REPORT

FUNCTIONALISATION OF PAPER AND CARDBOARD

HOW TO MAKE PAPER/CARDBOARD IMPERVIOUS FOR PACKAGING?

M. Mme RECYCLAGE

ABOUT

PUBLISHED FEBRUARY 2024.

M. & Mme Recyclage is an independent consultancy specialising in recycling, reuse, and packaging, led by two engineers: Lise Nicolas and Enzo Muttini.

Their true expertise lies primarily in their extraordinary ability to simplify highly complex content and issues in a very coherent manner.

As a mission-driven company, M. & Mme Recyclage has made every effort to provide readers with an easily understandable and freely accessible overview of industrial best practices. This dossier has been subject to critical review by peers in the French paper industry.

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FINANCING

THE FOLLOWING ORGANISATIONS CONTRIBUTED FINANCIAL SUPPORT TO THE DEVELOPMENT OF THIS INFORMATION BOOKLET ON THE STATE-OF--THE-ART OF PAPER AND CARDBOARD PACKAGING.

VILLE DE PARIS

"Paris, a city without single-use plastic by 2024. The cornerstone of this ambition is the exemplary nature of the Parisian administration, whether it be in its purchases, organization, or hosting of events in its premises or in public spaces, or in welcoming employees and the public within its services and establishments. This dossier is funded by the Directorate for Ecological Transition and Climate (DTEC)." https://www.paris.fr/

ZERO WASTE EUROPE

The European network of communities, local leaders, experts, and change agents working towards the prevention and elimination of waste in our society. We advocate for sustainable systems; for the redesign of our relationship with resources; and for a global shift towards environmental justice, accelerating a just transition towards zero waste for the benefit of people and the planet. www.zerowasteeurope.eu

RETHINK PLASTIC

An alliance of leading European NGOs working towards ambitious EU policies on plastics. It brings together the Center for International Environmental Law (CIEL), ClientEarth, Environmental Investigation Agency (EIA), European Environmental Bureau (EEB), European Environmental Citizen's Organisation for Standardisation (ECOS), Greenpeace, Seas At Risk, Surfrider Foundation Europe, and Zero Waste Europe. Together they represent thousands of active groups, supporters and citizens in every EU Member State working towards a future free from plastic pollution. Rethink Plastic is part of the Break Free From Plastic movement www.rethinkplasticalliance.eu

RSVP ReuSe Vanguard Project

The ReuSe Vanguard Project (RSVP) aims to put to put reusable systems in the center of the solutions agenda and create the conditions for these systems to get to scale in Europe. www.reusevanguardproject.eu

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ABSTRACT

Paper and cardboard require functionalisation so that they can be used in contact with food. Functionalisation may include adding a barrier function to water, grease, gases, etc. This is mainly achieved through the use of plastic, i.e. the combination of polymer(s) + additive(s). Paper and cardboard food packaging are therefore, not free from plastic. As such, most of these paper and cardboard packaging remain at the same level as "single-use plastics", as defined in the European Directive on Single-Use Plastics.

Given the paper industry's current practice, overly simplistic commercial claims such as "100% natural", "plastic-free", or "compostable" on packaging items are misleading. Reusing packaging is the first waste reduction point alongside material reduction, and should remain the priority. However, technological developments should allow for the reduction of plastic used to functionalise paper and cardboard, provided that regulation supports its deployment at the industrial level.

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GLOSSARY 1/2

FUNCTIONALISATION
Adding a function to a material. For example , this function can take the form of a barrier to water or water vapor.

COATING
Surface treatment which consists of applying a coating, generally liquid, to a support. When the substrate is not flat, we rather speak of dipping.

CHEMISORPTION
Establishment of a strong chemical bond between the surface of a material and a chemical compound.

SOLUBILISE
Dissolving a substance into another element so that the two compounds form a uniform mixture called a solution.

GLOSSARY 2/2

CELLULOSE PULP

Cellulose pulp is a fibrous material obtained from the mechanical or chemical processing of wood, plants, or other sources of cellulose. It is widely used in the paper industry for the production of paper, cardboard, and other derivative products.

FORMULATION

Specific composition and manner in which ingredients are combined to create a substance or preparation.

EMULSION

A dispersion of small droplets of one liquid in another immiscible liquid, often stabilised by an emulsifying agent. Water and oil form an emulsion.

PFAS

Per- and polyfluoroalkyl substances are chemicals with specific chemical properties used in many industrial sectors and everyday products. Extremely persistent in the environment, they are sometimes referred to as forever chemicals.

INTRO FUNCTIONALISATION OF PAPER AND CARDBOARD

Dozens of patents, scientific articles, field feedback, reports, and analysed packaging inform about the state of the art of our paper/cardboard packaging. Three categories structure this condensed knowledge:

THE KEY BASICS TO REMEMBER

CONDENSED SIMPLIFICATION

TO PUSH FURTHER INTO THE TECH

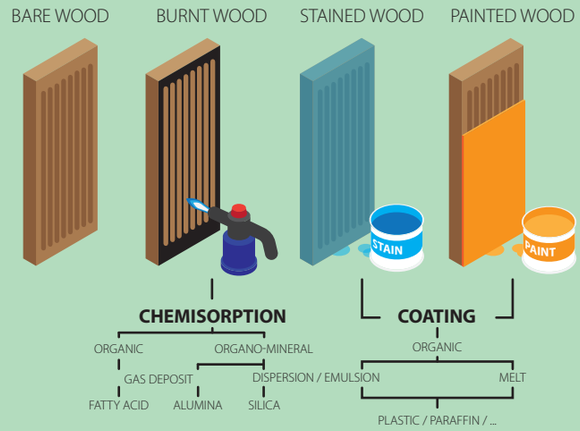
PART. 2

HIGHLIGHTS

- **PAPER AND CARDBOARD REQUIRE BARRIER FUNCTIONS FOR PACKAGING;**
- **IN PACKAGING, PAPER AND CARDBOARD ARE BROADLY FUNCTIONALIZED WITH PLASTIC;**
- **OTHER FUNCTIONALIZING MATERIALS SUCH AS CERAMICS ARE NOT YET INDUSTRIALIZED ON A LARGE SCALE.**

PART 2. FUNCTIONALISATION OF PAPER AND CARDBOARD

A parallel with wood protection informs on how to categorise barrier layers for paper/cardboard.



Traditional coatings take advantage of the roughness of the paper to maintain physical cohesion. Chemical grafting modifies the paper surface.

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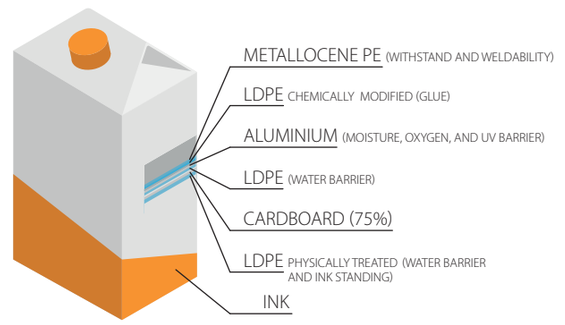
PART. 2 FUNCTIONALISATION OF PAPER AND CARDBOARD

For a technology to spread across the packaging industry, paper/cardboard must offer multiple functions at the same time: water barrier, UV resistance, sealability, printability, etc.



The most common functionalised papers contain multi-barrier materials, such as polyethylene which acts as a barrier to water and grease while also serving as a sealant, or aluminum which acts as a barrier to water vapor, oxygen, and UV rays.

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PART. 1

PAPER AND CARDBOARD 101

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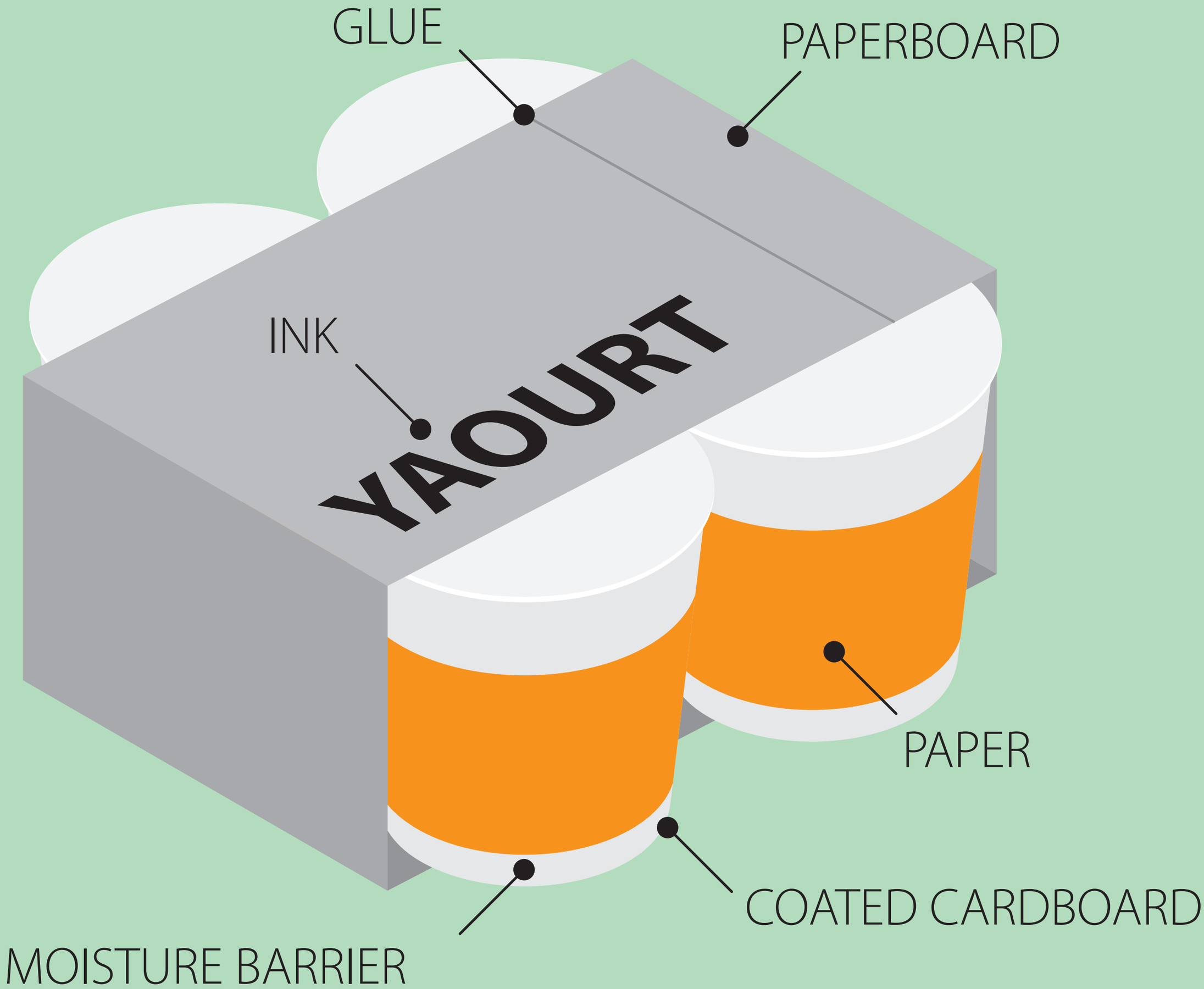
PART. 1 PAPER AND CARDBOARD 101



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PART. 1 PAPER AND CARDBOARD 101

PAPER ⟵ **~200 g /m²** ⟶ CARDBOARD

Cellulose fibers (a natural polymer), primarily extracted from trees, make up paper and cardboard. The grammage (the surface density in grams per square meter) distinguishes paper from cardboard. ISO 4046 standardises these terms.

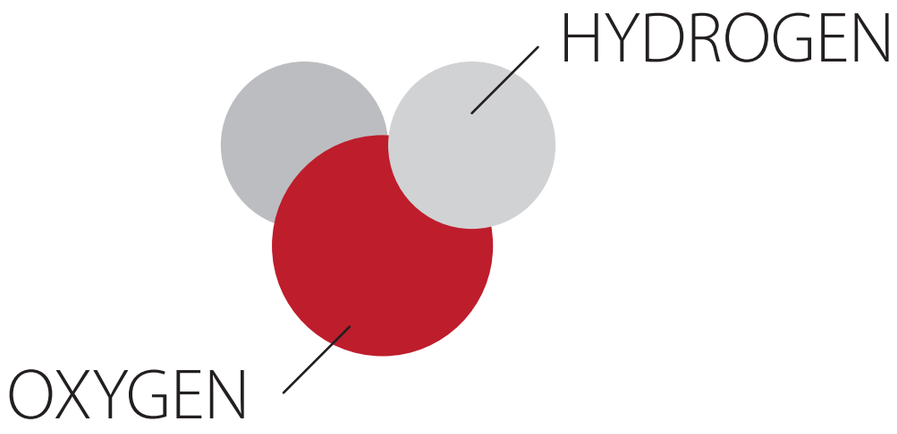
Cellulose is present in all plants and in some fungi. The main sources are:

PLANTS	% of cellulose
Bagasse	35-45
Bamboo	40-55
Cotton	90-99
Flax	70-75
Hemp	60-65
Jute	60-65
Kapok	70-75
Ramie	70-75
Straw	40-50
Wood	40-50

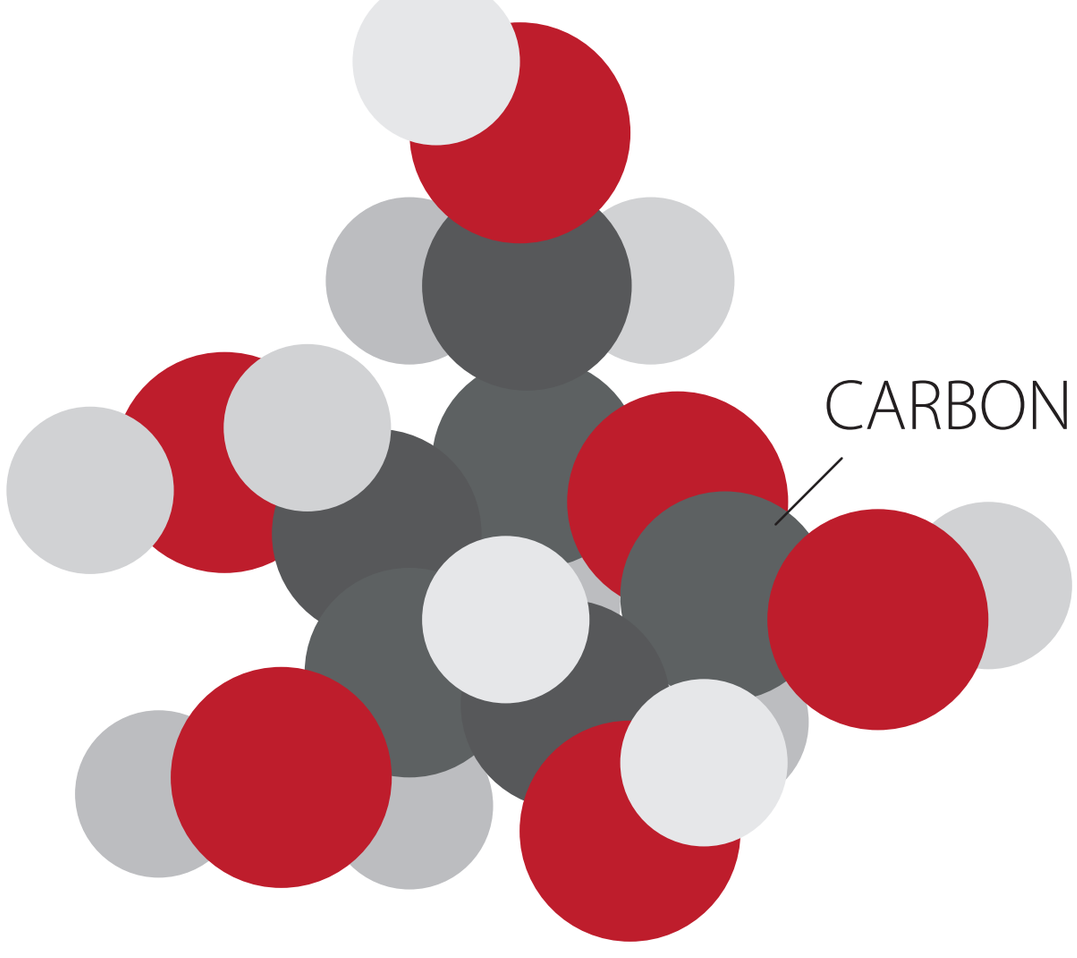
Considering the extraction costs, refining challenges, and the quality obtained, cotton (textile) and wood (paper) are the only sources industrialised on a large scale.

The repetition of a basic monomer (a molecule composed of several atoms) forms a polymer. While our commodity plastics are essentially produced from ethylene and propylene, cellulose is a repetition of glucose. Water has 3 atoms, glucose: 24 (carbon, hydrogen, and oxygen).

WATER

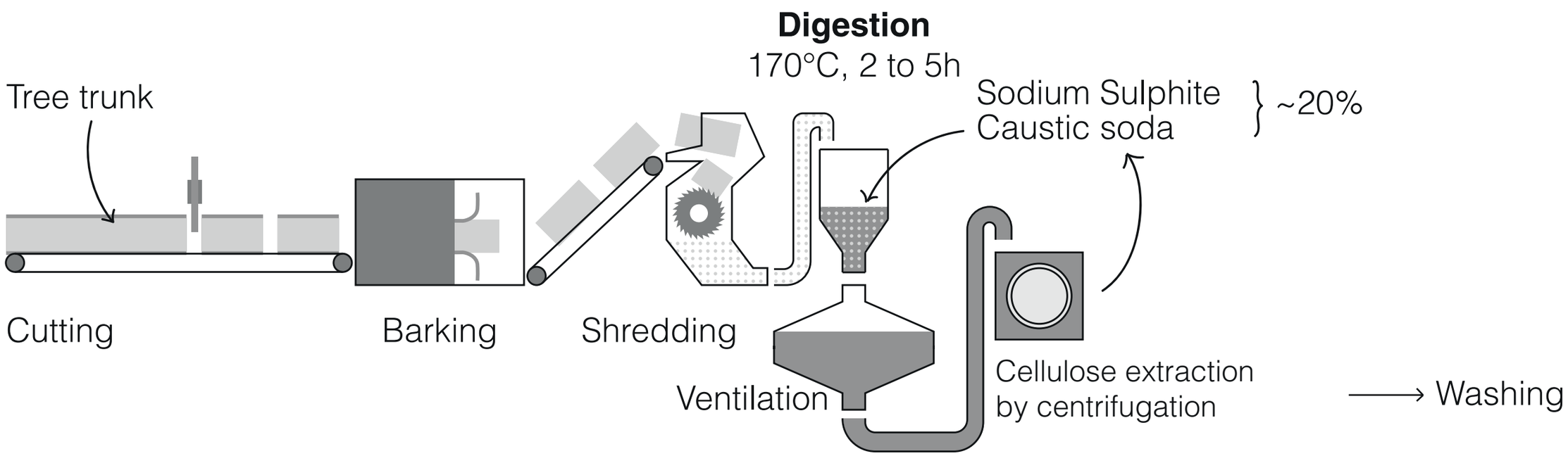


GLUCOSE



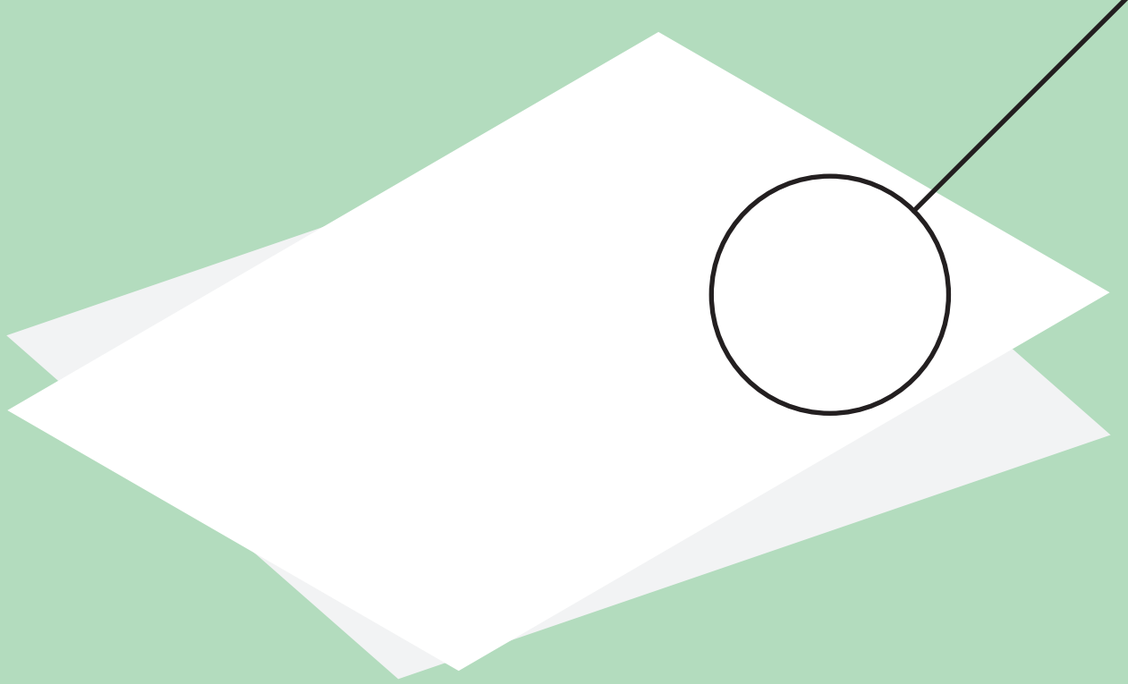
PART. 1 PAPER AND CARDBOARD 101

Wood consists mainly of cellulose, but also hemicellulose, lignin, a little resin, wax, and fats. To transform wood into paper pulp, these different components must be solubilized and filtered.



7% of the wood industry is used for paper/cardboard (excluding energy). The strength of paper pulp depends on the length of cellulose fibers, which in turn depends on the wood species and the cellulose refining process. Pine, spruce, aspen, eucalyptus, and birch remain the most commonly used species. The Kraft process (using sodium sulfite) remains the most widespread worldwide. Its efficiency revolves around ~50% (the cellulose concentration in wood). Many details on paper pulp production are provided in document J6900 of the French Techniques de l'ingénieur.

Just like plastic, paper/cardboard is composed of polymer(s) (cellulose at least) and additives. These additives efficiently produce various papers for different applications by precisely balancing water retention, interaction of cellulose fibers, and the porosity of the final product. Many details about additives are provided in document J6901 of the French Techniques de l'ingénieur



ADDITIVES

FILLERS (- up to 30%)
(talc, kaolin, calcium carbonate, ...)

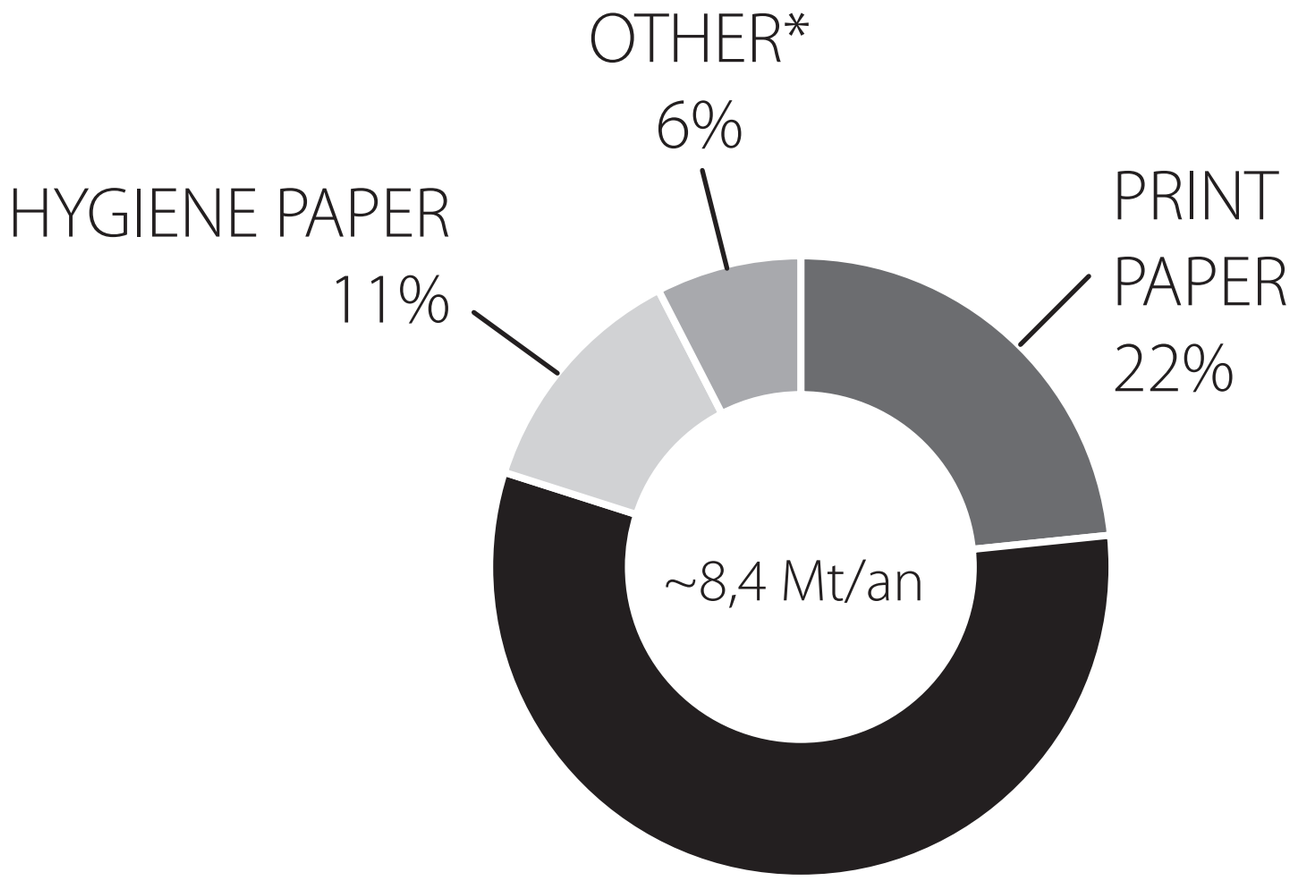
BINDERS (0,5 to 5%)
(starch, SBR ...)

RETENTION AGENTS (0,05 to 1%)
(PAM, PEM, ...)

SIZING AGENTS (0,5 to 1%)
(AKD, ASA, ...)

BLEACHING AGENTS (0 to 1%)
(stilbenes, ...)

The addition of additives to paper/cardboard will depend on the application sectors, such as inked paperboard for packaging, printed paper for magazines, etc. According to the 2022 statistical report of the French paper industry (COPACEL), the sectors are as follows in France:



PACKAGING

66% (~5Mt/year)

*Paper pulp, sold by paper mills and categorized under "other," can be used to produce packaging, known as molded cellulose pulp, which represents 1.3% of paper/cardboard packaging.

