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Imaging equipment and its consumables. Preparatory study for ecodesign.

Task 1 and Task 4. Drafts.

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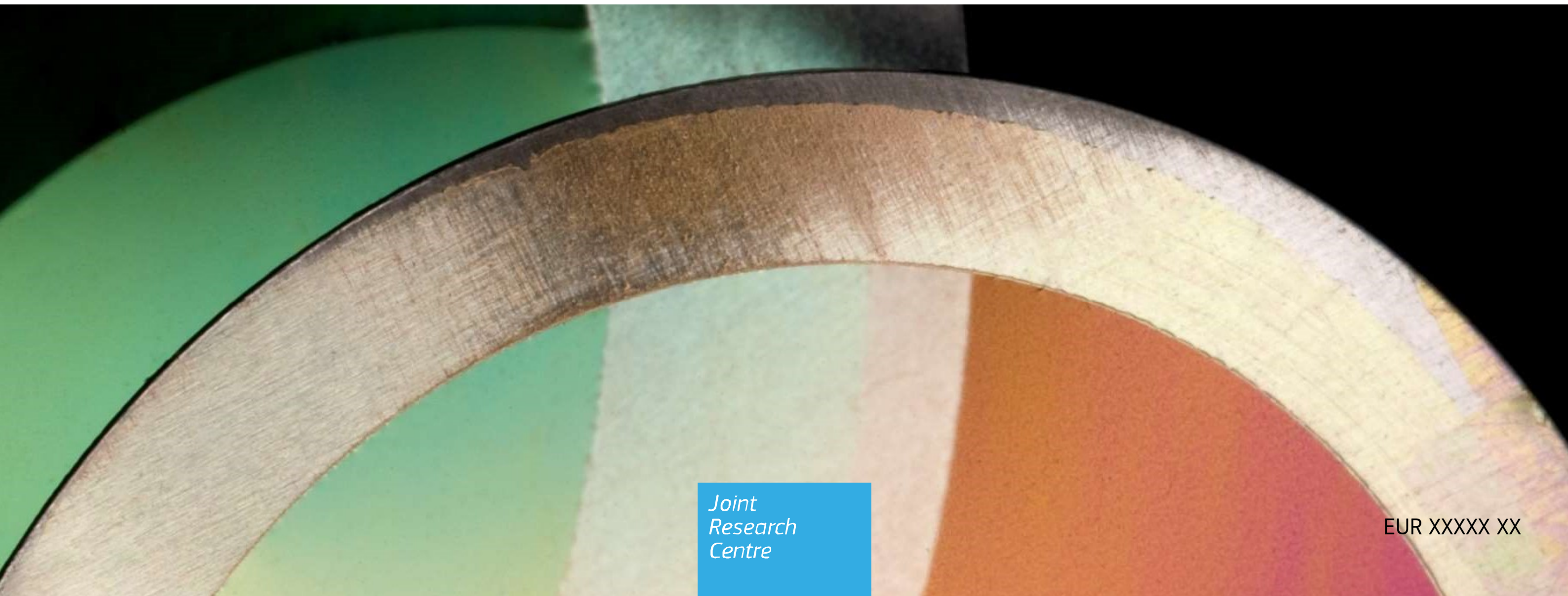

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Contents

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:

> _Imaging equipment devices:_ *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:

> _Printer:_ *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).*
>
> _Copier:_ *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).*
>
> _Multifunctional device_: *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).*
>
> _Scanner:_ *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:

> _Fax machine:_ *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)*
>
> _Digital Duplicator_: *A product sold as a fully-automated duplicator system through the method of stencil duplicating with digital reproduction functionality (Energy Star v3.2)*
>
> _Mailing Machine_: *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:

> _Professional imaging product_: *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:

> *Cartridge: 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:

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

> *All-in-one toner cartridge: 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 cartridges:

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

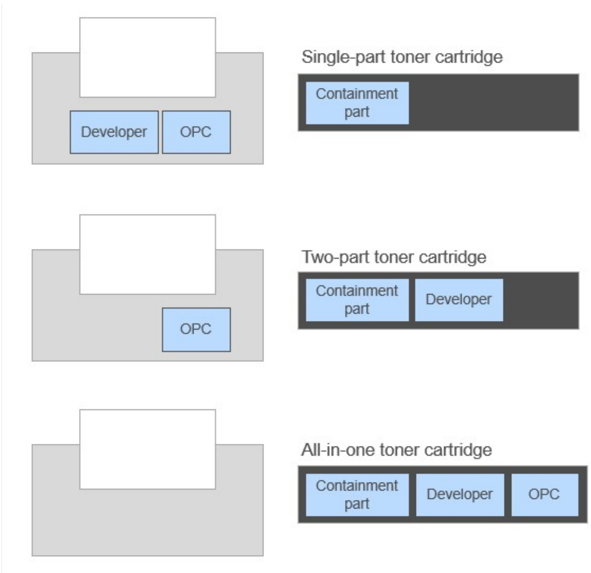
b) <u>two part toner cartridge</u>: a toner cartridge that includes a toner containment part and a developer part and does not include a photoreceptor part

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

For ink cartridges (Figure 2):

a) <u>Single part ink cartridge</u>: a cartridge that includes only an ink containment part

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



OPC: Organic Photoconductor
Figure 1. Toner cartridge configurations in ISO/IEC 29142

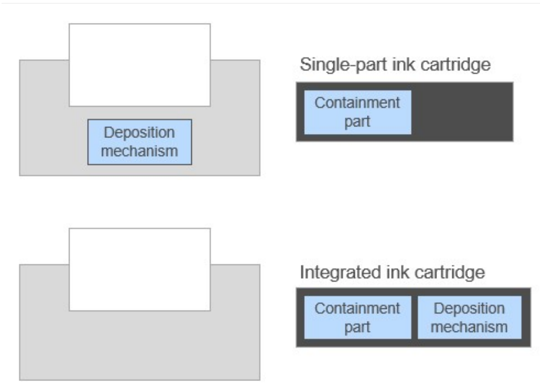


Figure 2. Ink cartridge configurations in ISO/IEC 29142

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

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

<u>Non-original cartridge</u>: 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:

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

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

<u>Reuse</u>: 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.

Photoreceptor part (photoconductor): 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.

Ink deposition mechanism: 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':

Consumable: 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):

Cartridge: 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.

Container: 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) for the integrated components or moving parts of cartridges:

> <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 (2020) 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 the table below.

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.

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 place 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; and

iii) 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.

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.

Where a modified product is considered as a new product, it must comply with the provisions of the applicable legislation when it is made available or put into service.

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

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

Imaging equipment has been regulated with a Voluntary Agreement (VA) under the Ecodesign Directive since 2013. However, 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	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 3,00 W applicable).

According to the Regulation (EU) No 801/201 , 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.

[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;

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	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 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-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.

[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

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

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. Between 2019 and 2021, the industry has been working on 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 2020 Circular Economy Action Plan (European Commission, 2020) refers 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'.

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 et al, 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:

- 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 Type I Ecolabels

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

Table 5. Scope of Type I Ecolabels regarding devices

Type I 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	-3D printers

	inkjet devices by using inks	
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 Type I Ecolabels evaluated regarding consumables.

Table 6. Scope of Type I Ecolabels regarding consumables

Voluntary scheme	Consumables in scope	Consumables explicitly excluded from scope
EPEAT – Global Electronic Council Imaging equipment	Not indicated	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	Not indicated

	equipment with printing function.	
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	✗	✓	✓	✗	✗	✓
	Recycled content	✗	✓	✓	✓	✓	✓
	Recyclability	✗	✓	✓	✓	✓	✓
	Use of renewable materials	✗	✗	✗	✗	✗	✓
	Durability	✗	✓	✗	✓	✓	✓
	Repairability	✗	✓	✓	✓	✓	✓
	Reusability	✗	✓	✗	✗	✓	✗
	Interoperability	✗	✓	✗	✗	✗	✗
	Compatibility with reused consumables	✗	✓	✓	✓	✓	✓
	Reliability	✗	✗	✗	✗	✗	✗
	Remanufacturability	✗	✗	✗	✗	✗	✗
	Take back systems	✗	✗	✗	✓	✗	✓
Device - Energy	Energy efficiency of device and components	✓	✗	✗	✓	✗	✗
	Energy consumption of device and components	✓	✓	✓	✗	✗	✗
	Standby, Sleep, Off mode requirements	✓	✓	✗	✗	✗	✓
	Energy consumption reporting information	✓	✗	✗	✗	✗	✗
	Compliance with Energy-related Ecolabels	✗	✗	✗	✗	✓	✓
Device - Other aspects	Duplex printing	✓	✓	✓	✓	✓	✓
	Declaration of product category (Professional/Private)	✗	✓	✗	✗	✗	✗
	Description of product characteristics	✗	✗	✓	✗	✓	✓
	Printers - Usability of recycled paper	✗	✓	✗	✓	✓	✗
	N-up printing	✗	✓	✗	✓	✓	✗
	Packaging	✗	✓	✓	✗	✓	✓
	Restricted substances	✗	✓	✓	✓	✓	✓
	Emissions to air	✗	✓	✓	✓	✗	✓
	Noise	✗	✓	✓	✓	✗	✗
	Product information	✗	✓	✓	✗	✓	✗
	Design provisions	✗	✗	✗	✗	✗	✗
	Carbon footprint	✗	✗	✗	✗	✓	✓
	Characteristics of paper supplied with printer	✗	✗	✗	✓	✗	✗
	Characteristics of consumables supplied with printer	✗	✗	✗	✓	✗	✗

