

White Paper

Design and Management for Circularity – the Case of Paper

January 2016



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Objective and Approach

As an industrial system, the circular economy is restorative or regenerative by intention and design. It replaces the “end-of-life” concept with restoration, shifts towards using renewable energy, minimizes the use of toxic chemicals that impair reuse, and aims to limit waste through the superior design of materials, products, systems and, within this, business models. Many times, however, choices made early in the value chain (in the design stage) hinder the shift towards more circular models and material flows. While eco-efficiency is not a new term in the design world, effectiveness – a key circularity principle – has not been adopted as a core design principle to date.

Project MainStream, a collaboration between the World Economic Forum, the Ellen MacArthur Foundation and the McKinsey Center for Business and Environment, seeks to remove bottlenecks in the large-scale transitioning to the circular economy. The MainStream team recognized through its analysis that much value is destroyed, even for commodities commonly perceived as closed-loop success stories, such as aluminium and paper, and much of that lost value results from suboptimal design choices. To remediate this situation, and because design choices are not only made by designers, Project MainStream decided to convene representatives along an entire value stream, namely paper.

Although highly recyclable, paper is usually converted by various downstream industries that add chemicals through printing inks and other auxiliary materials. This leads to problems when deploying circular value chains: these chemicals cannot be sorted out of paper in the dry-sorting steps before the paper mill. In Europe alone, over 2 million tons of such chemical formulations enter paper mills every year through secondary fibre, greatly damaging the fibre and, hence, limiting its value for further use cycles.

The recycling processes themselves cannot be readily optimized further. Ink formulations and printing techniques are instead developing towards more variety and many smaller streams; even within one technology (e.g. digital printing), competitors may have totally different types of toners or inks, each requiring different recycling and deinking techniques. Inaction is also not an option: the industry would be unable to maintain even the current rates of recycling. The upside, in contrast, comes in many guises – not only through higher recycling rates, but also from new circular avenues for residues and by-streams, such as deinking sludge.

How can this situation be remediated? Refining a system of positive and/or negative lists that pro-actively inform all actors along the supply chain seems problematic, as over 6,000 chemical compounds are deployed in printing inks alone. The industry’s transition, as already described, further aggravates the task’s complexity, from big volumes through few mainstream printing and converting techniques, to a

significant diversity of various technologies and tailor-made product. In fact, the chemicals used in the paper value chain are projected to grow slightly faster over the next five years than the paper-product industry itself.

This report offers a useful alternative through simple eco-design rules for paper products, in order to provide essential guidance to all actors in the supply chain without limiting innovation and the introduction of new techniques. Initiators of orders for a fibre-based graphic paper or packaging product have many priorities on their agendas, such as meeting customer requirements, creating functionalities that meet purpose and profitability, and respecting certain environmental considerations. To help businesses also consider design and management for circularity, this document summarizes the key choices to be made and identifies the important actors that can influence these choices.

“Riding the fibre” for a moment can help to understand the needs that these new principles of design for circularity must meet. A fibre would say:

“Don’t do this to me, or else I’ll break”

“Don’t attach that to me – I’m unable to shed it and will remain dirty”

“Don’t attach that to me – getting rid of it might consume a lot of energy”

“Don’t attach that to me – I’ll be thrown away”

The guidelines apply to fibre-based printing paper and packaging products, as well as to other fibre-based products that a designer wants to make more suitable for recycling. Considering the particular end-of-life management operations, these guidelines are not applicable to both sanitary products (waste water treatment) and construction paper products (construction and demolition waste). The guidelines cover:

- The paper or board substratum
- Any materials applied to paper or packaging products to meet their end-user application requirements
- The processes and consumables needed to produce the paper and packaging product

Paper Product Life Cycle and the Circular Economy

The life cycle of a paper product is composed of a series of value-adding steps, from the extraction of natural resources until the end of the paper product's life.

In a circular economy scheme, the product's end of life is reconnected with its production by reusing the already extracted resources, which are contained in used products. This circular economy scheme is particularly suitable for the pulp and paper sector, thanks to the possibility of producing paper and packaging from used paper products.