PACKAGING

66% (~5Mt/year)

FLEXIBLE PAPER
(Sac, sachet, ...)
22% (~1,1 Mt)

PAPERBOARD
8% (~0,4 Mt)

CORRUGATED BOARD
70% (~3,5Mt)
of which 60% is for the agri-food sector

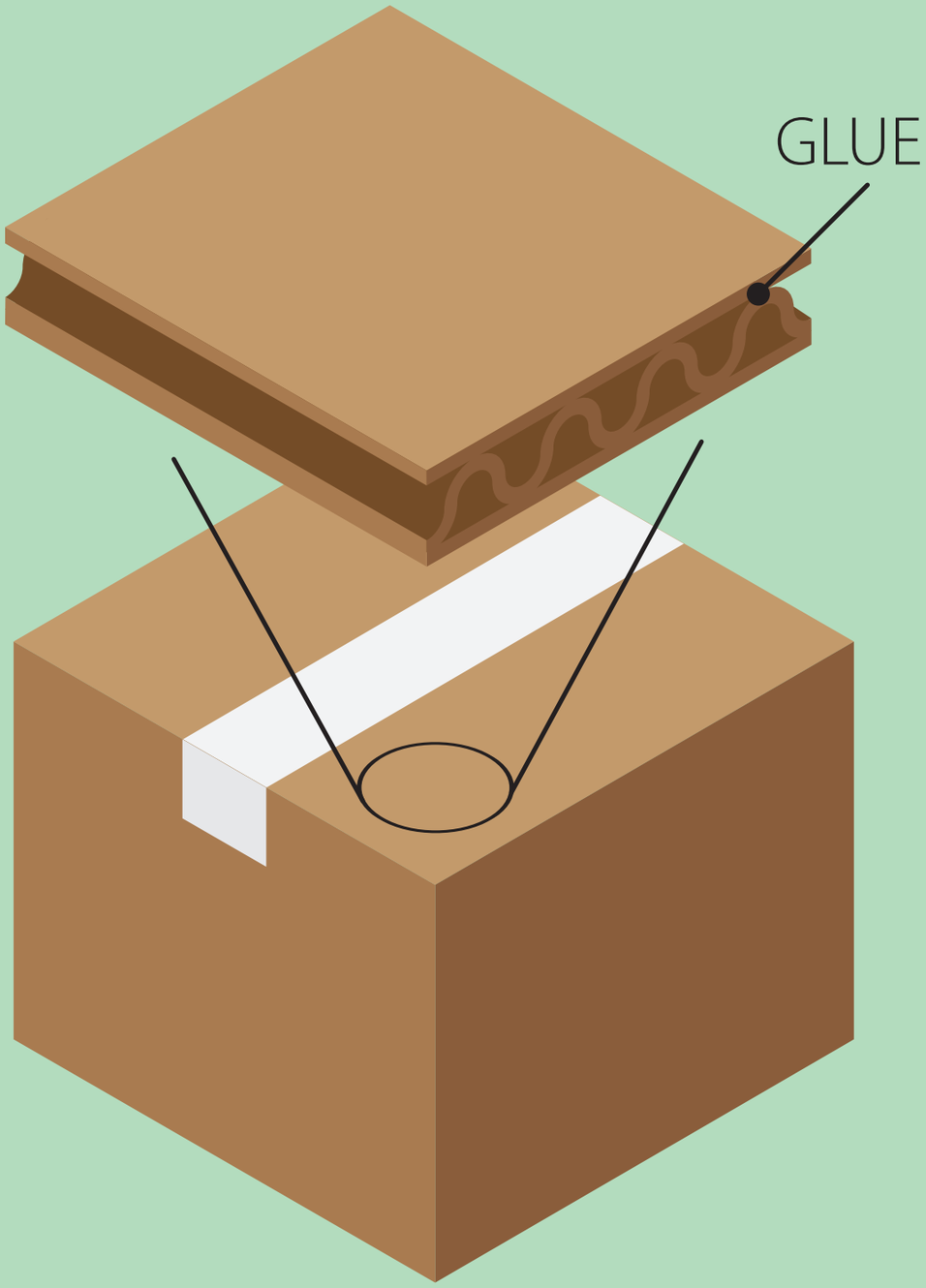
In France, packaging made of paper/cardboard accounts for approximately 40% of all packaging:

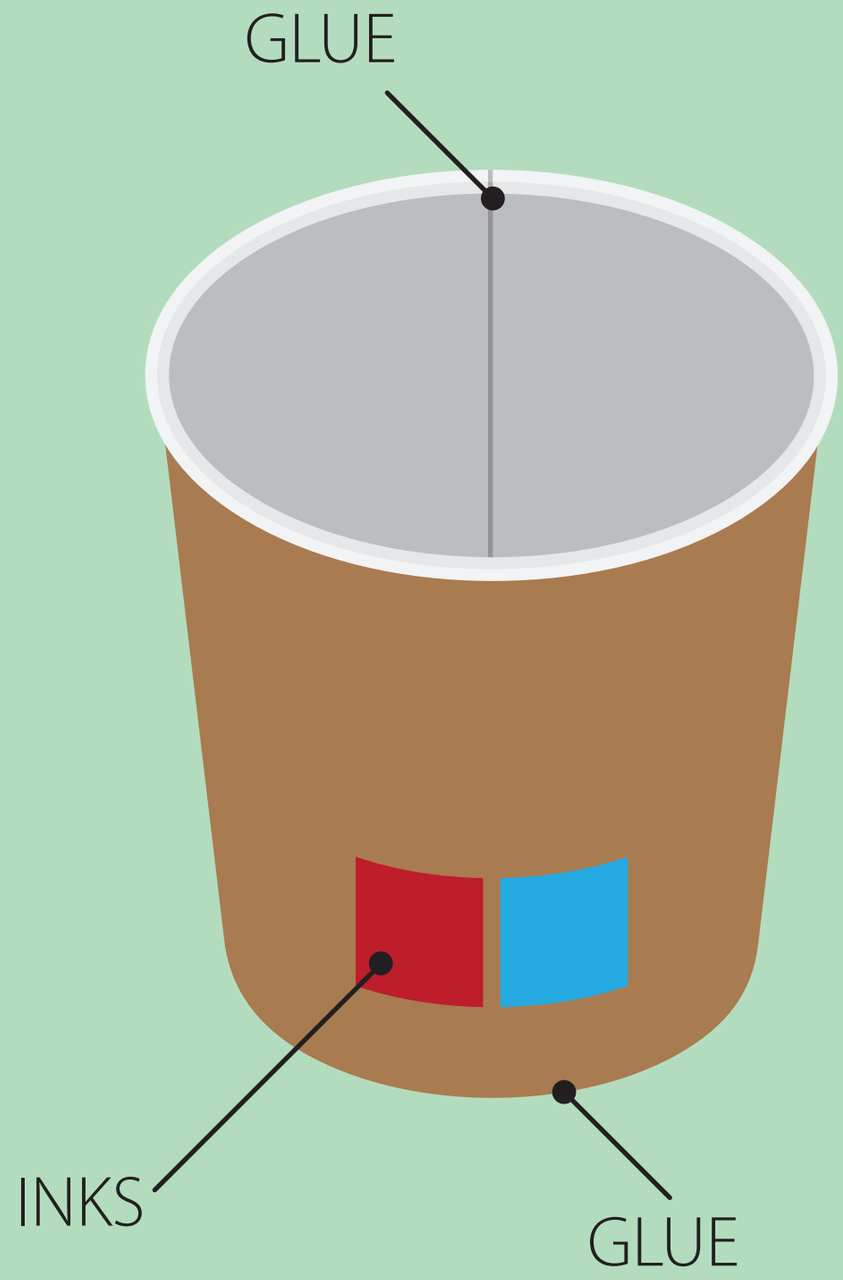
~Approximately 52% of commercial and industrial packaging;
about 3.8 Mt/year out of a total of about 7 Mt/year of commercial and industrial packaging.

~Approximately 22% of household packaging;
about 1.2 Mt/year out of a total of about 5 Mt/year of household packaging.

3/4 of these packaging materials are produced in France. The REVIPAC report, "The Paper-Cardboard Packaging Industry: Facts and Figures 2022," covers this French sector in detail.

ADHESIVE & INK





In addition to additives incorporated into the paper pulp, adhesives and inks play a role in the manufacturing of packaging. Starch (additivated with biocides like DBNPA) serves as adhesive in corrugated cardboard, whereas polyethylene serves, among other purposes, as a sealant in the cup. Inks are formulations based on pigments, a plastic binder, and additives such as surfactants

PART. 1

HIGHLIGHTS

- **PAPER AND CARDBOARD ARE MADE FROM CELLULOSE FIBERS;**

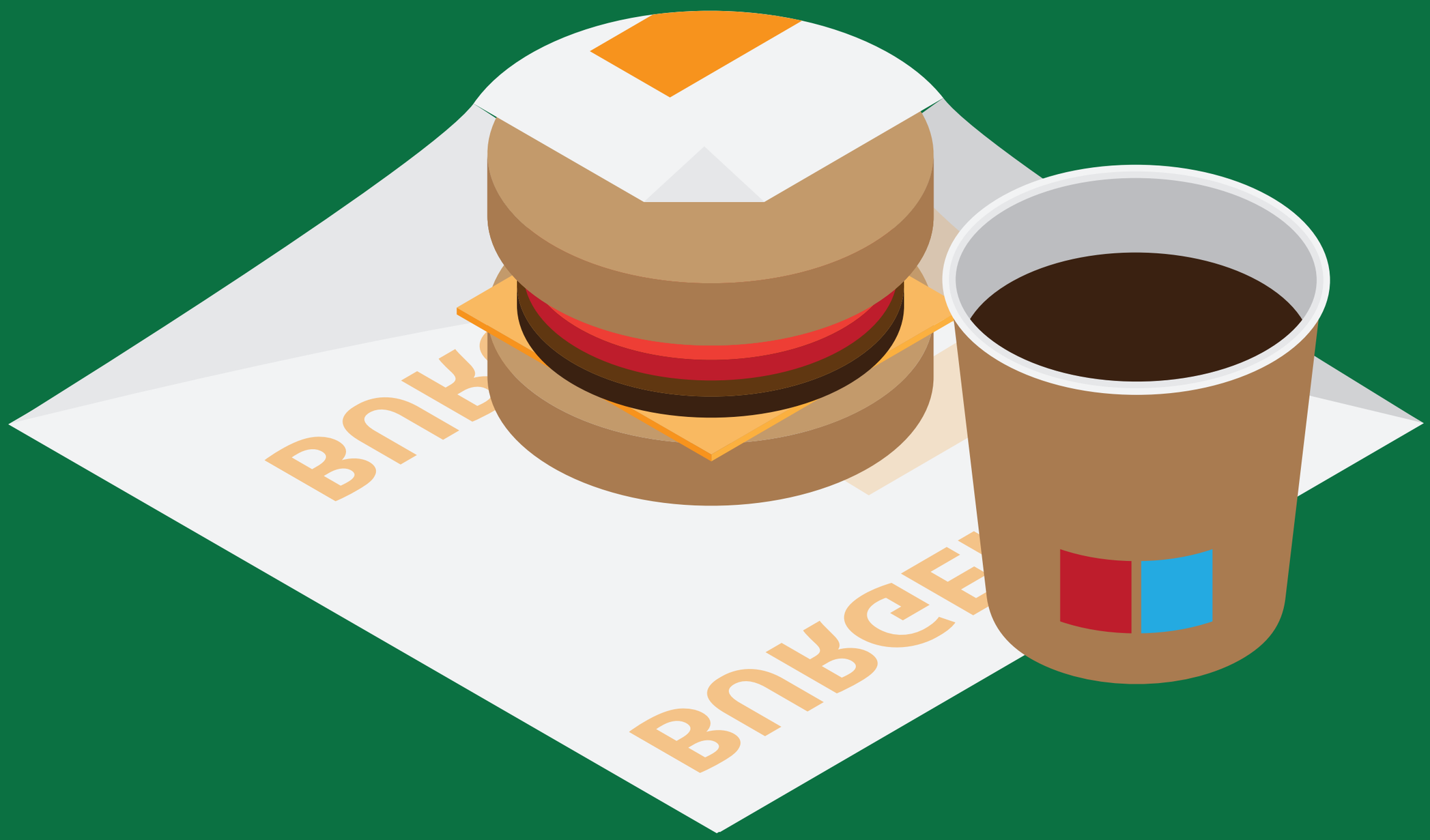
- **THE DIFFERENCE BETWEEN BOTH IS THE GRAMMAGE (THE SURFACE DENSITY), MEASURED IN GRAMS PER SQUARE METER (G/M^2);**

- **PAPER AND CARDBOARD ARE USED WITH ADDITIVE MATERIALS & ARE NEVER 100% NATURAL;**

- **IN PAPER/CARDBOARD, WE FIND NOT ONLY ADDITIVES, BUT ALSO ADHESIVES AND INKS.**

PART. 2

FUNCTIONALISATION OF PAPER AND CARDBOARD



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PART. 2 FUNCTIONALISATION OF PAPER AND CARDBOARD

Paper/cardboard remains porous, thus permeable to liquids and gases. Without advanced functionalisation, such as a water barrier function, a cardboard cup would not retain the beverage it contains.

The addition of barrier functions is the technical key to unlock the maximum use of paper/cardboard in primary packaging (in contact with food) and not just in secondary or tertiary packaging (grouping packaging).

Whereas the cup requires resistance to liquid water, dry ground coffee, which loses its aroma in the presence of oxygen and water vapor, requires a barrier to these elements for maximum preservation.

BARRIER FUNCTIONS

OXYGEN

CARBON DIOXIDE

NITROGEN

WATER VAPOR ----------→

WATER

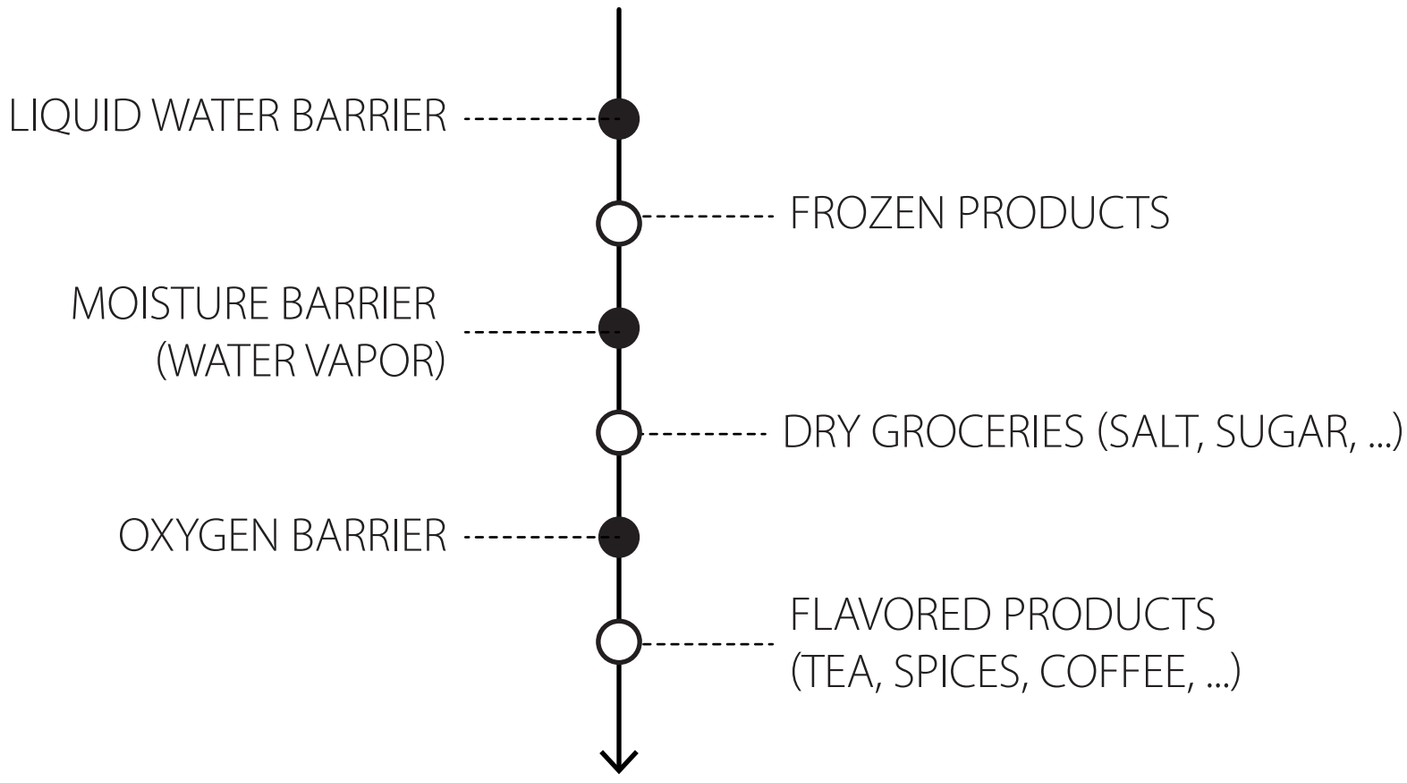
GREASES

LIGHTS (UV)

FLAVORS

Materials	WVTR* (g/m²-day)
Kraft	~1300
LDPE	~20
PVDC	~1

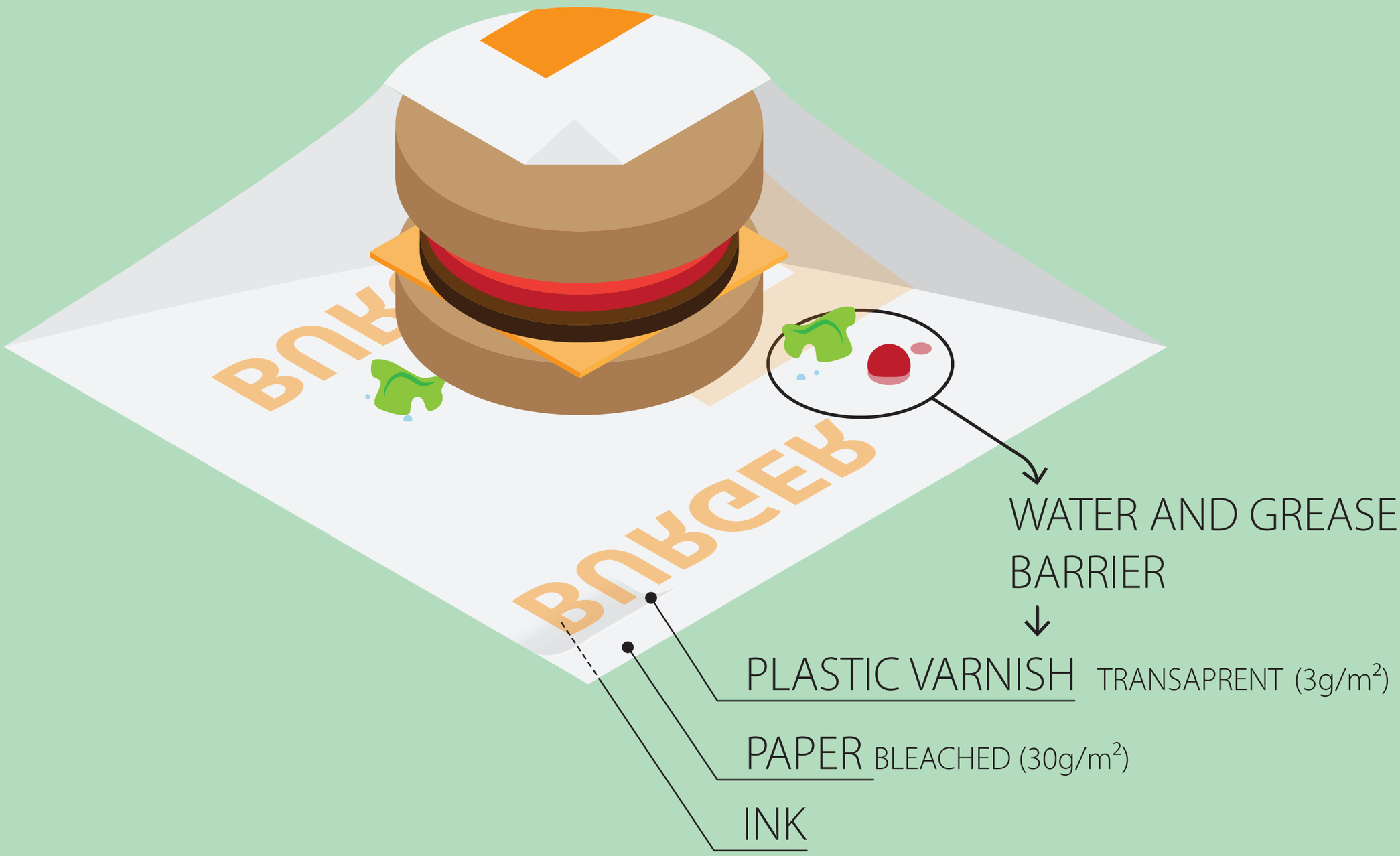
*The oxygen transmission rate (OTR) and the water vapor transmission rates (WVTR, mainly under standard conditions: 23°C - 50% humidity, or tropical conditions: 38°C - 90% humidity), are the primary indicators informing about the performance of the packaging material.



The choice of barriers and their effectiveness scales depend on the desired applications: packaging integrity (e.g., coffee cup) or food preservation (e.g., pouch of ground coffee). The duration and conditions of product storage dictate the need for effectiveness and thus the choice of barrier materials to be applied to papers/cardboards. For example, red meat needs partial oxygen permeability to remain bright red: a semi-permeable barrier is required. Potatoes need UV protection to prevent greening. Onions require semi-permeability to water vapor to avoid condensation in the packaging, etc

PART. 2 FUNCTIONALISATION OF PAPER AND CARDBOARD

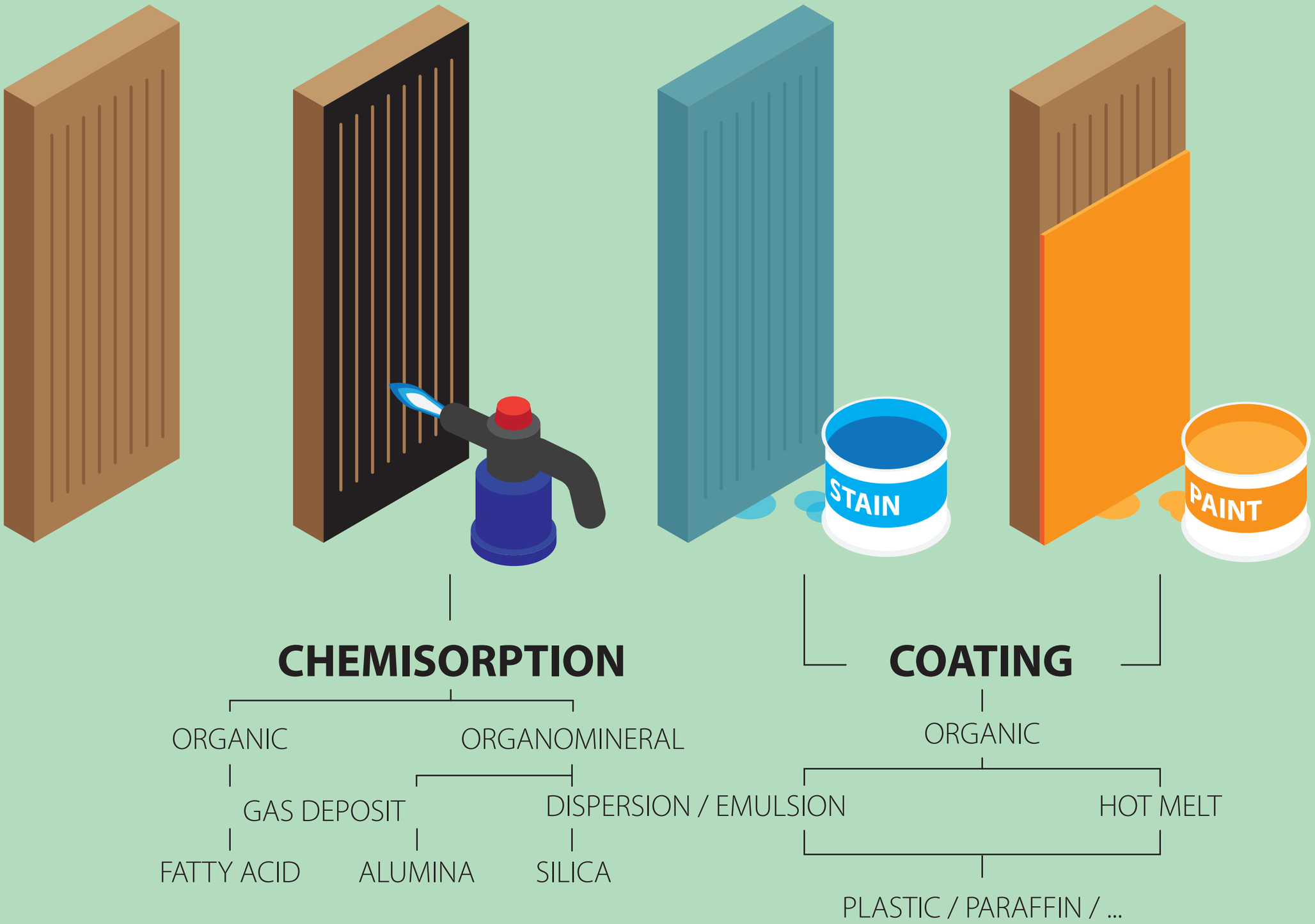
Plastic plays a major role in providing a barrier function to papers and cardboard. It's not the only family of materials that can do this: ceramic enamels, for example, protect clays, but it is the most common for packaging (plastic is low-cost and relatively easy to work with).



In this example, plastic represents ~10% of the weight of the packaging.
An example of a patent for food wrap paper at Mondi: 9797096

PART. 2. FUNCTIONALISATION OF PAPER AND CARDBOARD

A parallel with wood protection informs on how to categorise barrier layers for paper/cardboard.



Traditional coatings take advantage of the roughness of the paper to maintain physical cohesion. Chemical grafting modifies the paper surface.

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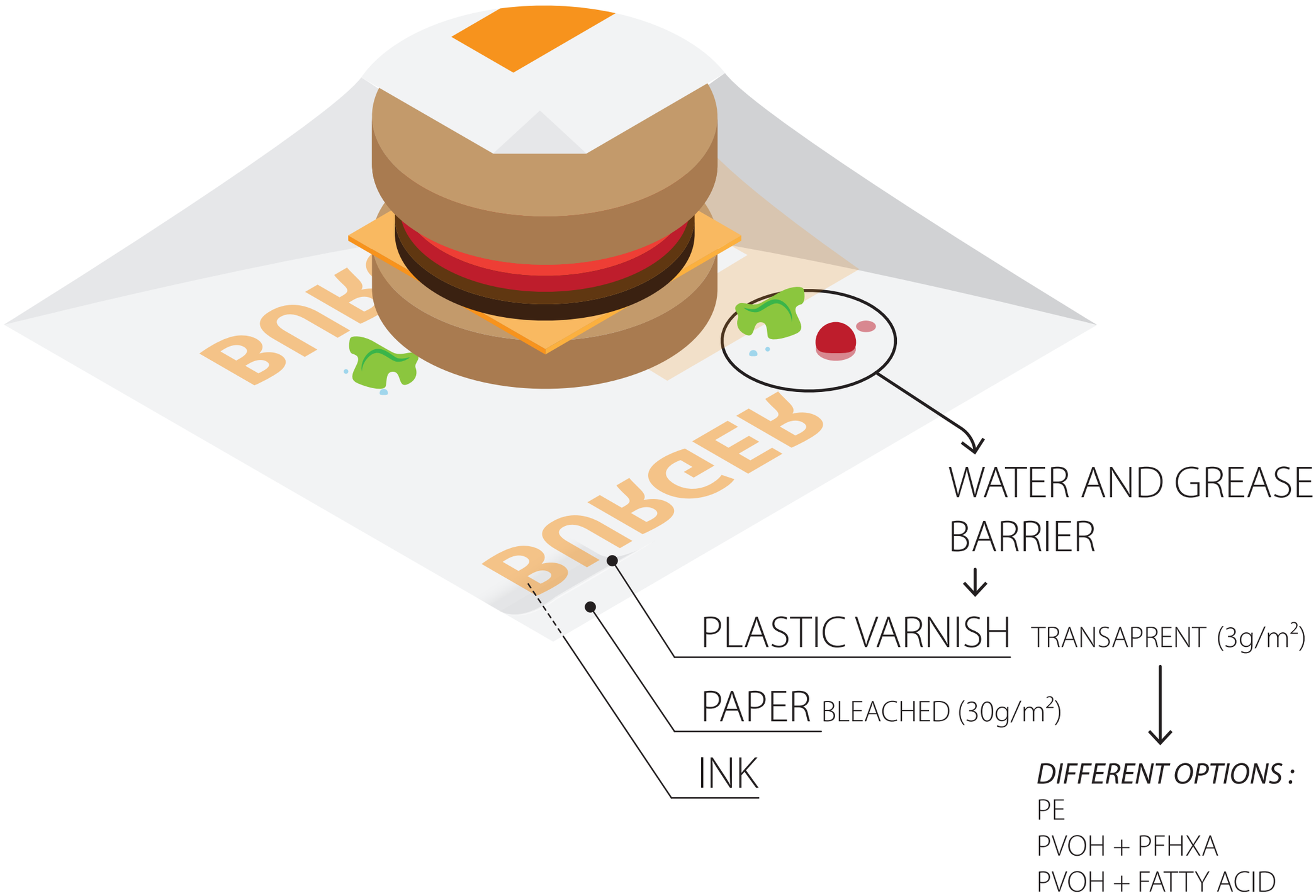
PART. 2 FUNCTIONALISATION OF PAPER AND CARDBOARD

The burger paper, which was coated with polyethylene, can be functionalised similarly through an aqueous emulsion of a greaseproof plastic: PVOH, and a surfactant that acts as a water barrier: perfluoro-n-hexanoic acid (PFAS - now prohibited). The same result is also achieved by PVOH coating followed by chemisorption of fatty acid onto the PVOH.



