stream, too.[117]

---

114 European Commission (2022, November 30), *Commission Staff Working Document. Impact Assessment Report. Accompanying the document Proposal for a Regulation of the European Parliament and the Council on packaging and packaging waste, amending Regulation (EU) 2019/1020, and repealing Directive 94/62/EC*, p. 240, 244.

115 Gesellschaft für Verpackungsmarktforschung (2021, May), *Substitution von Kunststoffverpackungen durch papierbasierte Verbunde*, IK Industrievereinigung Kunststoffverpackungen e.V., p. 27-50.

116 Food Packaging Forum Foundation(n.d.), *Factsheet multimaterial food packaging*, p. 1-2

117 Peters, R. et all (2019, March), "Review of analytical approaches for the identification of non-intentionally added substances in paper and board food contact materials ", *Trends in Food Science & Technology*. Volume 85, March 2019, Pages 44-54. Trends in Food Science & Technology Review;

Netherlands Institute for Sustainable Packaging (2022, May), *Fact Sheet NIAS – Non-intentionally added substances in packaging*, p. 3.

Firstly, the chemical composition of waste streams is hard to determine, since it depends on several factors, including wood source, manufacturing processes, the operational conditions, the type and grade of final products, etc. Secondly, chemical substances present in waste paper are difficult to remove during the recycling process, and therefore occur in recycled paper products. Over the years, numerous studies have found hundreds of chemicals in recycled paper and cardboard food packaging products.[118] One study identified more than 250 substances in recycled paperboard used for food packaging.[119] Other examples of compromised chemical safety include:

- Infant foods packed in recycled paperboard boxes with coated paper liners were found to be contaminated with different phthalates. Some samples contained diisobutyl phthalate (DIBP) at levels exceeding European Commission limits for food contaminants;[120]
- Bisphenols (e.g., BPA and BPS) have been detected in waste paper and/or recycled paper and cardboard by several studies. Contamination of recycled pulp with bisphenols can occur when thermal paper and ink and glue added to paper products are included in the feedstock to the recycling process. An analysis of 15 types of paper from different fractions of household waste detected BPA and BPS in 100% and 73% of samples respectively. A study from Spain found BPA in all the food contact materials made of recycled paper tested. A paper tablecloth, pizza carton, and packaging box had the highest BPA concentrations. An US study found BPA and BPS in recycled paper goods including food contact papers and food cartons, among numerous other consumer products;[121]
- Mineral oil hydrocarbons have been measured frequently and at high concentrations in many food contact materials made from recycled paper and board and in the packaged food.[122]

118 Geueke, B., K. Groh, J. Muncke (2017, December 21), "Food packaging in the circular economy: Overview of chemical safety aspects for commonly used materials", *Journal of Cleaner Production*, pp. 496-497;

HBM4EU (2022, July 7), *Chemicals in a Circular Economy. Using Human Biomonitoring to Understand Potential New Exposures*, p. 23-24.

119 HBM4EU (2022, July 7), *Chemicals in a Circular Economy. Using Human Biomonitoring to Understand Potential New Exposures*, p. 24.

120 Deshwal, G. N. Raju Panjagari, T. Alam (October 2019), "An overview of paper and paper based food packaging materials: health safety and environmental concerns", *Journal of Food Science and Technology*, 2019 Oct; 56(10): 4391–4403.

121 HBM4EU (2022, July 7), *Chemicals in a Circular Economy. Using Human Biomonitoring to Understand Potential New Exposures*, pp. 23-24.

122 Geueke, B., K. Groh, J. Muncke (2017, December 21), "Food packaging in the circular economy: Overview of chemical safety aspects for commonly used materials", *Journal of Cleaner Production*, p. 497.

In general, higher repetition of recycling generally lowers the quality and value of the paper and may lead to the accumulation of unintended chemical substances in it.[123] As a result, recycled paper and paperboard can only be used to a limited extent for food and beverage packaging.[124]

- **Mixed waste streams**

Mixed waste streams and the fact that recycling industries are dependent on consumers and municipalities collecting and sorting the waste streams, also affect the recyclability of waste paper and paperboard. According to industry expert Igor Karlovits: *"Households only separate 55% of the waste. For example, a pizza box with grease is not recyclable and should not be disposed for paper recycling. But people don't separate it correctly, and paper mills can also not separate it."*[125]

National collection systems within countries across Europe are not harmonised. Some countries collect all paper-based packaging in one stream, while other countries differentiate a separate paper and board fraction.[126]

Another aspect to take into account is take-away food packaging, an increasing packaging segment, but less likely to be recycled because as the food item is consumed on-the-go. The package is thus more likely to be littered or to be ended up in the mixed waste stream.[127] For example, disposable beverage cups, whether made of plastics or coated paperboard, are amongst the top items found littered on beaches around the world. Globally, of the more than 500 billion disposable cups that are consumed annually, between 250 and 300 billion are plastic-lined paper cups.[128] This is among the reasons why the Single-Use Plastics Directive included plastic-lined paper cups into its scope and why they are subject to consumption reduction targets.

Food items are more likely to contaminate the packaging, for example if the package is difficult to fully empty, making the packaging all the more difficult to recycle.[129]

---

123 Bandara, R., G.M. Indunil (2022, July 1), "Food packaging from recycled papers: chemical, physical, optical properties and heavy metal migration", *Heliyon 8* (2022), p. 2.

124 European Commission (2022, November 30), *Commission Staff Working Document. Impact Assessment Report. Accompanying the document Proposal for a Regulation of the European Parliament and the Council on packaging and packaging waste, amending Regulation (EU) 2019/1020, and repealing Directive 94/62/EC*, pp. 278-279.

125 Karlovits, I. (2023, April 26), *Interview with Manon Stravens of Profundo*.

126 4EverGreen (n.d.), "A journey through recycling into fibre-based packaging", online: https://4evergreenforum.eu/a-journey-through-recycling-of-fibre-based-packaging/, viewed in May 2023.

127 European Commission (2022, November 30), *Commission Staff Working Document. Impact Assessment Report. Accompanying the document Proposal for a Regulation of the European Parliament and the Council on packaging and packaging waste, amending Regulation (EU) 2019/1020, and repealing Directive 94/62/EC*, pp. 216.

128 United Nations Environment Programme (2021), *Single-use beverage cups and their alternatives - Recommendations from Life Cycle Assessments*, p.14.

129 European Commission (2022, November 30), *Commission Staff Working Document. Impact Assessment Report. Accompanying the document Proposal for a Regulation of the European Parliament and the Council on packaging and packaging waste, amending Regulation (EU) 2019/1020, and repealing Directive 94/62/EC*, pp. 216.

- **Limitations of paper recycling industry**

The recycling industry also struggles with the increasing complexity of formats within the packaging industry, for example the development and use of new coatings and biobased foils which cannot be processed by standard paper recycling mills.[130]

For paper processing, there is generally a maximum limit of between 3 to 10% of other 'non-pulpable' materials, materials other than fibres. If this limit is exceeded when entering the stream, this can be detrimental to the recycling process.[131] This means that the average beverage carton, existing of 25% of non-paper materials[132], or the newly launched Absolut Vodka bottle existing 43% plastic barrier lining are difficult to recycle.[133]

This is not only the consequence of the fast developments in the packaging universe, but also due to the conservative and little innovative character of the recycling industry which is considered as *"a kind of dinosaur that moves very slowly"*, in the words of industry expert Igor Karlovits.[134]

In addition, the different industries have a narrow perspective towards recycling. The paper industry is mostly interested in the fibres. They are less or not interested in the foils and plastics which they could sell to a plastics facility, but which is in reality mostly burned. Karlovits: *"These industries are not thinking about the whole packaging system."* He notes that a *"unified testing method of recyclability for complex packaging is needed."*[135]

Market demand and price influence

Similar to all markets, the recycling industry is influenced by demand. The cost of recycling increases when more complex products need to be recycled, but there is no demand for these types of recyclates.

130 Karlovits, I. (2023, April 26), *Interview with Manon Stravens of Profundo*.

131 European Commission (2022, November 30), *Commission Staff Working Document. Impact Assessment Report. Accompanying the document Proposal for a Regulation of the European Parliament and the Council on packaging and packaging waste, amending Regulation (EU) 2019/1020, and repealing Directive 94/62/EC*, pp. 217;

The Grocer (2023, July 3), "Is paper really better for the Earth than plastic?", online: https://www.thegrocer.co.uk/sustainability-and-environment/is-paper-packaging-really-more-sustainable-than-plastic/680773.article, viewed in July 2023.

132 Food Packaging Forum Foundation(n.d.), *Factsheet multimaterial food packaging*, p. 1-2

133 The Grocer (2023, July 3), "Is paper really better for the Earth than plastic?", online: https://www.thegrocer.co.uk/sustainability-and-environment/is-paper-packaging-really-more-sustainable-than-plastic/680773.article, viewed in July 2023.

134 Karlovits, I. (2023, April 26), *Interview with Manon Stravens of Profundo.*

135 Karlovits, I. (2023, April 26), *Interview with Manon Stravens of Profundo*.

According to Emmanuel Katrakis of EuRIC: *"When you have complex products, the costs are exceeding, exceeding the value that you get from the materials, because market prices are not factoring in these extra costs."*[136] Specific targets for recycled content in paper and card packaging, not existing at present, could stimulate that demand.[137]

New regulations of trade partner countries also affect the recycling industry. This was clearly the case when China imposed a ban on the import of waste, including paper waste, in 2018. This country used to import the bulk of the structural oversupply of recovered paper in the EU. While the EuRIC firmly stated that this ban *"seriously disrupted"* the recovered paper market, new markets – mainly in Asia - for the paper waste have been found already.[138]

Still, the waste trade can be affected by other bans or regulations imposed by countries. Prices can drop and remain volatile, negatively affecting the collection and recycling of paper as lower prices would no longer cover the costs of collection and processing in quality grades.[139]

In addition, the relative environmental impacts of the production of virgin materials compared to the secondary materials are not reflected in their market prices, which means that external costs are not incorporated into the price paid by producers.[140]

As a result, the current recycling of waste is dominated by downcycling, where the recycled material is of lower quality and functionality than the original material. Many materials are not being recycled into a quality that allows them to be recycled back into packaging.[141]

3.3.3 Recycling rates

According to the industry (EPRC and Cepi), Europe reached a 71.4% recycling rate of all paper and board consumed in Europe in 2021.[142] This is a decline from 73.3% recycling in 2020, which is a result of the fact that the collection of paper (+2%, to 57.1 million tonnes) did not cope with an

136 Katrakis, E. and J. Blees (2023, May 11), *Interview with Manon Stravens of Profundo*.

137 European Commission (2022, November 30), *Commission Staff Working Document. Impact Assessment Report. Accompanying the document Proposal for a Regulation of the European Parliament and the Council on packaging and packaging waste, amending Regulation (EU) 2019/1020, and repealing Directive 94/62/EC*, pp. 278-279.

138 Katrakis, E. and J. Blees (2023, May 11), *Interview with Manon Stravens of Profundo*.

139 Waste Management, (2023, May 23), "The volatile global recycling market ", online: https://www.wastemanagement.co.nz/news-and-media/volatile-recycling-market/, viewed in July 23.

140 European Commission (2022, November 30), *Commission Staff Working Document. Impact Assessment Report. Accompanying the document Proposal for a Regulation of the European Parliament and the Council on packaging and packaging waste, amending Regulation (EU) 2019/1020, and repealing Directive 94/62/EC*, p. 18.

141 Karlovits, I. (2023, April 26), *Interview with Manon Stravens of Profundo*.

142 European Paper Recycling Council (2022, September 5), *Monitoring Report 2021, European Declaration on Paper Recycling 2021-2030*, p. 2

increased consumption of paper and board (+4.8%, to 80 million tonnes) in that period. [143] Overall, the recycling rate increased by 2.8% since 2010.[144]

The recycling rate of general packaging waste is lower and only went up slightly from 63% in 2009 to 64% in 2020. Since 2016 this rate has been stable and has even fallen back to 2011 levels since then. The recovery rate, that includes recycling and energy recovery, rose from 76% in 2009 to 80% in 2020.[145] According to EuRIC, only 56% of the recovered paper is used for new paper production.[146] However, large and assumably growing shares of the recovered waste are incinerated or landfilled.[147]

It is, however, unclear what exactly is meant with the recycling rate as defined by Cepi, and what is actually recycled. Cepi defines the recycling rate as *"the ratio between the recycling of used paper, including net trade of Paper for Recycling (PfR), and paper and board consumption"*. This does, however, not mean that all collected and recovered material is recycled into new products, let alone used for the production of new paper.[148]

Furthermore, "Paper for Recycling" is defined as *"Used paper and board separately collected and in general recovered, meaning cleaned, sorted, and baled, according to the European Standard List of Grades of Paper and Board for Recycling (EN 643)."*[149] While the terms suggests that this volume of collected paper will all be used for recycling, it actually means the volume that is incorporated in the paper mill to produce new paper (not for direct food contact materials). However, an unknown percentage will still be rejected.[150] As Cepi states: *"Paper for recycling is composed of fibres but also unusable materials–- non-paper components as well as paper and board detrimental to production. The share of unusable materials depends on the actual sorting and collection of used paper. It varies according to grades of paper for recycling and countries. The volume of recycled fibres actually used to produce new paper is therefore lower than the volume of paper for recycling considered."*[151]

Other studies note that a consistent calculation methodology is lacking in the EU, and that data collected by countries is not accurate which poses a challenge.

---

143 European Paper Recycling Council (2022, September 5), *Monitoring Report 2021, European Declaration on Paper Recycling 2021-2030*, p. 3.

144 Confederation of European Paper Industries (2022), *Key Statistics 2021, European Pulp & Paper Industry*, p. 5.

145 Ragonnaud, G. (2023, March), *Revision of the Packaging and Packaging Waste Directive*, European Parliamentary Research Service (EPRS) Members' Research Service PE 745.707, p. 2.

146 EuRIC (n.d.), "What we recycle. Paper", online: https://euric-aisbl.eu/what-we-recycle/paper, viewed in May 2023.

147 European Commission (2022, November 30), *Commission Staff Working Document. Impact Assessment Report. Accompanying the document Proposal for a Regulation of the European Parliament and the Council on packaging and packaging waste, amending Regulation (EU) 2019/1020, and repealing Directive 94/62/EC*, p. 3.

148 Katrakis, E. and J. Blees (2023, May 11), *Interview with Manon Stravens of Profundo.*

149 European Paper Recycling Council (2022, June 21), *European Declaration on Paper recycling 2021-2030*, p. 11.

150 Katrakis, E. and J. Blees (2023, May 11), *Interview with Manon Stravens of Profundo*.

151 Confederation of European Paper Industries (2022), *Key Statistics 2021, European Pulp & Paper Industry*, p. 22.

The recycling rate reported by the industry is supposed to be *"independently verified by Deloitte"*, however, no further information was found on this audit. The authors asked Cepi for the report but no response has been received by the time of writing.[152]

3.3.4 Use of recycled content

Of the global production of 412 million tonnes of paper and board in 2019, 202 million tonnes (49%) were exclusively produced with virgin fibres, while almost 211 million tonnes (51%) were produced using recovered fibres. In 2020, according to industry statistics, the rate remained more or less the same, i.e., 208 million tonnes recovered fibre out of 399 million tonnes of global production, i.e., 52%.[153] No information was found on the trends of recycled fibre supply.

Of the volume produced using a proportion of recovered fibres, approximately 86% were packaging materials. The use of recycled content in some categories of paper and board has been increasing over the years, as is shown by UN Comtrade data. For example, a large part of the paper and board supply is made up of Testliner and Kraftliner paper. Testliner is made of 100% recycled paper, Kraftliner consists of virgin paper. In the EU, the share of Testliner increased from 13% to 20% between 2011 and 2021. Kraftliner, made of virgin materials, decreased from 20% to 16%.[154]

While the portion of recycled content may be high in corrugated cardboard, this is negligible for beverage cartons. No information was found about other paper-based packaging formats. Many materials are not being recycled to a quality that allows them to be recycled back into packaging, as is explained in section 3.3.2. This is also a result of lack of information on the quality and availability of recyclates, which presents a risk for producers.[155]

3.3.5 Exports of (contaminated) paper waste

A significant portion of the paper waste that is collected for recycling in Europe, i.e., 12.4%, will be exported. Paper waste is the second largest waste stream shipped to non-European countries, after ferrous materials. This amounted to 4.4 million tonnes in 2021 or 13% of the EU's waste exports.[156]

The bulk of exports (almost 77%, 2021) goes to Asia. China used to be the first destination, until the country posed a ban on waste imports in 2018 as it wanted to reduce dependency on secondary raw materials originating from third countries. India was the major destination of paper waste, receiving 1.2 million tonnes (26%), followed by Indonesia (0.9 million tonnes or 22%) and Turkey (0.4 million tonnes or 10%). Other countries, such as Vietnam and Thailand, have increased imports of European

---

152 European Paper Recycling Council (2022, September 5), *Monitoring Report 2021, European Declaration on Paper Recycling 2021-2030*, p. 2

153 Bureau of International Recycling (2023), *Annual Report 2022*, p. 23.

154 UN Comtrade (n.d.), "Paper and Cardboard Trade 2011-2021", retrieved May 2023

155 European Commission (2022, November 30), *Commission Staff Working Document. Impact Assessment Report. Accompanying the document Proposal for a Regulation of the European Parliament and the Council on packaging and packaging waste, amending Regulation (EU) 2019/1020, and repealing Directive 94/62/EC*, pp. 17-18.