Aspect is covered in Ecolabel ✓
Aspect is not covered in Ecolabel ✗

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)

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

Concept	Definition	Source
Imaging equipment device (or 'device')	Product marketed for office or domestic use, or both, and whose function is one or both of the following: 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.	adapted from Kaps et al, 2020
Printer	Device intended to apply ink or toner to a substrate in response to a digital signal.	Adapted from ISO/IEC 29142

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.	adapted from ISO/IEC 29142
Copier	A product whose sole function is to produce paper duplicates from paper originals	adapted from Kaps et al, 2020
Scanner	A product whose primary function is to convert paper originals into electronic images	adapted from Kaps et al, 2020
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	adapted from Huang et al (2019)
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.	as in Energy Star v2.3

1.7.2 Definitions related to cartridges

Concept	Definition	Source
Consumable	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. 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.	Adapted from IEEE (2012)
Cartridge	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 (1)	As in ISO/IEC 29142
Single part toner cartridge	A toner cartridge that includes only a toner containment part (2)	As in ISO/IEC 29142
Two part toner cartridge	A toner cartridge that includes a toner containment part and a developer part and does not include a photoreceptor part	As in ISO/IEC 29142
All-in-one toner cartridge	A toner cartridge that includes a toner containment part, a developer part and a photoreceptor part	As in ISO/IEC 29142
Single part ink cartridge	A cartridge that includes only an ink containment part (3)	As in ISO/IEC 29142
Integrated ink cartridge	A cartridge that includes an ink containment part and a ink deposition mechanism	As in ISO/IEC 29142
Tank (4)	Printer component used to hold toner or ink, used in specific technologies, which is filled from an external container that will not be inserted into the device	JRC
OEM cartridge	An OEM branded cartridge produced by or for the OEM, for use with an OEM device	Adapted from EVAP
Compatible cartridge (also called 'new built cartridge')	A cartridge for use with an OEM device, but not produced by or for the device OEM.	Adapted from EVAP
Remanufactured cartridge	Cartridge resulting from a commercial process where an empty cartridge is collected, remanufactured, filled with ink or toner, labelled, and repackaged. Components may be replaced in order to return the cartridge to working condition and to meet desired functionality requirements, provided that the cartridge retains all or as much as possible of the original body. The cartridge shall contain: a) for toner cartridges, greater than 50% by weight of reused parts not counting toner; b) for ink cartridges, greater than 75% by weight of reused parts not counting ink. The fraction of reused parts shall be calculated from the parts which are	Adapted from EVAP

	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.	
Refilled cartridge (5)	Cartridge resulting from a process where an empty cartridge is refilled with ink or toner without replacement of components.	Adapted from EVAP
Cloned cartridge (6)	A compatible cartridge for use with an OEM device, not produced by or for the OEM, and violating some intellectual property (patent, copyright, trademark)	Adapted from EVAP
Counterfeit cartridge (7)	A cartridge not produced by an OEM, labelled, packaged, and marketed in such a way that is intended to mislead a customer into thinking it is an OEM cartridge	Adapted from EVAP

(1) no specific definition is provided for 'container', since a container is a sub-type of cartridge

(2) a 'single part toner cartridge' is a 'toner container'

(3) a 'single part ink cartridge' is a 'ink container'

(4) a 'tank' is therefore not a consumable, but rather a printer component.

(5) a 'refilled cartridge' is also a 'remanufactured cartridge', since refilling is one of the possible scenarios of cartridge remanufacturing

(6) a 'cloned cartridge' is also a 'compatible cartridge'

(7) a 'counterfeit cartridge' is also a 'compatible cartridge'

1.8 Scope proposal

Table 11 summarizes the scope proposal in terms of devices, as defined in section 1.7.1.

Table 11. Scope proposal in terms of devices

In scope of this study	Excluded from scope of this study
Printer Multi-function printer Copier Scanner Fax machine	Digital duplicator Mailing machine Professional imaging equipment device

Devices such as copiers, scanners and fax machines will be initially included into the scope of this Preparatory Study, even though this may change when Market data is available in Task 2. If those devices are not relevant from market perspective, they may be removed in subsequent sections of this report. Devices such as digital duplicators and mailing machines are excluded from the beginning due to their very specific and limited applications. Professional imaging equipment devices are also excluded from the scope due to their relevant differences with home and small office devices, in terms of design, performance, use pattern and final use.

Cartridges will also be within the scope of this study, as defined in section 1.7.2. This will include all the typologies of cartridges, as described in Table 12.

Table 12. Scope proposal in terms of devices

Deposition material	Structure / Design	Life condition	Supplier
-Ink cartridge -Toner cartridge	-Single part toner cartridge -Two part toner cartridge -All-in-one toner cartridge -Single part ink cartridge -Integrated ink cartridge	-New products, including remanufactured cartridges	-Original cartridge -Compatible cartridge

The aim of this Preparatory Study is to include initially into the scope every cartridge that may be used in a home or small office environment: a cartridge that can be used with any of the devices included into the scope. This would include ink and toner cartridges in any of their possible configurations (single part, all-in-one, etc). The scope would apply to every new cartridge placed on the market (including new remanufactured cartridges). The scope also applies to both original and compatible cartridges.

2 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.

2.1 Devices

In this section, a brief technical description of the different types of printing devices is given, focusing on the main marking technologies, device components and relevant technology aspects.

2.1.1 Electrophotographic printers

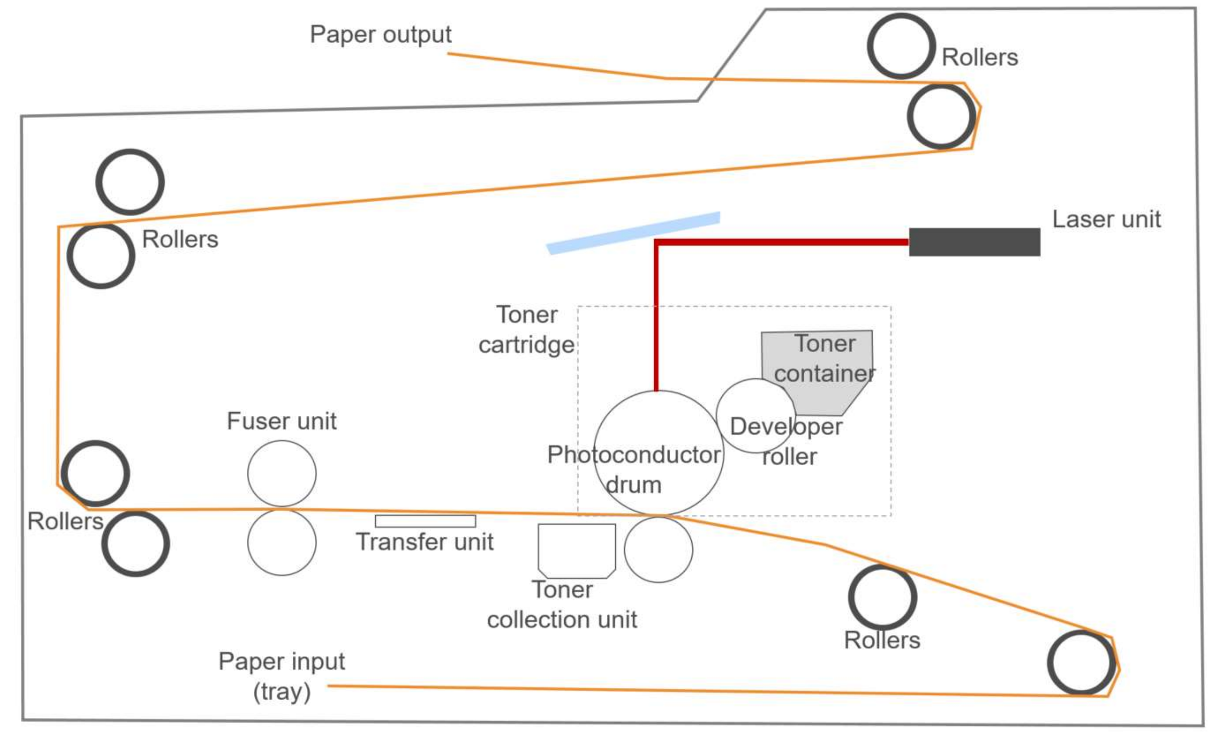
Electrophotographic printers (EP) –also known as laser printers- are defined in ISO 29142-1:

> *An electrophotographic (EP) printer is a printer principally using optoelectronic phenomena and electrostatic attraction to move toner to a substrate.*

More detail on this marking technology is provided in Energy Star v3.2:

> *A marking technology characterized by the illumination of a photoconductor in a pattern representing the desired output image via a light source, development of the image with particles of toner using the latent image on the photoconductor to define the presence or absence of toner at a given location, transfer of the toner to the final print media, and fusing to cause the output to become durable. Color EP products simultaneously offer three or more unique toner colors, while Monochrome EP products simultaneously offer one or two unique toner colors.*

A schematic description of an EP printer is provided in Figure 3.