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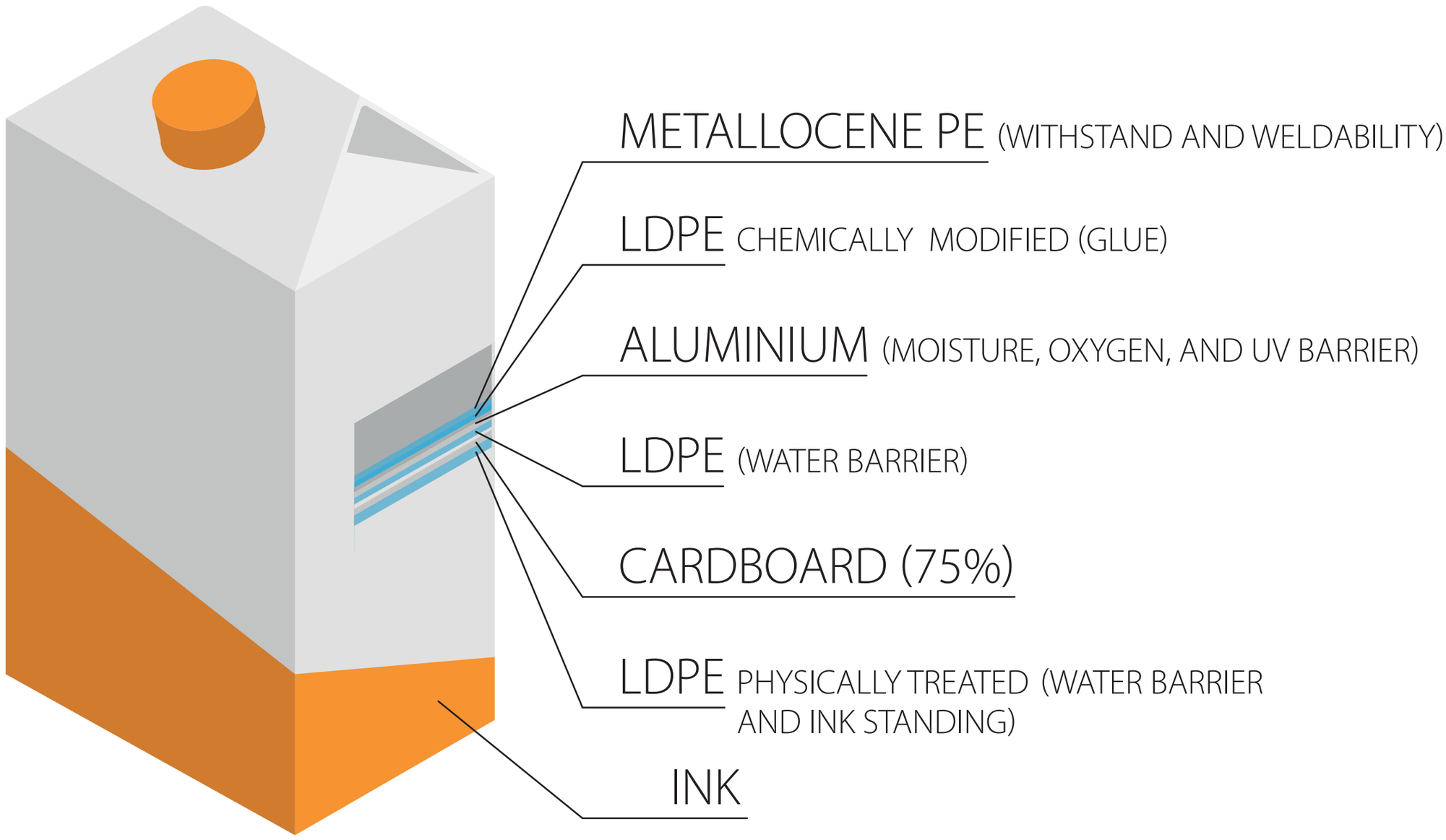

The most common functionalised papers contain multi-barrier materials, such as polyethylene which acts as a barrier to water and grease while also serving as a sealant, or aluminum which acts as a barrier to water vapor, oxygen, and UV rays.

PART. 2

HIGHLIGHTS

- **PAPER AND CARDBOARD REQUIRE BARRIER FUNCTIONS WHEN USED FOR PACKAGING;**

- **IN PACKAGING, PAPER AND CARDBOARD ARE BROADLY FUNCTIONALISED WITH PLASTIC;**

- **OTHER FUNCTIONALISING MATERIALS SUCH AS CERAMICS ARE NOT YET INDUSTRIALISED ON A LARGE SCALE.**

PART. 3

HOTMELT LAMINATIONS

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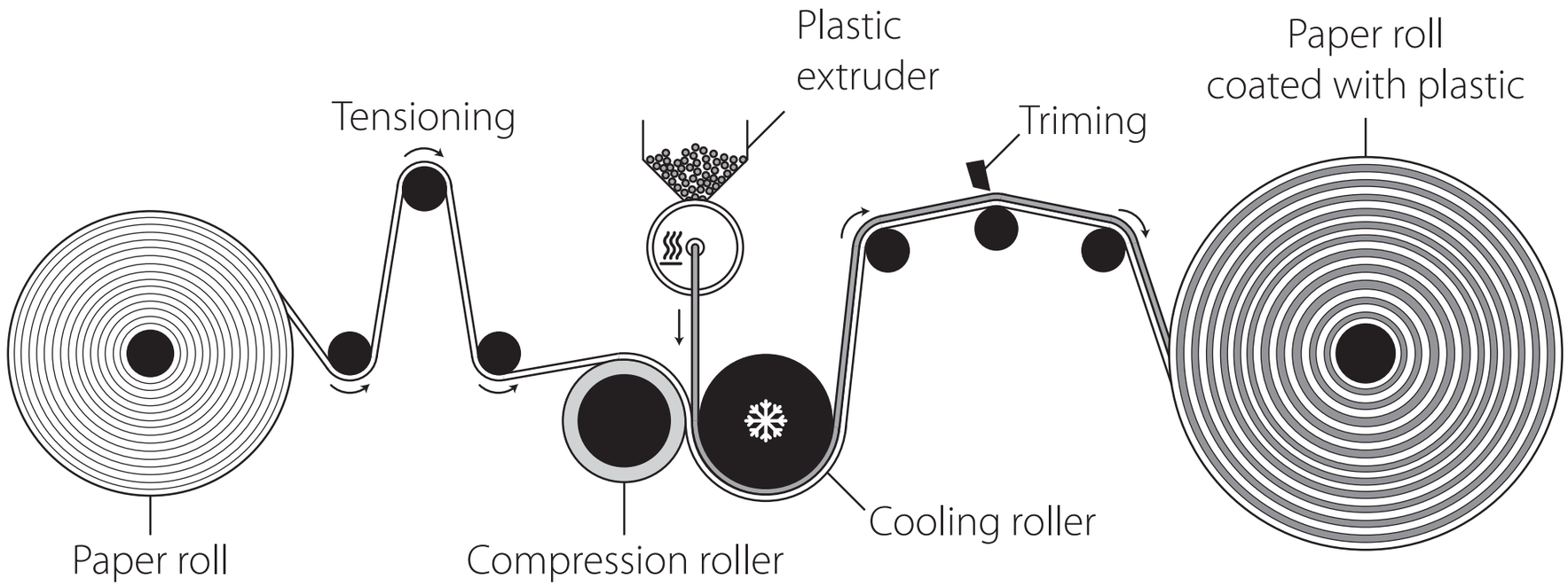
PART. 3 HOTMELT LAMINATIONS

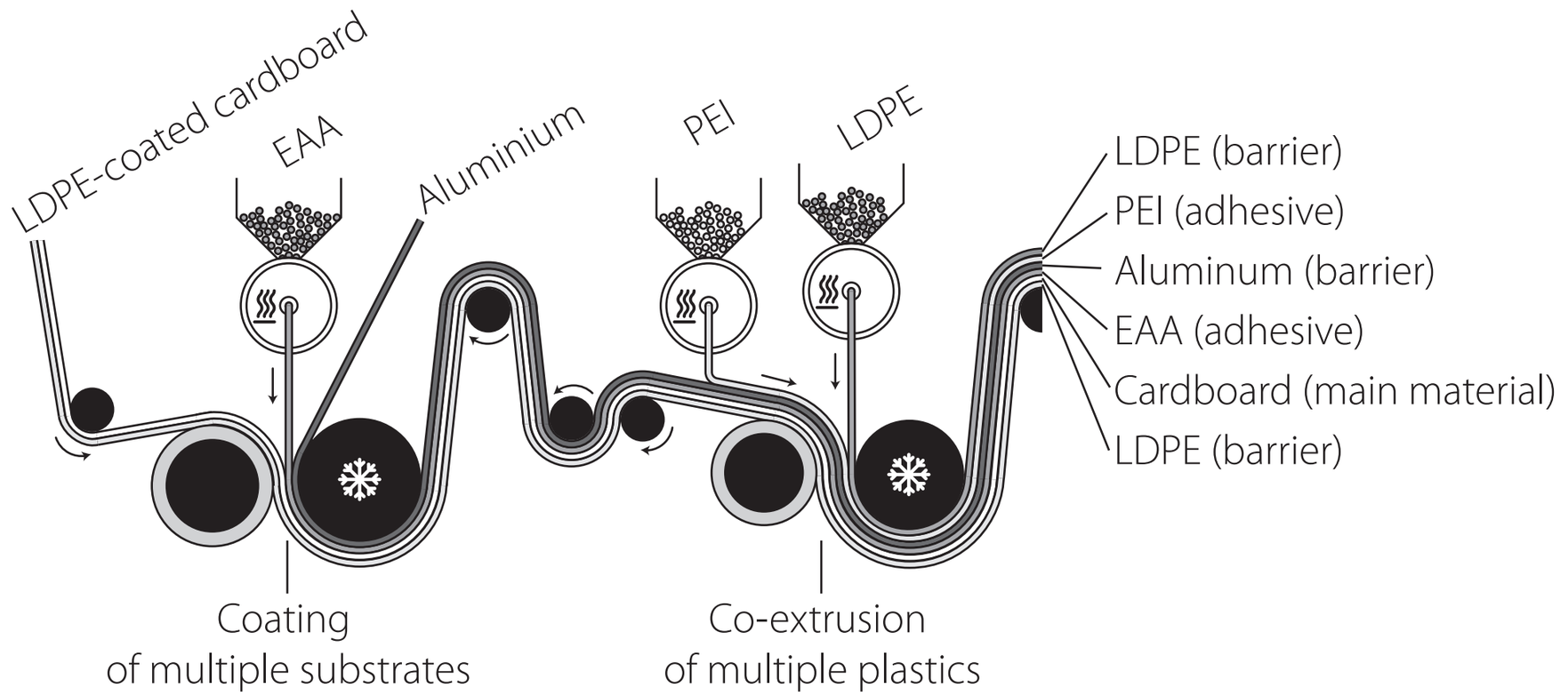
The paper/cardboard pulp, in the form of jumbo rolls, which once unwound spans several kilometers in length, is continuously coated with melted plastic(s) before being shaped for packaging (printing, cutting into smaller width or length, folding, heat sealing, filling, etc.).



For proper adhesion, the paper is heated, and the molten plastic is kept sufficiently distant to allow oxidation upon contact with the air. The use of ozone accelerates oxidation. Polyethylene producer Qenos provides more details in its freely accessible technical guides, such as No. 4: Extrusion Coating and Lamination.

PART. 3 HOTMELT LAMINATIONS

The coated paper/cardboard pulp can be coated again until the completion of all layers providing the necessary barrier functions for its packaging role. Multiple substrates can be coated at once, such as paper and aluminum, and several plastics can be molten simultaneously during co-extrusion to limit the number of coating steps.



The choice of adhesive plastics depends on the layers to be bonded. For instance, ethylene-acrylic acid (EAA) copolymers have excellent adhesion to both paper and aluminum. The composite roll will undergo additional treatments such as corona treatment for printing.

PAPER/CARDBOARD COATED WITH MOLTEN PLASTIC

- WITHOUT O_2 BARRIER -------- CASE N°1
- WITH O_2 BARRIER
  - WITH ALU
  - WITHOUT ALU -------- CASE N°2
    - BIODEGRADABLE
      - CASE N°3

PART. 3 HOTMELT LAMINATIONS

The paper is functionalised with a plastic layer (~5-7%) coated in a molten state. This same layer enables the sealing of the bag.

CASE N°1

SILICONE

PLASTIC COATING (10g/m²)

- LOW-DENSITY POLYETHYLENE

FLEXIBLE PAPER FILLED & SMOOTHED (120g/m²)

- KAOLIN PARTICLES
- CALCIUM CARBONATE PARTICLES
- PLASTICIZED STARCH BINDER

INKED VARNISH

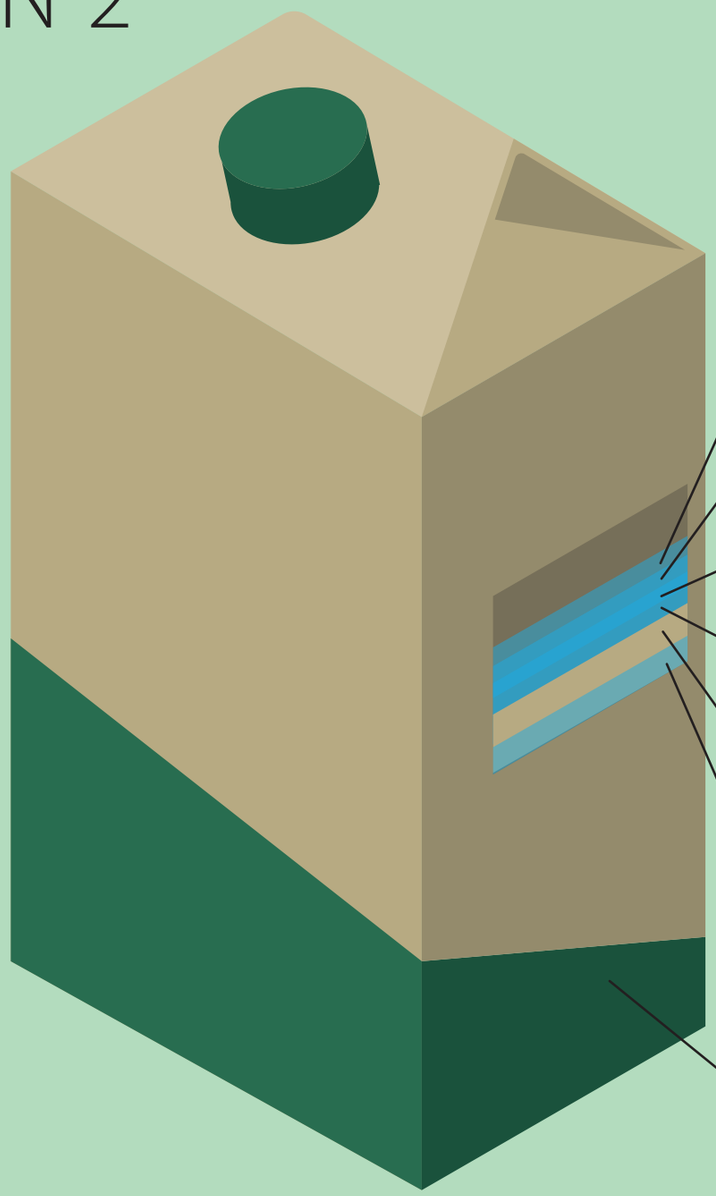
- NITROCELLULOSE (PLASTIC)
- ETHYL LACTATE SOLVENT (EVAPORATED)
- PIGMENTS

Example of a patent for packaging at Mondi: 20220403602

PART. 3 HOTMELT LAMINATIONS

A coating of EVOH, possessing a very low oxygen transmission rate, replaces the layer of aluminum. EVOH loses its barrier properties in the presence of humidity, so it needs to be combined with Nylon, chosen both for its barrier effect against water vapor and its good adhesion to EVOH in industrial processes (no need for additional glue).

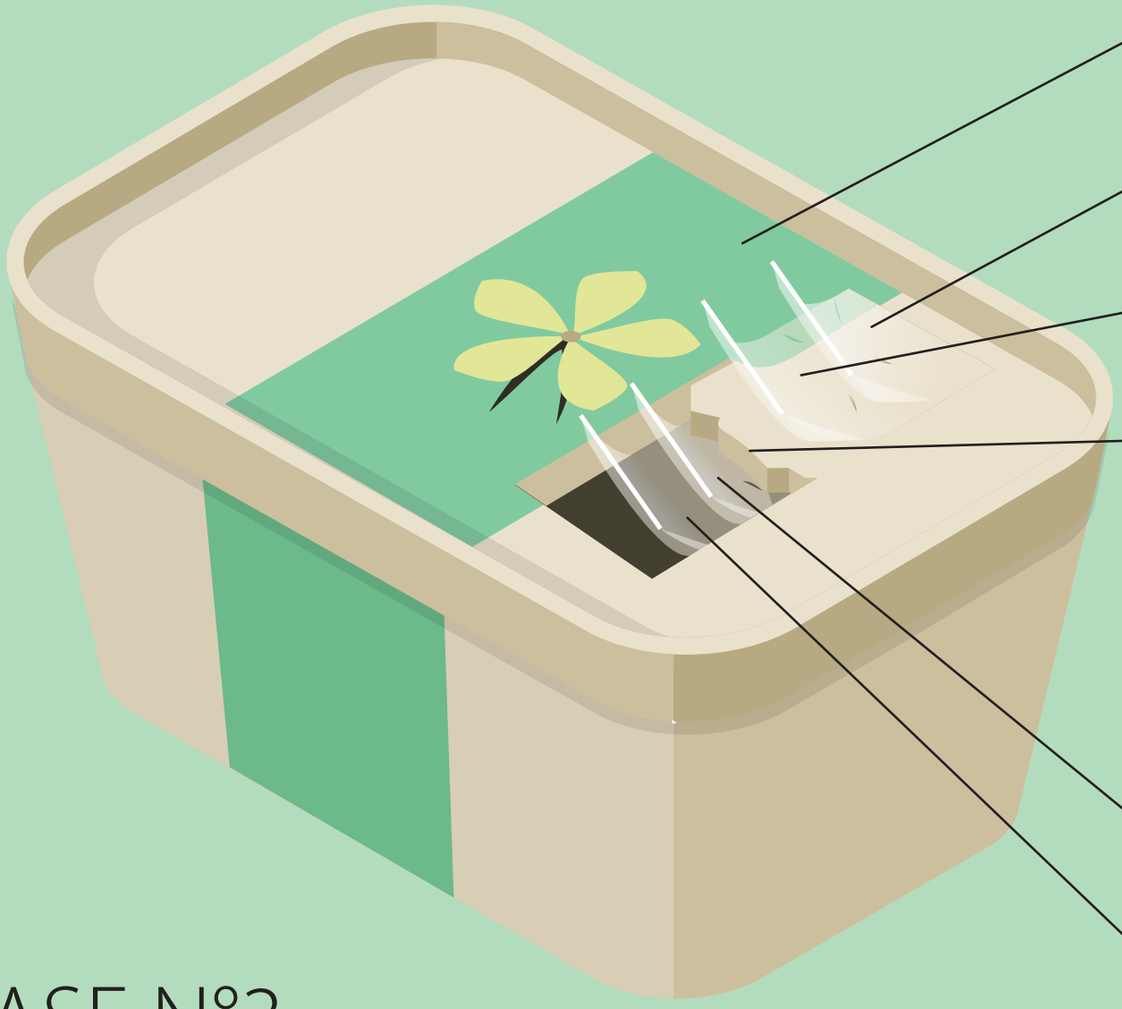
CASE N°2



This type of beverage paper cardboard is developed, for example, by SIG with its SIGnature EVO range.

PART. 3 HOTMELT LAMINATIONS

Biobased and biodegradable plastics, such as PLA, replace fossil-based plastics in the functionalisation of paper/cardboard. PLA is co-coated with a stickier plastic to adhere well to the cardboard and a more flexible plastic in negative temperatures (PBAT) for better resistance.



CASE N°3

INKED VARNISH

PLA OUTER COATING (5g/m^2)

CO-POLYESTER ADHESIVE (5g/m^2)

CARDBOARD (225g/m^2)

ADDITIVATED AND SMOOTHED FOR COATING/PRINTING

- KRAFT (20%)
- THERMOMECHANICAL PULP (60%)
- KRAFT (20%)

CO-POLYESTER ADHESIVE (5g/m^2)

PBAT (40%)/PLA(60%) (15g/m^2)

BARRIER TO WATER, WATER VAPOR, AND OXYGEN

An example of a patent application for Cupforma Dairy 2Bio at Stora Enso: 20220403602. An example of a patent for bioplastic coating at Stora Enso: WO20000001530.

PART. 3

HIGHTLIGHTS

- **DIFFERENT PLASTICS PROVIDE DIFFERENT BARRIER PROPERTIES TO PACKAGING;**
- **APPART THEIR BARRIER EFFECTIVENESS, SOME PLASTICS ARE COMBINED WITH OTHERS TO INCREASE RESISTANCE, ADHESION, ETC.**

PART. 4

DISPERSIVE & EMULSIVE COATINGS

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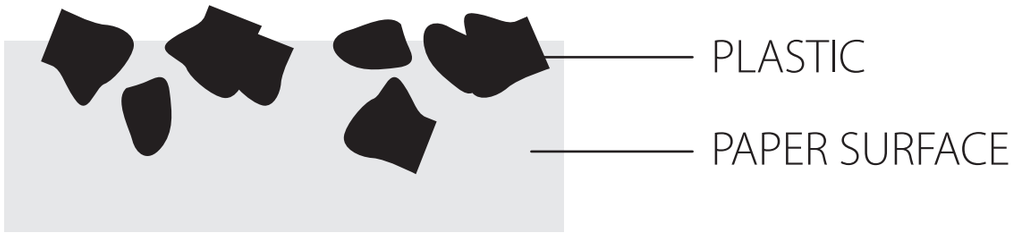
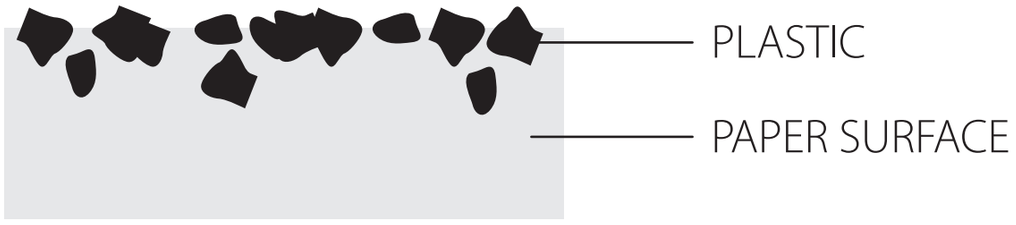
PART. 4 DISPERSIVE AND EMULSIVE COATINGS

Coatings where the plastic is mixed in a solvent rather than melted help reduce the amount of plastic providing barrier functions. This liquid solvent, coated on the paper, leaves a thin layer of plastic once evaporated. The plastic can be dispersed and micro-dispersed (in solid form in the solvent - colloidal dispersion). The plastic-forming reactants can be in emulsion (in liquid form in the solvent) and then polymerized in the solvent: emulsion-dispersion.

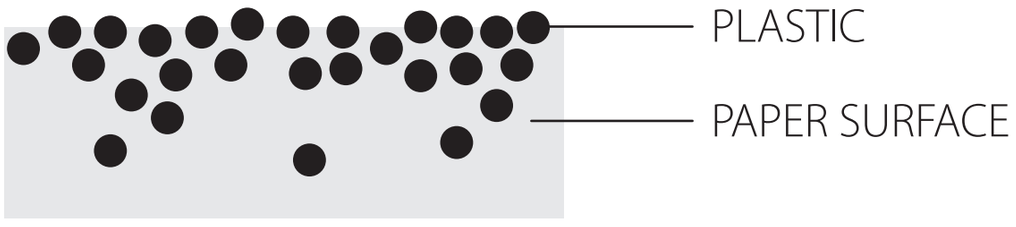
DISPERSION



MICRO DISPERSION



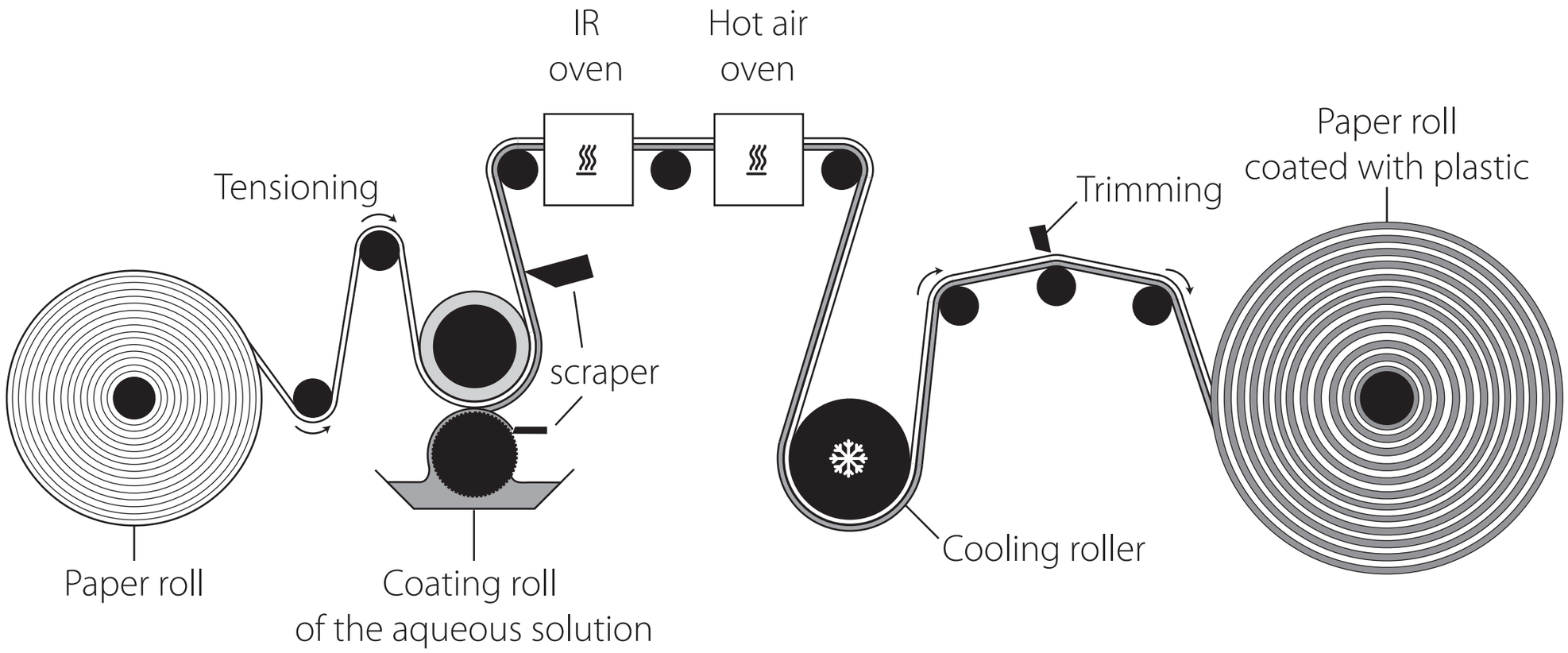
EMULSION-DISPERSION



Water-based emulsion dispersions (when water is the solvent) are the most commonly used to avoid the use of volatile organic solvents. However, most plastics are not soluble in water, so this approach is not industrially straightforward.

PART. 4 DISPERSIVE AND EMULSIVE COATINGS

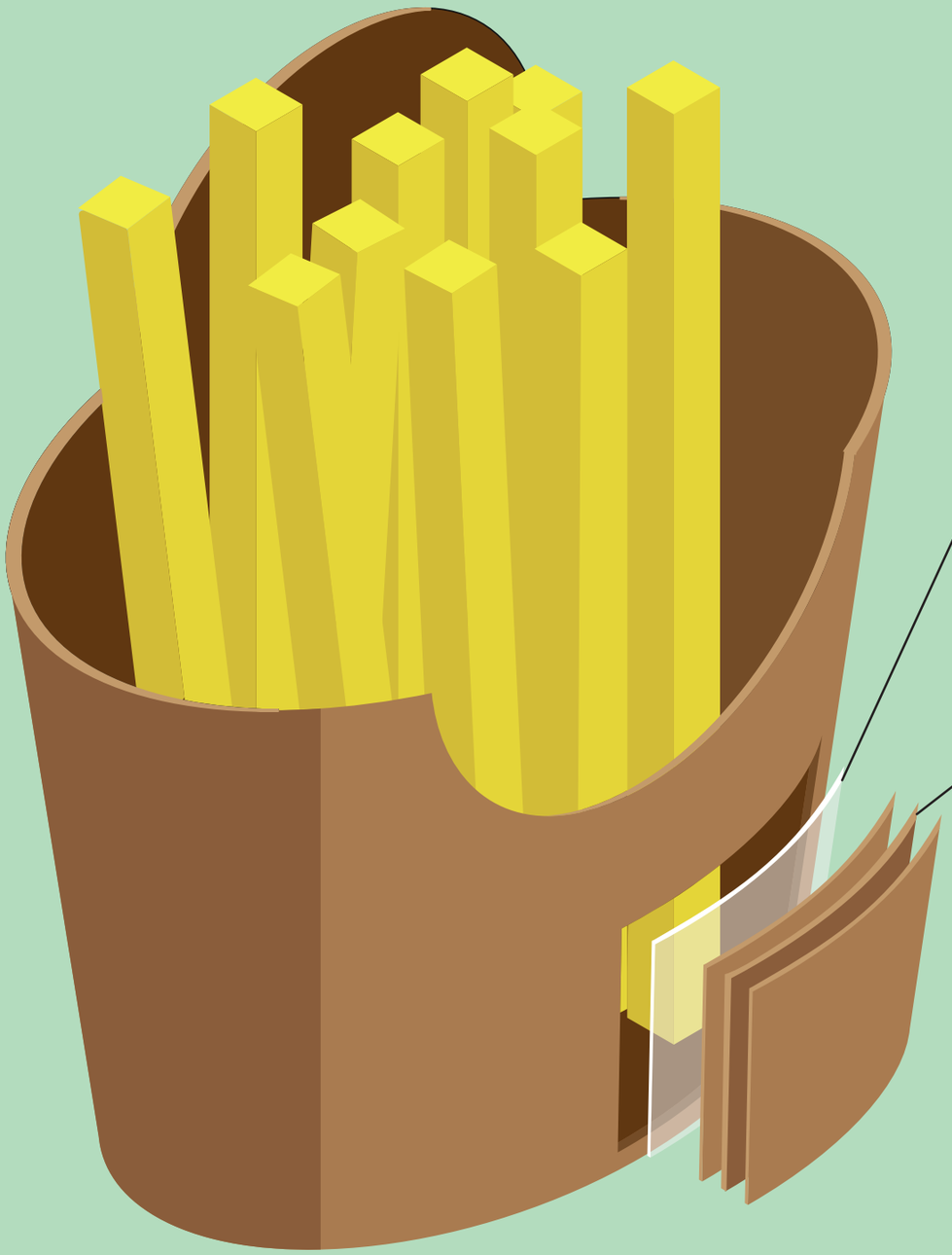
The jumbo roll of paper/cardboard pulp is continuously coated with plastic(s) dispersed in water-based solution before being shaped for packaging (printing, cutting into smaller width or length, folding, thermo-sealing, filling, etc.).



