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Imaging equipment and its consumables. Preparatory study for ecodesign.

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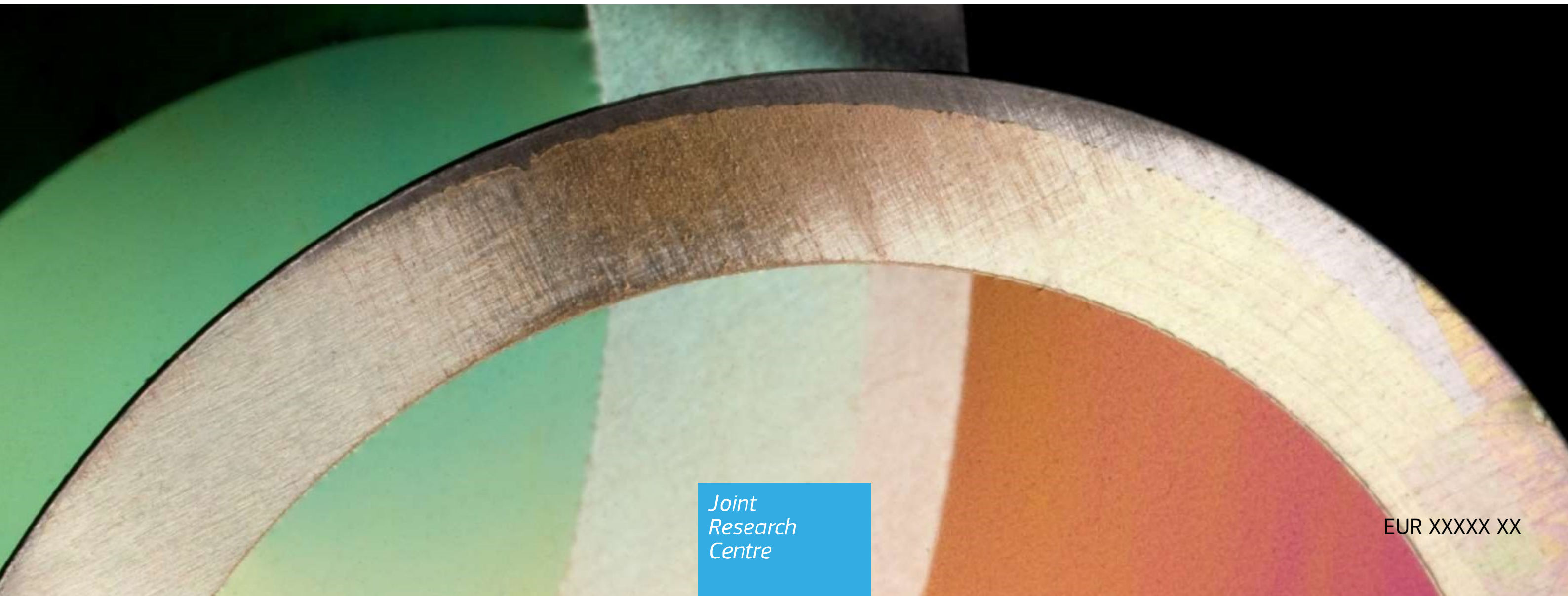

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Contents

1 Task 1 – Scope

The aim of Task 1 is to provide definitions of the key products and aspects that will be covered in this Preparatory Study and to make a scope proposal.

In order to provide definitions for key products and aspects, already published definitions in reference documents will be evaluated and presented, including regulation, standards and voluntary schemes (Sections 1.1, 1.2 and 1.3).

To support the scope proposal of this Preparatory Study, different instruments will be evaluated in terms of scope: currently applicable regulation, standards and voluntary schemes. Key aspects covered by each of those instruments will be presented and compared (Sections 1.4, 1.5 and 1.6).

Definitions for this Preparatory Study will be presented in Section 1.7. A scope proposal will be made in Section 1.8.

1.1 Definitions – Imaging equipment devices

Definitions for imaging equipment (IE) devices can be found in a variety of sources. In this section, the following documents have been consulted:

- The ISO/IEC 29142-1:2021 – Information Technology – Print Cartridge characterization – Part 1: General: Terms, symbols, notations and cartridge characterization framework. (ISO, 2021)
- The Voluntary Agreement (VA) for Imaging Equipment 2015 (Eurovaprint, 2015)
- The proposed Voluntary Agreement for Imaging Equipment 2021 (Eurovaprint, 2021)
- The EU Green Public Procurement (GPP) criteria for Imaging Equipment (Kaps et al, 2020)
- The Energy Star v3.2 product specification for imaging equipment (Energy Star, 2020)
- The Blue Angel Ecolabel for office equipment with printing functions (DE-UZ 219) (Blue Angel, 2021a)
- The Nordic Ecolabelling for Imaging equipment version 6.7 (Nordic Ecollabelling, 2020a)
- The EPEAT Ecolabel, based on the IEEE Standard for Environmental assessment of imaging equipment (IEEE, 2012)
- The TCO Certified Generation 9, for imaging equipment, Edition 1 (TCO Development, 2022).

1.1.1 Definitions of imaging equipment devices according to ISO 29142-1

ISO/IEC 29142-1:2021 provide definitions for different types of printers:

> *Printer: device intended to apply colourant(s) to a substrate in response to a digital signal.*
>
> *Monochrome printer: a printer only capable of printing black and not configurable to print another colourant.*
>
> *Colour printer: a printer with an operating part to apply ink or toner on a substrate, with a functionality to produce print output containing colours.*
>
> *Single-function printer: printer with an operating part to apply ink or toner on a substrate, having no additional functions such as fax or scan.*
>
> *Multi-function printer: printer with an operating part to apply ink or toner on a substrate, and also providing additional functions such as fax and copy.*
>
> *Electrophotographic (EP) printer: a printer principally using optoelectronic phenomena and electrostatic attraction to move toner to a substrate*
>
> *Inkjet (IJ) printer: a printer with an operating part, for example a printhead, to apply ink on a substrate (ISO 29142-1).*

1.1.2 Definitions of imaging equipment devices in other sources

The EU GPP criteria (SWD(2020) 148 final) and (Kaps et al, 2020), provide additional definitions for imaging equipment devices, beyond printers:

<u>Imaging equipment devices:</u> Products marketed for office or domestic use, or both, and whose function is one or both of the following:

a) to produce a printed image in the form of a paper document or photo through a marking process either from a digital image, provided by a network/card interface or from a hardcopy through a scanning/copying process;

b) to produce a digital image from a hard copy through a scanning/copying process.

In Kaps et al, 2020, imaging equipment devices are classified by type:

<u>Printer:</u> A product whose primary function is to generate paper output from electronic input. A printer is capable of receiving information from single-user or networked computers, or other input devices (e.g., digital cameras). This definition is intended to cover products that are marketed as printers, and printers that can be field-upgraded to meet the definition of a Multifunctional Device (MFD).

<u>Copier:</u> A product whose sole function is to produce paper duplicates from paper originals. This definition is intended to cover products that are marketed as copiers, and upgradeable digital copiers (UDCs).

<u>Multifunctional device</u>: A product that performs two or more of the core functions of a Printer, Scanner, Copier, or Fax Machine. An MFD may have a physically integrated form factor, or it may consist of a combination of functionally integrated components. MFD copy functionality is considered to be distinct from single-sheet convenience copying functionality sometimes offered by fax machines. This definition includes products marketed as MFDs, and "multi-function products" (MFPs).

<u>Scanner:</u> A product whose primary function is to convert paper originals into electronic images that can be stored, edited, converted, or transmitted, primarily in a personal computing environment. This definition is intended to cover products that are marketed as scanners.

In addition, the following product categories are defined in other relevant documents and reports:

<u>Fax machine:</u> A commercially-available imaging product whose primary functions are scanning hard copy originals for electronic transmission to remote units and receiving similar electronic transmissions to produce hard copy output. Electronic transmission is primarily over a public telephone system, but also may be via computer network or the Internet. The product also may be capable of producing hard copy duplicates. The unit must be capable of being powered from a wall outlet or from a data or network connection. This definition is intended to cover products that are marketed as fax machines (Huang et al, 2019)

<u>Digital Duplicator</u>: A product sold as a fully-automated duplicator system through the method of stencil duplicating with digital reproduction functionality (Energy Star v3.2)

<u>Mailing Machine</u>: A product whose primary function is to print postage onto mail pieces. (Energy Star v3.2)

Kaps et al (2020) also provide a definition for professional imaging products. This definition is equivalent in to the definition in Energy Star v3.2:

<u>Professional imaging product</u>: A printer or MFD marketed as intended for producing deliverables for sale, with the following features:

a) Supports paper with basis weight greater than or equal to 141 g/m2;

b) A3-capable;

c) If product is monochrome, monochrome product speed equal to or greater than 86 ipm;

d) If product is colour, colour product speed equal to or greater than 50 ipm;

e) Print resolution of 600 x 600 dots per inch or greater for each colour

f) Weight of the base model greater than 180 kg; and

Five of the following additional features for colour products or four for monochrome products, included standard with the Imaging Equipment product or as an accessory:

g) Paper capacity equal to or greater than 8,000 sheets;

h) Digital front-end (DFE);

i) Hole punch;

j) Perfect binding or ring binding (or similar, such as tape or wire binding, but not staple saddle stitching);

k) Dynamic random access memory (DRAM) equal to or greater than 1,024 MB.

l) Final-party color certification (e.g., IDEAlliance Digital Press Certification, FOGRA Validation Printing System Certification, or Japan Color Digital Printing Certification, if product is color capable); and

m) Coated paper compatibility.

1.2 Definitions – Cartridges

Definitions for imaging equipment cartridges can be found in a variety of sources. In this section, the following documents have been consulted:

- The ISO/IEC 29142-1:2021 – Information Technology – Print Cartridge characterization – Part 1: General: Terms, symbols, notations and cartridge characterization framework. (ISO, 2021)
- The proposed Voluntary Agreement for Imaging Equipment 2021 (Eurovaprint, 2021)
- The Green Public Procurement (GPP) criteria for Imaging Equipment (Kaps et al, 2020)
- The Blue Angel Ecolabel for remanufactured toner cartridges and ink cartridges for printers, copiers and multifunction devices (DE-UZ 177) (Blue Angel, 2021b)
- The Nordic Ecolabelling for remanufactured OEM toner cartridges version 5.6 (Nordic Ecollabelling, 2020b)
- The EPEAT Ecolabel, based on the IEEE Standard for Environmental assessment of imaging equipment (IEEE, 2012)
- The TCO Certified Generation 9, for imaging equipment, (TCO, 2022)
- Key Point Intelligence (2020). Primary Research. WEU Cartridge Collections & Recycling - Refresh 2020.
- EVAP provided additional definitions via direct email

1.2.1 Definitions of cartridges according to ISO 29142-1

The definitions provided in ISO/IEC 29142-1:2021 will be taken as reference in the first place:

> *<u>Cartridge:</u> a user replaceable unit operating with a printing system that includes at least a containing mechanism designed for materials intended for deposition on a substrate.*

According to ISO/IEC 29142-1:2021, cartridges can be classified in terms of the deposition material:

> <u>Toner cartridge</u>: a user replaceable unit of a printing system that includes at least a containing mechanism designed for toner intended for deposition on a substrate.
>
> <u>Ink cartridge</u>: a user replaceable unit of a printing system that includes at least a containing mechanism designed for ink intended for deposition on a substrate

ISO/IEC 29142-1:2021 provides definitions for toner and ink cartridges, in terms of their design or structure:

> *<u>All-in-one toner cartridge</u>: a cartridge that includes at least a toner containment part, a photoreceptor part and a developer part*
>
> *<u>Integrated ink cartridge</u>: cartridge that includes at least an ink containment part and an ink deposition mechanism*

In section 6.2, ISO/IEC 29142-1:2021 provides the different functional configurations of toner cartridges:

> *a) <u>single-part toner cartridge</u>: a toner cartridge that includes only a toner containment part*

b) two part toner cartridge: a toner cartridge that includes a toner containment part and a developer part and does not include a photoreceptor part

c) all in one toner cartridge: a toner cartridge that includes a toner containment part, a developer part and a photoreceptor part.

Similarly, for ink cartridges:

a) Single part ink cartridge: a cartridge that includes only an ink containment part

b) Integrated ink cartridge: a cartridge that includes an ink containment part and a ink deposition mechanism (example: a printhead)

ISO/IEC 29142-1:2021 also provides definitions for cartridges depending on the supplier:

Original cartridge: cartridge that is marketed by the company that markets the printing system for which the cartridge is intended.

Non-original cartridge: cartridge that is marketed by a company other than the company that markets the printing system for which the cartridge is intended.

In terms of the lifetime condition of the cartridge, in ISO/IEC 29142-1:2021 definitions are provided to different end of life activities for cartridges:

Refill: operation to replace ink or toner in a customer's cartridge that does not involve the replacement or refurbishing of worn cartridge components

Remanufacture: operation to replace or clean component and add ink or toner using cartridges from cartridge take-back or collection programs

Reuse: operation in which a whole or a component part of a cartridge is incorporated in the manufacture or remanufacture of a cartridge, such that the whole or component part is intended to be put into service for the same purpose for which it was conceived.

Other relevant definitions included in ISO/IEC 29142-1:2021 are:

Substrate: User selectable imageable surfaces (for example paper or cloth)

Deposition material: Material, ink or toner, liquid or solid, colourant or non-colourant, that can be contained in a cartridge, and that is designed for deposition on a surface by means of a printing system.

Ink: material, which often includes colourant, designed for liquid state deposition on a substrate

Dye ink: material designed for liquid state deposition on a substrate, including a chemical dye colourant

Pigment ink: material designed for liquid state deposition on a substrate, including a chemical pigment colourant

Non-colourant ink: material designed for liquid state deposition on a substrate, such as gloss optimizers and fixatives, not containing colourant.

Toner: Solid material, capable of taking on an electrostatic charge, designed for deposition on a substrate under the control of electrostatic forces in conjunction with a surface having a controlled distributed charge.

Non-colourant toner: solid material, not containing colourant, capable of taking on an electrostatic charge, designed for deposition on a substrate under the control of electrostatic forces in conjunction with a surface having a controlled distributed charge such as gloss optimizers and fixatives.

Cartridge element: sub piece of a cartridge other than the containment part of the cartridge

Developer part: physical mechanism, which is often a cartridge element, which functions to apply toner particles to the latent image on the photoreceptor part of an electrophotographic printing system.

<u>Photoreceptor part (photoconductor)</u>: physical mechanism that includes a surface that accepts a uniform electrostatic charge, with a surface that can subsequently be selectively discharged by exposure to light, and which facilitates transfer of toner to media after such exposure.

<u>Ink deposition mechanism</u>: Imaging apparatus for depositing ink on a printing substrate

1.2.2 Definitions of cartridges according to other sources

Other sources present a different approach to define cartridges. For instance, IEEE (2012) uses the generic term 'consumable':

<u>Consumable</u>: A product integral to the functioning of the imaging equipment product with the intent, when depleted or worn, to be replaced or replenished by the user during the normal usage and life span of the imaging equipment product.

NOTE—Consumables may include: toner, toner containers, toner bottles, toner cartridges, waste toner cartridges, ink cartridges, ink heads, ink sticks, ribbon ink, thermal paper, copy paper, imaging units, transfer belts, transfer roller, fusers, drum maintenance units, and other associated items. Items not intended to be replaced or replenished by the user would be not be considered consumable supplies, but rather "spare parts."

ISO 29142-1 does not provide a definition for 'container'. In fact, the definition of 'cartridge' states that it "*includes at least a containing mechanism*". In essence, ISO 29142-1 considers that a 'container' is one of the potential configurations of a 'cartridge'. On the contrary, other sources do have difference definitions for cartridges and containers, for instance the GPP criteria (Kaps et al, 2020):

<u>Cartridge</u>: An end-user replaceable product, which fits into or onto an imaging equipment product, with printing-related functionality that includes integrated components or moving parts integral to the imaging equipment's function beyond holding the ink or toner material. Cartridges can be: new built (OEM and non-OEM manufactured, including counterfeits); remanufactured (by OEM and non-OEM); refilled (by OEM and non-OEM). Cartridges may also be called modules.

<u>Container</u>: An end-user replaceable product that holds toner or ink and that fits onto or into or is emptied into an imaging equipment product. Containers do not contain integrated components or moving parts integral to the imaging product's function. Containers can be: new built (Original Equipment Manufacturers (OEM) and non-OEM manufactured, including counterfeits); remanufactured (by OEM and non-OEM); refilled (by OEM and non-OEM). Containers may also be called bottles or tanks.

Complementary definitions are provided in Kaps et al (2020):

<u>Drum unit</u>: An end-user replaceable product, which fits into an imaging equipment product and which includes a photosensitive drum

<u>Fuser unit</u>: An end-user replaceable product, which fits into an imaging equipment product and which consists of a pair of heated rollers that fuse toner onto output media

<u>Transfer unit</u>: An end-user replaceable product, which fits into an imaging equipment product, and which supports the transfer of toner onto output media ahead of a fusing process

In terms of supplier, ISO 29142-1 only establish a difference between 'original' and 'non-original' cartridges. Other definitions, from a variety of sources, establish other categories based on the supplier. For instance, in Kaps et al, 2020, the following definitions are given:

<u>New built</u>: A new cartridge/container

<u>Counterfeit</u>: Counterfeits are new cartridges/containers manufactured by a third party (not an OEM), but illegally branded under an OEM brand name

In terms of lifetime condition, two additional categories are given in Kaps et al (2020).

<u>Remanufactured</u>: A cartridge/container that, after having been used at least once and collected at its end-of-life, is restored to its original as new condition and performance, or better, by for example replacing wear parts and filled in with new toner or ink (incl. solid ink). The resulted product is sold like-new with warranty to match

<u>Refilled</u>: A cartridge/container that has been used and filled with new toner or ink (incl. solid ink)

Keypoint Intelligence (2022) provides an even more comprehensive classification of cartridges based on supplier:

> <u>New build compatible (NBC):</u> *A 3rd party replacement cartridge that does not use an empty cartridge from an OEM, but rather uses a newly moulded cartridge shell and internal parts*
>
> <u>Clones</u>***:*** *A New Build Compatible (NBC) that violates patents*
>
> <u>Virgin Empty</u>*: An empty cartridge that has not been remanufactured*
>
> <u>Bad Virgin Empty</u>*: A virgin empty that cannot be remanufactured or one for which there is no market*
>
> <u>Good Virgin Empty</u>*: A virgin empty that can successfully be remanufactured*
>
> <u>Non-Virgin Empty</u>*: An empty cartridge that has previously been remanufactured*
>
> <u>Bad Non-Virgin Empty</u>*: A non-virgin empty that cannot be successfully remanufactured or one for which there is no market*
>
> <u>Good non-Virgin Empty</u>*: A non-virgin empty that can successfully be remanufactured*

In addition to the above, EVAP also provided definitions to be considered during the development of this study. First, EVAP establishes a difference between cartridges and containers:

> <u>Cartridge</u>*: a customer replaceable unit that holds toner or ink and that must be inserted into or connected to an imaging product for the imaging product during print. Containers or similar units designed to refill ink or toner tanks are not "Cartridges"*
>
> <u>Container</u>*: a container that holds toner or inks and is designed to refill ink or toner tanks of an imaging product with or without Electronic Circuitry.*
>
> <u>Electronic Circuitry</u>*: chips, printhead, or any other electronics included in the Cartridge or Container.*

EVAP define an OEM as "a manufacturer under whose owned brand name(s) or trademark(s) imaging products and OEM Cartridges/Containers for those imaging products are placed on the market". Based on that, definitions based on the supplier are given:

> <u>OEM Cartridge/Container</u>*: an OEM branded or trademarked Cartridge/Container produced by or for the OEM for use in or with the OEM branded or trademarked imaging products. An OEM Cartridge/Container can be a Remanufactured or Refilled Cartridge/Container.*
>
> <u>Non-OEM Newbuild Cartridge/Container (NBC)</u>*: a new Cartridge/Container for use in or with an OEM branded or trademarked imaging product that is not produced by or for the OEM.*
>
> <u>Counterfeit Cartridge/Container:</u> *a Cartridge/Container that is labelled, packaged, and marketed in such a way that is intended to mislead a customer into thinking it is an OEM Cartridge/Container. Counterfeit Cartridges/Containers could be produced from Remanufactured, Refilled, or Non-OEM Newbuild Cartridges/Containers. In addition to other potential legal claims, Counterfeit Cartridges/Containers violate OEM trademarks. Counterfeiting Cartridges/Containers is a criminal activity.*

Additional definitions provided by EVAP based on lifetime condition are:

> <u>Empty Cartridge/Container</u>*: Cartridge/Container that is depleted of the ink or toner and can be refilled, remanufactured, or recycled.*
>
> <u>Refilled Cartridge/Container</u>*: Cartridge/Container resulting from a process where Empty Cartridges/Containers are simply refilled with ink or toner without replacement of components.*
>
> <u>Remanufactured Cartridge/Container</u>*: Cartridge/Container resulting from a commercial process where Empty Cartridges/Containers are collected, remanufactured, filled with ink or toner, labelled, and repackaged. Components may be replaced in order to return the Cartridge/Container to working condition and to meet desired functionality requirements, provided that the Cartridge/Container retains all or as much as possible of the original body. The Cartridge/Container shall contain:*
>
> *a) for toner Cartridges/Containers, greater than 50% by weight of reused parts not counting toner;*
>
> *b) for ink Cartridges/Containers, greater than 75% by weight of reused parts not counting ink.*

The fraction of reused parts shall be calculated from the parts which are typically replaced/reused during remanufacturing and the bill of materials. Where a bill of materials is not available the fraction of reused parts may be measured as a mass balance average over at least 100 units.

1.3 Definitions – Circularity concepts

Key circularity aspects relevant for imaging equipment and consumables are defined in Table 1.

Table 1. Circularity aspects in imaging equipment

Circularity Aspect	Definition
Durability	Ability to function as required, under defined conditions of use, maintenance and repair, until a limiting state is reached {EN45552:2020} Individual Cartridge yield: value determined by counting the number of test pages printed between cartridge installation and end of life
Reliability	Probability that a product functions as required under given conditions, including maintenance, for a given duration without limiting event {EN45552:2020}
Repair	Process of returning a faulty product to a condition where it can fulfil its intended use {EN45552:2020}
Upgrade	Process of enhancing the functionality, performance, capacity, or aesthetics {EN45552:2020}
End of life (cartridge)	Phase in a cartridge life cycle when the cartridge can no longer be used for its intended purposes without additional non-customer interaction (ISO/IEC 29142:2021)
Expected cartridge life (cartridge)	Approximate number of pages likely to be printed from a cartridges when ran to cartridge end-of life (ISO/IEC 29142:2021)
Reuse	Process by which a product or its parts, having reached the end of their first use, are used for the same purpose for which they were conceived {EN45552:2020} Reuse of cartridges: operation in which a whole or a component of a cartridge is incorporated in the manufacture or remanufacture of a cartridge, such that the whole or component part is intended to be put into service for the same purpose for which it was conceived (ISO/IEC 29142:2021)
Refill (cartridge)	Operation to replace ink or toner in a costumer's cartridge that does not involve the replacement of refurbishing of worn cartridge components. (ISO/IEC 29142:2021)
Remanufacturing and refurbishing*	Industrial process which produces a product from used products or used parts where at least one change is made which influences the safety, original performance, purpose or type of the product. {EN45553:2020} Note 1 to entry: The product created by the remanufacturing process may be considered a new product when placing on the market. Refer to the EU Blue Guide [1] for additional information. Note 2 to entry: Refurbishing is a similar concept to remanufacturing except that it does not involve substantial modifications influencing safety, original performance, purpose or type of the product. It is not covered by this standard. Remanufacture of cartridges: operation to replace or clean components and add ink or toner using cartridges from cartridge take-back or collection programs (ISO/IEC 29142:2021)
	Remanufactured Imaging Equipment :Products … which has been returned to a "like new" state of the base model, including energy performance, by the manufacturer,

	utilizing new and/or reused components from the original equipment manufacturer {Energy Star}
	Remanufacturer: Cartridge supplier that produces or markets remanufactured cartridges
Recycling	Recovery operation of any kind, by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes excluding energy recovery {EN45555:2019} Recycling of cartridges: reuse, remanufacture or otherwise divert from a solid waste stream
Recovery	Process to divert cartridges and/or cartridge materials from the solid waste stream into productive uses.
Critical Raw Materials	Critical raw material CRM materials which, according to a defined classification methodology, are economically important, and have a high-risk associated with their supply {EN45558:2019}
Post-consumer recycled content	The amount of post-consumer recycled material that goes into the manufacturing of a new product {EN45557:2020}

Among the definitions listed above, it is important to highlight how product modification by refurbishing and remanufacturing processes can influence the consideration of products as legally as "new products" or as "second hand products". This distinction has an effect on the applicability of ecodesign and energy labelling requirements, which are only applicable at the moment of placing products on the market.

1.3.1 Repairs and modifications to products according to the EU Blue Guide

According to the Ecodesign Directive 2009/125/EC (European Commission, 2009) and the Energy Labelling Regulation (EU) 2017/1369 (European Commission, 2017) 'placing on the market' means making a product available for the first time on the Community market with a view to its distribution or use within the Community, whether for reward or free of charge and irrespective of the selling technique.

The EU Blue Guide (European Commission, 2022) provides clarifications on when a modified (e.g. remanufactured) product must be considered a new product. Where a modified product is considered as a new product, it must be considered as placed on the market for the first time, and therefore comply with the provisions of the applicable legislation, including the Ecodesign Directive.

According to the EU Blue Guide, a product, which has been subject to important changes or overhaul aiming to modify its original performance, purpose or type after it has been put into service, having a significant impact on its compliance with Union harmonisation legislation, must be considered as a new product if:

i) its original performance, purpose or type is modified, without this being foreseen in the initial risk assessment;

ii) the nature of the hazard has changed or the level of risk has increased in relation to the relevant Union harmonisation legislation;

iii) and the product is made available (or put into service if the applicable legislation also covers putting into service within its scope).

This has to be assessed on a case-by-case basis and, in particular, in view of the objective of the legislation and the type of products covered by the legislation in question. In any case, a modified product sold under the name or trademark of a natural or legal person different from the original manufacturer, should be considered as new and subject to Union harmonisation legislation.

1.4 Standards

The following standards are relevant for imaging equipment consumables:

- ISO/IEC 29142-1:2021 — Information technology - Print cartridge characterization - Part 1: General: terms, symbols, notations and cartridge characterization framework
- ISO/IEC 29142-2:2013 — Information technology -- Print cartridge characterization -- Part 2: Cartridge characterization data reporting
- ISO/IEC 29142-3:2013 — Information technology — Print cartridge characterization — Part 3: Environment

Specifically on page yield the following standards are applicable to ink cartridges:

- ISO/IEC 22505:2019 — Information technology — Office equipment — Method for the determination of ink cartridge yield for monochrome inkjet printers and multi-function devices that contain printer components
- ISO/IEC 24711:2021 — Information technology — Office equipment — Method for the determination of ink cartridge yield for colour inkjet printers and multi-function devices that contain printer components

On page yield the following standards are applicable to toner cartridges:

- ISO/IEC 19752:2017 — Information technology — Office equipment — Method for the determination of toner cartridge yield for monochromatic electrophotographic printers and multi-function devices that contain printer components
- ISO/IEC 19798:2017 — Information technology — Office equipment — Method for the determination of toner cartridge yield for colour printers and multi-function devices that contain printer components

Finally the following standards describe requirements for the preparation of remanufactured toner cartridges with monochrome toner designed for use in office equipment with printing function. They also specify test methods for quality characteristic features and the determination of yield. The aim of this document is to specify minimum requirements for consistent print quality and trouble-free operation over the entire time of use of the toner cartridge.

- DIN 33870-1 — Office machines - Requirements and tests for the preparation of refilled toner modules for electrophotographical printers, copiers and facsimile machines - Part 1: Monochrome
- DIN 33870-2 — Requirements and tests for the preparation of refilled toner modules for electrophotographical printers, copiers and facsimile machines - Part 2: 4-colour printers
- DIN 33871-1 – Office machines, inkjet print heads and inkjet tanks for inkjet printers – Part 1: Preparation of refilled inkjet print heads and inkjet tanks for inkjet printers.

Table 2: Scope of different standards aiming to evaluate cartridge yield.

Standard	Deposition technology	Colour	Size
ISO/IEC 22505:2019	Inkjet	Monochrome (black)	≥A4 and ≤A3
ISO/IEC 24711:2021	Inkjet	Colour	≥A4 and ≤A3
ISO/IEC 19752:2017	Toner	Monochrome	---
ISO/IEC 19798:2017	Toner	Colour	≤A3
DIN 33870-1	Toner	Monochrome	---
DIN 33870-2	Toner	Colour	---

1.5 Legislation and voluntary instruments

Imaging equipment has been regulated with a Voluntary Agreement (VA) under the Ecodesign Directive since 2013. In the Ecodesign and Energy Labelling Working Plan 2022-2024 (European Commission, 2022), the

Commission announced the intention to develop regulatory measures for imaging equipment. Other existing relevant legislation and voluntary instruments are also applicable to some aspects of the life cycle of imaging equipment devices and consumables. In particular:

- Stand by Regulation
- RoHS Regulation
- REACH Legislation
- WEEE Directive

1.5.1 Stand by Regulation

Commission Regulation (EC) No 1275/2008 of 17 December 2008 implementing Directive 2005/32/EC of the European Parliament and of the Council (European Commission, 2008) established ecodesign requirements for standby and off mode electric power consumption of electrical and electronic household and office equipment.

The Commission Regulation (EU) No 801/2013 of 22 August 2013 (European Commission, 2013) amended the standby Regulation by introducing requirements for devices with networked functionalities and networked equipment with high network availability (HiNA equipment)

According to the Commission Regulation (EU) No 801/2013 the following thresholds currently apply (Table 3):

(a) Power consumption in 'off mode': Power consumption of equipment in any off-mode condition shall not exceed 0,50 W. (b) Power consumption in 'standby mode(s)': The power consumption of equipment in any condition providing only a reactivation function, or providing only a reactivation function and a mere indication of enabled reactivation function, shall not exceed 0,50 W.

(b) The power consumption of equipment in any condition providing only information or status display, or providing only a combination of reactivation function and information or status display shall not exceed 1,00 W

Table 3: Energy Efficiency Requirements in Off-Mode and Stand-by Mode for electrical and electronic household and office equipment

Energy Efficiency Requirement	Thresholds
Power Consumption in Off-Mode	0,50 W
Power Consumption in Stand-by Mode (only reactivation function)	0,50 W
Power Consumption in Stand-by Mode (reactivation function and information or status)	1,00 W
The power consumption in Networked Stand-by Mode* of networked equipment, other than HiNA equipment or other than equipment with HiNA functionality, in a condition providing networked standby into which the equipment is switched by the power management function, or a similar function	2,00 W
The power consumption of HiNA equipment* or equipment with HiNA functionality**, in networked standby,	8,00 W
*network stand by 'networked standby' means a condition in which the equipment is able to resume a function by way of a remotely initiated trigger from a network connection; *'networked equipment with high network availability' or 'HiNA equipment' means equipment with one or more of the following functionalities, but no other, as the main function(s): those of a router, network switch, wireless network access point, hub, modem, VoIP telephone, video phone; **'networked equipment with high network availability functionality' or 'equipment with HiNA functionality' means equipment that has the functionality of a router, network switch, wireless network access point or combination thereof included, but not being HiNA equipment;	

It can be assumed that many of the imaging equipment in the scope of this preparatory study can be characterised by an off mode and network stand by conditions, with the corresponding thresholds (0,50 W and 2,00 W applicable).

According to the Regulation (EU) No 801/2013 the power consumption limits described above shall not apply to "large format printing equipment", meaning printing equipment designed for printing on A2 media and larger, including equipment designed to accommodate continuous-form media of at least 406 mm width.

The review study[1] (published in 2017) estimated that: (i) the energy consumption in standby, networked standby and off mode of all products in current scope will be approximately 14 TWh in 2020 and (ii) the consumption will increase to approximately 27 TWh in 2030 (due to rapid technological development leading to the appearance of networked standby, and the increased number of products in use).

The new "COMMISSION REGULATION (EU) …/… of XXX laying down ecodesign requirements for off mode, standby mode, and networked standby energy consumption of electrical and electronic household and office equipment"[2] aims to revise the thresholds and extend the scope to devices with low voltage power supplies[3], currently excluded from the scope of the regulation.

The scope of this new horizontal regulation makes direct reference to the Information technology equipment intended primarily for use in the domestic environment, including copying and printing equipment. This new Commission Regulation will apply two years after the entry in force.

Table 4: Energy Efficiency Requirements for electrical and electronic household and office equipment according to the new proposed regulation for off mode, standby mode, and networked standby energy consumption.

Energy Efficiency Requirement	Thresholds
Power Consumption in Off-Mode	0,50 W
Power Consumption in Stand-by Mode (only reactivation function)	0,50 W
Power Consumption in Stand-by Mode (reactivation function and information or status)	0, 80 W
The power consumption in Networked Stand-by Mode of networked equipment, other than HiNA equipment or equipment with HiNA functionality, in networked standby into which the equipment is switched by the power management function	2,00 W
The power consumption of HiNA equipment* or equipment with HiNA functionality**, in networked standby,	8,00 W
The threshold listed above are applicable to information technologies, including copying and printing equipment, but excluding desktop computers, integrated desktop computers and notebook computers covered by Commission Regulation (EU) No 617/20133 , as well as electronic displays covered by Commission Regulation (EU) 2019/20214 .	

1.5.2 RoHS Directive

The RoHS Directive (European Commission, 2011) aims to prevent the risks posed to human health and the environment related to the management of electronic and electrical waste. It does this by restricting the use of

[1] https://www.ecostandbyreview.eu/
[2] https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=PI_COM:Ares(2022)112397
[3] 'low voltage external power supply' means an external power supply with a nameplate output voltage of less than 6 volts and a nameplate output current greater than or equal to 550 milliamperes;

certain hazardous substances in EEE that can be substituted by safer alternatives. These restricted substances include heavy metals, flame retardants or plasticizers.

The RoHS Directive currently restricts the use of ten substances: lead, cadmium, mercury, hexavalent chromium, polybrominated biphenyls (PBB) and polybrominated diphenyl ethers (PBDE), bis(2-ethylhexyl) phthalate (DEHP), butyl benzyl phthalate (BBP), dibutyl phthalate (DBP) and diisobutyl phthalate (DIBP).

All products with an electrical and electronic component, unless specifically excluded, have to comply with these restrictions. The scope of the Restriction of Hazardous Substances Directive 2011/65/EU (ROHS) fully applies to printers and cartridges (except containers).

1.5.3 Reach Regulation

The Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) Regulation (EC) No 1907/2006 (European Commission, 2006) aims to improve the protection of human health and the environment from the risks that can be posed by chemicals. REACH establishes procedures for collecting and assessing information on the properties and hazards of substances.

REACH applies to all chemical substances, including those in articles such as electrical appliances.

The Regulation also calls for the progressive substitution of the most dangerous chemicals (referred to as "Substances of Very High Concern") when suitable alternatives have been identified. SVHCs are defined as:

1. Substances meeting the criteria for classification as carcinogenic, mutagenic or toxic for reproduction (CMR) category 1A or 1B in accordance with the CLP Regulation.

2. Substances which are persistent, bio-accumulative and toxic (PBT) or very persistent and very bio-accumulative (vPvB) according to REACH Annex XIII.

3. Substances on a case-by-case basis, which cause an equivalent level of concern as CMR or PBT/vPvB substances.

Once a substance is identified as an SVHC, it is included in the Candidate List (European Chemicals Agency 2022). ECHA regularly assesses the substances from the Candidate List to determine which ones should be included in the Authorisation List (Annex XIV). Once a substance is included in an Authorisation List (European Chemicals Agency), this can be used/produced only with authorisation under certain circumstances for defined applications.

A Restrictions List (Annex XVII) is also periodically revised. Once a substance is included in the Restrictions List, specific or general uses of such substance are prohibited.

Article 33 of REACH establishes the right of consumers to be able to obtain information from suppliers on substances in articles. Suppliers of articles are obliged to provide industrial/professional users or distributors with certain pieces of information on articles containing substances with irreversible effects on human health or the environment.

In the context of REACH a cartridge is considered a combination of an article (functioning as a container or a carrier material) and a substance/mixture (ECHA 2017)[4].

1.5.4 WEEE Directive

Directive 2012/19/EU on waste electrical and electronic equipment (European Commission, 2012) covers the products in scope of this study under category 6. Small IT and telecommunication equipment.

The WEEE Directive explicitly cross-references the Ecodesign Directive 2009/125/EC: EU member states shall take appropriate measures so that the ecodesign requirements facilitating re-use and treatment of WEEE established in the framework of the Ecodesign Directive are applied and producers do not prevent, through specific design features or manufacturing processes, WEEE from being re-used, unless such specific design features or manufacturing processes present overriding advantages, for example, with regard to the protection of the environment and/or safety requirements (WEEE, Art. 4).

Producers have to provide information about preparation for re-use and treatment for new electric and electronic equipment placed on the Union market. It shall be made available to centres which prepare for re-

[4] ECHA (2017). Guidance on requirements for substances in articles June 2017 Version 4.0 https://echa.europa.eu/documents/10162/2324906/articles_en.pdf

use and treatment and recycling facilities by producers of EEE in the form of manuals or by means of electronic media, free of charge (Article 15).

According to the Annex VII of the WEEE Directive, the following substances, mixtures and components, among others have to be removed from separately collected from WEEE (and therefore from imaging equipment and cartridges) for selective treatment:

- toner cartridges, liquid and paste, as well as colour toner,
- external electric cables
- plastic containing brominated flame retardants,
- printed circuit boards greater than 10 square centimetres,

As clarified by the European Commission in 2014[5] a printer cartridge falls within the scope of the Directive if it meets the definition of EEE given in Article 3(1)(a) and does not fall under the exclusions of Article 2 of the Directive. The decisive criterion is the fulfilment of the definition of EEE. Thus, printer cartridges which contain electrical parts and are dependent on electric currents or electromagnetic fields in order to function properly fall within the scope of the Directive. Printer cartridges which merely consist of ink and a container, without electrical parts, do not fall within the scope of the Directive.

1.6 Voluntary schemes

In this section, a summary will be presented with the different aspects covered in voluntary schemes, for devices and consumables.

1.6.1 The Voluntary Agreement for imaging equipment

In the context of the Ecodesign Directive, a Voluntary Agreement between manufacturers committing to a common level of environmental performance, can be considered as admissible alternative to a mandatory regulation, if such action is likely to deliver the policy objectives faster or in a less costly manner. Currently, this kind of approach is not commonly applied as only imaging equipment (European Commission, 2013) and games consoles (European Commission, 2015) are subject to self-regulation among the large number of product groups regulated under the Ecodesign Directive.

Imaging equipment has been regulated with such a Voluntary Agreement (VA) under the Ecodesign Directive since 2013.

The 2020 Circular Economy Action Plan (European Commission, 2020) referred to this product group, stating that ‘Printers and consumables such as cartridges will be covered [by the upcoming Ecodesign Working Plan] unless the sector reaches an ambitious voluntary agreement within the next six months’.

Between 2019 and 2021, the industry made a new VA proposal, including cartridges and containers, as well as other recommendations made by different stakeholders, including material efficiency requirements. This proposal was published in April 2021. The VA proposed by the imaging equipment industry in 2021 (Eurovaprint, 2021) was evaluated by the Directorate General Joint Research Centre (DG JRC) of the European Commission on behalf of Directorate General Environment (DG ENV). In this evaluation (Bernad-Beltrán and Alfieri, 2022), DG JRC identified various improvements from the current VA, such as the inclusion of cartridges within the scope of the document and the enhancement of resource efficiency commitments applicable to printers, including design for dismantling rules and a comprehensive list of spare parts. However, the analysis also identified some issues of concern regarding compliance with self-regulation criteria and with the level of ambition required by the CEAP20.

Based on evaluation conducted by the DG JRC, the European Commission considered that the VA proposal, despite the improvements introduced, had not reached the ambitious objectives in terms of circularity mandated by the CEAP20 and decided to work on mandatory regulatory measures under the Ecodesign Directive. Based on this decision, the imaging equipment was included in the list of new measures under the Ecodesign and Energy Labelling Working Plan 2022-2024 (European Commission, 2022).

Despite not endorsing the VA proposed by the industry in 2021, the JRC identified several aspects that may the basis for the development of new implementing measures in this sector, such as:

[5] https://ec.europa.eu/environment/pdf/waste/weee/faq.pdf

- Energy consumption requirements, default delay times and automatic duplexing capability, at the same level as in Energy Star v3.2
- Availability of n-up printing
- Design for recycling and for easy dismantling of devices
- Availability of spare parts for devices
- Availability of software and firmware updates
- Cartridge design requirements, in terms of reusability
- Product information requirements

1.6.2 The EU GPP criteria for imaging equipment

EU Green Public Procurement (GPP) is a voluntary instrument. It relies on the purchasing power of public authorities to promote environmentally friendly goods, services and works. Currently, there is EU GPP criteria for a number of products groups, including imaging equipment (Kaps et al, 2020).

The scope of the GPP Criteria for imaging equipment includes products marketed for office or domestic use, or both, and whose function is one of the following:

> *a) to produce a printed image in the form of paper document or photo through a marking process either from a digital image, provided by a network/card interface or from a hardcopy through a scanning/copying process*
>
> *b) to produce a digital image from a hard copy through a scanning/copying process*

The Criteria explicitly excludes devices such as digital duplicators, mailing machines and fax machines.

In terms of consumables, the scope includes:

> *A replaceable product that is essential to the functioning of the imaging equipment product. It can be replenished by either the end user or service provider during the normal usage and life span of the imaging equipment product. Imaging equipment consumables covered under the scope of this EU GPP include containers and cartridges.*

The GPP Criteria for imaging equipment includes 26 Technical Specifications, divided between Core (minimum level of ambition) and Comprehensive (highest level of ambition). It also contains 9 Award Criteria and 7 Contract Performance Clauses.

The criteria is focused on both the environmental performance of devices and consumables. As a few relevant examples, it contains Technical Specifications on topics such as:

- Post-consumer recycled content: The percentage of postconsumer recycled plastic content, calculated as a percentage of total plastic (by weight), must be declared.
- Device firmware updates: Any firmware update must not prevent the use of reused/remanufactured consumables.
- Reusability of consumables: cartridges or containers must not be designed to limit the ability to reuse/remanufacture. Examples of features which are deemed to limit the ability to remanufacture, or promote non-reuse, include, but are not limited to: cartridges or containers covered by patents or licence agreements which include statements that seek to limit remanufacturing; statements on the cartridge or container, or packaging, which declare, or imply, that the product is not designed to be remanufactured.
- Printing quality: any cartridges or containers must meet all requirements behind at least one widely recognised cartridge/container quality standard

Beyond those, there is also criteria on topics such as energy efficiency, design for disassembly, substance and noise emissions, hazardous substances, warranties, take-back systems, etc.

1.6.3 Ecolabels

Table 5 shows the scope of the different Ecolabels evaluated regarding devices.

Table 5. Scope of Ecolabels regarding devices

Ecolabel	Devices in scope	Devices explicitly excluded from scope
Energy Star v3.0 (2020) Imaging equipment	-Printers -Scanners -Copiers -Fax machines -Multifunction devices -Digital duplicators -Mailing machines -Professional imaging products -Remanufactured imaging products {from Energy Star 3.1.}	-Products covered under other Energy Star product specifications. -Products designed to operate directly on three-phase power -Standalone copiers -Standalone fax machines
Blue Angel (2021a) Office equipment with printing functions	Devices which at least: -Offer printing as their primary function -Are capable of producing monochrome colour printouts on standard paper with a grammage of 60-80 g/m2 -Are capable of processing media or a minimum format of DIN A4 and up to a maximum format of DIN A3+ -Work as electrophotographic devices by using toners or as inkjet devices by using inks	-3D printers
Nordic Ecolabelling (2020a) Imaging equipment	-Printers -Scanners -Copiers -Fax machines -Multifunction devices -Digital duplicators	- Computer equipment - Devices and systems that are operated using 3-phase alternating current (400 Volt)
EPEAT – Global Electronic Council Imaging equipment	-Copiers -Digital duplicators -Fax machines -Multifunction devices -Printers -Mailing machines -Scanners	Not indicated
TCO Certified (2022) Imaging equipment	Imaging equipment defined as a product group used to produce a printed image though a marking process either from a digital image or from a hardcopy through a scanning/copying process. It can also include functionality to produce a digital image from a hard copy through a scanning/copying process. Power cables and external power supplies are considered a part of the imaging equipment.	Not indicated

Table 6 shows the scope of the different Ecolabels evaluated regarding consumables.

Table 6. Scope of Ecolabels regarding consumables

Voluntary scheme	Consumables in scope	Consumables explicitly excluded from scope
EPEAT – Global Electronic Council Imaging equipment	Toner, toner containers, toner bottles, toner cartridges, waste toner cartridges, ink cartridges, ink heads, ink sticks, ribbon ink, thermal paper, copy paper, imaging units, transfer belts, transfer roller, fusers, drum maintenance units, and other associated items	Not indicated
TCO Certified (2022) Imaging equipment	Not indicated	Not indicated
Blue Angel (2021b) Remanufactured toner cartridges	Remanufactured ink cartridges and toner cartridges with toner or ink for use in office equipment with an electrophotographic printing function or in inkjet devices. The ink cartridges and toner cartridges may also contain additional parts required for the printing process that can be used on office equipment with printing function.	Not indicated
Nordic Ecolabelling (2020b) Remanufactured OEM toner cartridges	Toner cartridges originally manufactured by the OEM, and then reused, after refurbishment and refilling, as toner cartridges, drum units or containers for toner powder. They are used for monochrome and colour printing in printers, multi-function machines, copiers and fax machines.	Not indicated

1.6.4 Environmental aspects covered in device-related voluntary schemes

For devices, aspects covered in voluntary schemes have been classified between Material efficiency, Energy and Other aspects (Table 7).