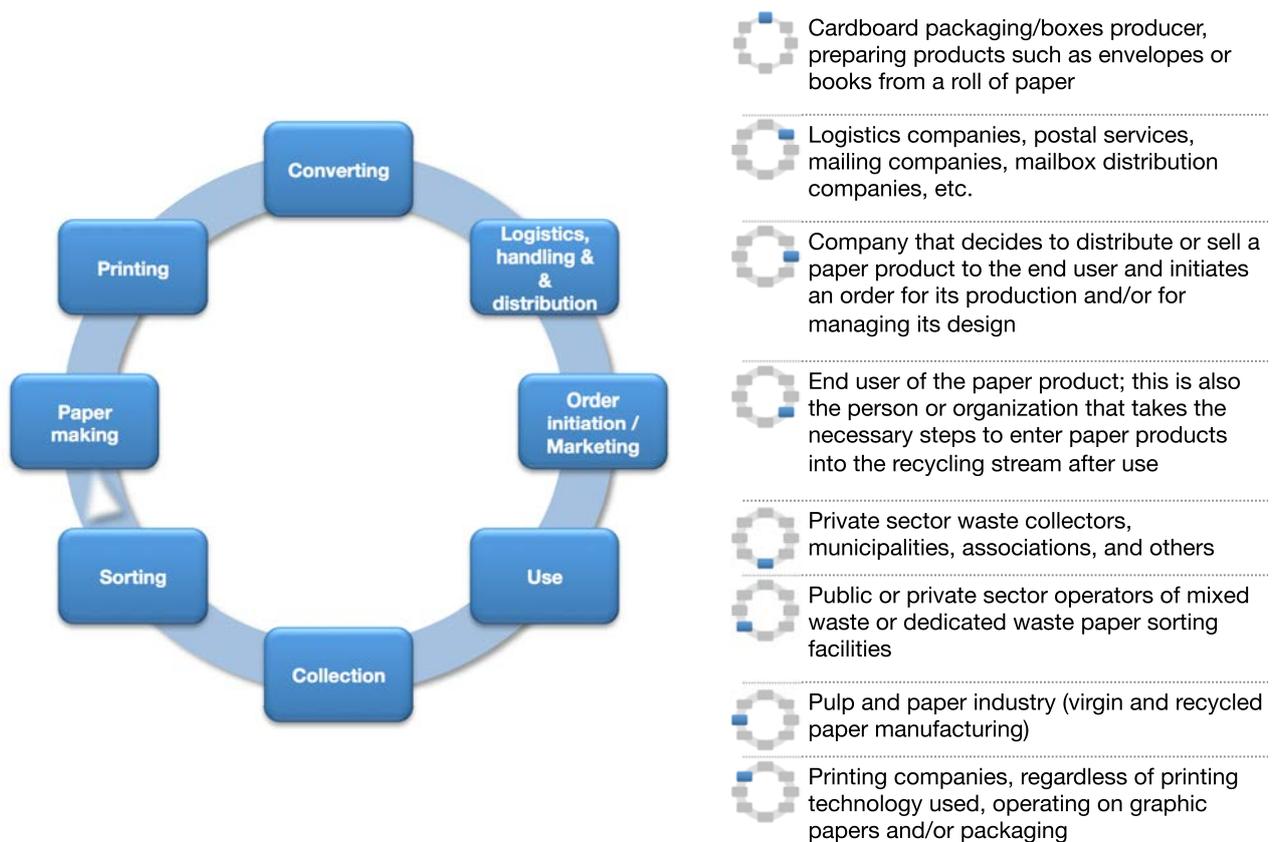
Using the right fibre for an application is important because fresh and recycled fibres have different characteristics. As fibre quality deteriorates in the recycling process, fresh fibres

are always needed in the recycling loop. Because of fast cycles, the quantity of fibre would run out in about six months if fresh fibre were not constantly added to the life cycle. The addition of fresh fibre starts either with the production of products that need specific fibre properties, or with the combination with recycled fibres.

For a dramatically improved performance in the circular paper product supply chain, both direct and indirect actors need to understand and familiarize themselves with the recommendations provided herein. The direct actors of the paper life cycle "touch" the fibre in paper-based products or directly influence its quality or lifetime (Figure 1).

Figure 1: Direct Actors in the Paper Product Life Cycle

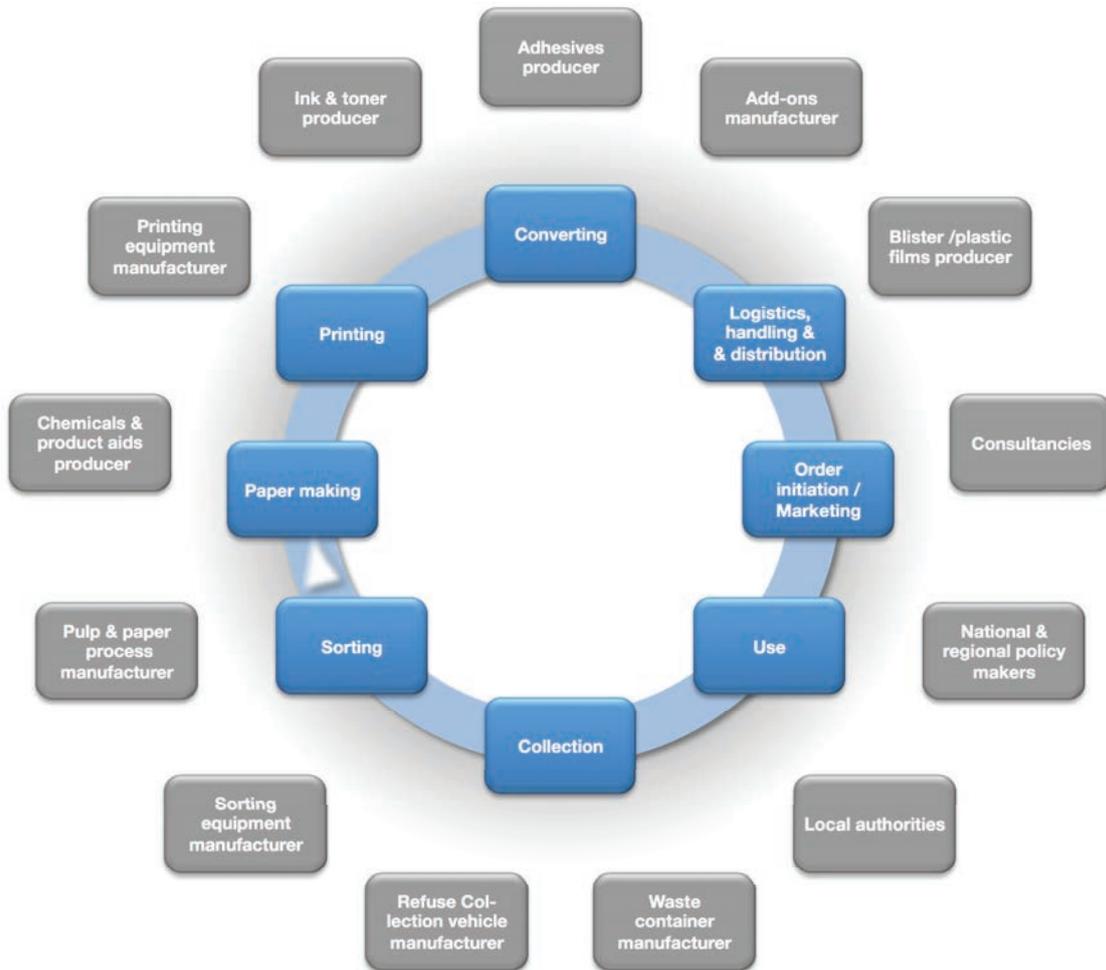
Note that the sequence of the actors does not necessarily illustrate the flow of materials