Like with hotmelt lamination, paper/cardboard pulp can be coated multiple times with emulsion-dispersion on one or both sides. The proper adhesion of the emulsion-dispersion depends on its viscosity, substrate porosity, and other parameters important to control.

PART. 4 DISPERSIVE AND EMULSIVE COATINGS

The cardboard is functionalised with a plastic layer coated in the form of an aqueous emulsion-dispersion. The dispersion is based on synthetic rubber, the styrene-butadiene copolymer (~3% of the cone), which provides a barrier against liquids and grease.



PLASTIC VARNISH (15 g/m²)

STYRENE-BUTADIENE COPOLYMERS ~45%
MICROCELLULOSE ~20%
CALCIUM CARBONATE ~5%
CARNAUBA WAX ~30%
ADDITIVES (AKD) ~0.01%

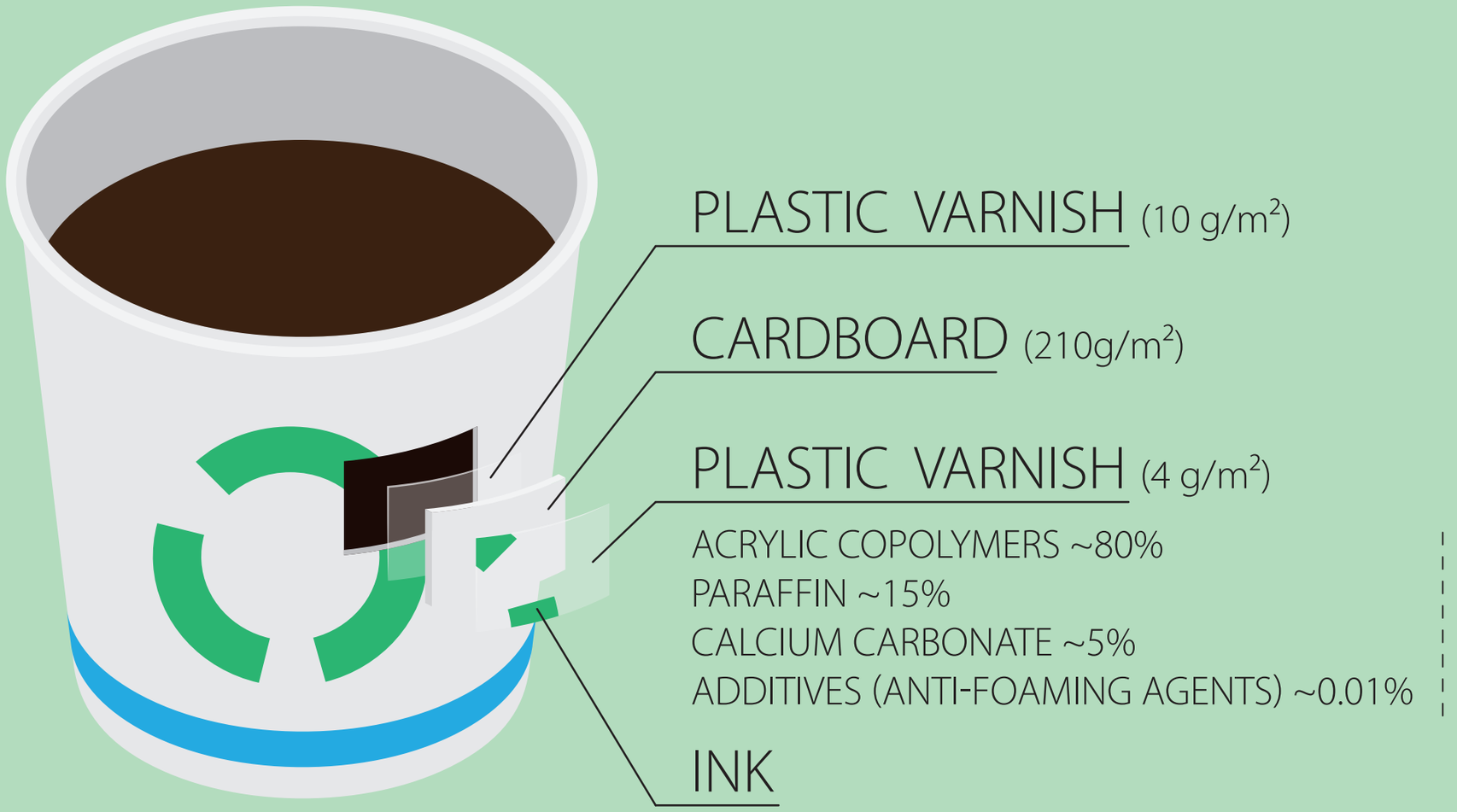
CARDBOARD (210 g/m²)

UNBLEACHED KRAFT
UNBLEACHED THERMOMECHANICAL PULP
UNBLEACHED KRAFT

The cardboard is multi-layered: the outer layers in kraft are more expensive than the inner layer in "thermo-mechanical" pulp, which is less solid. The patent for the CKB Nude Aqua from Stora Enso is WO2011056130A1.

PART. 4 DISPERSIVE AND EMULSIVE COATINGS

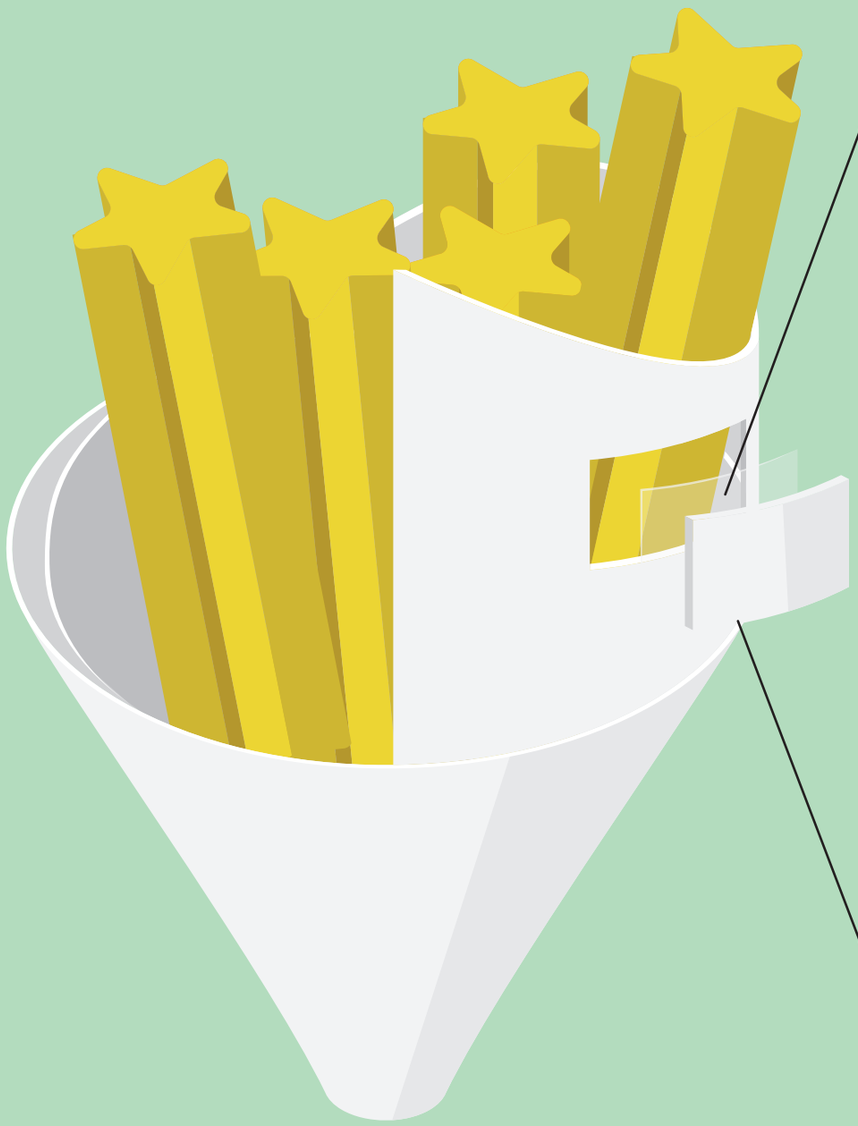
The cardboard is functionalised by a plastic layer coated in the form of an aqueous emulsion-dispersion. The emulsion is based on an acrylic resin (~5% of the cup) and provides a barrier against liquids and grease.



The patent for the EarthCup at CEE Schisler is FR3071190B1.
The patent for the Sunstar emulsion at SunChemical is WO2018200783.

PART. 4 DISPERSIVE AND EMULSIVE COATINGS

For thin papers, the amount of plastic could remain low (~4% of the packaging) thanks to the encapsulation of oil in the form of micro-droplets (its industrialization need to be verified). The porosity of the paper is limited by using fillers as well as a mixture of long and short fibers.



PLASTIC VARNISH (7 g/m²)

Binder and fillers (2/3) + water (1/3)

- OLIVE OIL (18%) & SOYBEAN OIL (18%) ENCAPSULATED IN A STYRENE MALEIC ANHYDRIDE COPOLYMER (<2%)
- PVOH (7%)
- STARCH(5%)
- STYRENE ACRYLATE COPOLYMER (14%)
- PARAFFIN (2%)
- ADDITIVES (2.5%) - e.g., dispersing agent
- TALC (20%)
- TITANIUM DIOXIDE (2.5%)
- KAOLIN (9%)

PAPER (35 g/m²)

- PAPER PULP (48% SPRUCE FIBERS AND 44% BIRCH FIBERS)
- TITANIUM DIOXIDE (7,5%) BLEACHING AGENT
- AKD (0,5%) SIZING AGENT

The Delfort patent for "wrap" papers: WO2016102094A1.

PART. 4

HIGHLIGHTS

- **THE PLASTIC IS NOT NECESSARILY MELTED ONTO THE PAPER;**

- **WATER-BASED EMULSION-DISPERSIONS OFFER BARRIER PROPERTIES WITH A LOW PERCENTAGE OF PLASTIC;**

- **THE FUNCTIONALISATION OF PAPERS AND CARDBOARDS DEPENDS ALMOST EXCLUSIVELY ON PLASTIC.**

PART. 5

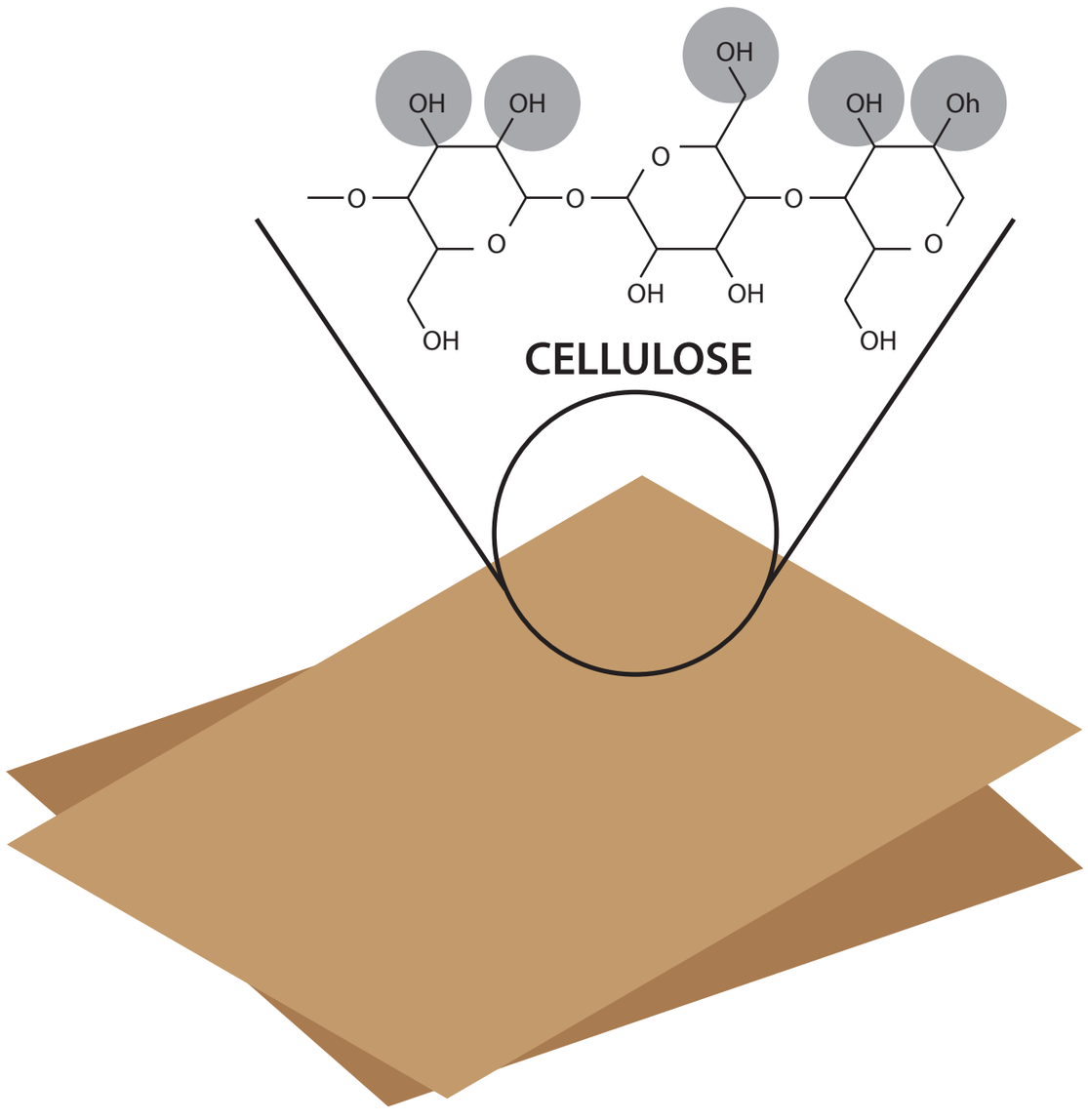
INTRODUCTION ON CHEMISORPTION

Functionalisation Of Paper And Cardboard Report - Feb 2024

M. ♻ Mme RECYCLAGE

PART. 5 CHEMISORPTION

Obtaining barrier function is achieved by chemically reacting the surface of the paper with hydrophobic, oleophobic, or gas-impermeable molecules. In doing so, the amount of material needed to functionalise the paper/cardboard can be significantly lower than coatings.



The weldability conferred by plastic barriers is lost. For 3D packaging "without plastics" and without additional adhesives, chemical grafting does not allow for subsequent sealing.

PART. 5 CHEMISORPTION

Apart from folded paper/cardboard packaging without adhesive, 3D packaging is obtained through cellulose molding: the paper pulp is directly molded into the shape of the packaging.

Without functionalisation, packaging is not waterproof and greaseproof. Molded cellulose is found, for example, in egg cartons or cup holders. Without subsequent sealing, the depth and shapes of the packaging are limited for technical reasons: it is impossible, for example, to create a completely waterproof vertical beverage paper cardboard.

PART. 5 CHEMISORPTION

To date, fluorinated compounds (PFAS) provide grease barrier properties to folded paper/cardboard or molded cellulose packaging. AKD, in combination with other polymers like PAE (Polyamideamine - epychlorohydrin), blocks water. Chemical grafting of cellulose could potentially limit the use of PFAS (persistent pollutants)

MOLDED PULP

- BLEACHED BAGASSE CELLULOSE (96%)
- AKD (1,5%)
- PAE (PLASTIC) (1%)
- CATIONIC STARCH (0,5%)
- PFPE (PLASTIC-PFAS) (1%)

Example of a patent for PFAS in paper by Solvay: EP1273704A1
Scientific article on the use of PAE and CS: Improving Mechanical Strength and Water Barrier Properties of Pulp Molded Product by Wet-End Added Polyamide Epichlorohydrin/Cationic Starch, Qin & al.

PART. 5

HIGHLIGHTS

- **SEALABILITY REMAINS AN ESSENTIAL FUNCTION OF MATERIALS FOR A NUMBER OF PACKAGING APPLICATIONS;**
- **CHEMICAL GRAFTING OFFERS AN ALTERNATIVE TO PLASTIC COATINGS FOR PACKAGING THAT DOESN'T REQUIRE SEALING;**
- **INDUSTRIALISING CHEMICAL GRAFTING COULD REDUCE THE USE OF PERPETUAL POLLUTANTS IN GRAFT-ELIGIBLE PACKAGING;**
- **THIS INDUSTRIALISATION WOULD DEPEND ON A FAVORABLE LEGAL FRAMEWORK, SUCH AS THE BAN OF PFAS IN PACKAGING.**

PART. 6

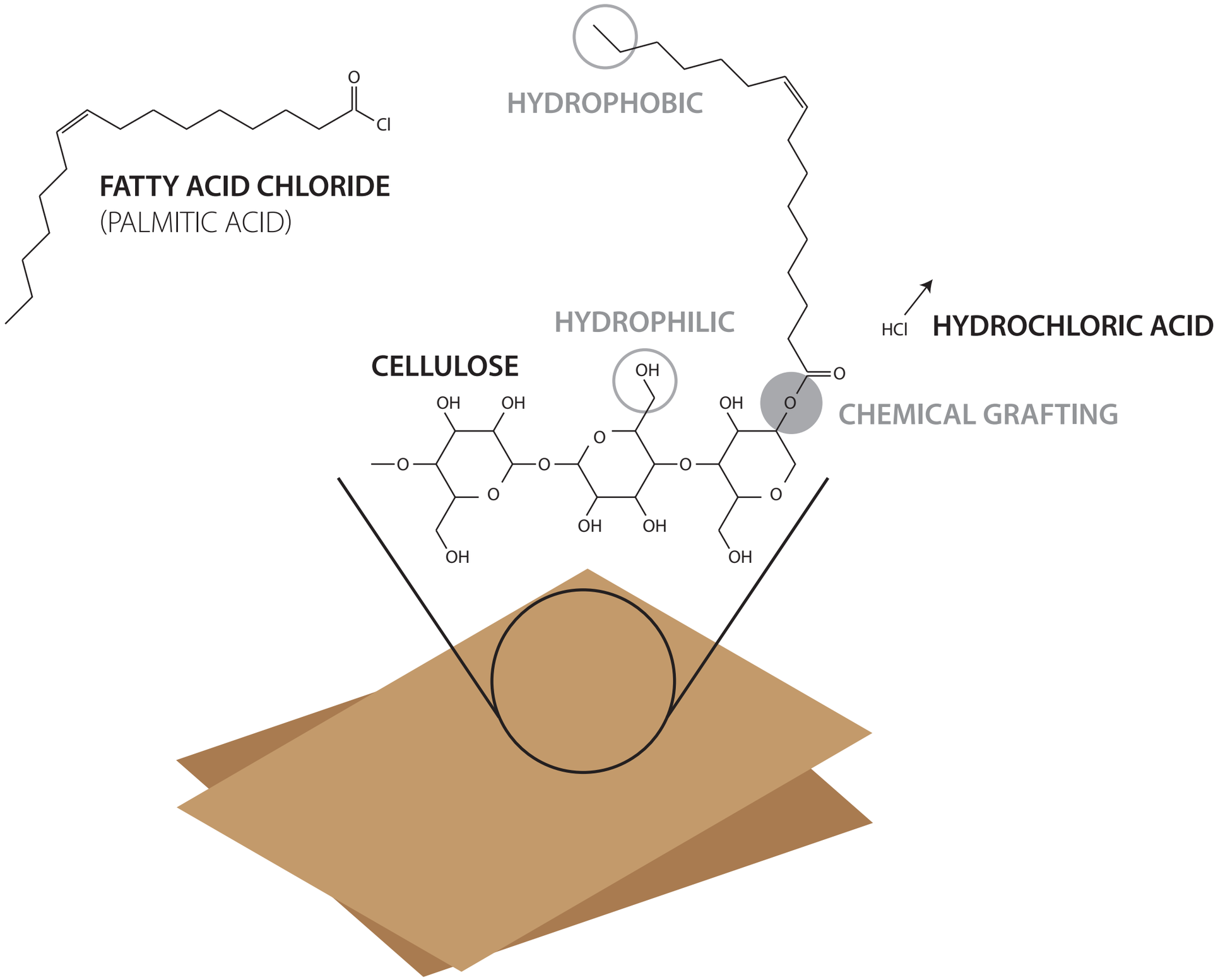
CHROMATOGENY

Functionalisation Of Paper And Cardboard Report - Feb 2024

M. ♻ Mme RECYCLAGE

PART. 6 CHROMATOGENY

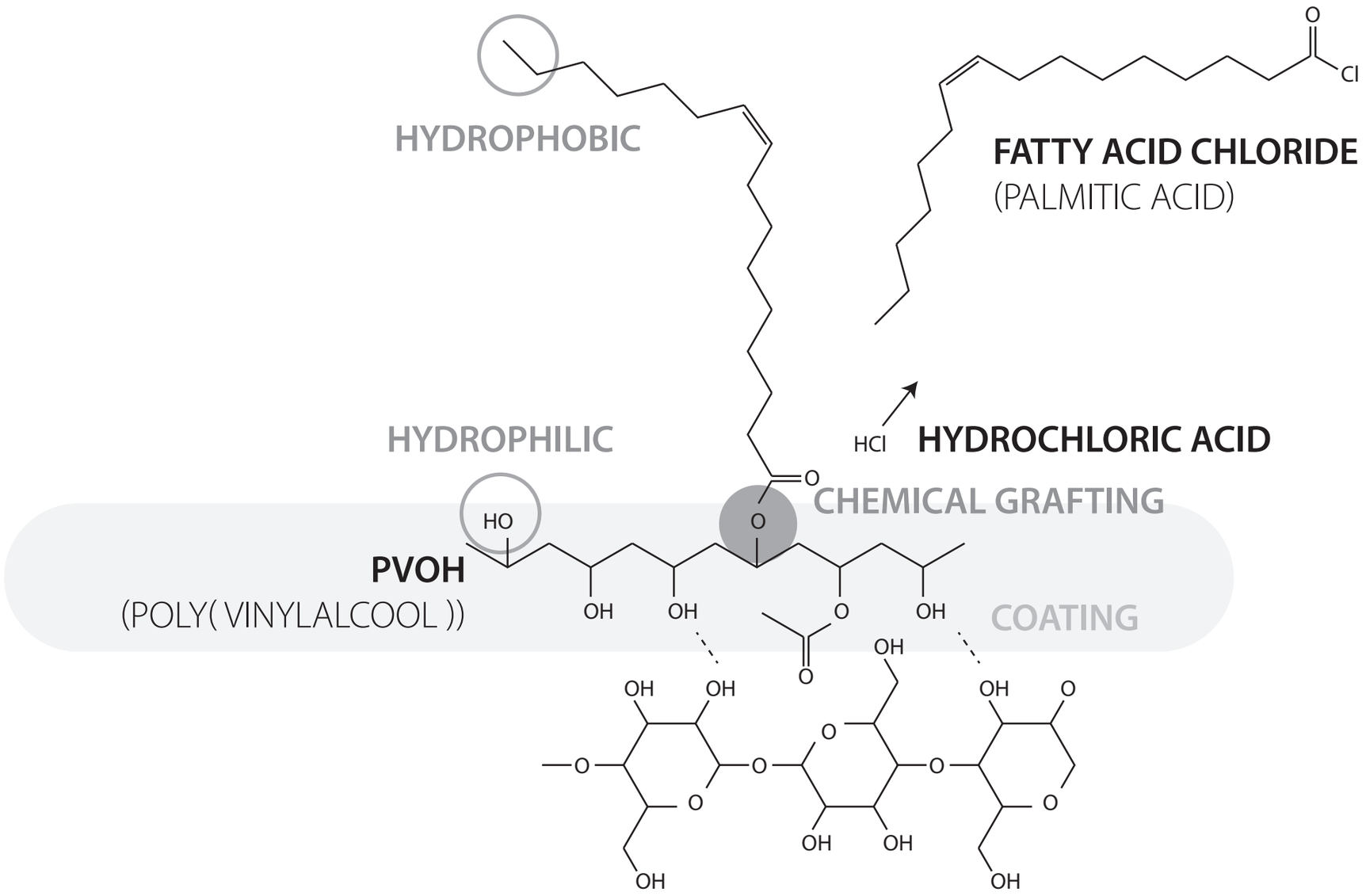
Cellulose is naturally hydrophilic. The water barrier function can be achieved by chemically reacting the hydrophilic part with fatty acid chlorides (stearic acid, palmitic acid, etc.). The fatty acid, grafted onto the cellulose, makes it hydrophobic: this is chromatogenic chemistry.



M. ♻ Mme RECYCLAGE

PART. 6 CHROMATOGENY

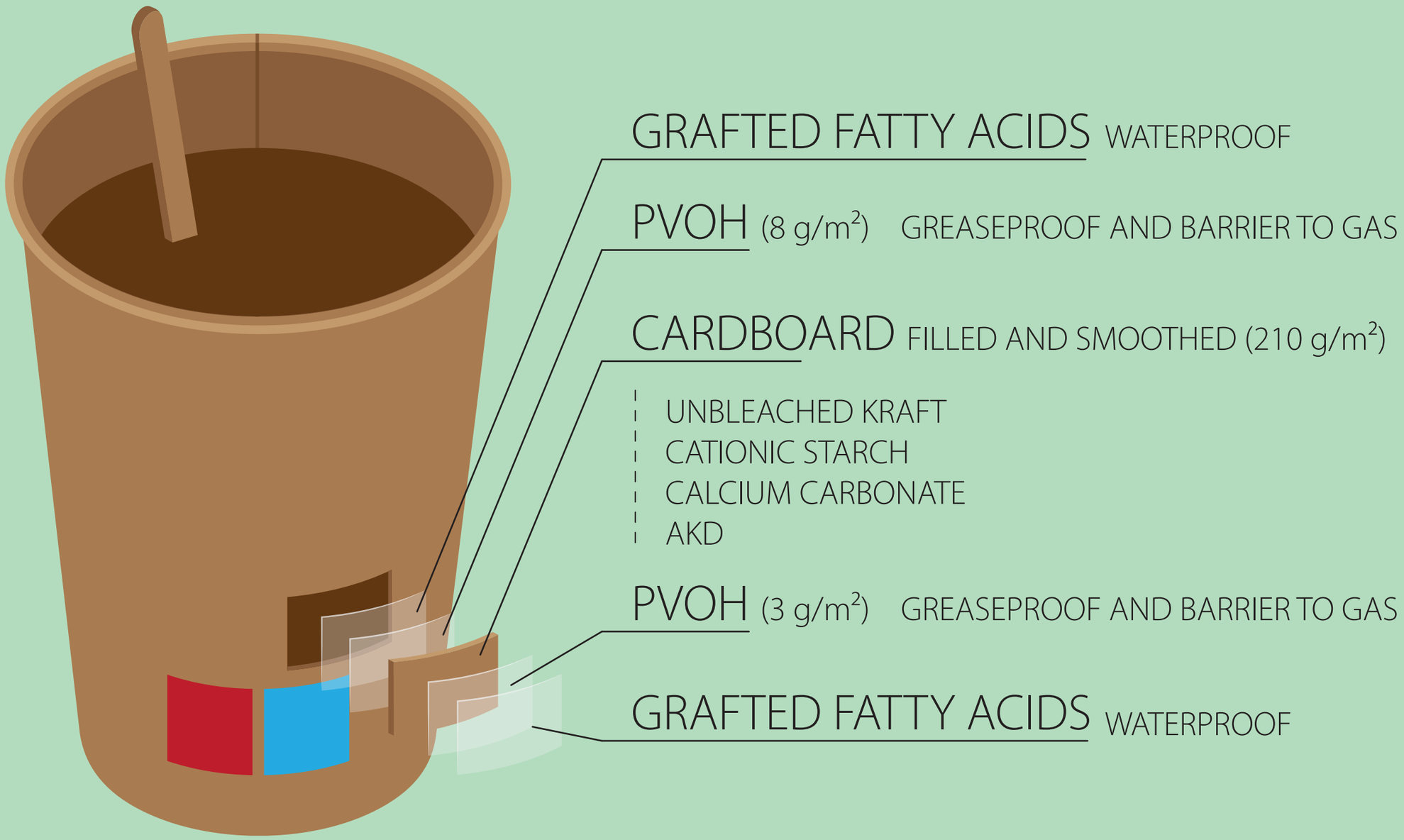
The grafted fatty acids do not provide barriers against greases or gases. A latte contains fatty substances (such as palmitic acid from the milk). A PVOH coating on the paper surface followed by a chemical grafting of fatty acid chlorides onto the PVOH provides all the desired barrier properties.



PVOH (Polyvinyl alcohol) is water-soluble and cannot be used alone for coating. However, unlike other coating plastics, its biodegradability in paper mill effluents has been proven. Although it is twice as expensive as PE (Polyethylene), it is an interesting alternative for limiting plastic pollution in paper mill sludge.

PART. 6 CHROMATOGENY

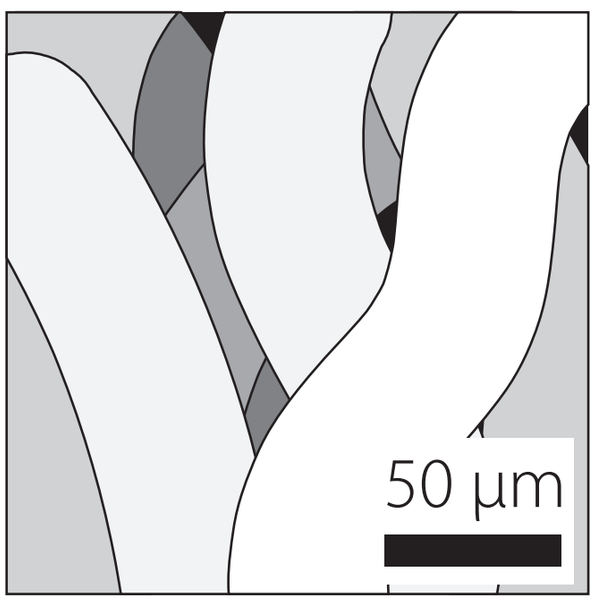
The chemisorption of PVOH coating reduces the amount of plastic by half (compared to a PE liner) while maintaining weldability. The food contact suitability required by the French Paper Technical Center in April 2023 has not yet been validated. The validation of new processes is lengthy and costly.