156 Eurostat (2022, May 25), "What are the main destinations of EU export of waste?", online: https://ec.europa.eu/eurostat/en/web/products-eurostat-news/-/ddn-20220525-1, viewed in June 2023.

Paper for Recycling (PfR), too, but overall net exports of PfR outside Europe have diminished by -24.7% compared to 2020.[157]

The majority of exported paper for recycling is assumed to be sent to the recycling industries in those countries. India produces new paper products, including printing, newsprint, and packaging papers.[158] Also Indonesia and Turkey use the recovered paper imports for their recycling industries.[159] In Turkey only recyclers, and not collectors, are allowed to import recovered paper for recycling.[160]

At the same time, the percentages of rejected paper waste of these streams are unknown. A recent study estimated that the level of contamination of exported paper bales (with for example plastic) ranges from 5-30%.[161] Due to toxic chemicals in plastic used as additives in paper, this contaminated paper can have severe impacts on the environment and human health in communities where this waste is discarded. For example, in 2022 an investigation on paper bales exported to India showed that the contamination with plastics had significant consequences for human health and the environment.[162]

As a result, importing countries increasingly impose stricter regulations on paper waste imports. For example, Indonesia recently imposed stricter controls on imported waste paper to limit the level of contamination. Also India tightened regulations to limit the contamination of mixed paper to a maximum of 1%.[163] In addition, the EU tightened waste shipments through its revised proposal of the EU Waste Shipment Regulation, noting that, apart from the economic value created, *"Waste shipped across borders can generate risks for human health and the environment, especially when not*

---

157 European Paper Recycling Council (2022, September 5), *Monitoring Report 2021, European Declaration on Paper Recycling 2021-2030*, p. 3.

158 Singh Khadka, N. (2019, March 12), "Why India is a world leader in waste paper", BBC World, online: https://www.bbc.com/news/world-asia-india-46641059, viewed in June 2023.

159 Romas, M., S. Martini (2021, April), *Recycling paper industry: Analysis of raw material consumption in Indonesia*, IOP Conference Series. Earth and Environmental Science; Bristol Vol. 733, Iss. 1;

Waste Management World (2019, October 25), "Turkey to Take Europe's Surplus Recovered Paper Fibre for Recycling?", online: https://waste-management-world.com/artikel/turkey-to-take-europe-s-surplus-recovered-paper-fibre-for-recycling/, viewed in June 2023.

160 Waste Management World (2019, October 25), "Turkey to Take Europe's Surplus Recovered Paper Fibre for Recycling?", online: https://waste-management-world.com/artikel/turkey-to-take-europe-s-surplus-recovered-paper-fibre-for-recycling/, viewed in June 2023.

161 Karlsson, T., J. Dell, S. Gündoğdu, and B. C. Almroth (2023, March), *Plastic Waste Trade. The hidden Numbers*, International Pollutants Elimination Network (IPEN), p. 5-8.

162 Karlsson, T., J. Dell, S. Gündoğdu, and B. C. Almroth (2023, March), *Plastic Waste Trade. The hidden Numbers*, International Pollutants Elimination Network (IPEN), p. 5-8.

163 Pyzyk, K. (2020, January 15), "India to enforce 1% contamination rate on paper imports, conduct random inspections", online: https://www.wastedive.com/news/india-enforce-contamination-rate-inspections-paper-imports/570427/, viewed in June 2023.

properly controlled."[164] The proposal entails stricter controls and prohibition of exports of certain hazardous wastes, in order to better protect the environment and human health.[165]

164 European Commission (2021, November 17), *Proposal for a Regulation of the European Parliament and of the Council on shipments of waste and amending Regulations (EU) No 1257/2013 and (EU) No 2020/1056*, p. 2.

165 European Commission (2021, November 17), *Proposal for a Regulation of the European Parliament and of the Council on shipments of waste and amending Regulations (EU) No 1257/2013 and (EU) No 2020/1056*, p. 3.

4

Chemical safety in paper-based packaging for food and beverages

Numerous chemicals and chemical additives are used to produce pulp and paper and to make it suitable for food packaging, including various substances of high concern. Despite some scientific efforts and recognised risks related to presence of substances including PFAS, bisphenols and phthalates, little is known about the potential hazards that all intentionally and unintentionally added chemicals may pose to human health and the environment. Meanwhile, specific legislation on food contact materials from paper and paperboards is still lacking at the EU level.

4.1 Introduction

Approximately 37% of all food packaging materials is made from paper and board of which circa 20% accounts for FCMs.[166] As plain paper packaging is insufficient to contain food and beverage products (due to poor barrier properties, low heat sealability and strength), paper and paperboard are always combined with chemical additives, coated or laminated with aluminium or plastic to improve the packaging properties. These may interact with the packed food and may have adverse human health implications.[167]

Additives to the papermaking process can be categorised into embedded and not embedded chemicals. Embedded chemicals are processing chemicals, added directly to the pulp, or applied as a coating during the final treatment of the product. Other, or not-embedded, chemicals can be used during processing and as functional additives without being embedded in the product.[168]

166 Peters, R. et all (2019, March), "Review of analytical approaches for the identification of non-intentionally added substances in paper and board food contact materials ", Trends in Food Science & Technology. Volume 85, March 2019, Pages 44-54. Trends in Food Science & Technology Review.

167 Geueke, B. (2016), "Paper and board food packaging", online: https://www.foodpackagingforum.org/food-packaging-health/food-packaging-materials/paper-and-board, Food packaging Forum, viewed in May 2023.

168 Confederation of European Paper Industries (2021, January), *Pulp and Paper Industry. Definitions and Concepts*, p. 8.

Another categorisation is chemicals being added intentionally or non-intentionally. Intentionally added substances (IAS) are the additives or production aids for a specific purpose during the manufacturing process. Non-intentionally added substances (NIAS) include impurities, degraded and residue products, which may have been generated during manufacturing or use, as a result of contamination or are introduced through the recycling process.[169]

In recent years, various studies have revealed that certain food packaging materials (called food contact materials, or FCMs) can cause chemical contamination of food when migration of their chemical constituents occurs. Some of these so-called food contact chemicals (FCCs) are known to be hazardous for both human health and the environment. **The impact of chronic chemical exposure during a human being's entire life, even if at very low levels, has been associated with the rising prevalence of several chronic diseases**.[170] Scientists from around the world working on developmental biology, endocrinology, epidemiology, toxicology, and environmental and public health, are concerned that **public health is insufficiently protected from harmful exposures to FCCs**.[171]

A complete overview of chemicals used in the paper and paperboard production processes is not available, and often the exact chemical composition within food packaging materials is not even known by the manufacturers themselves.[172] According to a researcher at the Food Packaging Forum Foundation, which analyses the use and impacts of chemicals in food packaging,[173] there are different explanations for this data scarcity: *"The information [from companies] is often confidential. The companies add chemicals to create special products and so they don't tell downstream users which chemicals they used. It could also be that there's so many players in the supply chain delivering to the converter, that they don't even have contact with. So, they don't know what was added when."*[174]

Moreover, as the packaging material consists of a wide variety of complex mixtures, in particular paper composites, it is currently impossible to identify and conduct toxicity testing for all single substances. Many IAS and NIAS therefore have inadequate or no toxicological data. It is also difficult, or even impossible, to detect all NIAS in finished products, as non-targeted analyses are not

---

169 Rosenmai, A. K. et all (2017, August), "An effect-directed strategy for characterizing emerging chemicals in food contact materials made from paper and board", *Food and Chemical Toxicology, Volume 106*, Part A, pages 250-259.

170 Geueke, B. et all (2022), "Systematic evidence on migrating and extractable food contact chemicals: Most chemicals detected in food contact materials are not listed for use", *Critical reviews in Food Science and Nutrition*, p. 1.

171 Muncke, J. et all. (2020). "Impacts of food contact chemicals on human health: a consensus statement", *Environmental Health,* vol. 19, 25.

172 Geueke, B. et all (2022), "Systematic evidence on migrating and extractable food contact chemicals: Most chemicals detected in food contact materials are not listed for use", *Critical reviews in Food Science and Nutrition*, p. 1.

173 European Commission (2020), Chemicals Strategy for Sustainability https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2020%3A667%3AFIN , and Zimmerman, L. et all (2022, May 14), "Implementing the EU Chemicals Strategy for Sustainability: The case of food contact chemicals of concern", Journal of Hazardous Materials, volume 437, 5 September 2022, 129167.

174 Boucher, J. (2023, April 27), *Interview with Manon Stravens of Profundo.*

comprehensive enough. As only the most prominent NIAS are regularly identified and measured only for well-known chemical processes, the majority of these substances remain unassessed.[175]

4.2 EU Chemicals Strategy for Sustainability and regulation of chemicals in paper-based packaging

Manufacturers of packaging materials must comply with good manufacturing practices and follow national as well as international legislation to ensure that the environment and consumer health is not compromised after intake of food impacted by migrating chemicals. As global chemicals production is expected to double by 2030[176], the EU has the clear ambition to reduce the use of hazardous chemicals, including in FCMs. This is laid down in the EU's Chemicals Strategy for Sustainability (CSS, 2020)[177] and in its Farm to Fork (F2F) strategy (2020).[178]

The CSS acknowledges that *"certain chemicals cause cancers, affect the immune, respiratory, endocrine, reproductive and cardiovascular systems, weaken human resilience and capacity to respond to vaccines, and increase vulnerability to diseases."* Apart from the risk for human health proven by human biomonitoring studies that have detected a growing number of different hazardous chemicals in human blood and body tissue[179], the CSS also mentions the risk of chemical pollution contributing to *"climate change, degradation of ecosystems and loss of biodiversity."*[180] **Consumer products (including FCMs) should therefore not contain the most harmful chemicals**, which the CSS defines as chemicals *"that cause cancers, gene mutations, affect the reproductive or the endocrine system, or are persistent and bioaccumulative."*[181]

Other chemicals, such as substances that affect the immune, neurological, or respiratory system and chemicals toxic to a specific organ might be included in the CSS. The CSS further mentions ambitions to introduce persistent, mobile, and toxic (PMT), as well as very persistent, very mobile (vPvM) substances (i.e., chemicals with persistence- and mobility-related hazards) as categories of

---

175 Geueke, B. et all (2022), "Systematic evidence on migrating and extractable food contact chemicals: Most chemicals detected in food contact materials are not listed for use", *Critical reviews in Food Science and Nutrition*, p. 1.

176 European Commission (n.d.), "Chemicals strategy. The EU's chemicals strategy for sustainability towards a toxic-free environment", online: https://environment.ec.europa.eu/strategy/chemicals-strategy_en, viewed in May 2023.

177 European Commission (n.d.), "Chemicals strategy. The EU's chemicals strategy for sustainability towards a toxic-free environment", online: https://environment.ec.europa.eu/strategy/chemicals-strategy_en, viewed in May 2023.

178 European Commission (n.d.), "Farm to Fork strategy. for a fair, healthy and environmentally-friendly food system", online: https://food.ec.europa.eu/horizontal-topics/farm-fork-strategy_en, viewed in May 2023.

179 European Commission (2020, October 14), *Communication from the Commission to the European Parliament, the Council, The European Economic and Social Committee of the Regions. Chemicals Strategy for Sustainability. Towards a Toxic-Free Environment*, p. 2.

180 European Commission (2020, October 14), *Communication from the Commission to the European Parliament, the Council, The European Economic and Social Committee of the Regions. Chemicals Strategy for Sustainability. Towards a Toxic-Free Environment*, p. 1.

181 European Commission (2020, October 14), *Communication from the Commission to the European Parliament, the Council, The European Economic and Social Committee of the Regions. Chemicals Strategy for Sustainability. Towards a Toxic-Free Environment*, p. 10.

substances of very high concern (SVHCs).[182] SVHCs are substances with hazard properties that may have serious and often irreversible effects on human health and the environment, requiring control, and as a consequence, should be phased-out and replaced by alternatives (ECHA, 2018).[183]

It must be noted that the CSS is a strategy and does not therefore set any legal requirements. Chemicals in food packaging are regulated in the *Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)* legislation (*EC 1907/2006*) as well as the *Food Contact Material Framework Regulation (EU 1935/2004)*. However, both regulations are not well aligned and planned revisions, which should address new packaging trends, face ongoing delays.[184]

Furthermore, where specific and harmonised regulation does exist for ceramics, plastics, including recycled plastics, among some other materials, it does not for paper and board. This is despite the fact that paper and board are the second most used type of FCMs in Europe, second only to plastics.[185]

Member States can adopt their own national measures and so far, only a few have such rules in place. According to the EU Impact Assessment (2022)[186], Belgium and the Netherlands, for example, have set a total migration limit for regulated substances found in recycled paper and board fibres. Czech Republic, Germany, France, and Slovakia have set restrictions for the total dry residue in hot and/or cold-water extracts for paper and fibres. Only Italy requires producers to declare compliance with migration levels from paper/board fibres. In addition, previous research has shown that only a fraction of the substances covered by these measures are actually regulated.[187] In short, a *"patchwork' of different national schemes for risk assessment, chemicals safety, compliance documentation and regulatory approaches exist"*, as stated by a recent study done by Zero Waste Europe.[188]

---

182 European Commission (2020, October 14), *Communication from the Commission to the European Parliament, the Council, The European Economic and Social Committee of the Regions. Chemicals Strategy for Sustainability. Towards a Toxic-Free Environment*, p. 13.

183 Zimmerman, L. et all (2022, May 14), "Implementing the EU Chemicals Strategy for Sustainability: The case of food contact chemicals of concern", *Journal of Hazardous Materials,* volume 437, 5 September 2022, 129167, p. 2.

184 Zero waste Europe (2023, July), *Food packaging: safety first. Towards toxic-free and future-proof packaging. Policy Briefing*, p. 3.

185 Zero waste Europe (2023, July), *Food packaging: safety first. Towards toxic-free and future-proof packaging. Policy Briefing*, p. 10.

186 European Commission (2022, November 30), *Commission Staff Working Document. Impact Assessment Report. Accompanying the document Proposal for a Regulation of the European Parliament and the Council on packaging and packaging waste, amending Regulation (EU) 2019/1020, and repealing Directive 94/62/EC*, p. 339.

187 BEUC (2019, July 18), *More than a paper tiger. European consumer organisations call for action on paper and board food contact materials*, p. 1.

188 Zero waste Europe (2023, July), *Food packaging: safety first. Towards toxic-free and future-proof packaging. Policy Briefing*, p. 10.

4.3 Chemicals used in paper and board food and beverage packaging

In the absence of a complete overview of chemicals used in the food and beverage packaging industry, there have been several scientific efforts to understand the universe of (hazardous) chemicals in food packaging. For example, a 2021 study on intentionally used food contact chemicals and their hazards compiled a database of 12,285 chemical substances that could possibly be used worldwide to make food packaging materials. This list, the so-called Food Contact Chemicals Database (FCCdb), is compiled based on 67 lists of FCCs from publicly available sources, including regulatory lists and industry inventories.[189] The report notes, however, that it needs to be confirmed whether all of the chemicals are still in use.

Including NIAS, up to 100,000 chemicals may be present in FCMs and migrate into food and beverage during processing, transport, storage, and food preparation.[190]

The researchers identified the chemical hazards of the identified chemicals in the FCCdb, based on different hazard classifications aligned with the Globally Harmonized System for classification and labelling of chemicals (GHS). However, the report also notes that authoritative hazard data are missing for the majority of FCCdb substances and that for over a quarter of all FCCdb chemicals no hazard information could be found.[191]

Based on the data available, **608 hazardous chemicals were identified to be *"the most urgent candidates to be further evaluated and targeted by substitution efforts"***. The study further mentions that an additional 1,411 substances in the database could present similar levels of concern but have not been officially classified so far. **Out of the 608 chemicals of concern, 256 (42%) are used in the paper and board (and similar cellulosic materials) food packaging industry, of which 39 uniquely used for paper and board**.[192]

Out of the 256 prioritised chemical substances used in the paper industry, 50 (20%) are listed on the EU Candidate list of Substances of Very High Concern (SVHC) for Authorisation, maintained under the EU REACH regulation.These include Bisphenol A, several phthalates including DBP and DiBP, and heavy metals such as cadmium, mercury, and lead.[193] The criteria for a SVHC are described in REACH article 57.

---

189 Food packaging Forum Foundation (n.d.), "Food contact chemicals database (FCCDB)", online: https://www.foodpackagingforum.org/fccdb, viewed in April 2023.

190 Zimmerman, L. et all (2022, May 14), "Implementing the EU Chemicals Strategy for Sustainability: The case of food contact chemicals of concern", *Journal of Hazardous Materials*. Volume 437, 5 September 2022, 129167, p. 2.