		Energy Star	Blue Angel	Nordic	GPP	TCO Certified	EPEAT
Device - Material Efficiency	Ease of disassembly	No	Yes	Yes	No	No	Yes
	Recycled content	No	Yes	Yes	Yes	Yes	Yes
	Recyclability	No	Yes	Yes	Yes	Yes	Yes
	Use of renewable materials	No	No	No	No	No	Yes
	Durability	No	Yes	No	Yes	Yes	Yes
	Repairability	No	Yes	Yes	Yes	Yes	Yes
	Reusability	No	Yes	No	No	Yes	No
	Interoperability	No	Yes	No	No	No	No
	Compatibility with reused consumables	No	Yes	Yes	Yes	Yes	Yes
	Reliability	No	No	No	No	No	No
	Remanufacturability	No	No	No	No	No	No
	Take back systems	No	No	No	Yes	No	Yes
Device - Energy	Energy efficiency of device and components	Yes	No	No	Yes	No	No
	Energy consumption of device and components	Yes	Yes	Yes	No	No	No
	Standby, Sleep, Off mode requirements	Yes	Yes	No	No	No	Yes
	Energy consumption reporting information	Yes	No	No	No	No	No
	Compliance with Energy-related Ecolabels	No	No	No	No	Yes	Yes
Device - Other aspects	Duplex printing	Yes	Yes	Yes	Yes	Yes	Yes
	Declaration of product category (Professional/Private)	No	Yes	No	No	No	No
	Description of product characteristics	No	No	Yes	No	Yes	Yes
	Printers - Usability of recycled paper	No	Yes	No	Yes	Yes	No
	N-up printing	No	Yes	No	Yes	Yes	No
	Packaging	No	Yes	Yes	No	Yes	Yes
	Restricted substances	No	Yes	Yes	Yes	Yes	Yes
	Emissions to air	No	Yes	Yes	Yes	No	Yes
	Noise	No	Yes	Yes	Yes	No	No
	Product information	No	Yes	Yes	No	Yes	No
	Design provisions	No	No	No	No	No	No
	Carbon footprint	No	No	No	No	Yes	Yes
	Characteristics of paper supplied with printer	No	No	No	Yes	No	No
	Characteristics of consumables supplied with printer	No	No	No	Yes	No	No

Aspect is covered in Ecolabel (Yes)
Aspect is not covered in Ecolabel (No)

Table 7. Device aspects in voluntary schemes

In terms of material efficiency, most of voluntary schemes include some requirement on recyclability and reparability of devices. Other common aspects covered by voluntary schemes are requirements to guarantee the compatibility with reused consumables, and requirements for a minimum amount of recycled content.

In terms of energy, four of the consulted voluntary schemes include requirements on standby, sleep and off mode energy consumption. Three of them include requirements on the actual energy consumption of the device in use mode.

The availability of duplex printing is a common requirement in every voluntary scheme consulted. Other common aspects are restrictions on specific substances, emissions to air, noise, packaging requirements and product information requirements.

1.6.5 Environmental aspects covered in consumable-related voluntary schemes

For consumables, aspects covered in voluntary schemes have been classified between Material efficiency, Yield and Other aspects (Table 8).

Table 8. Consumable aspects in voluntary schemes

		Energy Star	Blue Angel	Nordic	GPP	TCO Certified	EPEAT
Consumables - Material Efficiency	Ease of disassembly						
	Recycled content		✓				
	Recyclability						
	Use of renewable materials						
	Durability		✓				
	Repairability						
	Reusability			✓	✓	✓	✓
	Interoperability						
	Reliability					✓	
	Remanufacturability		✓				
	Take back systems			✓			✓
Consumables - Yield	Provision of Yield information				✓		
	Mass resource efficiency				✓		
	Print capacity			✓			
Consumables - Other aspects	Restricted substances		✓	✓	✓		
	Usability of recycled paper						✓
	Packaging		✓	✓			
	Printing performance		✓	✓	✓		
	Emissions to air		✓				
	Description of product characteristics			✓			
	Product information		✓	✓			

Aspect is covered in Ecolabel (✓)
Aspect is not covered in Ecolabel

In terms of Material efficiency, most of voluntary schemes include a requirement on the reusability of components. The availability of a take-back scheme is included in two of the schemes consulted.

Two of the schemes include a requirement related to print capacity of the consumable. The requirement of providing page-yield information is also included in two of these schemes. Only one of these schemes include a requirement which relates to minimum consumable page-yield per material used.

Other aspects covered in several schemes are the restriction of certain substances and requirements on printing performance. Requirements on the packaging and on product information can also be found.

1.6.6 Registered products in voluntary schemes

Table 9. Registered devices in voluntary schemes

Voluntary scheme	Number of registered models (September 2022)
EU GPP Criteria (Kaps et al, 2020) Imaging equipment	Not available
Energy Star v3.2 (2021) Imaging equipment	More than 2k models labelled Registry available **here**
Blue Angel (Edition 3 2021) Office equipment with printing functions	12 brands and more than 40 models labelled Registry of the labelled models available **here**
Nordic Ecolabelling (2020a) Imaging equipment	2 brands and 197 models labelled (statistics based on an interview to Nordic Ecolabelling)

Global Electronic Council IEEE (2012) Imaging equipment	Registrations by location of use: 15 brands globally labelled. In Europe 87 devices labelled in Germany, France, Sweden, 11 in Italy. Registry of the labelled models available here
TCO (2022) Imaging equipment	No products labelled Registry of the labelled models available **here**

Table 10. Registered consumables in voluntary schemes

Voluntary scheme	Number of registered models (September 2022)
Blue Angel (2021b) Remanufactured toner cartridges	No products labelled Registry of the labelled models available **here**
Nordic Ecolabelling (2020b) Remanufactured OEM toner cartridges	11 license holders and more than 500 models labelled (statistics based on an interview to Nordic Ecolabelling)

One stakeholder in this Preparatory Study argued that voluntary schemes have not been successful in some aspects, such as:

- Durability: printers do not provide data about the real durability of the cartridges used. Available data is limited to what the declaration of manufacturers (and not real-life information)
- Reusability: currently there is not an effective follow-up of the cartridges to identify whether they are actually reused. The current process is based on kg of plastic recuperated to measure how good the process of recycling has been (not focused on cartridge reuse). In their view, it should be possible to have data on how many cartridges are removed from each printer and what happens to them. This is already being done in many companies of all sizes, by using monitoring technology that does an end-to-end tracking of every single cartridge used by each printer.

Another stakeholder highlighted the introduction of a certification label for remanufactured cartridges[6].

1.7 Definitions proposal

In this section, the most relevant definitions concerning this Preparatory Study will be presented.

1.7.1 Definitions related to devices

Table 11. Definitions related to devices

Concept	Definition
Imaging equipment device (or 'device')	Product marketed for office or domestic use, or both, and whose function is one or both of the following:

[6] https://www.etira.org/about-etira/etira-certification-label/

	a) to produce a printed image, either from a digital image or from a hardcopy, through a scanning/copying process; b) to produce a digital image from a hard copy through a scanning/copying process.
Printer	Device intended to apply ink or toner to a substrate in response to a digital signal.
Multi-function printer	Printer with an operating part to apply ink or toner on a substrate, and also providing additional functions such as faxing, scanning or copying.
Copier	A product whose sole function is to produce paper duplicates from paper originals
Scanner	A product whose primary function is to convert paper originals into electronic images
Fax machine (or 'fax')	A product whose primary functions are scanning hard copy originals for electronic transmission to remote units and receiving similar electronic transmissions to produce hard copy output
Professional imaging product	A printer or multi-function printer marketed as intended for producing deliverables for sale, with the following features: a) Supports paper with basis weight greater than or equal to 141 g/m2; b) A3-capable; c) If product is monochrome, monochrome product speed equal to or greater than 86 ipm; d) If product is colour, colour product speed equal to or greater than 50 ipm; e) Print resolution of 600 x 600 dots per inch or greater for each colour f) Weight of the base model greater than 180 kg; and Five of the following additional features for colour products or four for monochrome products, included standard with the Imaging Equipment product or as an accessory: g) Paper capacity equal to or greater than 8,000 sheets; h) Digital front-end (DFE); i) Hole punch; j) Perfect binding or ring binding (or similar, such as tape or wire binding, but not staple saddle stitching); k) Dynamic random access memory (DRAM) equal to or greater than 1,024 MB. l) Final-party color certification (e.g., IDEAlliance Digital Press Certification, FOGRA Validation Printing System Certification, or Japan Color Digital Printing Certification, if product is color capable); and m) Coated paper compatibility.

Standard format	Products designed for standard-sized media (e.g., Letter, Legal, Ledger, A3, A4, B4), including those designed to accommodate continuous form media between 210 mm and 406 mm wide. Standard-size products may also be capable of printing on small-format media. a) A3-capable: Standard Format products with a paper path width equal to or greater than 275 mm
Large format	Products designed for A2 media and larger, including those designed to accommodate continuous form media greater than or equal to 406 mm wide. Large-format products may also be capable of printing on standard-size or small-format media.

1.7.2 Definitions related to cartridges

Table 12. Definitions related to consumables and cartridges in general

Concept	Definition
Consumable	A product integral to the functioning of the imaging equipment with the intent, when depleted or worn, to be replaced or refilled during the normal usage and life span of the imaging equipment.
Cartridge	A replaceable unit within a printing system that contains materials intended for deposition onto paper or other physical output media.
Starter cartridge	A cartridge which is sold together with a printer or multi-function printer.

Table 13. Definitions related to the configuration of cartridges

Concept	Definition
Two part toner cartridge	A toner cartridge that includes a toner containment part and a developer part and does not include a photoreceptor part
All-in-one toner cartridge	A toner cartridge that includes a toner containment part, a developer part and a photoreceptor part
Single part ink cartridge	A cartridge that includes an ink containment part and does not include an ink deposition mechanism.
Integrated ink cartridge	A cartridge that includes an ink containment part and a ink deposition mechanism
Tank	Printer component which is used to hold toner or ink, filled from an external container.
External container	Device which contains toner or ink, not intended to be inserted or connected to the imaging equipment device.

Table 14. Definitions related to the cartridge supplier

Concept	Definition

OEM cartridge	An OEM branded or trademarked cartridge produced by or for the OEM, for use in or with the same OEM's device.
Compatible cartridge (also called 'new built cartridge')	A cartridge for use with an OEM device, but not produced by or for the device OEM.
Remanufactured cartridge	Cartridge resulting from a remanufacturing process.
Remanufacturing process	Industrial process which produces a product from used products or used parts where at least one change is made which influences the safety, original performance, purpose or type of product (EN45553:2020).
Cloned cartridge	A compatible cartridge for use with an OEM device, not produced by or for the OEM, and violating some intellectual property (patent, copyright, trademark)
Counterfeit cartridge	A cartridge not produced by an OEM, labelled, packaged or marketed in such a way that is intended to mislead a customer into thinking it is an OEM cartridge

1.7.3 Definitions related to circularity aspects

Table 15. Definitions related to circularity aspects

Circularity Aspect	Definition
Durability	Ability to function as required, under defined conditions of use, maintenance and repair, until a limiting state is reached {EN45552:2020} Individual Cartridge yield: value determined by counting the number of test pages printed between cartridge installation and end of life {ISO test standards as defined in ISO/IEC 29142-1:2021}
Reliability	Probability that a product functions as required under given conditions, including maintenance, for a given duration without limiting event {EN45552:2020}
Repair	Process of returning a faulty product to a condition where it can fulfil its intended use {EN45552:2020}
Upgrade	Process of enhancing the functionality, performance, capacity, or aesthetics {EN45552:2020}
End of life (cartridge)	Phase in a cartridge life cycle when the cartridge can no longer be used for its intended purposes without additional non-customer interaction (ISO/IEC 29142:2021)
Reuse	Process by which a product or its parts, having reached the end of their first use, are used for the same purpose for which they were conceived {EN45552:2020}
Reprocessing	Restoration or modification of the functionality of a product or part Note 1 to entry: Reprocessing may consist of repairing, rework, replacement of worn parts, and/or upgrade of soft-, firm- and/or hardware. (based on the conversation with CEN/CENELEC JTC 10 WG4)

Refurbishing	Industrial process to return a used product(s) to its original requirements or to improve a used product(s) within the limits of its original requirements (based on the conversation with CEN/CENELEC JTC 10 WG4)
Remanufacturing	Industrial process which produces a product from used products or used parts where at least one change is made which influences the safety, original performance, purpose or type of the product. {EN45553:2020}
Recycling	Recovery operation of any kind, by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes excluding energy recovery {EN45555:2019}
Recovery	Process to divert cartridges and/or cartridge materials from the solid waste stream into productive uses.
Critical Raw Materials	Critical raw material CRM materials which, according to a defined classification methodology, are economically important, and have a high-risk associated with their supply {EN45558:2019}
Post-consumer recycled content	The amount of post-consumer recycled material that goes into the manufacturing of a new product {EN45557:2020}

1.8 Scope proposal

Table 16 summarizes the scope proposal for this Preparatory Study.

Table 16. Scope proposal

Device	In scope	Out of scope
General	Devices (as defined in Table 11) intended for household and office use	Devices (as defined in Table 11) intended for professional use or other than household / office use.
Printers, multi-function printers and copiers	- Standard format	- Large format - Devices designed to operate directly on three-phase power
Scanner	- All scanners	
Fax machine	- All fax machines	
Digital duplicators		- All digital duplicators
Mailing machine		- All mailing machines

As a general rule, the scope of this Preparatory Study is related to devices intended to be used in a household or in an office. Therefore, devices intended to be used in professional environments or environments other than household and office environment are excluded.

The exclusion of professional imaging equipment seems adequate at this point, considering the characteristics of those products, according to the definitions provided by Energy Star. Professional devices are large machines (at least 180 kg), with default features such as A3 capability, high printing speeds (86 ipm for monochrome and 50 ipm for color), high print resolution and able to support paper with high grammage (minimum of 141 g/m2 when typical office paper grammage is between 70-100 g/m2). They also may have additional features such as hole punch, color certification, digital front-end and paper capacity over 8000 sheets, among others.

This combination of features makes significant differences with the typical products used today in households and offices, in terms of performance, functionalities, mass and materials. Consumers and patterns of use of professional devices are also fundamentally different when compared with household and office products. The wide availability of products within the professional sector makes them also unsuitable for the scope of this Preparatory Study.

Digital duplicators and mailing machines are excluded at this point, since their use is intended applications that are professionals or, any case, their users and patterns of use are fundamentally different from household and office products.

Every consumable designed to be installed or used with any of the devices within the scope of this Preparatory Study is also included within the scope. This includes cartridges, external containers, drums, waste toner containers, fuser units and transfers units.

All scanners and fax machines are within the scope, since their use is fundamentally for households or offices.

1.9 Summary of changes in Task 1 after stakeholder consultation

First draft version of Task 1 was published in November 2022, before the 1st Technical Working Group Meeting. During the meeting and the weeks after, a consultation process was open for every stakeholder to provide feedback. Based on that feedback, the authors of this Preparatory Study have made changes to the draft version published initially. This section summarizes those changes.

Definitions

Several proposals were made from different stakeholders in terms of definitions, concerning devices, cartridges and circularity aspects.

- The definition of "multi function printer" has been changed to add the scanning function
- The definitions of "large format" and "standard format" have been added to the list
- A definition has been added for "starter cartridges"
- The definition of "consumable" has been changed, removing the list of examples.
- The definition of "cartridge" has been changed
- The definition of "two part toner cartridge" has been changed
- The definition of "single part ink cartridge" has been changed
- The definition of "tank" has been simplified for clarification. The definition of "external container" has been added to the list.
- The definition of "remanufactured cartridge" has been simplified for clarification. The definition of "remanufacturing process" has been added to the list.
- The definition of "refilled cartridge" has been removed from the list to avoid confusion with "remanufactured cartridge"
- The definition of "counterfeit cartridge" has been changed
- The definition of "OEM cartridge" has been changed
- The definition of "durability" has been changed
- The definition of "recycling" has been changed

Scope

Several proposals were made from different stakeholders in terms of scope, both for devices and cartridges. Most of these proposals required clarification on which devices and cartridges were part of the scope of the Preparatory Study. In order to provide clarification:

- A new table summarizing the scope of devices has been included
- The table summarizing the scope of cartridges has been removed, since every cartridge that operates with devices into the scope is also included within the scope of the Preparatory Study

Some stakeholders recommended including professional imaging equipment into the scope of the Preparatory Study. In response to these stakeholders, additional justification has been provided for the exclusion of professional imaging equipment from the scope.

2 Task 2 – Market

In Task 2 of this Preparatory Study, the main aspects of the imaging equipment market is evaluated. A summary of the most common business models operating in this sector is proposed. After that, sales data is presented for devices and cartridges.

2.1 Business models

A business model revolves around the logic of how a firm generates profits. It can benefit a firm in terms of growth and profits but, at the same time, it can encourage over-consumption and waste, generating negative environmental and social externalities (Han, 2020). Therefore, the prevalence of certain business models over alternative ones has consequences for the products that are placed on the market. There are business models that rely on a take-make-use-dispose approach to thrive; and there are alternative business models that make use of concepts such as reuse, repair, remanufacturing or servitization to make a profit.

The imaging equipment sector is a complex market, where companies operate under a wide variety of business models. This variety depends on the relationship established between the different actors: on one hand, business-to-consumer (B2C), on the other, business-to-business (B2B). Another factor affecting the variety of business models is related to ownership of the printer and/or the consumables, which can remain either with the supplier or with the consumer.

Considering this, a classification of different business models in the imaging equipment sector is proposed in Figure 1.

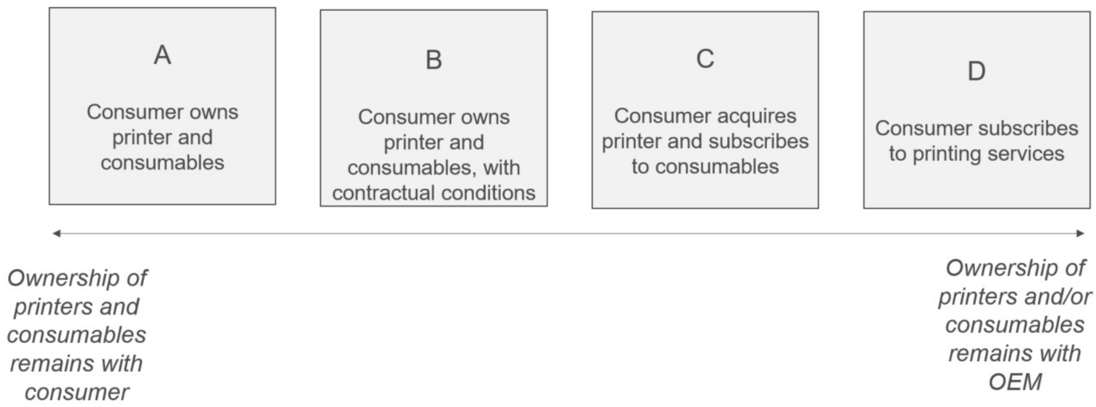


Figure 1. Classification of business models in the imaging equipment sector

The authors of the Preparatory Study acknowledge that this classification is a simplification of the complexity of the imaging equipment market and does not aim to catalogue every potential business model in the sector, simply the most prevalent ones.

2.1.1 Ownership of printer and consumables remains with the consumer

Category A: consumer acquires printer and consumables, without contractual agreement

The consumer acquires the printer and the consumables as a product, without establishing any contractual agreement with the OEM. In this case, the consumer owns the printer and purchases the consumables whenever they need them, without any commitment with the original manufacturer. When the consumables are depleted, the consumer has the option of purchasing new original, new-build compatible or remanufactured ones. In Category A, both the printer and the consumables remain under the ownership of the consumer. This business model is more common in the business-to-consumer (B2C) sector, although it is also present in the business-to-business (B2B) sector, particularly in small offices.

Category B: consumer acquires printer and consumables, with contractual agreement

The consumer acquires the printer and establishes a contractual agreement with the OEM, committing to buy and use only their original consumables for a specific period. These business models are often attractive for consumers because printers are offered at a discount or with additional functionality[7]. When the period

[7] https://www.hp.com/us-en/printers/hp-plus.html

established in the contract ends, the consumer can choose again between original, compatible or remanufactured consumables. However, during the contract period, the OEM may ensure that the consumer adheres to the contract by blocking the use of non-original consumables. This business model is more common in the B2C sector, although it can also be found in the B2B sector, particularly in small offices.

Category B can be taken as an example of the commonly known "razor and blade" pricing strategy, widely used in other products such as coffee machines and pods, consoles and games or cars and spare parts (Geursen, 2013). In a razor and blade pricing strategy, the marketer offers a durable product (the razor) at a low price (even at a loss) and makes up for the initial subsidy by charging a high price for the consumable complement (the blades) over the lifetime of the durable product (Dhebar, 2016). This is particularly representative of Category B in the imaging equipment sector, where the printer is sold cheaply, with margins made through the price of the consumables. The losses made by the OEM on the printer sale can be recouped by locking in the consumer to the purchase of the original consumables.

2.1.2 Ownership of printer and/or consumables remains with OEM

Consumers can also acquire imaging equipment as a service. These alternatives are often known as "subscription services", or Printing as a Service (PaaS). A variety of options can be found in the market that could fall within this category. According to feedback from OEMs, these business models represent around 10% of the sector today. Recent publications suggest that, for certain manufacturers, subscription models are growing around 1% per month (The Recycler, 2021a).

Category C: consumer acquires printer and subscribes to the use consumables

A common subscription service is one where the consumer acquires the printer but not the consumables. In this case, the OEM provides consumables when the consumer needs them. The OEM establishes a collection and delivery system for the new and depleted consumables, often via post. Typically, the consumer will subscribe to print a maximum number of pages over a period. The amount to pay per period will depend on the number of pages the consumer is subscribed to. The printer sends a signal to the OEM to inform that the consumables are running out of ink or toner, to optimise their collection and delivery, ensuring that the user can always print. If the user does not use the amount of pages they are subscribed to in the period, the OEM might offer to roll over them for the next period, or simply to lose them. If the user surpasses the maximum amount subscribed to, the OEM can either prevent them from printing or charge them an additional amount. It is common that the cartridges provided as part of this subscription can only be used with the printer registered in the scheme[8]. If the subcription is cancelled, the OEM may disable the cartridges from working, even if they still have some toner or ink[9]. It is also common under these subscription services for consumers to be prevented from using non-original consumables. In some cases, if cartridges that are not part of the scheme are used, the page counter of the service will continue counting as if the original cartridges were used[10]. Some authors (Dhebar, 2016) consider this type of subscription as a particular case of customer lock-in, because the marketer relies on consumer behaviour inertia: most modern-day consumers are busy and will likely not consider changing to non-original consumables if the marketer sets up an automatic replacement. This option can be found in both the B2C and B2B sectors.

Category D: consumer subscribes to printing services

A different subscription is one where the OEM keeps the ownership of both the printer and the consumables[11]. The consumer (typically a business) will pay depending on the number of pages they print, or the amount of ink or toner they use. Often, installation and maintenance services are included in the agreement. These options are commonly known as Managed Print Services (MPS) and are more common in the B2B sector.

Under these business models (category C and D), the OEM has the incentive to maximise printer lifetime and to optimise the use of toner or ink.

2.1.3 The influence of business models on product circularity

Categories A and B can be more associated with a linear production and consumption system, rather than with a circular one. In both cases, OEMs have the incentive of increasing the sales of new original consumables.

[8] https://www.brother.co.uk/about-brother/ecopro-terms-and-conditions
[9] https://images-eu.ssl-images-amazon.com/images/G/02/uk-pc/hp/InstantInk/HP_InstantInk_TandCs.pdf
[10] https://subscription.lexmark.com/en_gb/terms-and-conditions.html
[11] https://readyprint.epson.eu/gb/en/terms-of-use

Reuse of consumables by other operators is unattractive for OEMs because they compete directly with new original consumables and therefore can reduce their margins.

In the cases that operate under a “razor and blade” pricing strategy, the business model only works if the consumer, once convinced to purchase the durable product, is locked into the platform (Dhebar, 2016). According to feedback from some remanufacturers, the older the printer, the more likely it is that the consumer will switch to compatible or remanufactured cartridges. Therefore, in this pricing strategy, there could be less incentive for OEMs to prolong the lifetime of the printer beyond a certain limit (to avoid consumers from switching to non-original cartridges).

In such business models, OEMs tend to offer printers at a discount, in some cases at prices even below production costs. This strategy might convey the idea to consumers that printers are cheap devices that can be replaced easily, and that repair is not worthwhile from a financial point of view. It must be considered that for consumers the cost of the replacement is the most significant concern when faced with the choice between repair or replacement. The willingness to pay for repairs of small electronics is around 20% of the replacement cost (Svensson-Hoglund et al., 2021). A market full of low-cost printers could undermine the potential benefits of repair and generate the conditions for what Prakash et al. (2020) define as "economic obsolescence": the loss of the useful properties of a product because the costs of the resource inputs required to maintain or repair the product are excessive; or the difference to the cost of a new product is unfavourable. Consequently, Categories A and B can generate significant amounts of waste.

This hypothesis is supported by the results of studies such as the one conducted by the French Agency for the Ecological Transition (ADEME), where it is estimated that, while the potential lifetime of a printer is 6 years, the real lifetime of printers is often between 2 and 3 years, after which consumers perceive a printer obsolete (ADEME, 2019). In addition, according to Cool Products (2019), when replacement consumables cost as much as the printer, users often find themselves motivated to discard their appliance in favour of buying a new one after the first set of ink cartridges is used up.

Business models that prioritise larger and more reliable cartridges, with robust take-back systems and a strong commitment to printer repair and cartridge reuse, could still thrive under the logic of Categories A and B. In Dhebar (2016), additional innovation strategies are proposed for companies which seek to evolve from a razor-and-blade pricing strategy towards models based on alternative purchasing agreements, redefinitions of the value proposition or improved customer experience.

Categories C and D are more commonly associated with circular economy strategies. One of the main principles of circular economy is to design out waste from the outset, rather than relying solely on end-of-chain recycling. Therefore, approaches that focus on switching from physical products to immaterial products (also known as “servitization” or “Product-as-a-Service” approaches) can help to avoid the use of materials and their subsequent end-of-life management. Product-as-a-Service approaches are prioritised by the European Commission in the Circular Economy Action Plan and in the Communication on Making Sustainable Products the norm (COM(2022) 140), where it is stated that by selling products as a service the economic logic shifts and profits are no longer dependent on the volume of products sold. Instead, it becomes profitable to ensure that the products provided as a service are durable and reparable, as the ownership remains with the business and the need to buy new products is a business cost. Several examples have shown that the servitization of a product can extend its life (Han et al., 2020). It is also argued that an increase in service orientation, rather than product orientation, will facilitate the design of systems with significantly lower environmental impacts while maintaining economic prosperity (Lieder et al., 2016). Although PaaS is a strategy highlighted as beneficial in a Circular Economy logic, potential trade-offs must always be considered. In Goedkoop (2021), for instance, a few examples are given where product-as-a-service approaches may not provide an environmental benefit. Therefore, a comprehensive approach should always be followed to evaluate the environmental suitability of business strategies.

2.2 Print volume trends

In this section, data on print volume trends will be presented, in terms of total amount of images printed. This data has been supplied by the testing and consulting firm Keypoint Intelligence[12] and comprises the following countries: Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the UK. This represents a combined population of 414 million (in contrast with the total population of 446 million on the whole EU27).

[12] https://keypointintelligence.com/

It has to be taken into account that not all the countries of the EU27 are covered; and that data from Norway, Switzerland and the UK are included. Nevertheless, it is assumed that this data is a good representation of the market of imaging equipment, considering the percentage of population covered. For extrapolation purposes, a factor of 1.07 may be applied to account for the whole EU27.

In 2022, a total of 473 billion of images were produced in the analysed sample of countries (Figure 2). The majority of those images come from toner-based devices in office environments. Total printed ink images are projected to decline at a compound annual growth rate (CAGR) of 8.8%, while printed toner images show a CAGR of 5.4%.

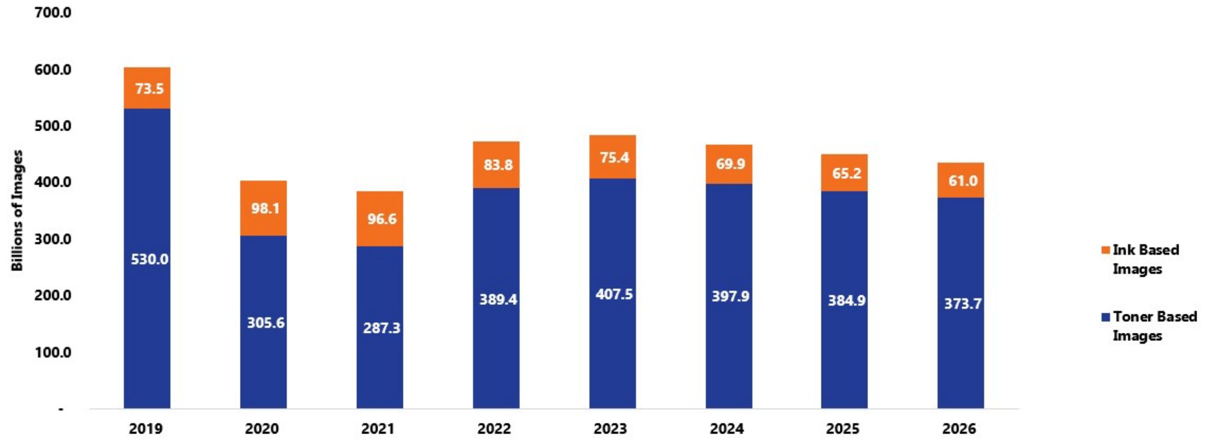


Figure 2. Total images printed by technology
Source: Keypoint Intelligence (2023)

Office print volumes are expected to peak in 2023, then gradually decline due to ongoing hybrid working and digital transformation efforts (Figure 3).

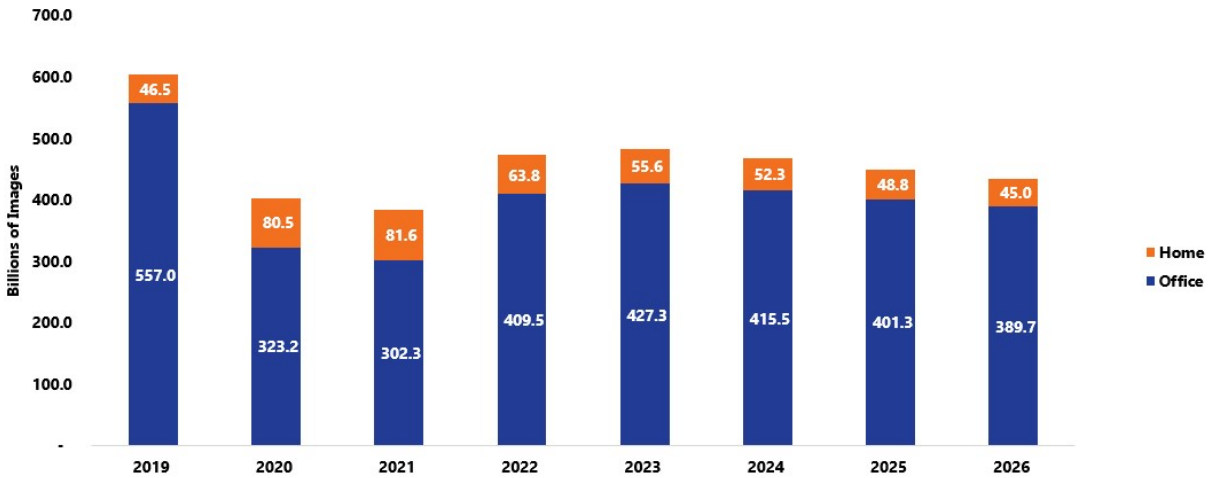


Figure 3. Total images printed by environment
Source: Keypoint Intelligence (2023)

Digital transformation continues to erode home print volume gains from hybrid working, which became more widespread during the COVID19 pandemic. A sharp rise of images printed at home can be observed during years 2020 and 2021 (from 46 billion to around 80 billion), due the high amount of people working from home during lockdowns and movement restrictions. The total amount of printed pages returned to lower values (around 63 billion) in 2022, and it is expected to decrease again in the following years.

2.3 The market of printers and multi-function devices

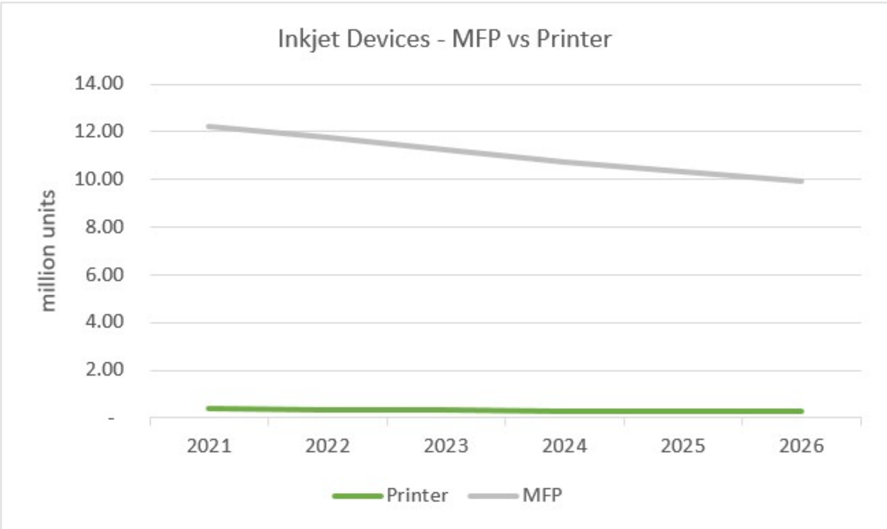
In this section, market data is presented in terms of sales of printers and multi-function printers. These data has been supplied by the market intelligence firm IDC[13] and contains information on 13 EU countries, Norway, Switzerland and the UK. This represents a combined population of 425 million (in contrast with the total population of 446 million on the whole EU27).

As in the previous section, it has to be taken into account that not all the countries of the EU27 are covered; and that data from Norway, Switzerland and the UK are included. Nevertheless, it is assumed that this data is a good representation of the market of imaging equipment, considering the percentage of population covered. For extrapolation purposes, a factor of 1.05 may be applied to account for the whole EU27.

The interpretation of this data has been done by the authors of the Preparatory Study with insight from experts in the imaging equipment industry from IDC.

2.3.1 Inkjet devices

In 2022, more than 12 million inkjet devices were sold in the sample of countries under evaluation. The vast majority of those sales (97%) were multi-function devices (Figure 4).

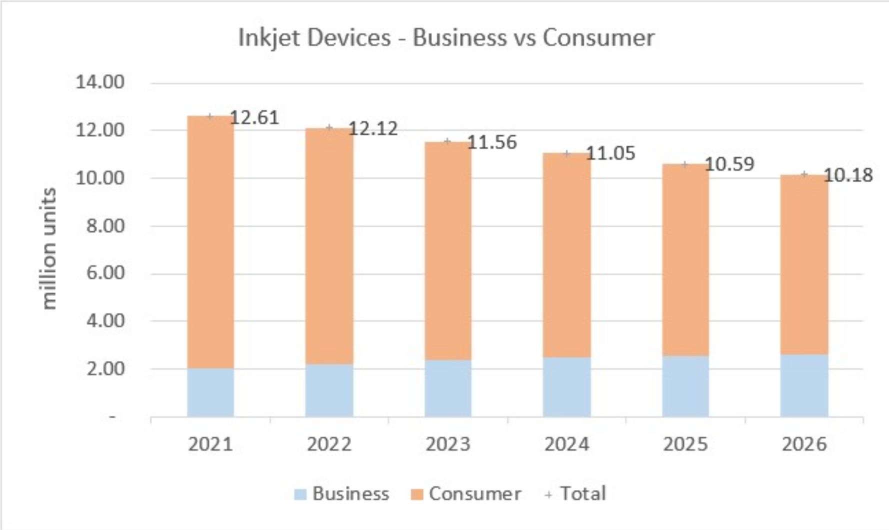


Source: IDC

Figure 4. Sales of inkjet devices in the EU

The overall market of inkjet devices is expected to decrease in the following years, from 12.6 million in 2021 to 10.2 million in 2026, a CAGR of -4.2%. Sales of inkjet devices for business applications will grow and for consumer applications will decrease (Figure 4). In any case, the market of inkjet devices is still expected to be focused on the consumer sector

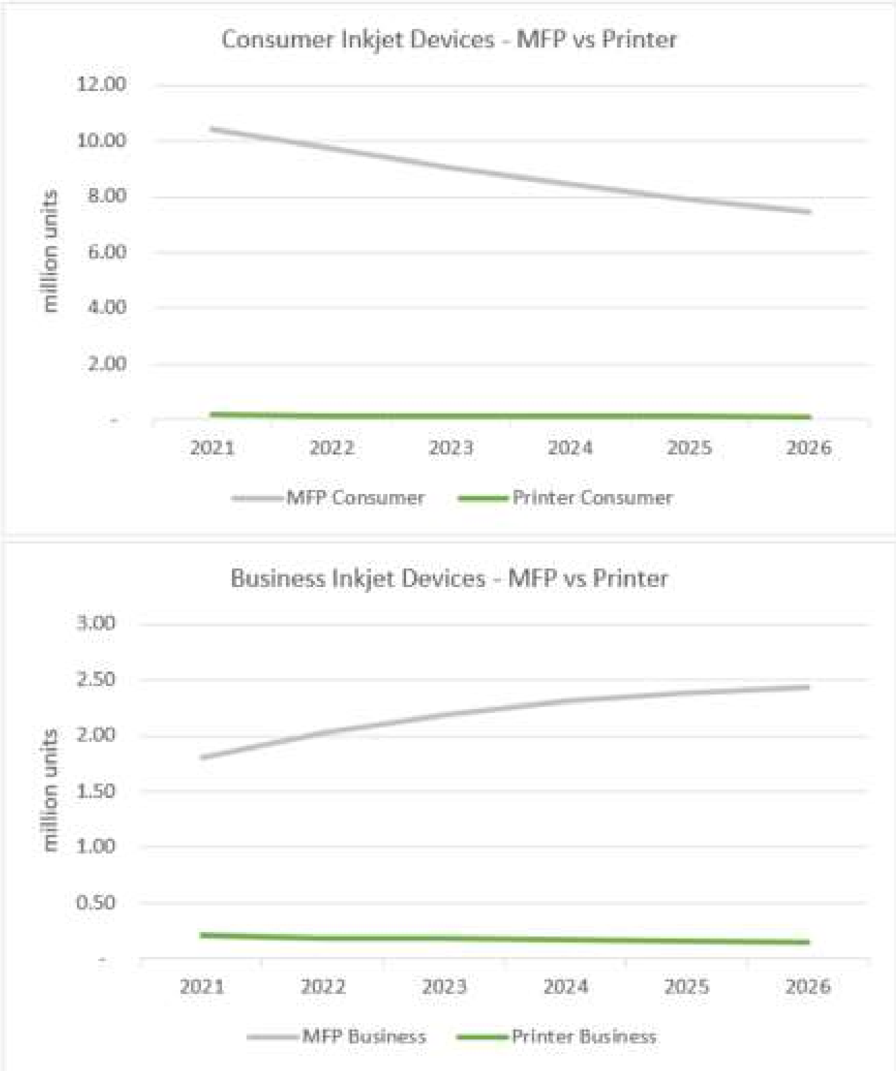
[13] https://www.idc.com/



Source: IDC

Figure 5. Sales of inkjet devices in the EU (business versus consumer)

Comparing the consumer and the business sector in detail, focusing on the type of products sold (Figure 6), it is possible to see that the only type of product growing in sales in the inkjet sector is the multi-function printer for business application, expected to grow between 2 million and 2.4 million in the evaluated period (a CAGR of 5.4%). Most of these devices will be A4 desktop models that include ink tank models and monochrome devices The business inkjet market is among the few segments in the whole industry that is increasing. In contrast, the highest decrease is expected in multi-function printers for consumer use, from 10.4 million to 7.5 million.



Source: IDC

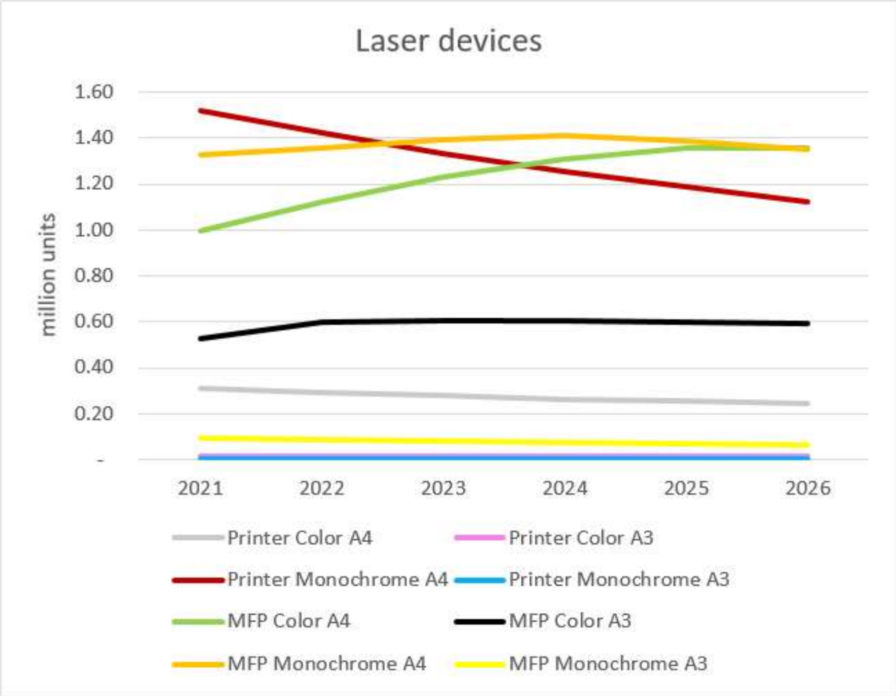
Figure 6. Sales of inkjet devices (business versus consumer, product types)

Around 19% of all MFDs have print, copy, scan and fax functions (4:1 devices), while the remainder are 3:1 (print, scan and copy). These figures show that the functionality is important even for home consumers.

2.3.2 Laser devices

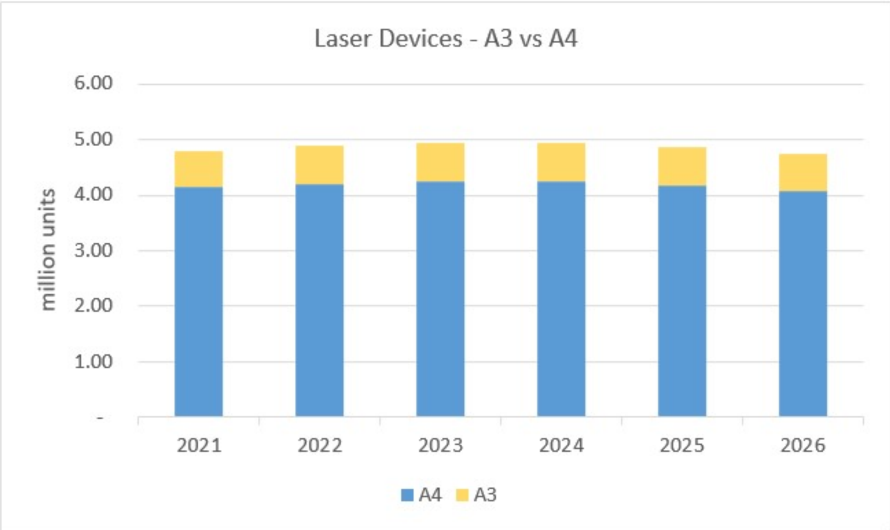
In 2022, nearly 5 million laser printers were sold in the sample of countries under evaluation. In terms of total units sold, the market of inkjet devices is 2.6 times higher than the market of laser devices.

The highest sales in the laser sector corresponded to printer monochrome A4 devices and MFP monochrome A4 devices, with around 1.4 million sales for each. The sales of MFP color A4 devices were 1.1 million with a growing trend. Sales of MFP color with A3 capability were stable at 0.6 million (Figure 7).



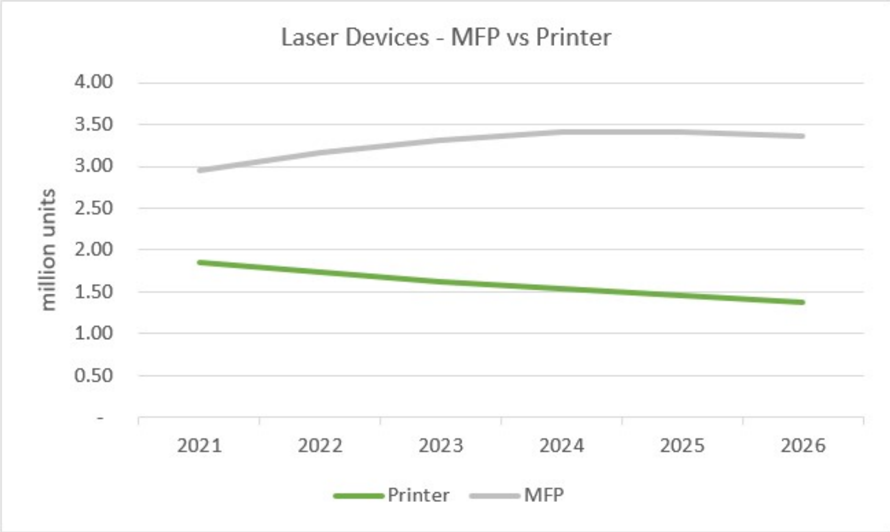
Source: IDC
Figure 7. Sales of laser devices in the EU

Overall, the market of laser devices is expected to remain stable, with sales around 4.7 million (Figure 8). The market of laser printers is clearly dominated by devices with A4 capability, typically used in small offices or in households with high printing needs. The combined sales of devices with A3 capability (typically used in large, shared offices) were nearly 0.7 million, with a stable expected trend between 2021 and 2026.