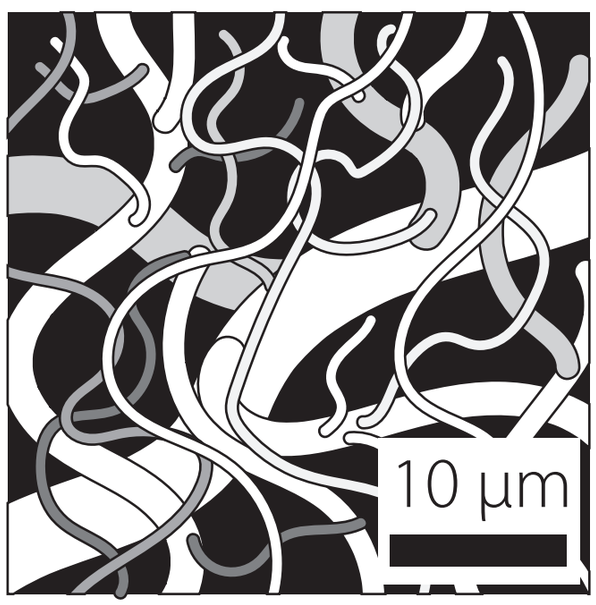
Many details about chromatogeny are provided in N.C. Stinga's thesis «Utilization of chromatogenic chemistry for the design and realization of cellulosic materials with barriers to water, fats, and gases.» University Joseph-Fourier - Grenoble I, 2008.

PART. 6 CHROMATOGENY

The use of microfibrillated cellulose (MFC) in coating could provide the paper/cardboard with the missing barriers to oxygen and grease to replace PVOH (in applications without welding). Once extracted from wood, the paper pulp undergoes an additional process to form a network of cellulose fibrils of quasi-nanoscale size:



Cellulose fibers
in the paper pulp

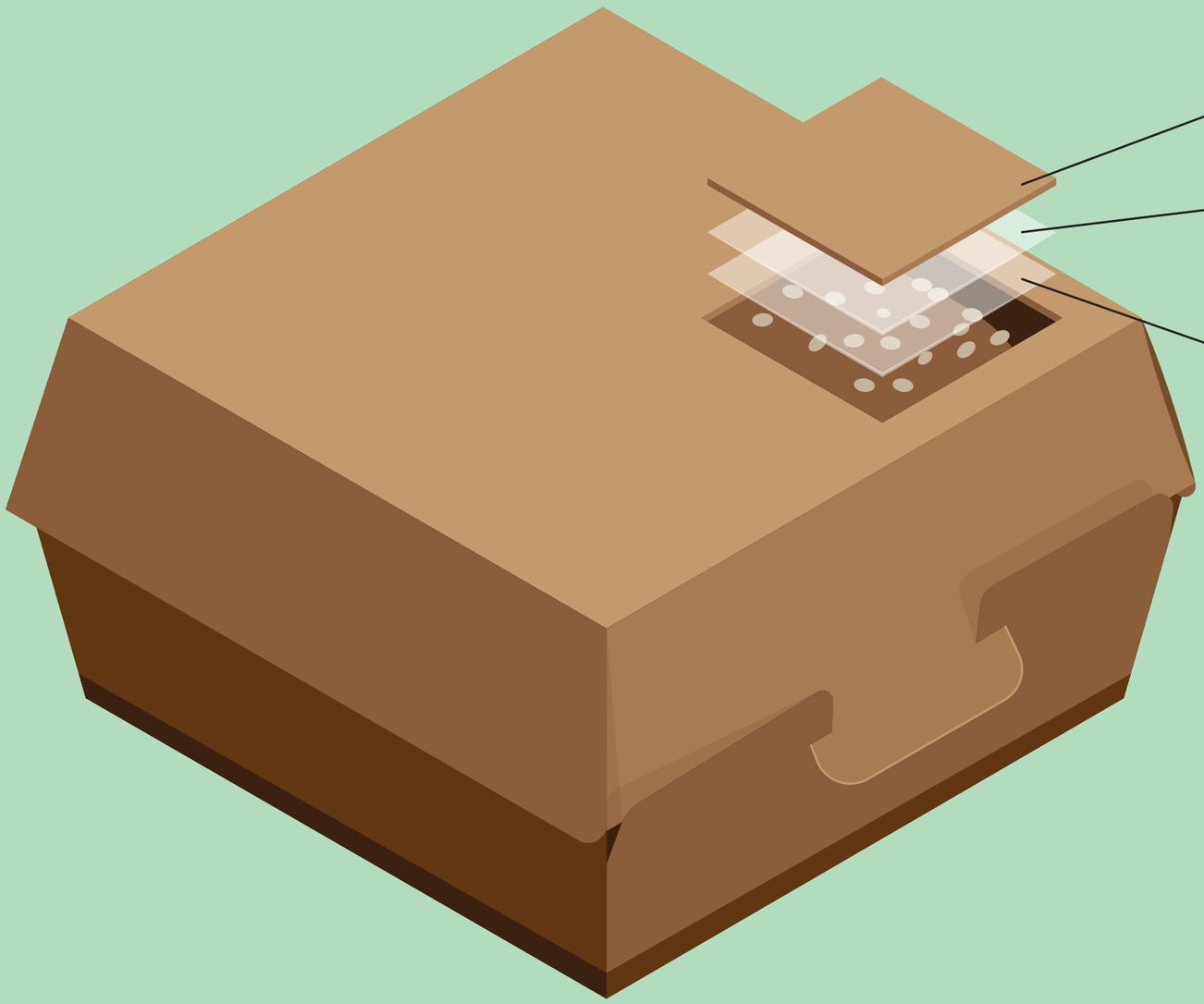


Microfibrillated
cellulose

The microfibrillated cellulose, suspended in water, is coated onto the paper/cardboard. The porosities of the paper/cardboard are partially blocked, and the surface area for chemical grafting is significantly increased. The scientific article "Oxygen and oil barrier properties of microfibrillated cellulose films and coatings" by Aulin, C. et al. details the barrier properties of MFC against oxygen and oils based on ambient humidity.

PART. 6 CHROMATOGENY

Sensitive to water vapor, microfibrillated cellulose (MFC) does not form a sufficient barrier when ambient humidity increases. By combining MFC with a coating that acts as a vapor barrier, there is no longer a need for the addition of "plastic" in a number of packaging solutions (excluding those containing ink formulations with additivated polymers).



CARDBOARD (230 g/m²)

MFC (20 g/m²)

RESISTANCE O_2 AND GREASES

GRAFTED FATTY ACIDS

RESISTANCE TO WATER AND WATER VAPOR

Not yet industrialised, this solution is driven by the Celluwiz project. More details can be found in François Bru's thesis: "Hydrophobization of Cellulosic Biosourced Materials" (available separately from July 2024).

PART. 6

HIGHLIGHTS

- **GRAFTING FATTY ACID CHLORIDE PROVIDES PAPER/CARDBOARD WITH A WATER BARRIER;**

- **WITHOUT ADDING A COATING (PLASTIC OR MFC), PAPER AND CARDBOARD LACKS FUNCTIONALITY FOR PACKAGING;**

- **THE PLASTIC (PVOH) COATING GRAFTED WITH FATTY ACID CHLORIDES, UNDUSTRIALLY READY IS NOT YET SUITABLE FOR FOOD CONTACT (TO BE CHECKED MID-2024).**

PART. 7

ALUMINA CHEMISORPTION

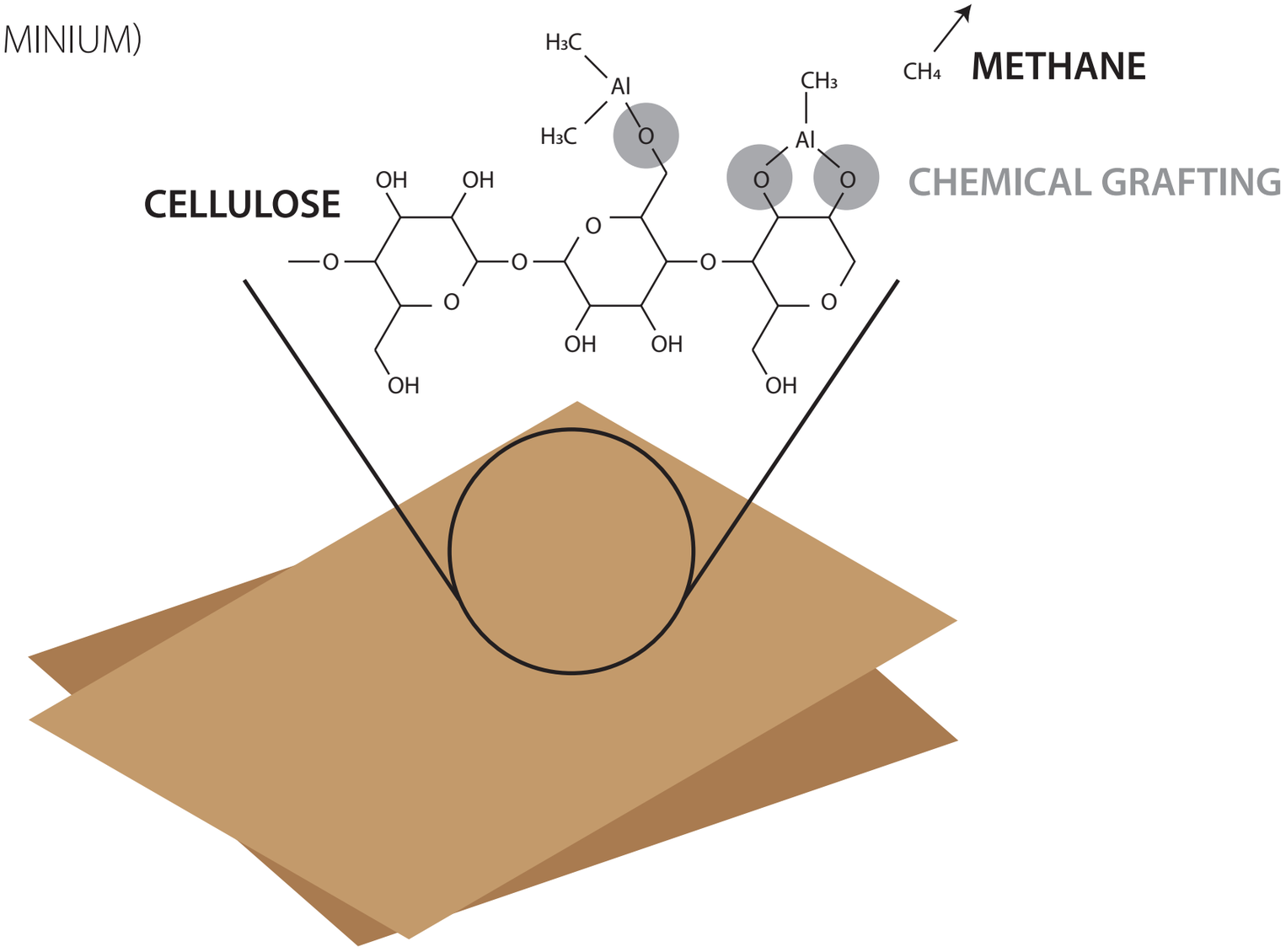
Functionalisation Of Paper And Cardboard Report - Feb 2024

M. Mme RECYCLAGE

PART. 7 ALUMINA CHEMISORPTION

Aluminum oxide (alumina) serves as a ceramic barrier against gases, water, and grease. The homogeneous deposition of a thin layer of alumina on cellulose is achieved by reacting aluminum, water vapor, and oxygen in contact with cellulose. Aluminum complexed with chloromethane forms TMA, which is gaseous around 125°C and reacts with cellulose without burning it. Gas phase grafting requires very little material.

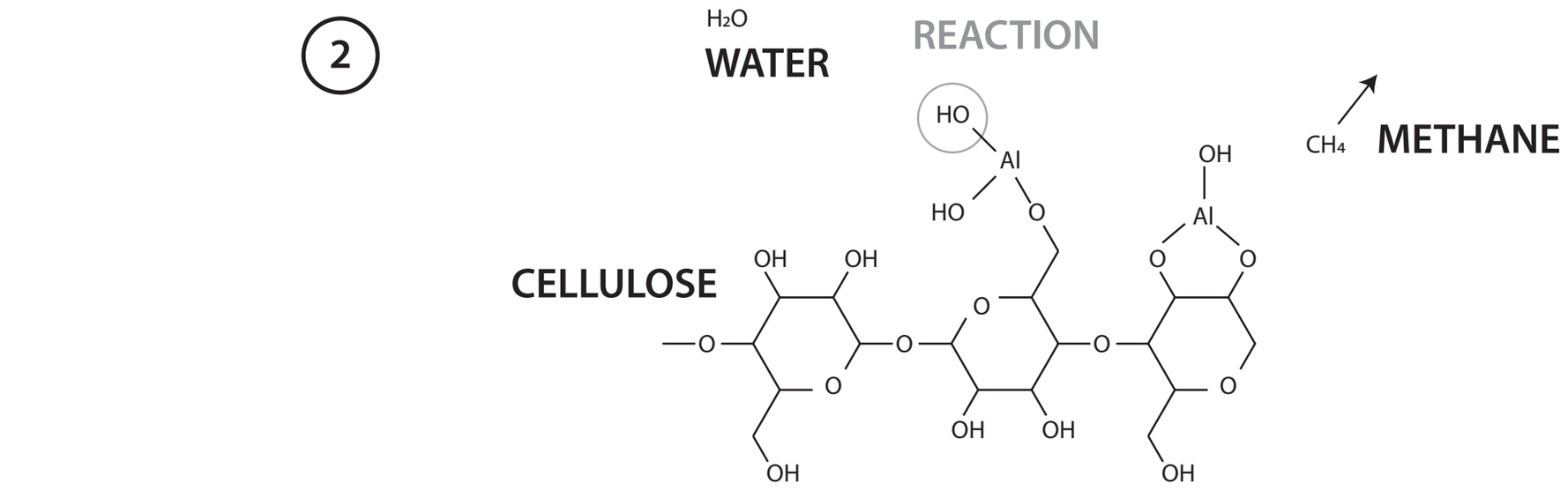
TMA
(TRIMETHYLALUMINIUM)

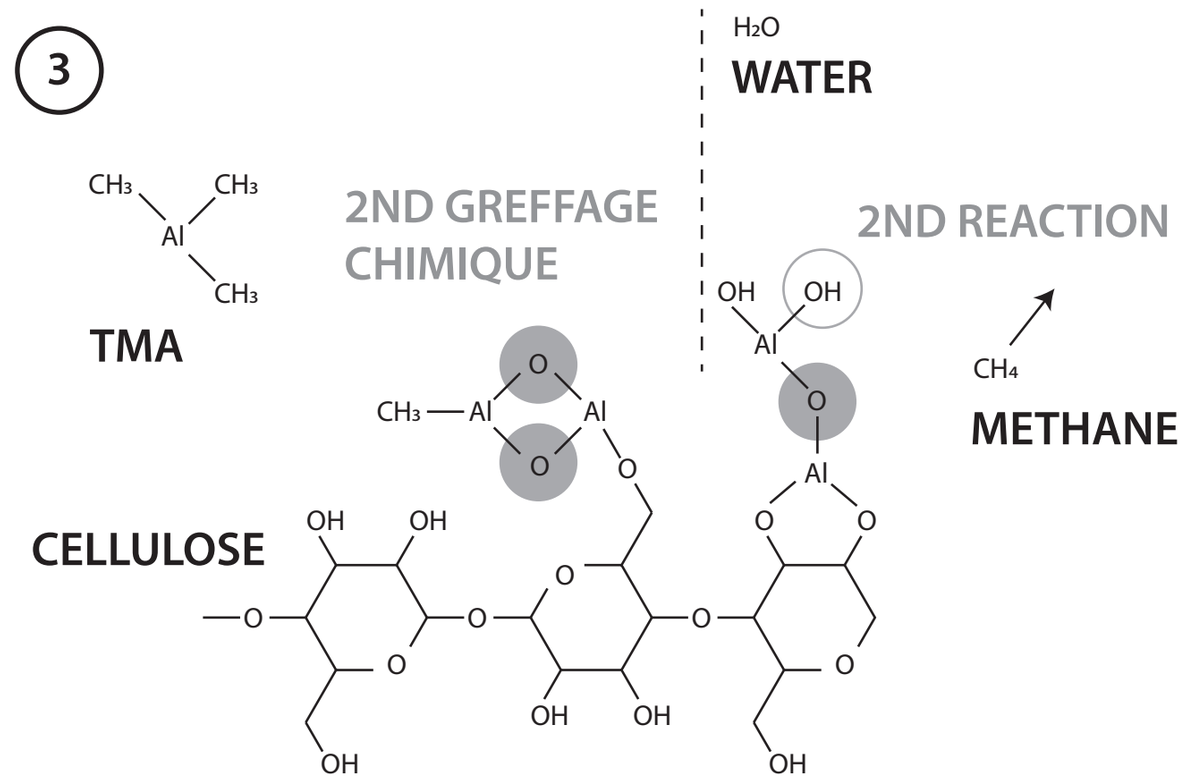


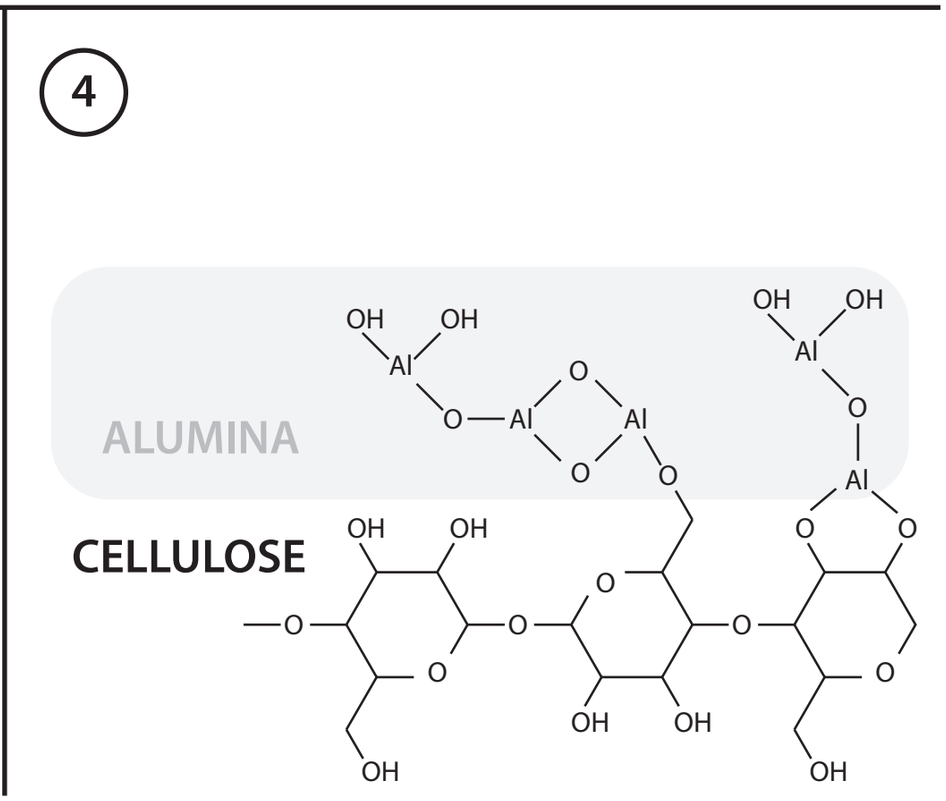
M. ♻ Mme RECYCLAGE

PART. 7 ALUMINA CHEMISORPTION

The surface-grafted cellulose is then exposed to water and again to trimethylaluminum, allowing the grafting of as many layers as desired.



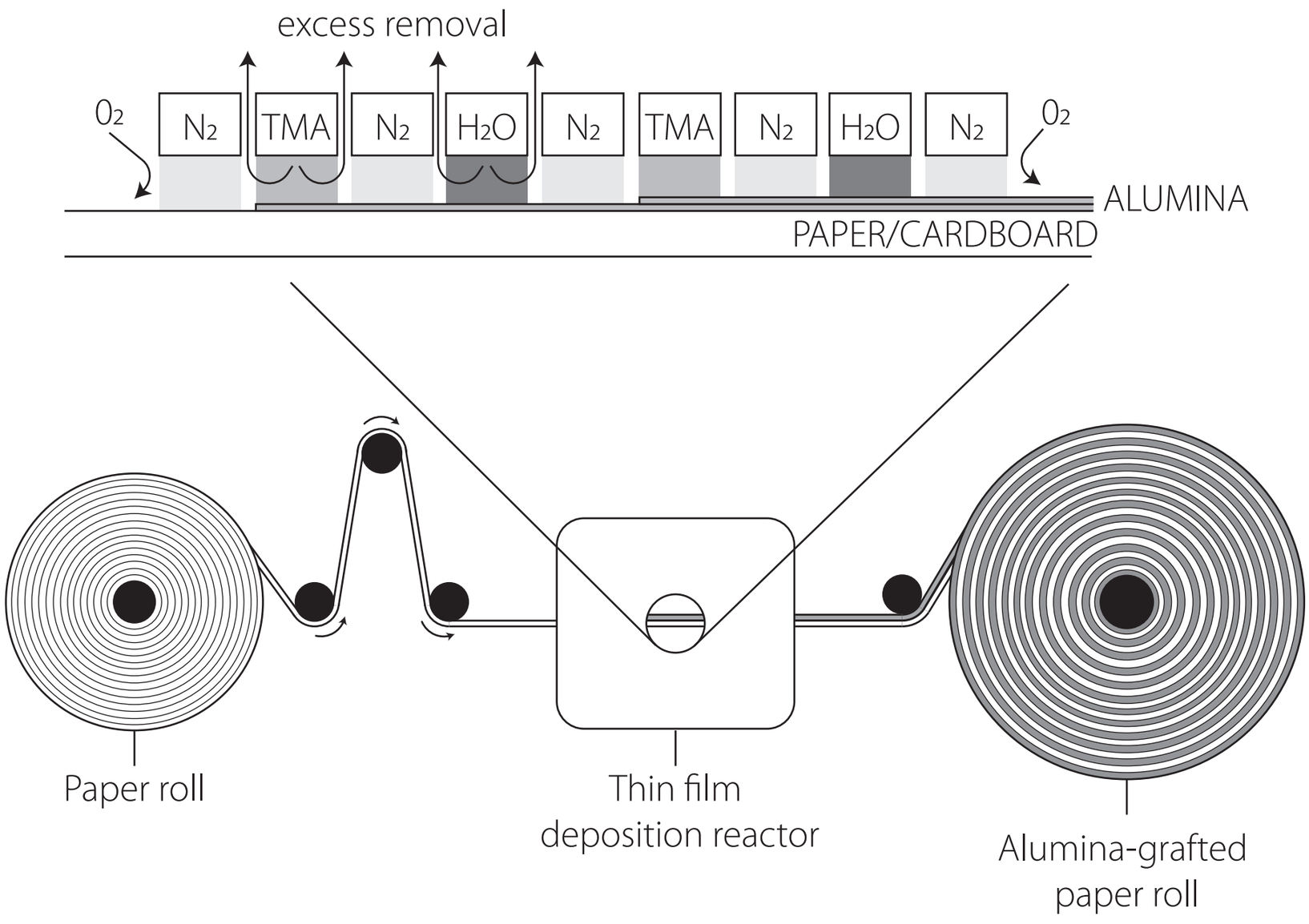




More details can be found in "Surface chemistry of atomic layer deposition: A case study for the trimethylaluminum/water process" by R.L. Puurunen.

PART. 7 ALUMINA CHEMISORPTION

The trimethylaluminum and the water vapor deposits occur successively either within a thermal atomic layer deposition (T-ALD) reactor or a spatial atomic layer deposition (S-ALD) reactor. The difference between the two techniques lies in how the gases are injected. As an example, here is a schematic for S-ALD:



The surface alumina layer on the paper is only a few atoms thick and represents less than 1% of the mass of the paper/board.

PART. 7 ALUMINA CHEMISORPTION

Only articles without heat sealing (such as molded cellulose) will be without added plastic, provided that the cellulose formulation does not contain any.

MOLDED CELLULOSE

- BLEACHED BAGASSE CELLULOSE GRAFTED WITH ALUMINA (95%)
- AKD (1%) SIZING AGENT
- PEI (0,5%) RETENTION AGENT
- CATIONIC STARCH (0,5%)
- MICROCELLULOSE PARTICLES (3%)

Patent for paper functionalisation at Cilkoa: WO2022018100
Details on the composition of molded cellulose are provided in: "Molded pulp products for sustainable packaging: Production rate challenges and product opportunities," by M. Debnath et al.