191 Ksenia J. Groh, B. Geueke, O. Martin, M. Maffini, and J. Muncke (2021), "Overview of intentionally used food contact chemicals and their hazards", *Environment International*. Volume 150, May 2021, 106225, p. 12.

192 Ksenia J. Groh, B. Geueke, O. Martin, M. Maffini, and J. Muncke (2021), "Overview of intentionally used food contact chemicals and their hazards", *Environment International*. Volume 150, May 2021, 106225, p. 6.

193 European Chemicals Agency (n.d.), "REACH Legislation", online: https://echa.europa.eu/regulations/reach/legislation, viewed in April 2023.

Moreover, out of the 256 chemicals used in paper and board, 118 (46%) are mentioned on the internationally recognised Substitute It Now (SIN) List, established by the NGO ChemSec, that identified these chemicals as having hazardous properties, based on the criteria defined under REACH.[194] The criteria describe the three categories of chemicals:[195]

- Carcinogenic, Mutagenic, or Toxic to reproduction (CMRs): chemicals that can cause cancer, alter DNA or damage reproductive systems;
- Persistent, Bioaccumulative and Toxic (PBTs): harmful substances that do not easily break down and accumulate in the food chain;
- Endocrine-Disrupting Chemicals (EDCs): substances that may interfere with the hormone system.

Table 3 gives an overview of the number and some examples of chemicals used in paper and board identified having specific hazardous properties, according to the FCCdb. The table also shows how many of the chemicals are mentioned at least 10 times (by different sources). Some chemicals are mentioned by many different sources according to the database, such as Formaldehyde (38), Styrene (36), and Ammonia (33).

194 ChemSec (n.d.), "What is the SIN List?", online: https://sinlist.chemsec.org/what-is-the-sin-list/, viewed in April 2023.

195 ChemSec (n.d.), "The SIN List is based on the EU REACH criteria", online: https://sinlist.chemsec.org/what-is-the-sin-list/the-sin-list-is-based-on-the-eu-reach-criteria/, viewed in April 2023.

Table 3 Numbers of chemicals of concern used in paper and board

Hazard	No. of chemicals	No. of chemicals mentioned at least 10 times	Including
HH	121	51	Formaldehyde, DBP, DiBP, Styrene, Silicon dioxide, Acrylonitrile
ENVH	117	46	Ammonia, Benzyl butyl phthalate, Zinc Oxide, Chlorine
HH + ENVH	25	6	Benzyl butyl phthalate, Dibutyltin dilaurate, DiPB, Chlorine dioxide, Thiram, 4,''-Diaminobiphenyl methane
CMR	0	0	-
EDCs	14	10	DBP, DiBP, DEHP, Bisphenol A
PBTs	7	0	Lead, Cadmium, Mercury

Chemicals are classified as having health hazards (HH) and/or environmental hazards (ENVH) . Source: Food Contact Chemicals database, 2020.

The study concluded that *"[…] also **paper and board FCMs appear to be a significant source of hazardous substances**, even when printing inks are not considered."*[196]

The printing inks include the highest number of identified hazardous substances (377), while many of those inks remain unassessed. **Apart from printing inks, paper-based food contact articles (FCAs) can also contain coatings and adhesives, both characterised by a high diversity of potentially hazardous food contact chemicals and little oversight to ensure their safe use**. The study states: *"This lack of transparency with regard to hazardous chemicals used in paper-based FCAs is of concern, especially considering the current trend towards increasing the use of paper-based products as alternative to single-use plastics, and the common use of recycled paper materials in direct contact with food in countries where this practice is not banned."*[197]

Peer-reviewed studies provide growing scientific evidence on the **presence of per- and polyfluoroalkyl substances (PFASs)** in food packaging,[198] including in twenty-five paper and board packaging materials,[199] and in moulded "compostable" fibre bowls, paper sandwich and burger wrappers.[200] A recent European wide investigation showed that PFAS are present in disposable food packaging and tableware used by popular fast-food chains and takeaway restaurants across Europe. All 42 analysed items had measurable levels of PFAS chemicals, and the highest PFAS

196 Ksenia J. Groh, B. Geueke, O. Martin, M. Maffini, and J. Muncke (2021), "Overview of intentionally used food contact chemicals and their hazards", *Environment International Volume*. 150, May 2021, 106225, p. 12.

197 Ksenia J. Groh, B. Geueke, O. Martin, M. Maffini, and J. Muncke (2021), "Overview of intentionally used food contact chemicals and their hazards", *Environment International Volume.* 150, May 2021, 106225, p. 12.

198 Sapozhnikova, Y., Taylor, R. B., Bedi, M., & Ng, C. (2023). "Assessing per- and polyfluoroalkyl substances in globally sourced food packaging". Chemosphere, 337, 139381.

199 Zabaleta I. et al. (2020); " Occurrence of per- and polyfluorinated compounds in paper and board packaging materials and migration to food simulants and foodstuffs". Food Chemistry. Volume 321, 15 August 2020, 126746

200 Schwartz-Narbonne, H. et al. (2023). "Per- and Polyfluoroalkyl Substances in Canadian Fast Food Packaging". Environmental Science & Technology Letters, 10(4), 343–349.

concentrations were consistently found in moulded fibre products, (e.g. bowls, plates, and food boxes), advertised as biodegradable or compostable disposable products.[201]

The researchers state that regulatory concerns regarding FCC so far have focused on a small group of chemicals with well-studied and described hazards, such as phthalates and bisphenols. Some of these substances have already been addressed by specific regulations (e.g., restriction of phthalates; EU, 2018) and/or have been substituted by alternatives (whereas these substitutes could be equally harmful, which is the case with for example bisphenol A substituted by similar bisphenols).[202]

Scientists emphasise that less attention is given to many more chemicals with well-described hazardous properties. Again, as there is no science-based overview of these so-called "food contact chemicals of concern" (FCCoCs) that may be used in the production of FCMs or FCAs, the researchers compiled a FCCoC-database which makes a clear link with the EU's CSS. The researchers define this group of chemicals as the *"FCCs with hazard properties defined by the CSS as "most harmful" (CMR chemicals, EDCs, chemicals with persistence-bioaccumulation-related hazards), "further harmful" (chemicals with specific target organ toxicity (STOT)) as well as chemicals mentioned to be introduced as SVHCs (chemicals with persistence mobility-related hazards)."*[203] Other hazardous properties are given, including very persistent and very bioaccumulative (vPvB), Persistent Organic Pollutants (POP), and Persistence-Mobility-related hazards (PMT).

Based on the earlier mentioned Food Contact Chemicals database (FCCdb), this study identified 388 intentionally used chemicals that are most harmful according to the EU's CSS. **Paper and boards rank third with 168 chemicals**, behind printing inks (238) and plastics (197). The majority of FCCoCs are used in more than one FCM type. For example, 84 of the chemicals are not only used in paper and boards, but also in plastics and printing inks.

Table 4 gives an overview of the total number of 168 FCCoC and their known hazards, that may be used in paper and board packaging. Given one or more of their identified hazard properties, these chemicals should not be present in FCMs, according to the CSS.[204]

---

201 Straková, J., Schneider, J., Cingotti, N. et al. (2021). "Throwaway Packaging, Forever Chemicals: European wide survey of PFAS in disposable food packaging and tableware". 54p (https://chemtrust.org/wp-content/uploads/PFASreport_FCM_May2021.pdf)

202 Zimmerman, L. et all (2022, May 14), "Implementing the EU Chemicals Strategy for Sustainability: The case of food contact chemicals of concern", *Journal of Hazardous Materials*. Volume 437, 5 September 2022, 129167, p. 2.

203 Zimmerman, L. et all (2022, May 14), "Implementing the EU Chemicals Strategy for Sustainability: The case of food contact chemicals of concern", *Journal of Hazardous Materials*. Volume 437, 5 September 2022, 129167, p. 2.

204 Boucher, J. (2023, April 27), *Interview with Manon Stravens of Profundo.*

Table 4 Food Contact Chemicals of Concern

	CMRs	EDCs	STOT hazards	PBT, vPvB, POP	PMT	Total number of chemicals
Paper and board	156	14	1	6	4	168
Total	**352**	**22**	**3**	**32**	**8**	**388**

Source: FCCoC databas e; Zimmerman, L. et al. (2022, May 14), "Implementing the EU Chemicals Strategy for Sustainability: The case of food contact chemicals of concern", *Journal of Hazardous Materials*. Volume 437: 129167.

Out of these 168 chemicals, 45 are classified for their CMR properties and known to have migrated into food.[205] The list of these chemicals can be found in Appendix 3.

As of October 2021, 70 of all the FCCoCs were registered under REACH in the EU, and 253 were included in the US EPA HPV list with an overlap of 50 chemicals being both REACH registered and on the EPA HPV list.[206]

Lastly, the chemical safety of paper straws is increasingly being brought into question. Paper straws are often used as a single use alternative to plastic straws now restricted under the single use plastics directive. Several studies have identified CMRs in paper-based drinking straws. In a test of 12 straws in Switzerland multiple straws contained chloropropanols, mineral oil hydrocarbons or photoinitiators.[207] Consumer NGO BEUC tested 76 samples of printed paper or board food packaging, such as coffee cups, paper straws, printed napkins and grocery products again showing high levels of carcinogens such as primary aromatic amines and UV filters.[208] Most recently, a study of 39 brands of straws found the highest concentration of PFAS in plant based (paper or bamboo) straws.[209] Although straws are not usually considered to be packaging products the example illustrates the safety risks of simply substituting one single use material for another.

4.4 Migration of chemicals into food

Chemical migration into food is the contamination of packaged foods with the chemicals or chemical compounds that are present in the packaging material. Such migration depends on

[205] FCCoC databas e; Zimmerman, L. et al. (2022, May 14), "Implementing the EU Chemicals Strategy for Sustainability: The case of food contact chemicals of concern", Journal of Hazardous Materials. Volume 437: 129167.

[206] Zimmerman, L. et all (2022, May 14), "Implementing the EU Chemicals Strategy for Sustainability: The case of food contact chemicals of concern", *Journal of Hazardous Materials. Volume 437*, 5 September 2022, 129167, p. 3.

[207] Food Packaging Forum Foundation (2019, July 30) "Contaimination found in paper straws", online: https://www.foodpackagingforum.org/news/contamination-found-in-paper-straws (viewed August 2023)

[208] BEUC (2019, July 25) "The EU needs rules on chemicals in coffee cups, straws and other paper food packaging, consumer test shows" online: https://www.beuc.eu/press-releases/eu-needs-rules-chemicals-coffee-cups-straws-and-other-paper-food-packaging-consumer (viewed August 2023)

[209] Boisacq et al. (2023) "Assessment of poly- and perfluoroalkyl substances (PFAS) in commercially available drinking straws using targeted and suspect screening approaches", Food Additives & Contaminants: Part A, DOI: 10.1080/19440049.2023.2240908

different factors including food type, temperature, contact time, storage time, surface-volume ratio, as well as the concentration of a chemical substance present.[210]

So-called "off-set migration" means that the printed, outside layer of a food packaging can transfer chemicals to the inside, direct food contact layer when both layers are in direct contact with each other. **Paper and board are porous materials, which cannot easily resist the migration of chemical compounds.[211] Substances such as printing inks can even migrate through the paper or board into the foodstuffs**.[212] Off-set migration occurs when for example beverage carton sheets are stored in rolls, or when paper cups are stacked into each other. Barrier materials used in paper and board packaging, such as aluminium foil or plastics with barrier properties, can reduce food contamination significantly. [213]

In general, contamination of food with chemicals migrating from food packaging is an under-investigated area of food safety. Nevertheless, several studies have found clear evidence of such contamination. For example, in a 2022 study, **migrating chemicals from common paper-based food packaging materials including pizza boxes, pizza box liners, butcher paper and egg** containers were analysed and **153 chemicals were identified, including chemicals of toxicological concern such as Bisphenol A**.[214] A 2023 review compiled available knowledge regarding the migration into real food of **PFAS from paper based FCMs**, and concluded that PFAS exclusively migrated from FCMs **can considerably contribute to consumers' dietary exposure potentially impacting human health**.[215]

Recent study established a database on migrating and extractable FCCs, the so-called FCCmigex, referring to it as a *"[…] unique, first-of-its-kind evidence base of empirical data on FCCs in all types of FCMs and FCAs"*.[216]

---

210 Geueke, B. et all (2022), "Systematic evidence on migrating and extractable food contact chemicals: Most chemicals detected in food contact materials are not listed for use", *Critical reviews in Food Science and Nutrition*, p. 7.

211 Muncke, J. (2013, April 22), "Migration", Food Packaging Forum, online: https://www.foodpackagingforum.org/food-packaging-health/migration, viewed in April 2023.

212 Peters, R. et all (2019, March), "Review of analytical approaches for the identification of non-intentionally added substances in paper and board food contact materials ", Trends in Food Science & Technology. Volume 85, March 2019, Pages 44-54. Trends in Food Science & Technology Review.

213 Muncke, J. (2013, April 22), "Migration", Food Packaging Forum, online: https://www.foodpackagingforum.org/food-packaging-health/migration, viewed in April 2023.

214 Sapozhnikova, Y. and A. Nuñez (2022, August 2), "Non-targeted analysis with liquid chromatography - high resolution mass spectrometry for the identification of food packaging migrants", *Journal of Chromatography A*, Volume 1676, 2 August 2022, 463215, Journal of Chromatography.

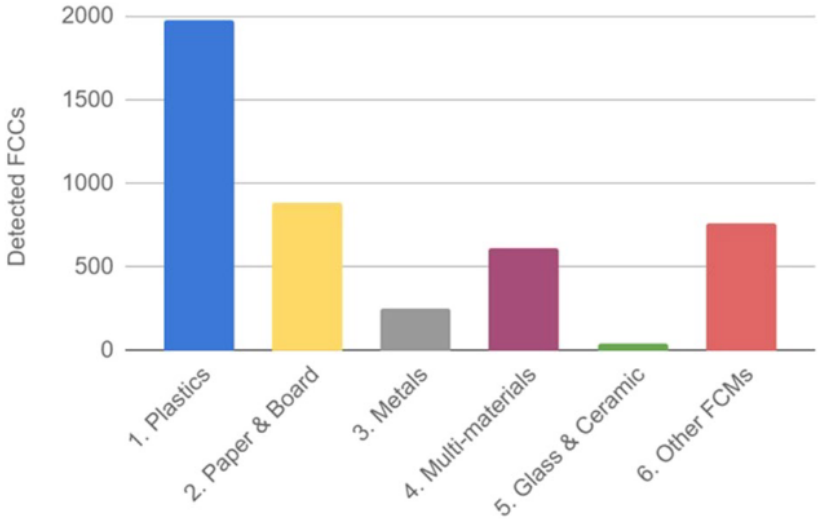
215 Lurch, M., Fengler, R., Mbog, G., Nguyen, K.H., and Granby, K. (2023). "Food simulants and real food – What do we know about the migration of PFAS from paper based food contact materials?" Food Packaging and Shelf Life. 35, 100992

216 Geueke, B. et all (2022), "Systematic evidence on migrating and extractable food contact chemicals: Most chemicals detected in food contact materials are not listed for use", *Critical reviews in Food Science and Nutrition*, p. 1;

Food Packaging Forum, "FCCmigex", online: https://www.foodpackagingforum.org/fccmigex, viewed in April 2023.

This study found more than 4,000 FCCs in at least one experiment, having evidence of detection in food. Of those, **more than two thirds were identified in plastic FCMs, followed by paper and board with a count of 887 FCCs**.[217] The most frequently detected FCCs in paper and board were MOSH and MOAH, both complex mixtures of hydrocarbons that cannot be resolved into individual substances, according to the study. But they have frequently proven to have migration potential.[218] Figure 5 shows the absolute number of FCCs found in the different packaging groups. Figure 6 provides more details, showing the types of FCCs found in the different FCM groups, including paper and board.