Source: JRC, adapted from Farratech (2015)
Figure 3. Schematic description of EP printer

The main components of an electrographic (EP) printing system are:

- An organic photoconductor (OPC), also known as 'drum'. This is equivalent to the 'photoreceptor' defined in ISO 29142-1 (see section 1.1.1). Its function is to attract the toner powder particles and transfer the toner to paper. The drum is a cylinder and can be positioned either close or inside the toner cartridge.
- A 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.
- A light source (laser), which imprints the image onto the drum. Its function is to create an electrostatic image onto the photoconductor drum.
- A toner cartridge. As explained in previous sections, the toner cartridge can be:

  -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 (in Figure 3, the cartridge has been drawn as an all-in-one cartridge).
- A toner collection unit, which collects the waste toner during the printing process
- A fuser unit, which melts the toner and secures the image to the page. The fuser consists of a pair of heated rollers that fuse toner onto output media. In laser printers that print only one side of the paper, there will be only one heated roller (the upper one), where the other roller is used only to apply pressure on the paper. In a laser printer with duplex printing, both rollers are heated and melt toner powder onto both sides of the page.
- A 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.
- Internal or external power supplies

The process of electrophotographic priting is described in Huang et al (2019):

> *The light may be produced from a laser (e.g. an aluminium gallium semiconductor laser) and mirror array, or more recently via a light emitting diode (LED). The first stage in the EP process involves the use of a primary charge roller (PCR) to place either a negative or positive charge onto an organic photoconductor (OPC) drum. A light source is then used to imprint the desired image onto the OPC drum. As the light hits the OPC it alters the electrostatic charge in the contact area. Charged toner particles are then transferred onto the OPC, where they become attracted to the area with altered charge. A transfer belt rolls the output media (e.g. paper), which is given a strong opposite charge to the toner particles, past the OPC. As the charged output media passes the OPC it picks up the toner in the form of the image to be printed. The output media then passes through a fuser unit which melts the toner and secures the image to the page. Colour EP imaging equipment contain at least four OPCs (i.e. most often black, cyan, magenta and yellow). Toner is either stored in cartridges, which typically contain the OPC, or containers with the OPC as a separate component. In colour-based EP imaging equipment, the toner colours are blended to provide the desired colour output.*

An example of EP printer can be seen in Figure 4.

Figure 4. Electrophotographic printer
Source: EVAP

In general, businesses opt for laser printers because they need high print speeds and volumes and lower costs per page, and are able to bear the higher costs associated with purchasing a laser printer (Waugh et al, 2018).

Laser printers and copiers use toners, either in the dry form or wet form. Dry toners consist of acrylic and styrene powders together with colour pigments. Liquid toners consist of acrylic resins with added dye pigments to provide bright colour images. Plastic resins constitute a major portion (45–90%) of toner powder and are generally made of styrene and acrylic polymers. Magnetic properties are imparted to the toner through iron oxide ingredients. In addition, various metals and semiconductors are added to the toner powder to induce triboelectric and superflow properties (Parthasarathy, 2021).

2.1.2 Inkjet printers

According to ISO 29142-1, an inkjet (IJ) printer is:

A printer with an operating part, for example a printhead, to apply ink on a substrate

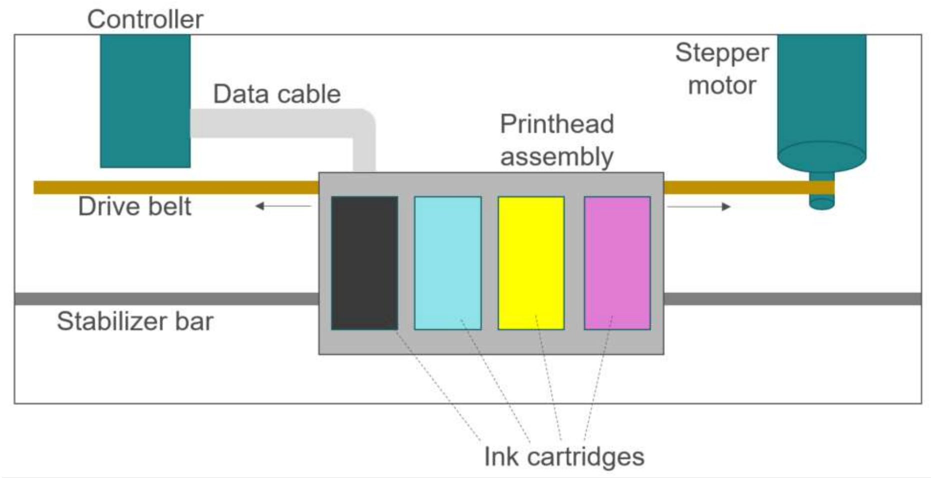
As a marking technology, Energy Star v3.2 define IJ as:

A marking technology characterized by the deposition of colorant in small drops directly to the print media in a matrix manner. Color IJ products offer two or more unique colorants at one time, while Monochrome IJ products offer one colorant at a time.

In Huang et al (2019), it is specified that:

There are a number of sub-types of IJ technologies, including Piezo-Electric (PE) IJ, IJ Sublimation, and Thermal IJ which largely dictate the way in which ink is removed from a reservoir and placed on the output media. IJ based products utilise cartridges or containers which contain ink.

A schematic description of an inkjet printer is can be seen in Figure 5.



Source: JRC, adapted from Britannica (2022) and Tyson (2022)
Figure 5. Schematic description of inkjet printer

The main components of an inkjet printer are:

- A 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.
- A stepper motor, which moves the printhead assembly back and forth across the paper
- A drive belt, used to attach the printhead assembly to the stepper motor
- A stabilizer bar, to ensure that movement of the printhead assembly is precise and controlled
- An ink collection unit, aiming to collect waste ink during printing
- 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 either a simple container, or a combination of container and printhead.
- A set of rollers, which pull the paper from the tray and advance the paper
- Internal and external power supplies

Fundamentally, inkjet printing consists in the distribution of materials (ink) across substrate areas that are ultimately useful for communication purposes or in digital manufacturing processes. In inkjet printing, materials are transferred as liquid drops, without requiring any mechanical contact between the print head producing the drops and the substrate receiving them (Hoath et al, 2016).

Inkjet printers use printing inks, which contain chemicals such as butyl urea, cyclohexanone, ethoxylated acetylenic diols, ethylene diamine tetra-acetic acid, ethylene glycol, and several sulfur-containing dyes (Parthasarathy, 2021).

An example of EP printer can be seen in Figure 6.

Source: EVAP

Figure 6. Inkjet printer

Home-printing customers can generally tolerate lower print speeds due to lower print volumes and more intermittent printing demand. The lower print volumes and more intermittent printing demand makes lower-cost inkjet printers more attractive than laser printers for home-print consumers. In addition, while the price per page of laser printing may be comparable to or lower than that of inkjet printing, the higher up-front cost per unit for a toner cartridge may make laser printing less accessible to home-print consumers than inkjet printing. Home-print consumers therefore most commonly use inkjet cartridges (Waugh et al, 2018).

2.1.3 Other marking technologies

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

2.1.3.1 High performance ink jet

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.

2.1.3.2 Solid ink

Solid ink (SI) 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 Huang et al (2019), it is added that:

> *The melted ink is applied to output media in a requested pattern via print-head nozzles (in a similar manner to inkjet printers).*

In Bozeman (2011), a description of how SI 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.

It seems to be a niche technology (to be confirmed in the Market section).

2.1.3.3 Direct thermal

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 7. Examples of direct thermal devices

2.1.3.4 Dye sublimation

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.*

2.1.3.5 Impact

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*

2.1.3.6 Stencil

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.*

2.1.4 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.

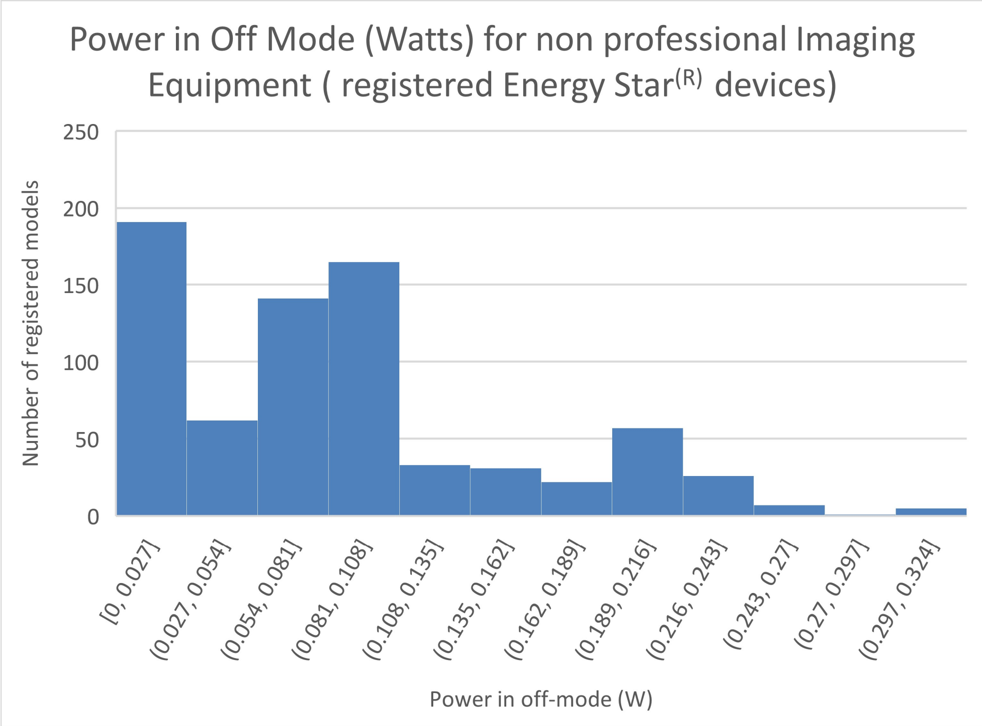
b) Ready State: The power state in which a product is not producing output, has reached operating conditions, has not yet entered into any lower-power modes, and can enter Active State with minimal delay. All product features can be enabled in this state, and the product is able to return to Active State 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.