PART. 7

HIGHTLIGHTS

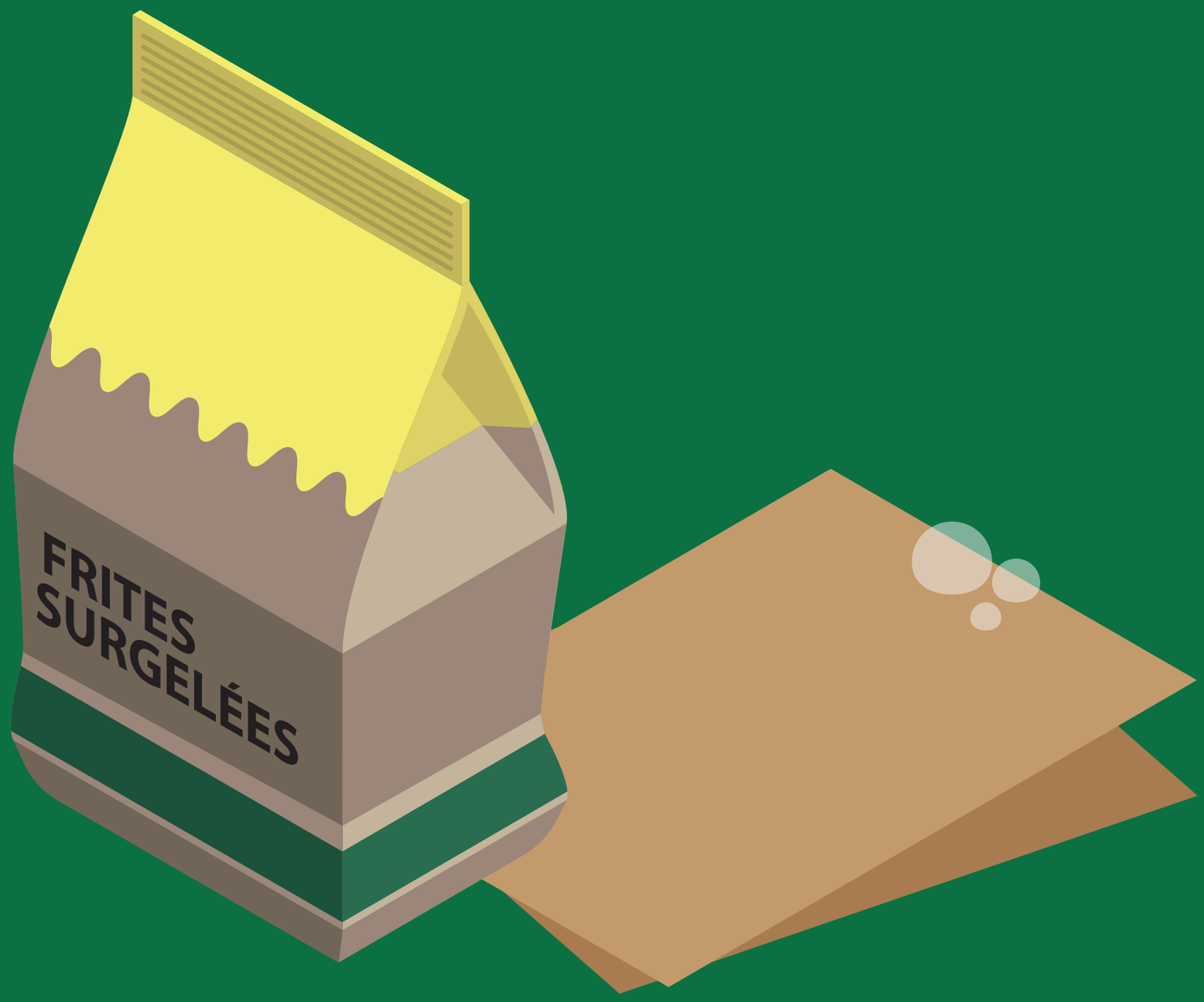
- **ALUMINA GRAFTING PROVIDES BARRIERS TO GASES, WATER, AND GREASES;**

- **ONLY PACKAGING WITHOUT SEALANT COULD POTENTIALLY CLAIM FUNCTIONALISATION WITHOUT PLASTIC;**

- **THE TECHNOLOGY IS NOT YET AVAILABLE FOR PACKAGING, AND NOT YET AUTHORISED FOR FOOD CONTACT.**

PART. 8

SILICA CHEMISORPTION

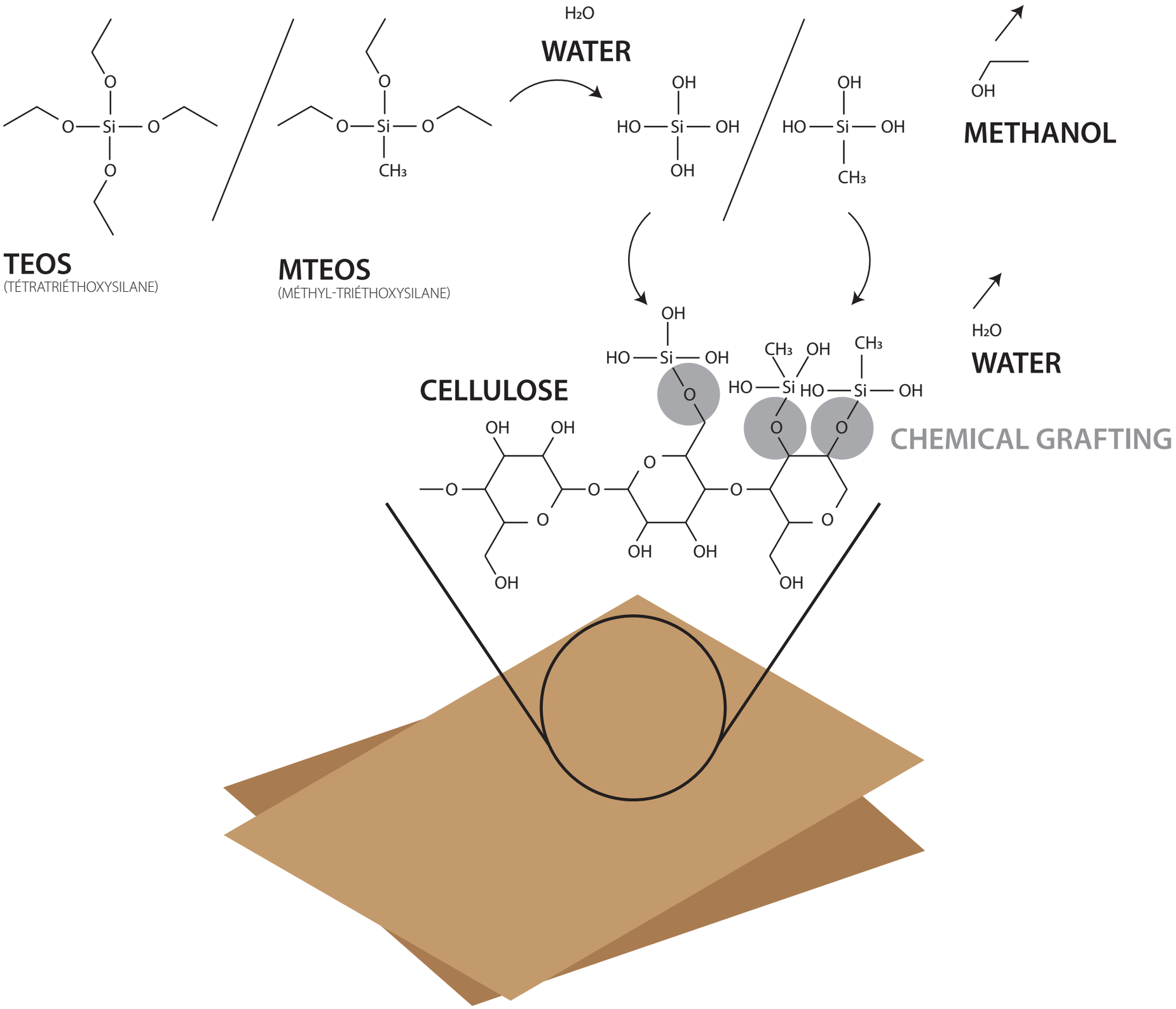


Functionalisation Of Paper And Cardboard Report - Feb 2024

M. Mme RECYCLAGE

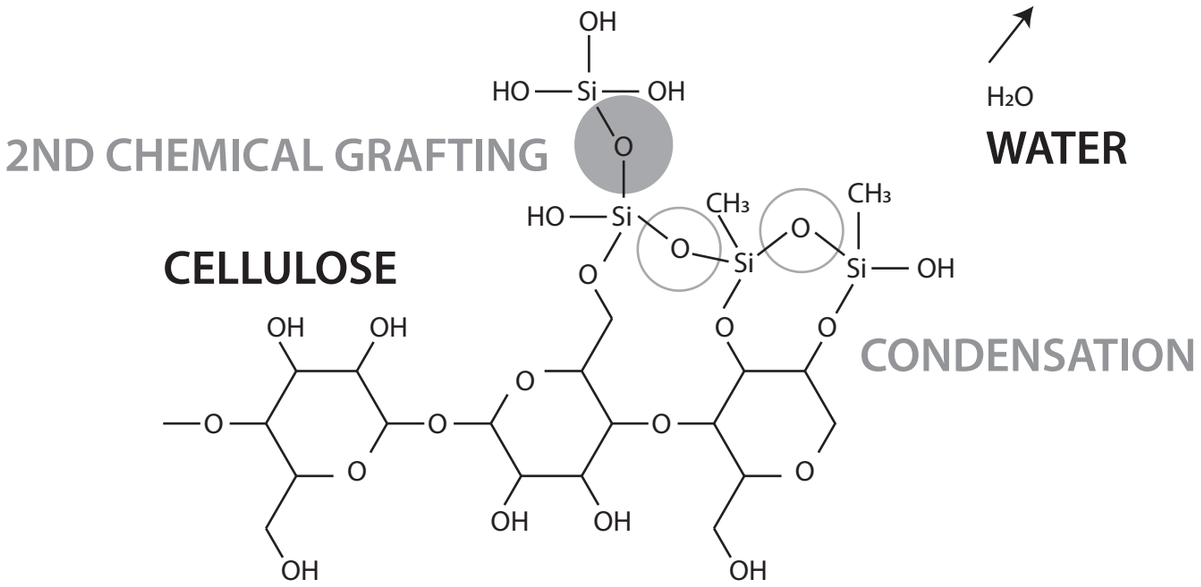
PART. 8 SILICA CHEMISORPTION

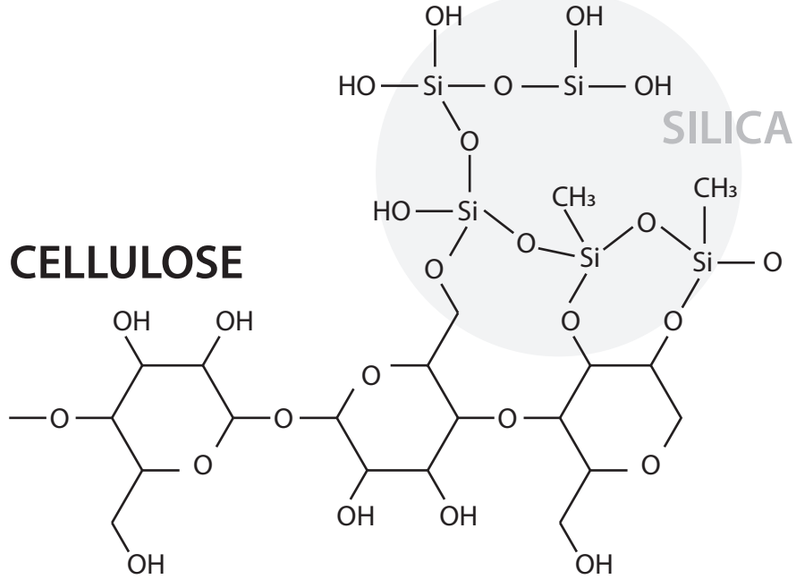
Silicon dioxide: silica, once grafted onto cellulose, provides the necessary barrier functions. To achieve this, a liquid dispersion of silicon and oxygen-based compounds (silanes) is hydrolyzed to create easily graftable reagents.



PART. 8 SILICA CHEMISORPTION

In the presence of ethanol, hydrolyzed TEOS and MTEOS polymerise into silica networks.

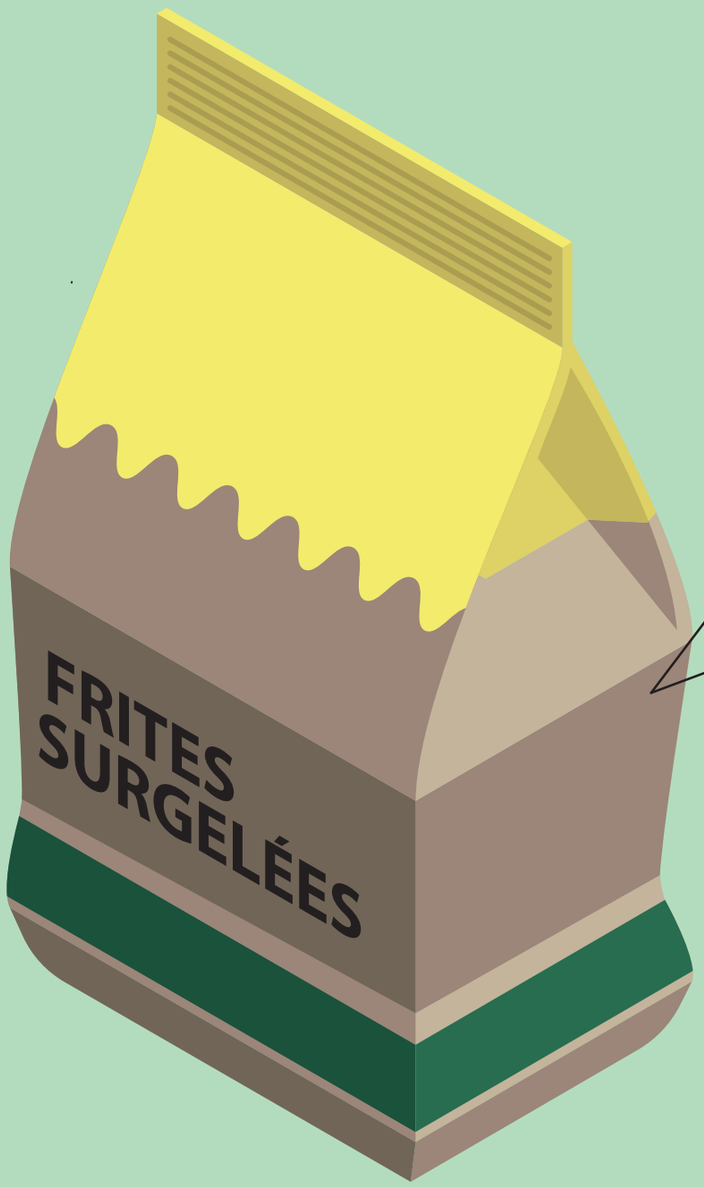




Details on the grafting of silica are provided in: "Theoretical study on the interactions between cellulose and different methyltriethoxysilane hydrolysis products" by T. Xing.

PART. 8 SILICA CHEMISORPTION

To fill the porosities of the paper/board, an initial silane grafting is performed in the aqueous dispersion on fillers such as microfibrillated cellulose (MFC). Coating and drying on paper/board lead to the grafting of silica, which in turn grafts the fillers.



PAPER (35 g/m²)

DISPERSION FUNCTIONALIZING (5 g/m²)

1/3 WATER-ETHANOL, 2/3 DISPERSION

- SILANES (E.G. MTEOS + TEOS) (89%)
- MICRO-FIBRILS OF CELLULOSE (5%)
- STARCH(3%)
- SILICA PARTICLES (3%)
- HYDROCHLORIC ACID (0.1%)

Papkot patent for a sol-gel functionalisation: WO2022112566A1
SGMA patent for a sol-gel functionalisation: WO2021019220A1
Qwarzo patent for a sol-gel functionalisation: WO2022171893A1

PART. 8

HIGHLIGHTS

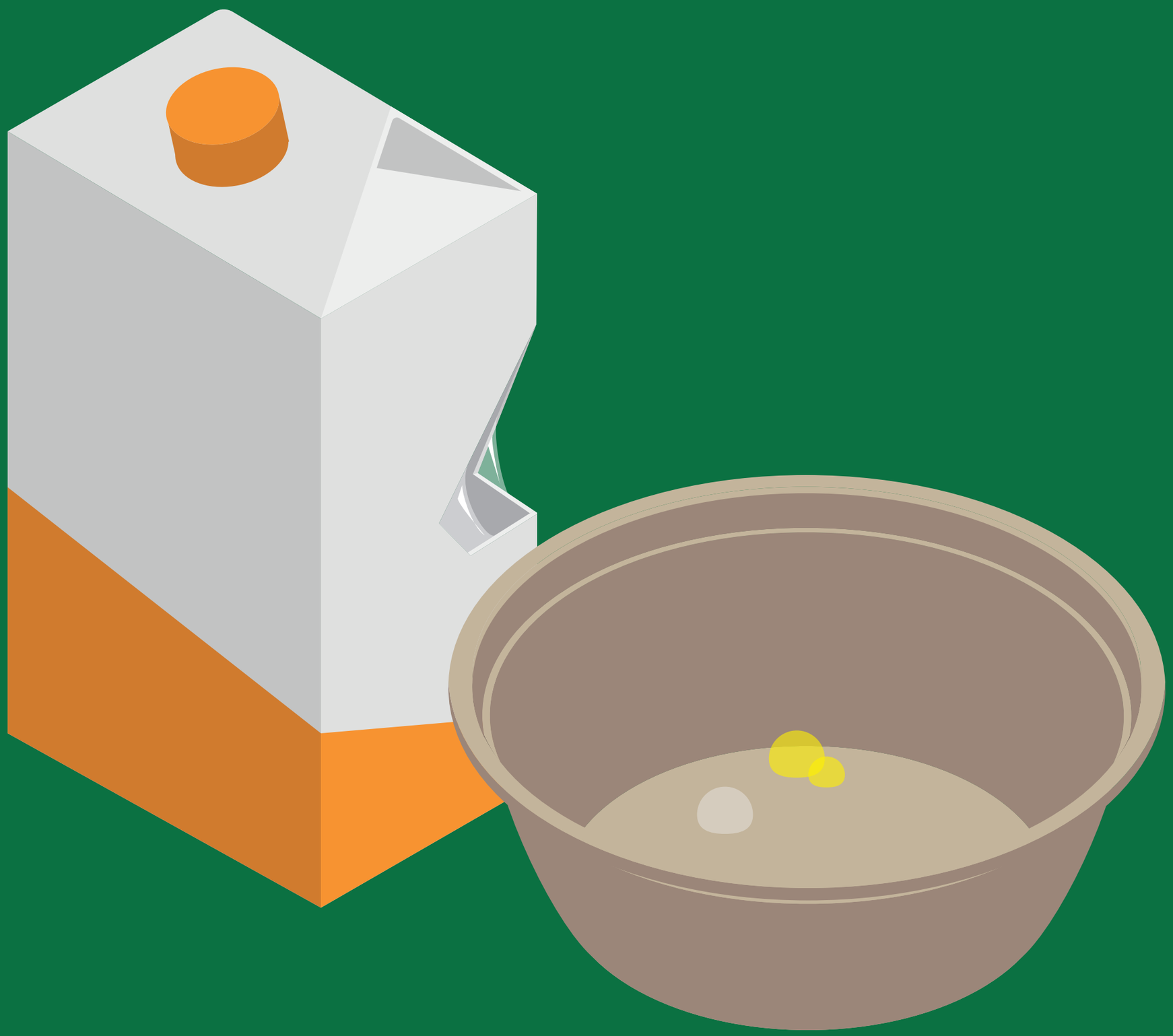
- **SILICA GRAFTING PROVIDES BARRIERS TO GASES, WATER, AND GREASES;**

- **ONLY PACKAGING WITHOUT SEALANT COULD POTENTIALLY CLAIM FUNCTIONALISATION WITHOUT PLASTIC;**

- **THE TECHNOLOGY IS NOT YET AVAILABLE FOR PACKAGING, AND NOT YET AUTHORISED FOR FOOD CONTACT.**

PART. 9

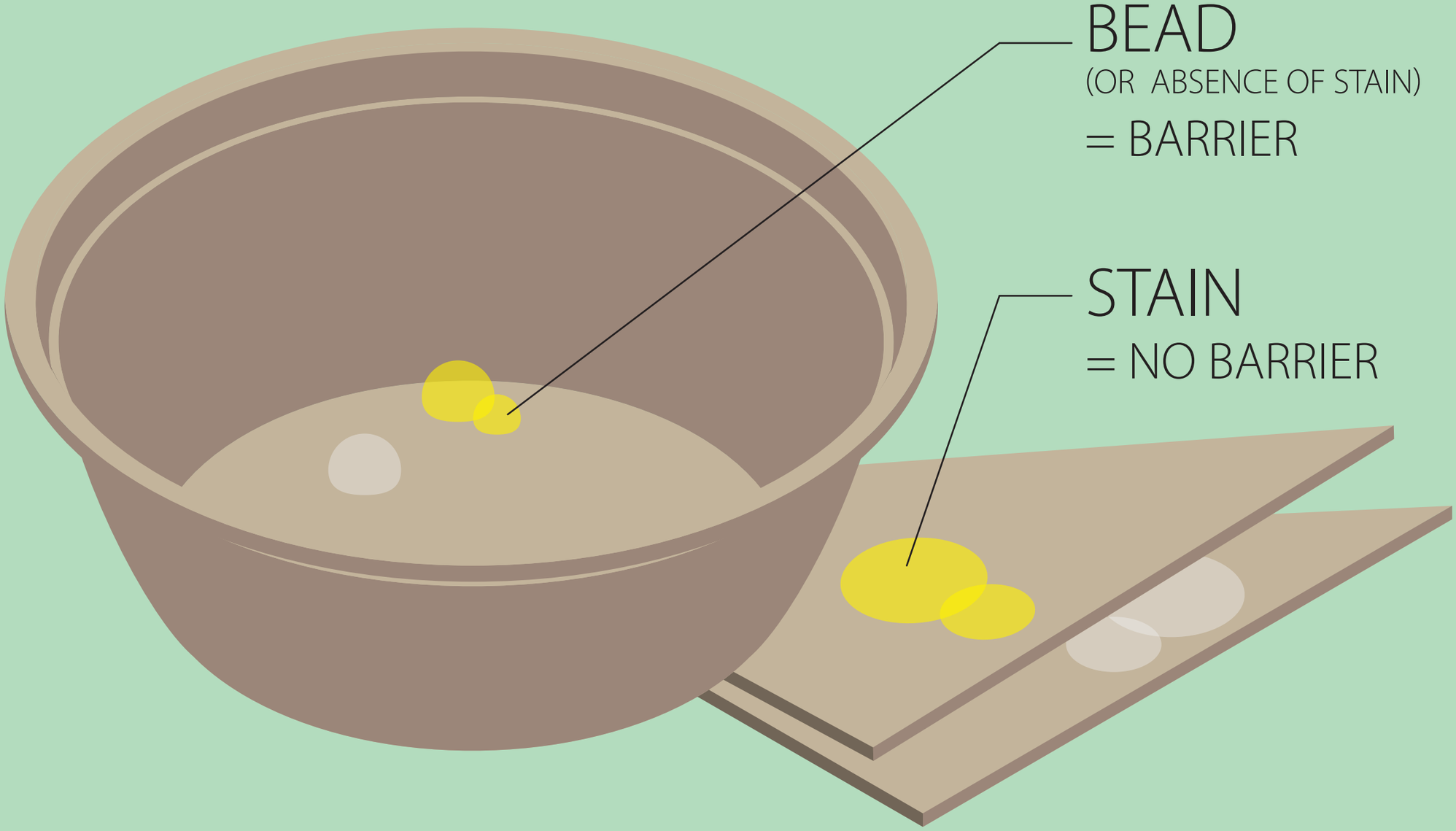
DETECTION OF BARRIER COATINGS



Functionalisation Of Paper And Cardboard Report - Feb 2024

M. Mme RECYCLAGE

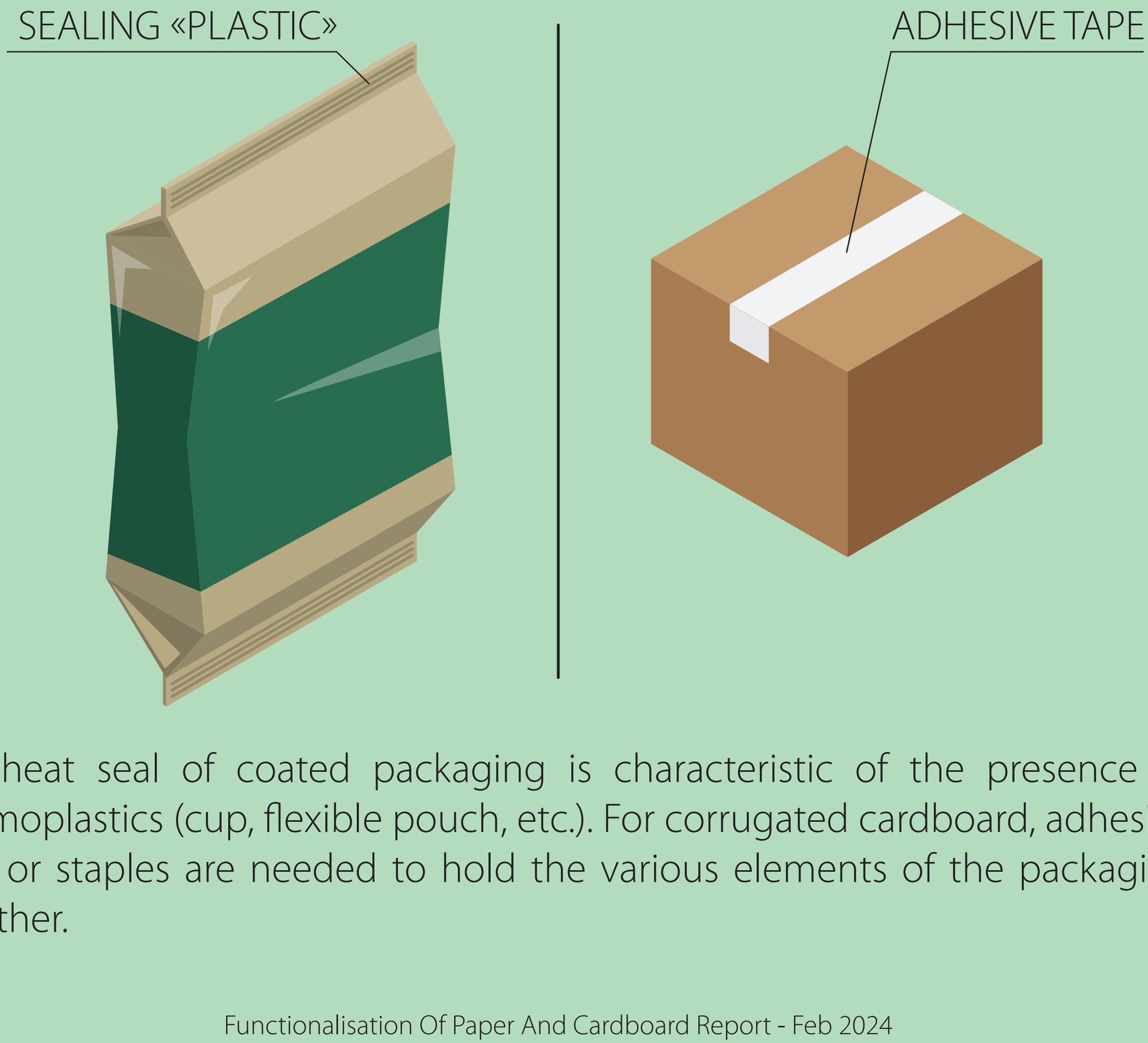
DROPLET TEST
WATER AND OIL



The functionalisation of paper/cardboard for packaging results in a certain hydrophobicity (water) and oleophobicity (oils and fats). A small droplet of water and oil not forming a stain betrays the modification of the natural surface of the paper/cardboard.

SEALING TEST

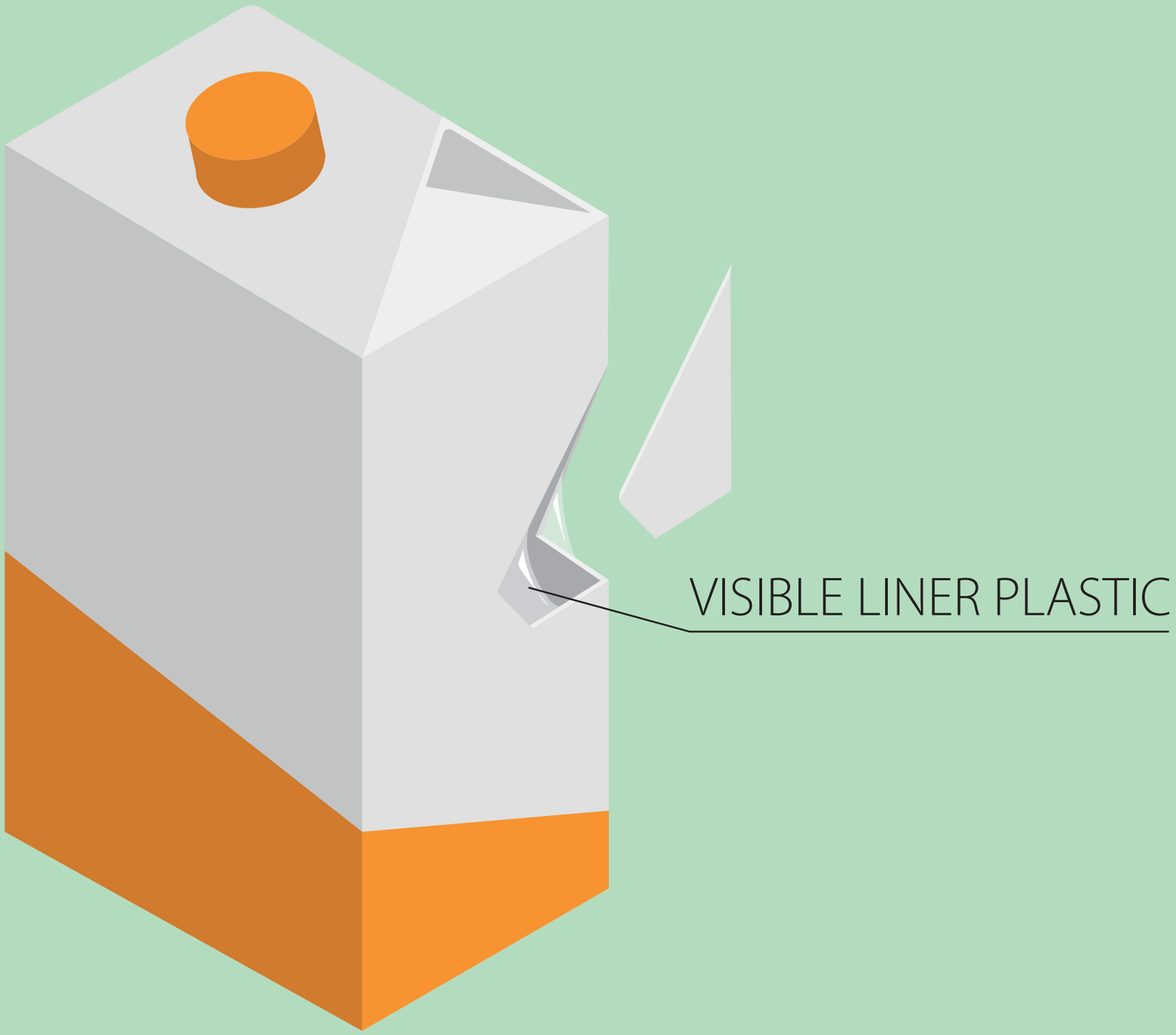
SELF-ADHESIVE OR NOT



The heat seal of coated packaging is characteristic of the presence of thermoplastics (cup, flexible pouch, etc.). For corrugated cardboard, adhesive tape or staples are needed to hold the various elements of the packaging together.

TEARING TEST

PLASTIC DELAMINATION



During a tear with a lot of stretching, the plastic, being more flexible than the paper/cardboard, does not break and may become visible. The thicker the coating, the more visible the layer of plastic. This is a good method for hotmelt lamination, but less effective for emulsions.