Source: IDC
Figure 8. Sales of laser devices in the EU (A4 versus A3 capability)

In terms of specific product types, the highest seller in 2022 (printer monochrome A4) shows a decreasing trend, expected to be overcome in the following years by MFP color and monochrome A4. These two product types are expected to be the highest sellers in the near future, with 1.3 million sales each. Similar to the inkjet sector, the market if laser MFP appears to be growing, whereas the market of printers shows a decreasing trend (Figure 9).



Source: IDC
Figure 9. Sales of laser devices in the EU (printer versus MFP)

2.4 The market of scanners, faxes and copiers

In this section, market data will be presented in terms of sales of scanners, fax machines and copiers. The data is from Huang et al (2019) and can be seen in Table 17.

Table 17. Sales of scanners, copiers and fax machines in the EU

Source: (Huang et al, 2019)

Million units	2020	2025	2030	2035	2040
Scanner	0.88	0.88	0.88	0.88	0.88
Copier	0[14]	0	0	0	0
Fax machines	0	0	0	0	0

When Huang et al (2019) was published, the sales of scanners were estimated at 0.88 million units per year, with a stable trend expected for the following years. In contrast, the sales of copiers and fax machines was estimated to be close to zero in 2020.

For the Preparatory Study, it is assumed that the trends published in Huang et al (2019) for scanners, copiers and fax machines are still valid. Based on that, copiers and fax machines will not be investigated further in the following tasks, due to their lower market relevance.

2.5 The market of cartridges

In this section, market data will be presented in terms of sales of cartridges. This data has been supplied by Keypoint Intelligence and contains information on Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the UK. Although not all the EU is covered with data from this section, it is assumed that it is a good representation of the market today. The interpretation of this data has been done by the authors of the Preparatory Study with insight from experts in the imaging equipment industry from Keypoint Intelligence.

[14] Huang et al (2019) reported zero sales of copiers and fax machines beteen 2020 and 2040. Most likely the number of sales is around a few thousand units per year, in any case negligible for the estimations carried out in the Preparatory Study.

2.5.1 Ink cartridges

In 2022, 359 million cartridges were sold in the sample of countries under evaluation. The majority of ink cartridges were sold to be used in the household environment. The number of units sold peaked in 2021 during the COVID19 pandemic. With a 2021 baseline, ink cartridge units sold into office environments are expected to remain flat, whereas units for household environments are projected to decline at a CAGR of 11.3% (Figure 10).

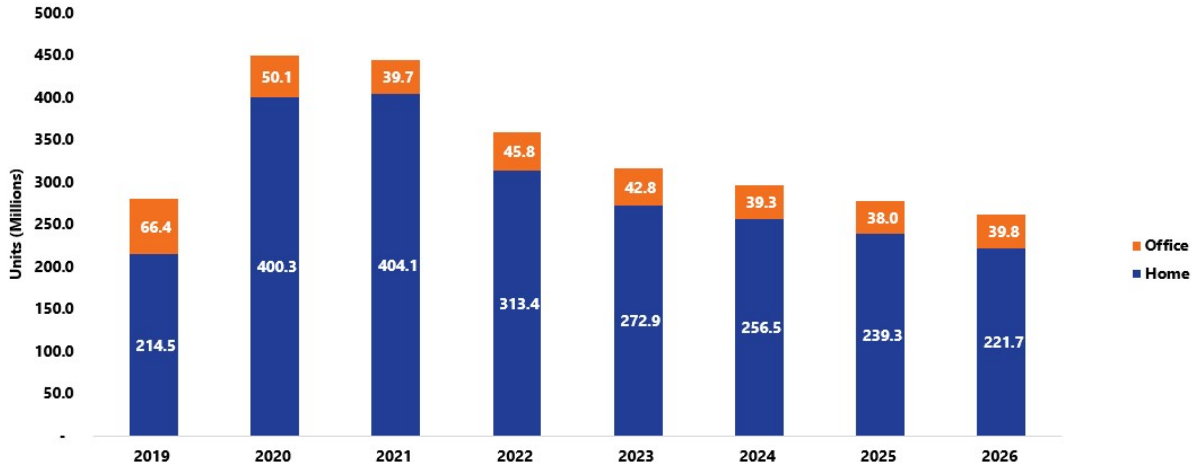


Figure 10. Ink cartridge sales by environment

The number of monochrome and color ink cartridges sold is roughly split 50/50% in the sample of countries evaluated. With a 2021 baseline, ink units are expected to decline at an almost equal pace (approximately 10% CAGR) for monochrome and color over the next five years (Figure 11).

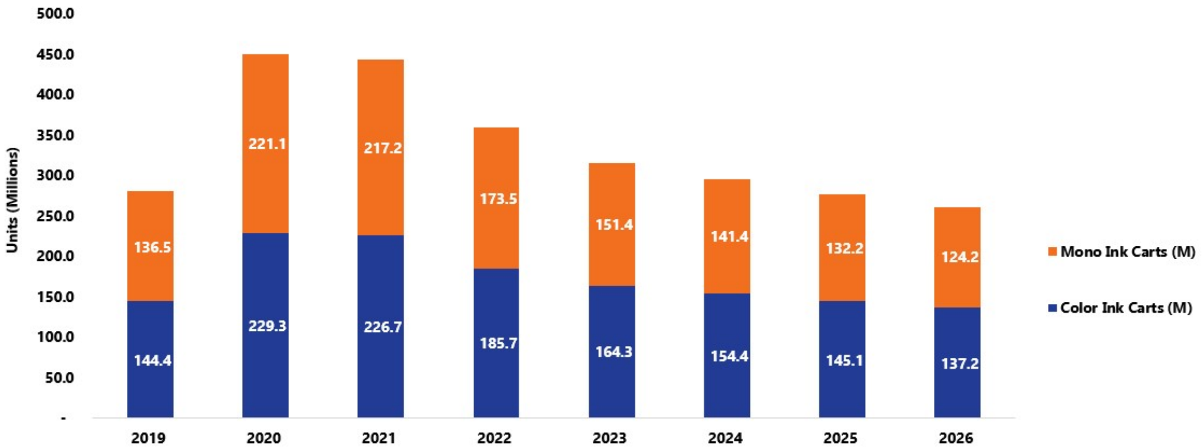


Figure 11. Ink cartridge sales by color type

2.5.2 Toner cartridges

In 2022, nearly 30.000 tonnes of toner was sold in the sample of countries under evaluation. Most of this toner was sold for the office environment (Figure 12). Assuming an average of 200 grams of toner per cartridge, this would mean a total of 150 million toner cartridges sold in 2022.

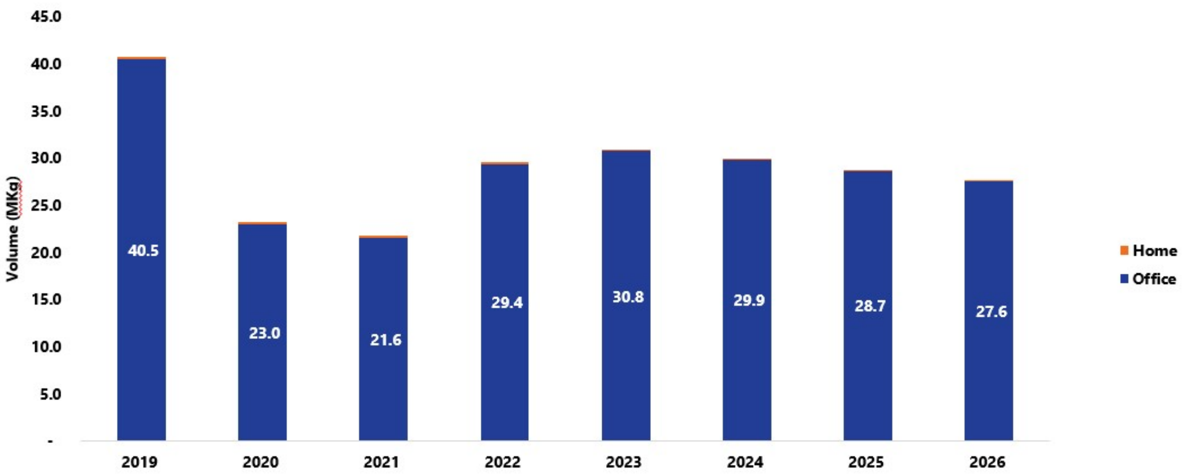


Figure 12. Toner sales by environment

The sales of toner volume are expected to peak in 2023 and will subsequently decline in the following years.

In the office environment –where most of the toner is used- the type of toner cartridges sold varies between single and dual cartridge packs with black single cartridges representing the most common type unit (Figure 13).

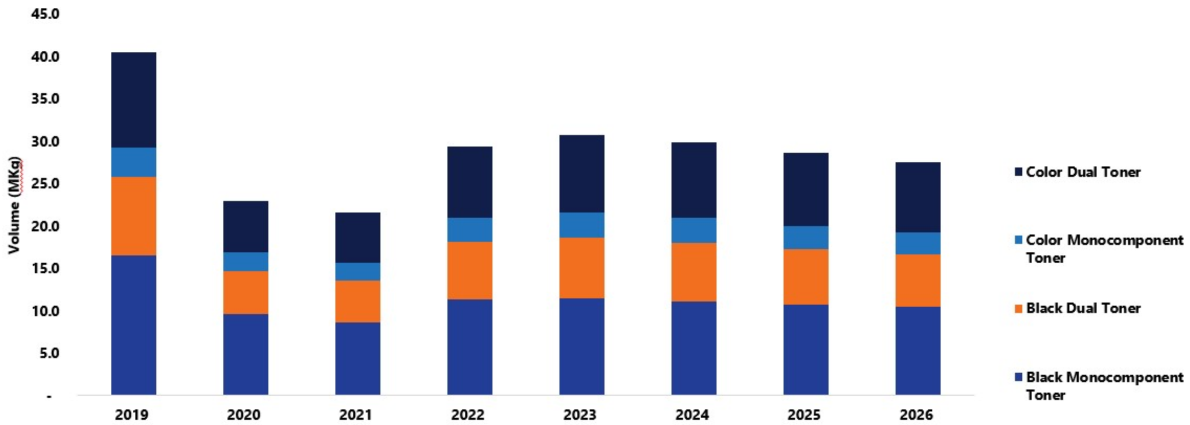


Figure 13. Toner sales by colour in the office environment

With a baseline forecast of 2021, unit volumes are expected to peak in 2023 followed by low-single digit CAGR declines in line with print volume projections.

In contrast, the small amount of toner used in home environments is comprised entirely of black single cartridge units (Figure 14).

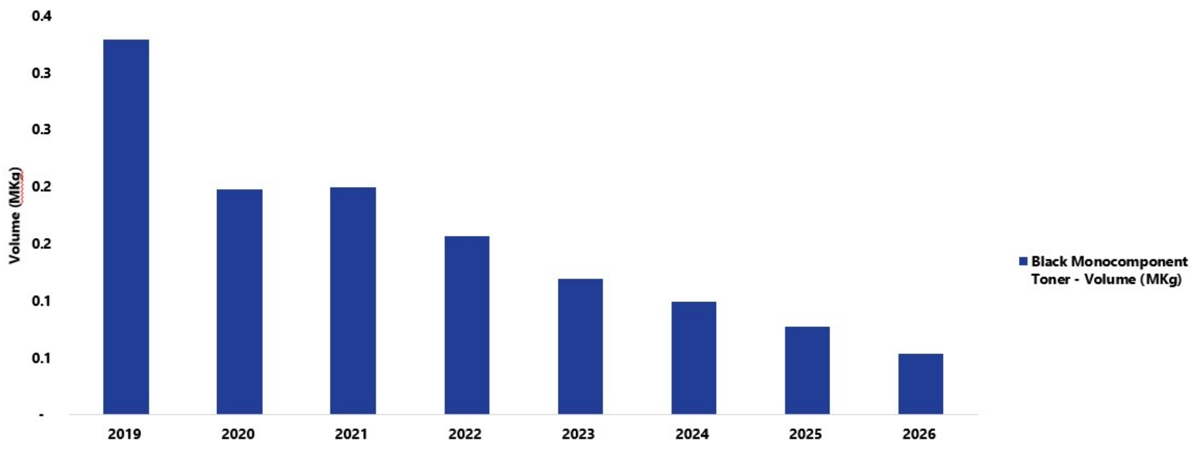


Figure 14. Toner sales by colour in the household environment

The unit volume of toner is expected to decrease due to digital transformation and the return to work – fewer units of toner will be sold into the home overall.

2.6 Relevant trends in the imaging equipment market

This section covers other relevant trends in the imaging equipment market. Information has been provided by experts in the industry from IDC[15] and Keypoint Intelligence[16].

2.6.1 Subscription services

Only a few percent of the printers installed in European households today are on a subscription service. Most consumers are still transactionally buying new cartridges, usually from online vendors. However, print service providers will increasingly focus on subscriptions, as many customers are looking to streamline their print services and make printing available for home and hybrid workers.

With more people working from home full-time or on a hybrid system, the appeal of subscription services has grown exponentially as more workers need a printer at home. Interest in subscription services accelerated as a result of the pandemic driven by the convenience of having supplies delivered to the door when staying at home was mandated. Sustainability-conscious consumers are also more willing to consider these services because the responsibility is with the OEM or service provider to reuse or dispose of older hardware responsibly.

There are no common standard offerings across brands, as it appears that some are adopting a wait-and-see approach to understand which services offer the best practice.

Print service providers are emphasizing the use of simple subscription services for offices rather than to households, since offices print more pages and therefore provide higher profits. The opportunities for a greater upsell are also higher. Many subscription and self-refill models will likely be scalable depending on customer requirements. Traditionally, subscription services have traditionally been used for inkjet devices. However, the number of laser devices being installed under these services will increase.

It is expected that some third-party suppliers will likely launch new services either on a local, national or EU level, as they see this as a significant revenue source. Competition for such services will intensify. Subscription services, by their very nature, enable users send back old cartridges, which can help to increase return rates.

2.6.2 The impact of COVID19 and the rise of teleworking

The COVID19 pandemic led to an increase in printer sales, to support the large share of population that started teleworking. However, as lockdowns across the EU were eased, many workers returned to their offices. Many of them will remain on a hybrid working model, meaning that employees will share their work times between the office and home. Most employees need some form of print for their day-to-day activities and therefore will need access to such devices at home.

[15] https://www.idc.com/getdoc.jsp?containerId=EUR148681822
[16] https://keypointintelligence.com/

The rise of teleworking initially led to opportunities for additional printer sales, and this will likely continue in the short term. These printers were mostly A4 monochrome single-function devices. Teleworking may also lead to greater opportunities in areas such as print management software, security and subscription business models.

Most models used in households are inkjet printers, since home users have been adept at working with inkjet technologies for a long time. Suppliers in a position to provide such devices for teleworkers are seeing increased sales.

2.6.3 Supply chain issues

Issues with scarcity of microchips, manufacturing capacity, transport containers and logistics impacted the imaging equipment market in 2021 and 2022. All product segments in the inkjet and laser markets were affected and the impact on revenues and profits for some leading brands was noticeable. However, not all OEMs were impacted as some have greater access to components than others. As a results, those with sufficient supply won tenders and contracts from their competitors.

In terms of inkjet, the current demand for inkjet devices is higher than the offer and major OEMs are having difficulty manufacturing enough products for their customers. Suppliers are having to choose between models, ensuring that priorities are given to business inkjet devices over consumer devices, as prices and number of pages printed on such devices are higher. These issues affect both devices and cartridges, and brands have the dilemma of withholding inventory of devices until cartridges are available, or losing out to third party compatible ink cartridge suppliers and remanufacturers that can take advantage.

Similarly in the laser sector, most suppliers are having difficulty in providing devices and cartridges to customers. Some OEMs decided shipping devices and cartridges without microchips to make sure they were able to retain their customers. Others redesigned devices to use less microchips and semiconductors.

2.6.4 Inflation and economic situation

The Russia-Ukraine War has led oil prices reach new highs. This inevitably drives up costs for manufacturing, supplies and logistics.

In terms of inkjet, increasing expenditures on oil, raw materials, transport containers and logistics are driving costs upward. This higher cost will inevitable be passed onto customers. Prices are increasing across all segments of the inkjet market, since customers have little choice due to the lack of products from other suppliers.

Both in the ink and toner sector, this is giving opportunities to third party remanufacturers that take used cartridges and remanufacture them. Some of these remanufacturers state that demand is high as not all customers can find suitable amounts of original cartridges. However, due to the design of some ink cartridges, remanufacturing of certain brands is more difficult than others, and often has smaller profits compared with toner cartridges.

3 Task 3 – Users

Task 3 of the Preparatory Study analyses user behaviour aspects related to imaging equipment devices and its consumables. To propose the most appropriate policies, it is essential to understand the behaviour of consumers in relation to this product group. The overall objective of Task 3 is to analyse how consumer behaviour may influence the environmental performance of products in scope.

A peculiarity of the imaging equipment sector is that, in terms of environmental hotspots, both the devices (printers) and the consumables (containers and cartridges) have environmental relevance. For instance, feedback provided by different stakeholders during the development of this Preparatory Study and during the evaluation of the Voluntary Agreement proposal (Bernad-Beltran and Alfieri, 2022) suggests that printers are generally replaced earlier than they need, so their technical lifetime is often not fulfilled. It has also been reported that despite a technical/economic potential to reuse more than 80% of cartridges, only 13% of inkjet cartridges and 20% of toner cartridges are reused. Both issues generate significant amount of electrical and electronic waste.

To enhance printer lifetime, it is important to confirm whether this early replacement is actually happening, and to understand the potential reasons for this. Similarly, to increase the reuse rate of consumables, it is essential to understand the barriers to reuse, whether they are related to technical, market, legal or user behavioural aspects.

Currently there are no similar studies available that provide clarity on the influence of user behaviour. Given the fact that consumer preferences play a key role in determining the wider demand for certain imaging equipment, it is essential to acquire an in-depth understanding of the ways in which consumers choose and utilise such devices. Obtaining comprehensive insight on users' purchase preferences and consumption patterns would allow for a better forecasting of their needs and adequate policy planning that would ensure that both user demand and environmental obligations are satisfied in equal measure. Therefore, a contract has been established with the consulting firm IPSOS in order to undertake a user behaviour study.

Disclaimer: at this stage of the Preparatory Study the user behaviour study has not been completed yet, as the analysis of the results is still ongoing. Nevertheless, the following chapters present the objectives, the methodology used and the preliminary results based on the raw data shared by IPSOS.

3.1 Objectives of the user behaviour study

This study aims to acquire improved understanding of the user behaviour in the business-to-consumer segment, and awareness with regards to the consumption of printers, cartridges and containers. As specifically indicated in the tender specifications, the study looks into:

- how the general performance of imaging equipment (i.e. energy consumption, price, reparability, page yield etc) affects consumers' purchase decisions;
- consumers' habits in relation to the use of printers, cartridges, and containers (i.e., how often do they use them, size, colour etc);
- Printers' and consumables' circularity (willingness to repair, reasons for disposal, willingness to use remanufactured consumables, barriers for circularity etc);
- Preferences regarding printing services and subscription schemes.

Obtaining in-depth information and understanding of the aforementioned indicators is much needed as a policy instrument to further advice on the development and implementation of concrete actions to successfully move to a circular economy and, ultimately, to achieve a cleaner and more competitive Europe.

In addition to these indicators, the survey focuses on circularity aspects of printers and their consumables. The main research questions in this regard are:

- How are consumers using imaging equipment and estimate printer typical lifetime?
- How is the business model of the imaging equipment market affecting user behaviour and the circularity of imaging equipment?
- How are relevant design aspects of imaging equipment (e.g. device's lifetime, page yield, durability of the cartridge, printing quality, failure rate, consumable's origin, etc.) affecting consumers' purchase decisions?

3.2 Methodology of the user behaviour study

Data for the Imaging Equipment User Behaviour Study has been collected by means of an online survey. The survey will primarily measure indicators about the behaviour of consumers when it comes to the purchase and use of regarding imaging equipment and its consumables. The questions will focus on four main dimensions of EU consumers' behaviour and perceptions:

- How aspects related to the performance, material efficiency and energy efficiency of imaging equipment and its consumables affect consumer purchase decisions per EU region;
- How EU printer consumers use imaging equipment and its consumables;
- What consumers think about the circularity of printers' and consumables' circularity;
- What are the preferred/most valued printing services/subscription schemes among EU consumers.

Based on that, the survey will consist of the following question blocks:

Screening questions and soft quotas. These questions are needed to confirm the eligibility of the respondent, who should either have access to and use a printer or a multifunctional imaging device in their household, or find it at least somewhat likely that they will buy such a device for private use in the next two years.

A series of questions is also asked to gather relevant background information about respondents in order to monitor for their distribution by age, gender, education level and employment status. The goal of these socio-demographic questions is twofold: First, they are needed to ensure that a representative sample is collected in each country. Second, they will also allow to compare differences in purchase and usage behaviours between population subgroups.

Purchase-impacting device features. A central objective of the survey is to identify which product features consumers take into consideration when comparing and purchasing printers or multifunctional printing device and their consumables. This will be measured separately for printers/devices and consumables.

Usage behaviour indicators. A second core area of the survey concerns the usage behaviour of consumers when it comes to the imaging equipment and their consumables in scope. Particularly, the survey will look at how consumers use imaging equipment and their consumables, by measuring usage frequency and printing trends.

Attitudes and awareness. To gain more fine-grained insights in the profiles of imaging equipment consumers/future consumers and identify user properties that could potentially impact usage behaviour as well as purchase preferences, the survey will also measure a set of indicators related to consumers' awareness of, and attitudes towards, the impact of their usage and purchase behaviour (e.g. questions on circularity and past usage/purchase behaviours).

Printing subscription services. After questions on consumers' attitudes and awareness, the survey will look at whether consumers have used printing subscription services in the past and reasons why they did (not) use it.

Other socio-demographics. The survey will ask one additional socio-demographic question about the household's financial situation.

3.2.1 Sociodemographic background indicators

In the first place, a set of sociodemographic indicators will be measured needed to ensure the representativity of the sample along the parameters agreed on:

- Age (at age groups 18-34, 34-50, and 51+)
- Gender (male and female)
- Education level (high, medium and low)
- Employment status (employed, unemployed/inactive)

In addition to these main sociodemographic indicators, the survey will also measure respondents' financial household situation, by asking them how easy they find it to make ends meet in their household (very easy, somewhat easy, somewhat difficult or very difficult). It is plausible that the financial household situation of a consumer will impact their purchase and usage behaviour, as well as attitudes/behaviour towards the replacement of devices.

3.2.2 Impact of product features on purchase decision

The goal of this part of the survey is to measure the relative importance of a large set of product factors when it comes to their impact on consumers' purchase decisions. Gauging the relative importance of factors can be challenging in the context of survey research as people sometimes find it cognitively difficult to rank multiple factors in a list – or simply lack the inclination to do so. Often they will pick factors placed towards the top of a list, ignoring those further down; or they may find it relatively easy to identify the most and least important factors but find discriminating between middling factors difficult. Multiple choice and grading questions aimed at gauging relative performance can be subject to further response effects, such as response set effects or 'straightlining'.

It is also important to consider that for some choice situations such as the purchase of new products where a range of (sometimes competing) factors are taken into account, ranking questions do not necessarily reflect accurately the real-life trade-offs that consumers often find themselves making. Certainly, in relation to the specific factors that are of interest for this study, it must be borne in mind that consumers will not consider factors relating to printing performance and factors relating to material efficiency/energy efficiency separately. Rather, they will tend to trade-off factors from across the two lists. However, listing all of these factors in one question for respondents to select or grade, would make for a very long list and a potentially onerous question for respondents (and thus increase the likelihood of response effects which would negatively impact the data quality).

Given these issues, the contractors were in favour of a more sophisticated form of stated importance analysis that both lowers the cognitive load on respondents and more accurately mimics the purchase decision-making process. Specifically, they recommended assessing the impact of different factors when purchasing imaging equipment (e.g. price, brand, printing quality, etc.) using a MaxDiff (Maximum Difference Scaling) approach – sometimes also referred to as "best-worst scaling".

In this approach, respondents are presented with subsets of factors based on an experimental design, and asked to choose the most and least important factors in each subset. The process is repeated multiple times per respondent. From the resulting data it is possible to derive an overall ranking of all the factors for the sample as a whole and to arrive at an importance score for each factor – which in turn means it is possible to identify exactly how important each factor is seen in relation to the others; something that is not possible with a simple ranking or grading approach. The higher the score, the more important the factor.

Table 18 on shows the different product features that are included in the survey. The development of this list has been developed in agreement between the JRC and IPSOS. In addition, it was taken into account that the individual features must not overlap and need to be maximally distinct, in order to allow respondents to easily make a choice between the features when asked to select which ones are most and least important. For the same reason, attention also went to describing the features concretely and clearly, adding examples where needed.

Table 18. Product features included in survey

Factor	Devices	Consumables
The price of the printer	X	
The (expected) price of the consumables	X	X
Consum knowledge about the manufacturer (e.g., the reputation of the model/brand/manufacturer, personal past experiences, reviews or ratings)	X	X
Performance and features of the printer (e.g. printing speed, quality, paper formats supported)	X	X
Other product characteristics (printing noise, size/weight of the printer)	X	
The energy consumption of the printer	X	

The expected lifetime of the printer before there is significant performance or usability decrease (e.g., poor printing quality or lack of compatible cartridges)	X	
Information on the number of pages printed with one consumable		X
How easy it is to have the printer repaired or to replace parts	X	
Whether and how you can use the printer together with other cartridges (e.g., refilling cartridges, remanufactured cartridges, etc.)	X	
The type of cartridges (e.g. refillable container, all-in-one cartridge, solid link, etc.)	X	
Availability of a take-back scheme for the empty consumables		X
Shelf life of the consumable (i.e. how long the consumable lasts on the shelf before it expires)		X
The sustainability and environmental impact (e.g. Ecolabel-certified, sustainability information on printing, etc.)	X	X
Full compatibility of the consumable with the printer/multi-function printer		X
Customer care offered by the manufacturer (e.g., repair services, help desk, warranty)	X	

3.2.3 Usage behaviour indicators

The usage behaviour of consumers will be measured via several indicators. These will cover firstly the frequency of use of imaging equipment and of consumables. In addition to that, questions will also be asked about use preferences in terms of paper size formats, paper colour format.

3.2.4 Attitudes and awareness indicators

In addition to indicators focussing on important product features when purchasing a device, and usage behaviour/preference indicators, the survey will also look at consumers' attitudes and awareness when it comes to the impact of their behaviour, particularly when it comes to the circularity of their printer/consumables, but also with regards their usage. Based on that, the following questions will be added to the survey:

<u>Reasons for replacing a device</u>

This first indicator will look at what would be important reasons for consumers to replace a printer. The question restricts the scope to the replacement of a working device. This allows to determine for what reasons a consumer would consider valid to replace a printer other than the simple fact that the printer no longer functions.

This indicator will allow to identify varying consumer attitudes with regards to the point at which they think a printer no longer serves their needs, providing insights into the frequency with which new printers are

<u>Expected usage length of the printer</u>

In addition to the above indicator, a second indicator that allows to gain insight in the impact of usage behaviour on the life cycle of the printer is how long they expect to use the printer before replacing it with a new one. Combined with the previous indicator, this will allow to determine what the impact is on different factors taken into consideration when deciding to replace a device on the length that a device is used

This question is asked for any printer owned or found at least somewhat likely to be purchased in the near future (as determined in the screener).

Printer/consumable failures

The next set of questions asked relates to the most common printer and consumable failures experienced by consumers.

Circularity of printers and their consumables

The last set of questions in the attitudes and awareness section relates to the circular behaviours of consumers towards printers and their consumables in the past five years and reasons behind their (non)circular behaviours.

Printing subscription services

The last section of the questionnaire enquires on usage of printing subscription services in the past and reasons for having or having not used such services in the past.

3.2.5 Survey implementation

The survey will run in a selection of EU Member States, but has the aim to result in data that provide insights relevant for the whole of the EU. In order to achieve this, the Member States were carefully selected to represent a broad diversity in terms of geography, population size, economy and consumer behaviour regarding sustainability and imaging device ownership. This ensures that a considerable degree of representativity is built into the survey sample itself without having to survey all EU countries.

The following seven countries were selected for the survey: Germany, France, Hungary, Italy, Poland, Spain and Sweden. Together, these countries cover a large proportion of the population of the EU27 (71%), while at the same time representing a diverse range in terms or geography, as well as GDP and imaging equipment -related indicators.

The target population of the survey will be any adult consumer who either has access to and uses a printer or a multifunctional printer (e.g., printer + copier) in their household, or finds it at least somewhat likely that they will buy such a printer for private use in the next two years.

The overall final sample size will be 800 complete interviews per country.

For the survey, Ipsos will draw random samples of respondents from their online access panel network in each of a selection of target countries. Sufficient sample will be drawn to deliver 800 completed surveys in each country.

All sampling will be carried out via Ipsos' proprietary sampling application that facilitates the construction of complex samples based on screening procedures. The selection of respondents is based on a quota selection system; the sample will be based on the available profile data (e.g. gender, age) and pre-defined sub-sample sizes (i.e., soft quota) provided by official statistics (e.g. as sourced by Eurostat or national statistical offices). The software selects potential respondents that balance according to the targets. As part of the process, Ipsos also applies exclusion rules which take into account the type of study, the number of surveys respondents have already participated in, etc. These rules are based on the company's panel management expertise and are aimed at eliminating potential bias resulting from overusing the same respondents.

3.2.6 Preparation of data for analysis

Before the analysis of the data can start, the necessary calculations will be conducted to calculate for all indicators the aggregates at country and all-country level. This involves the following steps:

- Calculation of the MaxDiff indices;
- In-country weighting of the data;
- Population weighting to determine all-country level aggregates.

Extrapolation of the survey results to the 27 Member States (i.e. calculating actual data for other Member States not included in the survey) will not be practically feasible. Indeed, extrapolation as a statistical practice is typically used for the imputation of small sets of missing data (i.e., single indicators) in one or more countries based on an expected correlation of existing data. IPSOS are not aware of concrete examples of extrapolations of complete survey data sets to countries where the survey has not taken place. IPSOS will be able to aggregate the results of all countries included in the survey. Because of the diverse selection of countries, those results can be taken to reflect behaviours and attitudes across the EU. However, when reporting and interpreting results, the geographic scope of the survey should always be kept in mind.

Starting from the raw, unweighted data, the first step will be to perform the MaxDiff analysis. This analysis, based on Bayesian hierarchical modelling, will be done using dedicated analytical software, resulting in MaxDiff indices for each purchase-impacting factor included in the survey, at respondent level and separately for the imaging equipment/consumables. When aggregated, these indices result in a score for each factor that indicates how important the factor is found compared to other factors, allowing for a ranking of factors according to their relative importance, for the imaging equipment/consumables separately.

The most common techniques to make an online panel more closely mirror the population at large occur either at the sample selection stage or after all data has been collected. As described in above, at the selection stage, purposive sampling techniques may be used to draw samples that match the target population on key demographic measures. The most impactful of these measures is setting quota on several parameters.

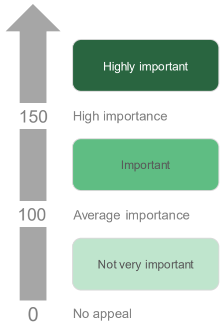
A final step to ensure that the sample accurately reflects the socio-demographic structure of the target population is a post-data collection weighting adjustment. After data collection, a post-stratification weighting procedure will be carried out. To the extent possible based on the achieved sample distribution (as only soft quotas would be applied), the post-stratification weights would aim to align as closely as possible the sample profile to the population profile on relevant socio-demographic variables, such as gender and age (not interlocked). Where possible, the data source for population weights will be Eurostat or other official sources.

The quantitative analysis of the results will focus on the core objectives of the survey:

- Determining the relative importance in consumers' purchase decisions of a range of features/characteristics relevant to imaging devices/consumables.
- Assessing how different imaging devices/consumables are used.
- Assessing the importance of circularity of imaging devices/consumables for users and preferences with regards to products' end-of-life (including more general aspects of consumers' environmental awareness).
- Determining the behaviours and preferences of EU consumers towards printing subscriptions and services schemes.

Determining the relative importance in consumers' purchase decisions of a range of features/characteristics relevant to imaging devices/consumables will be done by analysing the results of the MaxDiff exercise conducted as part of the survey. The answers to the MaxDiff questions in the survey will be subjected to statistical modelling that will result in a ranking of all features on a scale from least important to most important. This ranking is based on an index assigned to each feature, centred around 100 as the index for average importance. Lower values signal lower importance (a value of 50 reflecting 50% of the importance compared to a value of 100) and a higher value signals higher importance (a value of 150 meaning that the feature is on average considered 50% more important). Note that these indices and the resulting ranking will be calculated on all features combined – i.e., printing devices'/consumables' features. The diagram below shows how to interpret the max diff indices. A score of 150 means that the item is 50% more important than the average. If all attributes would be equally important or were selected at random, they would all have a score of 100.

Figure 15: How to interpret Max-Diff indices. Source (IPSOS 2023).



The indicators related to usage behaviour, behaviour related to circularity and end-of-life, environmental awareness and awareness of/interest in printer subscription services will be analysed using bivariate analyses to determine means and proportions (depending on the question type) for each indicator and comparing these between the different sociodemographic subgroups. This analysis will focus in the first place on the different use purposes for imaging devices and consumables (i.e., which device/consumable is used for what purposes), as well as related indicators collected in the survey such as, potentially, frequency and intensity of use, etc.

3.3 Results of the user behaviour study

This section provides preliminary results from the IPSOS Survey. A complete and more structured analysis will be presented in the next version of the Preparatory Study, based on the final delivery of the study from IPSOS. In the meantime preliminary snapshots of the survey results are presented in the following sections.

3.3.1 Impact of product features on purchase decision

Table 19 and Table 21 summarise the main results of the MaxDiff analysis with the elements influencing the purchase decision of printers and consumables (Source: IPSOS Survey, 2023).

Table 19: Relevance of different elements when buying a printer or a multifunction device.

Q1. Which of the following elements is MOST IMPORTANT and which one is LEAST IMPORTANT to you when deciding which single-function or multi-function printer to buy?	
Highly important / Important / Not very important	
The price of the printer	151
The expected price of the ink cartridges/toner cartridges	165
Availability of the printer as part of a subscription service	25
Your knowledge about the manufacturer of the printer (e.g. the reputation of the model/brand/manufacturer, personal past experiences, reviews or ratings of the printer or multifunctional device	66
Performance and features of the printer (e.g. type of cartridges, printing speed, paper formats supported, size/weight of the device)	151
The energy consumption of the printer	64
The expected lifetime of the printer before there is significant performance or usability decrease	129
Whether and how you can use the printer together with other cartridges (e.g. refilling cartridges, remanufactured cartridges, etc.)	120
The environmental sustainability of the printer (e.g. Ecolabel-certified, sustainability information on printing, etc.)	63
Customer care offered by the manufacturer (e.g. spare parts, repair services, help desk, warranty)	67

In the case of printers it can be noted that "price" is the main element considered by consumers in purchase decisions, according to the survey results. It is interesting to notice that the expected price of cartridges is considered even more important than the printer price. Another highly important aspect is the performance and feature of the printer. According to the survey results, users with a higher frequency of use tend to take in consideration more elements in their purchase decision as equally or even more important than price: performance, the expected features, compatibility. Moreover other aspects like customer care, product quality, energy consumption and sustainability are considered more relevant from frequent users (Table 20: Relevance of different elements when buying a printer or a multifunction device for users with different usage frequency..

Table 20: Relevance of different elements when buying a printer or a multifunction device for users with different usage frequency. (Source: IPSOS Survey, 2023)

Q1. Which of the following elements is MOST IMPORTANT and which one is LEAST IMPORTANT to you when deciding which single-function or multi-function printer to buy?	Usage Frequency						
	Single Function Printer				Multi-function printer		
	Heavy	Medium	Light		Heavy	Medium	Light
The price of the printer	108	145	180		121	150	176

The expected price of the ink cartridges/toner cartridges	127	154	179		145	169	188
Availability of the printer as part of a subscription service	51	31	15		38	24	18
Your knowledge about the manufacturer of the printer (e.g. the reputation of the model/brand/manufacturer, personal past experiences, reviews or ratings of the printer or multifunctional device)	92	71	56		80	64	59
Performance and features of the printer (e.g. type of cartridges, printing speed, paper formats supported, size/weight of the device)	144	145	143		160	152	150
The energy consumption of the printer	72	69	61		69	62	51
The expected lifetime of the printer before there is significant performance or usability decrease	121	127	138		123	130	139
Whether and how you can use the printer together with other cartridges (e.g. refilling cartridges, remanufactured cartridges, etc.)	116	116	117		110	123	120
The environmental sustainability of the printer (e.g. Ecolabel-certified, sustainability information on printing, etc.)	85	70	51		76	62	43
Customer care offered by the manufacturer (e.g. spare parts, repair services, help desk, warranty)	86	71	60		77	64	56

Price" and "printing quality" are considered highly important when purchasing consumables. Important elements are also the number of pages and the full compatibility of the consumable with the printer.

Table 21: Relevance of different elements when buying a consumable. (Source: IPSOS Survey, 2023)

Q2. Which of the following elements is MOST IMPORTANT and which one is LEAST IMPORTANT to you when deciding which consumable to buy?	
Highly important / Important / Not very important	
The price of the consumable	163
Availability of a take-back scheme for the empty consumables	43
Shelf life of the consumable (i.e. how long the consumable lasts on the shelf before it expires)	71
Your knowledge about the manufacturer of the consumable (e.g. the reputation of the model/brand/manufacturer, personal past experiences, reviews or ratings of the consumable, whether the consumable was produced by an original equipment manufacturer, remanufactured and/or other manufacturers)	58
The printing quality of the consumable	156
The number of pages that can be printed with one consumable	131
The sustainability of the consumable (e.g. Ecolabel-certified, sustainability information on printing, etc.)	60
Full compatibility of the consumable with the single-function/multi-function printer (e.g. no error messages, no issues during the installation of the consumable)	117

Also for consumables, according to the survey results, users with a higher frequency of use tend to take in consideration more elements in their purchase decision (Table 22), with a less dominant focus on the price parameter.

Table 22: Relevance of different elements when buying a consumers for users with different usage frequency. (Source: IPSOS Survey, 2023)

Q2. Which of the following elements is MOST IMPORTANT and which one is LEAST IMPORTANT to you when deciding which consumable to buy?	Usage frequency						
	Single function Printer				Multi-function printer		
	Heavy	Medium	Light		Heavy	Medium	Light

The price of the consumable	123	157	169		137	166	178
Availability of a take-back scheme for the empty consumables	59	48	48		52	42	38
Shelf life of the consumable (i.e. how long the consumable lasts on the shelf before it expires)	80	77	74		72	69	77
Your knowledge about the manufacturer of the consumable (e.g. the reputation of the model/brand/manufacturer, personal past experiences, reviews or ratings of the consumable, whether the consumable was produced by an original equipment manufacturer, remanufactured and/or other manufacturers)	87	64	50		70	55	46
The printing quality of the consumable	136	153	153		151	158	156
The number of pages that can be printed with one consumable	112	125	135		124	134	142
The sustainability of the consumable (e.g. Ecolabel-certified, sustainability information on printing, etc.)	83	64	57		72	58	47
Full compatibility of the consumable with the single-function/multi-function printer (e.g. no error messages, no issues during the installation of the consumable)	119	111	115		122	118	116

3.3.2 Usage behaviour indicators

In terms of usage frequency it is interesting to notice that only a small fraction of the participant declared making a daily use of their printers. More frequently survey respondents indicated a weekly or monthly use of their device.

Table 23: Usage Frequency (Source: IPSOS Survey, 2023)

Question	Selected options (%)	
D4_1 How often do you use these devices? - Single-function printer that can only print	Daily	13.02%
	At least once a week	42.45%
	At least once a month	32.75%
	At least once a year	10.22%
	Never	1.56%
D4_2 How often do you use these devices? - Multi-function printer that also has other features besides printing (e.g. copying, scanning or faxing)	Daily	11.91%
	At least once a week	49.88%
	At least once a month	31.26%
	At least once a year	6.07%
	Never	0.88%

The low frequency of use in consumer environment is somehow confirmed by the results of the survey in terms of printed pages, with more than 50% of participant in the survey declaring a printing intensity of less than 50 pages/month associated to their devices. The survey also asked participants to indicate how many pages they print every month with their device and the resulting average was 88,49 pages.

Table 24: Usage intensity in terms of printed pages per month (Source: IPSOS Survey, 2023)

Q3 Imaging equipment usage intensity - Amount of pages printed in a month	Less than 10 pages/month	29.04%
	10-49 pages/month	36.35%
	50 pages or more/month	34.61%

The survey also asked about the age of the printers owned by the survey participants. It is interested to notice that single function printers appear to be slightly older in terms of age distribution. Most of multi-function printers currently in use are less than three years old (37.40% of respondents), or between three and five years (34.54%) old (see Table 25).

Table 25: Age distribution for single function and multi-function printers used by the survey respondents (Source: IPSOS Survey, 2023)

		Single Function Printer	Multi-function Printers
D3_Age_1 How old is this device?	1 Less than three years	27.81%	37.40%
	2 Between three and five years	32.38%	34.54%
	3 Between five and ten years	28.47%	21.78%
	4 More than ten years	9.46%	5.16%
	5 Don't know	1.87%	1.11%

In terms of use of consumables, a relevant percentage was not able to identify the average consumption in terms of cartridge / year. Nevertheless, when specifically asked on average annual use of consumables the resulting mean from the respondents was 7.74 consumables/year.

Table 26: Consumables usage intensity (Source: IPSOS Survey, 2023)

rQ6 Consumables usage intensity - Number of consumables used in a year	2 or fewer consumables	20.87%
	Between 3 and 4 consumables	12.00%
	Between 5 and 9 consumables	9.90%
	10 or more consumables	10.01%
	Don't know	47.22%

3.3.3 Attitudes and awareness indicators

Preliminary results in terms of attitude and awareness are discussed in this section. Question Q7 provided evidence on which reasons other than the simple fact that the printer no longer function, can lead to the replacement of the device. Among the reasons considered more relevant by the participant in the survey there are the performance degradation, the high cost of printer's consumables and the incompatibility with remanufactured/third party consumables. Only 16% of the respondents consider the availability of a new printer on the market with better or newer features an important reason for the replacement of the device.

Table 27: Reason for replacement (Source: IPSOS, 2023)

$Q7 What would be an important reason for you to consider buying a new printer to replace your current one?	My printer is no longer performing as well as it used to	37.05%
	There is a new printer on the market that has better or newer features than the one I own now	16.41%
	My current printer is no longer compatible with remanufactured/third-party consumables	16.96%
	The cost of the printer's consumables is too high	28.10%
	No customer care is offered anymore by the manufacturer for this printer	8.56%
	My printer is no longer updated or supported by the manufacturer and/or software providers	16.12%
	None of the above - I intend to keep using the printer until it no longer works	29.90%

In terms of expected use length the survey shows that around 50% of the respondents intend to keep their device in use for a period of time longer than 5 years.

Table 28: Intended use length for devices (IPSOS, 2023)

		Single-function printer	Multi-function printer
Q8_1 How long do you intend to use this device before you buy a new one, assuming that it does not break down or gets lost/stolen? -	Less than three years	14.45%	12.90%
	Between three and five years	26.71%	28.79%
	Between five and ten years	33.97%	33.01%
	More than ten years	14.46%	14.76%
	Don't know	10.41%	10.54%

In terms of printers and consumable failures, it is interesting to notice that only 34% of respondents have not experienced printer failures, with the most common failures related to physical components (35%) and also a relevant 25% of respondents that have experienced compatibility issues between the printer and the cartridges.

Table 29: Frequency of printer failures (IPSOS, 2023)

$Q9 Thinking about the most common printer failures you have experienced. Which, if any, of the following, have happened to you in your household?	There was a fault or a problem with the software of the printer	19.87%
	There was a fault or a problem with a physical component of the printer (e.g. the paper jammed)	35.27%

	There was a compatibility issue between the printer and cartridges (e.g. the printer refused to print with the consumable or registered it as empty when it was not)	25.03%
	Other	5.58%
	We have experienced no printer failures in our household	33.95%

Also a relevant percentage of participants (around 57%) have experienced failures at cartridge level. Most common issues are related to the cartridge compatibility (21%) and more in general to the replacement (15%) or refilling (10%). Another relevant factor is the ink drying/clogging (15%).

Table 30: Frequency of consumables failure

$Q14 Thinking about the most common consumables failures you have experienced. Which, if any, of the following, have happened to you in your household?	There was a fault or a problem with a physical component/part of the consumable	10.33%
	There was a fault or a problem when replacing consumables	15.22%
	There was a compatibility issue with my printer/multi-function printer	21.25%
	There was a fault or a problem when refilling the ink tank of the printer	9.91%
	There was a fault or a problem with the toner or ink drying/clogging	15.19%
	There was a fault or a problem with the toner or ink leaking	6.99%
	Other	4.15%
	We have experienced no cartridge/tank failures in our household	42.93%

Regarding the circularity attitudes of consumers a specific question was raised on reasons for not using remanufactured cartridges. Interestingly, the main reasons seem to be associated to lack of knowledge and trust, more than previous bad experiences with remanufactured cartridges.