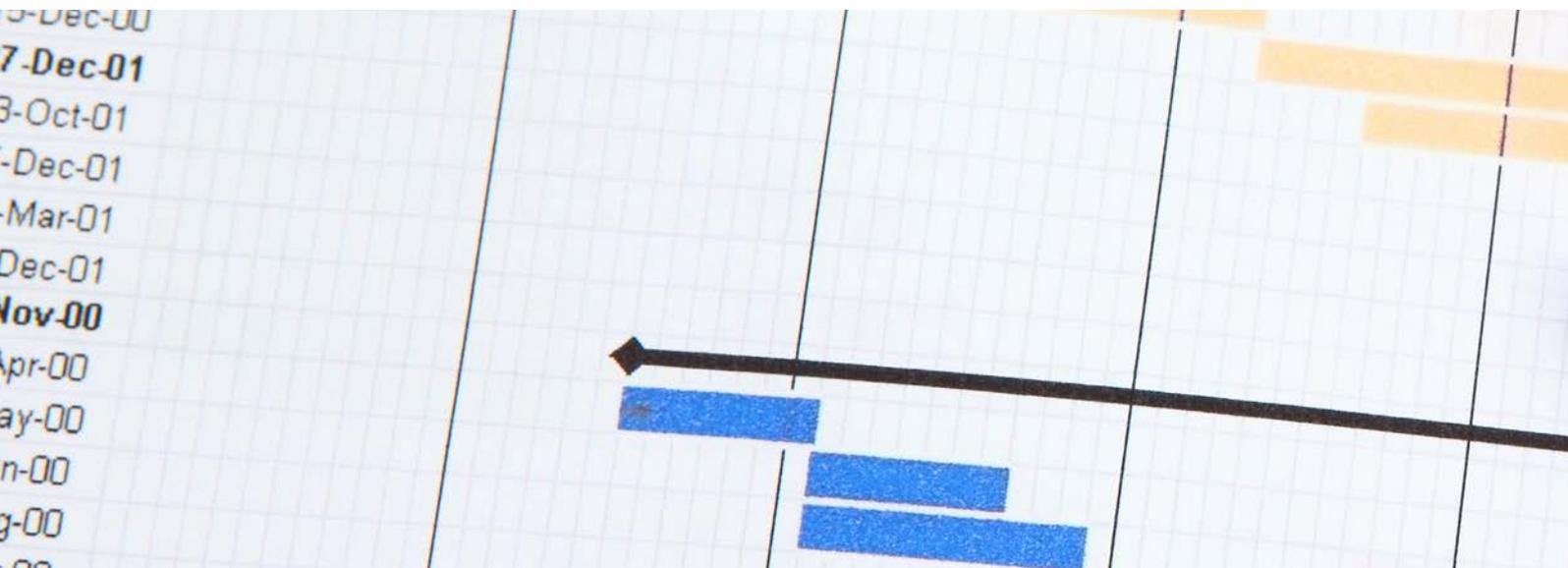
Source: Report contributors

To consider the recommendations contained in this document, a direct actor will need access to new solutions developed by its partners and suppliers – the indirect actors – since they do not have direct contact with the fibre (Figure

Figure 2: Indirect Actors in the Paper Product Life Cycle



Source: Report contributors



Recommendations for Better Design and Management for Circularity

A circular economy seeks to maximize not just efficiency, but also effectiveness. Achieving this requires awareness and knowledge of circular economy principles at each step of the value chain and a holistic approach to applying them. The three core principles of the circular economy of paper products are:¹

- **Preserve and enhance natural capital** by controlling finite stocks and balancing renewable resource flows; optimize resource use and preserve value all along the value chain
- **Optimize resource yields** by circulating products, components and materials in use at the highest utility at all times in both technical and biological cycles; connect the downstream value chain back into the upstream value chain
- **Foster system effectiveness** by revealing and designing out negative externalities; systemic impacts are identified, understood and potentially mitigated, and are taken into account together with the total value of the paper or packaging item

By following these three principles, the value of materials will not be destroyed. In cases where current technology does not allow full recovery of all of such materials, those materials will at the very least not destroy the value of other materials that can already be recovered, thus supporting circularity. This document offers three types of recommendations and a transversal principle as support:

- **Eco-design:** what to do or avoid doing to the fibre in order to optimize its lifetime (Figure 3), and make it easier and safer to recycle. These recommendations will mainly concern actors along the supply chain, from the paper industry to order initiators.