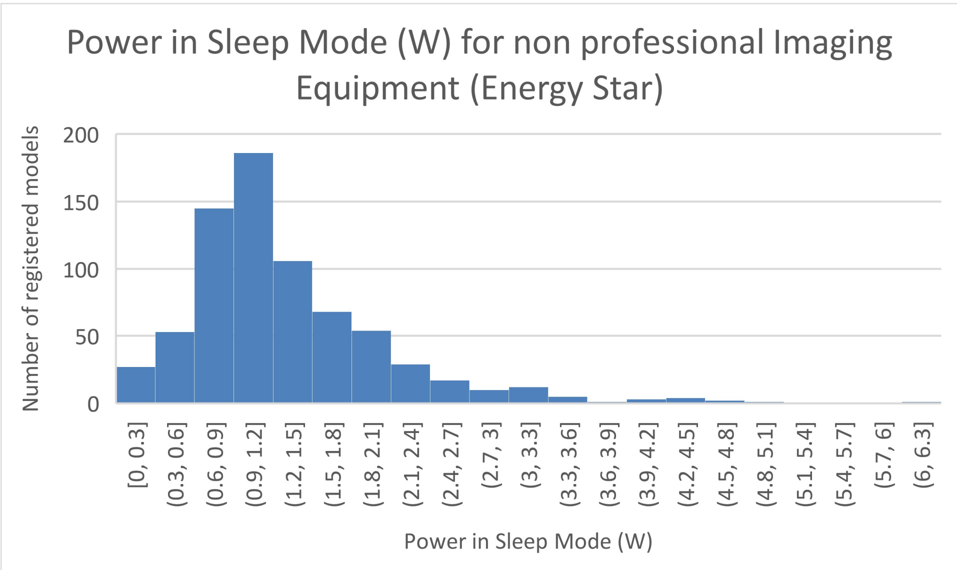
Different energy performance evaluation methods are used to benchmark the energy performance of imaging equipment products. In Energy Star (2021) IE products are classified as "Typical Energy Consumption (TEC)" and "Operating Modes (OM)" products, and different methodologies are applicable to each of 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 8 and Figure 9, most of the Imaging Equipment device models registered under the Energy Star scheme have an Off Mode Power below 0.2 W and a Sleep Mode Power below 2W. Energy Star performance data presented in the figures above can be taken as reference for evaluating improvement potentials. The Energy Star criteria for Ink-jet devices (multifunctional devices and printers) are based on the energy performance of the off-mode and sleep-mode. Maximum allowed Off-Mode Power for Energy Star devices is 0.3 Watts. The allowed Sleep mode threshold is a bit more complex, as it is based on a base case threshold (e.g. 1.1 W for inkjet multifunctional devices) plus additional allowances based on features and performance. (e.g. additional 2W in case of Bluetooth connection and 0.1W in case of wireless IR connection).



Source: JRC, based on data from Energy Star database

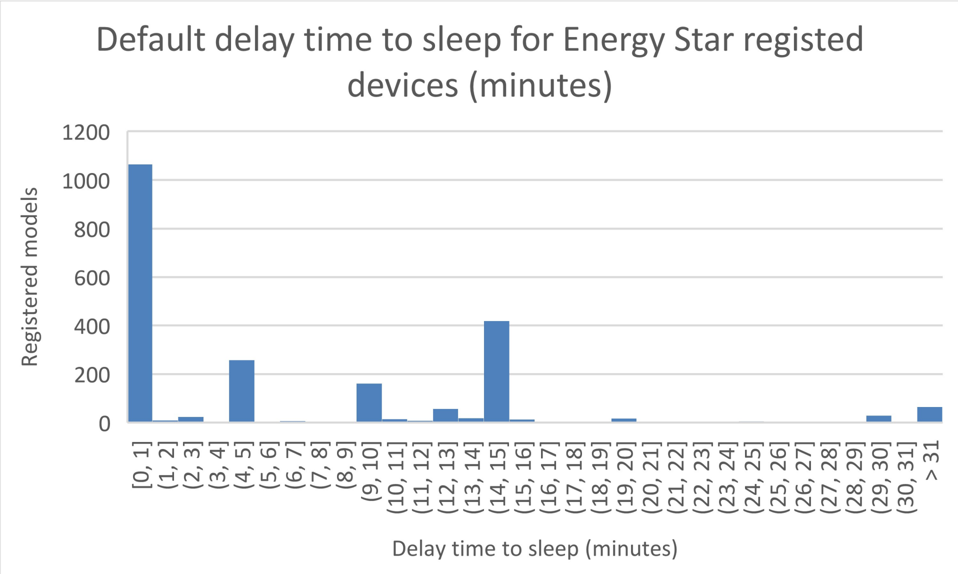
Figure 8: Power in off mode (W) for OM non-professional products registered under Energy Star



Source: JRC, based on data from Energy Star database

Figure 9: Power in sleep mode for OM non-professional products registered under Energy Star.

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, we 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.



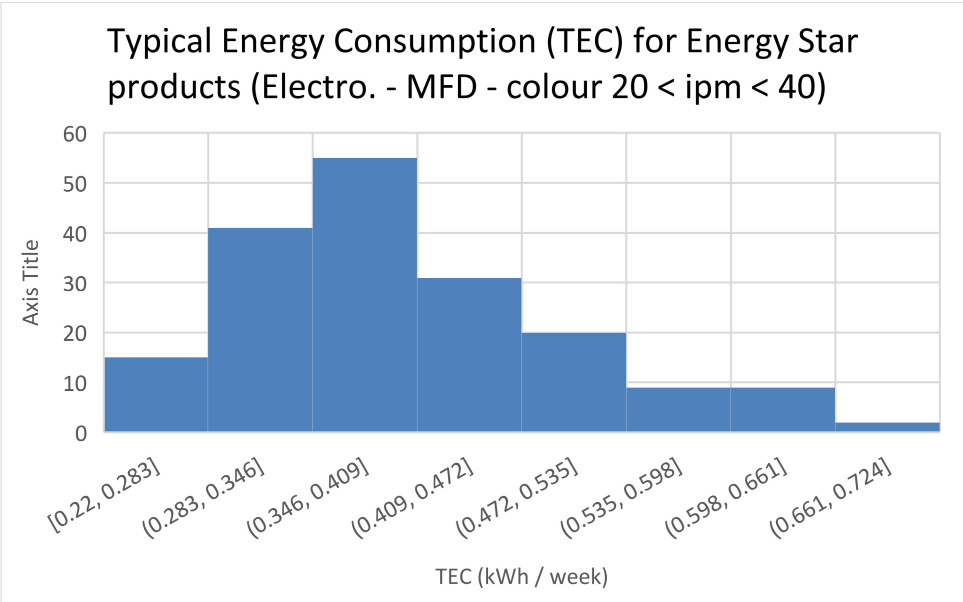
Source: JRC, based on data from Energy Star database

Figure 10: Default delay time to Sleep for Energy Star devices with delay time to sleep functionality.

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 11 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 11: 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 13 below and can be taken as reference for evaluating improvement potentials. On average, Energy Star inkjet printers registered under Energy Star requires around 0.1 Watts in off-mode and around 1 W in sleep mode (see figure below).

Table 13: 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	Professional	Marking Technology	Colour Format Monochrome	Page Format	Product Speed (ipm)*	Average Energy/Power TEC (kWh/week)	Average Sleep Mode Power (W)	Average Off Mode Power (W)	
MFD	No	EP	Mono	Standard	< 85	0.612			5,46
MFD	No	EP	Colour	Standard	< 50	0.431			7,18
Printer	No	EP	Mono	Standard	< 85	0.544			7,37
Printer	No	EP	Colour	Standard	< 50	0.441			1,00
MFD	No	Inkjet	Colour	Standard	<85**		1.035	0.123	8,27
Printer	No	Inkjet	Colour	Standard	<85**		1.017	0.137	8,52

*These are considered the thresholds applicable for professional imaging equipment

** For Ink Jet Printers products registered under Energy Star do not go beyond 35 ipm

2.1.5 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, a simple 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 and will be complemented when market data on devices is available.