Table 31: Reason for not using remanufactured cartridges (Source: IPSOS Survey, 2023)

$Q12 You previously stated that you did not use remanufactured cartridges in the past 5 years. Which of the following, if any, are the main reasons why?	I fear that the printing quality of remanufactured cartridges will be lower than traditional cartridges	18.66%
	I fear that the number of pages printed with one remanufactured cartridge will be lower than the number of pages printed with a traditional cartridge	11.86%
	I fear that the price of remanufactured cartridges will be too high	10.23%
	I do not trust the manufacturers of remanufactured cartridges	19.35%

	I don't know enough about remanufactured cartridges	23.92%
	Previous bad experiences with remanufactured cartridges	16.98%
	Other	10.28%
	My printer does not work with remanufactured cartridges	11.66%
	My printer does not need cartridges	5.62%
	Don't know	0.03%

Finally, participants to the survey were also asked about their experience and attitude toward printing subscription services.

Table 32: Experience with subscription services

Q17 In the past 12 months, have you used a printing subscription service?	1 Yes, for printer and consumables	11.78%
	2 Yes, but only for consumables	11.69%
	3 No	71.00%
	4 Don't know	5.54%
	Total	5675

4 Task 4 – Technologies

Task 4 covers the assessment of current and future product technologies in the EU market at different life cycle stages, i.e. production, distribution and end-of-life. This information is used to establish "base-cases" for average products in the established product categories in Task 5. Also Best Available Technologies (BAT) are identified which will be the basis for modelling in Task 6. Most of the environmental and life cycle cost analyses throughout the rest of the study will be built on base-cases and the technology analysis serves as the point of reference for Tasks 5, 6, and 7.

4.1 Electrophotograpy

Electrophotography is an imaging technology commonly used in printers, copiers and faxes, in which a printed output is produced from a digital file, using a photoreceptor, a light source, electrostatic principles and toner. The photoreceptor is commonly referred to as a drum. It is a cylinder coated with material that becomes conductive when exposed to light. Areas that are not exposed have a high resistance which allows these areas to hold the electrostatic charge necessary for the process. Light sources used in printing include LED arrays or, more commonly, lasers (Jeffery et al, 2015).

Electrophotography uses toner as deposition material. Toner is a fine, dry power medium composed primarily of a resin, pigments, wax and other process-enhancing additives. Toner particles become electrically charged when stirred or agitated, trough what is known as a triboelectric effect (when certain materials such as toner are rubbed with each other, they can become electrically charged). The composition and the shape of the toner not only contributes to its imaging characteristics but to its ability to maintain and control its charge properties. This electrical charge is what allows the toner to be precisely manipulated throughout the process.

In Jeffery et al (2015), the electrophotographic process is divided in seven stages:

1-Charging: a high negative voltage of approximately -900V is provided to a charge roller. The charge roller applies a uniform layer of negative charge to the surface of the drum. The resistivity of the photosensitive drum coating allows the charge to remain on the surface.

2-Exposure: a laser is used to write the image onto the charge surface. The photosensitive coating on the drum becomes conductive when exposed to light. The charges on the surface of the drum exposed to the laser conduct to the base layer (which is connected to a ground). A latent image is created (a near zero volt image with a negative background).

3-Development: the developer is a mixture of non-magnetic toner and magnetic carrier. As the developer is stirred and the particles rub up against each other, a triboelectric charge is generated between them. The toner becomes negatively charged while the carrier becomes positive. These opposite charges cause the toner to be attracted to the carrier. A magnetic brush carries the attracted toner to the surface of the drum. The toner is attracted to the areas of the drum exposed by the laser. Therefore, the latent image is developed.

4-Transfer: a sheet of paper passes between the drum and a transfer charge roller that has a high positive voltage applied to it. The negatively charged toner of the developed latent image is attracted to the more positive transfer roller and adheres to the sheet in-between. The charge applied to the back of the sheet causes the paper to cling to the drum. A high negatively voltage is applied to a discharge plate immediately after the transfer charge roller to aid in the separation of the sheet from the drum. More advanced methods of transfer use an intermediate transfer belt system.

5-Cleaning: after the transfer stage, some toner may be left behind on the surface of the drum. If left there, the background of each successive print would slowly become darker and dirtier. To prevent this, a cleaning blade removes any residual toner from the drum's surface. Some systems recycle this toner back to the developing unit, but mostly the waste toner is collected in a container for disposal.

6-Erasing: a LED array exposes the drum, bringing this area to near zero volts. This prepares the drum surface for the charging stage of the next print cycle.

7-Fusing: this is the final stage of the EP process. The most common fusing technology is roll fusing. In this case, the fuser consists of a heat roller, a pressure roller and a cleaning mechanism. When the toner is heated by the heat roller and pressure is applied by the pressure roller, it melts and is pressed into the fibres of the sheet. The toner is bonded to the surface.

According to additional technical information provided by a stakeholder, there are alternatives to roll fusing:

Radiant fusing: this technology uses a lamp and reflector to focus radiant energy on the printed image. This is likely the simplest means of fusing an image, although with shortcomings: paper ignition in the case of paper stoppage and difficulty fusing toner of colors other than black. Overall energy efficiency is low.

Cold pressure fusing: in this case, two highly loaded steel rollers are used to press the toner into the paper. This technology offers instant-on and low power consumption. This system requires a toner that will flow under pressure. Only mechanical power is required (no heat).

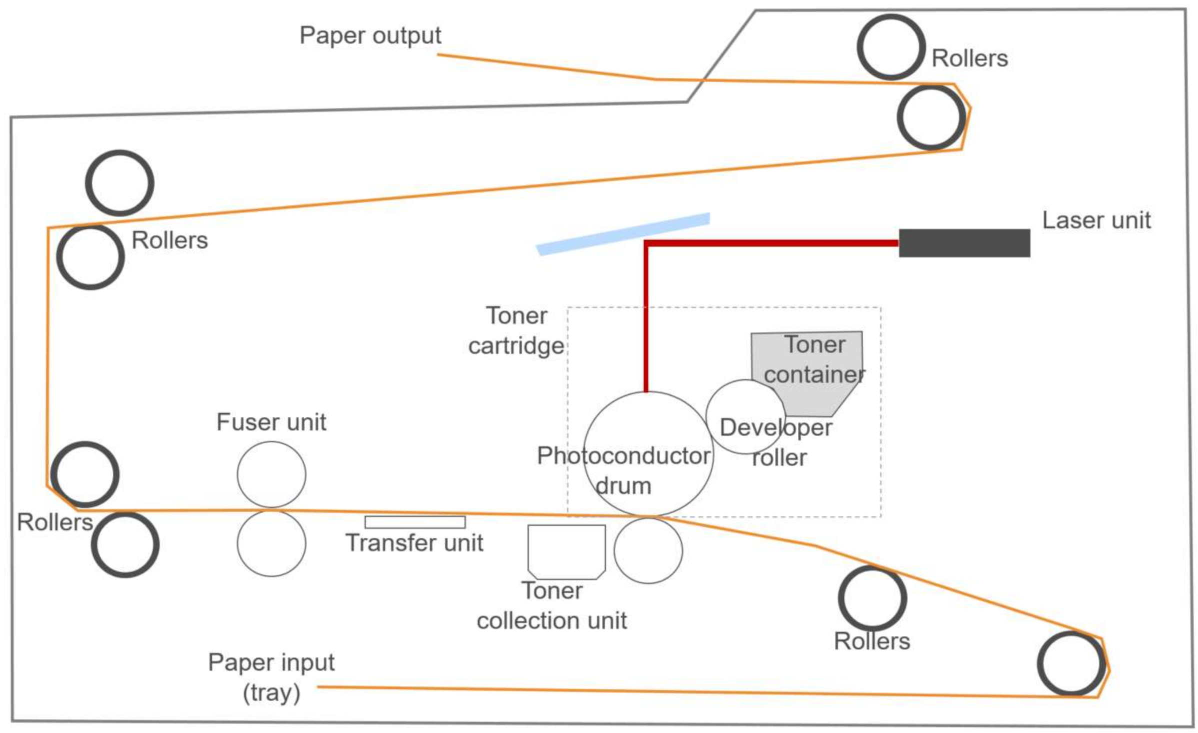
Flash fusing: similar to radiant fusing, in this cases using a xenon-filled flash tube inside a deflector. A power supply charges capacitors, which are then discharged through the flash tube to create instantaneous radiant energy, absorbed by the toner.

Belt fusing: in a monochrome printer, the belt can be polyamide or stainless steel, coated with a fluorinated polymer release layer. In a color printer, the belt is typically a stainless steel tube of approximately, a soft elastomer layer and an outer layer of fluorinated polymer. Their primary advantage if fast warmup time with low power consumption. Drawbacks are mechanical reliability and lifetime.

Inductive heating: this system uses a coil inductively couple to a fusing member (a belt or a roller) containing a magnetic material. A high frequency alternating current in the coil induces eddy currents in the metal fusing member. This system offers the capability to decouple the fusing pressure zone from the heating zone while maintaining a fast warmup time if the mass of the fusing member is low. This technology is predominantly used in A3 printing and copying devices.

4.1.1 Electrophotographic devices

Electrophotographic (EP) printers are also known as laser printers. They are defined in ISO 29142-1 as a printer principally using optoelectronic phenomena and electrostatic attraction to move toner to a substrate. A schematic description of an EP printer is provided in Figure 16.



Source: JRC, adapted from Farratech (2015)
Figure 16. Schematic description of EP printer

Considering the description of the electrophotographic process, the main components of a laser printer are:

- The photoconductor, also known as ‘drum’, which attracts the toner powder particles and transfers the toner to paper. The drum is a cylinder and can be positioned either next to or inside the toner cartridge. Most photoconductors use an organic material (organic photoconductor, or OPC), although ceramic photoconductors can also be found.
- The developer roller, a cylindrical sleeve used to transfer image forming toner particles. The developer roller can be a part of the printer or located within the cartridge.
- The light source (laser), which imprints the image onto the drum, creating an electrostatic image onto the photoconductor drum.
- The toner cartridge, which holds the toner and which can be found in different configurations (Figure 17)

-Single-part: comprising only the toner container

-Two part: comprising the toner container and the developer roller

-All in one: comprising the toner container, the developer roller and the photoconductor drum.

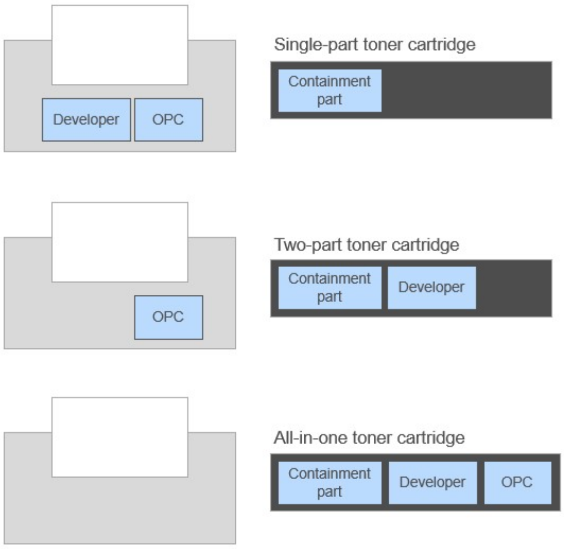


Figure 17. Toner cartridge configurations

- The waste toner collection unit, which collects the waste toner during the printing process
- The fuser unit, which melts the toner and secures the image to the page.
- The transfer unit, used to transfer the toner image onto paper. It is located after the photoconductor drum and before the fuser unit. It must be noted that not every EP printer contains a transfer unit.
- The internal or external power supplies

Laser printers tend to offer higher printing speeds and are able to withstand higher printing volumes, therefore they are the most common choice in offices.

4.1.2 Toner cartridges

Laser printers use toner as deposition material, which is held in toner cartridges. These cartridges can come in different configurations (Figure 17) and they may consist of a significant number of different components and materials. A schematic description of a generic monochrome toner cartridge is shown Figure 18.

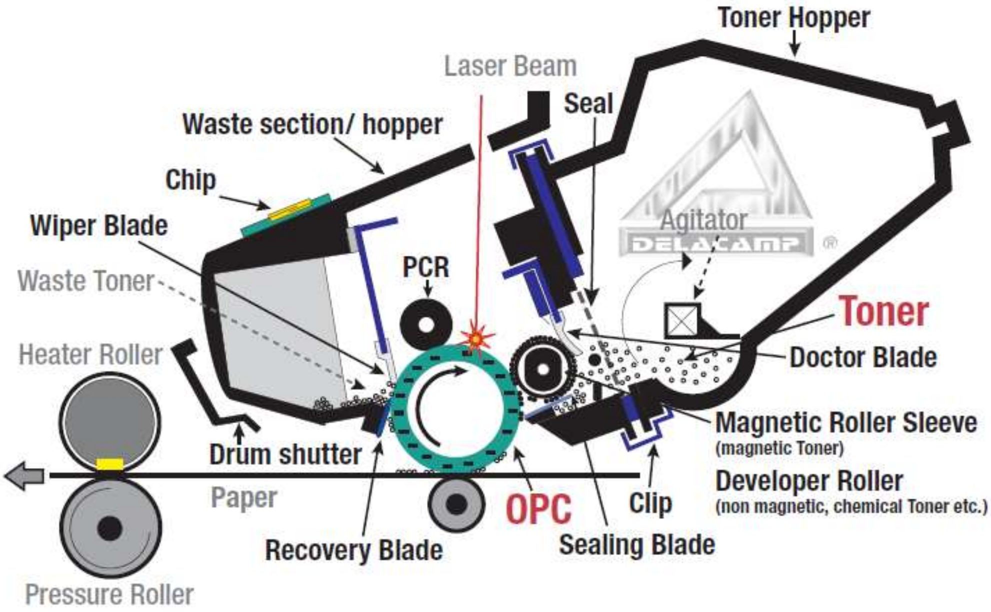


Figure 18. Schematic description of generic monochrome toner cartridge
Source: Delacamp

Some of the main components of a toner cartridge are (Josiah et al, 2013; Farratech, 2021; Tonerbuzz, 2021):

- The photoconductor drum: typically organic photoconductors (OPC) although ceramic photoconductors can also be found. All drums are light sensitive. There are normally three different layers of chemicals: an insulator, a reactive layer that reacts to light and a protective layer. The latter is the layer that determines how long a drum will last.
- The primary charge roller (PCR): it has two functions. The first is to apply a DC signal to the surface of the drum so that the laser from the printer can write to it. The second is where an AC signal is applied to the drum to help erase any residual charges left on the drum surface after printing.
- The developer roller: consists of a metal shaft with molded rubber around it and a conductive sleeve on the outside. Toner is attracted to the roller by electrical signals from the high-voltage power supply in the printer.
- The doctor blade: it regulates the amount of toner on the magnetic roller by using pressure fom its silicon rubber blade rubbing against the magnetic roller sleeve. This friction also helps statically charge the toner so that an even layer of toner is on the magnetic roller sleeve.
- The wiper blade: the rubber edge of a wiper blade cleans the drum of any toner that was not transferred to the paper. The blade rides directly on the drum and is one of the main causes of drum wear.
- The recovery blade: a thin blade that guides toner that was wiped off the drum by the wiper blade into the waste chamber.
- Waste chamber: collects and holds all the waste toner.
- The electronic circuitry –also known as the chip- which supports a variety of functions (anti-counterfeit, the number of pages printed, etc.) through communication with the device.

Figure 19, Figure 20 and Figure 21 provide examples of the three toner cartridge configurations describe above.

Figure 19. Single part toner cartridge

Figure 20. Two part toner cartridge

Figure 21. All-in-one toner cartridge

In single part toner cartridges, the cartridge is restricted only to carrying the toner. The two-part toner cartridges incorporates a toner storage unit and at least a developer part. The all-in-one toner cartridge includes the photoconductor drum as well. Unbundling components such as the developer and the photoreceptor part from the cartridge has, in principle a material efficiency advantage, because the different components can have a different lifespan.

4.2 Inkjet printing

Inkjet printing is a type of digital imaging where drops of ink are jetted onto the substrate in a very precise patterns from a nozzle, also known as the print head (Jeffery, 2015). The most common method of inkjet printing is called drop-on-demand (DOD). This type of inkjet print head only fires each individual droplet when needed and comes in two types, thermal and piezoelectric. Accuracy in DOD inkjet printing is achieved by keeping the print head close to the substrate, as the velocity of the jetted ink is low.

In a thermal print head, each nozzle contains a special reservoir that is bounded by a heating element. When current is passed through the heating element, it causes the ink to expand rapidly, ejecting out of the nozzle to land on the substrate in a given position. The print head is made up of a matrix of many of these chambers, and each print head is connected to a different colour of ink. As the ejected ink leaves the chamber, fresh ink is drawn into the reservoir by surface tension and the vacuum created by the previous drop of ink leaving.

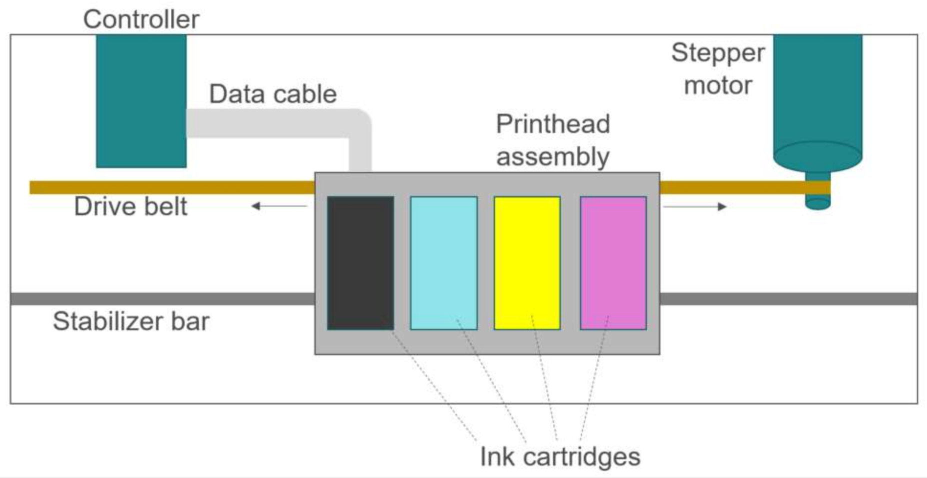
Thermal inkjet is most common in household inkjet printers. A major benefit to using thermal printhead technology is the relatively inexpensive print head. Since each colour printed requires a separate print head, and some print devices can contain eight or more colours of ink, thermal technology keeps the initial cost of the device low and reduces replacement costs when a print head fails, or is damaged.

Piezoelectric print heads also use a tiny reservoir to hold a droplet of ink. However, unlike thermal print heads, piezoelectric heads contain a small flexible membrane, or diaphragm, that moves up and down to squirt the ink out of the print nozzle. The pressure caused by the flexing of the piezoelectric material is very precise, allowing a drop, or multiple drops, to strike the substrate accurately. Similar to thermal, the print head is made up of a matrix of a number of these individual nozzles. And by using multiple print heads, multiple colours are possible.

Piezoelectric is more common in commercial and large-format printing applications, although there are a few consumer printers that use piezoelectric. Piezoelectric technology is more accurate, and because the ink in the chamber does not have to be vaporized to form the droplets of ink, piezoelectric can print with a wider variety of inks such as aqueous, ultraviolet, and latex.

4.2.1 Inkjet devices

ISO 29142-1 define an inkjet (IJ) printer as a printer with an operating part, for example a printhead, to apply ink on a substrate. A schematic description of an inkjet printer is can be seen in Figure 22.



Source: JRC, adapted from Britannica (2022) and Tyson (2022)
Figure 22. Schematic description of inkjet printer

The main components of an inkjet printer are:

- The printhead assembly, which holds the printhead and the ink cartridges. The printhead contains a series of nozzles used to spray drops of ink onto paper. There is a wide variety of print head designs: print heads designed to be replaced with each cartridge (typically used for low usage); print heads designed to last the life of the product (usually replaced at a service center); and print heads designed to have long life but replaceable by the customer.
- The stepper motor, which moves the printhead assembly back and forth across the paper
- The drive belt, used to attach the printhead assembly to the stepper motor
- The stabilizer bar, to ensure that movement of the printhead assembly is precise and controlled
- The ink collection unit, aiming to collect waste ink during printing
- The controller, electronic circuitry built into the printer to control all the mechanical aspects of the operation, as well as decode the information sent to the printer from the computer. Information is sent to the printhead assembly via a data cable.
- Ink cartridges, which can be found in different configurations (Figure 23):

-Single-part: comprising only the containment part

-Integrated: comprising the containment part and the deposition mechanism

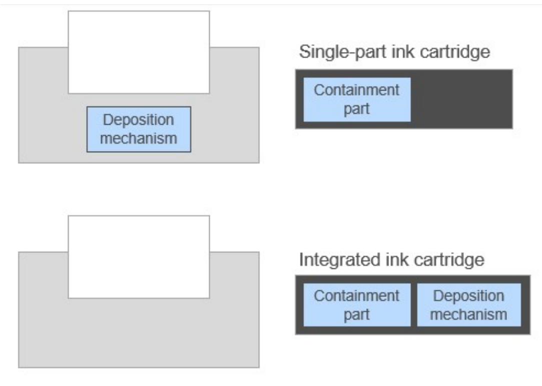


Figure 23. Ink cartridge configurations

- A set of rollers, which pull the paper from the tray and advance the paper
- The internal and external power supplies

Inkjet printers tend to provide lower printing speeds when compared to laser printers. The lower print volumes and more intermittent printing demand makes lower-cost inkjet printers more attractive than laser printers for home-print consumers.

4.2.2 Ink cartridges

Inkjet printers use ink as deposition material, which is held in ink cartridges. Typically, ink cartridges are made of two main components: the body of the cartridge that acts as a container for the ink, and the printhead that transfers the ink onto paper during the printing process (Noe, 2014).

Ink cartridges can be found in different configurations: as a separate printhead and ink cartridge, also known as 'container' (Figure 24); or as a combined unit including the ink reservoir and a print-head (Figure 25).

Figure 24. Single part ink cartridge

Figure 25. Integrated ink cartridge

In single part ink cartridge systems, the printhead is located in the printer and contains most of the electronics required to fire drops with the ink stored in a separate cartridge. The ink reservoir is essentially a small plastic vessel containing ink and is the only item which needs replacing when refilling the printer with ink. Reservoirs are generally low in value, contain only small amounts of electronics and are relatively easy to produce (Waugh et al, 2018).

Integrated ink cartridges are more complex units. Some of them contain a spongy material called hydrophobic foam, often made of a synthetic, porous rubber that contains water-repelling agents. This foam is used to hold the ink and at the same time repel outside water or humidity in the air, which can cause problems for the cartridge's functioning and the delicate chemistry of the printer ink.

The casing in which the ink is housed is generally made out of a plastic such as PET. Ink can be either black (monochrome) or coloured (generally cyan, magenta and yellow). Ink cartridges often contain some electronic circuity, which support a variety of functions (anti-counterfeit, the number of pages printed, etc.) through communication with the device.

Some inkjet printers do not use an ink cartridge. Instead, these printers have a permanent reservoir -also known as tank- which is refilled by the user from an external container (usually a bottle).

Solid ink marking technology is defined in Energy Star v3.2 as a marking technology characterized by ink that is solid at room temperature and liquid when heated to the jetting temperature. In Bozeman (2011), a description of how solid ink technology works is given: it creates an image by applying melted ink to paper where it instantly solidifies. Solid ink sticks are melted into the printhead which jets the ink onto the print drum. Paper is passed between a roller and the print drum under pressure and the image is transferred from the print drum to the paper. Solid ink is a patented colour print technology offered only by Xerox. Xerox uses solid inks which are dropped into chambers in the imaging equipment almost completely removing packaging. A more robust print head is required, thus leaning these products towards the large office markets (Waugh et al, 2018).

4.3 Other marking technologies

In this section, other marking technologies different to electrophotography and inkjet are briefly defined.

High Performance ink jet (HPIJ) is defined in Energy Star v3.2 as:

> *An IJ marking technology that includes nozzle arrays that span the width of a page and/or the ability to dry ink on the print media via supplemental media heating mechanisms. High-performance IJ products are used in business applications usually served by electro-photographic marking products.*

This marking technology is out of the scope of this study as HPIJ products are used in business applications.

Direct thermal (DT) marking technology is defined in Energy Star v3.2 as:

A marking technology characterized by the burning of dots onto coated print media that is passed over a heated print head. DT products do not use ribbons.

Direct thermal printers are usually applied in products for the printing of labels and receipts. Out of the scope of the study.

Figure 26. Examples of direct thermal devices

Dye sublimation (DS) marking technology is defined in Energy Star v3.2 as:

A marking technology characterized by the deposition (sublimation) of dye onto print media as energy is supplied to heating elements.

Impact marking technology is defined in Energy Star v3.2 as:

A marking technology characterized by the formation of the desired output image by transferring colorant from a "ribbon" to the print media via an impact process

Stencil marking technology is defined in Energy Star v3.2 as:

A marking technology characterized by the transfer of images onto print media from a stencil that is fitted around an inked drum.

Marking technologies described in this section are out of the scope of the Preparatory Study since they are mostly used for commercial applications.

4.4 Technical aspects affecting environmental performance of devices

4.4.1 Devices energy use

From the operational perspective imaging equipment are characterized by the following modes, affecting the energy consumption of the device (Energy Star, 2021):

1) On Mode:

a) Active State: The power state in which a product is connected to a power source and is actively producing output, as well as performing any of its other primary functions.

b) Ready State: The power state in which a product is not producing output, has reached operating conditions, has not yet entered into any lower-power modes, and can enter Active State with minimal delay. All product features can be enabled in this state, and the product is able to return to Active State by responding to any potential inputs, including external electrical stimulus (e.g., network stimulus, fax call, or remote control) and direct physical intervention (e.g., activating a physical switch or button).

2) Sleep Mode: A reduced power state that a product enters either automatically after a period of inactivity (i.e., Default Delay Time), in response to user manual action (e.g., at a user-set time of day, in response to a user activation of a physical switch or button), or in response to external electrical stimulus (e.g., network stimulus, fax call, remote control).

3) Off Mode: The power state that the product enters when it has been manually or automatically switched off but is still plugged in and connected to the mains. This mode is exited when stimulated by an input, such as a manual power switch or clock timer to bring the unit into Ready State. When this state is resultant from a manual intervention by a user, it is often referred to as Manual Off, and when it is resultant from an automatic or predetermined stimulus (e.g., a delay time or clock), it is often referred to as Auto-off.

According to the Standby Regulation, equipment shall, except where this is inappropriate for the intended use, provide off mode and/or standby mode, and/or another condition which does not exceed the applicable power consumption requirements for off mode and/or standby mode when the equipment is connected to the mains power source.

In the context of this preparatory study, the off-mode performance under Energy Star can be considered as equivalent to the off-mode under the Standby Regulation, and the sleep mode performance under Energy Star a proxy of the "standby mode" required under the Standby Regulation. The table below show the differences in the definitions applied by the two initiatives.

Table 33: Comparison of definitions for different modes under Energy Star and the Standby Regulation

Energy Star	Standby regulation
Off Mode: The power state that the product enters when it has been manually or automatically switched off but is still plugged in and connected to the mains. This mode is exited when stimulated by an input, such as a manual power switch or clock timer to bring the unit into Ready State. When this state is resultant from a manual intervention by a user, it is often referred to as Manual Off, and when it is resultant from an automatic or predetermined stimulus (e.g., a delay time or clock), it is often referred to as Auto-off.	**Off mode:** It means a condition in which the equipment is connected to the mains power source and is not providing any function, or it is in a condition providing only: (a) an indication of off-mode condition; (b) functionalities intended to ensure electromagnetic compatibility under Directive 2014/30/EU7
Sleep Mode: A reduced power state that a product enters either automatically after a period of inactivity (i.e., Default Delay Time), in response to user manual action (e.g., at a user-set time of day, in response to a user activation of a physical switch or button), or in response to external electrical stimulus (e.g., network stimulus, fax call, remote control).	**Standby mode:** means a condition where the equipment is connected to the mains power source, depends on energy input from the mains power source to work as intended and provides only the following functions, jointly or separately, which may persist for an indefinite time: - reactivation function or reactivation function and only an indication of enabled reactivation function; - information or status display;

Under Energy Star different energy performance evaluation methods are used to benchmark the energy performance of imaging equipment products. In Energy Star (2021) IE products are classified as "Typical Energy Consumption (TEC)" and "Operating Modes (OM)" products, and different methodologies are applicable to each of these product groups respectively. The main reason for differentiating between TEC and OM products is that OM evaluation method is typically used in household devices (e.g. consumer inkjet printers). These products spend a significant part of their time in low power modes and have a wide range of usage profiles, which can vary tremendously depending on the type of the user. TEC products are typically used in business/office environment where power consumption from active use can be considered relevant.

As shown in Figure 27, most of the inkjet models registered under the Energy Star scheme have an Off Mode Power around 0.1 W (average 0.11W). It is interesting to note that most of the devices registered under Energy Star perform much better than the maximum allowed threshold under Energy Star (0.3 Watts) and, even more considering the applicable threshold under the European Stand-by regulation (0.5 Watts). Moreover, according to the data collected, the off-mode performance seems to be not affected by the device features and performance.

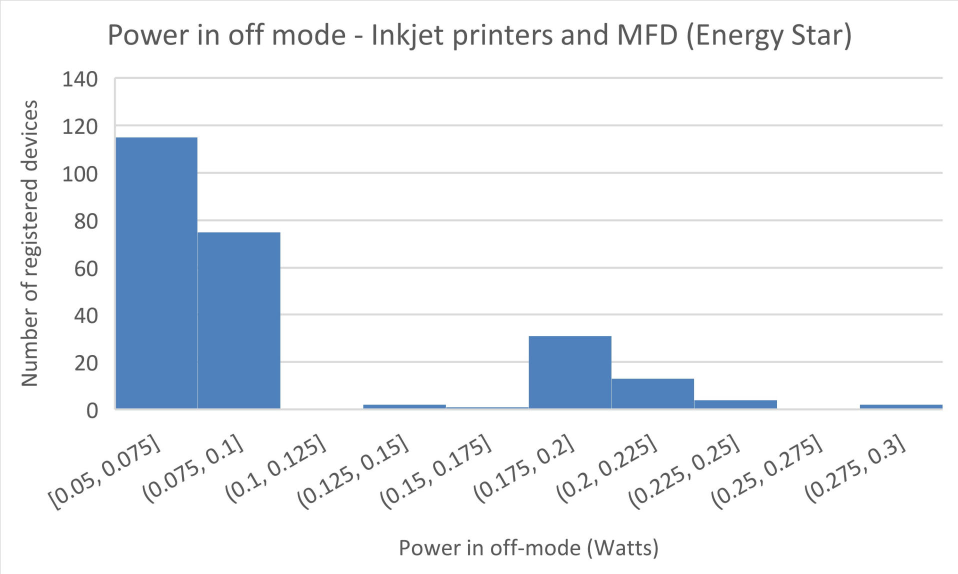


Figure 27: Power in off mode (W) for inkjet printers and MFD registered under Energy Star
Source: JRC, based on data from Energy Star database

According to the data from the Energy Star Database the average Sleep Mode Power for Standard Inkjet devices is 1,1 W (SEQ Figure * ARABIC). Printing speed and other functionalities seems to have relatively low impacts on the sleep mode energy consumption. The Energy Star thresholds for Sleep Mode is calculated as the sum of base allowance for the marking engine (e.g. 1,1 W for inkjet multifunctional devices) plus additional allowances based on features and performance. (e.g. additional 2,0 W in case of Bluetooth connection and 0.1W in case of wireless IR connection). Under the Standby regulation a 2,00 W threshold in standby mode of networked equipment applies to this product.

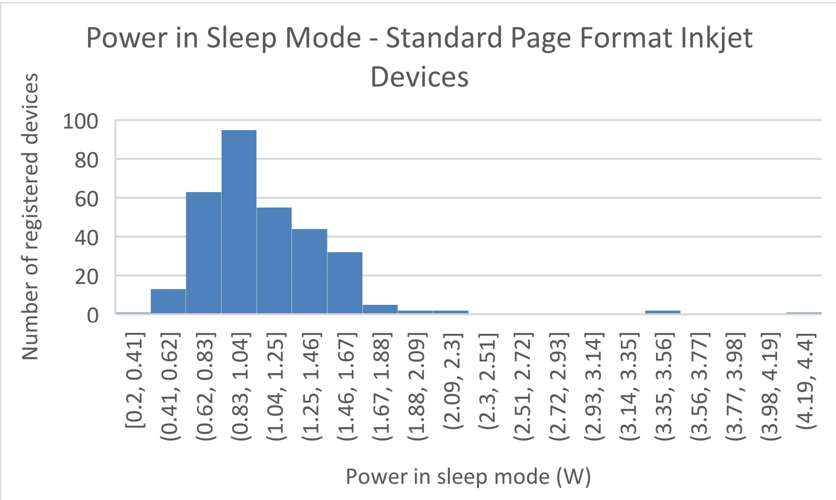


Figure 28: Power in sleep mode for Standard Page format Inkjet printers and MFD

Source: JRC, based on data from Energy Star database

Nevertheless, as showed in Figure 29, Large Page Format[17] Inkjet devices, not included in the scope of this study, are characterised by an average energy consumption in sleep mode equal to 2.0 W, with some device up to 7 W. Large format printers are also exempted by the application of the 2.00 W threshold under the Standby regulation.

[17] According to Energy Star, products designed for A2 media and larger, including those designed to accommodate continuous form media greater than or equal to 406 mm wide. Large-format products may also be capable of printing on standard-size or small-format media.

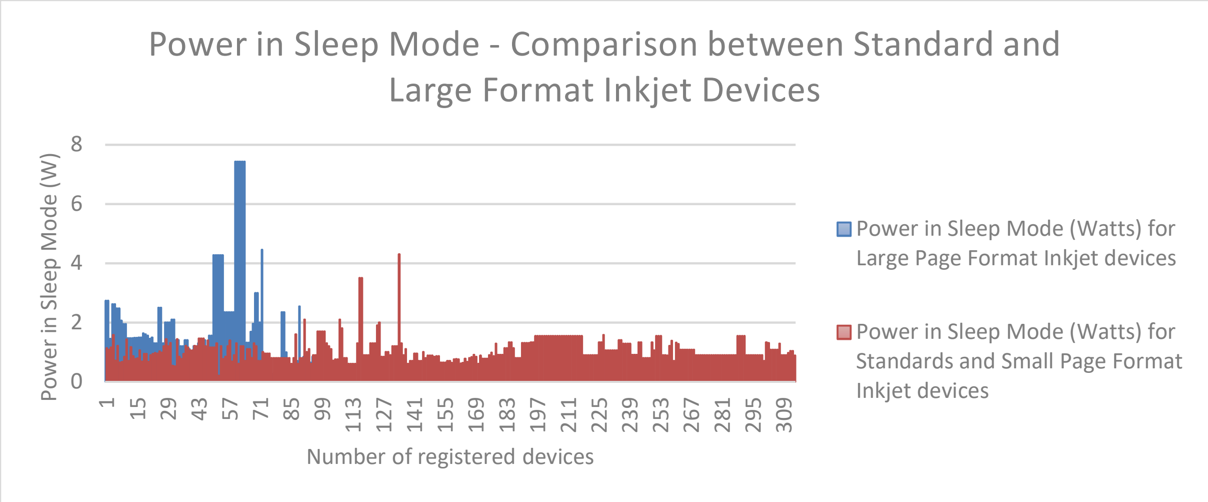


Figure 29: Power in sleep mode for standard and large page inkjet devices registered under Energy Star.

Source: JRC, based on data from Energy Star database

Another important parameter affecting the energy consumption of imaging equipment is the default transition time from active-ready/mode to sleep mode (also called default time to sleep). This functionality is very relevant for the consumer IEs, considering that these devices for most of time are not in operational status. Analysing the Energy Star data base, it was found that most of the IJ and EP have a transition to sleep modes. For both categories of products the time to sleep can vary from model to model. The most common transition to sleep period is 1 minute, other typical transition periods are 5-10-15 or 30 minutes (Figure 30).

The required default delay times to enter sleep mode for MFDs and printers defined in ENERGY STAR v3.0 specification vary between 5 and 45 minutes depending on product type and printing speed. It has to be noted that according to the Standby Regulation a power management function, or a similar function, shall be available for all network ports of the networked equipment. The default period of time after which the power management function, or a similar function, switches the equipment automatically into a condition providing networked standby shall not exceed 20 minutes. Moreover, information on this default time to standby shall be available on the manufacturer website together with the power consumption in networked standby.

Energy Star defines also maximum delay times the user can adjust either 60 or 120 minutes also depending on product type. The difference between these two requirements can be up to 75 minutes, showing the user can significantly prolong the default delay time and keep power consumption levels higher.

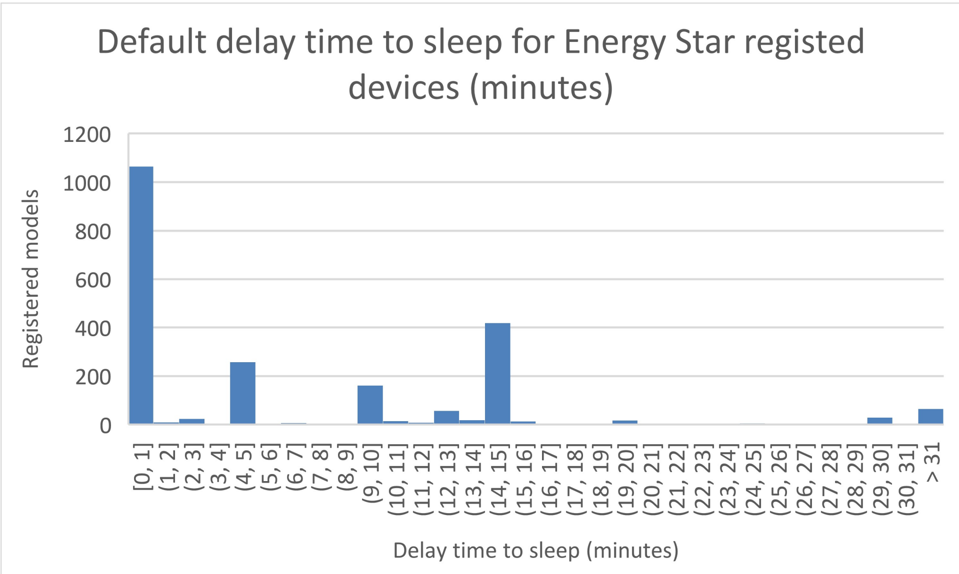


Figure 30: Default delay time to Sleep for Energy Star devices with delay time to sleep functionality.
Source: JRC, based on data from Energy Star database

Energy Star methodologies for energy performance evaluation of electrographic devices are based on a more complex methodological approach that considers also the active states (ready state and active printing). The result of the evaluation is a “Typical Energy Consumption (TEC)” in kWh/week for the device. Figure 31 presents data of TEC for Energy Star registered devices with the following specifications:

- Electro-photographic printers
- Multi-functional devices
- Printing speed between 20 and 40 images per minute.

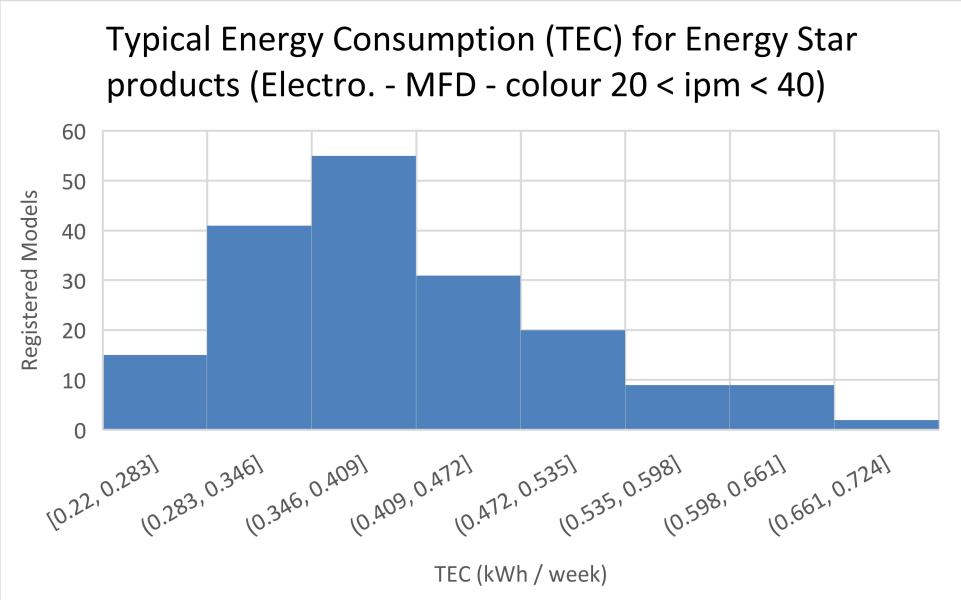


Figure 31: Typical Energy Consumption for non-professional electroph. - Colour - MFD – 20<ipm<40 registered under Energy Star. JRC data elaboration from the Energy Star Database (September 2022)

Energy Star performance statistic from the Energy Star database are summarised in Table 34 below and can be taken as reference for setting base cases and evaluating improvement potentials. Compared to the data on energy performance from Huang et al (2019) it can be seen that the values of TEC are now much lower than the previous study (as example average TEC for devices in the 20-40 ipm decreased from more than 60 kwh/week to 40 kWh/week) . The main reason is the change in TEC calculation method between ENERGY STAR v.2.0 and v3.0. In revising from v2.0 to v3.0 ENERGY STAR made a significant change to the TEC equation, reducing the number of pages printed during the test by a factor of four. As a result, v2.0 and v3.0 TEC values are not comparable.

Table 34: Average energy efficiency performance for different categories of devices.
Source: JRC elaboration of raw from the Energy Star Database (September 2022).

Technology					Average Energy / Power				Transition to sleep (minutes)
Imaging Equipment Type	Prof.	Marking Tech.	Page Format	Product Speed (ipm)*	Average TEC (kWh/week)	BAT (best 10% (kWh/week)	Average Sleep Mode Power (W)	Average Off Mode Power (W)	Default Delay Time to Sleep (minutes)
MFD	No	EP	Standard	20- 40	0,41				4,38

MFD	No	EP	Standar d	28- 32	0,39	0,34			3,52
MFD	No	EP	Standar d	40 - 60	0,65				4,97
MFD	No	EP	Standar d	48 - 52	0,69	0,60			6,84
MFD	No	EP	Standar d	60 - 80	1,34				7,71
MFD	No	EP	Standar d	70 - 72	1,12	0,92			7,40
Printer	No	EP	Standar d	20 - 40	0,39				4,88
Printer	No	EP	Standar d	28 - 32	0,37				3,52
MFD	No	Inkjet	Standar d	20 - 40			1,10	0,10	7,35
Printer	No	Inkjet	Standar d	20 - 40			1,02	0,15	5,00

4.4.1.1 Overall energy consumption

As showed in previous studies (Huang et al. 2019; Öko-Institut and Fraunhofer IZM, 2007) laser printers spend most of their time in standby or off mode and spent very little time in active state (i.e. performing jobs) at households but also at offices (Figure 32).

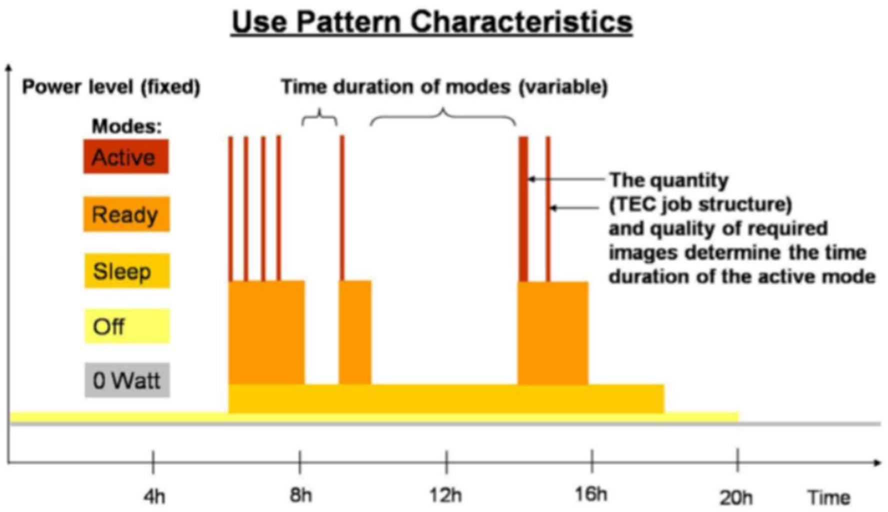


Figure 32: Schematic description of use pattern factors during the course of a day

The example in the table below, although quite anecdotic and based on the power specification of a single device[18] and assumptions on time duration of modes, aims to highlight where the main saving opportunities are. In particular, it shows the important power gaps between the ready state mode (85W) and the sleep (16.8W) and deep sleep (1.1W). In this context, ensuring a short delay time to sleep can save a relevant quantity of energy with a relatively low impact on the printing performance. The main reasons for the relative high consumption in ready mode are the display units kept on and the fusing unit kept ready at high temperature (through the fusing unit heater).

Table 35: Example of power and energy consumption in different modes for a laser printer

	Small Office device – Laser Printer						
		Power		Time		Energy Consumption	
ACTIVE MODES	Printing	770	W	0.40	hours	308	Wh/week
	Printing in quiet mode19	430	W	0.20	hours	86	Wh/week
	Ready	85	W	1.40	hours	119	Wh/week
STANDBY MODE	Sleep	16.8	W	6.00	hours	100.8	Wh/week
	Deep Sleep (standby mode)	1.1	W	60.00	hours	66	Wh/week
OFF MODE	Power Off	0.04	W	100.00	hours	4	Wh/week
TOTAL	Total			168.00	hours	683.8	Wh/week
	Reference Energy Star TEC	0.687 kWh/Week		Total Modelled Energy Consumption		0.686 kWh/Week kWh/week	

The example in Table 36 shows how, on the contrary, the power use (and energy consumption) in use/ready mode is less relevant for inkjet devices, characterised by a less energy intensive process. Energy consumption for inkjet printers seems to be mostly related to the energy consumption in sleep mode. As above, the example is based on the specific power configurations of a device placed on the market[20] .