- **Eco-management:**² how to handle or manage the paper product in order to limit fibre losses (Figure 3). These recommendations will mainly concern actors along the supply chain, from the end user to the paper recycling industry.
- **Environmental impact:** how to reduce the environmental footprint along the paper product life cycle.
- A **transversal principle** supporting the three types of recommendations: establish and maintain a communication channel or a platform that allows good transmission of information and cooperation between stakeholders along the entire value chain (e.g. eco-design and eco-management actors). This principle will be crucial to ensuring an optimal flow of materials and high circularity rates by avoiding leakage at sorting and/or recycling stages.

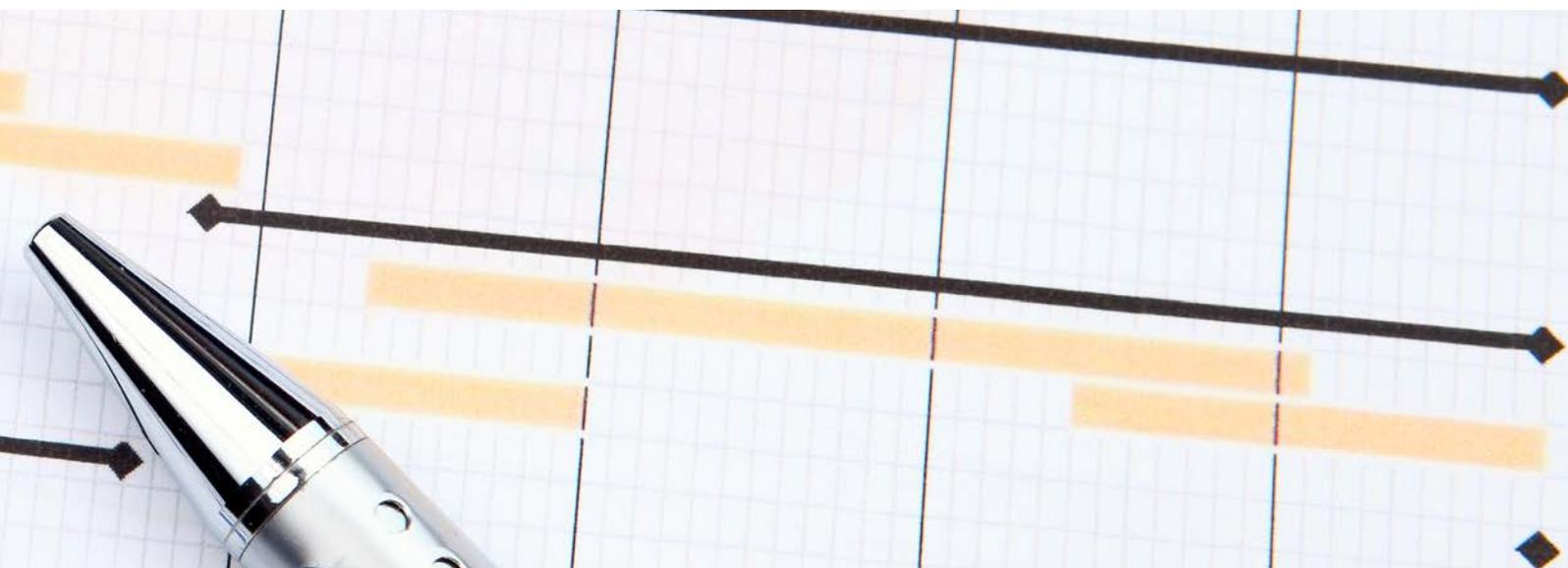
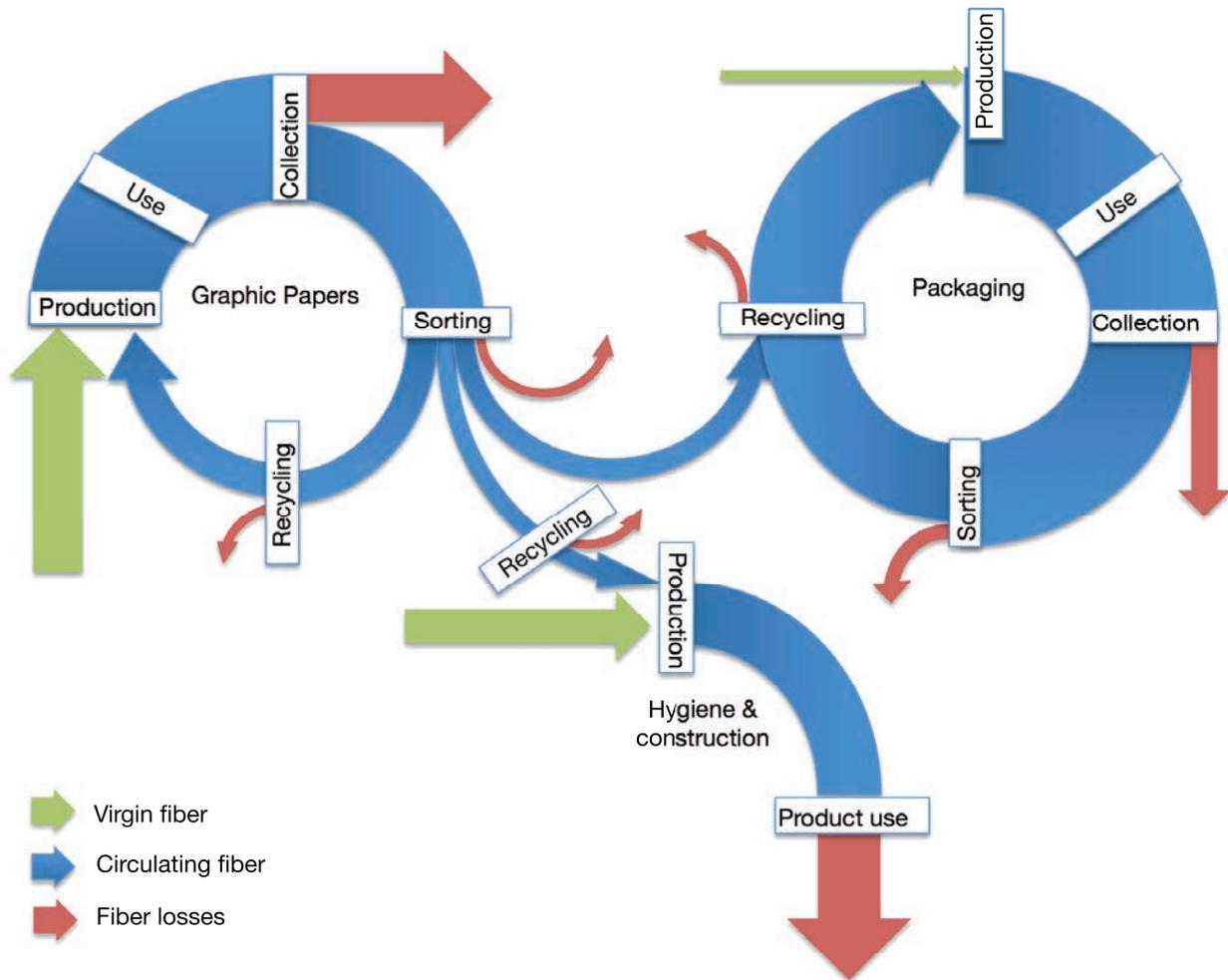