Figure 12Figure 12 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.

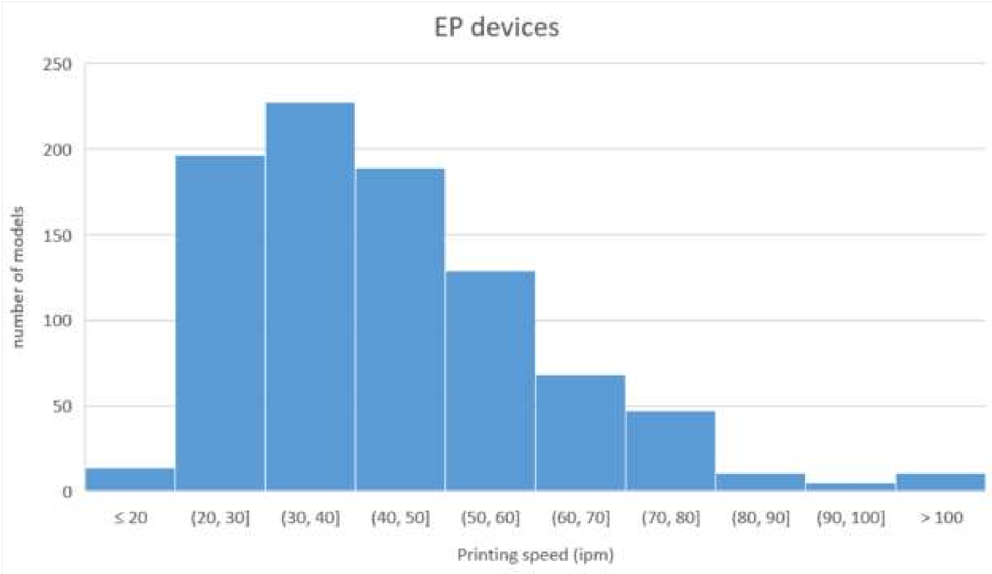


Figure 12. Printing speed of electrophotographic devices

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

Figure 13 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.

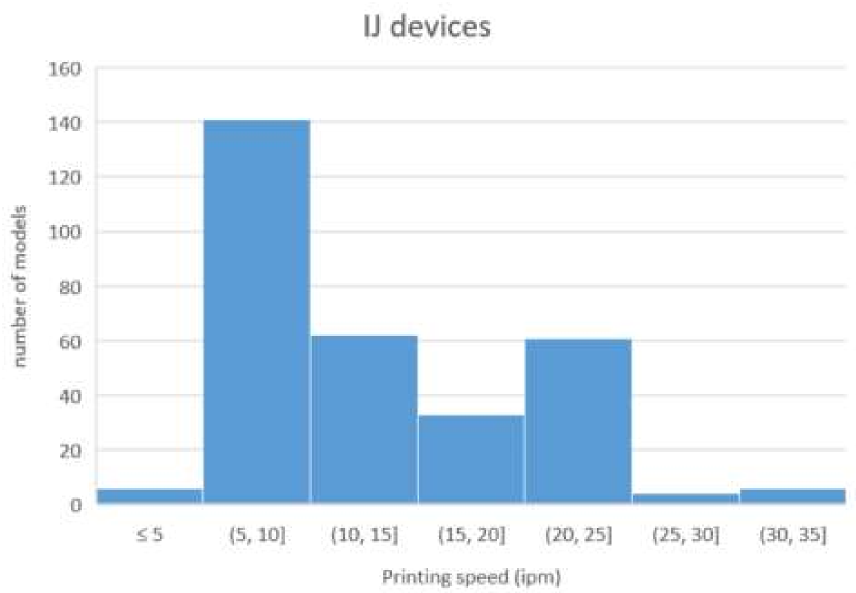


Figure 13. Printing speed of inkjet devices

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

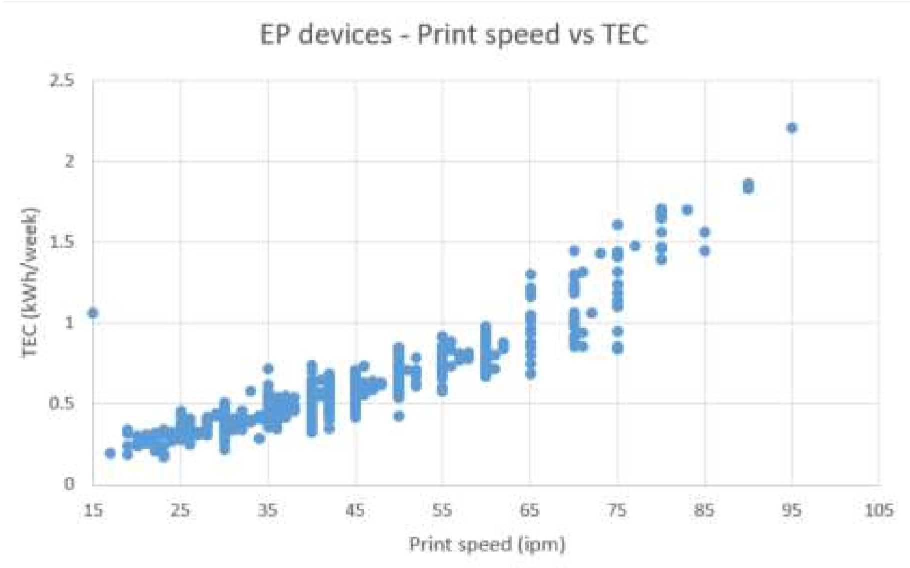


Figure 14. Printing speed and energy consumption of EP devices
Source: JRC elaboration of raw from the Energy Star Database (September 2022).

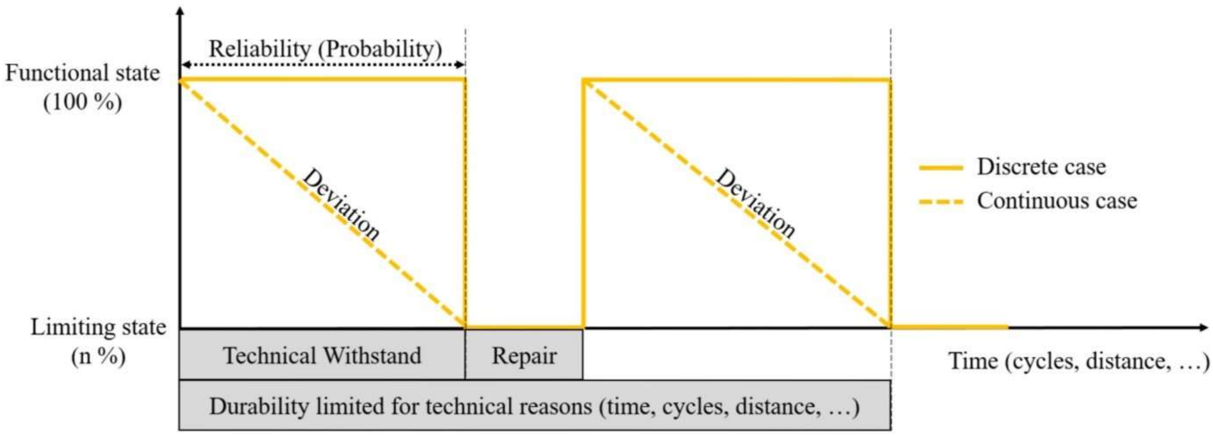
There is a clear correlation between printing speed and energy consumption of EP devices. Highest energy consumptions are associated with higher printing speeds.

2.1.6 Design aspects affecting durability

Material efficiency of ICT products can be improved first of all making sure that product are designed to be reliable and durable. Reliability, according to the standard EN45552:2020, is defined as the probability that a product (or a part) functions as required, under given conditions. According to the EN45552:2020, reliability and durability convey similar concepts but have distinct and separate 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.

For electronics and ICT in commercial applications common reliability testing can ensure that products do not fail when exposed to specific events and stresses including electric stresses, thermal stresses, vibration, shocks due to accidental drops, exposure to dust and liquids.

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 (discrete or continuous case, respectively) as described in Figure 15Figure 15 below.



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

Figure 15. Relationship between reliability, repair and durability

The Design of the imaging equipment parts can affect the ability to maintain its functional state but also the ability to maintain and repair the device and fulfil the expected lifetime. Apart from the cartridges, discussed in Section 2.2, other parts of the imaging equipment device can be expected to be maintained or replaced during the lifetime of the device as part of expected maintenance or repair.

2.1.6.1 Toner and ink collection units

The toner collection unit (also called excess toner reservoir) is a special container aiming to collect waste toner during printing. This collection unit can have a sensor that halts the printing processes on the machine once the collection unit is full. Alternatively the waste ink level is estimated/calculated by the devices based on the number of printing/maintenance operations. The printer stops in order to avoid any damage that may occur if toner were to get into the main body of the device. The collection units needs to be emptied or replaced to bring the device back to the functional state. An example of waste toner collection is shown in Figure 16.