Figure 5 **Absolute number of FCCs found in different FCM groups**

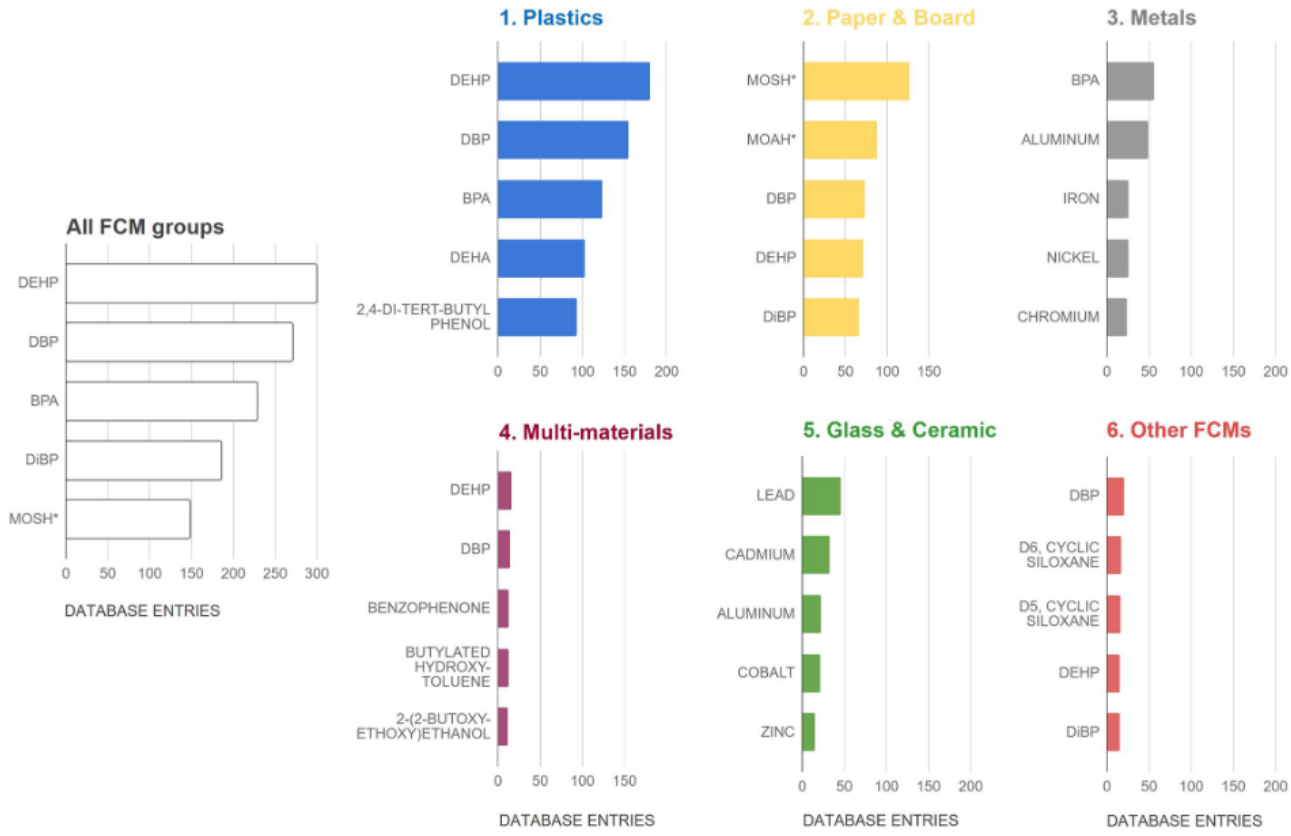


Sourc e: Geueke, B. et al. (2022), "Systematic evidence on migrating and extractable food contact chemicals: Most chemicals detected in food contact materials are not listed for use", *Critical Reviews in Food Science and Nutrition*, p. 6.

217 Geueke, B. et all (2022), "Systematic evidence on migrating and extractable food contact chemicals: Most chemicals detected in food contact materials are not listed for use", *Critical reviews in Food Science and Nutrition*, p. 5.

218 Geueke, B. et all (2022), "Systematic evidence on migrating and extractable food contact chemicals: Most chemicals detected in food contact materials are not listed for use", *Critical reviews in Food Science and Nutrition*, p. 6.

Figure 6 Top-5 most frequently detected FCCs detected in different FCM groups



Note: Abbreviations: BPA, bisphenol A; DBP, dibutyl phthalate; DEHA, diethylhexyl adipate; DEHP, diethylhexyl phthalate; DiBP, diisobutyl phthalate; MOAH, mineral oil aromatic hydrocarbons; MOSH, mineral oil saturated hydrocarbons; D5, decamethylcyclopentasiloxane; D6, dodecamethylcyclohexasiloxane. *MOSH and MOAH were included due to their high relevance despite being chemical mixtures and not individual FCCs.

Source: Geueke, B. et al. (2022), "Systematic evidence on migrating and extractable food contact chemicals: Most chemicals detected in food contact materials are not listed for use", *Critical Reviews in Food Science and Nutrition*, p. 7.

An extract from the recently updated FCCmigex database shows that for paper and board, there were 119 studies that detected some chemicals to have migrated into food or food simulants (Figure 7).[219] **In total, 525 chemicals were detected for paper and board, known to have migrated into food or food simulants**. **Out of these, 70 chemicals (13%) were found in recycled paper**.[220]

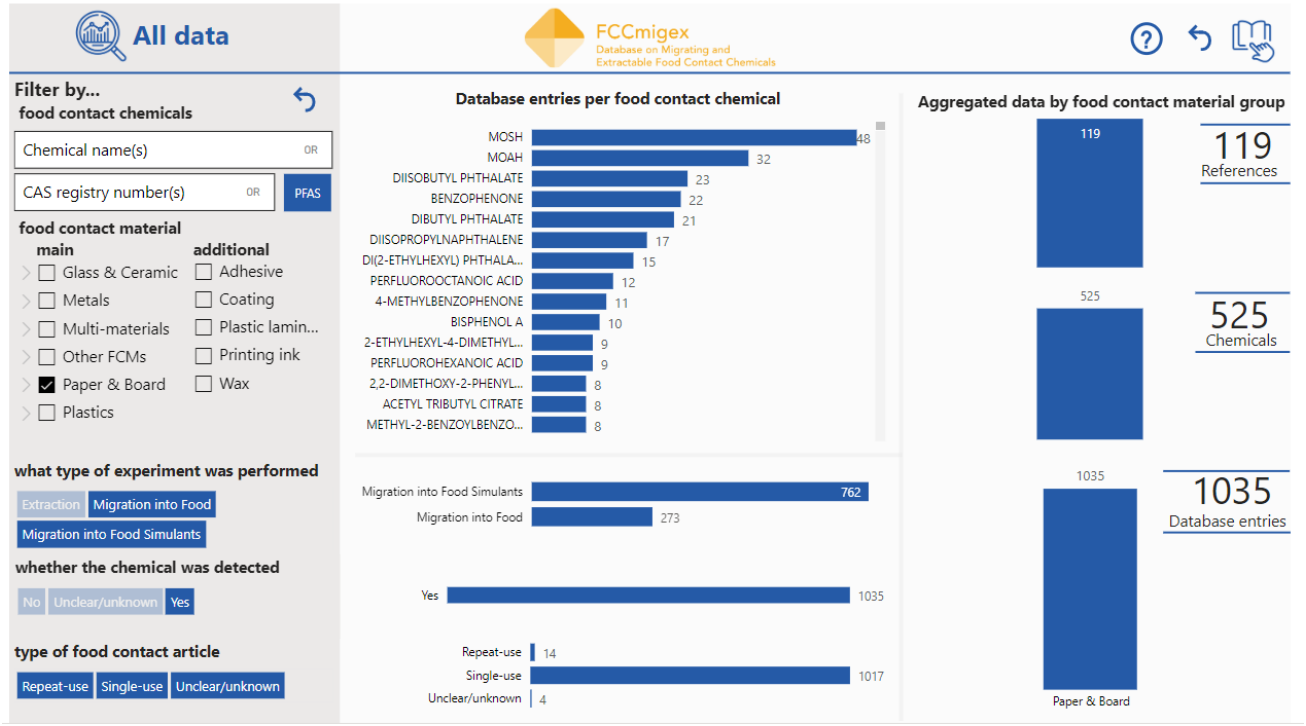
The database also shows that compared to 824 studies on plastics, only 254 studies were done on paper. As stated by a representative of the Food Packaging Forum Foundation: *"This means that the database is a snapshot, and depends on what scientists have worked on. Fewer references and fewer*

219 Boucher, J. (2023, April 27), *Interview with Manon Stravens of Profundo.*

220 Boucher, J. (2023, April 27), *Interview with Manon Stravens of Profundo.*

chemicals only mean that the scientists have focused more on plastics. There could be more on paper. This could be a bias of the research community."[221]

Figure 7 Extract of FCCmigex on migrating chemicals in paper and board



Source: FCCmigex, viewed 28 April 2023.

221 Boucher, J. (2023, April 27), *Interview with Manon Stravens of Profundo.*

Examples of chemicals of concern detected in different paper-based food packaging

Molded fiber takeaway boxes

Study concludes that per- and polyfluoroalkyl substances are clearly present in food packaging on the UK market with a widespread use among product types,included in packaging such as bakery bags, pizza boxes, takeaway bags, and molded fiber takeaway boxes. (FIDRA,2020)

The testing revealed products containing PFAS present in 8 of 9 major UK supermarkets and in all of the takeaway restaurants tested. 18 of the 20 tested samples had fluorine concentrations higher than background levels. The highest PFAS content was consistently found in molded fiber takeaway boxes.

Source: Boucher, J. (2020, February 13), "Study measures PFAS in UK food packaging", Food Packaging Forum Foundation, online: https://www.foodpackagingforum.org/news/study-measures-pfas-in-uk-food-packaging, viewed in September 2023).

Pizza boxes

Fluorocarbons, mineral oils, phthalates, bisphenol A, and nonylphenol were detected in three different, randomly selected pizza boxes, as tested by the Danish Consumer Council THINK in 2015. All three boxes contained fluorocarbons in amounts exceeding the guiding limit value set by the Danish Minister of the Environment. These chemicals, assumed to originate from recycled content, are known or suspected to be endocrine disruptors or cancer-causing. Migration into the pizza's was not tested.

Source: Stieger, G. (2015, October 20), "Chemicals of concern in pizza boxes. Danish Consumer Council THINK Chemicals tests pizza boxes and finds fluorocarbons and other chemicals of concern in all samples", Food Packaging Forum Foundation, online: https://www.foodpackagingforum.org/news/chemicals-of-concern-in-pizza-boxes, viewed in June 2023).

Coffee-to-go cups

Diisodecyl phthalate (a plasticizer) was measured in one coffee to go cup, and a mix of hydrocarbons was measured in two other coffee cups, in a test of the inner plastic coating of coffee to go cups by a German journalist. Samples of cups were collected from McDonald's, Tchibo, Starbucks, von Allwörden, and an unspecified canteen. These chemicals can migrate into hot and fatty drinks such as coffee with milk. None of the cups exceeded the legal migration limit, but according to experts from the Food Packaging Forum, the detected long-chain hydrocarbons could accumulate in body fat.

Source: Stieger, G. (2017, May 24), "Chemicals in coatings of coffee to go cups", Food Packaging Forum, online: https://www.foodpackagingforum.org/news/chemicals-in-coatings-of-coffee-to-go-cups, viewed in June 2023.

Microwave popcorn bags

PFAS chemicals have been detected by a global network of interest groups in paper-based microwave popcorn bags, manufactured by the US to be exported to Indonesia. PFAS are a group of thousands of related chemicals, often used as water- and grease-resistant additives in many products. PFAS persist in the environment and are a potential threat to our health. All of the 29 microwave popcorn samples contained one or more PFAS chemicals.

Source: Ipen, Nexus3 Foundation, and Tox-free future (2023, March), *Toxic Hazards in Microwave Popcorn. PFAS in Popcorn Exported from the U.S. to Indonesia Poses Health Threats to Consumers.*

4.5 Impact of chemicals in paper-based food packaging on human health

Like plastics, paper and board FCMs are complex materials that can contain hundreds of different chemical substances (both intentionally and non-intentionally added). The fact that potentially hundreds of them are hazardous chemicals which may migrate into food, has a direct impact on human exposure and general public health. **Exposure to these chemicals is linked to a wide range of health disorders — some of which are serious and irreversible**. Certain chemicals contribute to cancer, infertility, obesity, cause chronic diseases and immunosuppression, among others. Diet, including via food contact materials, is a major source of exposure to hazardous chemicals in Europe.[222]

Europe's largest ever screening programme for toxic chemicals has found significant parts of the population exposed to multiple hazardous substances above levels that could cause serious illnesses.[223] **The Europeans were found to be polluted with the most harmful chemical groups, including those frequently present in paper-based food packaging: 'forever chemicals' PFAS, phthalates and bisphenols**. For many substances, action seems to be long overdue.[224] All young people tested were found polluted with PFAS, with over 14% of teenagers showing levels that exceed safe levels set by the European Food Safety Agency. 17% of European children and adolescents were found at risk from exposure to a mixture of reprotoxic phthalates. The EFSA's latest opinion highlights the alarming fact that dietary exposure to BPA poses a health concern for EU consumers of all ages.

European legislation addressing chemical safety for food contact materials, assessment of which points to many gaps, inconsistencies and a need for a thorough revision,[225] is lacking specific rules and requirements for paper and board packaging. The widespread use of and contamination by PFAS in disposable paper food packaging we are dealing with now, proves that the current system allows dangerous chemicals to "slip through the cracks". That means that - if not improved - regulatory control over all future alternatives, such new innovative functional barriers and coatings being used by manufacturers of paper for food applications, may easily be overlooked from their safety point of view.

While little is known about the environmental effects of disposable paper-based packaging in terms of their chemical leachates, a recent study showed that **single-use take-away cups of paper can be as toxic to aquatic organisms as plastic cups**.[226]

Considering all above, we can conclude that in terms of chemical safety - **disposable paper and board food packaging are not necessarily safer than single-use plastics, and their growing use poses increased risks to human and environmental health**.

---

[222] https://www.eea.europa.eu/publications/zero-pollution/health/chemicals

[223] https://eeb.org/european-citizens-alarmingly-high-chemical-exposure/

[224] April 2022 HBM4EU Newspaper European Human Biomonitoring Initiative." www.hbm4eu.eu/wp-content/uploads/2022/05/HBM4EU-Newspaper.pdf.

[225] COMMISSION STAFF WORKING DOCUMENT Evaluation of the legislation on food contact materials - Regulation (EC) No 1935/2004- SWD(2022)163

[226] Carney Almroth, B. et al. (2023). "Single-use take-away cups of paper are as toxic to aquatic midge larvae as plastic cups". Environmental Pollution, Volume 330, 121836

5

Environmental and social impacts

The major environmental impacts of pulp and paper-based food and beverage packaging are related to energy, water and wood consumption, waste generation, toxic emissions, and loss of biodiversity. The sector is considered to be a major contributor to climate change, forest loss and pollution, as is shown in five selected origin countries.

5.1 Introduction

Despite technological innovations and improved energy management and recycling, the pulp and paper industry remains a major consumer of natural resources, energy, and water. In addition, waste and wastewater generation, toxic emissions, and loss of biodiversity due to forest loss have important environmental impacts as well.[227] Table 5 provides an overview of the use of water, wood, energy and emitted greenhouse gases per tonne of a range of paper and board materials used in paper-based food and beverage packaging.

Table 5 Environmental impacts of paper-based food packaging products (per tonne)

Type of Paper and Board	End use in food packaging	Water use (litre)	Wood use (Mt)	Energy Use (GJ)	Forest disturbance (ha)	GHG (Mt)
Solid Bleached Sulfate	Food packaging for perishables and some frozen foods; cartons for products such as baked goods, ice cream, milk and juice; candy.	125,676	4.17	34,8	0.20	9,52
Coated Unbleached Kraft	Beverage carriers for beer and soft drinks, some packaging for frozen foods.	99,935	4.08	33,8	0.24	9,21

227 Schönheit, E. (2012, November), „Papier. Wald und Klima Schützen“, Forum Ökologie & Papier (FÖP), p. 13;

Suhr, M. et all (2015), “Best Available Techniques (BAT). Reference Document for the Production of Pulp, Paper and Board. Industrial Emissions Directive 2010/75/EU (Integrated Pollution Prevention and Control), European Commission, JRC Science and Policy Reports, p.24;

Interview Evelyn Schönheit, d.d. 26 April 2023

Coated Recycled Board	Packaging for dry foods such as cereal, pasta, rice, cookies, crackers. Made with 100% recycled fibre and coated.	41,640	0	20,0	0	1,71
Liner Board	Butcher paper, kraft wrapping paper, multi-wall sacks.	73,816	4.08	33,6	0.36	9,16
Corrugated Container	Shipping boxes, pizza boxes.	73,058	3.99	30,5	0.32	8,48

Source: Environmental Paper Network (n.d.), "Paper Calculator. Version 4.0.", online: https://c.environmentalpaper.org/, viewed in June 2023.

- **Water consumption**

The pulp and paper industry is the world's third largest consumer of water.[228] Of the total papermaking process, the pulping process is the most water intensive.[229] It is however very difficult to get detailed data about water use or water footprints in the pulp and paper sector, as estimates per unit of wood, pulp or paper differ. According to the European industry, water intake has been 3,407 million m^3 in 2020, of which almost 90% is composed of surface water. Water intake has seen a slight reduction in the 1990s, but remained more or less stable since 2000, though the industry does not provide detailed statistics.[230]

The production of one kilo of virgin paper requires on average 50 litres of water, or 50,000 litres per tonne.[231] According to a recent WWF Germany-report, on average, 10 litres of water are needed to make one A4 sheet of paper. The same report states that in some countries, paper production accounts for more than 10% of all freshwater consumption.[232] According to the Paper Calculator, developed by Environmental Paper Network (Table 5), the water intake differs per paper and product used for food and beverage packaging. For example, more than 125,000 litres of water are needed to produce one tonne of solid bleached sulfate paper and board, used to produce among others food packaging for perishables and some frozen foods and cartons for products such as baked goods, ice cream, milk, and juice. Almost 100,000 litres are required to produce one tonne of coated unbleached kraft, used for, for example, beverage carriers for beer and soft drinks and some frozen

228 International Energy Agency (2022, September.), "Pulp and Paper. Tracking Report, September 2022", online: https://www.iea.org/reports/pulp-and-paper, viewed in April 2023.