PART. 10

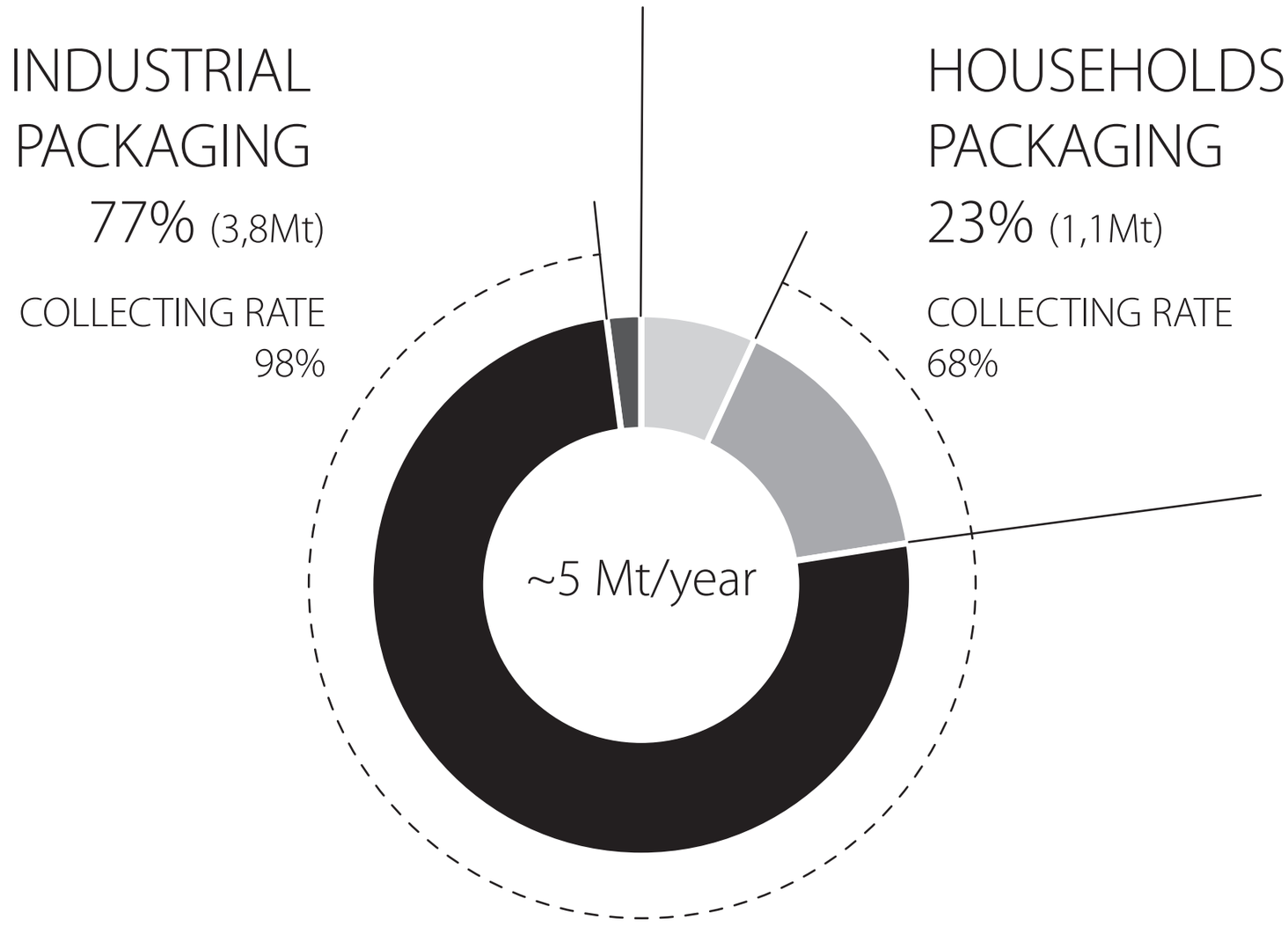
RECYCLING & BIODEGRADATION

Functionalisation Of Paper And Cardboard Report - Feb 2024

M. Mme RECYCLAGE

PART. 10 RECYCLING & BIODEGRADATION

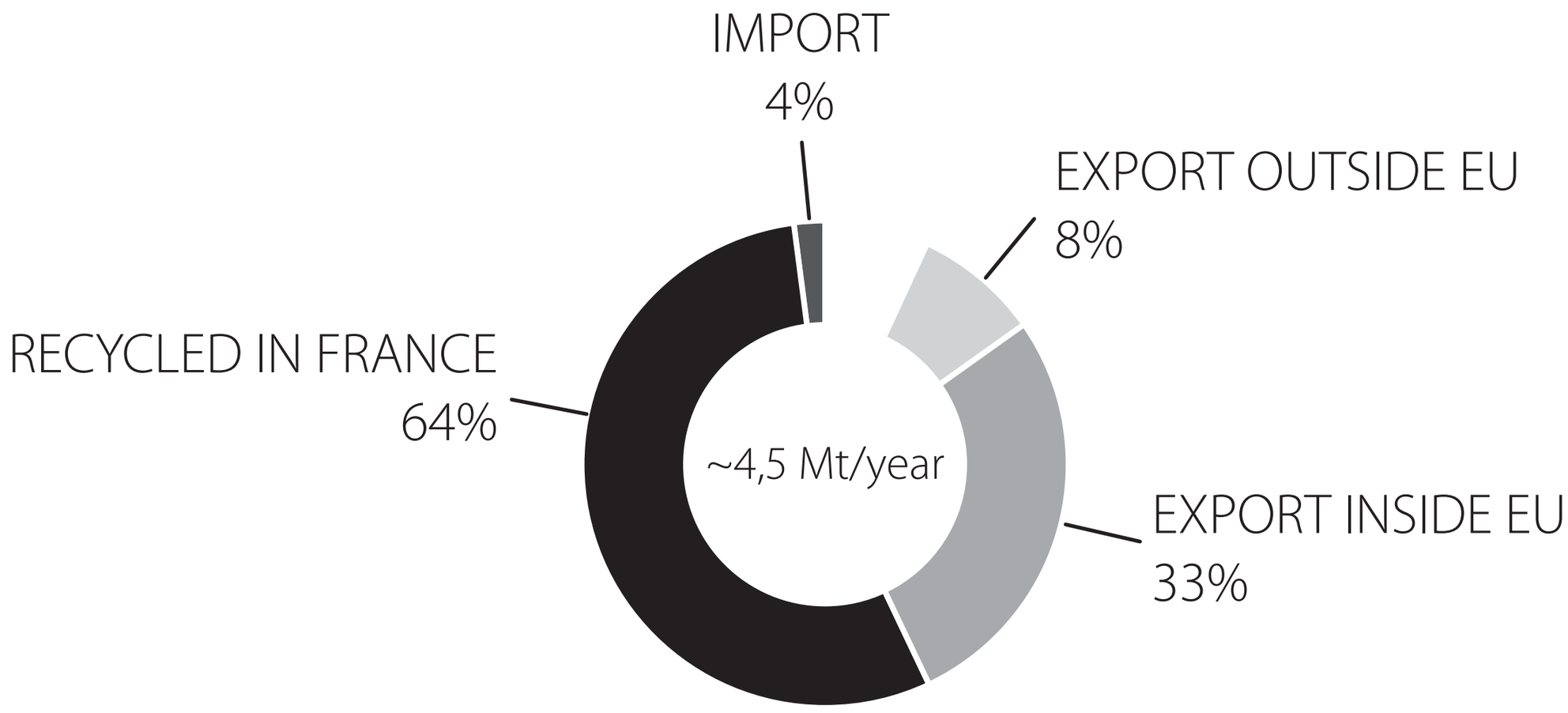
The collection rate is not the same for packaging from industry and commerce as it is for those from households. According to the 2022 facts and figures from the French paperboard packaging industry (COFEPAC), the recycling rates are as follows:



PACKAGING COLLECTED IN FRANCE

91% (~4,5Mt/year)

To the packaging collected in France, one must add the imported packaging for recycling and subtract the packaging exported for recycling:



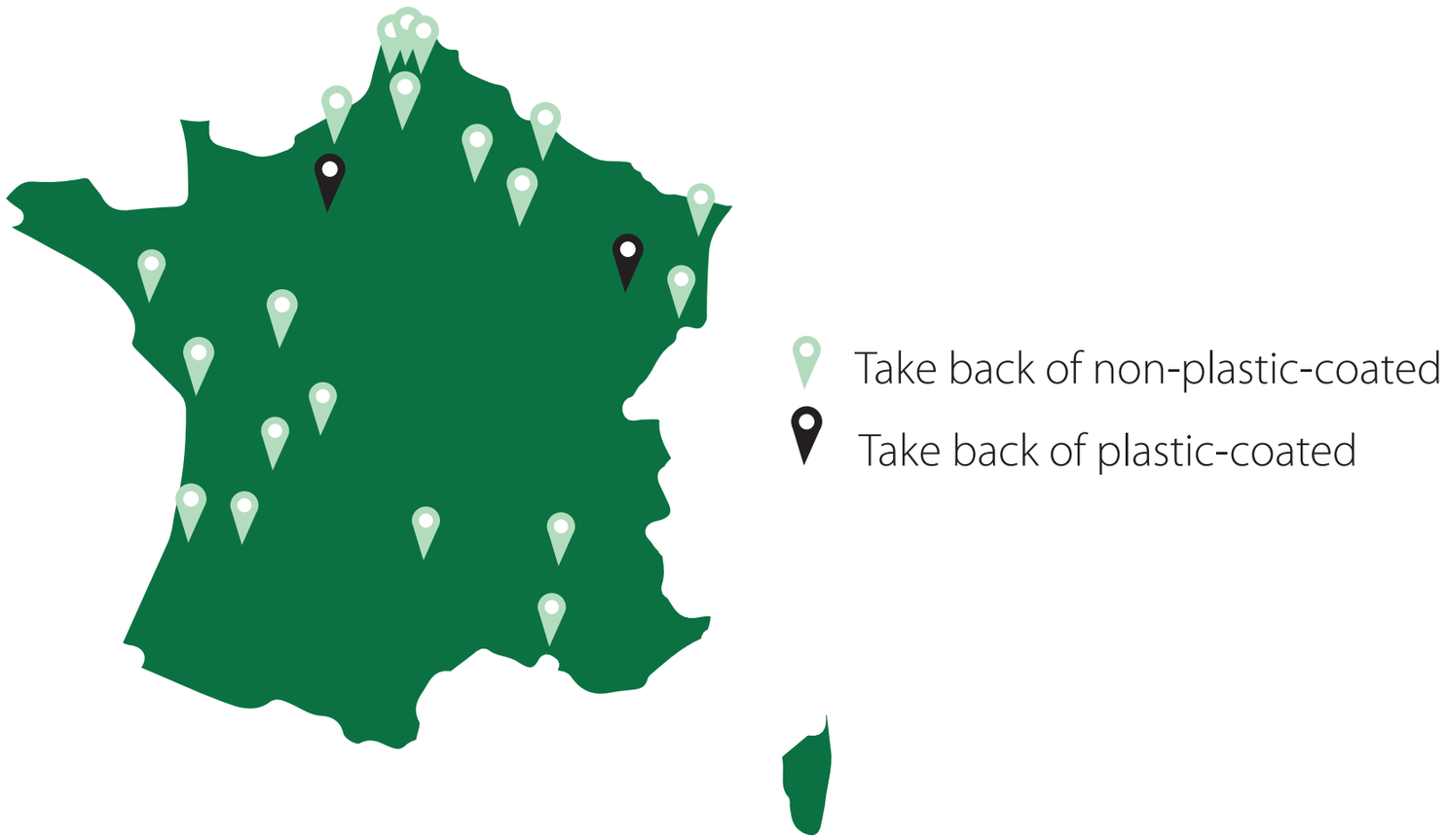
PACKAGING RECYCLED IN FRANCE

68% (~3Mt/year)

Approximately 90% of the recovered waste, across all sectors, is used to make paper/cardboard pulp for packaging (including 70% corrugated cardboard).

PART. 10 RECYCLING & BIODEGRADATION

In France, out of the 81 paper/cardboard mills federated by COPACEL, 37 are in packaging. 22 sites collect recycled paper/cardboard from municipalities through the standardised Revipac recovery system. Two of them collect plastic-laminated beverage paper cardboard.



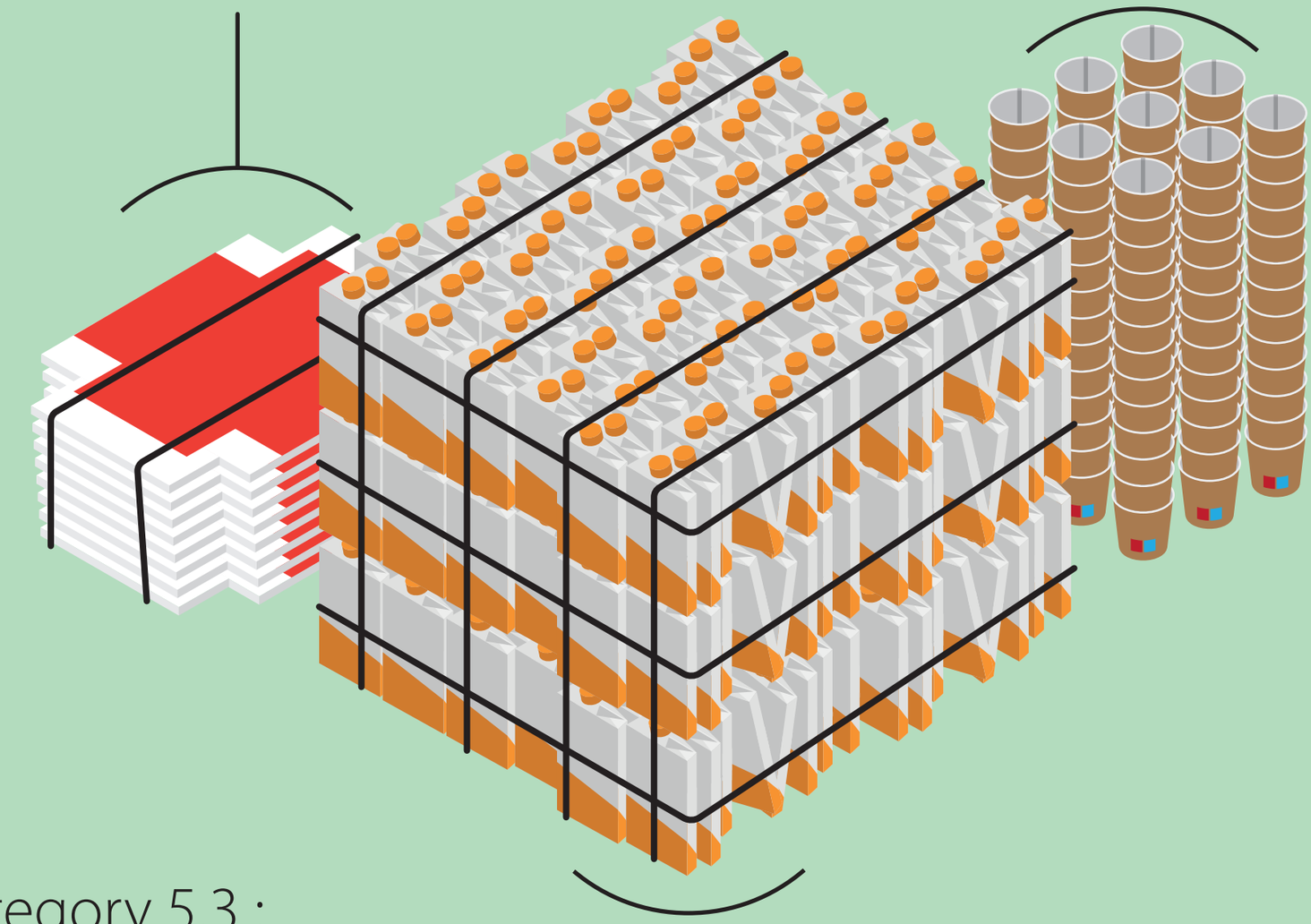
Corrugated cardboard represents the main outlet. Molded pulp (egg cartons, cup holders, etc.) represents a much smaller outlet. Not all packaging is recycled into packaging. Food beverage paper cardboard are used to make hygiene papers. A small portion of the packaging will be used to produce paper/cardboard for products like plasterboard, for example.

PART. 10 RECYCLING & BIODEGRADATION

A paper/cardboard recycler buys sorted waste by product type. There are more than thirty types of paper/cardboard.

Category 3.11 :
WHITE MULTI-LAYERED CARDBOARD HIGHLY PRINTED
Recent waste without gray layers

Category 5.14 :
OLD PAPER CUPS
With plastic layer,
but at least 75% fibers



Category 5.3 :
USED PACKAGING CARTONS FOR LIQUID FOOD
With plastic layer, with or without aluminum, but at least 50% fiber

The NF EN 643 standard details the list of paper/cardboard types with allowed recycling disruptors below a certain threshold and prohibited contaminants.

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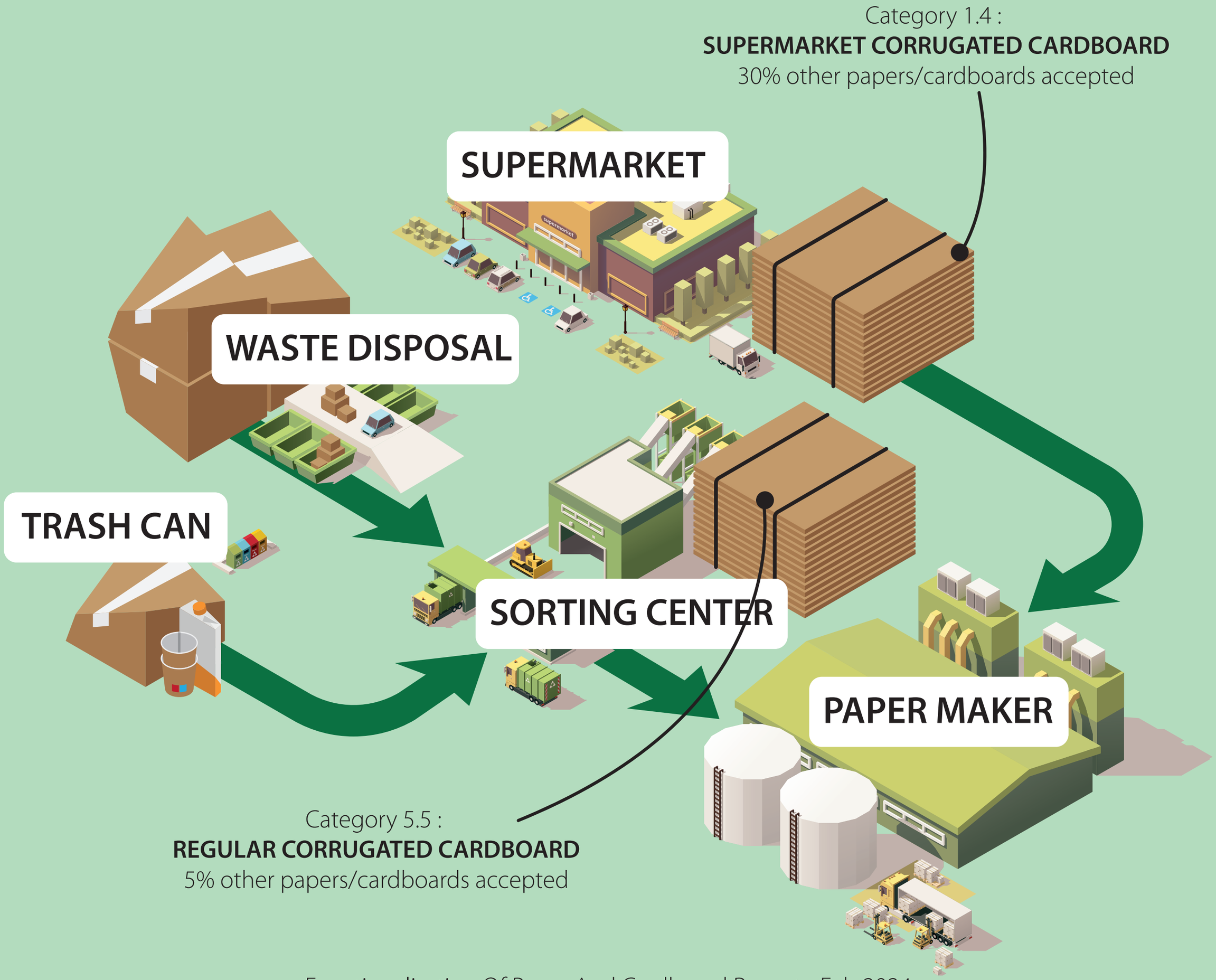
PART. 10 RECYCLING & BIODEGRADATION

The collection, sorting, and aggregation of paper and cardboard packaging depend on the consumption circuit:



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As an example, in France, two standards regulate the recovery of household paper and cardboard packaging at the exit of sorting centers and waste disposal sites:

NCPC

Non-complex Papers and Cardboards

1.05.1 : **Corrugated cardboard**
~75€/ton

5.02.1 : **Mixed packaging**
~45€/ton

CPC

Complex Papers and Cardboards

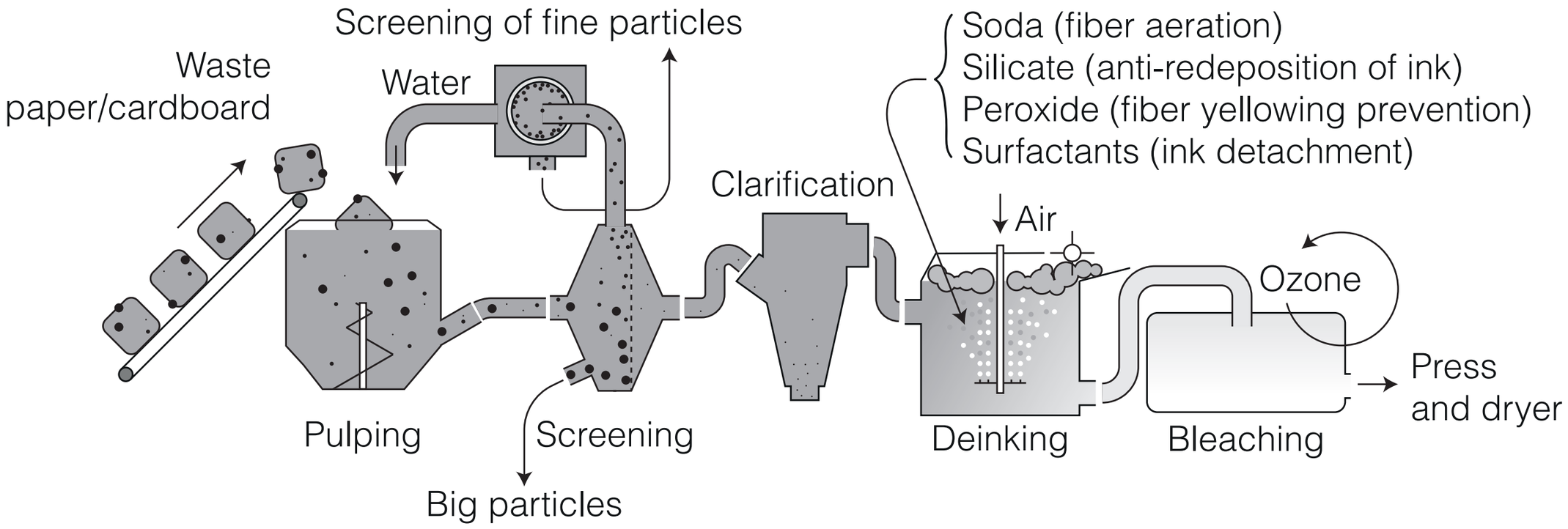
5.03.0 : **Packaging cardboard for liquid food**
~13€/ton

Other complex packaging

The sortability of packaging is observed by checking the stream in which it ends after passing through various screens: volumetric, densimetric, optical, etc. Pulping tests of the packaging must confirm the proper delamination of the cellulose. The CPC/NCPC standard is not entirely adapted to new complex packaging that will end up in 5.02.1: mixed packaging in the non-complex paper category, even if the plastic it content is significant

PART. 10 RECYCLING & BIODEGRADATION

The steps in recycling waste into paper/cardboard pulp depend on their origin and the needs for deinking, bleaching, hot pulping, etc. The recycling line is not the same for making tissue paper from beverage cardboard as it is for making corrugated cardboard from corrugated cardboard.



Certain packaging requires significant strength from the paper pulp. Once the waste treatment steps are completed, the recycled pulp can be mixed with virgin pulp (for example, 50/50) to ensure the mechanical strength of the new pulp. Details on paper pulp recycling are provided in document F1315 of the French Techniques de l'Ingénieur database.

PART. 10 RECYCLING & BIODEGRADATION

During the recycling of paper/cardboard pulp, plastic and aluminum coatings are sacrificed. The same applies to the ink, and depending on the process, additives such as kaolin, talc, or calcium carbonate may also be sacrificed.

✓ RECYCLED
✗ NON RECYCLED

PE BOTTLE CAP* ✗

INKED VARNISH ✗

- PIGMENTS
- NITROCELLULOSE (PLASTIC)
- ADDITIVES

FLEXIBLE PAPER FILLED AND SMOOTHED (55%) ✓

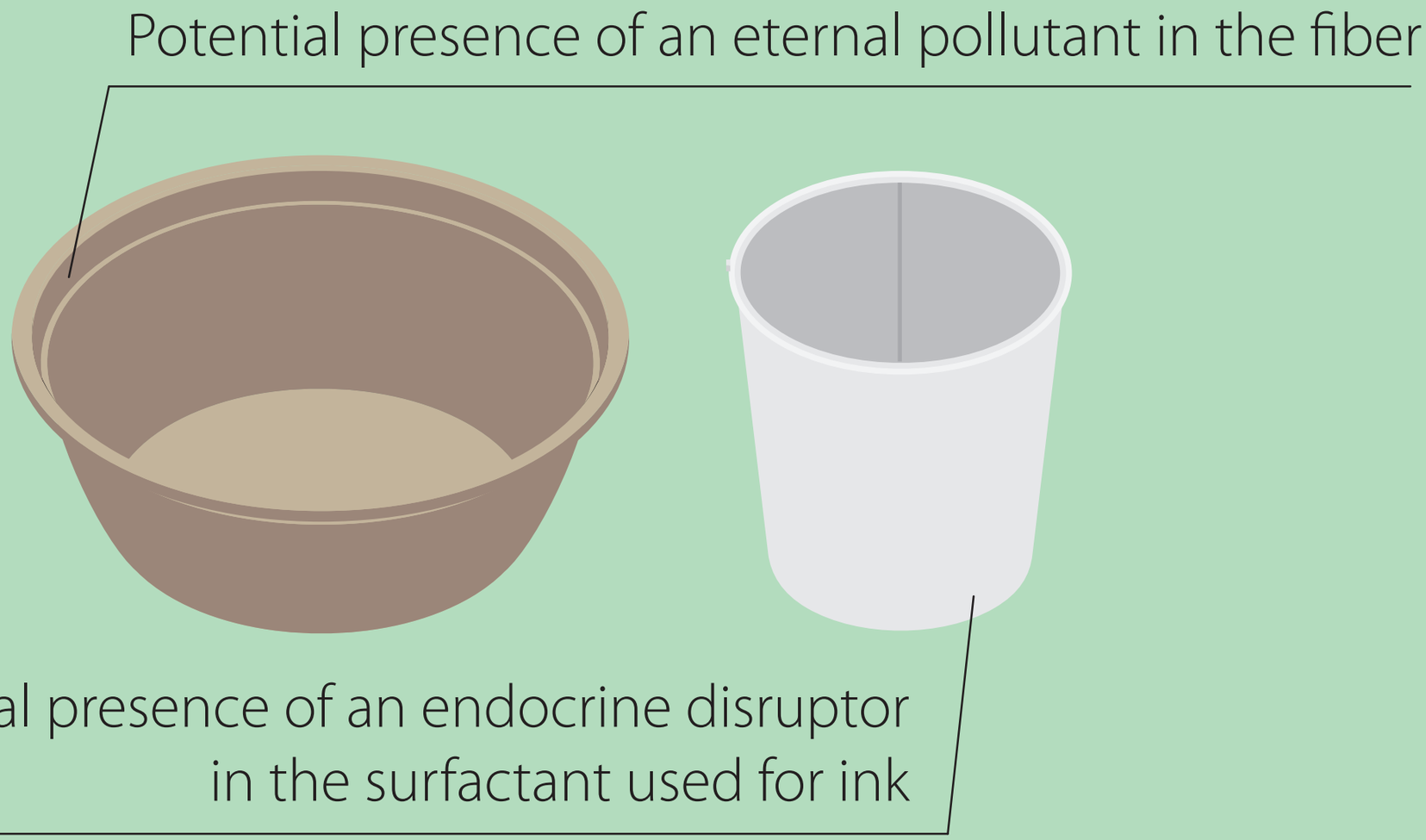
- KRAFT
- STARCH-BASED BINDER
- SMOOTHING TALC PARTICLES
- ADDITIVES

PE COATING OXIDIZED (45%) ✗

*Only the caps of PET and PE bottles are recycled. The recovery of caps from other packaging is not guaranteed.

PART. 10 RECYCLING & BIODEGRADATION

Due to the presence of ink, adhesives, or functional barriers, which may contain non-biodegradable materials, current paper/cardboard packaging should neither be composted nor digested for methane production.



Although there are lists of banned hazardous substances in packaging in Europe, the importation of packaging does not always comply with current legislation. In addition, PFAS, which act as grease barriers (including degradation products such as PFHxA), are carcinogenic, mutagenic, and/or reprotoxic, and accumulate in the environment.

PART. 10

HIGHLIGHTS

- **PAPER AND CARDBOARD PACKAGING DO NOT GET RECYCLED ALL TOGETHER;**
- **THEY ARE SORTED INTO OVER 30 DIFFERENT CATEGORIES: CONSUMMED VS. WASTES / INKED /COATED / VOLUME / SOFTNESS;**
- **A RECYCLER BUYS AND MIXES DIFFERENT CATEGORIES BASED ON THEIR NEEDS FOR FINISHED PRODUCTS;**
- **DURING RECYCLING, ELEMENTS OTHER THAN PAPER / CARDBOARD PULP ARE SACRIFIED.**

PART. 11

ECOLOGICAL RELEVANCE OF PAPER AND CARDBOARD

Functionalisation Of Paper And Cardboard Report - Feb 2024

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PART. 11 ECOLOGICAL RELEVANCE OF PAPER AND CARDBOARD

According to a consumer study presented by the Mondi Group during a live LinkedIn event on November 21, 2023, by Thomas Lunz (Industry Group Manager for Functional Paper) and Maria Ley (Industry Group Manager for Technical Packaging):

55%

Of Europeans prefer paper/cardboard packaging
because they believe it is better for the environment.