Figure 16. Toner collection unit

Inkjet printers have to manage a similar issue for waste ink. They have collection units /ink pads designed to collect any residual ink from the print-heads. Similarly to what happens for toner based devices, a sensor can monitor the status of the deposit (or this can be estimated based on the use) and it can halt the printing processes once the waste ink collection unit is full (or estimated to be full). This is to avoid any damage that may occur if ink were to get into the main body of the printer. Also in this case the collection units needs to be emptied or replaced to bring the device back to the functional state.

Some OEMs suggest to do not attempt to empty the toner or cartridge collection units and reuse it, as the toner collection unit is designed for a single use. According to an OEM, doing so could lead to toner/ink being spilled inside the product, which could result in reduced print quality[6].

The easy access and replacement of the collection units (as well as the availability of spare parts) are key aspects to ensure an appropriate maintenance of the collection units, however questions on the design of these parts are related also to other aspects like:

- How is the ink level estimated or measured?

- Are there any minimum capacities recommended based on printing capabilities/speed?

- Once the collection unit is full, is the user of the printer correctly informed about the maintenance operation needed?

- Is the risk of toner/ink spilling a valid reason for limited reusability of collection units (or in general not recommending their reuse)?

- Is the end user access to reset functionality ensured after the replacement process? Is it only accessible through OEMs? Is it free of charge for users?

2.1.6.2 Inkjet Print heads

There are two main design philosophies in inkjet printhead design: fixed-head and disposable head.

[6] 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

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. Every time a cartridge is exhausted, the entire cartridge and print head are replaced with a new one.

Each has its own strengths and weaknesses from environmental 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/replaced, the printer itself will then needed to be replaced.

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.

2.1.6.3 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 (see section 2.2.2) or sold separately as a single unit, depending on the consumable requirements of the printer (Figure 17).

Figure 17. Drum unit

Laser printers and their consumables vary across printer models. Some printers only need you to replace the toner cartridge, and others require that you 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[7] (e.g. 12.000 pages).

2.1.6.4 Fuser unit

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 (Figure 18). Fusers are reported to need replacement every 75,000 - 300,000 pages depending on the printer model[8].

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

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

Figure 18. Fuser unit

2.1.6.5 Transfer unit

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 (Figure 19). Some OEMs report the page yield after which a periodic replacement of the transfer belt is needed (e.g. 359 or 5010 pages). Moreover an OEM report use patterns that may significantly reduce the life of the Transfer Roller (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 printing; printing with high toner coverage).

Figure 19. Transfer unit

2.1.6.6 Summary of spare parts relevant for repair

Spare Part means a separate part that can replace a part with the same or similar function in an equipment. The part is considered necessary for use if the equipment cannot function as intended without that part. The functionality of the equipment is restored or is upgraded when the part is replaced by a spare part. Spare Parts may also be orderable as an assembly (also known as a spare unit) (Eurovaprint, 2021).

Some spare parts are all components or assemblies that are expected to need replacement within the service life of the product are sometimes grouped by OEMs and included the so called maintenance kits[11].

Eurovaprint (2021) identified a list of replaceable spare parts that includes a) Hard disc drives (HDD), b) Solid state drives (SSD), c) Print heads, d) Laser unit, e) Fuser unit, f) Drum unit, g) Transfer belts, h) Roller kits, i) Internal power supplies, j) Control circuit boards, k) External power supplies, l) Control panels including electronic displays, m) Toner collection unit, n) Ink collection unit, o) Power cords and cables.

The EU GPP Criteria (Kaps et al. 2020) also identified a list of priority parts: at core level the list of spare parts is restricted to print heads, laser unit, fuser units, drum units. At comprehensive level the list is wider and also includes the scanning units, transfer belts/kits, maintenance kits, paper feed components, density sensors, power and control circuit boards, cartridge/container attachment components, external power supplies, hinges.

The Blue Engel provides a list of spare parts (Table 14) and classifies them by technology (inkjet vs electro-photographic devices) and by availability (spare parts to consumers and spare parts to professional repairers).

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[9] https://www.support.xerox.com/en-us/article/en/x_6300_en-O3068

[10] https://help.brother-usa.com/app/answers/detail/a_id/57830/~/how-can-i-check-the-remaining-life-of-the-belt-unit%3F

[11] https://www.suppliesguys.com/info/what-is-a-maintenance-kit.html

Table 14: identified priority parts relevant for maintenance and repair according to Blue Angel criteria for Office Equipment with Printing Function
Source: Printers and Multifunction Devices (DE-UZ 219 Blue Angel, 2021a).

	Spare parts	
	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) Paper cassettes External power supplies/power cable	Storage Devices (HDD and SDD) Roller kits, paper feed rollers Print head (not integrated into the ink cartridges) External power supplies / power cables Control circuit boards Control panel Ink collection tank / excess ink reservoirs

A recent report from the German Environmental Agency (UBA, 2022) provides a conceptual framework for assessing the reparability of electrical and electronic products, including the selection of priority parts in the context of a reparability assessment. Also in this case, different lists of priority parts are identified for inkjet and laser printers.

2.1.7 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 15).

Table 15. Air emissions rates in voluntary schemes

		Emission rates (mg/h)						
		TVOC	Benzene	Styrene	Unidentified single substances VOC	Ozone	Dust	PM10
Blue Angel (2021a)	Colour	18	<0.05	1.8	0.9	1.5	4.0	$2.5*10^{11}$
	Monochrome	10	<0.05	1.0	0.9	3.0	4.0	$2.5*10^{11}$
Nordic Ecolabelling	Colour	18	<0.05	1.8	0.9	1.5	4.0	n/c
	Monochrome	10	<0.05	1.0	0.9	3.0	4.0	n/c
EPEAT	Colour	18	<0.05	1.8	n/c	1.5	4.0	n/c
	Monochrome	10	<0.05	1.0	n/c	3.0	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.

2.2 Cartridges

As indicated in section 1.2.1 of this study, ISO/IEC 29142-1:2021 defines 'cartridge' as 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. Cartridges design are different depending on their application, whether they are for inkjet or for laser printing.

2.2.1 Ink cartridges

Ink cartridges are used in inkjet (IJ) printers. Typically, ink cartridges are made of two main components: the body of the cartridge that acts as a container for the ink and the foam, and the printhead that transfers the ink onto paper during the printing process. (Noe, 2014).

A schematic description of an inkjet printhead is shown in Figure 20.

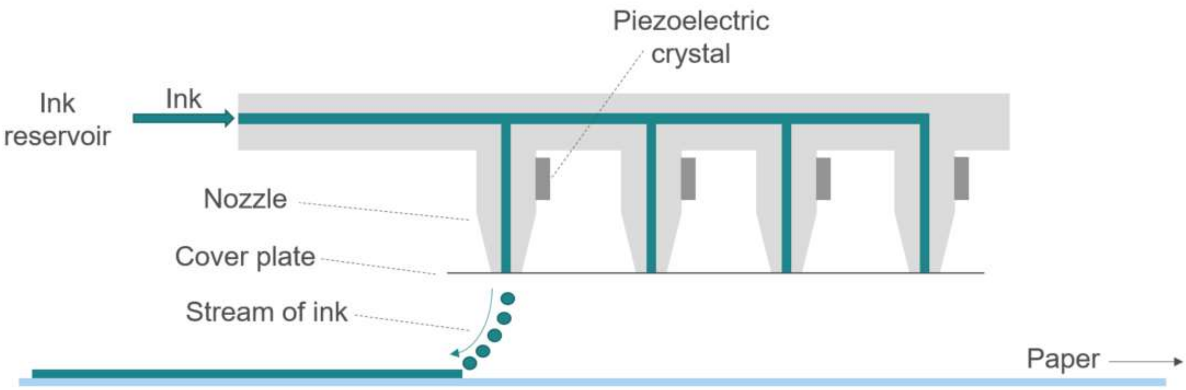


Figure 20. Schematic description of inkjet printhead
Source: JRC, adapted from Więcławska (2021)

A printhead is comprised of four main parts: the nozzle where ink is ejected onto paper during printing, the cover plate that shields the nozzles, the common ink chamber where ink is housed immediately before printing, and the substrate which houses a piezoelectric crystal. The piezoelectric crystal vibrates within the body of the cartridges to cause the stream of ink ejected from the nozzles to break into droplets at regular intervals (Noe, 2014).

Ink cartridges can be found in different configurations: as a separate printhead and ink cartridge, also known as ‘container’ (Figure 21); or as a combined unit including the ink reservoir and a print-head (Figure 22).

Figure 21. Single part ink cartridge

Figure 22. Integrated ink cartridge

In separated systems (Figure 21, for instance) the printhead, located in the printer, 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 (Figure 22) are more complex units. Accordingly, they have a higher inherent value than the separate cartridges. Many of them contain a spongy material called hydrophobic foam, often made of a synthetic, porous rubber that contains water-repelling agents. The 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).

As stated in section 2.2.3, 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.

In GEC (2022), material composition for different types of ink cartridges are provided (Table 16, Table 17 and Table 18).