229 Schönheit, E. (2012, November), „Papier. Wald und Klima Schützen", Forum Ökologie & Papier (FÖP), p. 13.

230 Confederation of European Paper Industries (2022), *Key Statistics 2021, European Pulp & Paper Industry*, p. 28.

231 Wellenreuther, F., A. Detzel, M. Krüger, M. Busch (2022, November), *Updated Life-cycle Assessment of Graphic and Tissue Paper. Background Report*, German Environment Agency.

232 Beck-O'Brien, M., V. Egenolf, S. Winter, J. Zahnen, N. Griesshammer, N. (2022). *Everything from wood – The resource of the future or the next crisis? How footprints, benchmarks and targets can support a balanced bioeconomy transition.* WWF Germany, p. 77.

foods packaging. And around 73,000 litres of water are needed to produce one tonne of corrugated container (used for shipping, but pizza boxes as well).[233]

- **Energy consumption**

The pulp and paper industry is the world's fifth largest consumer of energy for their manufacturing process.[234] The energy required for paper production is comparable to that of other energy-intensive products, such as cement or steel.[235]

Of the total papermaking process, the pulping process (detaching the individual fibres from the wood) is the most energy intensive.[236] The drying process, in which large amounts of water are being evaporated, accounts for about 70% of energy used for pulp and papermaking.[237]

The global pulp and paper industry still uses fossil fuels as an important energy source. European industry figures show that the share of fossil fuels (gas, fuel oil, coal, and other fossil fuels) in the total energy mix has remained quite stable since 2015, i.e., from 35% in 2015 to 33% in 2020. The use of biomass, owing to the use of pulp by-products such as black liquor, has increased with only 3% from 50% in 2015 to 53.7% in 2020.[238]

The International Energy Agency (IEA) states that the pulp and paper sector is 'not on track', and it notes that the sector needs to shift away from fossil fuels towards the use of near zero-emission alternatives. The agency further notes that energy efficiency of the sector has been *"roughly flat"*, and that: *"Little recent progress has been made in this area, as the share of energy provided by fossil fuels has remained at about 30% since 2018."*[239]

---

233 Environmental Paper Network (n.d.), "Paper Calculator. Version 4.0.", online: https://c.environmentalpaper.org/, viewed in June 2023.

234 International Energy Agency (2022, September.), "Pulp and Paper. Tracking Report, September 2022", online: https://www.iea.org/reports/pulp-and-paper, viewed in April 2023.

235 Suhr, M. et all (2015), "Best Available Techniques (BAT). Reference Document for the Production of Pulp, Paper and Board. Industrial Emissions Directive 2010/75/EU (Integrated Pollution Prevention and Control), European Commission, JRC Science and Policy Reports, p.28.

236 Schönheit, E. (2012, November), „Papier. Wald und Klima Schützen", Forum Ökologie & Papier (FÖP), p. 13.

237 International Energy Agency (2022, September.), "Pulp and Paper. Tracking Report, September 2022", online: https://www.iea.org/reports/pulp-and-paper, viewed in April 2023.

238 Confederation of European Paper Industries (2022), *Key Statistics 2021, European Pulp & Paper Industry*, p. 26

239 International Energy Agency (2022, September.), "Pulp and Paper. Tracking Report, September 2022", online: https://www.iea.org/reports/pulp-and-paper, viewed in April 2023.

- **Carbon emissions**

Key sources of direct emissions are forest management practices, including the use of diesel in harvesting and in timber transportations to pulp mills, but also road construction, as well as the production and use of fertilizer and pesticides in tree plantations, and the energy used in the mills and energy plants. Indirect emissions are caused by purchased electricity.[240]

While the industry aims to promote the use of wood as a key natural and renewable resource for paper manufacturing, and therefore considered CO_2-neutral by the industry, there have been serious objections against this assumption.[241] For example, the conversion of primary forests into reforested commercial forests releases CO_2 and also reduces the ability in the long term for forests to capture CO_2. It is however difficult to measure the CO_2 emissions as a result of forest loss. In addition, the CO_2 storage capacity of a forest depends on factors such as climate zone, forest type, tree species, as well as what grows back on the deforested area.[242]

According to the European industry, it has an annual direct emission of about 28.17 million tonnes in 2021, compared to 39.05 million tonnes in 2010, which is a 25.5% decrease. Despite that decrease, emissions of the sector are still considered 'historically high', according to the IEA. The IEA calculated that the global pulp and paper sector was responsible for about 190 million tonnes of CO_2 emissions in 2021, which is about 2% of all emissions from industry.[243]

Compared to other packaging materials, paper and board comes second to plastic packaging, which is the most carbon intensive material (1.8 tonnes of CO_2e emitted for the lifecycle of one tonne of plastic packaging). Paper/board have emissions of 809 kg CO_2e per tonne, followed by glass having 565 kg CO_2e per tonne, respectively.[244] It is obvious that there is a difference when products are used multiple or a single time. As paper production is projected to increase, its environmental footprint is also expected to increase as the sector not only heavily relies on fossil fuels as an energy source, but it is in urgent need of energy efficiency improvements (which render renewable energy sources ineffective as inefficiency contributes to resource depletion, leading to a greater environmental footprint).[245]

---

240 Suhr, M. et all (2015), "Best Available Techniques (BAT). Reference Document for the Production of Pulp, Paper and Board. Industrial Emissions Directive 2010/75/EU (Integrated Pollution Prevention and Control), European Commission, JRC Science and Policy Reports, p.29.

241 Suhr, M. et all (2015), "Best Available Techniques (BAT). Reference Document for the Production of Pulp, Paper and Board. Industrial Emissions Directive 2010/75/EU (Integrated Pollution Prevention and Control), European Commission, JRC Science and Policy Reports, p.28.

242 Schönheit, E. (2012, November), „Papier. Wald und Klima Schützen", Forum Ökologie & Papier (FÖP), p. 18-19;

Interview Evelyn Schönheit, d.d. 26 April 2023.

243 International Energy Agency (2022, September.), "Pulp and Paper. Tracking Report, September 2022", online: https://www.iea.org/reports/pulp-and-paper, viewed in April 2023.

244 European Commission (2022, November 30), Commission Staff Working Document. Impact Assessment Report. Accompanying the document Proposal for a Regulation of the European Parliament and the Council on packaging and packaging waste, amending Regulation (EU) 2019/1020, and repealing Directive 94/62/EC", p. 6.

245 International Energy Agency (2022, September.), "Pulp and Paper. Tracking Report, September 2022", online: https://www.iea.org/reports/pulp-and-paper, viewed in April 2023.

- **Wood use and forest disturbance**

As one of the world's largest industrial sectors, the pulp and paper industry has a great impact on global forests and forest biodiversity. According to WWF, the sector accounts for 13–15% of total wood consumption and uses between 33–40% of all industrial wood traded globally.[246]

Around 90% of the paper pulp is currently made of wood, and as such, paper production is responsible for about 35% of clear-felled trees.[247] Around 3 billion trees are used annually to meet global demand for paper packaging.[248]

Unsustainable pulp and paper operations such as the use of fire to clear natural forests have contributed to conversion of high conservation value forests, illegal harvesting, and devastating plantation development in among others Southeast Asia and the Amazon. Natural forest clearance to produce pulpwood have been one of the main drivers of deforestation in Sumatra and Borneo in Southeast Asia.[249]

Deforestation, degradation and fragmentation of forests due to the above mentioned practices are devastating biodiversity at great levels and are the biggest drivers of species loss. An estimated 25% of species in animal and plant groups are threatened with extinction. [250]

As the global paper and paperboard consumption is expected to nearly double between 2010 and 2050, this would have a significant impact on total wood demands and consequently the levels of biodiversity.[251]

Section 5.2 refers to deforestation among other environmental and social impacts in a number of selected countries.

---

246 WWF (n.d.), "Pulp and paper", online: https://www.worldwildlife.org/industries/pulp-and-paper, viewed in June 2023.

247 Bandara, R., G.M. Indunil (2022, July 1), "Food packaging from recycled papers: chemical, physical, optical properties and heavy metal migration", *Heliyon 8* (2022), p. 1.

248 The Grocer (2023, July 3), "Is paper really better for the Earth than plastic?", online: https://www.thegrocer.co.uk/sustainability-and-environment/is-paper-packaging-really-more-sustainable-than-plastic/680773.article, viewed in July 2023.

249 Pacheco, P., Mo, K., Dudley, N., Shapiro, A., Aguilar-Amuchastegui, N., Ling, P.Y., Anderson, C. and Marx, A. (2021), *Deforestation fronts: Drivers and responses in a changing world*, WWF, Gland, Switzerland, p. 118, 120.

250 Beck-O'Brien, M., V. Egenolf, S. Winter, J. Zahnen, N. Griesshammer, N. (2022). *Everything from wood – The resource of the future or the next crisis? How footprints, benchmarks and targets can support a balanced bioeconomy transition*, WWF Germany, p. 21.

251 Beck-O'Brien, M., V. Egenolf, S. Winter, J. Zahnen, N. Griesshammer, N. (2022). *Everything from wood – The resource of the future or the next crisis? How footprints, benchmarks and targets can support a balanced bioeconomy transition*, WWF Germany, p. 74.

5.2 Environmental and social impacts in selected countries

This section gives brief (and non-exhaustive) overviews of environmental and social issues in a selected number of pulp origin countries and includes references to key literature.

5.2.1 Brazil

Brazil is the biggest supplier of pulp to Europe (Figure 1 in section 2.2.1). In the last two decades the country's industry has tripled its pulp production capacity, from 6.7 to 21.5 million tons per year. The eucalyptus or pine plantation area has expanded to 7.2 million hectares by 2018 (more than twice the area of Belgium). Eucalyptus plantation development has been heavily encouraged by local authorities through fiscal and legal incentives, including the exemption from conducting Environmental Impact Assessments.[252]

With nearly a million hectares of eucalyptus plantations and two processing plants, Três Lagoas and the surrounding municipalities in the eastern part of Mato Grosso do Sul in the Cerrado biome are at the heart of Brazilian industrial pulp production and expansion. Four additional plants are planned, which will double the production capacity in the area.[253]

Environmental impacts

Key environmental impacts highlighted in recent studies are:

- Water tables have been seriously reduced as a result of the loss of native Cerrado vegetation. This has already been the result of decades of cattle range expansion but is further exacerbated by eucalyptus plantations draining the soil. Rivers have dried up and disappeared. According to Brazilian scientists this may result in a nationwide critical water shortage, impacting country's hydropower energy supply and agricultural production.[254]
- Eucalyptus plantations fuel fires by creating a drier environment. According to Global Forest Watch data fire outbreaks often coincide with plantation areas. The Brazilian Environmental Military Police has reported an increase of casualties related to fires and eucalyptus plantation expansion and monocultures.[255]

---

252 Environmental Paper Network (2022, December), *Scorching the earth. Pulp and paper expansion in Três Lagoas, Brazil. Summary Report*, # Conflict Plantations 4, p. 3;

Centro de Agricultura Alternativa Vicente Nica (2022, July 19), *Environmental Safeguards. An analysis of the impacts of eucalyptus monoculture on waters and rural communities. Summary*, p. 1.

253 Environmental Paper Network (2022, December), *Scorching the earth. Pulp and paper expansion in Três Lagoas, Brazil. Summary Report*, # Conflict Plantations 4, p. 3.

254 Environmental Paper Network (2022, December), *Scorching the earth. The impacts of pulp and paper expansion in the Três Lagoas region – Brazil*, #Conflict Plantations 4.

255 Environmental Paper Network (2022, December), *Scorching the earth. The impacts of pulp and paper expansion in the Três Lagoas region – Brazil*, #Conflict Plantations 4.

- The use of agrochemicals, pesticides, and herbicides in eucalyptus plantations, often air sprayed in Brazil (a prohibited practice in the European Union) to promote tree growth and eliminate weeds and insects have poisoned land and water, and decimated wildlife and biodiversity. Out of the 27 pesticides, 21 have been detected in Brazilian water. Those are banned in the EU due to the health and environmental risks they pose.[256]
- Cerrado species are threatened with extinction: 903 species were included in the National Red Lists of Brazil (266 species of fauna and 637 species of flora), among which are the jaguar, armadillo, tapir, giant anteater, and the maned wolf.[257]

Social impacts

Key social impacts highlighted in recent studies are:

- Eucalyptus monoculture and accompanying privatization of lands expropriated family farmers in the Cerrado. They have lost a large part of their common water and lands, which were essential to their livelihoods.[258]
- The drying up of the natural water sources decreased the water sources and increased water insecurity for communities surrounding eucalyptus plantations. Farmers stopped or reduced farming.[259]
- Significant numbers of pesticides found in the tests are classified as 'probable carcinogen' by the United States Environmental Protection Agency, are causing endocrine dysfunction according to the European Union.[260]

More details about the environmental and social impacts of the pulp and paper industry in Brazil can be found in the following sources:

- Environmental Paper Network (2022, December), *Scorching the Earth. The Impacts of Pulp and Paper Expansion in the Três Lagoas Region – Brazil*, #Conflict Plantations 4;
- Centro de Agricultura Alternativa Vicente Nica (2022, July 19), *Environmental Safeguards. An Analysis of the Impacts of Eucalyptus Monoculture on Waters and Rural Communities. Summary*.

---

256 Environmental Paper Network (2022, December), *Scorching the earth. The impacts of pulp and paper expansion in the Três Lagoas region – Brazil*, #Conflict Plantations 4;

Centro de Agricultura Alternativa Vicente Nica (2022, July 19), *Environmental Safeguards. An analysis of the impacts of eucalyptus monoculture on waters and rural communities. Summary*, p. 10, 11.

257 Environmental Paper Network (2022, December), *Scorching the earth. The impacts of pulp and paper expansion in the Três Lagoas region – Brazil*, #Conflict Plantations 4.

258 Centro de Agricultura Alternativa Vicente Nica (2022, July 19), *Environmental Safeguards. An analysis of the impacts of eucalyptus monoculture on waters and rural communities. Summary*, p. 6.

259 Centro de Agricultura Alternativa Vicente Nica (2022, July 19), *Environmental Safeguards. An analysis of the impacts of eucalyptus monoculture on waters and rural communities. Summary*, p. 8, 9.

260 Environmental Paper Network (2022, December), *Scorching the earth. The impacts of pulp and paper expansion in the Três Lagoas region – Brazil*, #Conflict Plantations 4.

5.2.2 Chile

Chile is the fourth non-European suppliers of pulp to Europe, after Brazil, Uruguay and the United States (Figure 1). Decades of policies of deregulation and privatisation, started by the Pinochet regime in the 1970s, have led to a huge expansion of plantations. Pulp and paper companies were enabled by the military junta to take land and to convert these into timber plantations with large subsidies. Pine and eucalyptus plantations have been actively promoted by law and so-called 'forest subsidies' and continue to be promoted.[261]

Environmental impacts

Key environmental impacts highlighted in recent studies are:

- Deforestation and natural forest loss has been a result of expanding pine and eucalyptus plantations in Chile.[262]
- Depletion of water supplies has contributed to drought and forest fires. The most recent fires, having started at the end of January 2023 across the south of the country, destroyed more than 430,000 hectares and killed at least 24 people.[263]

Social impacts

Key social impacts highlighted in recent studies are:

- The Indigenous Mapuche people, Chile's largest Indigenous group, in southern central Chile have lost large areas of land being appropriated and converted into pine and eucalyptus monocultures to feed the pulp and paper industry over the past 50 years. Pulp and paper companies did not consult nor paid compensation to the affected Indigenous communities residing in the area. Instead, these peoples were forcibly removed from their land.[264]
- Conflicts, violence, and criminalisation of communities wanting to have their ancestral lands back. This resulted in a declaration of the state of emergency in May 2022, as the conflict in the southern areas intensified.[265]
- Forestry industry's expansion increased poverty and inequality among both Indigenous and non-Indigenous population.[266]

More details about the environmental and social impacts of the pulp and paper industry in Chile can be found in the following sources:

---

261 Environmental Paper Network (2023, April), *Unwrapping a disaster. The human cost of overpackaging*, p. 16, 17.

262 Uribe, S.V., C.F. Estades , V.C. Radeloff (2020, March 13), *Pine plantations and five decades of land use change in central Chile*, PLoS ONE 15(3): e0230193, p.1.

263 Environmental Paper Network (2023, April), *Unwrapping a disaster. The human cost of overpackaging*, p. 17.

264 Environmental Paper Network (2023, April), *Unwrapping a disaster. The human cost of overpackaging*, p. 16.

265 Environmental Paper Network (2023, April), *Unwrapping a disaster. The human cost of overpackaging*, p. 16.

266 Hofflinger, A., Nahuelpan, H., Boso, À. et al (2021, October). *Do Large-Scale Forestry Companies Generate Prosperity in Indigenous Communities? The Socioeconomic Impacts of Tree Plantations in Southern Chile*. Hum Ecol 49, 619–630 (2021), p. 1.