Figure 4: Fibre Life Cycles



Source: Report contributors



The life cycle of chemicals follows similar pathways; these components will either end up in solid waste or effluent water, or be retained in the fibre – and, hence, into the next production cycle. The following two considerations are therefore critical to a healthy circular economy:

- Recirculating material tends to increase the concentration of substances of concern, calling upon each actor to consider this tendency and limit such substances.
- The fibre could travel through different business sectors, which calls for considering the current uses for recycling and their requirements, and being aware of new or additional requirements to the overall recycling stream. For example, a graphic paper could be recycled into a packaging product, which might add requirements that limit residual chemical contamination.

Eco-design guidelines

In addition to the following actor-specific guidelines (Table 1), general eco-design recommendations are applicable to each actor in the paper life cycle. A greater degree of stewardship is beneficial across the board:

“I’m at your service now because I was respected by the previous users. Please do the same so I can serve again! Minimize the amount and maximize the safety of chemicals retained in me. Always offer the most recyclable solution.”

Table 1: Eco-Design Recommendations for Direct Actors in the Paper Life Cycle

		Type of direct actor	How to maintain my lifetime (recyclability)	How to optimize my use and quantity (resource efficiency)
Eco-design	Papermaking	The pulp and paper industry (virgin and recycled paper manufacturing)	If you colour me, use colourants that are easily removed with standard bleaching agents employed in paper recycling processes	Select fillers, coatings, colourants and laminates that don't disrupt my move to another cycle
			Respect my ability to keep my hydrogen bonding sites free after recycling	If I'm used to produce a recycled paper, strengthen me and enable my cleaning because I will return as raw material in your paper mill Use primarily recycled fibre (like me), and add virgin fibres to me that come from sustainably managed forests, in order to renew the fibre "stock" in the global flow
	Converting <small>(changing the shape of, treating and modifying paper/cardboard)</small>	Producers of cardboard packaging/boxes, preparing products such as envelopes or books from a roll of paper	Ensure that any other added materials can be readily separated from me	Order paper with near net size
			If glues/adhesives are needed to form me into the final product shape, use adhesives that can be easily removed from paper pulp, or if not, then without detrimental impact on pulp quality and waste water treatment	Recycle my scraps; sort them by homogenous grades to optimize my recycling
			Minimize adding non-paper components to me	Adjust the paper/board weight or thickness with the packaging objective (weight and other packed-product properties) Use closures and seals that contain no adhesives or readily removable adhesives
	Printing	Printing companies, regardless of the printing technology used, operating on graphic papers and/or on packaging	Choose printing processes and materials that can be removed efficiently, and optimize the use of resources	Minimize the need to downcycle me
			If I'm a graphic paper, use ink with a good deinkability performance when printing on me (which will allow for my recycling in the graphic paper or tissue/hygienic paper industry)	Order paper/board with near net shape
			Use elements for binding (e.g. spirals, agraffes, heat-sealed bindings) that can be easily removed from paper pulp, or that have no detrimental impact on pulp quality and waste water treatment (for fold binding, for example) Use inks with low migration for packaging and graphic paper	Recycle my trims/scraps, and sort my scraps by homogenous grades to optimize my recycling Adjust the number of copies to the real needs of your target (avoid an invoicing system based on the "additional 1,000" principle); the required quantities should determine the choice of printing technology, not the opposite
	Logistics, handling & distribution	Logistics companies, postal services, mailing companies, mailbox distribution companies and others	Minimize the use of ultraviolet (UV) varnishes on me, or, preferably, use UV varnishes with low impact on the recycler pulp quality (less specks)	Adjust the paper's weight with the paper product's objective
			If I'm a personalized mailing piece, use personalization printing technology with good deinkability performance	Collect and recycle the unsold or distributed products
Order initiation/Marketing	Companies that decide to distribute or sell a paper product to the end user and initiate orders for their production and/or for managing their design	If samples are attached to me, choose adhesives with low impact on recycling processes (easily extracted from pulp)	Update the distribution database regularly	
		Choose logistics/distribution processes that don't require extra non-fibrous materials or elements added to me that are detrimental to recycling	Simplify sorting, minimize any need for downcycling me and minimize fibre losses	
		Clearly define the paper product's objectives before making design choices	Request a printing method compatible with the total quantity needed; avoid ordering extra copies, and optimize the product's size/format	
			Design and order the production of paper product, taking into account all the above listed elements	
			Define a procurement policy for purchasing graphic paper and/or packaging	
			Define procurement rules for advertising substrate/support (e.g. magazines, posters)	