70%

of consumers are trying to avoid single-use plastic packaging.

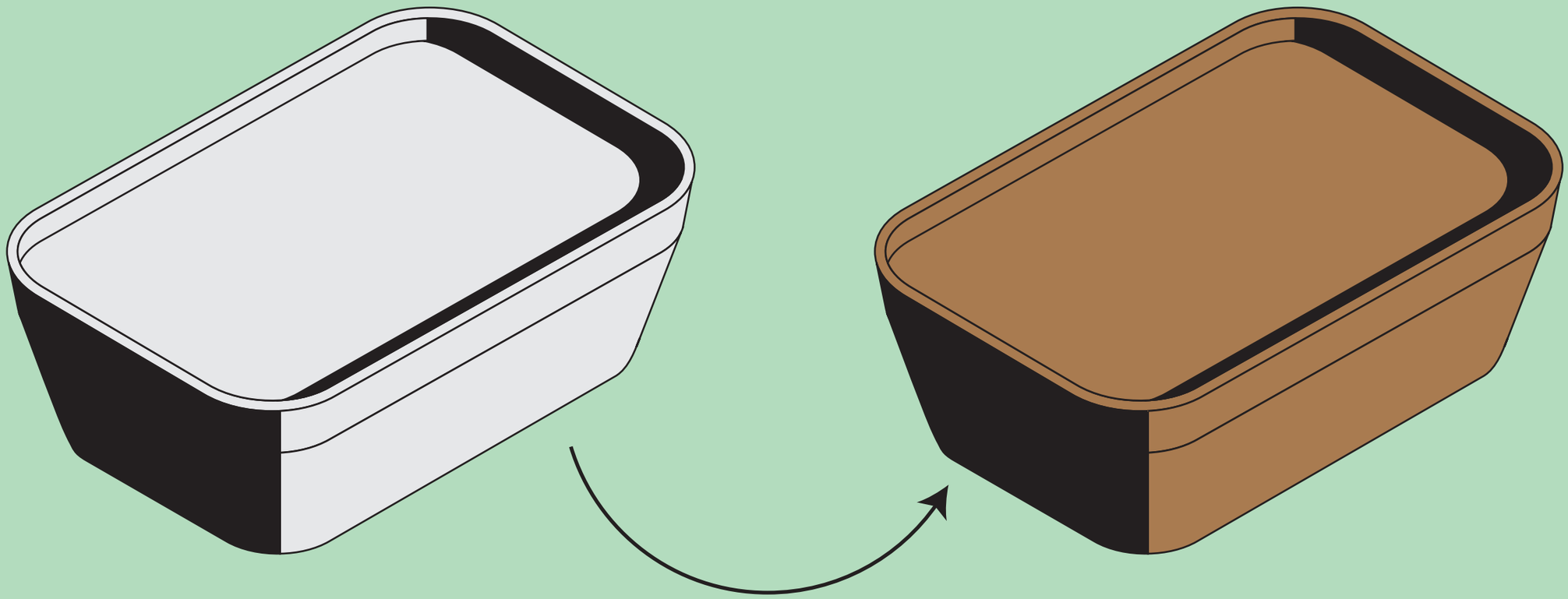
The ecological relevance of switching from plastic to paper/cardboard must be assessed through scientific life cycle analysis (LCA) studies. LCA compares various pollution indicators, and the results vary depending on the country studied and the study parameters such as the packaging incineration rate.

PART. 11 ECOLOGICAL RELEVANCE OF PAPER AND CARDBOARD

Example: What is the impact of switching from plastic to paper/cardboard?

PLASTIC

CARDBOARD



- ✓ Less CO_2 emissions
- ✓ Less fossil resources consumed
- ✗ More water consumed
- ✗ More NOx emissions
- ✗ More dioxin emissions
- ✗ More O_2 consumed in water

...

In terms of NOx, NO_2 contributes 300 times more to the greenhouse effect than CO_2, for example.

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PART. 11 ECOLOGICAL RELEVANCE OF PAPER AND CARDBOARD

Several scientific articles decipher the ecological relevance of switching from disposable plastic to disposable paper/cardboard. Ideally, these articles contextualise the change with the reuse of packaging. For example, a Chinese study conducts a life cycle analysis (LCA) on several pollution indicators based on Chinese consumption statistics. (2020 - NATURE FOOD - Y. Zhou, Y. Shan & al. - sharing tableware reduces waste generation, emissions and water consumption in China's takeaway packaging waste dilemma)

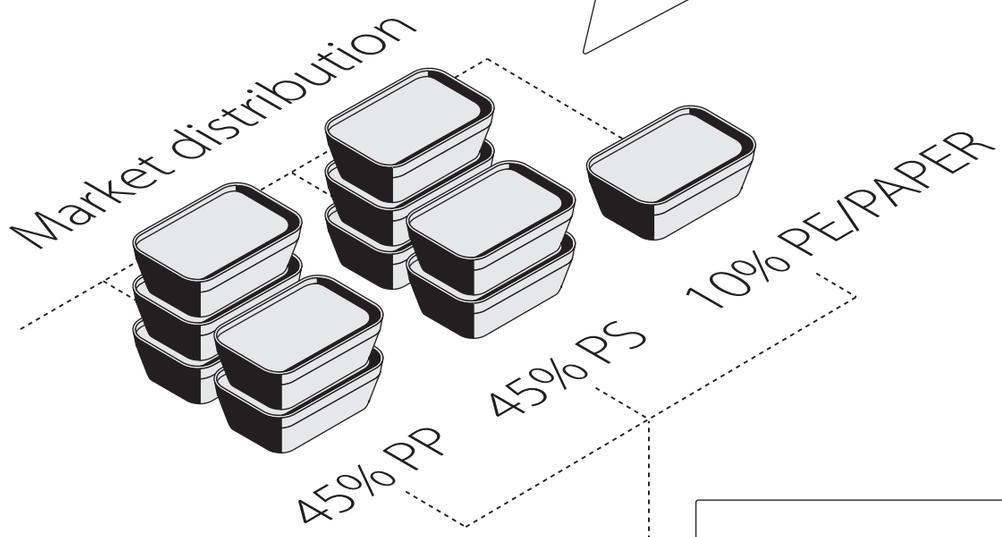
What is the impact of switching from plastic to paper/cardboard?

1 plastic bag,
1 plastic container,
2 wooden sticks in 1 plastic blister,
1 plastic spoon,
2 paper napkins,
1 wooden toothpick in 1 plastic blister.

Takeaway packaging kit

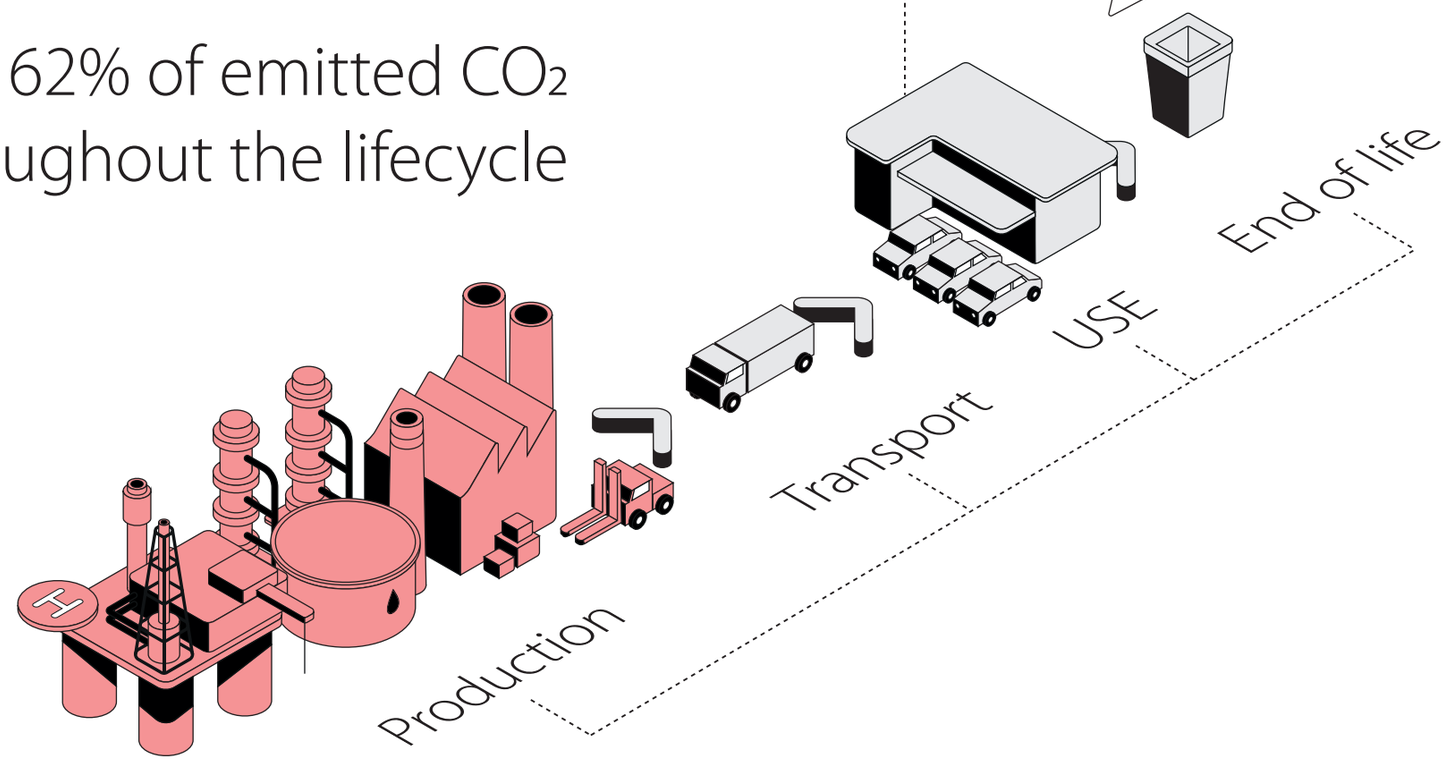
PART. 11 ECOLOGICAL RELEVANCE OF PAPER AND CARDBOARD

The impact of each element, such as the container, is calculated by averaging the impacts of the same element in different materials.



Among all the life cycle stages of disposable plastic containers, production is the most CO2-emitting stage.

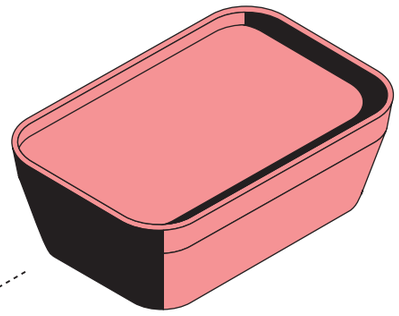
62% of emitted CO_2 throughout the lifecycle



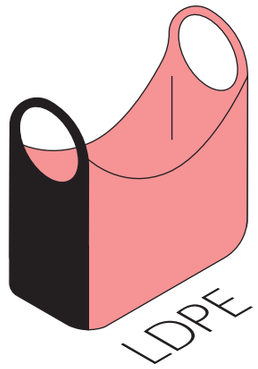
PART. 11 ECOLOGICAL RELEVANCE OF PAPER AND CARDBOARD

According to the study, within the kit, the disposable plastic container is the largest contributor to greenhouse gas emissions, followed by the bag.

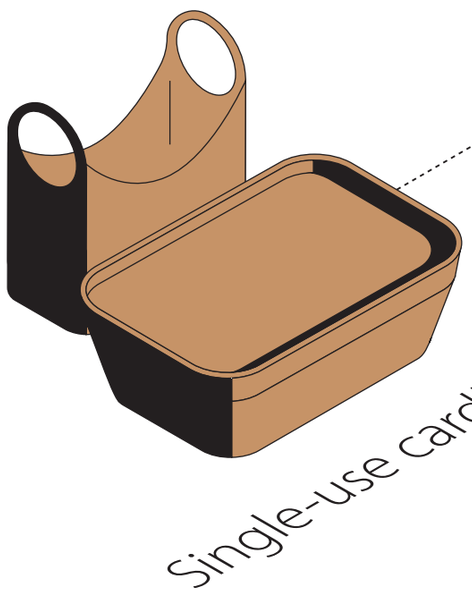
By replacing disposable plastic with disposable cardboard, we greatly reduce CO2 emissions, but it may not necessarily be more ecological depending on the pollution indicators we consider.



57%
of CO_2 emissions
from the kit



25%
of CO_2 emissions
from the kit



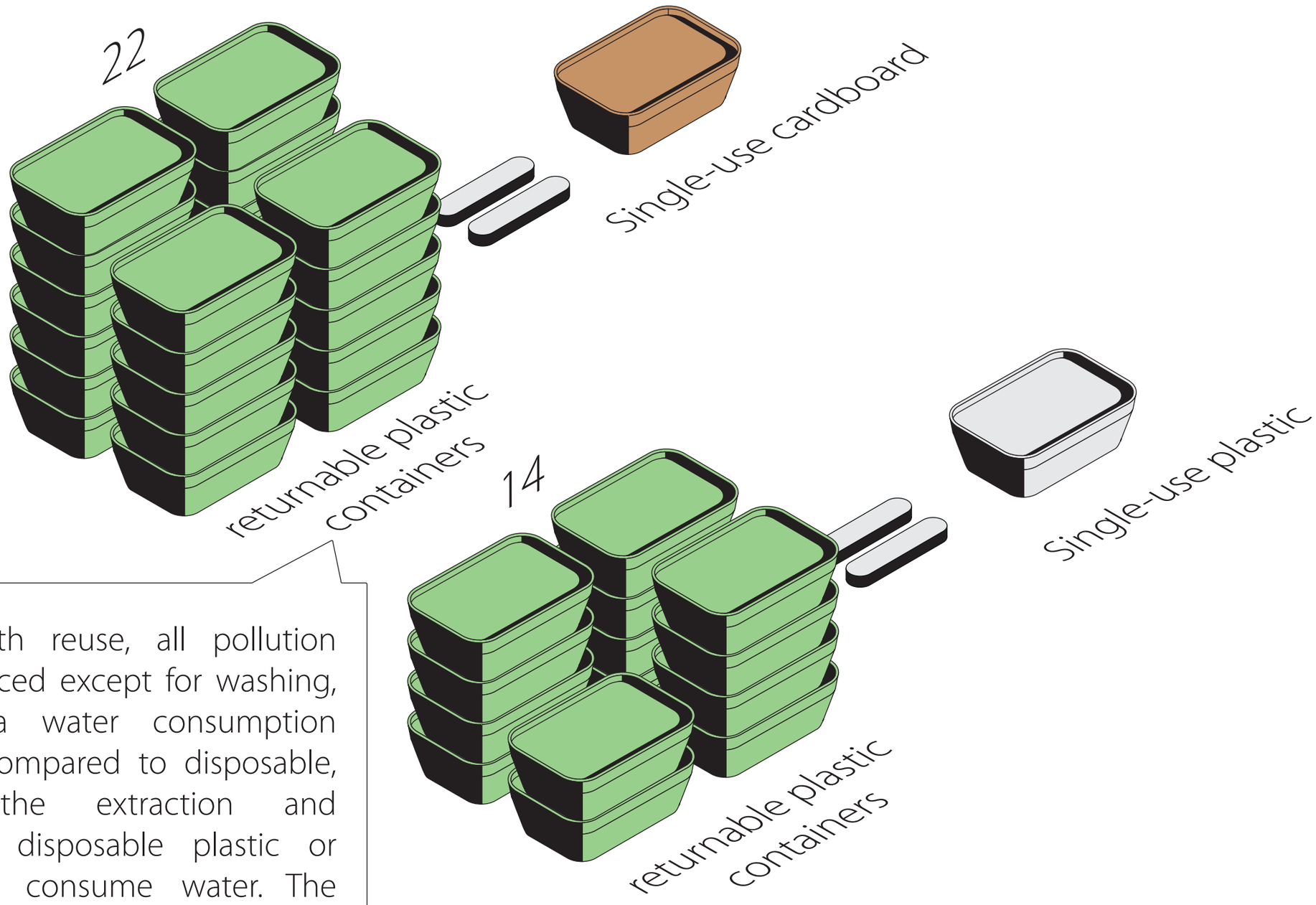
-50%
Of CO_2 emissions compared to plastic

+79% of NOx emissions
+465% of dioxin emissions
+89% of oxygen consumed in water
+41% of water consumed

Providing a simple answer is not permitted with life cycle assessments. For example, the SO_2 gas contributes to the greenhouse effect but condenses water vapor into clouds, which tends to cool the atmosphere. However, SO_2 acidifies rain, which has a negative effect on soil and vegetation.

PART. 11 ECOLOGICAL RELEVANCE OF PAPER AND CARDBOARD

So, how do disposable paper/cardboard packaging compare to reusable packaging? In the Chinese study, 6 reuses of a silicone container with a 75% return rate for an average distance of 250 km traveled by diesel truck between the restaurant and the washing center seemed relevant to the authors to bring the comparison back to a consumption cycle:



In this study, with reuse, all pollution indicators are reduced except for washing, which involves a water consumption increase of 30% compared to disposable, even though the extraction and transformation of disposable plastic or cardboard already consume water. The impact of transportation for the reuse cycle is minimal compared to the impact of the initial production of disposable items.

PART. 11

HIGHLIGHTS

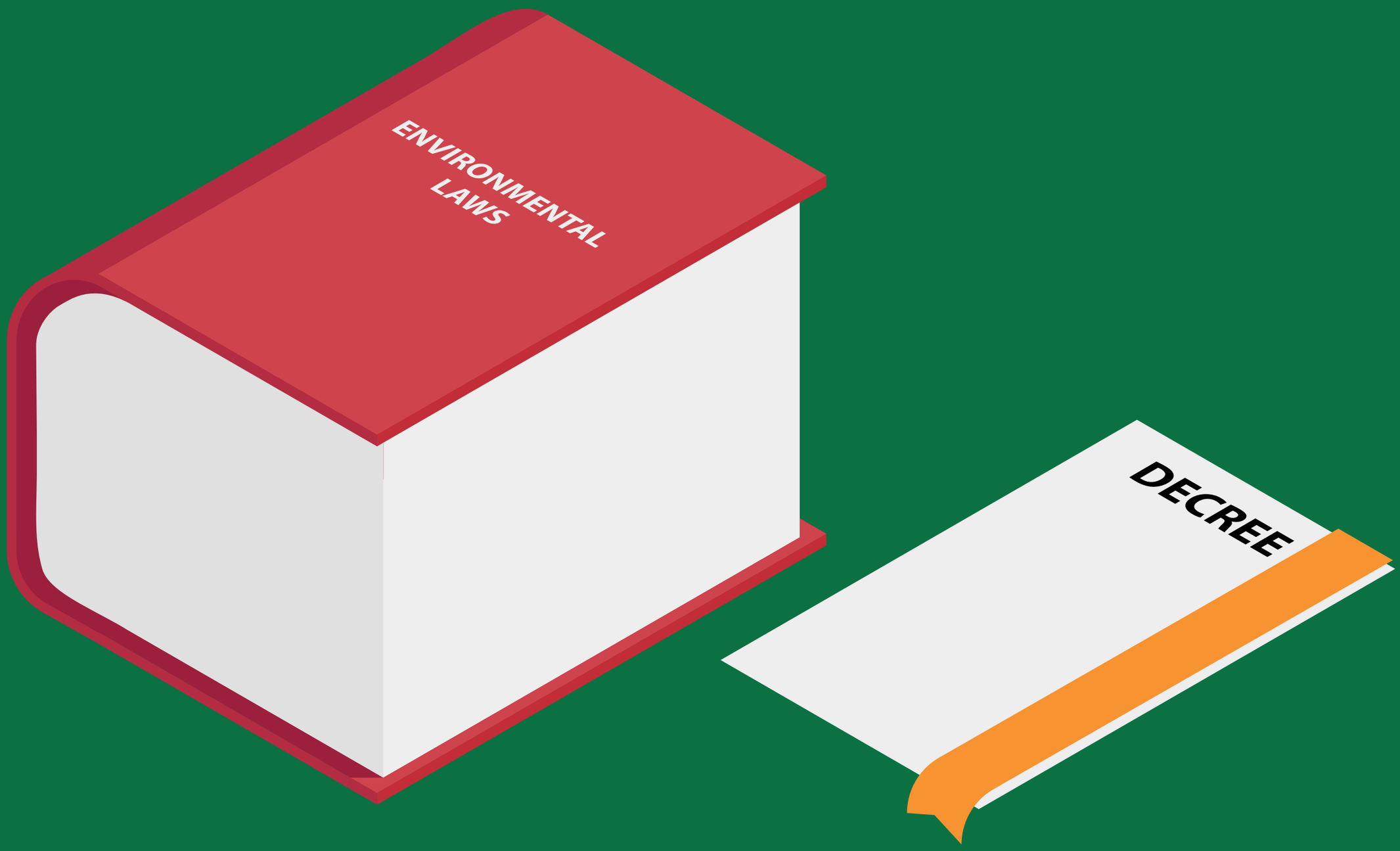
- **MOST OF THE ENVIRONMENTAL IMPACT OF DISPOSABLE PLASTIC PACKAGING OCCURS AT PRODUCTION STAGE;**

- **USING CARDBOARD INSTEAD OF PLASTIC REDUCES SOME IMPACTS, BUT INCREASES OTHERS;**

- **REUSE IS A MORE RELEVANT CHANGE AS LONG AS THE RETURN RATE AND MINIMAL NUMBER OF REUSES ARE GUARANTEED.**

PART. 12

REGULATORY OVERVIEW ON SINGLE-USE PLASTIC



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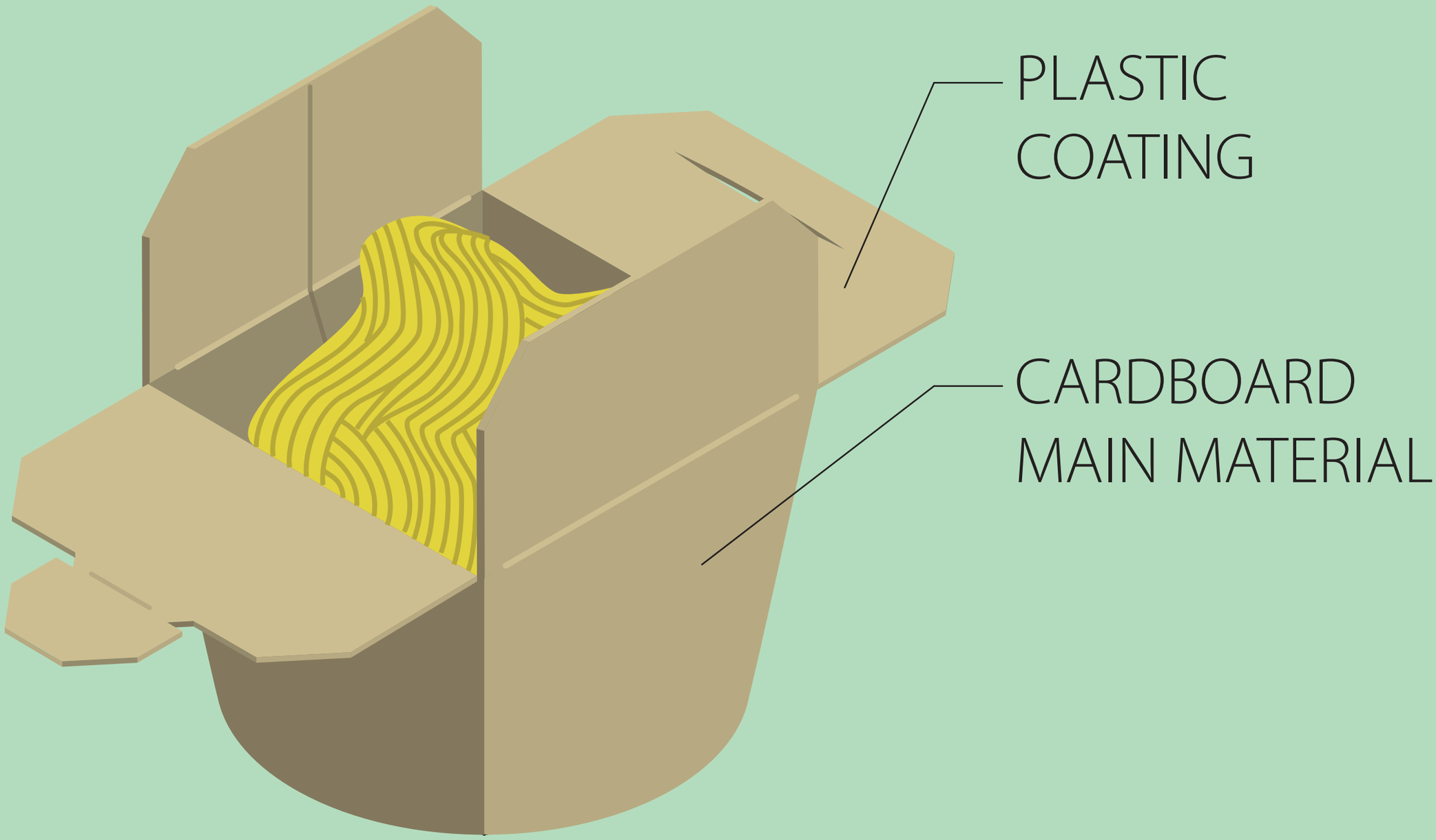
EUROPEAN DEFINITION



= SINGLE-USE PLASTIC

Partially plastic-made packaging, for immediate consumption without further preparation within the packaging, is considered single-use plastic packaging.

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As they are coated with plastic(s), some paper/cardboard packaging could fall into the single-use plastic category. These are legally regulated by several definitions and laws:

REACH REGULATION (CE 1907/2006)

«polymer»: a substance consisting of molecules characterized by the sequence of one or more types of monomer units. These molecules must be distributed over a range of molecular weights, with differences in molecular weights primarily due to variations in the number of monomer units. [...]

DIRECTIVE SUP (EC 2019/904)

«plastic»: a material consisting of a polymer as defined in Article 3, point 5), of Regulation (EC) No 1907/2006, to which additives or other substances may have been added, and which may serve as the main structural component of final products, excluding natural polymers that have not been chemically modified;

«Single-use plastic product»: a product made entirely or partially from plastic that is not designed, created, or placed on the market to fulfill, over its life span, multiple trips or rotations by being returned to a producer to be refilled or reused for an identical purpose for which it was intended.

>> Disposable paper/cardboard packaging, coated with plastics, could be, according to the definition of the SUP directive, classified as single-use plastics at the European level.

TELCV LAW (2015-992) - FRANCE

Disposable polystyrene plastic cups have been banned since January 1, 2020.

AGEC LAW (2020-105) - FRANCE

The AGEC law transposes the SUP directive into French law without any direct prohibition on single-use cardboard packaging containing plastic, which could be considered by the SUP directive as a single-use plastic product composed partially of single-use plastic.

DECREE OF SEPTEMBER 24, 2021

The decree complements the AGEC law, the maximum mass percentage of plastic in a cup decreed to be single-use plastic follows the following trajectory: 15% from January 1, 2022, and 8% from January 1, 2024. Nothing on other packaging.

>> Apart from cardboard cups, disposable paper/cardboard packaging coated with plastics is not subject to specific legal restrictions in France.

A progress report is conducted in 2024 to assess the progress made and the technical feasibility of eliminating plastic in single-use cups.

European harmonisation regarding the mass percentage of plastic allowed in single-use products could emerge with a paper/cardboard percentage possibly around 70%. Apart from a few rare flexible pouches with more than 30% plastic inside, most paper and cardboard packaging functionalised with plastic would not be affected.

PART. 12

HIGHLIGHTS

- **UNMODIFIED CELLULOSE IN PAPER/CARDBOARD PACKAGING, EVEN WITH ADDITIVES, IS NOT CONSIDERED A PLASTIC (ACCORDING TO THE SUP DIRECTIVE);**
- **HOWEVER, PAPER/CARDBOARD PACKAGING COATED WITH PLASTICS, IF INTENDED FOR IMMEDIATE FOOD CONSUMPTION WITHOUT FURTHER PREPARATIONS, IS INDEED CONSIDERED SINGLE-USE PLASTICS (ACCORDING TO THE SUP DIRECTIVE);**
- **IN EUROPE OR FRANCE, THERE ARE NEITHER REDUCTIONS NOR PROHIBITIONS ON THE MARKETING OF THESE PACKAGING MATERIALS AS OF NOW.**

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CONCLUSION

FUNCTIONALISATION OF PAPER AND CARDBOARD

Functionalisation Of Paper And Cardboard Report - Feb 2024

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CONCLUSION
AREAS OF IMPROVEMENT 1/2

To promote circular approaches prioritising reuse systems over single-use products, with the primary goal of reducing waste generation, public demand should not encourage the use of single-use paperboard packaging intended for food contact, as defined by the Single-Use Plastics Directive.

To avoid penalizing a particular type of paper/cardboard packaging, French laws should extend existing regulations from just cups to all paperboard packaging intended for food contact and single-use purposes.

To reduce the accumulation of Persistent organic pollutants (PFAS) in the environment, regulatory framework could prohibit their use in paper/cardboard packaging intended for food contact and single-use purposes.

CONCLUSION
AREAS OF IMPROVEMENT 2/2

To promote the deployment of reusable packaging and the industrial deployment of new paper/cardboard functionalisation technologies, plastic-based functional coatings for paper/cardboard packaging intended for food contact and single-use purposes could be banned within a specified time frame.

To limit greenwashing, marketing claims that overly simplify the papermaking processes inclunding the almost systematic use of plastic in paper/cardboard packaging intended for food contact and single-use purposes could be prohibited.

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