- Environmental Paper Network (2022, May), *Conflict Plantations. Chapter 3: Stolen Land and Fading Forests in Chile;*
- Environmental Paper Network (2023, April), *Unwrapping a Disaster. The Human Cost of Overpackaging*;
- Uribe, S.V., C.F. Estades , V.C. Radeloff (2020, March 13), "Pine plantations and five decades of land use change in central Chile", *pLoS ONE*, 15(3);
- Hofflinger, A., Nahuelpan, H., Boso, À. et al (2021, October), "Do large-scale forestry companies generate prosperity in Indigenous communities? The socioeconomic impacts of tree plantations in Southern Chile*", Human Ecology*, 49, 619–630 (2021).

5.2.3 Finland

Finland is the EU's fourth largest pulp supplier (Figure 1 in section 2.2.1) and the third largest supplier of paper and board for packaging (Figure 2 in section 2.2.2). Finland's forests are of great importance to its economy and culture. In 2021, cardboard and paper were the forest industry's most significant exports, accounting for 47% of the total value.

Environmental impacts

Key environmental impacts highlighted in recent studies are:

- Finland's forests have become a net emitter of carbon dioxide and are projected to further decrease carbon sink with the building of new production facilities by the Metsä Group, one of the three big players in the Finnish forest and paper industries.[267]
- Due to an increase in felling and a slowdown in tree growth, 76% of Finland's forest habitats, home to the majority of threatened species (31%), have reportedly been classified as threatened.[268]
- Over-logging is driving the loss of biodiversity in Finland. A 2018 report emphasises that *"increasing forest harvest level to the maximum economically sustainable harvest will harm biodiversity and non-timber ecosystem services"*. Forestry is considered as one of the major reasons for decreasing biodiversity, though not as rapid as before anymore.[269]

Social impacts

Key social impacts highlighted in recent studies are:

- The Finnish forestry sector is criticised for a lack of participation and a high concentration of power, despite communication efforts from local authorities and forest companies.[270]

More details about the environmental and social impacts of the pulp and paper industry in Finlandcan be found in the following sources:

---

267 Environmental Paper Network (2023, April), *Unwrapping a disaster. The human cost of overpackaging*, p. 11-12.

268 Greenpeace (2022, November), *Products of Nordic forest destruction end up on EU supermarket shelves*, p. 4.

269 Holz, J.R. (2023, February 22), *Threatened sustainability: extractivist tendencies in the forest-based bioeconomy in Finland*, Sustain Sci 18, 645–659 (2023), p. 653.

270 Holz, J.R. (2023, February 22), *Threatened sustainability: extractivist tendencies in the forest-based bioeconomy in Finland*, Sustain Sci 18, 645–659 (2023), p. 653.

- Environmental Paper Network (2023, April), *Unwrapping a Disaster. The Human Cost of Overpackaging*;
- Greenpeace (2022, November), *Products of Nordic Forest Destruction End Up on EU Supermarket Shelves*;
- Holz, J.R. (2023, February 22), "Threatened sustainability: extractivist tendencies in the forest-based bioeconomy in Finland", *Sustainability Science*, 18: 645–659.

5.2.4 Sweden

Sweden, almost 70% covered by forests (of which 10-15% are natural forests),[271] is the third largest pulp supplier (Figure 1) and the second largest supplier of paper and board to the EU (Figure 2). Sweden has a strong pulp and paper industry, known for its lobbying power in Brussels.[272] Due to the key role of forests in Sweden's economy, the industry has benefitted from electricity tax rebates as the industry consumes about half of all energy used in Swedish industry.[273]

Environmental impacts

Key environmental impacts highlighted in recent studies are:

- In 2017, the Swedish company Essity, Europe's largest (and the world's second largest) supplier of sanitary paper, was *"directly linked to the ongoing destruction of the critical forest landscapes in Sweden"*, thereby furthering endangering more than 1,300 red-listed species, according to a Greenpeace report.[274]
- Between 2015 and 2020, the number of red-listed species in Sweden has increased by 11%: 40% of these red-listed species depend on forests.[275]
- From 2001 to 2021, Sweden lost 5.17 million of hectares of tree cover, equivalent to a 19% decrease in tree cover since 2000.[276]

Social impacts

Key social impacts highlighted in recent studies are:

- The Greenpeace report mentioned under 'environmental impacts' also reported that the Indigenous Sámi people were affected by Essity, as their traditional lands and livelihoods were threatened by the clearcutting of old growth boreal forests for Essity's raw materials.[277]

---

271 Forest Europe (2020), *State of Europe's Forests*, p. 31;

Greenpeace (2022, November), *Products of Nordic forest destruction end up on EU supermarket shelves*, p. 3.

272 Environmental Paper Network (2023, April), *Unwrapping a disaster. The human cost of overpackaging*, p. 19-21.

273 Environmental Paper Network (2023, April), *Unwrapping a disaster. The human cost of overpackaging*, p. 19-21.

274 Environmental Paper Network (2023, April), *Unwrapping a disaster. The human cost of overpackaging*, p. 19-21.

275 Greenpeace (2022, November), *Products of Nordic forest destruction end up on EU supermarket shelves*, p. 2.

276 Global Forest Watch (n.d.), "Sweden", viewed in June 2023.

277 Environmental Paper Network (2023, April), *Unwrapping a disaster. The human cost of overpackaging*, p. 19-21.

- Another Greenpeace report (2022) stated that forestry practices in Sweden threaten the livelihood of Indigenous reindeer herders, as old-growth and natural forests provide shelter and food (i.e. ground and hanging lichens). As a result of clear-cutting forests, reindeer herding territories experienced a decrease in lichen by 70% since 1950. Hanging lichen has decreased by 51%;[278]
- High logging levels and poorer forest growth have decreased the country's net storage of carbon dioxide from 30 million tonnes to 25 million tonnes, *"complicating Sweden's ability to reach the EU's climate targets for the land use sector"*.[279]

More details about the environmental and social impacts of the pulp and paper industry in Sweden can be found in the following sources:

- Environmental Paper Network (2023, April), *Unwrapping a Disaster. The Human Cost of Overpackaging*;
- Greenpeace (2017), *How Europe's Tissue Giant is Wiping Away the Boreal;*
- Greenpeace (2022, November), *Products of Nordic Forest Destruction End Up on EU Supermarket Shelves*.

278 Greenpeace (2022, November), *Products of Nordic forest destruction end up on EU supermarket shelves*, p. 3.

279 Greenpeace (2022, November), *Products of Nordic forest destruction end up on EU supermarket shelves*, p. 3.

6

Policy impacts and recommendations

This study is intended to inform the proposed revision of the EU Packaging and Packaging Waste Regulation (PPWR), to mitigate identified sustainability impacts of paper-based packaging for food and beverages. This chapter presents main conclusions on the paper-based packaging trends, the use of hazardous chemicals, waste management as well as environmental and social impacts. Based on these conclusions, policy recommendations are proposed.

6.1 Background

The Packaging and Packaging Waste Directive (PPWD) requires Member States to prevent the production of packaging waste, limit the use of virgin materials, limit unnecessary packaging, promote reuse of packaging, recycling, and other ways to recover packaging waste. The Directive covers all packaging and all packaging waste, including glass, paper, wood, metals, and plastics.[280]

The 2018 amendment increased recycling targets for 2025 and 2030, introduced new calculation methods of recycling percentages and reporting rules. Targets for overall recycling for packaging are set at 65% in 2025 and 70% in 2030. For paper and board, the targets set are 75% (2025) and 85% (2030).[281]

In November 2022, the Commission published the proposal for the revision of the PPWD, as part of the European Green Deal and the Circular Economy Action Plan. The key objective is to tackle the uncontrolled growth of packaging waste and *"to ensure that all packaging is reusable or recyclable in an economically feasible way by 2030"*.[282]

280 European Commission (2022, November 30), *Proposal for a regulation of the European Parliament and of the Council on packaging and packaging waste, amending Regulation (EU) 2019/1020 and Directive (EU) 2019/904, and repealing Directive 94/62/EC*, p. 20.

281 European Commission (2022, November 30), *Proposal for a regulation of the European Parliament and of the Council on packaging and packaging waste, amending Regulation (EU) 2019/1020 and Directive (EU) 2019/904, and repealing Directive 94/62/EC*, p. 84 - 85.

282 European Commission (2022, November 30), *Proposal for a regulation of the European Parliament and of the Council on packaging and packaging waste, amending Regulation (EU) 2019/1020 and Directive (EU) 2019/904, and repealing Directive 94/62/EC*, p. 1.

It means a reinforcement of the essential requirements for packaging to ensure reuse and recycling, the use of recycled content, and to improve the requirement of enforceability. Measures are further tailored to tackle over-packaging and limit waste generation.[283]

The three main objectives of the revised PPWR are[284]:

- Reduce the generation of packaging waste;
- Promote a circular economy for packaging in a cost-efficient way; and
- Promote the uptake of recycled content in packaging.

Moreover, Recital (14) of the revised text clearly states that: *In line with the objectives of the Circular Economy Action Plan and the Chemicals Strategy for Sustainability, and* ***to ensure the sound management of chemicals throughout their life cycle and the transition to a toxic-free and circular economy****, and considering the relevance of packaging in everyday life,* ***it is necessary that this Regulation addresses impacts on human health and on the environment and on broader sustainability performance, including circularity, resulting from impacts of substances of concern on the whole life cycle of packaging****, from manufacture to use and end-of life, including, waste management*.[285]

Packaging waste should be reduced by 15% by 2040 per Member State per capita, compared to 2018. This would lead to an overall waste reduction in the EU of around 37%, compared to a scenario without changing the legislation.[286]

6.2 Main conclusions from the study

The following conclusions can be drawn from this study that are relevant for the Packaging and Packaging Waste Regulation proposal. The study shows that it is necessary to give more policy attention to paper as a packaging material. Not only because the consumption of paper-based packaging is a growing rapidly , but also because it is a very resource-intensive and wasteful industry, impacting people and the planet throughout the value chain.

283 Ragonnaud, G. (2023, March), *Revision of the Packaging and Packaging Waste Directive*, European Parliamentary Research Service (EPRS) Members' Research Service PE 745.707, p. 1.

284 European Commission (2022, November 30), *Proposal for a regulation of the European Parliament and of the Council on packaging and packaging waste, amending Regulation (EU) 2019/1020 and Directive (EU) 2019/904, and repealing Directive 94/62/EC*, p. 100.

285 European Commission (2022, November 30), Proposal for a regulation of the European Parliament and of the Council on packaging and packaging waste, amending Regulation (EU) 2019/1020 and Directive (EU) 2019/904, and repealing Directive 94/62/EC, p. 21.

286 European Commission (2022, November 30), *Proposal for a regulation of the European Parliament and of the Council on packaging and packaging waste, amending Regulation (EU) 2019/1020 and Directive (EU) 2019/904, and repealing Directive 94/62/EC*, p. 16.

Opaque industry. The pulp and paper industry is an opaque industry, as a result of which independent data availability is extremely limited. The food and beverage packaging sector is continuously developing new (paper) packaging products, with ever-changing end-use properties. Food and beverage packaging products become even more complex and multi-layered using other materials such as plastics and aluminium. This complicates recycling and increases the costs of managing waste.

Paper-based packaging for food and beverages is a rapidly growing segment. While the pulp and paper industry shows an overall declining trend in terms of output, production capacity, and consumption, the (food and beverage) packaging segment is showing growth and is expected to further increase. Approximately 37% of all food packaging materials is made from paper and board of which circa 20% accounts for FCMs (Food Contact Materials). Paper and board consumption is expected to double between 2010 and 2050, which is largely due to increased demand for paper-based packaging.

- This is driven by the growing popularity of paper-based packaging as a disposable replacement of plastics, which will outweigh the declining outputs of graphic, tissue and other paper segments than packaging;
- A segment with particularly high growth is that of paper-based multilayer multimaterial packaging (products that combine paper with plastics, aluminium or other materials). Germany, for example, is expected to see almost 32% growth of this segment by 2025; and
- Overall, the percentage of recycled content in paper-based packaging remains the same, and virgin resources, of which the majority is wood and just a minor percentage of other materials, still make up a considerable amount of the pulp and paper produced.

Paper accounts for the biggest share of packaging waste. Paper-based packaging has the largest share of the total packaging waste and is the second fastest growing waste stream after plastics. Paper is also the second biggest waste stream exported to non-European countries.

Recycling has its limitations. Whereas Europe has one of the highest official paper recycling rates of the world, recycling has serious limitations, especially for the food and beverage packaging sector.

- The recyclability of in particular paper composite packaging, a growing segment in the packaging industry, is very limited. These multilayered food packaging materials are often incinerated or sent to landfills. In theory, paper and board fibres can be recycled up to eight times. In reality, European paper fibres were used 3.5 times on average, compared to a global average of 2.5 times. The recycling of paper-based food and beverage packaging into new food and beverage packaging materials is very limited compared to, for example, glass and metal food packaging;
- Hazardous chemicals contaminate recycled content, not only limiting the possibilities to produce safe new food and beverage packaging products, but also polluting environment once recycled paper products reach end of life (e.g. via composting);
- The recycling industry has to cope with a packaging industry that continues to develop new, more complex, packaging products; and
- The growing on-the-go segment increases mixed waste streams, further complicating collecting and separating paper-based waste for recycling; and

- Stricter regulations imposed by the EU as well as paper waste importing countries, especially in Asia, intended to reduce health and environmental impacts, influence the price, the costs and may negatively influence incentives for the industry to recycle paper.

Hazardous chemicals in paper-based packaging pose risks to human health and the environment. Despite growing scientific evidence on chemical use in paper products, a comprehensive overview of chemicals and chemical additives used in paper food packaging on EU-level is still absent. Nevertheless, scientists do find strong evidence on hazardous chemicals being used and being present in paper and board food contact materials, as well as their migration from the packaging material into the packed food.

- Out of 608 chemicals of concern used in food packaging, 256 (42%) are used in the paper and board food packaging industry;
- Out of 388 Food Contact Chemicals of concern identified due to their hazard as most harmful by the EU Chemicals Strategy for Sustainability, 168 are used in paper and board food packaging. The majority of these (156) can cause cancer, alter DNA or damage human reproductive systems, and 14 chemicals can disturb the hormone system. Out of these 168 chemicals, 45 are known to migrate into food;
- In total, 525 of migrating chemicals were detected for paper and board, out of which 70 chemicals (13%) were found in recycled paper;
- Europe's largest ever screening programme for toxic chemicals has found significant parts of the population exposed to multiple hazardous substances, including from paper-based food packaging, above levels that could cause serious health damage. We are currently dealing with widespread use of and contamination by PFAS in disposable paper-based food packaging across Europe.
- From a chemical safety point of view, paper and cardboard food packaging /other FCMs, which are not controlled by harmonised specific rules at the EU-level, are questionable alternatives to single-use plastics.

Limited requirements for paper-based packaging. Whereas plastics are increasingly regulated, this is not the case for pulp, paper and packaging yet, even if paper and board is the second most used type of FCMs in Europe, after plastics. However, specific and harmonised EU legislation for paper and board FCMs does not exist. Member States can adopt their own national measures and so far, only a few have such rules in place. There are also no recycled content targets set for the paper industry, which could limit environmental impact on the one side but carries the risk of additional chemical contamination.

Environmental and social impacts in origin countries. A brief literature review identified a number of key (but not exhaustive) environmental and social impacts in general and in five selected countries, i.e. Brazil, Chile, Finland, Italy and Sweden. These impacts can be summarised as follows. The pulp and paper industry is:

- the world's third largest consumer of water;

- the world's fifth largest consumer of energy for their manufacturing process, comparable to that of other energy-intensive products, such as cement or steel. Fossil fuels are still the most important source of fuel for the industry, urging the International Energy Agency (IEA) to state that the sector is 'not on track' to moving to zero-emission alternatives;
- responsible for about 190 million tonnes of CO_2 emissions in 2021, which is about 2% of all emissions from industry.

Regarding impacts in specific countries:

- Water resources depletion due to eucalyptus plantations used for pulp and paper production cause drought, water scarcity and fuel fires (Brazil and Chile);
- Deforestation and natural forest loss reduced biodiversity (Brazil, Chile, Finland, Sweden);
- The use of agrochemicals and pesticides poisoned land and water (Brazil), reduce biodiversity and are a risk to human health (Brazil, Chile);
- Local communities nearby plantations experienced loss of land and access to water, or forced evictions, increasing poverty (Brazil, Chile, Finland);
- Forests have become a net emitter of carbon dioxide, thereby contributing to climate change (Finland, Sweden);
- Limited public participation and concentration of power make the industry untransparent and not democratic (Finland).

6.3 Recommendations

Based on the outcomes and the conclusions of this study, the following recommendations are made.

The EU and Member States should develop specific and harmonised EU legislation for paper-based packaging.