Table 16. Material composition of OEM inkjet cartridge 1

Component	Material	Mass (g)	Weight percentage (%)
Housing	Polymer (PET)	23.6	59%
Inkjet circuitry	Printed circuit board	0.10	0.25%
Ink delivery system / foam	Polymer (PUR)	1.3	3.3%
Print head	Semiconductor (integrated circuit)	0.11	0.27%
Ink	Organics	15.0	37&

Source: GEC (2022)

Table 17. Material composition of OEM inkjet cartridge 2

Component	Material	Mass (g)	Weight percentage (%)
Ink reservoir	Polymer (PET)	23.9	41%
Sponge	Polymer (PS foam)	2.80	4.8%
Transit cap	Polymer (PET)	8.40	14%
Ink	Organics	23.3	40%

Source: GEC (2022)

Table 18. Material composition of OEM inkjet cartridge 3

Component	Material	Mass (g)	Weight percentage (%)
Ink reservoir	Polymer (PET)	28.0	38%
Sponge	Polymer (PS foam)	2.0	3%
Transit cap	Polymer (PET)	8.4	14%
Ink	Organics	20.0	34%

Source: GEC (2022)

In Huang et al (2019), alternative bill of materials for inkjet cartridges can be found.

2.2.2 Toner cartridges

Toner cartridges are used in electrophotographic (EP) printers, also known as laser printers. They are typically more complex than inkjet cartridges. They contain a solid toner powder and they may consist of a significant number of different components and materials. A schematic description of an all-in-one toner cartridge is shown in Figure 23.

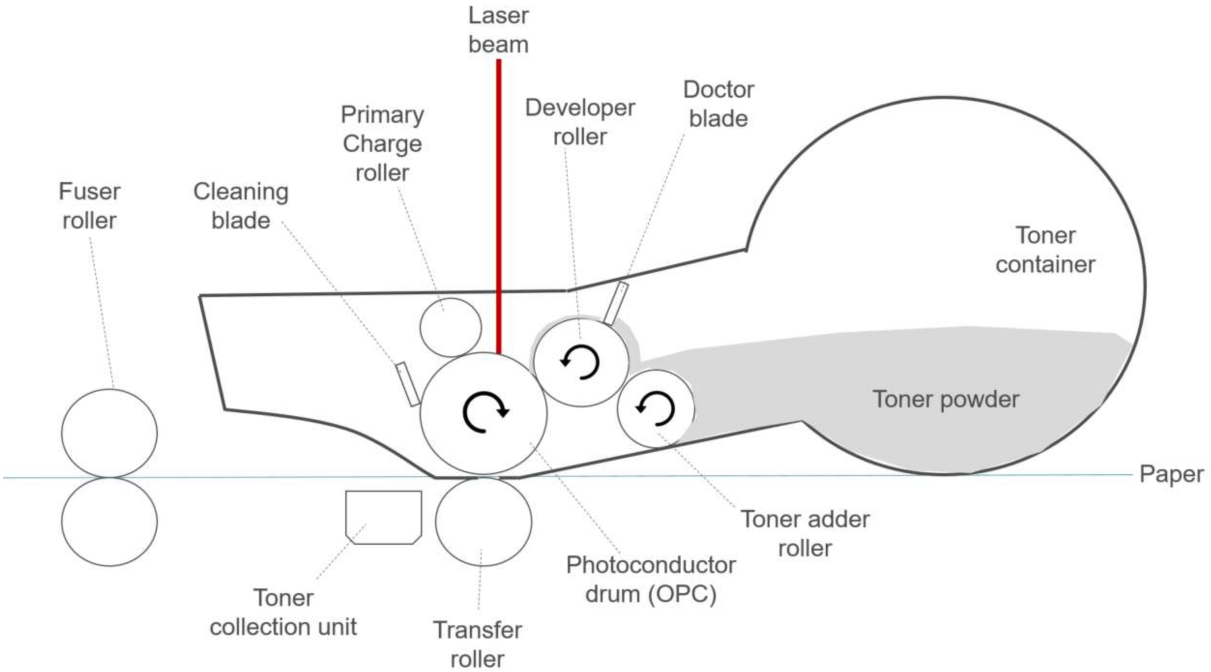


Figure 23. Schematic description of toner cartridge
Source: JRC, adapted from Tonerbuzz (2021)

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

- Organic photoconductor (OPC) drum: a cylinder coated with a substance whose electrical properties change when exposed to light. The drum is electrically charged and a laser within the printer changes the electrical charge on areas of the drum. Those areas then pick up toner and transfer it to the page.
- Primary charge roller: a rubber roller inside the toner cartridge which places the electrical charge on the OPC drum. It also erases the residual charge once the print cycle is complete.
- Developer roller: a cylindrical sleeve used to transfer image forming toner particles. The hollow cylinder is a non-magnetic material with a textured exterior surface. The interior contains a magnet producing a magnetic field to hold toner particles on the textured surface of the cylindrical sleeve.
- Toner adder roller: a cylinder that coats the developer roller with a layer of toner powder, while electrostatic charging the particles
- Doctor blade: a precise levelling blade which serves to keep toner on the magnetic developer roller to a single layer.
- Cleaning blade: a blade that cleans the surface of the OPC drum by scraping off the waste toner into the toner collection unit.

As in the case of inkjet, they can be found in different configurations (Figure 24, Figure 25, Figure 26).

Figure 24. Single part toner cartridge, also known as 'container'

Figure 25. Two part toner cartridge

Figure 26. All-in-one toner cartridge

In single part toner cartridges, the cartridge is restricted only to carrying the toner. The integrated design incorporates a toner storage unit and at least a developer part. Some integrated components include the organic photoconductor (OPC) drum as well (Figure 1). Integrated toner cartridges may contain more than 100 moving parts. Unbundling components as the developer and the photoreceptor part from the cartridge has, in principle a material efficiency advantage, due to the fact that the different components can have a different lifespan

Toner 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.

Toner cartridges can be either black (monochrome) or coloured.

In GEC (2022), material composition for a toner cartridge is provided (Table 19)

Table 19. Material composition of OEM toner cartridge 1

Component	Material	Weight percentage (%)
Housing	Polymers	45%
Toner mixture	Fe3O4	25%
Toner mixture	Carbon black	20%
Toner mixture	Additives	5%
Toner mixture	Wax	3%
Toner mixture	Cellulose/Kaolin	1%
Toner mixture	Surfactants	1%

Source: GEC (2022)

In Huang et al (2019), alternative bill of materials for toner cartridges can be found.

2.2.3 Electronic circuitry in cartridges

Key components in cartridges are the electronic circuitries, commonly known as chips. These components are typically mounted on a small circuit board and support communication between the cartridge and imaging equipment (through either direct contact or radio frequency connections). Typically, these electronic 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
- Contain 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.

The greater use of electronics in printer cartridges has also resulted in barriers to reuse for independent remanufacturers and refillers. 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). This aspect will be covered in more detail in section 2.2.7.3.1.

2.2.4 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).

Starter kits, also known as introductory cartridges, are a particular version of low page yield cartridges. They are often sold together with new printers, included in the price of the device. Generally, starter kits have significantly lower page yields than standard ones.

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.

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 (Table 20).

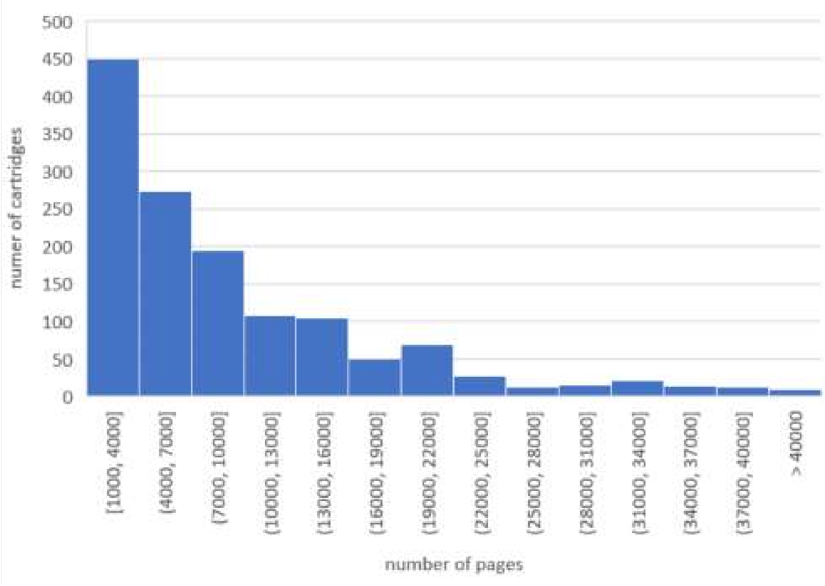
Table 20. Page yield of consumables.