Source: Report contributors

Eco-management guidelines

Actor-specific recommendations for these guidelines (Table 2) should also be informed by the general principle of stewardship:

“I’m at your service now because I was respected by the previous users. Please do the same so I can serve again! Minimize my degradation.”

Table 2: Eco-Management Recommendations for Direct Actors of the Paper Life Cycle

Eco-management	Use	End users of paper products; these are also people or organizations that take the necessary steps to enter used paper products into the recycling stream after their use	Use me in such a way that the fibre can be reused	Inform all users (households, professionals) on a global, national or local basis that all paper – graphic and packaging – is recyclable
			Avoid destroying and dirtying me	Inform all users (households, professionals) on a global, national or local basis to put me into a container dedicated to paper for recycling
			Throw me out as I am; don't crumple or shred me (except for confidential documents)	Print me on both sides where applicable
	Collection	Private-sector waste collectors, municipalities, associations and others	Throw me in a recycling bin – even when you're away from home	
			Avoid collecting me in a waste stream with materials other than fibrous products (e.g. plastic, metal, glass)	Do not landfill or incinerate me
			Avoid collecting me with dirty materials and containers, and dirty refuse collection vehicles	Recycling me is preferable to composting or subjecting me to methanization (I have no specific added value for the quality of compost)
	Sorting	Public- or private-sector operators of mixed waste or dedicated waste paper sorting facilities	Avoid humidity and long storage times	Avoid mixing different paper types
			Sort to grades that maximize my service/added value to the circular economy (e.g. maximize my lifetime, reduce the need for virgin fibres, emphasize cost-efficiency)	Minimize my idle time and travel distance
			Sort grades with respect to quality norms/standards	Optimize the sorting process to avoid fibre losses (effectiveness on small elements, efficiency of separation processes, adjust bailing)
			Avoid humidity on stocks, where possible	
			Sort grades that are "locally" requested, optimize transport distances and find a local user for me	