Table 36: Example of power and energy consumption in different modes for an inkjet printer

EPSON EcoTank L1250	Inkjet consumer printer				
	Power		Time	Energy Consumption	
PRINTING (ISO/IEC24712)	12	W	30 minutes	9.5	Wh/week
Ready	3	W	4,5 hours	13.5	Wh/week
SLEEP	0.7	W	114 hours	79.8	Wh/week
OFF MODE	0.2	W	48 hours	9.6	Wh/week

[18] https://www.brother.ee/printers/laser-printers/mfc-l9670cdn#specifications

[19] Printing in quiet mode reduce the power demand but increase the printing time. It is unclear if the quiet mode can provide relevant benefits from energy efficiency performance. Otherwise to be still considered from acoustic performance point of view.

[20] https://www.epson.eu/en_EU/products/printers/inkjet/consumer/ecotank-l1250/p/30220

TOTAL			168 hours	112.4	Wh/week
				0.1124	kWh/week

4.4.2 Printing speed

Printing speed is generally measured as the amount of images that a device can print in a minute. Printing speed is related with energy consumption of the devices. In this section, an analysis of the printing speed of devices registered in the Energy Star database is conducted. This analysis includes both printers and multifunction printers, for EP and IJ marking technologies.

Figure 33 shows the number of models, in intervals of 10 images per minute (ipm), for EP devices registered under Energy Star. The range of printing speeds in EP devices is wide, from less than 20 ipm to more than 100 ipm. Most of the devices range between 20 ipm to 50 ipm. The most common category is the one between 30-40 ipm. Average printing speed of EP devices is 45 ipm.

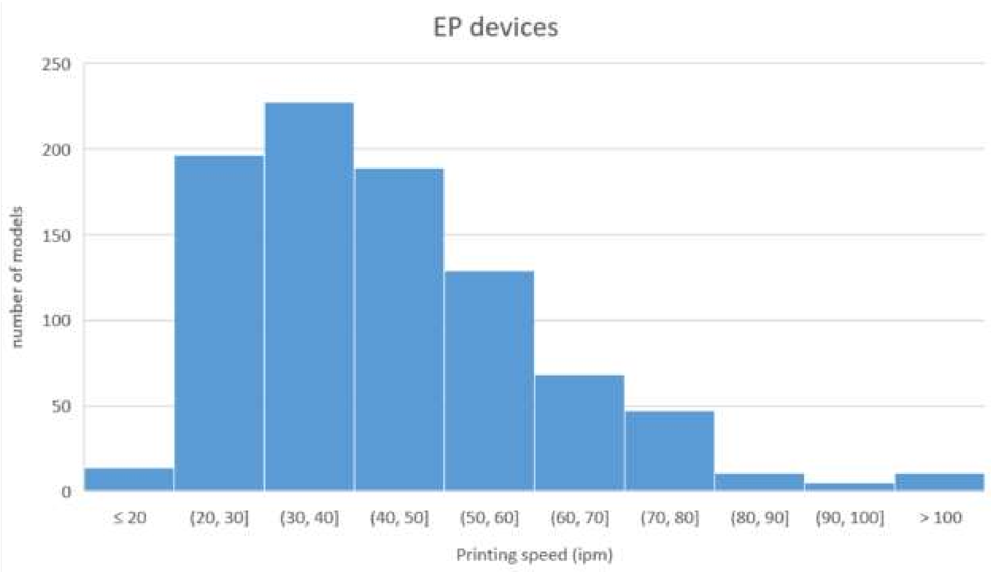


Figure 33. Printing speed of electrophotographic devices

Source: JRC elaboration of raw from the Energy Star Database (September 2022).

Figure 34 shows the number of models, in intervals of 5 images per minute (ipm), for IJ devices. The range of printing speeds in IJ devices is narrow, from less than 5 ipm to less than 40 ipm. Most of the devices range between 5 ipm to 25 ipm. The most common category is the one between 5-10 ipm. Average printing speed of IJ devices is 14 ipm.

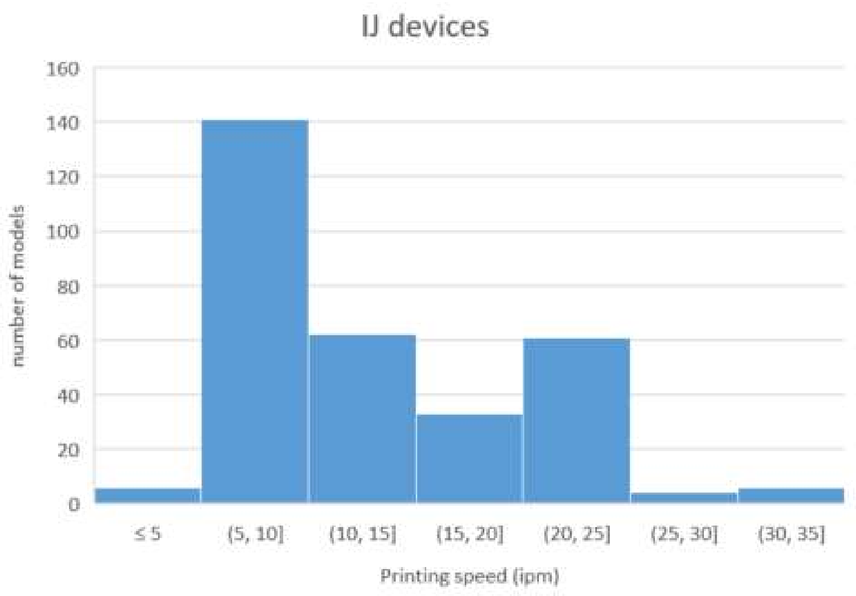


Figure 34. Printing speed of inkjet devices
Source: JRC elaboration of raw from the Energy Star Database (September 2022).

The differences in printing speed between EP printers and IJ printers explain why each of these devices are used in different applications. The highest speeds required in offices make EP printers more suitable for those environments. The range of speeds in EP printers (from 20 to 140 ipm) shows the wider availability of EP printers in terms of performance.

Figure 34 shows the relation between printing speed and energy consumption (measured as TEC in kWh/week) in EP devices.

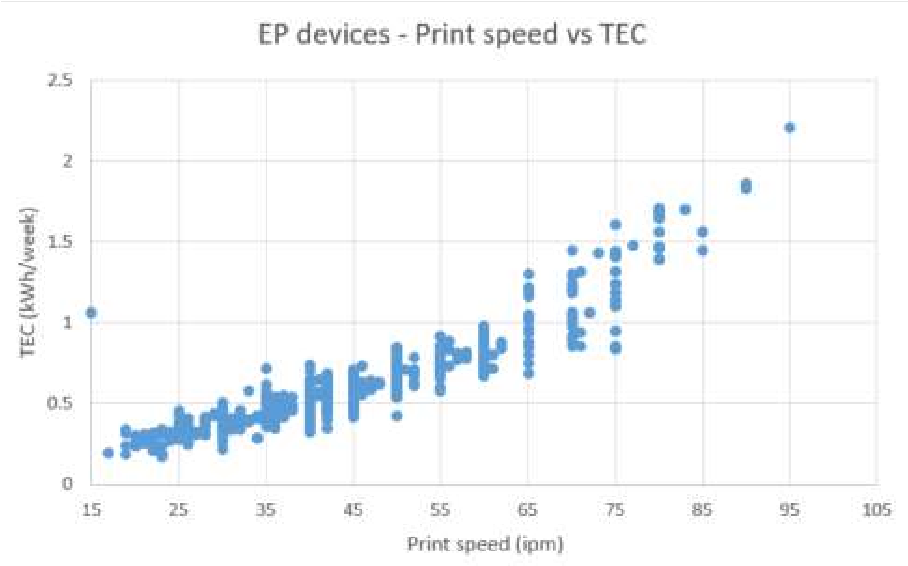


Figure 35. Printing speed and energy consumption of EP devices
Source: JRC elaboration of raw from the Energy Star Database (September 2022).

There is a clear correlation between printing speed and energy consumption of EP devices. Devices with higher printing speed have a higher energy consumption.

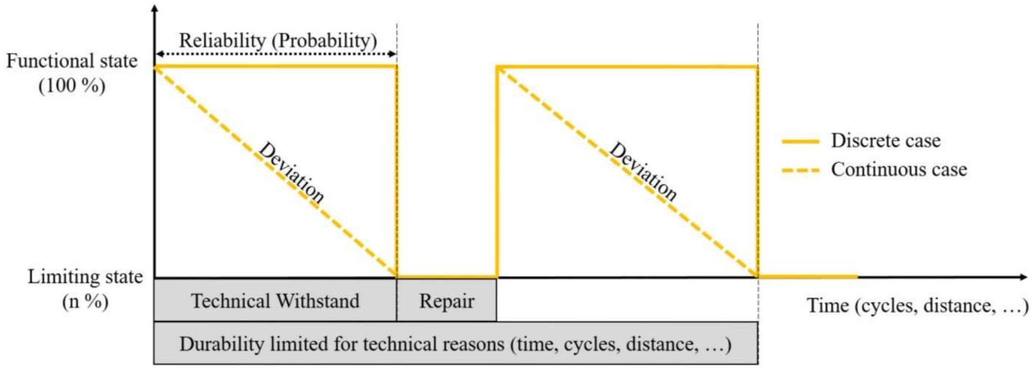
4.4.3 Device lifetime

Improving the material efficiency of products has the potential of bringing benefits to the environment, by saving resources and by avoiding the production of waste. According to estimates in Oldyrevas (2021), half a million tonnes of electronic waste is produced from discarded imaging equipment in the EU every year, with just over 10 thousand tonnes subsequently reused in new products.

Material efficiency of ICT products can be improved ensuring that products are designed to be reliable and durable. Reliability is defined as the probability that a product (or a part) functions as required, under given conditions (EN45552:2020). Reliability and durability convey similar concepts but have different meanings. At the simplest level, reliability and durability are both concerned with the ability to function as required under certain conditions until a limiting state is reached. Both reliability and durability expect that maintenance will be undertaken as applicable to the product (by the user/a professional service provider), to retain the product in a condition where it is able to function as required. However durability includes also the possibility of extending the use-phase by one or multiple repairs, potentially involving different parts, to return the product to a functional state.

Repair has been defined as the process of returning a faulty product to a condition where it can fulfil its intended use. Therefore, reparability can be understood as the ability of a device to be repaired.

It is important to note that the reliability and durability issues can be due to events by which the functional state immediately drops, or progressively degrades to a limiting state as described in Figure 36.



Source: Adapted from EN 45552:2020. Cordella et al. 2021

Figure 36. Relationship between reliability, repair and durability

A product can function as required, under defined conditions of use, maintenance and repair, until a limiting state is reached. A limiting state is reached when one or more required functions/sub-functions are no longer delivered (Alfieri et al 2018a). The limiting state could either be due to technical failure and/or other socio-economic conditions, so that the lifetime of a product can be differentiated between (European Environmental Agency 2017):

- Technical lifetime, which is the time span or number of usage cycles for which a product is considered to function as required, under defined conditions of use, until a first failure occurs
- Functional lifetime, which is the time a product is used until the requirements of the user are no longer met, due to the economics of operation, maintenance and repair or obsolescence.

Printers are products were the difference between technical lifetime and functional lifetime is significant, due to prevalent business models. Domestic printers –generally inkjet devices- are products usually not subject to significant stress in terms of frequency of use and are not placed in hostile environments, so they can technically last for a considerable number of years. However, according to HOP (2017), it is considered that the average lifetime of an inkjet printer is around 3 years (a period which could be increased 2 additional years if reparability was adequately promoted). Similar conclusions are made in ADEME (2019), where the authors consider that the potential lifetime of a printer is 6 years. Their hypothesis is that lifetime of printers is generally not fulfilled. The authors consider that the dates of onset of the failure or perceived obsolescence by the consumer is between 2-3 years.

Printers in the business sector –generally laser devices- are usually devices with higher performance and value and subject to more intense frequency of use. Therefore they are generally designed to last longer and withstand tougher conditions. The disparity between technical and functional lifetime in the business sector seems to be related to the early replacement of devices before technical lifetime of devices is reached. Usually, when MPS contracts end, the whole fleet of devices installed is replaced with new devices, without considering the available lifetime of the installed devices. More detail is provided on these topics in the sections ahead.

4.4.3.1 Device lifetime in the business sector

Technical lifetime of devices in the business sector is often not fulfilled due to short replacement cycles promoted by prevalent business models, based on feedback from stakeholders. Data gathered during interviews with device refurbishers, plant visits and stakeholder communication indicates that:

- Average lifetime of devices collected at the end of their use in the business sector is between 4 and 6 years. The estimated remaining lifetime of devices is:

  -4 year-old devices: 85% remaining lifetime in terms of printed pages

  -5 year-old devices: 75% remaining lifetime in terms of printed pages

  -6 year-old devices: 60% remaining lifetime in terms of printed pages

- In the public sector, remaining lifetime of collected devices tends to be lower (around 20% in terms of remained printed pages) because they are used for longer periods (up to 10 years).
- In organisations with large budgets, devices are replaced every 3-4 years, usually when MPS contracts expire.

During the development of this Preparatory Study, a provider of monitoring software for MPS in the printing sector (Nubeprint) shared data regarding the age of printers in active contracts:

- Almost 75% of printers in active contracts have an age of 2 years or less, whereas only 6% have an age of 4 years or more (Figure 37). The low average age of printers under MPS contracts also suggests that replacement cycles are usually short.
- Average printed pages in a 36 months period is 100.000.

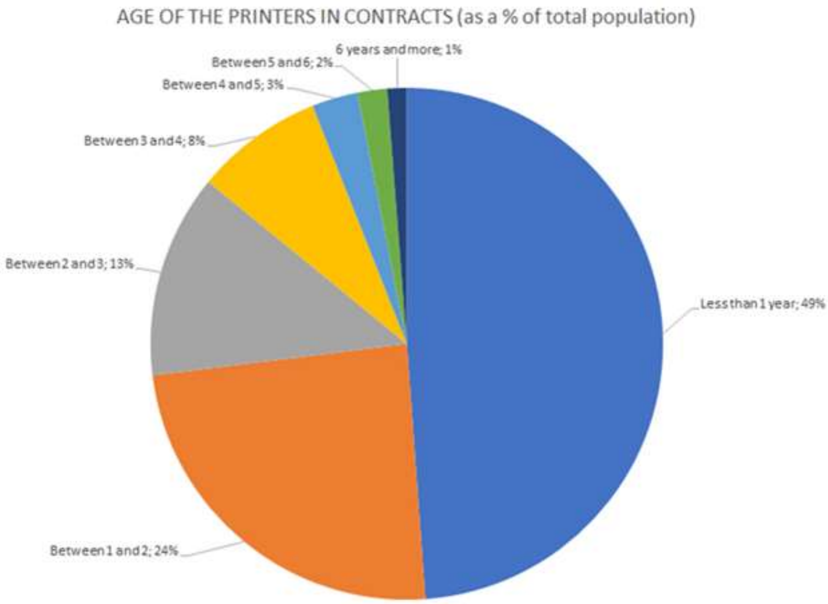
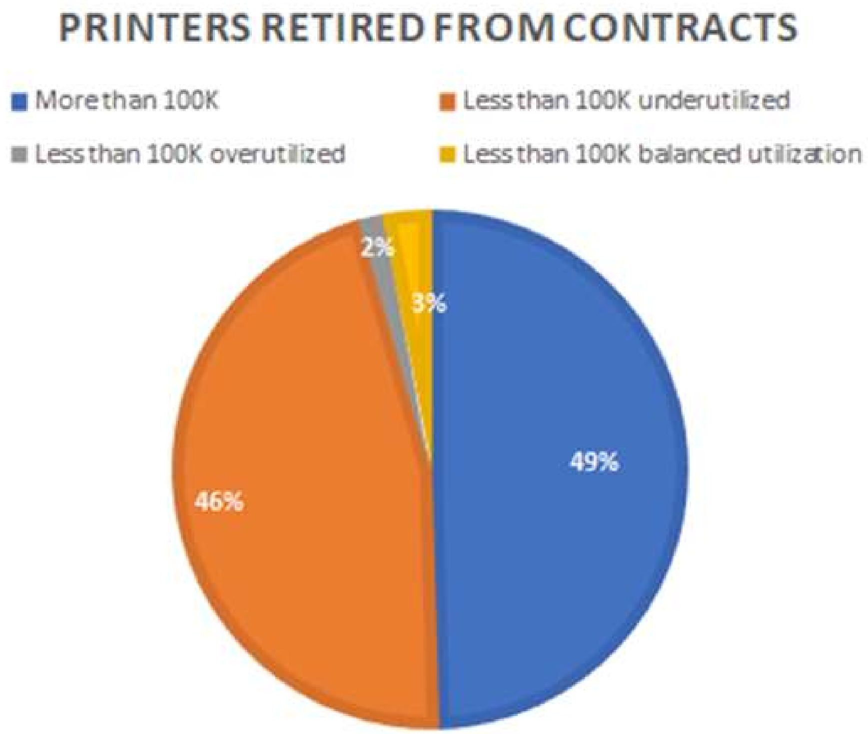


Figure 37. Age of printers in active MPS contracts
Source: Nubeprint

- Almost 100% of the devices in the market do not fulfil their technical lifetime. Around 50% of printers under MPS contracts are retired with less than 100.000 pages printed. Most of them (46% of total sample shared by a stakeholder) were underutilized in terms of their regular activity (Figure 38).



Source: Nubeprint
Figure 38. Printers retired from active contracts

Interview with stakeholders in the refurbishing sector have highlighted that:

- Assemblies and key components such as fusers, transfer units or drums often have 70% of remaining lifetime when they are discarded.
- In terms of the capacity of the refurbishing process to increase device lifetime, it can be estimated that a 4-year old device with 85% of remaining lifetime can be refurbished up to its initial conditions. A device can be refurbished up to 3 times. Its technical lifetime can be estimated between 12-14 years.
- Regarding the introduction of new product models in the market, before the supply crisis caused by COVID19, OEMs used to launch new product models every 2-3 years, with the same engines and minor updates. Currently, average age of devices is around 4 years.
- The demand of refurbished printers is higher than the supply. A small percentage of printers placed on the market is refurbished when MPS contracts end. There is no data available on the destination of printers replaced but not refurbished.

The data above indicate that a relevant share of devices used in the office environment are replaced before 100,000 pages. Most of these devices are underutilised during their life. Huang et al. (2019) estimated the average lifetime in terms of printed pages for laser MFD is 350,000 pages for monochrome and 576,000 for colour laser, with lower numbers of printed pages for laser printers: 53,000 for monochrome device and 120,000 for colour. However a huge drop in printed pages/images occurred during the COVID crisis (almost 50% during the 2020 and 2021) and printed pages are not expected to recover to the pre-covid level (Keypoint Intelligence, 2023). Data collected seem to suggest that many of the devices reaching the end of life in the next few years will be devices underutilised compared to their designed duty cycle. Based on the current market situation it can be reasonably estimated that in a base-case scenario devices in office environment will print around 200,000 pages in a 6 years lifetime.

4.4.3.2 Device lifetime in the domestic sector

The analysis of the results from the user behaviour are used in this section to characterize define lifetime in the domestic sector. In contrast with data published in HOP (2017) and ADEME (2019) –where lifetime of devices was estimated between 2-3 years-, data gathered in the survey conducted as part of Task 3 suggests that most of single-function printers in use today are between 3 and 5 years old (32%). A significant percentage have been used for less than 3 years (28%). A very similar proportion of single-function printers have been used between 5-10 years (28%). Less than 10% of single-function printers have been used for more than 10 years.

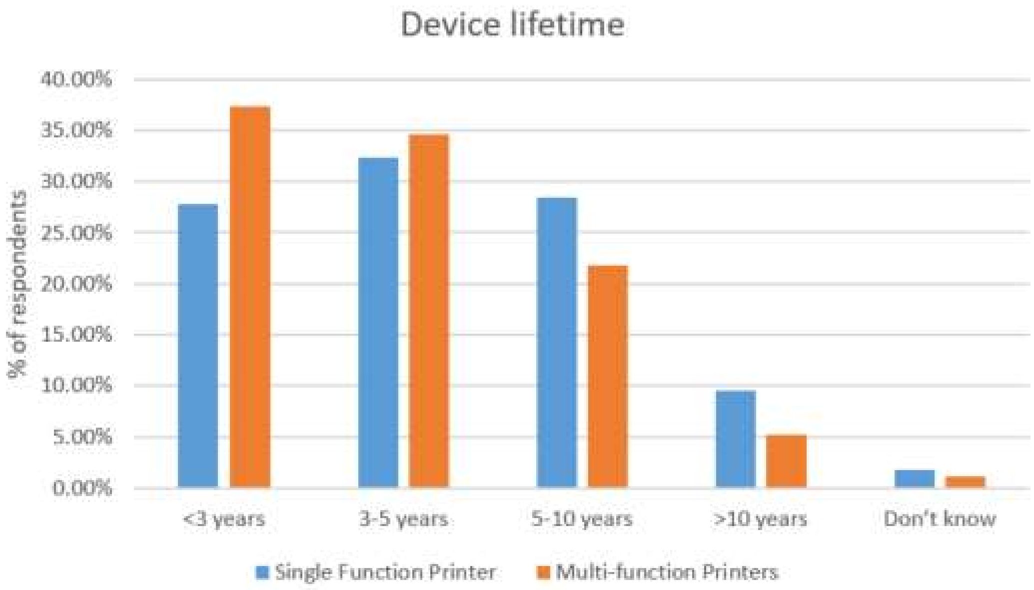


Figure 39. Device lifetime in the domestic sector based on user behaviour survey

In terms of multi-function printers, most of them (37%) have less than 3 years, whereas 35% are between 3 and 5 years old. Around 5% of multi-function printers have been in use for more than 10 years.

Real device lifetime presented in Figure 39 can be compared with expected device lifetime shown in Figure 40. Most of users of single-function and multi-function printers intend to use their device between 5-10 years before they buy a new one (around 33% of respondents). Between 25-30% of respondents intend to use their device between 3-5 years, whereas 15% of them intend to use it for more than 10 years.

Data from Open Repair Alliance (2021) seem to confirm in some way the longer lifetime expectation, at least for the part of consumers that is also willing to repair. Over 74% of the printers brought for repair were at least 4-year-old, 46% were in between 5 to 10-year-old and 17% were older 10-year.

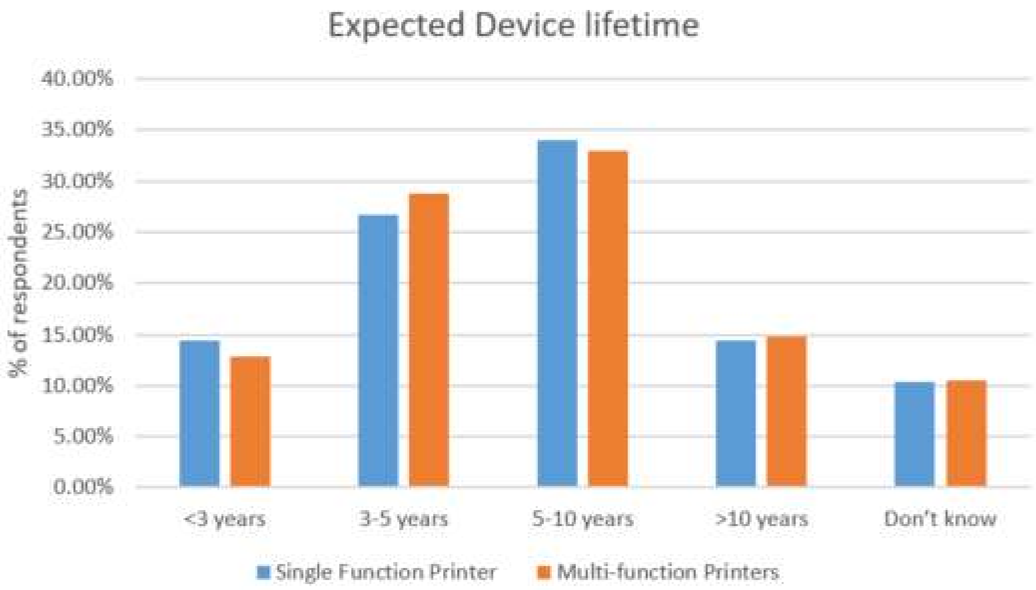


Figure 40. Expected device lifetime in the domestic sector based on user behaviour study

4.4.3.3 Measuring device lifetime

The lifetime of electronic devices is usually expressed in years. However, in the case of printers this is not the only relevant parameter. Since their use is rather discontinuous, the same printer may last a very different amount of years depending on the intensity of use. For printers there are other parameters that are relevant to describe lifetime:

The total number of printed pages. Lifetime of the device will be directly affected by the intensity of use in terms of printed pages. Manufacturers usually provide information on the recommended and maximum frequency of use in terms of printed pages (duty cycle).

However, during the 1st Technical Working Group Meeting, a stakeholder highlighted that currently there is a lack of common definition among manufacturers on how the device counter counts the number of printed pages. This makes lifetime comparisons between different models not possible. This phenomenon (having different definitions of what 1 printed page is) is relatively recent. They recommend the development of a standard for measuring number of printed pages.

Engine cycles. This parameter is suggested by the same stakeholder as a valid substitute to measure printer lifetime instead of total number of printed pages. The engine cycle counter still exists in all printers (although in the most recent ones the manufacturer hides it by relegating it to an "internal" use). In some OEMs it is known as “service counter”. Manufacturers set maintenance policies based on engine cycles.

4.4.4 Offline use of devices

As indicated by some stakeholders, some devices are currently designed in way that intended to print only if connected to the internet network. These devices make use software updates (dynamic security measures) to block cartridges using non-OEM new or remanufactured. Periodic firmware updates enabled by the internet connection can ensure to maintain the effectiveness of these OEM measures and block cartridges.

Although the OEM carrying out this practice justify this measure as a protection against cloned or counterfeited cartridges, it can negatively impact legal remanufacturing practices carried out by independent operators and reduce opportunities for circularity and also in terms of energy consumption of the devices.

4.4.5 Device reparability

Waste streams can be reduced by extending the service life of devices by repair. As a general rule, repair is more material efficient than recycling and has positive effects at local level for jobs and value creation (Ritthoff et al, 2023).

Data provided by Open Repair Alliance (2021), based on the analysis of over 800 repairs of consumer printers at community repair events, provide some initial basis in terms of most common failures in printers. It has to be not that data from community repairs events could represent only a proxy and not able to fully reflect the real distribution of failure events, due to the following reasons: some types of failure are not easy to be identified and could fall in wide categories as “software” or “other failures”. Moreover some failures tend to occur in later stage in the product lifetime (e.g. ink/toner collection unit) when the willingness to repair could be lower and the OEM could most of time decide for the replacement without attempting any repair.

Table 37: Statistic on consumer printers failures. Source: Open Repair Alliance

Failure type	Percentage of total failures evaluated
Paper feed	25%
Ink cartridge	17.5%
Printhead cleaning	9.6%
Power supply/connectors	7.4%
Printhead failure	6.1%

Software	5.9%
Print quality	5.9%
Internal damage	5.5%
Paper output	5.3%
Scanner	2.6%
Other failures	9%

Other insightful information from this study (Open Repair Alliance, 2021) includes the following:

- Over 74% of the printers brought for repair were at least 4-year-old, 46% were in between 5 to 10-year-old and 17% were older 10-year.
- Faults seen at repair events highlight the need for access to many spare parts: Power supply/connectors (7.4% of all faults), Printhead failure 6.1%, internal damage 5.5%, paper output 5.3%
- Frequent problems related to printhead cleaning (9.6%) were identified. The repair success rate for this cause of failure was only 58%.

In the following sections, several aspects affecting the reparability of printers will be discussed.

4.4.5.1 Priority parts for repair

The design of imaging equipment can affect the ability to maintain its functional state but also the ability to maintain and repair the device and fulfil the expected lifetime. In this context, priority parts are those that typically fail during the normal use of a product. Therefore, priority parts are usually those targeted to be provided as spare parts by environmental schemes. In this section, a review of priority part lists in different schemes is presented.

In their proposal of a reviewed Voluntary Agreement, Eurovaprint (2021) identified the list of replaceable spare parts presented in Table 38.

Table 38. Priority parts in Eurovaprint (2021)

Priority parts identified in Eurovaprint (2021)	Hard disc drives (HDD) Solid state drives (SSD) Print heads Laser unit Fuser unit Drum unit Transfer belts Roller kits Internal power supplies Control circuit boards External power supplies Control panels including electronic displays Toner collection unit Ink collection unit

	Power cords and cables.

The EU GPP Criteria (Kaps et al. 2020) also identified a list of priority parts, divided between core level (minimum compliance) and comprehensive level (Table 39).

Table 39. Priority part in Kaps et al (2020)

	Core level	Comprehensive level
Priority parts identified in Kaps et al (2020)	Print heads Laser unit Fuser unit Drum unit	Print heads Laser unit Fuser unit Drum unit Scanning unit Transfer belts/kits Maintenance kits Paper feed components Density sensors Power and control circuit boards Cartridge/container attachment components External power supplies Hinges

Blue Angel (Blue Angel, 2021) provides a list of spare parts (Table 40) and classifies them by technology (inkjet vs electro-photographic devices) and by target group (to consumers and to professional repairers).

Table 40. Priority parts in Blue Angel (2021)

	For consumers	For professional repairers
Electro-photographic devices	Excess toner reservoir Paper cassettes External power supply / power cable	Storage Devices (HDD and SDD) Laser unit Drum unit Fuser unit Transfer belts, kits Toner collection unit Roller kits, paper feed rollers Control circuit boards Internal power supplies Control panel Maintenance kit
Inkjet devices	Excess ink reservoirs incl. ink sponges Print head (not integrated into the ink cartridge)	Storage Devices (HDD and SDD) Roller kits, paper feed rollers Print head (not integrated into the ink cartridges)

	Paper cassettes External power supplies/power cable	External power supplies / power cables Control circuit boards Control panel Ink collection tank / excess ink reservoirs

In their study “Methods and standards for assessing the reparability of electrical and electronic devices”, Ritthoff et al (2023) proposed a methodology to assess how reparable electrical and electronic devices are. To test the methodology, the authors conducted a comprehensive analysis of aspects affecting the reparability of inkjet and laser printers. This analysis was conducted on 6 inkjet printers and 4 laser printers. Although the sample of devices is small, their results can provide useful information on the current status of device reparability. In Ritthoff et al (2023), a list of priority parts is proposed, differentiating between inkjet and laser devices (Table 41).

Table 41. Priority parts in Ritthoff et al (2023)

Inkjet devices	Laser devices
Print head Internal power supply External power supply Sheet feeder Ink sponge	Drive motor paper transport Main memory Feed rollers Fuser unit Laser unit Paper tray Separation rollers Control board/display Internal power supply External poser supply Transfer belt Transfer unit Drum unit Closing lid

Although the terminology used in the presented schemes may be different, some priority parts are common in most of them, which may indicate they have a particular relevance in terms or printer reparability. The most common priority parts in the lists described above are:

- Print heads
- Internal and external power supplies, power cables
- Laser unit
- Fuser unit
- Power and control circuit boards
- Transfer belt
- Drum unit
- Storage devices
- Sheet feeders, paper trays and rollers

- Toner and ink collection units and sponges

The relevance of some of this priority parts is described in more detail in this section.

Toner and ink collection units

The toner collection unit (also called excess toner reservoir) is a container aiming to collect waste toner during printing. This collection unit may have a sensor that halts the printing processes on the machine once it is full. Alternatively the waste toner level is estimated by the device based on the number of printing/maintenance operations. After a specified threshold, the printer stops to avoid damages if toner were to get into the main body of the device. At that point, collection units needs to be emptied or replaced to bring the device back to the functional state.

Inkjet printers need to manage a similar issue for waste ink. They have collection units or ink pads designed to collect any residual ink from the print-heads. Similarly to what happens in toner devices, a sensor monitors the status of the deposit or is estimated based on its use. After a specific threshold, the device halts the printing processes when the waste ink collection unit is full (or estimated to be full). Again, this is to avoid damaging the device if ink were to get into the main body of the printer. The collection units needs to be emptied or replaced to bring the device back to the functional state.

In some cases, waste collection units are designed for a single use. According to an OEM, emptying and reusing the waste collection unit could lead to toner or ink being spilled inside the product, which could result in reduced print quality[24]. An additional reason provided by OEMs is that recommending to return the waste toner to the manufacturer for proper recycling prevents the toner from being improperly deposited in the waste stream (as opposed to the customer emptying the toner in the trash and reusing the container).

Ensuring an easy access and replacement to waste collection units (together with availability as a spare part) may enhance the reparability of printers. No data has been found in a few aspects related to waste collection units that may be relevant for reparability:

- There is no information in terms of how the estimation of waste collection unit level of fill is conducted, and it is likely that there are differences between OEMs.
- Minimum waste collection unit capacities based on printing capabilities or speed are not available
- Maintenance instructions for users once the waste collection unit is full have not been found.
- It is unclear whether reset functionality is available for users after replacing the waste collection unit (including information about price).

Inkjet Print heads

There are two main design philosophies in inkjet printhead design: fixed-head and disposable head. The fixed-head design provides an inbuilt print head within the device that is designed to last for the life of the printer. The printhead does not need to be replaced every time the cartridge runs out of ink. In contrast, the disposable head design uses a print head which is supplied as a part of a replaceable ink cartridge (Figure 41).

Figure 41. Printhead assembly in integrated cartridge

[24] https://support.hp.com/lt-en/product/hp-laserjet-enterprise-500-color-printer-m551-series/4184772/document/c03039384 and https://support.hp.com/id-en/document/c05075065

Every time a cartridge is exhausted, the entire cartridge and print head are replaced with a new one (integrated ink cartridge). Fixed print-head designs are available in consumer products, but are more likely to be found on professional, high-end printers and large format printers.

Each has its own strengths and weaknesses from reparability point of view. Fixed print head can reduce the generation of waste due to cartridges replacement. On the other hand, if a fixed head is damaged and cannot be repaired, the whole printer will needed to be replaced.

Drum unit

The drum unit is an end-user replaceable component, which fits into an imaging equipment product and which includes a photosensitive drum (i.e. electro-photographic printer). A drum unit can be incorporated with the toner cartridge or sold separately as a single unit.

Laser printers and their consumables vary across printer models. Some printers only need you to replace the toner cartridge, and others require that the user regularly replace both the toner cartridge and the drum unit. The drum can be provided as a separate consumable with a specific lifespan specification. Drums units are reported to be typically replaced after the use of 3-4 toners[25] (e.g. 12.000 pages).

Fuser unit

The fuser unit is an end-user replaceable component, which fits into an imaging equipment product and which consists of a pair of heated rollers that fuse toner onto output media. Fusers are reported to need replacement every 75,000 - 300,000 pages depending on the printer model[26]. Some OEMs report specific usage patterns that significantly reduce the life of the fuser unit. In particular:

- printing large numbers of transparencies or other specialty media;
- printing on unsupported paper or special media, such as paper or transparencies made specifically for inkjet printers;
- not setting the paper type correctly on the Control Panel as this causes the Fuser to be set at an incorrect temperature

Transfer unit

The transfer unit is an end-user replaceable component, which fits into an imaging equipment product, and which supports the transfer of toner onto output media ahead of a fusing process.

Some OEMs report the page yield after which a periodic replacement of the transfer belt is needed. Moreover, an OEM report use patterns that may significantly reduce the life of the transfer unit (e.g. printing jobs that are less than 4 pages; excessively opening and closing; frequently powering the printer off and on; printing on transparencies or other specialty media; performing automatic two-sided (duplex) printing; printing with high toner coverage).

4.4.5.2 Ease of disassembly of priority parts

One of the aspects that defines device reparability is the ease of disassembly. Quick and easy disassembly processes for priority parts help to enhance device reparability.

In Rithoff et al (2023), ease of disassembly of printers is measured using disassembly time as an indicator. The authors conducted disassembly operations on 6 inkjet printers and 4 laser printers. Time to reach access to priority parts was measured. Table 42 presents disassembly times for some priority parts in inkjet printers.

Table 42. Disassembly time in inkjet printers

Priority part	Disassembly time
Print head	0.33 - 90 min
Feed roller document feeder	1 - 3 min
Internal power supply unit	0.16 - 25 min

[25] https://www.ldproducts.com/blog/whats-the-difference-between-a-toner-cartridge-and-a-drum-unit/
[26] https://www.metrofuser.com/post/symptoms-of-bad-fuser

Ink sponge	0.5 - 27 min
Total disassembly of devices	8.5 - 118.5 min

Disassembly time of priority parts can differ greatly between inkjet devices. Print head removal was conducted in 20 seconds in one device (0.33 minutes) but required 90 minutes in another device. Similarly, internal power supply unit disassembly time ranged between 10 seconds and 25 minutes; or ink sponge (waste ink collection unit), between 30 seconds and 27 minutes.

Despite the low number of models tested, a correlation was found between total time needed and total number of fasteners. No correlation was found between disassembly time and purchase price.

Table 43 presents disassembly times for some priority parts in laser printers.

Table 43. Disassembly time in laser printers

Priority part	Disassembly time
Drum	0.16 - 1 min
Feed rollers document feeder	2.5 min
Transfer roll	1 min
Transfer unit	1.5 - 18 min
Paper tray	7 - 25 min
Closing lid	0.33 - 15 min
Laser unit	12 - 45 min
Transfer belt	11 - 20 min
Fuser unit	15 - 50 min
Internal power supply unit	9 - 22 min
Display and control board	1.5 - 25 min
Drive motor for paper feed	12 - 25 min
Total disassembly	72.5 - 137.5 min

Disassembly time of priority parts can differ greatly as well between laser devices. Transfer unit replacement ranges between 1.5 and 18 minutes. Laser unit ranges between 12 and 45 minutes. Fuser unit ranges between 15 and 50 minutes.

Despite the low number of models tested, a correlation was found between total time needed and total number of fasteners. In this case, a correlation was found between disassembly time and purchase price. The cheapest device presented the lowest (fastest) disassembly time. This might suggest that more complex (more difficult to disassembly) devices are generally more expensive.

These differences in disassembly time suggest that not all printers are designed with reparability in mind. Total disassembly of inkjet printers ranges between 8.5 minutes and nearly 2 hours, whereas for laser printers the rage is between 72 and 137 minutes. These large differences can play a significant role in the costumer decision of repairing a device.

4.4.5.3 Spare part provision

The first prerequisite for procuring spare parts is always that they can be clearly identified and matched to the correct printer model. According to the authors of Rithoff et al (2023), identifying the part that needs repair is often a challenging task today. The authors highlighted that the clear identification of spare parts depends on whether an exploded view is available that clearly shows the spare parts and their installation in the device. However, exploded views are not provided for every printer model today, hindering the ability for identifying necessary spare parts and therefore printer repair.

There are significant differences between OEMs in terms of availability of spare parts for printers. This availability can vary between a wide range of spare parts available for some printers and no parts at all for others (Rithoff et al, 2023). There seems to be a correlation between printer price and spare part availability, both for inkjet and laser printers (cheaper models provide less spare parts).

The duration of the availability of spare parts is also a relevant aspect. Is a spare part cannot be obtained any more after a short time the product has been placed on the market, this severely limits the reparability of devices. Currently, the duration of the availability of spare parts depends, among other things, on sales. Therefore, this duration can be flexible in time, without guarantee from the OEM, and changed by the manufacturer depending on market conditions (Rithoff et al, 2023). Therefore, it is not possible for consumers today to know for how long the availability of spare parts will be guaranteed for the model they purchase.

The delivery time of spare parts is also important. If spare parts are available but are only delivered after a long period, this influences consumer repair decisions. Delivery time of spare parts ranges between 1-2 days for ink and laser cartridges, 10-12 days for ink sponges, up to 8-10 weeks in some cases for laser printers.

The cost of spare parts can also have an influence on the repair decision by consumers. The authors Rithoff et al (2023) pointed out that in many cases, the prices of spare parts are in ranges that can prevent printer repairs. For instance, although most of the spare part prices for inkjet devices vary between 1-25% of the purchase price of the printer, in one model the print head price was 75% of the price of the device. Ink cartridges ranged between 2% and 25% of the initial price.

For laser devices, the cost of priority parts was even more significant. Drum units ranged between 14-43% of the initial price of the printer. Laser units between 24-57%. Fuser units between 51-79%. Internal power supplies between 38-86%.

Beyond the provision of spare parts, another aspect that can enhance printer reparability is the provision of relevant information for repair. Repair manuals can facilitate the repair of equipment and lead to cost and time savings. However, although OEMs tend to provide user manuals for printers, they contain little or no information on repair (Rithoff et al, 2023). Repair manuals may be obtained in some occasions from 3rd party suppliers. Error code tables are included in some cases, whereas in others the user needs to check the error code online.

4.4.5.4 Software and firmware updates

Users need to upgrade to newer operating systems for their computers periodically. Due to regular new versions of operating systems, this occurs regularly in practice. On occasions, this leads to printers not working. It can also happen that functional printers can no longer be used if the user buys a new computer with a new operating system. These cases are commonly known as software obsolescence.

Software obsolescence can be prevented with guaranteed availability of printer software and firmware (printer drivers). Many printer drivers can be downloaded free or charge from the OEM website. The authors of Rithoff et al (2023) highlighted that the general availability of drivers at the time of the case studies was good overall. However, for software and firmware it does not just matter if a driver is available for download on the internet for a number of years. It does matter that an offered driver will be updated for a number of years and will be compatible with operating systems that are newly placed on the market within this number of years. The authors of Rithoff et al (2023) observed that in the evaluated devices there are no guaranteed periods for which new operating systems are guaranteed to be covered. In some cases, printer drivers simply cannot be found. This lack of software availability can make operating printers unusable simply due to software incompatibility.

4.4.6 Emissions to air

The use of ink and toner may release harmful chemicals into the environment during the operation of imaging equipment, leading to adverse impacts on indoor air quality. Printers can release Volatile Organic Compounds (VOCs) partly generated by toners and inks that are subject to heating during the printing process, as well as particles of paper. Air emissions may include ozone, nitrogen oxides, VOCs, aldehydes, polycyclic aromatic compounds and ultrafine particles. The toner particles, which have mean aerodynamic diameter of 6–8 μm facilitate deep penetration into the human respiratory system (Kowalska et al, 2015).

Emissions of VOCs from printers have been reported in Lee et al (2001), Kagi et al (2007) and Destaillats et al (2008), among others. In Kaps et al (2020), it is reported that chamber concentrations of styrene, xylenes and ozone are increased in printing process of the laser printer, and pentanol is detected from the inkjet printer. The emission rates of laser printers were the highest and found to be about 6 times that of inkjet printers. In Kowalska et al (2015), test chamber studies indicated that operation of the office printer and copier would contribute to the significant concentration level of VOCs in typical office indoor air. Among the determined volatile halogenated compounds, only chlorinated organic compounds were identified, such as trichloroethylene –carcinogenic- and tetrachloroethylene -possibly carcinogenic to human.

Based on the potential to harm human health, different voluntary schemes provide maximum emission rates of different VOCs (Table 44).

Table 44. Air emissions rates in voluntary schemes

		Emission rates (mg/h)						
		TVOC	Benzene	Styrene	Unidentified single substances VOC	Ozone	Dust	Ultra-fine particles
Blue Angel (2021a)	Colour	18	<0.05	1.8	0.9	3.0	4.0	2023: $3.0*10^{11}$ 2025: $2.5*10^{11}$
	Monochrome	10	<0.05	1.0	0.9	1.5	4.0	2023: $3.0*10^{11}$ 2025: $2.5*10^{11}$
Nordic Ecolabelling	Colour	18	<0.05	1.8	0.9	3.0	4.0	n/c
	Monochrome	10	<0.05	1.0	0.9	1.5	4.0	n/c
EPEAT	Colour	18	<0.05	1.8	n/c	3.0	4.0	n/c
	Monochrome	10	<0.05	1.0	n/c	1.5	4.0	n/c

Similarly, the GPP Criteria for imaging equipment (Kaps et al, 2020) provide maximum emission rates for TVOC, benzene, styrene, unidentified single substances VOC, ozone, dust and PM10.

4.4.7 Paper use

The use of paper is one of the most relevant environmental hotspots throughout the life cycle of printers. The consumption of paper contributes significantly to the device's total consumption of resources.

To reduce the consumption of paper, a common approach in voluntary schemes has been the mandatory inclusion of duplex imaging capability, which is the ability of the device to print on both sides of paper. Including this capability by default in printers can help to reduce the total consumption of paper.

The VA already included targets for default duplexing to reduce printer paper consumption (even though not mandatory 100% of models on the market). The impact assessment estimated 0.23 Mt/a of printing paper saved in 2020 (Directorate-General for Energy and VHK, 2022).

In Blue Angel (2021), the inclusion of default duplex printing is mandatory for all professional devices and for color and monochrome devices with speeds higher than 19 and 24 ipm, respectively. This requirement is equivalent to the one included in Energy Star v3.2. Similarly, in TCO Certified (2022), the inclusion of default duplex printing is mandatory for all printers, without specifying a minimum threshold on printing speed.

N-up printing is the ability to print multiple pages on a single sheet of paper, and is a printer feature that can also contribute to the reduction of paper consumption. The default availability of this function is included in voluntary schemes such as Blue Angel (2021), TCO Certified (2022) and GPP Criteria on Imaging Equipment.