Member States should be encouraged to establish specific and harmonised regulation for paper-based packaging, including and in particular for food contact materials. This legislation should focus and promote the design of packaging that, at least:

- Limits unnecessary packaging materials;
- Limits the production and use of not recyclable, multilayered and composite packaging materials;
- Facilitates reuse and refill;
- Is free from any substances of concern.

Well-designed reuse systems should be promoted to prevent waste generation.

The increased popularity and accompanying growing waste stream of paper-based food packaging, has adverse impacts on human health and the environment. In addition, importing countries of European paper waste have been tightening their regulation to limit imports, limit contamination of waste streams, and this must be seen as a future trend. As a result, Europe has to increasingly deal with its own waste. Instead of lobbying decision-makers to reduce ambition of legislation meant to reduce packaging waste , industry should be made to opt for and invest in the development of reusable materials instead of disposable ones, even if made from recycled materials.

The industry should come up with innovative schemes to reduce paper packaging and to design and implement systems of reutilisation with more durable materials. Policy makers should provide incentives for both industry and consumers to use reusable packaging.

The EU and Member States should enhance and harmonise collection, sorting and recycling systems.

While the waste problem should be tackled at its source, governments should be encouraged to improve and invest in smart collection, sorting and recycling systems of in particular composite and contaminated food packaging materials. These improved systems should be able to separate composite packaging and retrieve valuable materials for reuse.

The EU and Member States should establish recycled content targets for paper and board.

Recycling rates have been stable for years and are low for food and beverage packaging. Specific targets for recycled content in paper and card packaging are not existing at present. By establishing these targets, the industry would be encouraged to put in more effort to increase recycling rates, promote innovation to increase the use of recycled content in food packaging materials. However, special attention is to be given to ensuring the chemical safety of recycled paper and board Food Contact Materials.

The EU and Member States should revise and synchronise legislation on the use of chemicals and chemicals of concern in paper-based packaging.

The EU and Member States should revise, harmonise and synchronise all legislation that concerns all chemicals and additives used in packaging, with a particular focus on chemicals of concern. There should be:

- A clear, comprehensive, and regularly updated registry or database of all chemicals used in packaging, including information on their potential hazards;
- Based on that registry, there should be clear and timebound objectives to forbid and phase out any chemical of concern in packaging.

Legislation should enforce full transparency down the packaging value chain, particularly with regards to chemicals and actual recycling performances of paper-based food packaging.

The pulp, paper, and packaging industry, as well as the recycling industry and all their associations need to be more transparent and improve their disclosure about their performance. And this should be enforced by legislation. Transparency is specifically needed on the use of potentially hazardous chemicals and their potential migration into food, and the real recycling rates (including disclosure about rejects). Advocacy efforts could directly target the industry to improve reporting, but policy makers could be influenced as well to improve legislation regarding sustainability reporting.

The EU and Member States should promote and facilitate comprehensive and scientific research on the use and migration of chemicals in paper-based packaging.

This study has shown that plastic packaging and the chemicals in it were studied almost three times more than paper-based packaging. Following the growing popularity of paper-based food packaging, comprehensive scientific research on the use and presence of chemicals in paper-based food packaging should be promoted and financed, in order to increase understanding of the presence of these chemicals, their potential and actual migration into food and the impacts on human health and the environment.

Appendix 1 Appendix to the methodology

The tables in this Appendix belong to the chapter on methodology. Note that the numbers in the tables refer to their trading code.

Table 6 Paper and board grades for 2023

Final Alignment of CN (8 Digit) Product Headings with 11 CEPI Paper & Board Grades for 2023

NEWSPRINT	GRAPHIC: UNCOATED MECHANICAL	GRAPHIC: UNCOATED WOODFREE	GRAPHIC: COATED MECHANICAL	GRAPHIC: COATED WOODFREE	SANITARY & HOUSEHOLD	CASE MATERIALS	CARTON BOARD	WRAPPINGS UP TO 150gsm	ALL OTHER P & B MAINLY FOR PACKAGING	ALL OTHER P & B
4801 00 00	4802 61 15	4802 10 00	4810 22 00	4809 20 00	4803 00 10	4804 11 11	4804 42 00	4804 21 10	4805 93 20	4802 40 10
	4802 61 80	4802 20 00	4810 29 30	4810 13 00	4803 00 31	4804 11 15	4804 49 00	4804 21 90	4807 00 30	4802 40 90
	4802 62 00	4802 54 00	4810 29 80	4810 14 00	4803 00 39	4804 11 19	4804 51 00	4804 29 10	4807 00 80	4804 31 51
	4802 69 00	4802 55 15		4810 19 00	4803 00 90	4804 11 90	4804 52 00	4804 29 90	4823 70 10	4804 41 91
		4802 55 25		4816 20 00	4818 10 10	4804 19 12	4804 59 10	4804 31 58	4823 70 90	4804 41 98
		4802 55 30		4816 90 00	4818 10 90	4804 19 19	4804 59 90	4804 31 80		4805 40 00
		4802 55 90			4818 20 10	4804 19 30	4805 92 00	4804 39 51		4805 50 00
		4802 56 20			4818 20 91	4804 19 90	4805 93 80	4804 39 58		4806 30 00
		4802 56 80			4818 20 99	4805 11 00	4810 32 10	4804 39 80		4809 90 00
		4802 57 00			4818 30 00	4805 12 00	4810 32 90	4805 30 00		4810 99 80
		4802 58 10				4805 19 10	4810 39 00	4805 91 00		4811 60 00
		4802 58 90				4805 19 90	4810 92 10	4806 10 00		4812 00 00
		4823 90 40				4805 24 00	4810 92 30	4806 20 00		4813 10 00
						4805 25 00	4810 92 90	4806 40 10		4813 20 00
							4811 51 00	4806 40 90		4813 90 10
							4811 59 00	4808 40 00		4813 90 90
								4808 90 00		4823 20 00
								4810 31 00		
								4810 99 10		

Source: Cepi.

Table 7 Pulp grades relevant for food and beverage packaging

HS Code	Description
4701	Wood pulp, mechanical wood pulp
4702	Chemical wood pulp, dissolving grades
4703	Chemical wood pulp, soda or sulphate, other than dissolving grades
4704	Chemical wood pulp, sulphite, other than dissolving grades
4705	Wood pulp obtained by a combination of mechanical and chemical pulping processes
4706	Pulps of fibres derived from recovered (waste and scrap) paper or paperboard or of other fibrous cellulosic material

Source: Cepi.

Table 8 Paper and board grades relevant for food and beverage packaging

HS Code	Description
480240	Uncoated paper and paperboard (not 4801 or 4803); wallpaper base, in rolls or sheets
480411	Kraft paper and paperboard; kraftliner, uncoated, unbleached, in rolls or sheets, other than that of heading no. 4802 or 4803

HS Code	Description
480419	Kraft paper and paperboard; kraftliner, uncoated, bleached, in rolls or sheets, other than that of heading no. 4802 or 4803
480421	Kraft paper and paperboard; sack kraft paper, uncoated, unbleached, in rolls or sheets, other than that of heading no. 4802 or 4803
480429	Kraft paper and paperboard; sack kraft paper, uncoated, bleached, in rolls or sheets, other than that of heading no. 4802 or 4803
480431	Kraft paper and paperboard; uncoated, unbleached, weight 150g/m2 or less, in rolls or sheets, other than that of heading no. 4802 or 4803
480439	Kraft paper and paperboard; uncoated, bleached, weight 150g/m2 or less, in rolls or sheets, other than that of heading no. 4802 or 4803
480441	Kraft paper and paperboard; uncoated, unbleached, weight more than 150g/m2 but less than 225g/m2, in rolls or sheets, other than that of heading no. 4802 or 4803
480442	Kraft paper and paperboard; uncoated, weight between 150 and 225g/m2, bleached uniformly throughout, more than 95% of total fibre content consists of chemically processed wood fibres, in rolls or sheets
480449	Kraft paper and paperboard; uncoated, weight more than 150g/m2 but less than 225g/m2, in rolls or sheets, n.e.c. in item no. 4804.4, other than that of heading no. 4802 or 4803
480451	Kraft paper and paperboard; uncoated, unbleached, weight 225g/m2 or more, in rolls or sheets, other than that of heading no. 4802 or 4803
480452	Kraft paper and paperboard; uncoated, weight 225g/m2 or more, bleached uniformly throughout, more than 95% of total fibre content consists of chemically processed wood fibres, in rolls or sheets
480459	Kraft paper and paperboard; uncoated, weight 225g/m2 or more, in rolls or sheets, n.e.c. in item no. 4804.5, other than that of heading no. 4802 or 4803
480511	Paper and paperboard; uncoated, semi-chemical fluting paper, rolls or sheets
480512	Paper and paperboard; uncoated, straw fluting paper, rolls or sheets
480519	Paper and paperboard; uncoated, fluting paper other than semi-chemical or straw, rolls or sheets
480524	Paper & paperboard; uncoated, testliner (recycled linerboard), weight 150g/m2, or less, in rolls or sheets
480525	Paper & paperboard; uncoated, testliner (recycled linerboard), weight over 150g/m2, in rolls or sheets
480530	Paper and paperboard; sulphite wrapping paper, uncoated, in rolls or sheets
480540	Paper and paperboard; filter paper and paperboard, uncoated, in rolls or sheets
480550	Paper and paperboard; felt paper and paperboard, uncoated, in rolls or sheets
480591	Paper and paperboard; uncoated, weight 150g/m2 or less, in rolls or sheets, n.e.c. in heading no.4805
480592	Paper and paperboard; uncoated, weight more than 150g/m2 but less than 225 g/m2, in rolls or sheets, n.e.c. in heading no. 4805
480593	Paper and paperboard; uncoated, weight 225/m2 or more, in rolls or sheets, n.e.c. in heading no. 4805
480610	Paper; vegetable parchment, in rolls or sheets
480620	Paper; greaseproof papers, in rolls or sheets
480630	Paper; tracing papers, in rolls or sheets
480640	Paper; glassine and other glazed transparent or translucent papers, in rolls or sheets
480700	Paper and paperboard; composite (made by sticking layers together with an adhesive), not surface-coated or impregnated, whether or not internally reinforced, in rolls or sheets
480840	Paper and paperboard; kraft paper, creped or crinkled, whether or not embossed or perforated, in rolls or sheets, other than paper of heading 4803

HS Code	Description
480890	Paper and paperboard; other than corrugated (with or without glued flat surface sheets) or kraft paper, creped or crinkled, whether or not embossed or perforated, in rolls or sheets, other than paper of heading 4803
480990	Paper; carbon paper and other copying or transfer papers (including coated or impregnated paper for duplicator stencils or offset plates), whether or not printed, in rolls or sheets
481031	Kraft paper and paperboard; uniformly bleached throughout, coated with inorganic substances, more than 95% of chemically processed wood fibres, weight 150g/m2 or less, for non-graphic purposes, in rolls or sheets
481032	Kraft paper and paperboard; uniformly bleached throughout, coated with inorganic substances, more than 95% of chemically processed wood fibres, weight more than 150g/m2, for non-graphic purposes, in rolls or sheets
481039	Kraft paper and paperboard; coated with kaolin or other inorganic substances only, for non-graphic purposes, n.e.c. in item no. 4810.31 and 4810.32, in rolls or sheets
481092	Paper and paperboard; multi-ply, coated with kaolin or other inorganic substances only, for non-graphic purposes, n.e.c. in heading no. 4810, in rolls or sheets
481099	Paper and paperboard; coated with inorganic substances only, whether or not surface-coloured, surface-decorated or printed, n.e.c. in heading no. 4810, in rolls or sheets
481151	Paper and paperboard; coated, impregnated or covered with plastics (excluding adhesives), bleached, weighing more than 150g/m2, other than goods of heading no. 4803, 4809, or 4810
481159	Paper and paperboard; coated, impregnated or covered with plastics (excluding adhesives), other than bleached and weighing more than 150g/m2, other than goods of heading no. 4803, 4809, or 4810
481160	Paper and paperboard; coated or impregnated with wax, paraffin wax, stearin, oil or glycerol, other than goods of heading no. 4803, 4809, or 4810
481200	Paper pulp; filter blocks, slabs and plates of paper pulp
482320	Paper and paperboard; filter paper and paperboard
482370	Paper pulp; moulded or pressed articles or paper pulp

Source: Cepi.

Appendix 2 Overview of the pulp and paper supply chain in the EU

The pulp and paper supply chain that backs the packaging sector generally consists of five stages, i.e. plantation, raw material preparation, pulping, stock preparation and papermaking, and post use treatment. Each of the stages is briefly explained in this section.

- **Plantation**

  The raw materials inputted into the pulp and paper manufacturing include fibres - or fibrous materials - and non-fibrous materials. Fibres can be virgin fibres derived from wood and non-wood fibre sources such as straw, bamboo, bagasse (sugarcane), and other fibre crops. Fibres could also be derived from recycled, recovered, or secondary materials such as paper for recycling, or textiles.

  Wood is the most widely used source of fibres for the paper making process. Today, globally about 90% of the fibres used for papermaking are wood fibres, constituted of pulpwood, chips and sawmill residues.[287] Virgin wood pulp used to form the main fibre source for paper manufacture, but since around 2006 recovered paper has become the principal fibre used worldwide.[288] In 2021, 56% of the paper and board produced in Europe consisted of paper for recycling, 44% was based on virgin pulp.[289] It should be noted that 'paper for recycling' does not mean that all this paper is actually recycled. There is an unknown percentage of this collected paper that will end up as waste, not being recycled.

  Most of the paper today is manufactured from virgin or recycled softwood pulp of coniferous trees (mostly pine and spruce, though fir and hemlock could be used too) or from hardwood, i.e. deciduous trees, such as birch, eucalyptus, beech, aspen or acacia. Oak is hardly used. Softwood fibres are long, tough, and strong, and useful for paper grades for end products that require strong materials, such as cardboard boxes and milk cartons. On the contrary, hardwood fibres are short and thin, giving paper a smooth printing surface and high opacity. Hardwood is also easier to bleach as there is less lignin (the natural binding constituent of wood cells), making hardwood useful for printing papers. However, blends with softwoods are often used.[290]

---

287 ABB (n.d.), "Characteristics of wood and papermaking fibers", online: https://new.abb.com/pulp-paper/abb-in-pulp-and-paper/articles/characteristics-of-wood-and-papermaking-fibers, viewed in April 2023;

Confederation of European Paper Industries (2022), *Key Statistics 2021, European Pulp & Paper Industry*, p. 30.

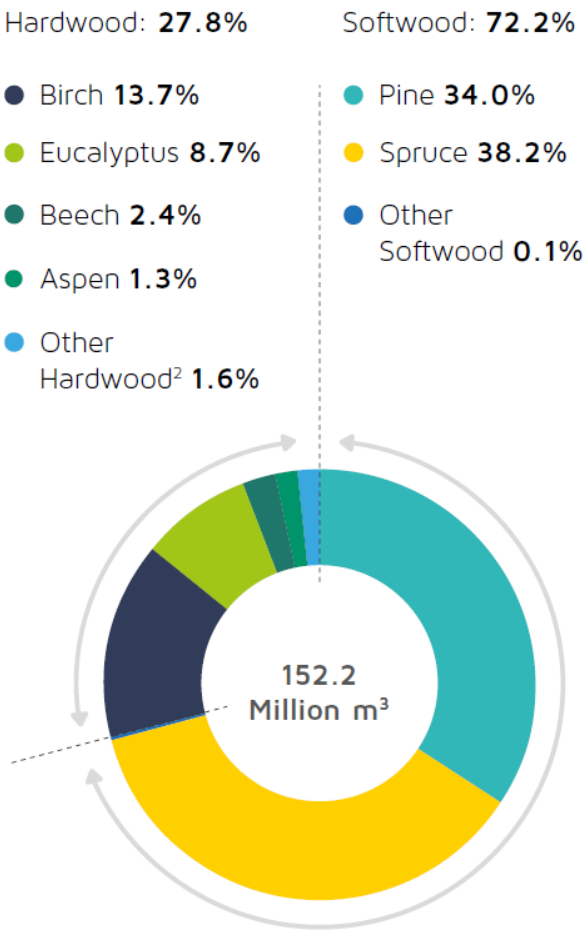
288 Chamberlain, D. and M. Kirwan (2013), *Paper and paperboard – raw materials, processing and properties*, in: *Handbook of Paper and Paperboard Packaging Technology*, Second Edition, John Wiley & Sons, Ltd., p. 7.

289 Confederation of European Paper Industries (2022), *Key Statistics 2021, European Pulp & Paper Industry*, p. 6.

290 ABB (n.d.), "Characteristics of wood and papermaking fibers", online: https://new.abb.com/pulp-paper/abb-in-pulp-and-paper/articles/characteristics-of-wood-and-papermaking-fibers, viewed in April 2023.

In 2021, the EU used approximately 152 million cubic metres (m3) of wood in the pulp and paper industry. This volume consisted of 112 million m3 of softwood (74%) and 40 million m3 of hardwood (26%).[291] The relative shares of softwood and hardwood used depend on the country considered and the pulp and paper grades produced.[292] But Figure 8, from the same source (Cepi), gives insight into the average share of the different types of wood used in the production of pulp and paper in the EU. Cepi represents 91% of the production in Europe,[293] meaning that total consumption reached an estimated 167 million tonnes.