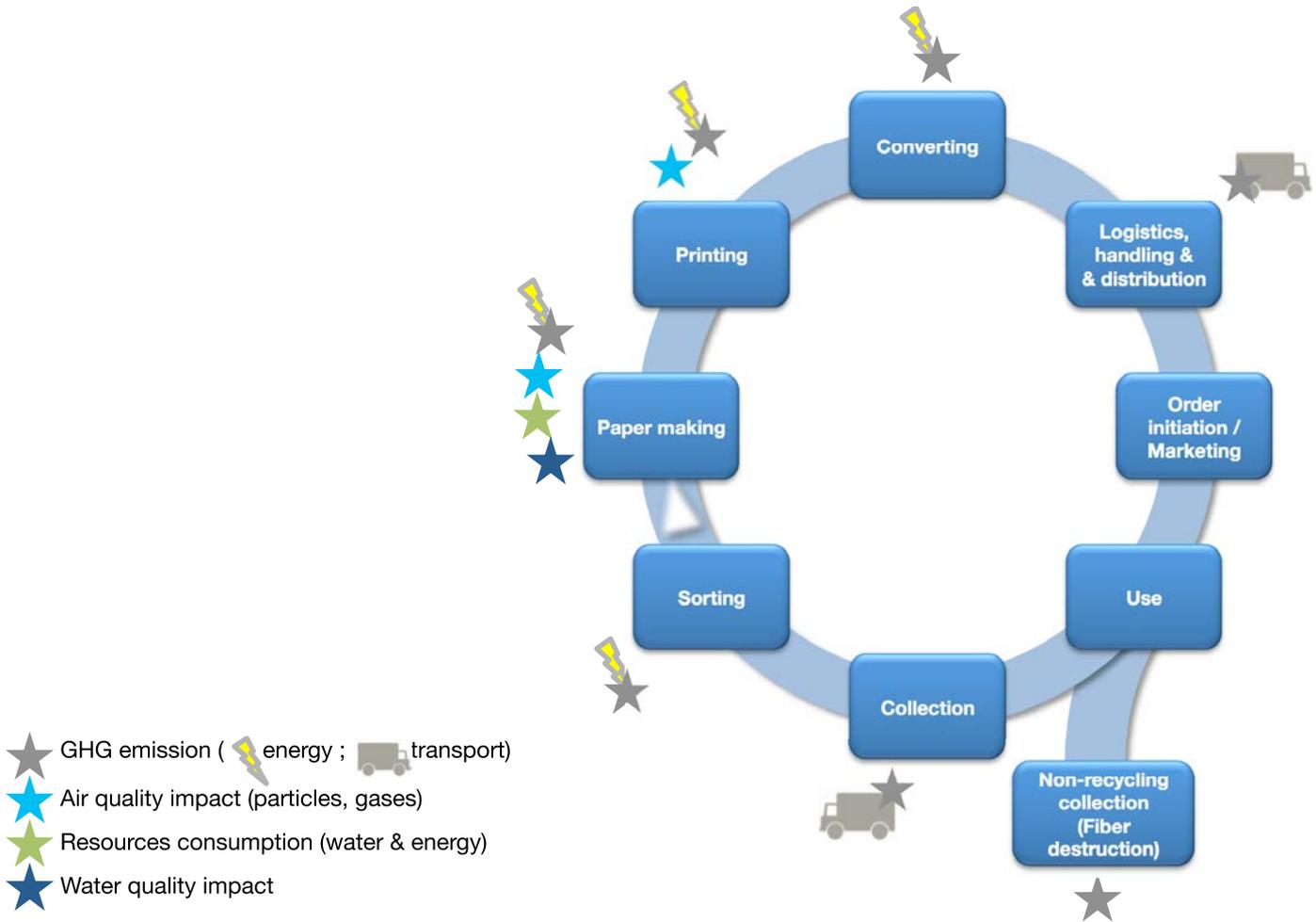
Source: Report contributors



Recommendations for environmental impact management

Figure 5 illustrates the key environmental impacts along the paper product value chain. In line with the third principle (foster system effectiveness) of the circular economy of paper products, the recommendation is to minimize system-level impacts and negative externalities, regardless of the fibre source, and to commit to continuous improvements in this area.

Figure 5: Main Environmental Impacts in the Paper Product Life Cycle



Source: Report contributors

Sustainable approaches for fibre resource management

Such approaches are crucial because fibre resource management represents a potentially significant environmental impact within the paper life cycle. Forests and trees capture and store carbon. Fibre extraction (for virgin pulp production) requires energy, and pulp production and paper forming are water- and energy-intensive. If fibre is not returned to the recycling loop, it degrades and thereby emits GHGs. Good fibre resource, energy and waste management (Table 3) should thus be an important goal for paper products.

Table 3: Key Aspects of Managing Fibre Resources, Energy and Waste

1. Fiber resource management	2. Energy Management	3. Waste Management
<ol style="list-style-type: none"> 1. Sustainable forest management 2. Efficient, fiber-protective pulp production and fiber recycling 3. Consumption optimization (production of right quantities...) 	<ol style="list-style-type: none"> 1. Energy efficiency (process optimization, transport optimization...) 2. Energy mix (choice of the optimum energy mix considering the energy need and environmental impact of each type of energy...) 3. Local energy cooperation (combined heat and power generation, sharing energy production capacities, identification of local energy resources ...) 	<ol style="list-style-type: none"> 1. Quantity reduction of final disposal 2. Waste treatment choices enabling recycling , as a priority, and energy recovery secondary 3. Local industrial cooperation (my waste is your resource)

Source: Report contributors



Checklist for the Order Initiator's Supply Chain

The end user's consumption of paper is more "push" than "pull"; this means that most paper products are sent or distributed to end users without their making a specific request. Consequently, the order initiator often dictates the design of circularity choices and orders and/or sells the final paper product, rather than working with end users through their consumption choices. Thus, a checklist was found to be useful specifically for the order initiator's supply chain. Through the order initiation process, the task of detailing out some of these choices may be delegated to other actors in the supply chain.

The checklist includes the following:

A. Rethink and define the paper product's goals

- What type of information is to be communicated, and what product objectives are to be accomplished?
- What reactions should be expected from readers/consumers?
- What is the end-reader/end-user target market?
- Have the number of copies required been adjusted to the real needs of the target? (Be careful with quotations referring to the "additional 1,000" products)
- What is the lifetime of the printed paper/packaging? How long is any information valid? (Or how long is it useful?)
- What image of the company should be upheld?
- How accurate is the size of the audience? How quickly can a response be made to increasing demand?

B. Identify different design choices and their impact

Making conscious choices should take into account the paper product's goals, efficiency and impacts. For instance, a paper-based product needs to be functional; packaging's primary role is to protect and promote the product inside. Functionality is the key design determinant for the quantity and type of paper used, as well as for the quantity and nature of ancillary materials, such as inks and adhesives. Functionality is essential to preserving both the value of the fibre in the packaging and the value of the materials used in the product.