Recycled paper can have substantially lower environmental impacts than virgin paper, so the ability of printers to use recycled paper can help to reduce the environmental impact of paper consumption. Recycled paper can already be used in many devices on the market. The default ability of using recycled paper is included in voluntary schemes such as Blue Angel (2021), TCO Certified (2022) and GPP Criteria on Imaging Equipment.

Paper use is related as well with printing quality. Devices and cartridges able to deliver quality printouts without failures will use less paper. This topic will be addressed in more detail in section 4.5.5 of this Preparatory Study.

4.4.8 Noise

Noise produced by imaging equipment devices has an effect on end-users, particularly when confined to a closed areas such as offices. Noise is relevant for this product group as larger products such as MFDs may create irritating noise to end-users while in operation. Some of the short and long term effects are (Kaps et al, 2020):

- It creates annoyance to the receptors due to sound level fluctuations.
- Physiological features like breathing amplitude, blood pressure, heart-beat rate, pulse rate, blood cholesterol are affected.
- Noise has negative impacts on cognitive performance. For attention and memory, a 5 dB(A) reduction in average noise level results in approximately a 2-3 % improvement in performance.
- It causes pain, ringing in the ears, feeling of tiredness, thereby effecting the functioning of human system.
- It affects sleepiness by inducing people to become restless and lose concentration during their activities.

In order to tackle these issues, the GPP Criteria for Imaging equipment included Technical Specification 10, which states that:

- The A-weighted sound power level LWA must be determined according to ISO 7779. Devices capable of colour printing must be tested in both monochrome mode (LWA,M) and colour mode (LWA,F).
- Noise measurements must be conducted without optional peripheral devices.
- A4 size paper of grammage 60 g/m^2 to 80 g/m^2 must be used for test operations.
- The four-page Adobe Reader file from the Office Test Suite according to B.1 of ISO/IEC 24734 must serve as test pattern.
- Only one-sided printing must be measured.
- The noise measurement must only be conducted during repetitive printing operation cycles. The measurement time interval must include at least three complete outputs of the four-page test pattern (12 pages). The interval must begin after the printing preparation.

At least three devices of one model have to be tested. The declared A-weighted sound power level LWAd must be determined following the procedures of ISO 9296:1988. It must be declared in decibels (dB) with one decimal place. If the noise emission measurement can be performed with one device, only the following formula may be used as a substitute to determine the declared A-weighted sound power level LWAd.

$$LW\text{Ad} = LW\text{A1} + 3{,}0\text{ dB}$$

The requirements included in GPP Criteria for Imaging Equipment are equivalent to the ones proposed in Blue Angel (2021) for this product group.

4.5 Technical aspects affecting environmental performance of cartridges

4.5.1 Electronic circuitry in cartridges

Some cartridges have electronic circuitry, commonly known as chips. These components are typically mounted on a small circuit board and support communication between the cartridge and the device, through either direct contact or radio frequency connections. An example of chip mounted on a toner cartridge can be seen in Figure 42.

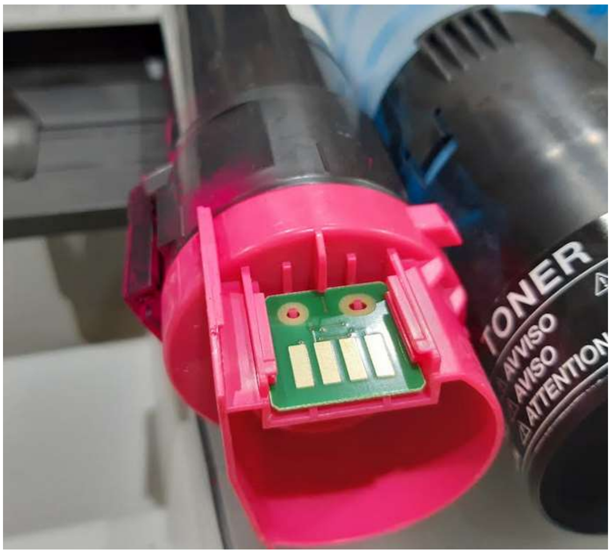


Figure 42. Chip in toner cartridge

. Typically, these chips perform a variety of functions (Huang et al, 2019):

- Store information (such as cartridge page yield, toner/ink level, and geographical region data)
- Calculate “correct responses” in requests sent from the imaging equipment
- Include a power control circuit to supply the processor
- Provide power protection from voltage spikes
- Store cartridge specific information (such as supplier)
- Support authentication to allow communication between the chip and the imaging equipment

According to Huang et al (2019), the first types of chips placed in cartridges were simple devices that could be easily reset at the end of a cartridge’s life. In the early 2000’s chips installed in cartridges started to become more complex. Today, they include extremely complex encryption codes.

Chip mission is an aspect under debate in the imaging equipment industry. Some OEMs use chips to enable cartridge authentication against counterfeit cartridges. They may also be used as a data security feature[33]. However, one stakeholder in the Preparatory Study suggested that placing security on the consumable is not necessary, since the only possible access to data is through the device. Another stakeholder added that ensuring the security of IT devices is important, although they have not been able to identify how malevolent actors could remotely access the hardware connection between the imaging equipment to steal users’ data from the imaging equipment. Moreover, there are cartridges in the market without chip, proving the same level of printing quality, without data security issues. On top of that, responding to global chip shortages in 2022, some OEMs that usually included chips in their cartridges, provided chip-free versions for a while[34].

The concern from the remanufacturing industry is that the greater use of electronics in printer cartridges has also resulted in barriers to reuse for independent remanufacturers. Some of these electronic components may make reuse difficult if they do not include provision for resetting the chip during reuse (Waugh et al, 2018). The

[33] https://h20195.www2.hp.com/v2/GetDocument.aspx?docname=4AA7-9396ENW
[34] https://www.therecycler.com/posts/canon-goes-chip-free/

location of the chip within the cartridge is also an important aspect. These topics will be covered in more detail in section 4.5.9.1 on barriers for cartridge reuse.

4.5.2 Cartridge page yield

According to ISO standards listed in section 1.2 of this study, “individual page yield” is the value determined by counting the number of test pages printed between cartridge installation and end of life. In other words, page yield is the number of pages that can be printed from a cartridge or container before a replacement is needed (Huang et al, 2019). It can be understood as the printing capacity of a cartridge and is a common metric to benchmark cartridges.

Page yield is important because it has a strong influence on the environmental performance of the cartridge: lower yields result in more frequent cartridge replacements. This factor is directly related to the generation of cartridge waste. Optimising the use of materials, simplifying cartridge design can help to increase the number of pages that can be printed with a single cartridge. Consequently, this can reduce the total amount of cartridges that are manufactured and therefore, managed at end of life (Kaps et al, 2019).

In the EU market, consumers can find cartridges with very different page yield. Small inkjet cartridge inkjet consumables may have page yields of less than 300 pages whereas high volume printing devices can print up to tens of thousands of pages. OEMs also offer cartridges with low and high page yield for the same device. In Huang et al (2019), data is published on cartridge page yield for different types of devices and printing speeds. In this Preparatory Study, new data will be gathered from different sources and presented in the following sections.

4.5.2.1 Measured versus real page yield

Cartridge page yield information is important for consumers. Some OEMs provide cartridge yield information in the package, whereas others provide it via website. Most OEMs do not provide page yield information for subscription and service model cartridges where customers pay based on actual page usage because the amount customers pay is not related to the ISO test standard page.

Measured page yield (according to ISO standards) and real page yield often differ, because a real life environment is the combination of multiple individual aspects. Measured page yield assumes an A4 page having an ink coverage of 5%. The value provided by the OEM in the cartridge packaging will relate to this profile of use. However, in real life, consumers have different use patterns. If a consumer prints pages with a larger coverage of ink, real page yield will be lower than the measured one.

The printer can also have an influence. Different printers use different amount of ink to print the same number of pages and it can vary from model to model. The age of the printer can also make a difference (newer models tend to be more efficient). If the printer offers different printing modes in terms of quality, that can also affect real page yield. Other aspects that can affect real page yield are printing frequency, temperature and humidity.

A stakeholder in this Preparatory Study provided feedback regarding measured versus real page yield[35]. A study was conducted by the stakeholder including 370.871 cartridges used by 51 customers on 5244 devices. This analysis was limited to ink cartridges of two OEMs (anonymised as A and B). The results from this study highlighted that on average, cartridges from OEM A performed 64% of their published yield, whereas cartridges from OEM B performed 78% of their published yield.

Some websites provide useful guidelines in terms of page coverage and page yield[36], as well as examples of the amount of pages that the user can expect to print with a cartridge based on different use patterns.

4.5.2.2 Page yield of starter cartridges

A starter cartridge is a cartridge which is sold together with a printer or multi-function printer. These cartridge generally offer lower page yield than standard cartridges, although their external appearance might be very similar or the same.

Figure 43 shows ink cartridges with different design of the inner compartments that results in different page yields. The sponge in the inner compartments contains the ink used to print. Cartridges A and B are two different ink monochrome cartridge models with different exploitation of the inner available volume. Cartridge A makes use of the full available volume, whereas cartridge B includes additional inner compartments to reduce the total

[35] https://www.nubeprint.com/

[36] https://www.stinkyinkshop.co.uk/articles/how-many-pages-will-an-ink-cartridge-print

amount of ink. Cartridge B is likely a starter cartridge. With the same amount of material, cartridge A makes a more efficient use of resources.

Similarly, cartridges C and D are two different ink colour cartridge models with different page yield. Whereas cartridge C exploits all the available inner volume, cartridge D limits the total amount of ink with the use of inner compartments. Cartridge D is likely a color starter cartridge. With the same amount of material, cartridges B and D are able to print less pages than consumables A and C, respectively.

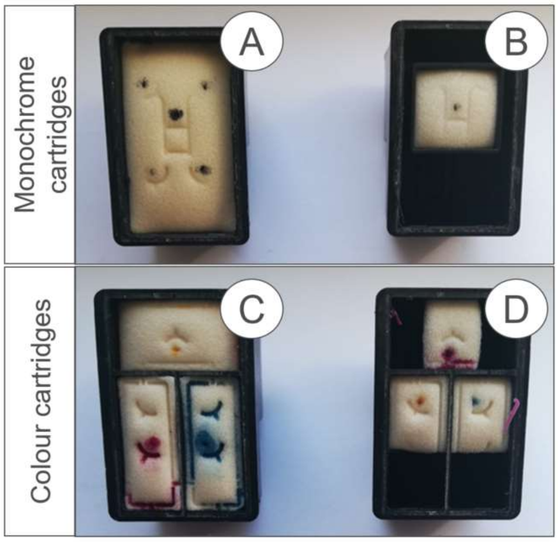


Figure 43. Monochrome and colour cartridges with different page yield

The inclusion of inner compartments to reduce the amount of ink or toner is also a barrier for consumable reuse. Remanufacturers often aim at making full use of the consumable capacity. To do that, they need to remove inner compartments, adding complexity and cost to the remanufacturing process.

OEMs highlight that decisions on these issues –reducing inner volume available in cartridges- take into account the complex interaction between a number of factors including printer architecture, monthly page volume printed by different types of customers, printer and cartridge price points and avoidance of waste. They add that focusing purely on page yield and assuming larger is always better while ignoring customer use rates could result in ink and toner being wasted or impact the printer size and therefore decrease overall system material efficiency.

4.5.2.3 Available page yield at cartridge end of life

Full capacity of cartridges is often not used due to early discarding of the cartridge. Feedback from a stakeholder in this Preparatory Study indicates that by default, printers show the message of "toner/ink low" at or before 20% level. The most usual behaviour at this point is to replace the cartridge, or in any case before the printer stops printing.

The authors of the Preparatory Study carried out visits to cartridge collection and remanufacturing facilities, mainly focusing on different types of toner cartridges. Feedback received during these visits confirmed this situation. Many of the empty cartridges collected by these operators are in practical terms not empty of toner or ink. This is due to users under MPS contracts that request cartridge replacements before needed, or due to device replacements that contain cartridges with available page yield. Some of these operators collect available toner on those end of life cartridges and commercialize it as original remanufactured toner[37].

In order to increase the usage of available cartridge page yield, a stakeholder in this Preparatory Study[38] carried out a study involving 4750 printers and copiers under an MPS tool. During an initial period of 6 months, the tool was used to track the behaviour of the user as to when the cartridges in the device were replaced: an average 14% of toner was wasted. The study also showed that other printer consumables such as drums (21%), fusers (17%) and transfer units (18%) were replaced earlier than required. In the next phase of the study, the information obtained through the MPS was used to influence the behaviour of when users should replace the

[37] https://gmtechnology.net/remanufactured-consumables/
[38] https://www.nubeprint.com/

cartridges. For instance, the shipment of new cartridges was based on remaining days, opposite to use remaining percentage. As a result of these measures, a reduction of waste of 85% was achieved.

This case describes the situation of printers under an MPS contract in the business sector. The stakeholder which conducted the study points out that in printers that are not under an MPS contract the situation might be worse in terms of wasted resources, since the end-customer has limited information on the available page capacity of the cartridge and other consumables such as drums, fusers or transfer units.

4.5.2.4 Cartridge material efficiency

Material efficiency encompasses a range of strategies that support the reduction of material consumption and waste production from a product's life cycle perspective (Cordella et al, 2019). It can also be understood as a metric which refers to decreasing the amount of a particular material needed to produce a specific product.

The purpose of cartridges is to produce printed pages. Therefore, a definition of material efficiency should consider the amount of material used to produce a specific number of pages. The number of pages that a cartridge is able to produce –its page yield- is influenced by a number of factors, including the efficient of the materials and its inner volume.

Cartridge page yield and material efficiency of cartridges are related. As seen in previous sections, there are different types of cartridges in the market. Each of them contain different amount and material types, from plastics to electronic circuitry.

Different cartridges types and OEMs may make different use of materials. Some may provide a large number of pages with less amount of material, whereas others may be less efficient in the use of materials. In some occasions, cartridges are not filled up to its maximum capacity (they are filled with 30% or 50% of the available volume).

A way to express material efficiency of cartridges is the ratio between the number of printed pages and the mass of cartridges consumed (Huang et al., 2019; Kaps et al., 2020). Some method apply the inverse indicator (mass of cartridges / printed pages) (Nordic Ecolabelling, 2020a). In this case a lower value means higher material efficiency.

In Huang et al (2019) and Kaps et al (2020), a proposal is made in terms of consumable mass efficiency. In those documents, it is stated that:

$$\frac{Page\ yield}{Cartridge\ mass}$$ shall not be lower than:

$$(2 \times [10 \times \tanh(0.1+0.0003 \times (CMass-10))-0.5]+1)$$ For toner cartridges

$$(2 \times [15 \times \tanh(0.2+0.0004 \times (CMass-8))-1]+2)$$ For ink cartridges

A slightly different approach is followed in Nordic Ecolabelling for imaging equipment. In that scheme, it is stated that

> *All consumables that the end user can exchange by themselves for the Nordic Swan Ecolabelled imaging equipment must meet set maximum limits below (21).*
>
> *For each consumable, if several variants can be used in the Nordic Swan Ecolabelled imaging equipment, the one with the highest index for weight/1000 pages must meet set limits in* Table 45.

Table 45. Page yield and material efficiency in Nordic Ecolabelling

Printing speed (images per minute)	Monochrome (kg / 1000 pages[1])	Colour (kg / 1000 pages[2])
> 19	< 0.65	<2
< 19	<1	<3

(1) According to ISO/IEC 19752

(2) According to ISO/IEC 19798

Material efficiency requirements based on page yield/consumable mass ratio could incentivise manufacturers to ensure more toner and ink is used before cartridges reach their end of life.

4.5.2.5 Material efficiency of ink cartridges based on JRC market analysis

An initial research has been conducted by the JRC, with the aim of getting a basic understanding of the current performance of cartridges in terms of page yield and material efficiency. This study is focused on ink cartridges currently available in the EU market. All the data collected is from retail operators in Spain.

A database of 150 cartridges was developed (known here as JRC Database). The sampling of the cartridges has been done based on the availability of cartridge models on retailers' websites and e-commerce platforms. The information collected for each model included the model identification code, the colour, the weight of the cartridge and the page yield.

First, page yield of ink cartridges was evaluated (Figure 44). Most of the cartridges in the sample provide between 100 and 400 pages. A limited number of ink cartridges available on retailers' websites provide 1000 pages or more.

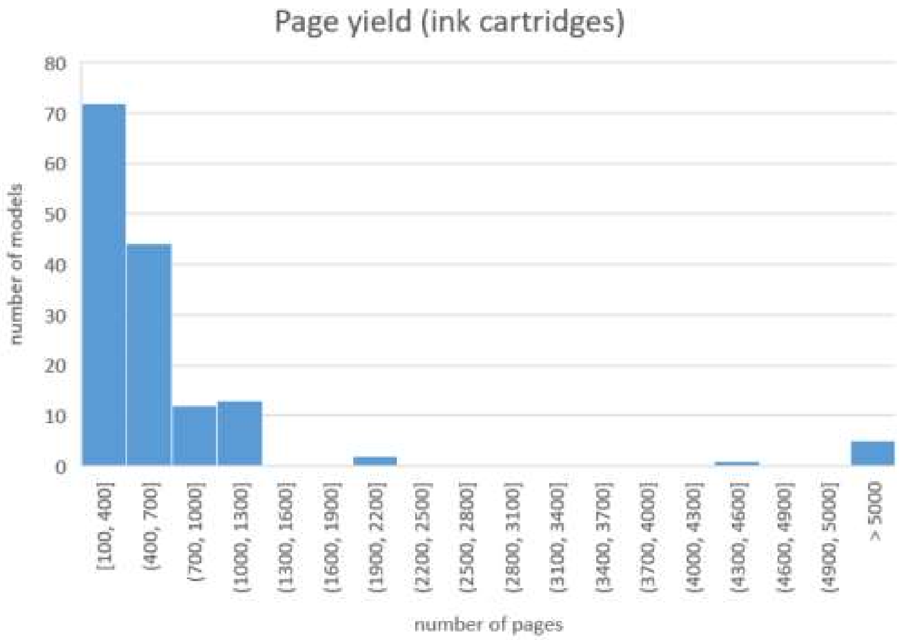


Figure 44. Page yield of ink cartridges (JRC market analysis)

Material efficiency, calculated as the ration between page yield and cartridge mass, is also evaluated for this sample of ink cartridges (Figure 45). Most of the cartridges in the sample provide 12 pages per gram of material or less. A limited number of cartridges in the sample provide 30 pages per gram of material or more.

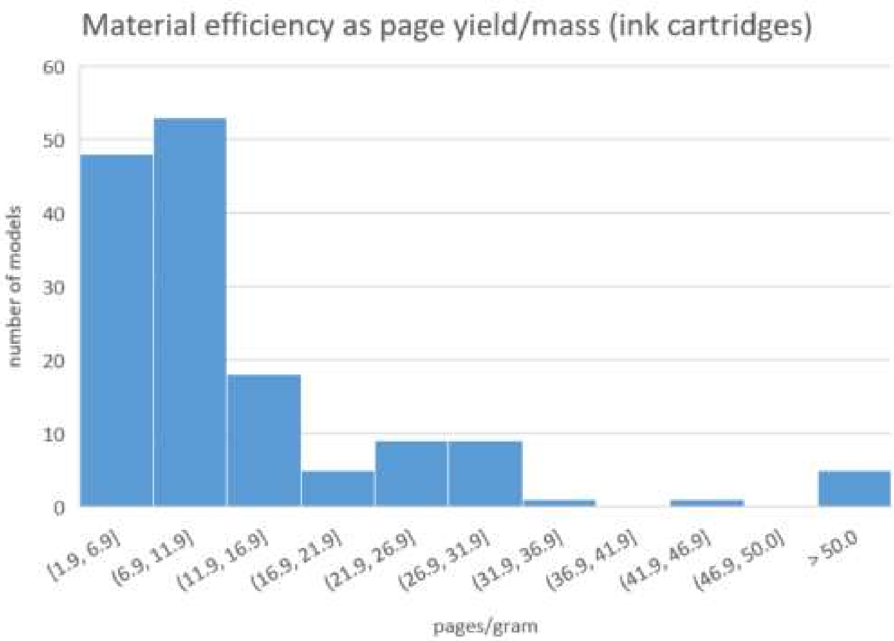


Figure 45. Material efficiency of ink cartridges (JRC market analysis)

Cartridge material efficiency and page yield are represented on a scatter plot in Figure 46. Most of the cartridges in the sample are located in a reduced area of the graph, between 0-2000 pages and 0-40 pages/gram. The only cartridges providing higher values of page yield and material efficiency are ink tank systems (described in section 4.5.7).

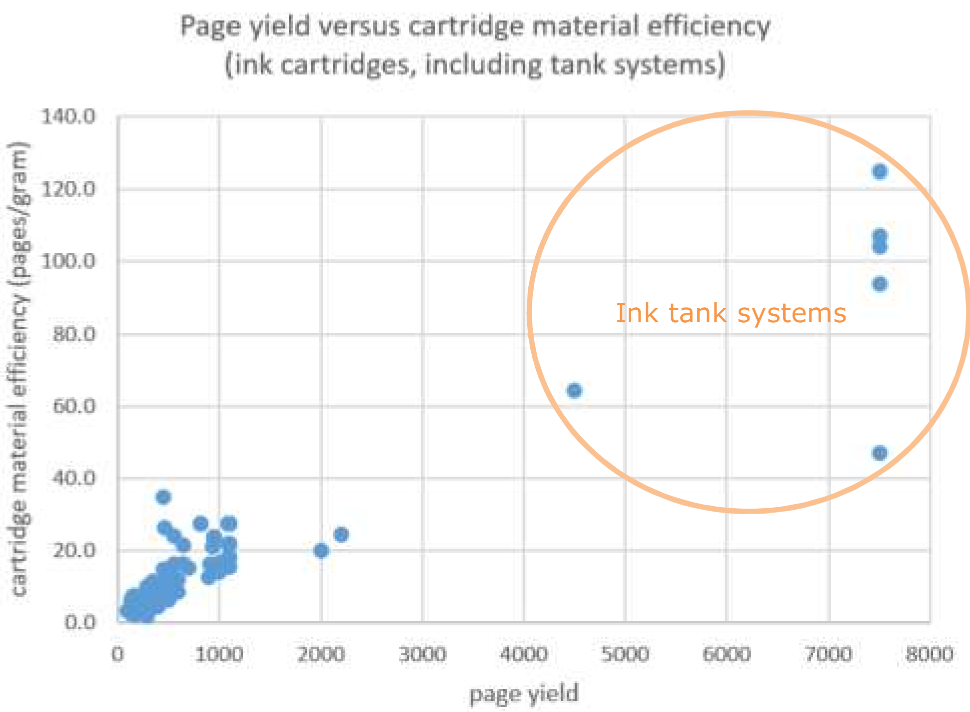


Figure 46. Page yield versus material efficiency of ink cartridges, including tank systems

If ink tank systems are removed from the above graph, a correlation can be observed between cartridge material efficiency and page yield (Figure 47). Generally, higher page yields are able to provide more pages per gram.

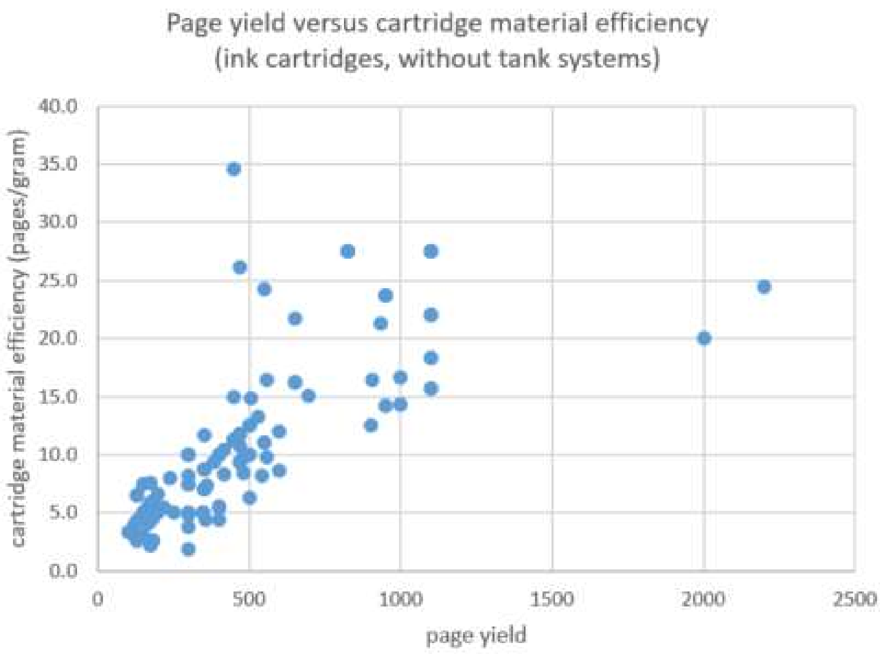


Figure 47. Page yield versus material efficiency of ink cartridges, without tank systems

The cost per page of cartridges is calculated as the ration between the purchase price and the cartridge page yield (expressed in EUR/page). In Figure 48, cartridge material efficiency and cost per page are represented in a scatter plot. Cartridges with the lowest cost per page and highest material efficiency are ink tank systems.

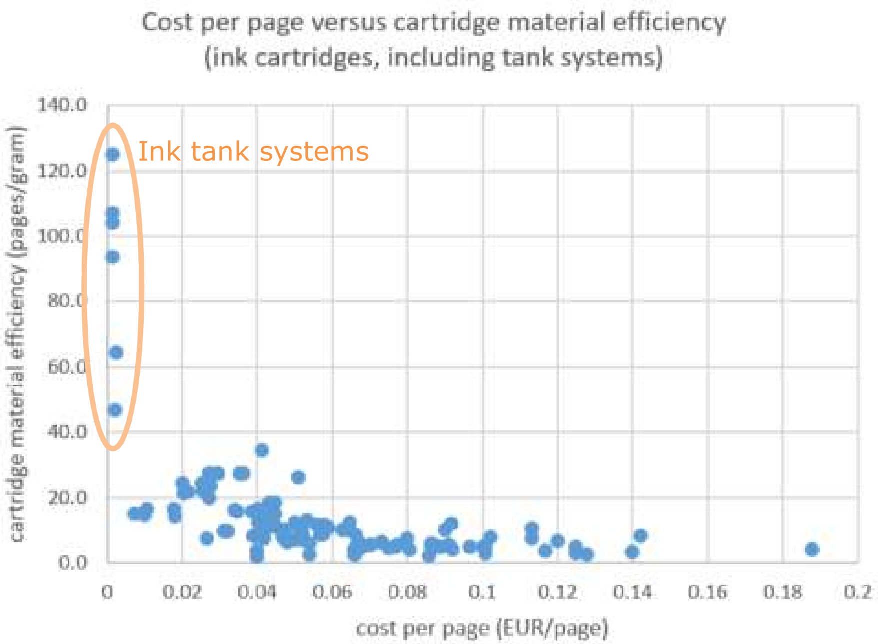


Figure 48. Cost per page versus cartridge material efficiency, including tank systems

If ink tanks systems are removed from the graph above, a slight correlation between cartridge material efficiency and cost per page can be observed (Figure 49). Generally, it is cheaper to print with cartridges with a higher material efficiency.

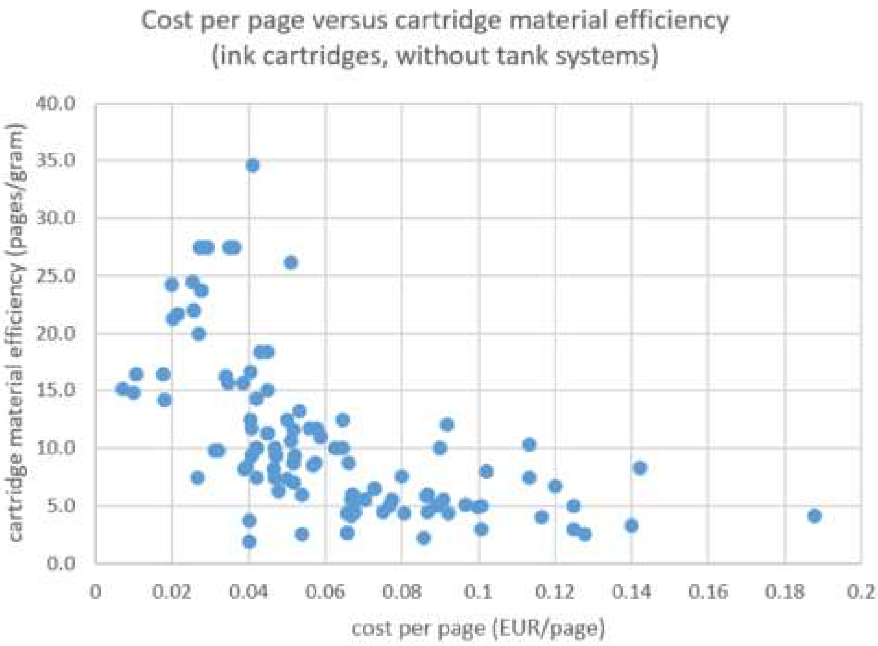


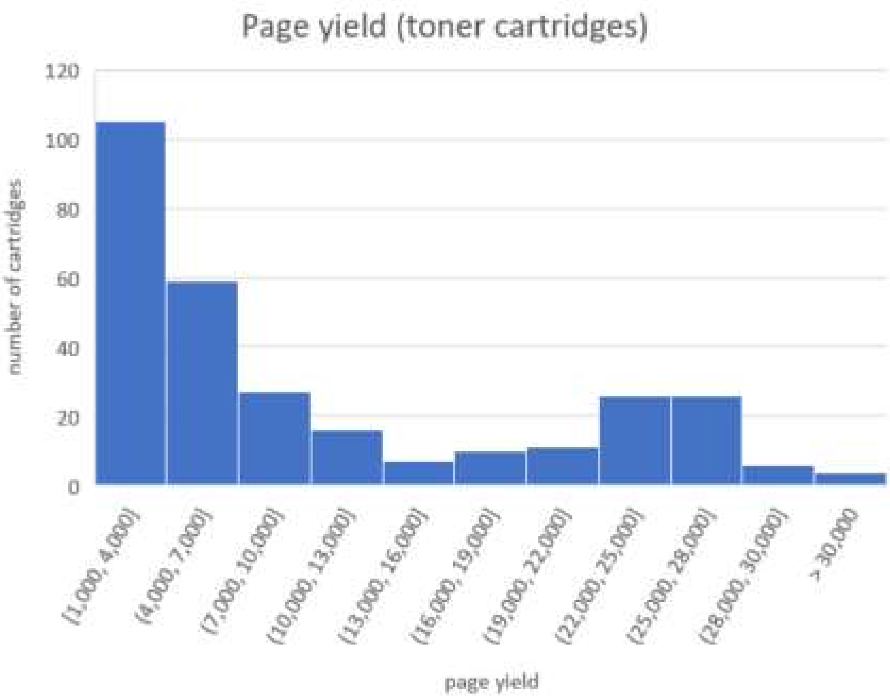
Figure 49. Cost per page versus cartridge material efficiency, without tank systems

The evaluation carried out in this section is based on a market analysis that has its limitations. The sample is reduced (150 models) and based on a single market (Spain). In order to contrast some of these findings, similar kind of analysis are carried out based on data provided by stakeholders in this Preparatory Study. This is presented in the following sections.

4.5.2.6 Material efficiency of toner cartridges based on ETIRA database

For the development of the Preparatory Study, the association of remanufacturers ETIRA shared with the JRC a database that included information on toner cartridges page yield. The database (referred in this report as 'ETIRA DB') contains information on 297 models of toner cartridges and 248 models of ink cartridges, from 13 different OEMs, in terms of cartridge type, page yield and cartridge mass.

In Figure 50, a histogram representing number of toner cartridges for different ranges of page yield is presented.

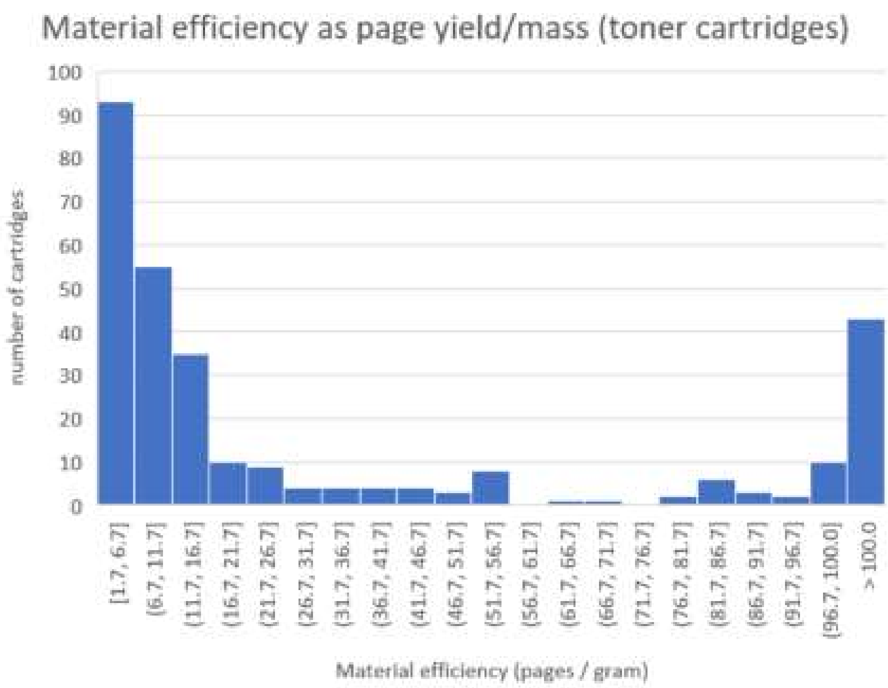


Source: ETIRA

Figure 50. Toner cartridge page yield

As it can be seen in Figure 50 35% of the toner cartridges provide 4000 pages or less, whereas 21% of cartridges provide 22000 pages or more.

In Figure 51, a histogram representing number of toner cartridges for different ranges of material efficiency (in terms of pages/gram) is presented.



Source: ETIRA

Figure 51. Cartridge material efficiency

As it can be seen in Figure 51, 31% of the toner cartridges provide 7 pages/gram or less, whereas 15% of toner cartridges provide more than 100 pages per gram of material.

In Figure 52, page yield versus material efficiency of toner cartridges is represented in a scatter diagram. Cartridges are classified between all-in-one toner cartridges (in red) and single-part and double-part toner cartridges (in blue).

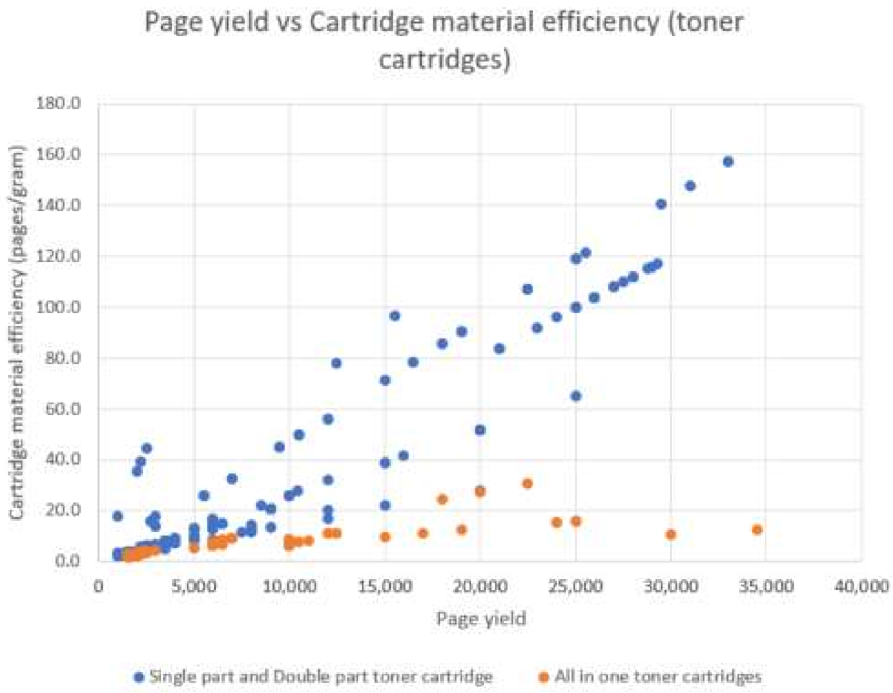


Figure 52. Page yield versus material efficiency of toner cartridges

As it can be seen in Figure 52, there seems to be a clear correlation between page yield and material efficiency, particularly for single-part and double-part toner cartridges. There is a clear separation between all-in-one toner cartridges and single-part/double-part cartridges in Figure 52. All-in-one toner cartridges tend to provide less pages per gram of cartridge material, since they contain both the photoreceptor and the developer part (they have less volume available to store toner).

4.5.2.7 Material efficiency of ink cartridges based on ETIRA database

In Figure 53, a histogram representing number of ink cartridges for different ranges of page yield is presented.

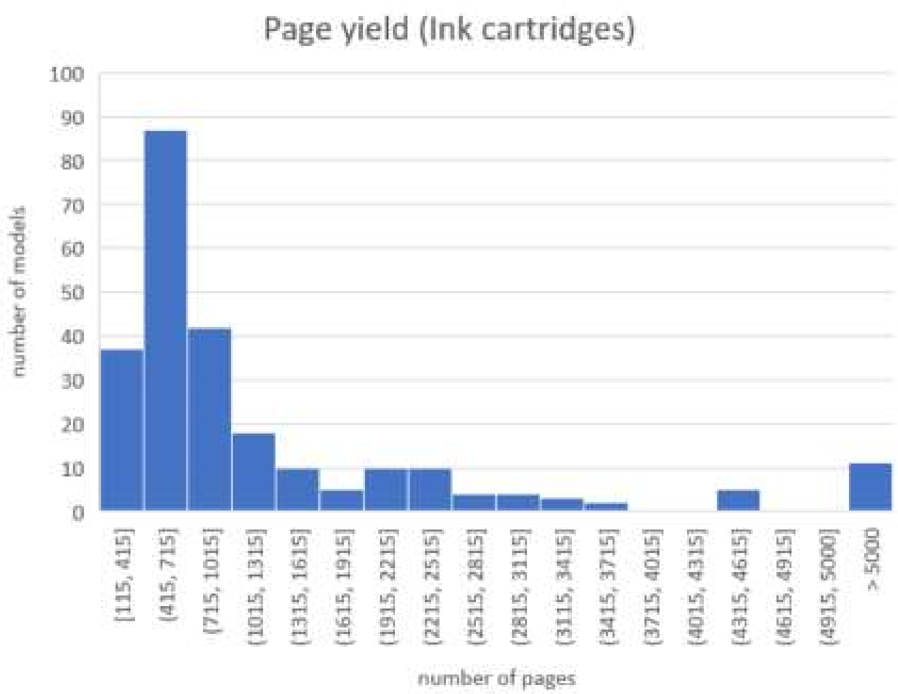


Figure 53. Page yield of ink cartridges

As it can be seen in Figure 53, 50% of the ink cartridges provide 700 pages or less, whereas 4% of cartridges provide 5000 pages or more.

In Figure 51, a histogram representing number of ink cartridges for different ranges of material efficiency (in terms of pages/gram) is presented.

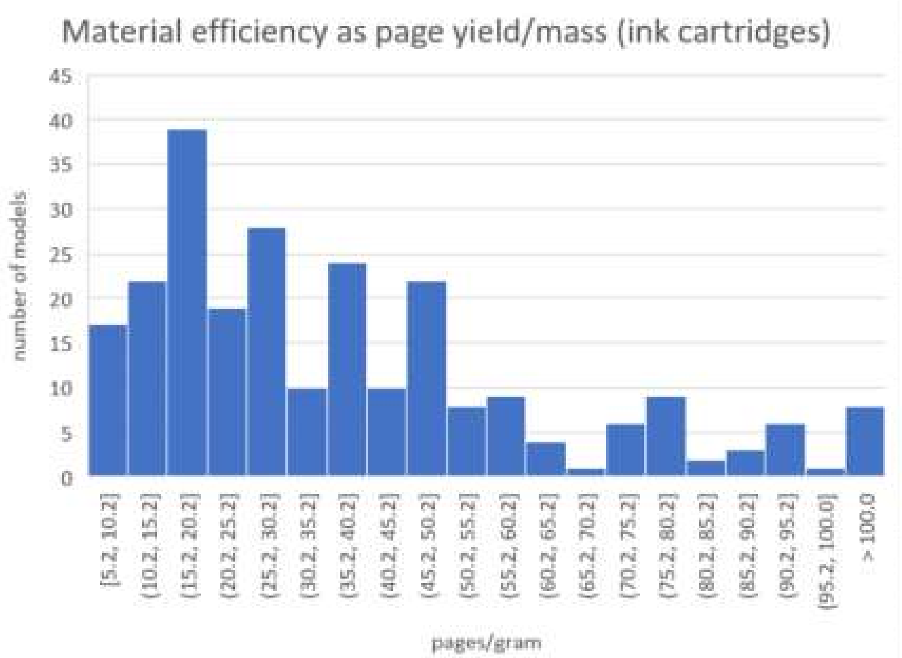


Figure 54. Material efficiency of ink cartridges

As it can be seen in Figure 54, 31% of the ink cartridges provide 20 pages/gram or less, whereas 8% of ink cartridges provide more than 100 pages per gram of material.

In Figure 55, page yield versus material efficiency of ink cartridges is represented in a scatter diagram. Cartridges are classified between integrated ink cartridges (in red) and single-part ink cartridges (in blue).

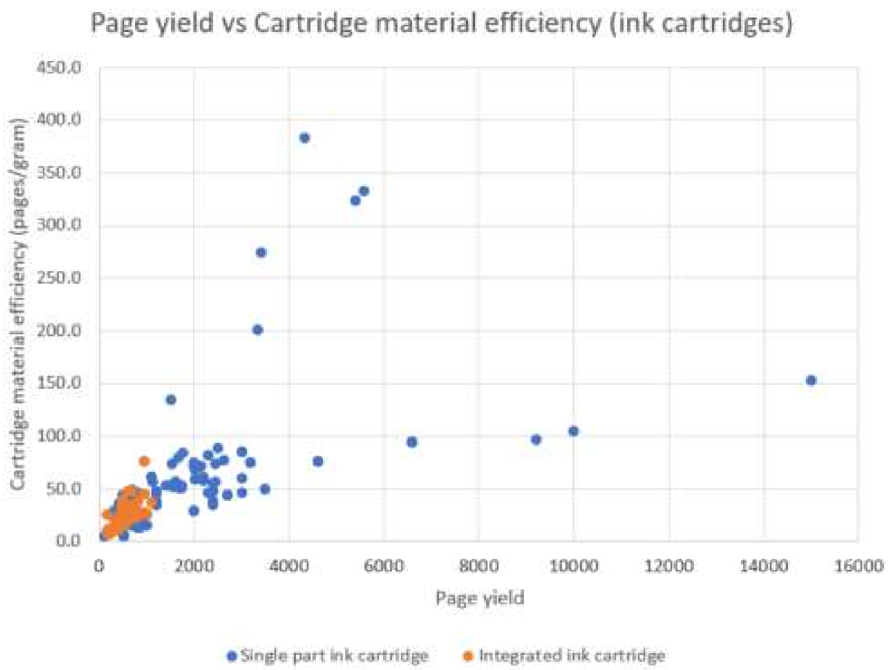


Figure 55. Page yield versus material efficiency of ink cartridges

As it can be seen in Figure 55, there seems to be a correlation between page yield and material efficiency. There is a clear separation between integrated ink cartridges and single-part ink cartridges in Figure 55. Integrated ink cartridges tend to provide 1000 pages or less. Within that range, material efficiency of integrated and single-part ink cartridges is similar. Only single-part ink cartridges seem to provide 1000 pages or more. Beyond 1000 pages, a wide range of material efficiency can be found, between 20 pages per gram and nearly 400 pages per gram.

4.5.3 Cartridge compatibility

Based on the feedback received by some stakeholders in the cartridge remanufacturing sector, the design of cartridges and other consumables is usually changed across several models and/or generation of printers/MFDs, resulting in a proliferation of cartridge models that are difficult to sort and re-use, being only linked to specific printers/MFDs models. According to stakeholders from cartridge collection sector, currently exist more than 25000 single cartridge models. Many of these cartridges are very similar in their design, with slight differences often not easy to identify.

For instance, Figure 56 shows five cartridges that share the same core design. However, they contain small plastic features (highlighted in the image with yellow rectangles) that make them slightly different between them. The function of these small plastic features appears to be matching each of those cartridge models with a specific printer model (making them, at the same time, incompatible with the rest of printer models).

Source: Bioservice

Figure 56. Cartridges with slight differences in their design (example 1)

A similar situation can be observed in Figure 57. This figure shows the caps of two toner cartridges (A and B). For proper installation into the printer, the cap needs to fit into a specific area within the printer. The cartridges contain slight design differences (highlighted in yellow). With the introduction of these design differences, each cartridge is only compatible with a specific printer model.

Source: Bioservice

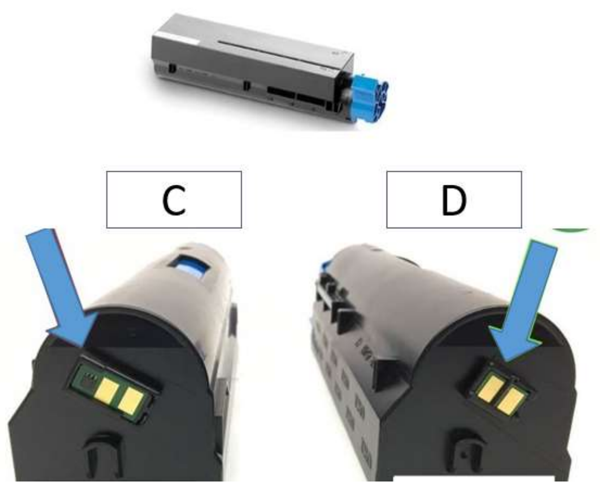
Figure 57. Cartridges with slight differences in their design (example 2)

These slight differences in cartridge design can be observed across multiple cartridge configurations. In Figure 58, it can be seen that a large format single-part toner cartridge can have multiple different caps. Each of those caps has different design features, making the cartridge compatible with a limited number of printers.