Figure 8 **Wood consumption of the EU pulp and paper industry by species**



Source: Confederation of European Paper Industries (2022), *Key Statistics 2021, European Pulp & Paper Industry*, p. 19.

- **Raw material preparation**

[291] Confederation of European Paper Industries (2022), *Key Statistics 2021, European Pulp & Paper Industry*, p. 5.

[292] Confederation of European Paper Industries (2022), *Key Statistics 2021, European Pulp & Paper Industry*, p. 30.

[293] Europe minus Russia.

Wood or raw material preparation comprises harvesting, debarking, chipping, and screening. Chipping and screening entail the conversion of wood into smaller pieces, before being screened to ensure an optimum size for the pulping process. Oversized pieces must be re-chipped, and undersized chips should be rejected.[294]

- **Pulping**

  Pulping is the processing of the fibres to obtain the primary raw material for making paper. These operations are carried out in the pulp and/or paper mill. In the pulp mill, pulpwood, wood chips or other such cellulosic material are processed into pulp. In an integrated paper mill all pulp and papermaking operations are conducted at one site. Manufacturing operations could be done too.[295]

  Pulping can be done by using mechanical or (semi-) chemical methods such as cooking, screening, and bleaching. In the mechanical process, fibres are teased apart. In the chemical process, non-cellulose and non-fibrous components of the wood such as lignin are removed by cooking the woodchips in chemicals. Lignin cannot be completely removed during pulping, giving the unbleached pulp a brown tint. Chemical pulping is the most used pulping method, representing around 70-80% of the total pulp in the EU.[296]

  There are two main chemical processes, i.e. 1) sulphate or kraft pulping, using a sodium hydroxide (soda) liquor, and 2) sulphite pulping, using bisulphite liquor. The sulphate process is most widely used today, as it can process all the main types of wood. The chemicals can be recovered and reused. After separation, the fibres are washed to remove remaining impurities and screened to remove any remaining fibre bundles.[297] In both processes, the dissolved materials are used as an energy source in the mills.[298]

  Figure 9 gives an overall overview of the inputs to the pulp and papermaking process, including water, energy, labour, and the type of chemicals used in the paper making process. Details about chemical use are discussed in Chapter 4.

---

294 Confederation of European Paper Industries (2021, January), *Pulp and Paper Industry Definitions and Concepts*, p. 8.

Suhr, M. et all (2015), "Best Available Techniques (BAT). *Reference Document for the Production of Pulp, Paper and Board. Industrial Emissions Directive 2010/75/EU (Integrated Pollution Prevention and Control)*, European Commission, JRC Science and Policy Reports, pp. 63-65.

295 Suhr, M. et all (2015), "Best Available Techniques (BAT). *Reference Document for the Production of Pulp, Paper and Board. Industrial Emissions Directive 2010/75/EU (Integrated Pollution Prevention and Control)*, European Commission, JRC Science and Policy Reports, p. 34.

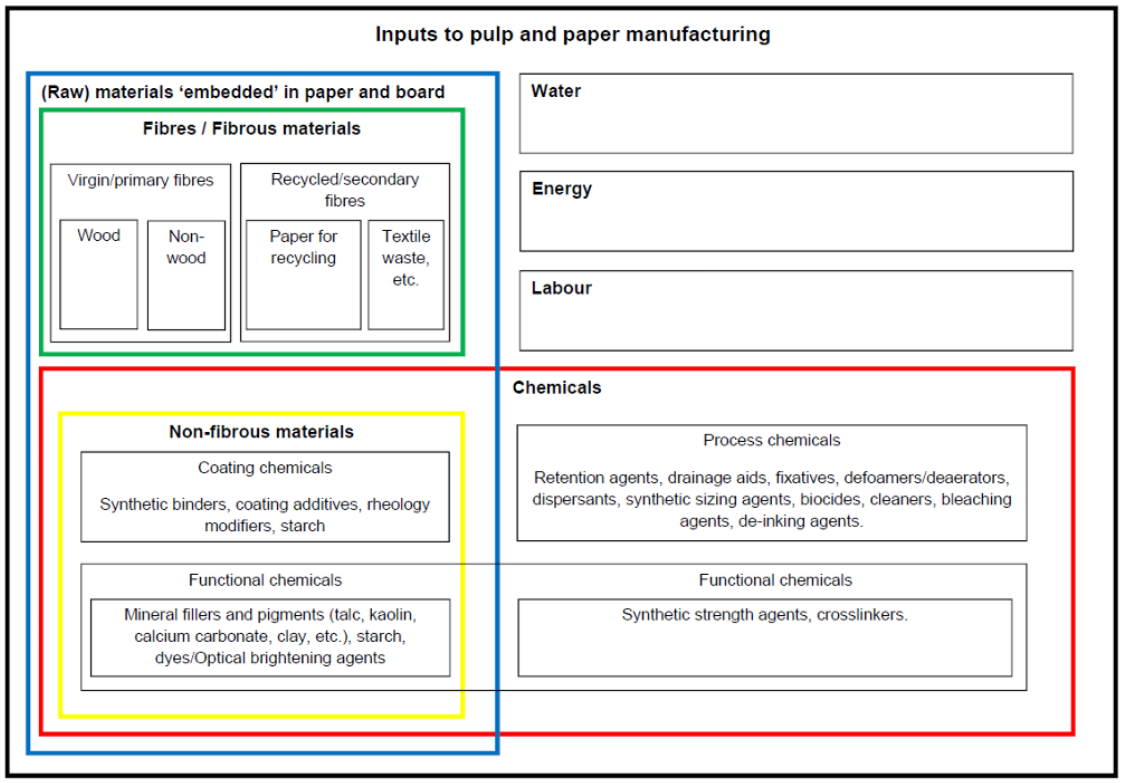
296 Confederation of European Paper Industries (2022), *Key Statistics 2021, European Pulp & Paper Industry*, p. 8.

297 Confederation of European Paper Industries (2021, January), *Pulp and Paper Industry Definitions and Concepts*, p. 12;

Amândio, M.S.T., et all (2022, June 2), "Getting Value from Pulp and Paper Industry Wastes: On the Way to Sustainability and Circular Economy", *Energies 2022*, 15, 4105, p. 5.

298 Chamberlain, D. and M. Kirwan (2013), "Paper and Paperboard – Raw materials, Processing and Properties", in: *Handbook of Paper and Paperboard Packaging Technology*, Second Edition, John Wiley & Sons, Ltd., p. 9.

Figure 9 Inputs to pulp and paper manufacturing



Black box: Total input to pulp and paper manufacturing.
Blue box: (Raw) Materials 'embedded' in paper and board.
Red box: Chemicals, embedded or not in the final product.
Green box: Fibres / Fibrous materials.
Yellow box: Non-fibrous materials.

Source: Confederation of European Paper Industries (2021, January), *Pulp and Paper Industry. Definitions and Concepts*, p. 8.

- **Stock preparation and papermaking**

  This phase of the production process comprises different steps, depending on the requirements and characteristics of the final product. It is partly a continuous dewatering operation to increase the dry content of the paper. In addition, chemicals and chemical additives are used to improve appearance or performance of the product or increase productivity of the process. Bleaching is done to improve the whiteness and brightness of the paper.[299]

  During dewatering, the fibrous material (containing approximately 99% water) is passed through rollers or wire mesh loaded under high pressure to remove water and form the paper web.[300] Drying by heating removes further water content.

299 Deshwal, G. N. Raju Panjagari, T. Alam (October 2019), "An overview of paper and paper based food packaging materials: health safety and environmental concerns", *Journal of Food Science and Technology*, 2019 Oct; 56(10): 4391–4403.

300 Deshwal, G. N. Raju Panjagari, T. Alam (October 2019), "An overview of paper and paper based food packaging materials: health safety and environmental concerns", *Journal of Food Science and Technology*, 2019 Oct; 56(10): 4391–4403.

Internal sizing is the process of coating paper to improve the surface strength, printability, and water resistance of the paper or material. The semi-dried paper is applied with a thin layer of starch and/ or other chemicals or synthetic sizing agents. Other treatments could include laminating, impregnating, or saturating the paper sheets.[301] Brightening agents may be added to improve the opacity and whiteness of the paper or material surface.[302] Fillers could be added to fill voids in the fibre structure but are not widely used in the manufacture of packaging grades. Mineral pigments account for an estimated 8% of the raw materials used by the paper industry, according to a 2013 study.[303]

Various other chemicals are applied as production aids, such as anti-foaming agents, flocculating agents to improve drainage, and biocides to restrict microbiological activity in the mill. Newer chemicals are increasingly based upon renewable feedstock instead of petrochemicals.[304]

Chemically separated and bleached fibre is pure cellulose. This characteristic has particular relevance for packaging products such as chocolate, butter, and tea whose flavour, odour or aroma should be prevented from being affected by the packaging materials.[305] Finally, calendering is used to smoothen dried paper under high loading and pressure. Supercalendering involves the addition of moisture and more pressure.[306]

The paper and paperboard material is now ready to leave the papermaking machine. Depending on the requirements of the customer, reels could be slit into narrower widths and smaller diameters, and subsequently further slit, sheeted, counted, palletised, wrapped and labelled. Final conversion processes could be applied, such as coating, lamination, and impregnation.[307]

The food and beverage packaging industry, representing two-thirds of the total packaging market in Europe, is one of the end users of the paper products and specialised in producing packaging out of a wide range of increasingly composite materials, with the objective to protect the food and beverage items and make it suitable for storage, transport, and consumption.

---

301 Wikipedia, "Paper machine". Online: https://en.wikipedia.org/wiki/Paper_machine, viewed in April 2023.

302 OECD (2020), "PFASs and alternatives in food packaging (paper and paperboard): Report on the commercial availability and current uses", *Series on Risk Management No. 58*, Environment, Health and Safety, Environment Directorate, OECD, p. 19.

303 Chamberlain, D. and M. Kirwan (2013), "Paper and paperboard – raw materials, processing and properties", in: *Handbook of Paper and Paperboard Packaging Technology*, Second Edition, John Wiley & Sons, Ltd., pp. 11-12.

304 Chamberlain, D. and M. Kirwan (2013), "Paper and paperboard – raw materials, processing and properties", in: *Handbook of Paper and Paperboard Packaging Technology*, Second Edition, John Wiley & Sons, Ltd., pp. 10-11.

305 Chamberlain, D. and M. Kirwan (2013), "Paper and paperboard – raw materials, processing and properties", in: *Handbook of Paper and Paperboard Packaging Technology*, Second Edition, John Wiley & Sons, Ltd., pp. 10.

306 Chamberlain, D. and M. Kirwan (2013), "Paper and paperboard – raw materials, processing and properties", in: *Handbook of Paper and Paperboard Packaging Technology*, Second Edition, John Wiley & Sons, Ltd., pp. 17-19.

307 Chamberlain, D. and M. Kirwan (2013), "Paper and paperboard – raw materials, processing and properties", in: *Handbook of Paper and Paperboard Packaging Technology*, Second Edition, John Wiley & Sons, Ltd., pp. 19-20.

Letterpress printing, lithography, flexography, gravure, and stamping processes are extensively used for printing of information and pictures on paper labels. Paper labels are attached to food packets or containers in forms of wet glue paper labels, gummed paper labels and self-adhesive labels.[308]

- **Post-use treatment**

  After being used, paper waste and paper waste products could be recycled, incinerated or landfilled. In the recycling process, the waste paper (and board) are mixed with water to form a slurry. Chemicals are then added to adjust the pH. The pulp is then filtered and screened to remove inks, fillers, coating particles, and glues as much as possible. The quality of the pulp depends on the nature of the original fibre, the way it was processed, and how the paper or board product was converted. The quality and fibre strength obviously reduces in each round of repulping.[309]

  The inks are removed in a flotation process called de-inking. Air is blown into the solution, and the ink adheres to bubbles of air and rises to the surface, where it is separated. The remaining fibrous material is the recycled pulp that needs to be pressed and dried.[310]

  The pulp is then processed into paper, and depending on the grade of paper being produced, virgin pulp may be added. The pulp is pressed and dried and rolled into large thin sheets of recycled paper ready to produce packaging paper, newsprint and other paper materials.[311] Some paper and paperboard products are either made exclusively from recycled pulp or contain a high proportion of recycled fibre. Others are made exclusively from either chemical pulp or a mixture of chemical and mechanical pulp.[312]

  There are different types of recycling facilities for fibre-based packaging, including standard recycling mills that can handle small amounts of non-fibre material, as well as specialised recycling mills that can handle larger amounts of materials that need dedicated conditions during pulping and cleaning. Some fibre-based packaging can also be recycled in deinking mills. Recycled fibres should fulfil food-safety requirements when used for food packaging.[313]

---

308 Deshwal, G. N. Raju Panjagari, T. Alam (October 2019), "An overview of paper and paper based food packaging materials: health safety and environmental concerns", *Journal of Food Science and Technology*, 2019 Oct; 56(10): 4391–4403;

Amândio, M.S.T., et all (2022, June 2), "Getting Value from Pulp and Paper Industry Wastes: On the Way to Sustainability and Circular Economy", *Energies 2022*, 15, 4105, p. 7.

309 4EverGreen (n.d.), "A journey through recycling into fibre-based packaging", online: https://4evergreenforum.eu/a-journey-through-recycling-of-fibre-based-packaging/, viewed in May 2023.

310 4EverGreen (n.d.), "A journey through recycling into fibre-based packaging", online: https://4evergreenforum.eu/a-journey-through-recycling-of-fibre-based-packaging/, viewed in May 2023.

311 HBM4EU (2022, July 7), *Chemicals in a circular economy. Using human biomonitoring to understand potential new exposures*, p. 23.

312 Chamberlain, D. and M. Kirwan (2013), "Paper and paperboard – raw materials, processing and properties", in: *Handbook of Paper and Paperboard Packaging Technology*, Second Edition, John Wiley & Sons, Ltd., pp. 10-11.

Karlovits, I. (2023, May 2), *Correspondence with Manon Stravens of Profundo*.

313 4Ever Green Alliance (2022), "Circularity By Design Guideline for fibre-based Packaging", p. 9.

The recycling process should be considered at an early stage of the packaging design and take into account the intended purpose and end-of-life of the packaging to optimise the recycling process.[314]

[314] Confederation of European Paper Industries (2021, January), *Pulp and Paper Industry Definitions and Concepts*, p. 6.

Appendix 3 Chemicals of Concern in Food Contact paper and board

Table 9 gives an overview of chemicals that may be intentionally used in paper and board food packaging and that are known to be extracted from and/or have migrated into food or food simulants. All of these chemicals have hazardous CMR properties. CMR stands for Carcinogenic, Mutagenic or Toxic to reproduction, classifying chemicals that can cause cancer, alter DNA or damage reproductive systems. No concentrations were tracked.

Table 9 Food Contact Chemicals of Concern in paper and board

CAS Number (identification number)	Name of Chemical
90-43-7	2-Phenylphenol
107-21-1	Ethylene glycol
25013-16-5	Butylated hydroxyanisole
98-83-9	alpha-Methylstyrene
80-05-7	Bisphenol A
88-06-2	2,4,6-Trichlorophenol
91-20-3	Naphthalene
84-65-1	Anthraquinone
123-31-9	Hydroquinone
1330-20-7	Xylenes
100-42-5	Styrene
100-41-4	Ethylbenzene
96-24-2	3-cloro-1,2-propanodiol
117-81-7	Di(2-ethylhexyl) phthalate
84-74-2	Dibutyl phthalate
84-61-7	Dicyclohexyl phthalate
84-69-5	Diisobutyl phthalate
85-68-7	Benzyl butyl phthalate
25154-52-3	n-Nonylphenol
7439-97-6	Mercury
7440-43-9	Cadmium
7440-38-2	Arsenic
10605-21-7	Methyl benzimidazolecarbamate
91-94-1	3,3'-Dichlorobenzidine
95-69-2	4-chloro-o-toluidine
92-87-5	benzidine
106-47-8	4-chloroaniline
101-77-9	4,4'-Diaminobiphenyl methane
838-88-0	4,4'-methylenebis(2-methylaniline)
60-09-3	4-aminoazobenzene
95-53-4	o-Toluidine
7439-92-1	Lead
615-05-4	4-methoxy-mphenylenediamine
50-00-0	Formaldehyde
108-88-3	Toluene

67-56-1	Methanol
96-23-1	1,3-Dichloro-2-propanol
10043-35-3	Boric acid
92-67-1	4-aminobiphenyl
79-06-1	Acrylamide
97-56-3	o-Aminoazotoluene
90-04-0	o-anisidine
95-80-7	2,4-Diaminotoluene
101-80-4	4-Aminophenyl ether
75-09-2	Dichloromethane

Source: Source: FCCoC database; Zimmerman, L. et all (2022, May 14), “Implementing the EU Chemicals Strategy for Sustainability: The case of food contact chemicals of concern”, Journal of Hazardous Materials. Volume 437, 5 September 2022, 129167