Specification and design of paper product

- Optimize the size of paper/board for the final product format to fit standard industry production sizes
- Optimize the paper weight
- Pay particular attention to the layout and model
- Limit the use of coloured (tinted) graphic paper
- Limit the addition of non-paper components and accessories, and the use of wet-strength papers
- Make sure any non-paper product components or accessories are compatible for recycling
- Take into account the obsolescence of the printed paper document/packaging and its contents (useful lifetime of the printed paper/packaging)
- Match appearance (e.g. brightness, specks, thickness) to the minimum viewer requirements



Specification for non-toxic materials in procurement

- Request that substances of concern be reduced or substituted
- Give priority to substances with an environmentally preferable profile – for example, lower toxicity and lower persistency
- Substitute substances that are carcinogenic, mutagenic and toxic for production (CMR) with non-CMR substances, as well as substances that are persistent, bioaccumulative and toxic (PBT) with non-PBT substances

Specification for paper product production

- Encourage the use of recycled fibre or fibre from sustainably managed forests, in compliance with an internationally acknowledged certification scheme
- Use inks with good deinkability
- Adjust the printing technology to product lifetime and quantities
- Limit the use of adhesives and UV varnishes
- Select suppliers committed to the environment (ISO 14001 or other environmental management system and policies)
- Identify and quantify substances of concern in products, as well as in materials in the final product's various supply chains
- Support risk management in circular flows by making information available on substances of concern along the value chain(s); such information may be chemical data or risk assessments

Specification for distribution and delivery

- Choose the most efficient distribution and delivery methods
- State the preference for adding fewer non-fibrous elements, for example add-ons (depending on the type of product)

Specification for policy-makers for sorting and return-rate incitement

(various actors might be in a position to address their audiences about this)

- Use national communication to inform about the recyclability of paper products
- Use local or company communications to clarify in which waste stream the paper products should be discarded
- Show recyclability and the recycled and certified fibre content (if applicable) via communication on paper/ packaging; indicate that the product should be recycled after use



Glossary

Board (Paperboard)	The generic term applied to certain types of paper frequently characterized by their relatively high rigidity. The primary distinction between paper and board is normally based on thickness or “grammage” (the basis weight), though in some instances the distinction will be based on the characteristics and/or end use. For example, some materials of lower grammage, such as certain grades of folding boxboard and corrugated raw materials, are generally referred to as “board”, while other materials of higher grammage, such as certain grades of blotting, felt or drawing paper, are generally referred to as “paper”.
CMR	Carcinogenic, mutagenic and toxic for reproduction (pertaining to substances).
Construction paper product	A heavy type of paper used for a variety of products where the paper does not return to the paper loop.
Deinking	The process of removing ink and/or toner from a printed product. This restores, as best as possible, the optical properties of the unprinted product.
Direct actors	Actors or designers in direct contact with the fibre.
Fibre	An elongated, tapering, thick-walled cellular unit that is the structural component of woody plants.
GHG (emissions)	Greenhouse gas. Any of the atmospheric gases that contribute to the greenhouse effect by absorbing infrared radiation produced by solar warming of the earth’s surface. They include carbon dioxide (CO ₂), methane (CH ₄), nitrous oxide (N ₂ O) and water vapour (H ₂ O).
Grammage	The basis weight of paper or paperboard, denoting a measure of the mass of the product per unit of area and expressed in grams per square meter.
Graphic paper	Paper made for printing text or images.
Indirect actors	Actors or designers not directly in contact with the fibre.
Non-fibrous elements	Substances such as coating, fibres, salts, binders and glues, used to derive an intended state of the fibre substrate.
Non-paper product components, accessories (e.g. add-ons)	Minerals, metals and synthetic materials, among others, that enter the paper-converting process or are joined to the final paper-based product.
Order initiator	The role in the paper loop that defines products, which either require the use of fibres, as they are made of fibre products due to their specific use case (such as books, newspapers and packaging), or need fibre products for shipping, storage or other secondary purposes.
Packaging paper	The type of high-strength paper used for wrapping and packing after conversion to packaging (boxes, bags). This covers both paper and board.
Paper	<p>The generic term for a range of materials in the form of a coherent sheet or web, excluding sheets or laps of pulp commonly understood as used for papermaking, dissolving purposes or producing non-woven products, made by depositing vegetable, mineral, animal or synthetic fibres, or their mixtures, from a fluid suspension onto a suitable forming device, with or without the addition of other substances.</p> <p>Papers may be coated, impregnated or otherwise converted, during or after their manufacture, without necessarily losing their identity as paper. In the conventional papermaking process, the fluid is water; new developments, however, include the use of other fluids and air.</p>
Paper product	Any product based on paper and/or board, printed and/or converted to fulfil its designated purpose. It may contain inks, varnishes, lamination, any type of bonding (e.g. glue, staples and threads) and non-paper material, such as product samples.
PBT	Persistent, bioaccumulative and toxic (as in substances or chemicals).
Sanitary product	Highly absorbent, bulky types of lightweight tissue paper used to make disposable sanitary items, where the paper usually does not return to the paper loop for hygienic reasons.

Virgin fibres	Papermaking fibre that has not been previously used in the papermaking process. Generally, it refers to fibre (pulp) produced for the first time* from raw materials using a chemical, mechanical or semi-chemical pulping process. * often as residues or by-products from other industries, such as saw mills or forest management
Wet-strength paper	A paper in which the fibre constituents and/or the sheet were chemically treated to enhance resistance to tearing, rupture or falling apart after becoming saturated with liquids.
For further definitions	See: Confederation of European Paper Industries (CEPI), Pulp and Paper Industry – Definitions and Concepts, 2014, at: http://www.cepi.org/system/files/public/documents/publications/statistics/2014/FINAL%20CEPI%20Definitions%20and%20Concepts_0.pdf . Lavigne, John R., Pulp & Paper Dictionary, 3rd Edition, Miller Freeman Books, 1998.

Endnotes

¹ Ellen MacArthur Foundation, SUN and the McKinsey Center for Business and Environment, *Growth Within: A circular economy vision for a competitive Europe*, 2015.

² While “eco-management” can be used as an overall term to include eco-design, it is used here to mean other actions taken in addition to eco-design.



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