Source: Bioservice

Figure 58. Cartridges with slight differences in their design (example 3)

Another example can be seen in Figure 59. In this case, cartridges C and D share the same core, the only difference being the shape of the chip holder.



Source: Bioservice

Figure 59. Cartridges with slight differences in their design (example 4)

The examples provided in Figure 56, Figure 57, Figure 58 and Figure 59 indicate that there is a wide range of variability in the design of cartridges, even between very similar models. The purpose of these small design changes between similar cartridge models is unclear, since they do not seem to provide critical functionality. These differences do not appear to be product improvements or innovations either. Based on feedback from stakeholders, these design variations have been purposefully included to limit printer and cartridge compatibility.

This limited printer and cartridge compatibility may have an effect on cartridge remanufacturers and on the access of consumers to remanufactured cartridges. Based on the experience of remanufacturers, new printer models are continuously placed on the market, with small design or functionality differences. These new printer models will be compatible only with new cartridge models (only different from previous cartridge models based on the features shown in this section). This proliferation of cartridge models has an impact on the remanufacturing sector, since it adds complexity to the process (cartridges need to be identified and properly sorted). Once a cartridge has been remanufactured, the opportunities to market it successfully are reduced if it is only compatible with a limited number of printer models.

Moreover, printer and cartridge compatibility is a very relevant issue for users, based on the preliminary results from the user behaviour study (section 3.3). Full compatibility of the consumable with the printer has been highlighted as an important aspect for users when buying a cartridge, only after price, page yield and printing quality.

4.5.4

4.5.4 Cartridge shelf life

Cartridge shelf life is the estimated length of time a cartridge will last in its sealed package. This aspect is potentially more relevant in ink cartridges, because over time ink dries out and settles inside the cartridge, which can cause the printer to clog. The sponge designed to deliver ink to the printheads can also dry out. Different factors contribute to the eventual deterioration of a printer cartridges, such as storage location, storage temperature, storage position, use of a sealed package, etc. (Figure 60). On occasions they will also include warranty dates.

Source: LD Products (Stowell, 2022)
Figure 60. Expiration date on ink cartridge

Some manufacturers provide an "install date" which is typically 18 months after the date of manufacture and 6 months before the warranty ends. Some others claim that their ink does not expire, and that as long as the seals on its ink tanks are unbroken, the ink will not dry out and will be good to use. There are manufacturers which provide a "best if used by" date of 2 years, and recommend replacing ink cartridges after six months, whether they are empty or not, to ensure high quality prints.

The industry standard in terms of shelf life for ink cartridges is 2 years if the package is not open, and 6 months after the package is opened. In any case, the expiration dates published by manufacturers have the aim of ensuring integrity and printing quality. However, ink cartridges may continue to perform well for 12-36 months beyond dates displayed on the package (Errera, 2018).

Expiration dates are also relevant for remanufactured cartridges, which may often keep the original cartridge expiration date in its casing, potentially creating confusion to the consumer. It is worth highlighting that remanufactured cartridges tend to come with protective packaging and that their shelf life can also be considered of 2 years.

Cartridge shelf life may also be relevant in toner cartridges. Due to the plastic nature of toner powder, toner cartridges will not dry out the same way an ink cartridge would, but internal cartridge components can wear out over an extended period. According to Errera (2021), as long as the toner cartridge is appropriately stored and managed, it can last several years. In any case, manufacturers still provide warranty and expiration dates.

4.5.5 Cartridge print quality

DIN 33870-1 and DIN 33870-2 define the quality requirements for the remanufacturing process of toner modules and appropriate test methods. These standards are used as a reference for various voluntary schemes regarding printing performance of consumables. This is the case of the GPP criteria in their Technical Specification 20 on Consumable quality (Kaps et al, 2020), as well as Blue Angel and Nordic Ecolabelling.

Cartridge print quality is directly related to the generation of waste and to the consumption of paper. The use of cartridges with low printing quality can result in excessive waste generation, since users dispose of them before their end of life. On top of that, due to frequent reprints, cartridges delivering lower quality print outs may need to use more paper in order to achieve the quality desired.

Print quality is a recurring theme when comparing OEM and reused cartridges. OEM have commissioned laboratory tests to compare cartridge reliability of original and reused cartridges (Spencerlab, 2016). Cartridge reliability factors, such as Dead-on-Arrivals (DOA) and Low Quality (LQ), were evaluated to determine the total number of Problem Cartridges for each brand. A total of 20 original cartridges and 110 non-original cartridges were tested. The key findings from this study are summarised below:

- Original cartridges yielded no Problem Cartridges, whereas 73% of non-original remanufactured cartridges exhibited some kind of reliability problem.
- Original cartridges also had the largest percentage of External Use Print Quality samples, surpassing the quality of non-original remanufactured brands.
- Original cartridges produced an average of 17% more usable pages than non-original remanufactured cartridges.

In another study conducted by Keypoint Intelligence (2017), commissioned by HP, parameters such as page yield, reliability and number of wasted pages, were compared for original and non-original cartridges. Non original included refilled, new build compatibles and remanufactured cartridges. A total of 1746 cartridges were tested on 48 printers. The main findings of this study were:

- When comparing the total pages printed from all cartridges tested, it was concluded that original inkjet cartridges produced an average of 85% more pages than the third-party aftermarket cartridges tested.
- No original inkjet print cartridges tested in the study were dead on arrival (DOA) or expired prematurely, whereas the third-party aftermarket cartridges had a collective problem cartridge rate of 42% (11% DOA, 31% Premature expiry).
- Some of the third-party aftermarket inks clogged printheads during testing, rendering 40 out of the 48 printers (83%) tested unusable due to major print quality defects that could not be fixed, even after using Original HP ink cartridges to perform repeated head cleaning routines.
- Third-party aftermarket cartridges produced 88 times more unusable/wasted pages then original HP cartridges.

According to a study published by the consumer organization Which? (Aston, 2022), only 4% of 3rd party ink cartridges had experienced problems with compatibility and only 1% found their cartridges leaked. The authors add that most 3rd party brands also offer guarantees if a cartridges does not work properly. The sample size of ink cartridges was 7524 units. In contrast, according to Tonerbuzz (2021b), prints made with compatible and/or remanufactured toner and ink cartridges often have inferior print quality, inaccurate colors and are prone to premature fading. According to their estimates, compatible toner cartridges often produce less than half the number of promised pages.

The association of cartridge remanufacturers ETIRA states that cartridge quality is the first priority of European remanufacturers who are member of the organisation. They claim that remanufactured cartridges marketed by these companies are the same of better quality as the new products (ETIRA, 2022). However, no test reports are available on the association's website. They also point out that print quality is a subjective term, and that customers may have different quality requirements for different types of outputs.

Stakeholders in the Preparatory Study highlighted that print quality of a cartridge is heavily influenced by the performance of other parts in the printing system (such as paper handling, fuser unit or transfer belt). For instance, transfer belt contamination can lead to poor printing results, although the transfer belt contamination may have not been caused by the cartridge. Therefore, it is important that printing quality and failure rates are attributed to the relevant component in each case.

Print quality was also addressed in Waugh et al (2018) as one of the aspects which could improve the market situation for both original and reused cartridge sales. The authors recommended to develop a rating system for cartridge quality (based on failure rates) matched to consumer expectations. They add that quality may be a question of fitness for purpose, rather than an absolute value. In Huang et al (2019), feedback was provided from an industry expert, indicating that failure rates were assumed 3% for OEM cartridges and 10% for non-OEM cartridges.

4.5.6 End of life of cartridges

The Waste Framework Directive sets the basic concepts and definitions related to waste management, including definitions of waste, recycling and recovery. It lays down basic management principles and a waste hierarchy, in terms of end of life management. The hierarchy is:

- Prevention

- Preparing for reuse
- Recycling
- Recovery
- Disposal

In the following sections, each of those aspects of the waste hierarchy will be described in detail, focusing on its applicability to cartridges.

4.5.7 Cartridge waste prevention

Waste prevention is achieved through appropriate design choices at the initial phases of product development. An example of waste prevention are cartridge-less systems. In these systems, the deposition material reservoirs, also known as 'tanks' are a permanent feature of the machine. They may be refilled externally using ink or toner supplied in a simple packaging (Waugh et al, 2018). The absence of a cartridge contributes to prevent the generation of waste. According to Aston (2022), some tank models cost less than £4 a year (4.6 EUR) to run, in contrast with comparable cartridges, which might cost up to £100 a year (115 EUR).

An example of this technology in the inkjet sector is the Ecotank format provided by EPSON (EPSON, 2022). According to the supplier, the system features a large ink tank that the user fills with the included ink bottles instead of cartridges (Figure 61). One of the disadvantages of this technology is that the ink may dry up when left unused, leading to clogged tubes or cartridge nozzles (Stowell, 2022).

Figure 61. Examples of re-fillable tanks

In the toner sector, Xerox has replaced the cartridge by a refillable toner reservoir replenished from simply-packaged toner refills (Figure 62). In another of its products, it uses solid inks which are dropped into chambers in the imaging equipment almost completely removing packaging. Again, a more robust print-head is required, thus leaning these products towards the large office markets (Waugh et al, 2018).

Figure 62. Solid ink

Cartridges with high page yield are another example of waste prevention. When a consumer purchases a cartridge that can print more pages, they will ultimately need a lower amount of cartridges.

4.5.8 Cartridge collection

Cartridge collection is key at end of life to ensure that the materials can be prepared for reuse or recycled, and to reduce the amount of material sent to recovery or disposal. In this section, the main aspects related to cartridge collection are summarised, and available data at this point is presented.

Cartridges can be collected via take-back schemes, which might operate in a variety of manners, depending on the location and the OEM. Information below on cartridge collection schemes has been gathered from OEMs Corporate Sustainability Reports (CSR).

- Lexmark began reclaiming material in 1991 through the Lexmark Cartridge Collection Program (LCCP). This program allows customers to return cartridges free of charge, with the purpose of reusing or recycling them. Individual customers may use a postal box which can fit up to 5 cartridges. Companies can request a container. According to Lexmark (2021), the LCCP collected 4689 tons of cartridge materials in 2021. According to the company, nearly 40% of the total toner cartridges shipped worldwide were returned through the LCCP.
- Brother (2022), for their operations in Europe, the portal site for recycling consumables and products provides information about how to return used toner cartridges, drum units, ink cartridges, and products and ask for collection boxes, etc. They also provide of recycling methods available in a total of 28 countries. Regarding collecting and recycling products, Brother utilizes the collection and recycling channels in place in respective countries, in compliance with the WEEE Directive.
- Canon (2022) has been collecting and recycling used ink cartridges since 1996. As of the end of 2021, Canon's collection program was operational in 35 countries and regions worldwide, and the total volume of cartridges that had been collected up to the end of 2021 reached 2616 tons. Both toner and printer cartridges are sent to local hubs for consolidation, before being sent to Canon's recycling facilities.
- Epson (2022) have established collection and recycling programmes for cartridges that consist of either single returns (via post) or bulk returns (via box collection). Programmes vary across our European markets, according to local legislation and our recycling partners. The collection scheme works differently depending on the type of cartridge (inkjet, toner, large format) and the number of devices owned by the user.
- HP (2022) provides take-back programs in 77 countries and territories worldwide through a global network of reuse and recycling vendors. HP provides free ways to recycle used Original HP Ink and Toner Cartridges and Samsung toner cartridges. Home and commercial customers can return Original HP Ink and Toner Cartridges for free to more than 18,500 authorized sites worldwide. Free pickup and mail-back options are available in most countries.
- Kyocera (2022) offer a number of ways to return used cartridges to their recycling partners, depending on customer location. They provide boxes of different sizes to customers, depending on the type and size of cartridges being returned.

A stakeholder in this Preparatory Study highlighted that it is relevant to understand how successful these collection schemes are, since postal service might not be the most appropriate solution in some cases, both in terms of environmental performance and in keeping the cartridge in good condition for reuse. In Waugh et al (2018), it is estimated that collection rate of printer cartridges via take-back schemes of OEMs is around 18% for ink and 25% for toner cartridges.

Public administrations may provide different solutions as well for the collection of empty cartridges. Municipalities may offer mobile or fix drop-off points where users can bring their depleted toner and ink cartridges. Information is given in terms of location of fix points and time availability of mobile points[39].

In a study conducted by Actionable Intelligence in 2021 (provided by EVAP), an industry overview is given on cartridge collection. In this report, the term 'core' is used to refer to a used empty cartridge. Collectors are also classified in four different categories:

> <u>Brokers</u>*: companies with business models based primarily –or exclusively- on the collection and sale of empty ink and toner cartridges. In some cases, firms differentiate "brokers" from*

[39] https://www.barcelona.cat/cuidembarcelona/es/reciclar/res/RM0030

“collectors” with the former being only interested in gathering cores for sale and the latter collecting all empties.

Remanufacturers: companies that generate most of their revenue from the sale of 3rd party cartridges. These participants make money selling cartridges that they refurbished. However, they also generate a revenue by selling new imports.

Dealers: companies that market office technologies and services that include printing devices and supplies. As part of their offering, they collect empties and dispose of them or return them to remanufacturers or brokers, sometimes for cash.

Dealer-Remans: companies that offer imaging equipment and other technologies and also have internal remanufacturing assets to refurbish cores. Many of these firms establish a closed-loop system where they supply their customers with cartridges as well as collect empties.

Cartridges cannot be reused indefinitely. When a cartridge has already been reused multiple times, another cycle could produce a product of insufficient quality. This aspect affects cartridge collection. Therefore, the study by Actionable Intelligence establishes differences between virgin OEM, remanufactured OEM and new build cartridges, in terms of their reusability.

Virgin OEM core. A spent OEM cartridge that has never been remanufactured. These are the most sough-after cores. Often, OEM virgin cores can be cleaned and refilled without any components being replaced. Virgins also deliver the highest performance because the tolerances are still close to those found in new OEM cartridges. Even damaged, these cores have value.

Remanufactured OEM core. An OEM cartridge that has already been remanufactured. Not enjoying much demand, these cartridges have grown in value over the years as OEM cores have gotten harder to find. They can be problematic if care was not taken when the core was refurbished. It can also be difficult to determine how many times it’s been remanufactured.

New build core. Non-OEM cartridges cannot be remanufactured because they are constructed differently than OEM cartridges. As a result, remanufacturers lack the replacement parts required to remanufacture them. The only option that currently exists for new build that are collected is disposal. Responsible disposing of new builds can be costly.

Some of the key findings of the Actionable Intelligence study shared by EVAP are summarised below:

- Cartridge consumers tend to value recycling activities. However, collection must be convenient and easy for them. Services such as drop-off points and collection schemes are important. This is enhanced if it is tied to an environmental message.
- For the four categories described above (brokers, remanufacturers, dealers and dealer-remans), their internal collection programs are essential to successfully running their business. Sophisticated reverse-logistic processes have been developed to ensure the programs run smoothly.
- To stay supplied with cores, most remanufacturers use some combination of their own internal collection programs, augmented by purchasing from a couple of brokers. In general, the bigger the remanufacturing company, the more reliant they are on brokers (larger remans purchase 30-50% of the cores they use).
- In the EU it is more common to find smaller brokers operating at country level, as well as larger brokers collecting cores across the continent.
- Cores are a commodity and pricing is purely based on supply and demand. Since COVID19, prices have soared. Factors like freight costs and the scarcity of HP chips are driving up prices. Core prices can range from 2-20 EUR. Toner cores average 5-8 EUR and ink cores 2-3 EUR.
- There is general consensus that cartridge collection systems are expensive. In addition to technology, companies must have a knowledgeable collections team, which should be aware of demand and meet it while controlling inventory levels. Non-OEM cores cannot be included in the mix.
- Respondents to the survey conducted by Actionable Intelligence indicate that 50-60% of the cores they collect are new build cores. Since these cores are so prevalent in this waste stream, brokers and remans limit what they will collect. In some cases, end users may be required to take extra measures to prove that the cores they return are OEM’s. However, regardless of safeguards, new builds still get into this waste stream.

- Many brokers and remanufacturers invest in proper disposal of non-OEM cores, but others do not. Some companies use recycling programs run by OEMs and their channel partners to dispose of non-OEM cores. Other companies simply discard these cores into the conventional waste stream.

In a study conducted by Keypoint Intelligence in 2020 (provided by EVAP), an industry overview is given on cartridge collection and recycling. The key findings of this study generally agree with the findings of the study by Actionable Intelligence:

- Some new build cartridges manufacturers are starting to collect back empty cores, mainly in the business-to-business sector, although volumes are still considered very small.
- Cloned cartridges are mainly found in Internet channels, but they are increasingly found in resellers and in tenders.
- Collection of new build cartridges is accidental and remains steady. Remanufacturers prefer to work with virgin OEM cores. However, the collection of non-OEM cores is expected to increase, particularly for toner, as new build cartridges make headway into business-to-business channels.
- Remanufacturers are increasing their vigilance on cartridge collection systems to screen out new build cartridges. Major manufacturers do not want to deal with these cartridges since they are regarded as low quality, unreliable, possibly patent infringing and containing toxic chemicals, susceptible to OEM firmware updates.
- A few large remanufacturers in the EU have invested in technology to increase efficiency in remanufacturing their own empties. Remanufacturers in China are more willing to remanufacture non-virgins. However, they may not be used for the European market.
- The amount sent directly to landfill (78% for toner and 86% for ink) is high because remanufacturers prefer to work with virgin cartridges and therefore fail to collect many of their used cartridges.

4.5.9 Cartridge reuse

When an ink or toner cartridge has been depleted, it can be refilled or remanufactured. By refilling or remanufacturing cartridges -reusing cartridges-, it is possible to reduce the consumption of virgin materials, hence minimising environmental impacts (Huang et al, 2019).

Cartridges cannot be reused indefinitely. The number of times a cartridge can be reused will depend greatly on their design and on their ability to be remanufactured or refilled. Currently, there is no clear available information on how many times each type of cartridge can actually be reused. In Waugh et al (2018), it is stated that “printer cartridges are a typical example of equipment that can be reused many times before coming to the end of its life”. However, no specific data is provided in terms of the average number of times a cartridge may be recycled.

Ink and toner cartridges are remanufactured in different proportions. Integrated ink cartridges, for instance, are regularly remanufactured. On the contrary, inkjet cartridges where the print-head is separated from the containing element tend to be sent for recycling, due to their lower value. Due to the higher value of toner cartridges, they are more widely remanufactured (Waugh et al, 2018).

Different cartridge reuse rates have been published in the past years:

- In Huang et al (2019), it is estimated that 15-20% of all cartridges in the EU are reused as a cartridge after first use, including OEM and non-OEM cartridges
- In Waugh et al (2018), it is estimated that 20% of toner and 13% of ink cartridges are remanufactured in the EU
- In The Recycler (2019), it is estimated that around 15%–20% of printer cartridges are remanufactured within the European Union and a further 10%–12% are from outside the EU
- In ECOS (2021), it is estimated that remanufacturing rates in Europe are around 10%

The low reuse rate figures are significantly influenced by low collection performance described in section 4.5.8.

During the development of the VA proposal of 2021 (explained in section 1.6.1), OEMs and remanufactures which were signatories of the VA agreed on cartridge reuse targets for 2025. In order to define those targets, assumptions were made regarding current collection rate, viable percentage and remanufacturing rate (Eurovaprint, 2021), parameters which were defined as:

Collection rate: estimate of % of cartridges collected through recognised collection processes.

Viable percentage: estimate of % collected/purchased by anticipated Signatories and considered viable for reuse. Takes into account cartridge lifecycles e.g. end of life of cartridges. Also takes into account market factors; Signatories won't remanufacture what they can't sell.

Remanufacturing rate: estimate reflecting loss due to damaged cartridges or loss in production process.

Based on the parameters above, the reuse rate was calculated as:

Reuse rate = Collection rate x Viable percentage x Remanufacturing rate

The agreed figures for collection rate, viable percentage and remanufacturing rate, for toner and ink cartridges, are presented in Table 46.

Table 46. Collection rates, viable percentages and remanufacturing rates estimated for the VA 2021 proposal

	Collection rate	Viable percentage	Remanufacturing rate	Reuse rate
Toner cartridges	70%	50%	76%	27%
Inkjet cartridges	15%	70%	68%	7%

In contrast to these figures, in Waugh et al (2018), technical potential to reuse cartridges are proposed (Table 47). Technical reuse potential refers to the ability of a printer cartridge to technically be processed for reuse. For example, the use of adhesives may make it impossible to disassemble a printer cartridge without damaging the components beyond repair. If a printer cartridge cannot technically be remanufactured or refilled, the only end-of-life options will be recycling, energy recovery, and landfill.

Table 47. Potential of cartridge reuse

	Technical reuse potential
Toner cartridges	92%
Inkjet cartridges	87%

Source: Waugh et al (2018)

Reuse precedes recycling activities in the waste hierarchy. However, according to Waugh et al (2018), OEMs currently prioritise waste recovery strategies such as recycling over cartridge reuse. In a material flow analysis published in that report, it can be seen that approximately 14% of inkjet and 33% of toner cartridges sold in the EU end up being recycled at end of life (against the 13% and 20% estimated to be remanufactured).

This trend is confirmed by checking OEMs Corporate Sustainability Reports. Although some of them are starting to develop reuse activities, most of toner and ink cartridges being collected are still sent to recycling operations. Lexmark collected 4,818 metric tons of returned cartridges from their customers worldwide with 39% being reused and 55% recycled (Lexmark, 2021). Brother toner cartridges (Brother, 2022) also undergo sorting, disassembly, cleaning and parts replacement for reuse (although no specific figures are provided regarding reuse). Similar information can be found in Canon (2022), where it is stated that returned used toner cartridges are brought to Canon recycling sites, where they are sorted by model and the reusable parts are picked out. Washing and maintenance are performed as needed, and the parts are then reused in new products. HP claims that 7200 tons of cartridge materials are reused, which is 0.8% of total material use (HP, 2022). Kyocera highlights that after being cleaned, the containers undergo strict inspections and tests that are the same as those performed for new containers, including visual inspection and airtightness testing. Those that have passed the inspections and tests are filled with toner and shipped to market as new products.

4.5.9.1 Barriers for cartridge reuse

Based on available bibliography, stakeholder feedback and visits conducted to cartridge remanufacturing facilities, a number of barriers for cartridge reuse have been identified. In this Preparatory Study, these barriers have been classified in two broad categories: design-related barriers and other barriers.

<u>Design-related barriers</u>

Design-related barriers are those that can be directly linked with the design of the cartridge. They may be related to specific elements in the cartridge itself (hardware or software). These barriers are:

a) *The use of chips that cannot be reset by third party operators when the cartridge is empty.*

   As explained in section 4.5.1, chips –not present in every cartridge in the market- provide functionality such as page count, which is useful for the consumer. In some cases, when the cartridge is refilled, the chip blocks the use of the cartridge unless a reset operation is carried out. This resetting is on occasions very complex or even not possible for independent remanufacturers, which have to undertake reverse engineering activities or replace the chip with a new one.

   The complexity of the resetting operations has increased over the past years. Stakeholders in the remanufacturing industry point out that such developments are largely driven to frustrate reuse, rather than for enhancing the performance of the cartridge. According to Aston (2022), some OEMs are employing systems that recognise cartridges with a non-original chip and prevents them from working.

b) *The use of software and firmware updates to block third party cartridges, including remanufactured cartridges.*

   Periodically, devices receive software and firmware updates from OEMs, in order to allow them to work properly with new operating systems (or with updated versions of existing ones). These updates are also sent to detect (and block) the use of counterfeit cartridges.

   On occasions, these software/firmware updates change to the encryption process between the device and the chip. Legal non-OEM cartridges –such as remanufactured cartridges- sometimes cannot adapt to these changes, making them unusable (Huang et al, 2019).

c) *The use of irreversible joining practices*

   Some cartridges are designed with irreversible joining practices –such as gluing, adhesive tapes and welding- that prevent the access to components key for remanufacturing. Some of these practices require cutting cartridges plastic bodies open to replace worn parts.

d) *The location of key components such as chips in areas which are not easily accessible.*

   Some cartridges are designed with key components in locations which are of very difficult access. For instance, chips are sometimes placed in areas which does not facilitate the resetting operation.

e) *The addition of superfluous design features to make cartridges compatible with a limited number of printer models.*

   As described in section 4.5.3 of the Preparatory Study, cartridges have external design features to facilitate their installation into the device. Often new printer models are placed on the market with small changes in terms of functionality, but with relevant changes regarding cartridge compatibility. These new devices have new design features which essentially make them incompatible with existing cartridges in the market. Superfluous design features need to be added to new cartridges, in order to make them compatible with new device models (see examples in Figure 56, Figure 57, Figure 58 and Figure 59). As a result, the market is filled with a wide variety of very similar models of devices and cartridges, which provide very similar –or the same- functionality, but incompatible between them.

   This is a barrier for remanufacturing because it adds complexity to the collection and remanufacturing process. Sorting activities need to be carried out. Then, the remanufactured product can only be used in a limited number of device models.

f) *The location of fragile components such as photoreceptors in exposed areas*

   Some cartridges contain parts that are fragile and key for their performance, such as photoreceptors in all-in-one cartridges. On occasions, these components are located in exposed areas without protection (Figure 63).

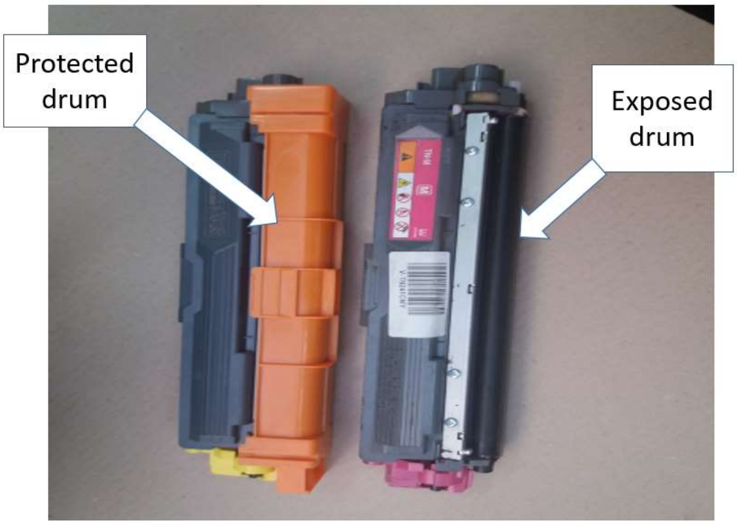


Figure 63. Examples of cartridges with protected and exposed drum

Therefore, during logistic operations of the remanufacturing process –collection, transport, storage– they get easily damaged, making the cartridge unsuitable for reuse. In order to ensure that cartridges will not get damaged during collection, some OEMs are already conducting drop tests as part of the cartridge development process.

g) *The use of fragile materials and non-durable design*

Products that are expected to be reused need to be designed with materials and features that make them durable. On occasions, cartridges are designed with fragile materials and non-durable design features, that make them unsuitable for reuse (or suitable for a very limited number of reuse cycles).

h) *The addition of logos from the OEM that need to be removed or covered by the remanufacturer*

Often cartridges are designed with incorporated OEM logos, which are usually placed to differentiate them from potential counterfeits or clones. During remanufacture, these logos may need to be removed or erased, to avoid infringing copyrights. The removal of logos can be a complex operation and even damage the cartridge, making it unsuitable for reuse.

i) *The design of cartridges with low capacity*

Similar cartridge models may have different internal capacity, and therefore page yield, as seen in section 4.5.2. Reducing the capacity of cartridges is a barrier for remanufacture since it reduces the economic viability of the remanufacturing process. In order to make full use of the cartridge capacity, the process itself is more complex, thus more expensive. Removing inner compartments can also damage or break the cartridge, making it unsuitable for reuse.

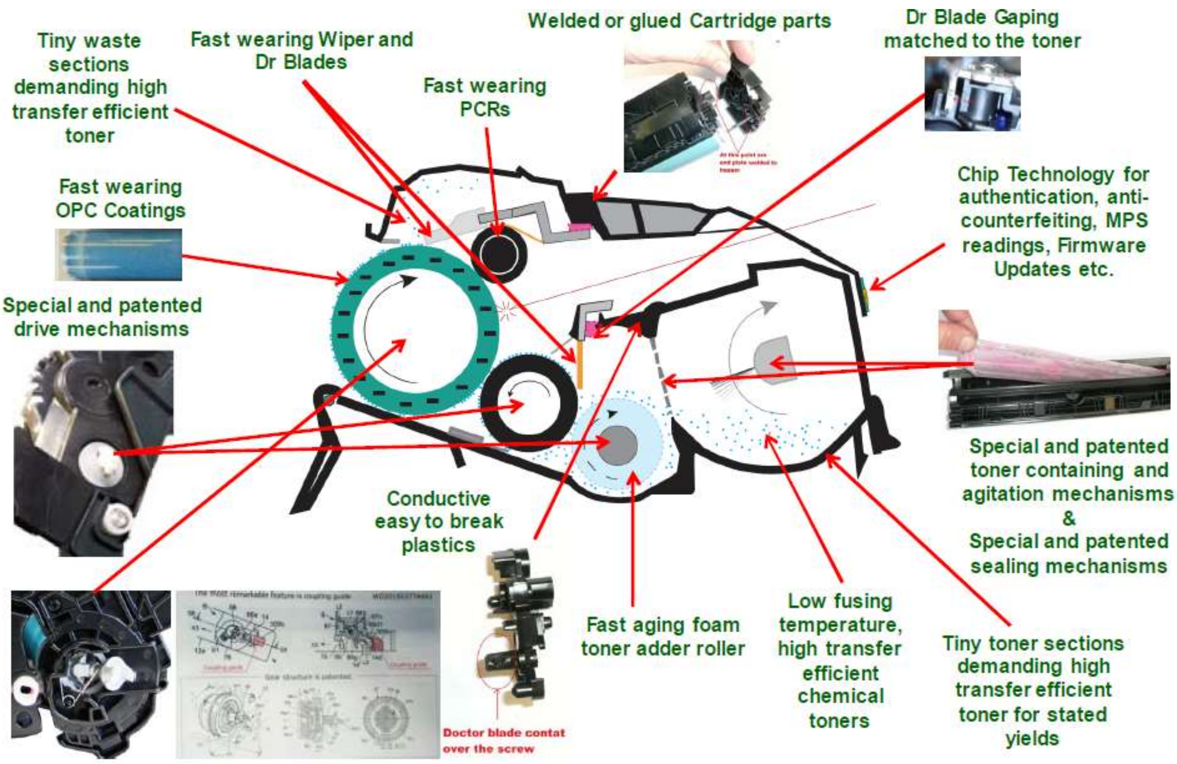
j) *The lack of information on cartridge life condition, model identification or device compatibility*

When a cartridge is collected, usually it is not possible to know how many times the cartridge has been remanufactured previously, who carried out the remanufacturing process and when. It is also difficult to identify at first sight the cartridge model and its compatibility with printer models in the market. This is all valuable information, which could help remanufacturers to determine whether or not the cartridge can be reused for one more cycle.

k) *The lack of information on how to remanufacture the cartridge*

When a cartridge is collected, often it is not possible to know the best approach for its proper remanufacturing, since no instructions are given in terms of this process.

A stakeholder from the remanufacturing industry contributed to this Preparatory Study with a graphic description of the most common barriers that remanufacturers find today in toner cartridges (Figure 64). Most of these barriers can be associated with the classification provided in a) to k).



Source: Delacamp

Figure 64. Summary of design-related barriers in toner cartridges

<u>Other barriers</u>

These are barriers that cannot be directly linked with the cartridge itself, but to market or legal aspects.

l) The sales of counterfeit cartridges

The rise of sales of counterfeits described in Section 4.5.12 is a market barrier for cartridge reuse. These cartridges are often unsuitable for subsequent reuse, as they contain toxic or restricted hazardous substances. They tend to be manufactured with lower quality materials, which reduces the cost of manufacturing. Their usual low price make them more attractive to consumers than legally remanufactured cartridges, displacing them from the market.

m) Published claims about poor quality of remanufactured cartridges

Published claims about poor quality issues with reused consumables has also been highlighted as a marketing barrier for reuse, together with the propagation of inaccurate claims about printer warranties, stating that they might be voided using non-original cartridges (Knerl, 2021). These claims can have an impact on the sales of remanufactured cartridges since consumers may fear that they will not perform appropriately. As stated in Dhebar (2016), the intent of this stratagem might be to incentivise the user to consume only the original brand.

n) Contractual bindings

Contractual aspects between OEMs and customers can operate as a barrier for cartridge reuse. Some printing subscription schemes available in the market today are an example of this. In some of these services[40] [41] [42] [43], the device will work with original supplies only. If the printer gets damaged, the cartridge may not be used in a different printer. In some other cases[44] the device may only work with

[40] https://www.epson.eu/en_EU/readyprint
[41] https://instantink.hpconnected.com/uk/en/l/v2
[42] https://www.brother.co.uk/ecopro
[43] https://www.lexmark.com/en_gb/services/lexmark-oneprint.html?cid=web-emea-gb-cust-SUBSCRIPTION-toner-finder
[44] https://www.hp.com/us-en/printers/hp-plus.html

original cartridges for the lifetime of the device. Therefore, if the user chooses to no longer use original devices, they will need to purchase a new device. These specific conditions under some subscription schemes are a barrier for cartridge reuse since they restrict customer possibility of choice in terms of cartridges, limiting it to only original ones.

o) *Closed collection programmes for used cartridges*

Some OEMs provide collection schemes in which the cartridge is sold at a discount in exchange for the customer's agreement that the cartridges will be used only once and returned only to OEM for remanufacturing or recycling[45]. These cartridges will stop working after reaching the end of the rated life established by the OEM. This can be a barrier for reuse since it limits the access to third party operators to the collection of used cartridges. If the OEM is not able to collect all cartridges that are placed on the market under these scheme, waste will be generated, since independent operators will not be able to remanufacture them.

p) *Copyrights or patents*

Legal barriers related to copyrights or patents have also been mentioned in Waugh et al (2018) as a barrier to cartridge reuse. Patents on cartridge components, or complete devices, make it harder for independent actors to undertake reuse activities as they must ensure any activity does not infringe upon the OEM's intellectual property. The authors highlight three main concerns: the inappropriate granting of patents on non-innovative aspects of cartridge design; the patenting of cartridge remanufacturing, even when the OEM does not intend to remanufacture its own cartridges; and the lack of resources of remanufacturing companies to participate in lengthy legal processes against large OEMs, even if they are operating legally.

4.5.9.2 Benefits of cartridge reuse

The potential benefits of cartridge reuse have been evaluated by a variety of authors, with studies published in peer-reviewed scientific journals, non-peer-reviewed journals, Universities, and studies commissioned by original cartridge manufacturers.

In Krystofik et al (2014), the authors compare the environmental impacts of remanufactured, refilled and new cartridges. The printing quality of the three types of cartridges is assumed the same. The study focuses on transport impacts: on one hand, the transport of a new cartridge from its manufacturing plant up to the retail shop; on the other hand, the transport related to remanufacturing/refilling it. In terms of end of life, the new refilled and remanufactured cartridges offer environmental improvement compared to new cartridges.

In Badurdeen et al (2018), a methodology is proposed to solve multi-objective product design problems considering conflicting economic and environmental objectives. The purpose is to ensure that product design is optimized considering a life cycle approach, considering the extraction of raw materials, product use and end of life alternatives. The methodology is applied on an industrial case study for the design of toner cartridges. The results show that reuse, remanufacturing and recycling strategies provide over 20% savings in total lifecycle cost, total global warming potential, and total water use in comparison to an equivalent new product.

In Berglind et al (2002), a study published by the University of Kalmar (Sweden), the authors compare the life cycle impacts of two end of life alternatives for a toner cartridge: recycling and remanufacturing. The printing quality of new, recycled and remanufactured cartridges is assumed the same. According to their results, reuse of toner cartridges is the option with the lowest environmental impacts.

In Gell (2008), a study commissioned by the UK Cartridge Remanufacturers Association, the carbon footprints of a remanufactured toner printer and a new cartridge are compared. The printing quality of the two types of cartridges is assumed the same. According to their results, the carbon footprint of remanufactured cartridges is lower: 40% lower in short-life cartridges and 60% in long-life cartridges.

In Ferrari (2008), a study conducted in the Universita di Modena e Reggio Emilia for SAPI (a company that remanufactures cartridges), the environmental impacts of new and remanufactured cartridges are compared. In this case, it is assumed that the remanufactured cartridge is able to print a higher number of pages than the new one. Based on this, it is concluded that remanufacturing a cartridge causes less environmental damage than producing a new equivalent cartridge.

[45] https://www.lexmark.com/en_gb/supply/14428/Lexmark-C-MC3224-3326-3426-Black-Return-Programme-1-5K-Print

In Kara (2010), a study conducted by the UK Centre for Remanufacturing and Reuse, the carbon footprints of a remanufactured toner cartridge and a new cartridge are compared. The printing quality of the two types of cartridges is assumed the same. According to their results, a remanufactured cartridge has a 46% lower carbon footprint than a new one. Significant materials savings are also made by remanufacturing a cartridge: a new cartridge requires 16 times more material than a cartridge refill.

In a study released by Clover[46], a company whose main business is cartridge remanufacturing, a life cycle assessment is conducted to compare remanufactured toner cartridges with equivalent OEM cartridges. Based on the environmental indicators evaluated, both black and color remanufactured cartridges were found to exhibit lower environmental impacts compared to their OEM counterparts in all significant impact categories evaluated. For instance, black and colour remanufactured cartridges had 53% and 49% less carbon footprint than OEM cartridges, respectively.

In Miyoshi et al (2022), the circularity of toner containers is evaluated using Life Cycle Simulation (LCS), focusing on component remanufacturing and the effect of circularity on life cycle cost and CO_2 emissions. The authors conclude that CO_2 emissions are reduced by 42% if the toner container is reused, compared with using a new container. The printing quality of the new and reused containers is assumed the same

In Fraunhofer Umsicht (2019), a study conducted by the Fraunhofer Institute for Environmental and Energy Technology for Interseroh, the authors evaluate the environmental savings of reprocessing and reusing toner cartridges. According to their results, reusing a single cartridge saves 4.49 kg of greenhouse gas emissions compared to new production. In addition, 9.39 kg of primary resources are saved per cartridge. In comparison, recycling a cartridge saves 0.41 kg of greenhouse gas emissions and 1.94 kg of resources.

In Chung et al (2013), a study conducted in the University of British Columbia (Canada), a comparison is made between original and remanufactured cartridges in terms of their environmental, economic and social impacts. Different printing qualities are assumed for each cartridges: remanufactured cartridges need 11% more paper to accomplish the same task. Considering this, the authors conclude that remanufactured cartridges impose a smaller toll on the environment based on material resources, greenhouse gas emissions, and waste generation.

4.5.9.3 Arguments against cartridge reuse

A variety of arguments have been given against cartridge reuse, mainly related to the factors below (Waugh et al, 2018):

- Print quality considerations.
- Unfavourable life cycle impacts.
- Non-adherence to safety, health, environmental and related issues.
- Infringement of intellectual property or brand distortion.
- Alternative printing technologies.
- Other generic issues.

In terms of print quality and the related unfavourable life cycle impacts, some organisations tend to argue that reused cartridges will not perform to the standards of OEM-approved new cartridges. In Waugh et al (2018), one OEM claimed that for highest quality demands, up to 150% more pages are required using an average remanufactured cartridge, though a 50% excess is typical over the range of quality uses envisaged. It must be noted that not every OEM considers different printing quality results between new and remanufactured cartridges: according to Waugh et al, 2018, Lexmark places the same quality guarantees on its new and remanufactured (toner cartridges).

Lower print quality with remanufactured cartridges might increase the need of reprinting documents, which would increase the amount of wasted paper. According to OEMs, the manufacturing of extra paper, substantially overwhelms the benefits of reuse. Following this approach, Since 2011, some original cartridge manufacturers (particularly HP) have been publishing studies where the environmental impact of new original and remanufactured cartridges are compared: First Environment (2004) and Four Elements (2011, 2014, 2019, 2021). The structure, assumptions and conclusions of these studies are very similar. A fundamental aspect of those studies is the printing quality difference established between new and remanufactured cartridges. In other words, more paper is used in remanufactured cartridges to produce the same amount of valid printed

[46] https://www.cloverimaging.com/lca

pages with original cartridges. The assumptions range from 8% more paper use with remanufactured cartridges in Four Elements (2021), to 38% in Four Elements (2019).

In First Environment (2004) a new HP cartridge is compared with a remanufactured cartridge. Their results indicate that critical drivers of environmental impacts over the life cycle are print quality, cartridge reliability and end of life management. According to the authors, a cartridge that reliably prints high quality pages and that is recycled at end of life, most likely has lower overall environmental impacts than a cartridge that does not share these attributes. However, the authors conclude that no definitive statement can be made about the environmental performance of one product type over the other.

In Four Elements (2011), it is assumed that remanufactured cartridges need 15% more paper to achieve the same amount of valid printed pages. It is also assumed that the original cartridge is 100% recycled, whereas the end of life fate of the remanufactured cartridge is a combination of landfill and incineration. Similar assumptions are made in the rest of studies commissioned by HP (Four Elements 2014, 2019 & 2021), both in terms of printing quality and end of life. In all those studies, the original cartridge provides better environmental performance than the remanufactured cartridge for every impact category evaluated.

4.5.9.4 Interim conclusions on cartridge reuse

The amount of published research in peer-reviewed journals addressing cartridge reuse is scarce, since only three studies have been found: Kristofik et al (2014), Badurdeen et al (2018) and Miyoshi et al (2022). In the three cases, remanufactured cartridges have been highlighted as having less environmental impact than new cartridges. It must be noted that available studies in the literature are mainly focusing on energy-dominated impact categories. Therefore, the known environmental impacts are mainly related to the energy aspects, while information and data on impacts related to materials and/or waste are lacking.

A wider variety of studies published in non-peer-reviewed journals can be found. These studies are commissioned by different actors, from remanufacturers to Universities. In all those studies, remanufactured cartridges have been highlighted as having less environmental impacts than new cartridges.

Original cartridge manufacturers have commissioned over the last years several environmental assessment studies involving cartridge reuse. In all those studies, differences in printing quality between original and remanufactured cartridges are assumed. These differences in printing quality are translated in a larger amount of paper needed to produce the same functional unit. In all those studies, original cartridges provide better environmental performance than remanufactured cartridges.

Printing quality is a parameter that influences environmental assessments and the related conclusions. In four of the studies presented, the larger paper consumption associated with remanufactured cartridges caused more favourable results for new cartridges. In contrast, despite this extra paper use, remanufactured cartridges were still the best option according to Chung et al (2013).

Cartridge print quality is a key factor when assessing whether remanufacturing is the most appropriate option from environmental perspective. Based on the analysis of bibliography, there seems to be discrepancies between the assumed printing quality of remanufactured cartridges. For a fair comparison, a common approach should be followed to establish minimum requirements in terms of printing quality. Standards such as DIN 33870-1 and DIN 33870-2, which define the quality requirements for the remanufacturing process of toner modules (monochrome and colour, respectively) may be of help.

4.5.10 Cartridge recycling

Cartridge recycling can be divided in the following steps:

- Cartridge collection, usually through a take-back scheme
- Transport to a recycling facility
- Manual sorting of cartridges, to remove packaging elements and sort them by cartridge type
- Optical sorting of cartridges
- Automatic disassembly, to separate different materials such as precious metals, foams and plastics.
- Plastic shredding, where different types of plastics are also separated
- Addition of plastic materials from other sources (such as discarded bottles), to create the final resin used to manufacture new cartridges.

Recycling activities are widely described in OEM's Corporate Sustainability Reports:

- In 2007 Lexmark established a recycling plant in Juarez, Mexico, to provide customers a place to return their empty laser cartridges for responsible end-of-life reuse or recycling (Lexmark, 2021)
- Brother collects end-of-life toner cartridges and remanufactures them at the Brother Group's recycling sites into toner cartridges having the same quality as brand new products, then delivered to customers again. In FY2021, the Brother Group as a whole remanufactured 2.78 million toner cartridges, (Brother, 2022).
- In a similar way, Canon, in order to maximize the value brought about by resource recycling, pursues product-to-product recycling. Canon collects cartridges post-use and making them into products with good-as-new quality. Currently, Canon has five sites conducting recycling, in Japan, Europe (two sites), the United States, and China (Canon, 2022).
- Epson states that following collection, from most of the EU countries, all treatment and recycling is managed by CloseTheLoop in Belgium (Epson, 2022).
- In HP (2022), the OEM states that 10,300 tonnes of Original HP and Samsung toner cartridges were recycled, and that 84% of materials recovered were used in other products. Moreover, 1,500 tonnes of Original HP Ink Cartridges were recycled, with 67% of materials recovered used in other products.
- Kyocera (2021) states that they have been working on collection and reuse of toner containers since 1998. Empty toner containers sent from customers are collected at a collection center and then transported to a recycling plant. After separating the cassettes into individual components, the polymers in the toner cassette are separated and then granulated and prepared for reuse as "recyclate" which can be added to brand new materials to manufacture a variety of products.

4.5.11 Cartridges sent to landfill and incineration

Printer cartridges constitute an important part of electronic waste, mainly due to their limited operational life, resistance to degradation after disposal, and environmental and economic challenges in recycling/reuse, as seen in previous sections. When disposed in landfills, they cause soil and water pollution leading to a multitude of health hazards (Parthasarathy, 2021).

There are no comprehensive studies analysing the amount of waste sent to landfill or incineration from discarded cartridges in the EU. The conclusions of the available studies are summarised below:

- In Huang et al (2019) it is published that 60-70% of all cartridges end on landfills or incinerated after a single use. As a whole industry, this meant around 30.000-50.000 tonnes of printer cartridges landfilled and incinerated in 2015
- In Waugh et al (2018), it is stated that a substantial fraction (over 70%) of used cartridges is consigned as waste and undergoes recovery operations. It is considered that very little of this undergoes preparation for reuse due to cartridges being easily damaged when a careful collection system is not in place. Based on material flows published, around 33% of inkjet cartridges and 14% of toner cartridges end up being landfilled.
- In the U.S., more than 500 million printer cartridges are sold per year in the U.S. Over 375 million empty ink and toner cartridges are thrown away and most of them end up in landfills (Ding et al, 2020).
- In Oldyrevas (2021), a study conducted by the organisation ECOS, the authors state that cartridges are responsible for 150000 tonnes of electronic waste, of which around half is estimated to be either incinerated or landfilled
- In Parthasarathy (2021), it is stated that about one million printer cartridges are disposed every day on a global scale. Each cartridge contains about eight percent of unused toner by weight, amounting to the release of 6000 tons of carbon powder into the environment

4.5.12 Legal aspects related to cartridges

Ecodesign regulation aims at implementing technical requirements to improve the environmental performance of products, focusing on significant environmental aspects. Despite not being technical issues strictly, some legal issues have been identified within this industry which indirectly may have an effect on environmental aspects. This section focuses on describing the nature of these legal issues.

Depending on the supplier, cartridges can be classified as OEM cartridges or compatible cartridges. OEM cartridges are manufactured by an OEM, branded as OEM, designed for use with an OEM device. Compatible cartridges are also known as new built cartridges (NBCs). These are not produced by an OEM, and are not branded as OEM, but have been designed for use with an OEM device.

When a compatible cartridge has been designed violating some intellectual property (patent, copyright, trademark), it is commonly known as a 'cloned' cartridge. When it has been labelled, packaged, and marketed in such a way that is intended to mislead a customer into thinking it is an OEM cartridge, it is known as a 'counterfeit' cartridge.

According to Huang et al (2019), the rise in sales of the counterfeit cartridges from Asia is seen as a high threat within the industry (it must be noted that in Huang et al, 2019, counterfeit and cloned cartridges are considered the same). The imports of clones can undercut original cartridge producers through a combination of lower quality units and lower manufacturing standards, particularly in their health and safety aspects.

In terms of compatible, cloned and counterfeit cartridges, some OEMs in Eurovaprint highlight that:

- *Newbuild/clone cartridges are not remanufactured due to low quality, IP risk and concerns over hazardous materials, and they add costs for those trying to collect OEM cartridges who then must pay to discard unwanted newbuild/clone cartridges.*
- *Newbuild/clone low prices (in many cases due to government subsidies) seriously impact market viability of remanufactured cartridges. They also reduce the value of and the incentive to collect empty cartridges.*
- *Many remanufacturers have been compelled to sell newbuild cartridges and some newbuild companies sell remans. Some companies have an incentive to confuse the issues to encourage the EU to enable newbuild cartridges rather than remanufactured cartridges.*
- *While some newbuild/clone companies invest in R&D, it is primarily to circumvent IP as opposed to add performance, improve customer experience, or reduce the environmental impact.*
- *Clones are simply newbuild cartridges that disregard OEM IP to produce the lowest price and get to market faster. Unfortunately, it can take technical knowledge and inspection to separate NBCs from clones.*
- *Counterfeiting is about deceiving customers into thinking they are buying an OEM cartridge. Counterfeiters need to source cartridges. While newbuilds/clones are generally the cheapest and therefore preferred by counterfeiters, remans will be used if the price difference is sufficient. When available, counterfeiters use a 3rd party chip configured to be recognized by the system as an OEM original. Therefore, authentication of chips is required to protect the OEM brand and consumers.*

In Waugh et al (2018) views from different members of the industry are also presented:

- *In response to increased market pressure from compatible cartridges, OEMs will continue to shift to print service business models. This may adversely affect remanufacturers, for example through their ability to collect core and access to customers who are tied to OEMs.*
- *There was a strong view that South-East Asian imports of compatible cartridges would put remanufacturers under severe pressure unless the imports are subject to the same stringent manufacturing and quality requirements as local production.*
- *A number of OEMs and third party refillers raise the issue of consumables which do not meet EU health and safety considerations being used in cloned and compatible cartridges. These issues largely originate from suppliers outside the EU. There are concerns that, for example, toners or inks contain substances not approved for use in the EU; or that the conditions under which these substances are made and placed into consumables do not conform to workplace conditions acceptable to the EU. Such short-cuts are likely associated with cost-cutting, thus presenting unfair cost advantages in addition to the health concerns.*

Cartridge collectors and remanufactured from ETIRA association shared examples of counterfeit cartridges packaging containing symbols mimicking environmental labels and compliance with other EU regulation such as RoHS. The packaging of these cartridges seemed undistinguishable from original cartridges for a non-expert in the market. The packaging did not contain information either about the supplier of the cartridge.

The potential presence of toxic chemicals is a concern as well related to low quality compatible cartridges. According to ETIRA[47], In October 2019 industry media reported that several newbuilt non-OEM cartridges had been found to contain excessive levels of Decabromodiphenylether (DecaBDE), a halogenated flame retardant that, because of its health risks, had been prohibited in the EU since 2008 in electronics above certain levels, and fully prohibited in many other products. The original OEM equivalent did not contain DEcaBDE. It was observed that four of those non-OEM cartridges had DecaBDE levels ranging from 2,000 mg/kg to 17,000 mg/kg, although only 1,000 mg/kg of (0.1% w/w). The wider group of polybrominated diphenyl ethers (PBDE) is also only allowed at levels lower than 0.1% w/w according to the RoHS Directive 2011/65/EU.

The Italian remanufacturing association PACTO also highlighted the issue of false "remanufactured origin" claims for products placed on Italian market in the context of the application of mandatory Green Public Procurement Criteria. In this context, the Ecodesign Directive could be ensure that correct information about the significant environmental characteristics of the product (e.g. remanufactured origin), first of off providing solid definitions and conditions (e.g. traceability) to claim "remanufactured origin", and having this information correctly accompanying the product when it is placed on the market.

As stated in Huang et al (2019), enforcement of existing EU legislation including WEEE, RoHS and patent rights on producers of cloned consumables would help to alleviate the negative impacts of these products. For example, enforcing WEEE obligations on producers of cloned cartridges would ensure that they were not only responsible for providing information on reuse and environmentally sound treatment of the products and components within one year but that they would also have to aim to improve product design to facilitate recycling and reuse of components and materials. Enforcement of RoHS restrictions on clone cartridges would ensure that these product types had a toxicity profile the same as OEM cartridges. However, enforcing environmental legislation is complicated by the fact that these cartridges infringe intellectual property rights, and so, should not be on the EU market at all.

4.6 Base cases

The base cases (BC) are used as reference for modelling the stock of products together with their environmental and economic impacts and the available improvement design options (Task 5). Base cases reflect average EU products. Due to the technical differences, market relevance, applications and users of the imaging equipment and consumables in the scope, multiple base cases are proposed for each product category identified.

4.6.1 Device base cases

The definition of the device base cases have considered market data described in Task 2 of this Preparatory Study. The market of consumer inkjet devices is dominated by the sales of multi-function printers (MFP) with 12 million units sold in 2022 in Western Europe (IDC, 2023). The trend for these devices is downwards but it is still expected to be the highest seller in the short-term. In contrast, around 0.35 million units of single-function inkjet printers were sold in 2022 (3% of market), with a very slight decrease expected in the following years (IDC, 2023).

In the laser printer sector, the highest sales in 2022 corresponded to printers A4 Monochrome devices, with 1.4 million and a downward trend and shift toward mulfi-function devices. Multi-function printers A4 monochrome achieved 1.3 million sales, with multi-function printers A4 monochrome showing the fastest-growing market, expected to be the dominant devices in the short-term. With 0.6 million, multi-function printers A3 colour are the most common device with A3 capability. Single-function printers with A4 capability and color have a downward trend and less than 0.3 million sales in 2022.

In laser printers a very relevant performance parameters is the printing speed (see section 4.4.2). As showed in Figure 34 this parameter has a relevant impact also in terms of energy consumption. For this reason, the base cases proposed below are also characterised in terms of printing speed range.

Based on this information, the following base cases are proposed.

Table 48. Device base cases

Base Case	Description
BC1Dev	Laser multi-function printer, with A4 capability, printing speed 20-40 ipm

[47] https://www.etira.org/posts/etira-commissioned-tests-find-hazardous-decabde-in-more-newbuilt-non-oem-cartridges/

BC2Dev	Laser printer, with A4 capability, printing speed 20-40 ipm
BC3Dev	Laser multi-function printer, with A3 capability, printing speed 40-60 ipm
BC4Dev	Inkjet multi-function printer, with A4 capability
BC5Dev	Inkjet printer, with A4 capability

The definition of device base cases has been done with the aim of covering typical uses of devices (home/small office versus big office) and features (single-function versus multi-function). This is summarized in Table 49.

Table 49. Device base cases, typical uses and features

	Single-function (printing)	Multi-function (printing, copying, scanning, fax)
Home (A4 capability)	BC5Dev	BC4Dev
Small office (A4 capability)	BC2Dev	BC1Dev
Big office (A3 capability)	--	BC3Dev

The base cases defined also intend to represent the characteristics of the market today:

- BC1Dev represents laser multi-function printers with A4 capability, monochrome and color (52% of laser market).
- BC2Dev represents laser printers with A4 capability with A4 capability, monochrome and color (38% of laser market)
- BC3Dev represents laser printers with A3 capability, monochrome and color (13% of laser market)
- BC4Dev represents inkjet multi-function printers with A4 capability (98% of inkjet market)
- BC5Dev represents inkjet printers with A4 capability (2% of inkjet market). Despite having a low market share within the inkjet sector, in absolute terms the total sales of inkjet printers (around 0.3 million per year) are still comparable to some categories of devices in the laser sector. Therefore, it has been decided to include a base case for single-function inkjet printers.

4.6.1.1 Energy and power consumption of device base cases

In section 4.4.1 of this Preparatory Study, an analysis has been carried out on device energy and power consumption. For the definition of the device base cases, data on more narrow ranges of printing speed have been used from the database of registered products in Energy Star in order to better represent the average performance of base case devices. As example, for the determination of the Energy Average TEC (kWh/week) for BC1Dev, covering devices in the interval 20-40 ipm, the base case TEC has been based on the average performance of devices in the central range of speed (28-32) ipm. A similar approach has been applied for BC2Dev and BC3Dev. Based on that, in terms of energy consumption, device base cases can be defined as in Table 50.

Table 50. Device base cases and energy consumption

Base case	Energy Average TEC (kWh/week)	Power Sleep state (W)	Power Standby/off (W)
BC1Dev	0,39 kWh/week	--	--

BC2Dev	0,41 kWh/week	--	--
BC3Dev	0,91 kWh/week	--	--
BC4Dev	--	1,10 W	0,10 W
BC5Dev	---	1,02 W	0,15 W

4.6.1.2 Lifetime of device base cases

In order to characterize the typical lifetime of inkjet devices, data from the existing literature and the consumer survey conducted in Task 3 have been considered:

- In HOP (2017), an analysis was conducted to better understand the environmental, social and technical issues behind printers and cartridges. In this study, it is estimated that the average lifetime of an inkjet printer is around 3 years.
- In ADEME (2019), an analysis is conducted on the environmental and economic consequences of product lifetime extension of different products, including printers. In this report, the authors consider that the potential lifetime of a printer is 6 years. In the analysis section, their hypothesis is that lifetime of printers is generally not fulfilled.
- In Huang et al. (2019) a typical lifetime of 5 years was applied to inkjet devices, based on the inputs of the stakeholders, although technical evidence collected in the preparatory study suggested 4 years.
- According to the consumer behaviour survey (IPSOS, 2023) carried out in the framework of this preparatory study, the most typical age interval of single-function consumer printers [48]in use is in the range of 3 to 5 years old. Nevertheless, the highest percentage of multi-function printers in use are in the 0 to 3 years old range.
- According to the interviews with stakeholders and evidence collected, the refurbished market for consumer inkjet printers is negligible and does not have a significant impact on the lifetime of this product category.

Based on the evidence above a lifetime of 4 years is considered a reasonable assumption for BC4Dev and BC5Dev.

In the case of laser devices, literature review and data gathered in stakeholder consultation and form visits to refurbishing plants have been used to define the typical lifetime (see more in section 4.4.3):

- In Huang et al. (2019) a typical lifetime of 6 years was applied to laser devices, based on the assumption of the Energy Star saving calculator[49]
- Based on interviews and data provided by a market relevant EU refurbisher of office printers, the devices are in general replaced after a period between 4 and 6 years.
- Interviews and evidence collected showed the existence of an already quite lively refurbishing sector managed by both OEMs and independent operators. There are not yet clear data on the market relevance of this refurbishing sector. However, it can be assumed that refurbishing activities are already partially contributing to extend the lifetime of a fraction of the laser devices placed in the EU market. In the absence of more comprehensive data, JRC has estimated that in a baseline scenario refurbishing activities are already able to extend the lifetime of the European laser printers fleet by one additional year.

Therefore, first use lifetime for base cases expected to be used in the office environment (BC1Dev, BC2Dev and BC3Dev) is assumed to be 5 + 1 years (6 years).

The lifetime of a printer can be also defined in terms of printed pages. In order to estimate the baseline average printed pages for inkjet printers and MFD the following data have been considered:

[48] Inkjet is the dominant technology in the home accounting for 95% of placements in 2021 and rising to more than 98% by 2026 (Keypoint Intelligence, 2023).
[49] https://www.sfwmd.gov/sites/default/files/documents/calculator_energy_star_res_appliance_savings.xlsx

- The study from Huang et al. (2019) estimated 6,500 pages for colour Inkjet MFD and 10,500 for Colour Inkjet Printers.
- According to Keypoint (2023), the COVID crisis and the digitalisation trend have been reducing the number of total printed pages, compared to the values of 2019 (see section 2.2). This trend is expected to continue in the next few years.
- Results from the IPSOS survey confirm this decreasing trend. According to the survey results consumers print a mean of 88.5 pages per month. Considering a lifetime of 4 years, it means around 4,250 pages over the entire lifetime of the printer.

In the case of laser devices, the available data/information considered are:

- Around 50% of printers under MPS contracts are retired with less than 100.000 pages printed (source: Nubeprint).
- Huang et al. (2019) estimated the average lifetime in terms of printed pages for laser MFD is 350,000 pages for monochrome and 576,000 for colour laser, with lower numbers of printed pages for laser printers: 53,000 for monochrome device and 120,000 for colour.
- A huge drop in printed pages/images occurred during the COVID crisis (almost 50% during the 2020 and 2021) and printed pages are not expected to recover to the pre-covid level (Keypoint Intelligence, 2023).

Data collected seem to suggest that many of the laser devices reaching the end of life in the next few years will be devices underutilised compared to their designed duty cycle. Based on the current market situation it can be reasonably expected a reduction compared to the number of printed copies estimated in the previous version of the Preparatory Study (Huang et al., 2019).

Baseline lifetime of device base cases is proposed in Table 51.

Table 51. Device bases cases and lifetime

Base case	Description	Average first use lifetime (years)	Average extension of the lifetime by refurbishing (years)*	Average total lifetime (years)	Average printed pages
BC1Dev	Laser multi-function printer, with A4 capability, printing speed 20-40 ipm	5	1	6	200.000
BC2Dev	Laser printer, with A4 capability, printing speed 20-40 ipm	5	1	6	100.000
BC3Dev	Laser multi-function printer, with A3 capability, printing speed 40-60 ipm	5	1	6	300.000
BC4Dev	Inkjet multi-function printer, with A4 capability	4	0	4	4.000
BC5Dev	Inkjet printer, with A4 capability	4	0	4	4.000
*this estimation take in to consideration that only a minor fraction of the EU fleet is reused at the end of the first lifetime.					

4.6.1.3 Reparability of device base cases

In section 4.4.3 an analysis is made on reparability of devices. Reparability is a semi-qualitative aspect of a product that cannot be directly measured and characterized with a specific value. However, it can be characterized with aspects such as:

- Spare part provision
- Duration of availability of spare parts
- Delivery time of spare parts
- Cost of spare parts
- Provision of relevant information of repair
- Availability of software and firmware updates

For the characterization of the base cases, information from Ritthoff et al (2023) will be used. In that study, a repair score methodology is proposed for printers. For each of the indicators above, four categories are defined from A-D (A being the best and D being the worst). In this Preparatory Study, it is proposed to use these categories to characterize device base cases and Best Available Technologies. It has been assumed that category C in Ritthoff et al (2023) for each of the indicators is the one that most accurately reflects device base cases. As a result, the characteristics of the base cases can be seen in Table 52. Those characteristics will be common for the 5 base cases proposed.

Table 52. Reparability of Base cases

Reparability aspect	Characteristics of Base Cases (BC1Dev, BC2Dev, BC3Dev, BC4Dev, BC5Dev)
Disassembly	High complexity
Spare part provision	A limited list of spare parts, most of them only available to authorised service partners
Duration of availability of spare parts	Short term availability of spare parts (2 years)
Delivery time of spare parts	15-21 working days
Provision of relevant information of repair	Basic information available
Availability of software and firmware updates	Short term availability of software and firmware updates (2 years after the placing on the market of the last unit of a product model)

4.6.1.4 Other aspects of device base cases

In this section, other relevant aspects of the device base cases are described (Table 53)

Table 53. Other relevant aspects of device base cases

Base case	Description	n-up printing	Duplexing capability	Noise[50]
BC1Dev	Laser multi-function printer, with A4 capability, printing speed 20-40 ipm	available	available	Noise level not provided
BC2Dev	Laser printer, with A4 capability, printing speed 20-40 ipm	available	available	Noise level not provided

[50] Compliance with Technical Specification 10 of the EU GPP Criteria for Imaging Equipment (Kaps et al, 2020)

BC3Dev	Laser multi-function printer, with A3 capability, printing speed 40-60 ipm	available	available	Noise level not provided
BC4Dev	Inkjet multi-function printer, with A4 capability, printing speed <20 ipm	available	available	Noise level not provided
BC5Dev	Inkjet printer, with A4 capability, printing speed <20 ipm	available	available	Noise level not provided

It has been assumed that all device base cases contain n-up and duplexing capability. It has also been assumed that all device base cases do not provide information on the sound level.

4.6.1.5 Materials used in device base cases

The bill of materials of the BC1Dev and BC2Dev are presented in Table 54.

Table 54. Device base cases bill of materials

Material breakdown	BC1Dev[51] (kg)	BC2Dev[52] (kg)	BC3Dev[53] (kg)	BC4Dev[54] (kg)	BC5Dev [55] (kg)
Bulk Plastics	11.5	4.9	26.2	3.7	2.2
TecPlastics	10.2	1.5	10.3	0.5	0.6
Ferro	27.7	4.4	94.1	1.3	0.8
Non-ferro	3.0	0.5	9.9	0.1	0.3
Coating	0	0.4	0	0	0
Electronics	6.3	1.5	2.9	0.6	0.2
Miscellaneous	9.6	2.1	5.3	1.1	0.4
Total weight	68.2	15.3	148.6	7.3	4.4

As it can be seen in Table 54, Huang et al (2019) has been used as a reference to define the bill of materials of the device base cases. For each base case in the current Preparatory Study, the closest one in Huang et al (2019) in terms of performance and functionalities has been selected. The bill of materials of the device base cases may be refined via stakeholder feedback. Stakeholders are encouraged to share with the JRC up to date data that reflects the bill of materials of devices more accurately.

4.6.1.6 Purchase price of device base cases

A simple market analysis has been carried out by the JRC to define purchase price of device base cases. Retail websites have been used as main source of data. Devices that comply with the characteristics of the base cases have been searched. Average purchase prices for these devices have been registered. Table 55 shows purchase price of the device base cases defined in this section.

Table 55. Purchase price of device base cases

Source: own market research

[51] Base Case 2 in Huang et al (2019)
[52] Base Case 3 in Huang et al (2019)
[53] Base Case 7 in Huang et al (2019)
[54] Base Case 5 in Huang et al (2019)
[55] Base Case 6 in Huang et al (2019)

Base Case	Description	Purchase price (EUR)
BC1Dev	Laser multi-function printer, with A4 capability, printing speed 20-40 ipm	500 EUR
BC2Dev	Laser printer, with A4 capability, printing speed 20-40 ipm	300 EUR
BC3Dev	Laser multi-function printer, with A3 capability, printing speed 40-60 ipm	2000 EUR
BC4Dev	Inkjet multi-function printer, with A4 capability, printing speed <20 ipm	200 EUR
BC5Dev	Inkjet printer, with A4 capability, printing speed <20 ipm	100 EUR

Table 55 is an initial attempt to characterize device base cases in terms of purchase price that may be refined in subsequent sections of this Preparatory Study, via stakeholder feedback and further market research. Stakeholders are encouraged to share with the JRC up to date data that reflects the market of devices more accurately.

4.6.2 Cartridge base cases

The definition of cartridge base cases will be done considering market data presented in Task 2 of the Preparatory Study.

The definition of cartridge base cases has also been done taking into account their function. It has been considered that the function of a cartridge is holding toner or ink, unrelated of its configuration (single-part cartridge, all-in-one cartridge, etc.). Therefore, the definition of cartridge bases has been done deliberately without specifying a specific configuration.

To define page yield of laser cartridges (BC1Car and BC2Car), data from ETIRA database has been used (Figure 50). According to data provided by ETIRA, most of the toner cartridges in the sample have a page yield between 1000 and 4000 pages. For BC1Car it will be assumed that page yield is 2500 pages. For BC2Car (expected use in a large office A3 capability device), page yield will be assumed as 7500 pages.

To define page yield of BC3Car, data from Figure 44 will be used, since it represents better the most common ink cartridges purchased by consumers. Therefore, it will be assumed that page yield is 300 pages.

Cartridge base cases for the Preparatory Study are defined in Table 56.

Table 56. Cartridge base cases

Base Case	Description
BC1Car	Toner cartridge for A4 capability device, page yield: 2500 pages
BC2Car	Toner cartridge for A3 capability device, page yield: 7500 pages
BC3Car	Ink cartridge for A4 capability device, page yield: 300 pages

The base cases defined also intend to represent the characteristics of the market today:

- BC1Car represents toner cartridges for A4 capability devices
- BC2Car represents toner cartridges for A3 capability devices
- BC3Car represents ink cartridges for A4 capability devices

Cartridge base cases can be aligned with device base cases (Table 57).

Table 57. Alignment of device base cases and cartridge base cases

Device Base Case	Description of Device Base case	Cartridge Base case
BC1Dev	Laser multi-function printer, with A4 capability, printing speed 20-40 ipm	BC1Car
BC2Dev	Laser printer, with A4 capability, printing speed 20-40 ipm	BC1Car
BC3Dev	Laser multi-function printer, with A3 capability, printing speed 40-60 ipm	BC2Car
BC4Dev	Inkjet multi-function printer, with A4 capability	BC3Car
BC5Dev	Inkjet printer, with A4 capability	BC3Car

4.6.2.1 Material efficiency of cartridge base cases

Page yield of cartridge base cases has been defined in section 4.6.1. In order to estimate cartridge material efficiency, the best-fit trendline will be calculated using data in Figure 52 and Figure 55.

For toner cartridges:

Material efficiency = 0.0039*Page yield - 7.35

For ink cartridges:

Material efficiency = 0.0163*Page yield + 20.15

Cartridge base cases are defined in terms of page yield and material efficiency, using data from

Table 58. Cartridge base cases, page yield and material efficiency

Base Case	Page yield (number of pages)	Material efficiency (pages/gram of material)
BC1Car	2500	2.4
BC2Car	7500	21.9
BC3Car	300	25.0

4.6.2.2 Reusability of cartridge base cases

Reusability is a semi-qualitative factor that cannot be directly measured, for which it is complex to assign a specific value (similar to the case of printer reparability). Therefore, cartridge base cases (and Best Available Technologies) will be defined using a series of indicators.

In this Preparatory Study, it is proposed that the list of indicators to characterize cartridge base cases is the list of barriers for cartridge reuse identified in section 4.5.8.1 of this report, a) to k). Therefore, a cartridge base case may be defined as a cartridge with the following characteristics:

> *The cartridge base case is a cartridge with a chip that cannot be reset by third party operators when the cartridge is empty. It uses irreversible joining practices such as gluing and welding in some components. It uses non-durable materials that can be broken during the remanufacturing process. Some fragile components are exposed. It is compatible with a limited number of printer models of the same OEM.*

Based on those characteristics, an average factor for reusability will be defined. This factor should reflect how likely a cartridge may be reused, based purely on its technical characteristics. Inefficiencies during collection and other economic and market aspects are not taken into account in the estimation of this factor. The aim is to focus only on aspects related to the design of the cartridge.

Therefore, values from Table 46 will be used to estimate cartridge reusability. For a given cartridge, it will be assumed that:

*Reusability = Viable percentage * Remanufacturing rate*

Based on that, reusability of cartridge base cases can be seen in Table 59.

Table 59. Cartridge base case reusability

Base case	Reusability (%)
BC1Car	38%
BC2Car	38%
BC3Car	48%

4.6.2.3 Printing quality of cartridge base cases

Print quality of the base cases will be defined based on the amount of usable pages they produce. For this, assumptions will be made based on the data presented in sections 4.5.5 (print quality) and 4.5.9.3 (arguments against cartridge reuse). Most of the studies presented on those sections compare the printing quality -in terms of paper use- between original and non-original/remanufactured cartridges. However, in this section it is necessary to establish differences between base case printing quality and best available technologies printing quality. The JRC team proposes to define printing quality as printing reliability, in terms of failure rate. For all cartridge base bases, a 3% failure rate is proposed.

Table 60. Printing quality

Base case	Failure rate (1)
BC1Car	3%
BC2Car	3%
BC3Car	3%

(1) Percentage of unusable sheets of paper

4.6.2.4 Materials used in cartridge base cases

As explained above, cartridge base cases have been defined without specifying a specific cartridge configuration, using a technology-neutral approach. The base cases do not represent a specific cartridge in the market, but a theoretical one that aims to represent the average product on market in terms of material use, emissions and functional performance within its segment.

According to the MEERP methodology, the BC may or may not be a real product that one can buy on the market. Especially when the market is made up of different technologies, the BC can be a virtual (non-existing) product with the average sales-weighted characteristics of all technologies around. Therefore, due to the configuration variety of toner and ink cartridges (described in Task 4) the bill of materials of the base cases will represent those theoretical products based on average design configuration. BC1Car is an 80/20 average bill of materials of an all-in-one toner cartridge and a single-part toner cartridge, based on the list of materials proposed in Huang et al (2019). BC2Car is a cartridge with the same proportion of materials, with A3 capability, so it has been assumed to have double mass for all materials and 3 times as much toner. BC3Car is a 20/80 average bill of materials of an integrated ink cartridge and a single-part ink cartridge.

The resulting bill of materials of the cartridge base cases can be seen in Table 61.

Table 61. Cartridge base cases bill of material

	BC1Car (g)	BC2Car (g)	BC3Car (g)
	Toner cartridge for A4 capability	Toner cartridge for A3 capability	Inkjet cartridge for A4 capability
Bulk Plastics	324	648	35.4

TecPlastics	98.8	197.6	1
Ferro	179.4	358.8	0.92
Non-ferro	50.2	100.4	0
Coating	8	16	0.02
Electronics	2.6	5.2	0.04
Deposition material	158.8	476.4	40
Miscellaneous	116.2	232.4	8.8
Total mass	938	2034.8	86.18

Stakeholders are encouraged to share with the JRC up to date data that reflects the bill of materials of cartridges more accurately.

4.6.2.5 Purchase price of cartridge base cases

In section 4.5.2.5, an analysis was presented on a market study conducted by the JRC on page yield and material efficiency of ink and toner cartridges. In that study, data on page yield, mass and price of the cartridges was collected. Based on that data, average cost per page can be calculated for ink (0.05 EUR per page) and toner cartridges (0.04 EUR per page). No market data was collected for cartridges used in large offices. It will be assumed that the cost per page in these environments is significantly lower than in small offices or in households (0.02 EUR per page). Based on this, the cost per page of the cartridge base cases can be seen in Table 62.

Table 62. Purchase price of the cartridge base cases

Base case	Cost per page (EUR/page)	Page yield (as in Table 58)	Purchase price (EUR)
BC1Car	0.04	2500	100
BC2Car	0.02	7500	150
BC3Car	0.05	300	15

Source: own market research

Page yield for cartridge base cases has been defined in Table 58. The purchase price of each device has been estimated as: Purchase price = Cost per page (EUR/page) * Page yield (pages). Stakeholders are encouraged to share with the JRC up to date data that reflects the market of cartridges more accurately.

4.7 Best Available Technologies

4.7.1 Devices Best Available Technologies

4.7.1.1 Energy and power consumption

In section 4.4.1, an analysis is made on average energy and power consumption of MFDs and printers, for different ranges of printing speeds. This analysis is used to define the base cases of this Preparatory Study.

For the identification of the Best Available Technologies regarding energy and power consumption, it will be assumed that they correspond to the best 10% percentile.

In laser printers, Typical Electricity Consumption (TEC) is correlated with printing speed (ipm). Therefore, a BAT will be identified for specific speed ranges:

- For a laser device in the range of 28-32 ipm, the BAT TEC is 0.34 kWh/week.
- For a laser device in the range of 48-52 ipm, the BAT TEC is 0.60 kWh/week
- For a laser device in the range of 70-72 ipm, the BAT TEC is 0.92 kWh/week
- The BAT default delay time to sleep in a laser device is 1 minute.
- The laser device contains a button or switch that immediately turns the device in standby mode.

In inkjet printers, Power in Sleep mode and Power in off mode are not correlated with printing speed. Therefore, the BAT will be identified without specifying a range of printing speed:

- For an inkjet printer, the BAT Power in Sleep mode is 0.6 W.
- For an inkjet MFD, the BAT Power in Sleep mode is 0.07 W.
- For an inkjet printer, the BAT Power in off mode is 0.75 W.
- For an inkjet MFD, the BAT Power in off mode is 0.07 W.
- The BAT default delay time to sleep in an inkjet printer or MFD is 1 minute.

In office printers an Availability of a clearly displayed energy saver programme like in the picture below:

- The availability of an easy to reach function allowing the machine to enter the Sleep mode in an easy and quick way, by pressing a simple button (Energy Saver)[56] (see Figure 65)
- The availability of an ECO Night Sensor that can detect darkness and automatically turn off this product's power. If ECO Night Sensor[57] is enabled and detects darkness in a room after the lights are turned off, the sensor automatically turns the power off and reduces the power consumption of this product to 1W or less.

Figure 65: Example of Energy Saver Functionality

4.7.1.2 Lifetime

In section 4.4.3.1 of the Preparatory Study, data provided by stakeholders on device lifetime in the business sector was presented. According to this feedback, a 4-year old device with 85% of remaining lifetime can be refurbished up to its initial conditions. A device can be refurbished up to 3 times. Its technical lifetime can be estimated between 12-14 years. It will be assumed that lifetime of the BAT in the office environment (laser printers) is 14 years.

As described in 4.4.3.2, there is a gap between actual device lifetime of domestic printers (between 3-5 years) and the expected lifetime by consumers before replacing it (between 5-10 years). Moreover, according to the

[56] http://ppbwiki.rz-berlin.mpg.de/uploads/Main.CanonImageRunnner/manual/uk_iRADV_500i_Manual/contents/1T0002183321.html

[57] http://support.ricoh.com/bb_v1oi/pub_e/oi_view/0001057/0001057280/view/manual/int/0052.htm

user survey a 5% of the respondents declared to have a printer older than 10 years. For the characterization of the BAT, it will be assumed that consumer expectations in terms of device lifetime are fulfilled. Therefore, BAT of inkjet printers longevity is considered to be 10 years.

4.7.1.3 Reparability

In this Preparatory Study, it is proposed to use the categories defined in Ritthoff et al (2023) to characterize device base cases and Best Available Technologies. It has been assumed that the 1st category in Ritthoff et al (2023) for each of the indicators is the one that most accurately reflects device Best Available Technologies. As a result, the characteristics of the BATs can be seen in Table 63.

Table 63. Reparability of Best Available Technologies

Aspect	Inkjet Printers	Laser Printers
Disassembly	Characteristics of Best Available Technology: - Repair feasible with basic tools - Use of removable fasteners - The number of work steps required to disassembly a priority part is ≤ 70% of the mean value	Characteristics of Best Available Technology: - Repair feasible with basic tools - Use of removable fasteners - the number of work steps required to disassembly a priority part is ≤ 70% of the mean value
Spare part provision	A comprehensive list of spare parts, available to end-users and professional repairers	A comprehensive list of spare parts, available to end-users and professional repairers
Duration of availability of spare parts	Long term availability of spare parts (10 years)	Long term availability of spare parts (14 years)
Delivery time of spare parts	2 working days for consumables 2 working days for other priority parts	2 working days for consumables 4 working days for other priority parts
Provision of relevant information of repair	Comprehensive information available for users and repairers	Comprehensive information available for users and repairers
Availability of software and firmware updates	Long term availability of software and firmware updates (10 years after the placing on the market of the last unit of a product model)	Long term availability of software and firmware updates (14 years after the placing on the market of the last unit of a product model)
Restoring of factory settings and resetting passwords	Restoring factory settings and resetting passwords is possible with the help of a function integrated in the device	Restoring factory settings and resetting passwords is possible with the help of a function integrated in the device

4.7.1.4 Other aspects

In this section, other relevant aspects of the device base cases are described:

- It is assumed that all n-up printing and duplexing capability are available by default in every Best Available Technology device
- Device Best Available Technologies are compliant with Technical Specification 10 of GPP Criteria for Imaging equipment on Noise (Kaps et al, 2020)
- Device Best Available Technologies are compliant with the air emissions thresholds in Table 64.

Table 64. Air emission rates of device Best Available Technologies

	Emission rates (mg/h)						
	TVOC	Benzene	Styrene	Unidentified single substances VOC	Ozone	Dust	Ultra-fine particles
Colour	18	<0.05	1.8	0.9	3.0	4.0	$2.5*10^{11}$
Monochrome	10	<0.05	1.0	0.9	1.5	4.0	$2.5*10^{11}$

4.7.2 Cartridges Best Available Technologies

4.7.2.1 Page yield and material efficiency

For the definition of page yield and material efficiency of cartridges, data in Figure 52 and Figure 55 has been used. It has been considered that page yield and material efficiency of cartridges are correlated (generally, cartridges with higher page yield also show a higher material efficiency).

The Best Available Technology in terms of page yield and material efficiency has been defined as a linear regression between these two parameters. The linear regression has been chosen in order to identify the best 20% of cartridges in the sample. The result of this analysis for toner cartridges can be seen in Figure 66.

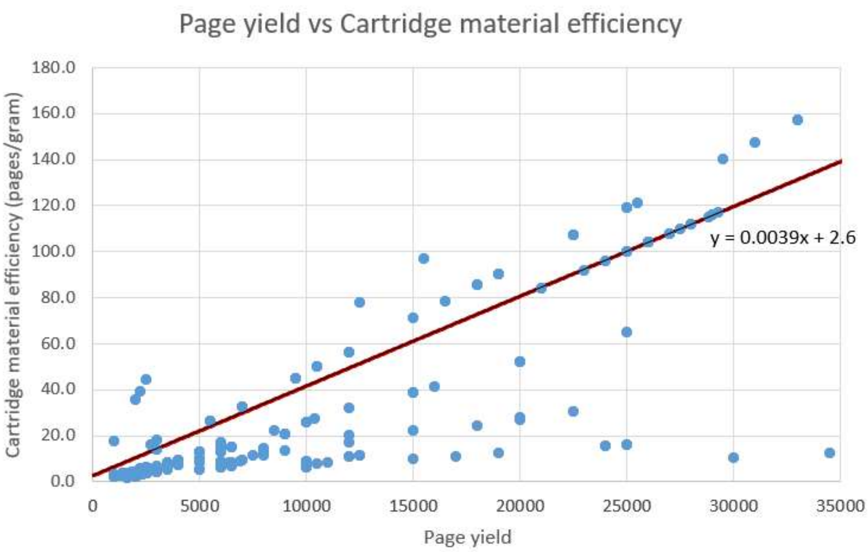


Figure 66. Best Available Technology of toner cartridges in page yield and material efficiency

Toner Cartridge BAT are those that comply with the following:

$Y > 0.0039*X + 2.6$ where

X = page yield (number of pages)

Y = material efficiency (pages per gram)

The result of this analysis for ink cartridges can be seen in Figure 67.

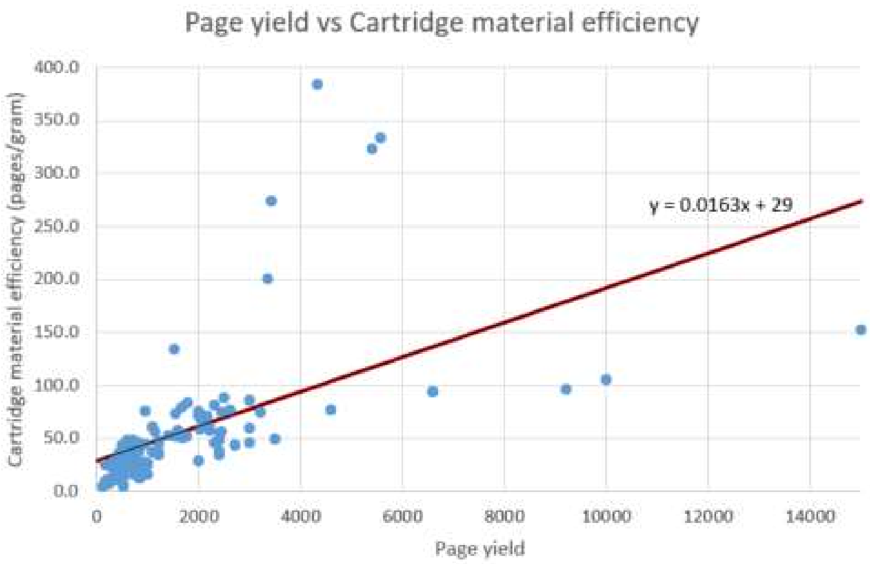


Figure 67. Best Available Technology of ink cartridges in page yield and material efficiency

Ink Cartridge BAT are those that comply with the following:

$Y > 0.0163*X + 29$ where

X = page yield (number of pages)

Y = material efficiency (pages per gram)

4.7.2.2 Reusability

In this Preparatory Study, it is proposed that the list of indicators to characterize cartridge Best Available Technologies is the list of barriers for cartridge reuse identified in section 4.5.8.1 of this report, a) to k). Therefore, a cartridge BAT may be defined as a cartridge with the following characteristics:

> *The cartridge Best Available Technology is a cartridge without chip, or with a chip that can be reset by third party operators when the cartridge is empty. The location of the chip is easily accessible. It does not use irreversible joining practices. Durable materials are used and fragile components are protected. It is compatible with a wide range of printer models of the same OEM.*

Based on those characteristics, an average factor for reusability will be defined. This factor should reflect how likely a cartridge may be reused, based purely on its technical characteristics. Inefficiencies during collection and other economic and market aspects are not taken into account in the estimation of this factor. The aim is to focus only on aspects related to the design of the cartridge. For the BAT, in this Preparatory Study it is proposed to use the technical potential in reusability estimated in Waugh et al (2018), which is 92% for toner cartridges and 87% for inkjet cartridges.

4.7.2.3 Printing quality

In terms of printing quality, considering that a 3% failure rate was assumed by the JRC for the base cases in section 4.6.2.3, a 1% failure rate is proposed for the cartridge Best Available Technologies.

4.7.2.4 Cartridge monitoring and traceability

Cartridge traceability has been mentioned by some stakeholders as an aspect that could contribute significantly to increase the amount of cartridges that are reused. Knowing who the original manufacturer was, how many times the cartridge has been reprocessed for reuse and who did the reprocessing is valuable information for the remanufacturers, in order to determine whether or not the cartridge can be reprocessed for one more use cycle.

A stakeholder in the Managed Print Services sector suggests that, as part of cartridge traceability strategy, the following data should be registered in the chip after every cycle of use:

- ID of remanufacturer
- Date of remanufacturing
- ID of manufacturer
- Serial number
- Compliance with regulation 2019/1020 on product market surveillance

With a proper cartridge and monitoring system, collectors of empty cartridges would have access to the data above online, making it easier to diagnose the quality of the empty cartridge and anticipating its destination.

Moreover traceability can be a way to avoid counterfeiting in the remanufacturing sector. An interesting example comes from Italy where the collection company Ecorecuperi, in collaboration with the association Pacto, has developed a traceability system based on blockchain technology, aiming to track the placing on the market of remanufactured cartridges from the collection of empty cartridges up to their deliver to the final users[58].

It is worth noting that currently existing subscription services require the use of monitoring technology, no matter if they are installed in a large corporate office or in a household.

4.8 Best Not Available Technologies

4.8.1 Printer easy to access page counter

As explained in section 4.4.3 printers' technical lifetime are often not fulfilled in terms of the amount of pages they can print. A potential solution to tackle these issues, proposed by a stakeholder on this Preparatory Study, is to include an easy-to-access page counter. Although page counting functionality is already available in all printers, easy user access to this information is not common. This page counter shall be available for users in the display –if the printer has a display- or in any other location of the printer accessible for the user.

Ideally, this page counter shall show the number of pages printed, relative to the total number of pages that the device is able to produce (its technical lifetime). That way, the user could be aware at each point of the remaining available life of the device, potentially avoiding the removal of printers with significant lifetime still available.

4.8.2 Cartridge standardization

As described in section 4.5.3, there seems to be a wide range of single product models in the cartridge market, often very similar between them in design, but only compatible with a limited number of printer models, due to the addition of superfluous design features. In section 4.5.9.1, this has been described as a barrier to cartridge reuse.

This strategy goes in the opposite direction of cartridge standardization. Designing cartridges with the aim of making them compatible with the highest amount of printer models could contribute significantly to increase cartridge reuse rates, and ultimately to the reduction of waste.

Printers that have similar functionality or performance could share the same design features that allow the use of a wider number of models today. The aim of this strategy would be to avoid the introduction of design features in printers or in cartridges, that do not add relevant functionality, and that avoid their interchangeability.

4.9 Summary of changes in Task 4 after stakeholder consultation

First draft version of Task 4 was published in November 2022, before the 1st Technical Working Group Meeting. During the meeting and the weeks after, a consultation process was open for collecting feedback from stakeholders. Based on the analysis of the feedbacks received, the authors of this Preparatory Study have made changes to the draft version published initially. This section summarizes those changes.

Base cases

Several stakeholders recommended a revision of the proposed base cases, both for devices and cartridges, in order to make an appropriate representation of the current market and differences in design. In response to

[58] https://www.ecorecuperi.it/tracciabilita_delle_cartucce/

these recommendations, five base cases have been proposed for devices and three base cases for cartridges, based on market data and with the aim of covering different profiles of use (home/office) and features. More detail has been provided to characterize the proposed base cases in terms of lifetime, energy efficiency, reparability, technical features and price.

Best Available Technologies and Best Not Available Technologies

Some stakeholders have provided information regarding printer and cartridge aspects that could be considered as Best Available Technologies (BAT) and Best Not Available Technologies (BNAT). In response to these recommendations:

- The BAT section has been re-arranged to describe the characteristics of printers and cartridges that can be considered as Best Available Technologies today, in terms of energy consumption, reparability, lifetime, page yield, material efficiency, monitoring and reusability.
- A BNAT section has been added, including some of the aspects suggested by stakeholders, such as page counting and standardization.

Technical description of marking technologies, devices and cartridges

Some stakeholders suggested that some sections of the Preparatory Study lacked some detail in terms of technical description. In response to these recommendations, the sections that provide technical background of marking technologies, devices and cartridges have been re-arranged and complemented with additional research from published bibliography and material provided by some of those stakeholders.

Devices energy

Some stakeholders pointed out aspects that could be improved in terms of presenting average energy consumption of devices. In particular it was considered that the average TEC value should not be based on a too wide printing speed interval, due to the strong correlation between printing speed and energy consumption of the process. In response to these recommendations, energy consumption has been provided for more narrow ranges of printing speed. Clarifications have also been provided in the definitions of off mode and standby modes. More examples of allocation of energy consumption across different modes have been also included.

Devices reparability

A study that provides relevant information on device reparability was published after the publication of the first draft of Task 4 (Ritthoff et al, 2023). Data relevant to this Preparatory Study has been used to describe the issue of device reparability and to provide clarity on base cases and Best Available Technologies.

Devices lifetime

Based on information gathered during stakeholder consultation and during visits to printer refurbishing plants, additional data has been presented on average device lifetime. In particular lifetime of devices has been qualified also in terms of printed pages, potential technical lifetime and expected lifetime following a refurbishing process.

Cartridge page yield and material efficiency

In order to have a broader understanding of the cartridge market in terms of page yield and material efficiency, data from different sources have been presented:

- A JRC-internal analysis has been conducted, showing worst and best performing ink cartridges in terms of material efficiency.
- An additional analysis has been carried out on a database provided by ETIRA.

Cartridge collection and reuse

Some stakeholders commented that the sections on cartridge collection and reuse contained inaccurate and out of date information and recommended a revision. Other stakeholders suggested that more detail was needed in terms of barriers for the reparability of devices and the reuse of cartridges. In response to these recommendations, more up to date and nuanced information is provided in terms of current recycling and reuse practices. On top of that, more details have been provided regarding printer reparability and barriers for cartridge reuse, based on recently published bibliography and visits to cartridge collection and remanufacturing facilities.

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