Product type	Product speed (ipm)	Page yield					
		OEM			Remanufactured / Compatible		
		Min	Max	Average	Min	Max	Average
Monochrome laser printer	<20	1600	1600	1600	1600	1600	1600
	20-40	1200	36000	9727	1200	18000	6978
	40-60	2600	40000	17152	3000	25000	14647
	60-66	10000	41000	24125	0	0	0
	66-135	11000	41000	25667	0	0	0
	>135	0	0	0	0	0	0
Monochrome laser MFD	<20	1000	7200	3267	1000	7200	3075
	20-40	3000	45000	15729	3000	9000	5525
	40-60	2500	45000	15077	3000	25000	12063
	60-66	6000	25000	18400	6000	25000	18667
	66-80	6000	70000	36880	6000	25000	15500
	>80	0	0	0	0	0	0
Colour inkjet printer	<20	180	10000	2371	500	1130	731
	20-40	700	5000	2069	1200	2500	1534

	40-51	0	0	0	0	0	0
	51-60	0	0	0	0	0	0
	>60	0	0	0	0	0	0
Colour laser printer	<20	1400	23000	6633	1400	23000	9185
	20-40	1500	30000	6409	1500	12000	5453
	40-51	6000	44000	18910	6000	36000	14500
	51-60	6000	44000	21117	27000	36000	29250
	>60	52000	80000	59000	0	0	0
Colour inkjet MFD	<20	165	1130	384	165	1130	527
	20-40	250	4000	1300	250	550	313
	40-51	250	4000	1300	250	550	313
	51-60	0	0	0	0	0	0
	60-80	0	0	0	0	0	0
	>80	0	0	0	0	0	0
Colour laser MFD	<20	1400	23000	5653	1400	23000	7129
	20-40	2900	15000	7646	5000	15000	7460
	40-51	10500	44000	25031	25000	36000	27375
	51-60	11500	44000	29550	25000	36000	27375
	60-80	8000	80000	28968	0	0	0
	>80	52000	80000	59000	0	0	0

Source: Huang et al (2019)

For the development of this 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 more than 1400 models from 22 different OEMs, in terms of cartridge type, page yield and cartridge mass. In Figure 27, a histogram representing number of cartridges for different ranges of page yield is presented.



Source: ETIRA

Figure 27. Toner cartridge page yield

As it can be seen in Figure 27, most of the toner cartridges in the ETIRA DB are in the low range of page yield: 33% of the cartridges provide 4000 pages or less. Only 13% of cartridges provide 20000 pages or more.

2.2.4.1 Cartridge material efficiency

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, in terms of efficiency. Some may provide a large number of pages with less amount of material, whereas others may be less efficient in the use of materials. The page yield of a consumable is influenced by several factors, including the efficient use of the consumable material and its inner 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.

Figure 28 shows consumables with different design that can result in different levels of material efficiency. The sponge in the inner compartments contains the ink used to print. Consumables A and B are two different monochrome cartridge models with different exploitation of the inner available volume. Consumable A makes use of the full available volume, whereas consumable B includes additional inner compartments to reduce the total amount of ink. With the same amount of material, consumable A makes a more efficient use of resources. Similarly, consumables C and D are two different colour cartridge models with different material efficiency. Whereas consumable C exploits all the available inner volume, consumable D limits the total amount of ink with the use of inner compartments. Therefore, material efficiency of consumables B and D is limited by reducing the amount of available ink. With the same amount of material, consumables B and D are able to print less pages than consumables A and C, respectively.

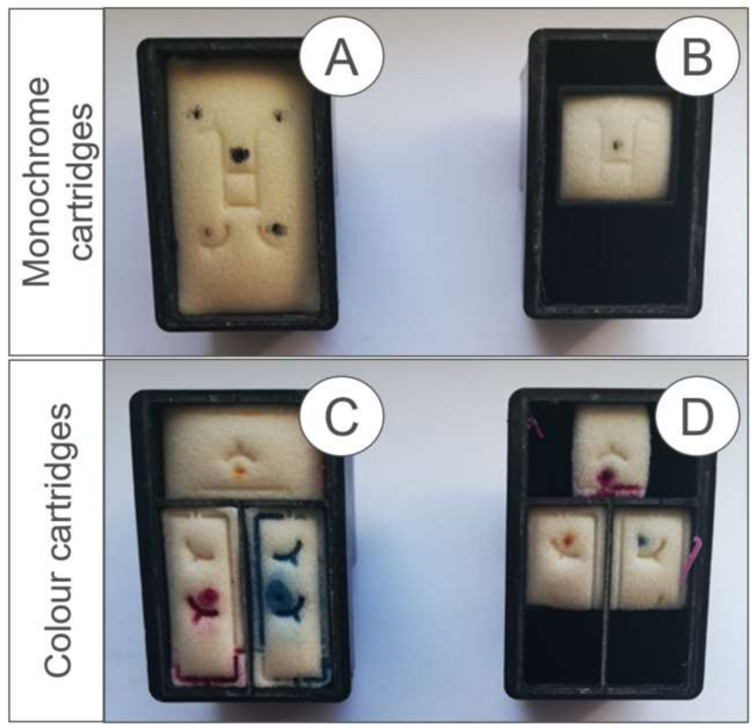


Figure 28. Monochrome and colour cartridges with different page yield

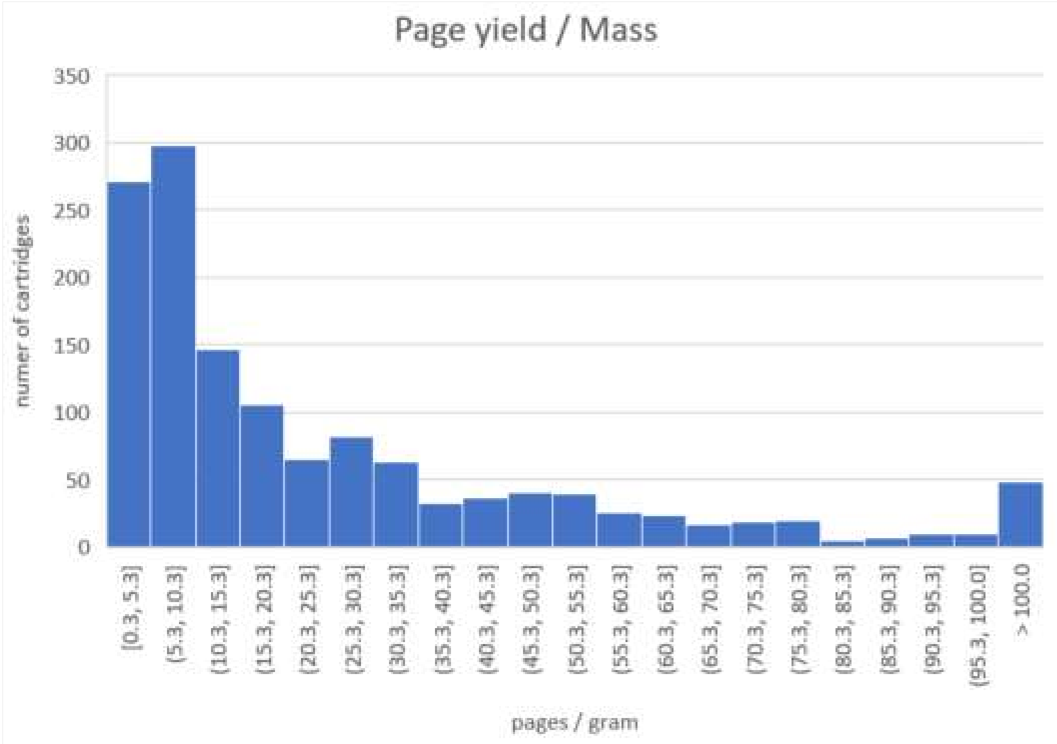
OEMs justify the need of placing in the market consumables such as B and D with the need of offering customers different price points. For instance, consumable B will be sold at a lower price than consumable A. However, it is very likely that the cost per page will be lower with consumable A.

A similar example in toner cartridges (where similar outer volumes provide different page yield) is presented in Tonerbuzz (2018).

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.

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.

In Figure 29, a histogram representing number of cartridges for different ranges of material efficiency (in terms of pages/gram) is presented.



Source: ETIRA

Figure 29. Cartridge material efficiency

As it can be seen in Figure 29, most of the cartridges in the ETIRA DB are in the lowest range of material efficiency: 43% of the cartridges provide 10 pages/gram or less. Around 20% of cartridges in the database produce less than 5 pages/gram. Only 16% of cartridges provide more than 50 pages per gram of material.

2.2.4.2 Cartridge material efficiency in GPP and voluntary schemes

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 × [10 × tanh(0.1+0.0003 × (CMass-10))-0.5]+1)	For toner cartridges
(2 × [15 × tanh(0.2+0.0004 × (CMass-8))-1]+2)	For ink cartridges

A slightly different approach is followed in Nordic Ecolabelling for imaging equipment (REF). 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 (*Table 21 *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 21*.*

Table 21. 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

2.2.5 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.

Ink cartridge manufacturers include expiration dates to encourage consumers use their ink before it becomes susceptible to clogs or print quality issues (Source: LD Products (Stowell, 2022)

Figure 30). On occasions they will also include warranty dates.

Source: LD Products (Stowell, 2022)
Figure 30. 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.

2.2.6 Cartridge print quality

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.

In terms of standards, 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.

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.

Print quality was also addressed in Waugh et al (2018) as one of the aspects which could improve the market situation for both legitimate new 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.

2.2.7 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

As described earlier, some cartridges contain electronic circuitry so can be considered within the scope of the WEEE Directive. In this Directive it is stated that from 2019 onwards, the minimum collection rate to be achieved annually shall be 65% of the average weight of Electrical and Electronic Equipment (EEE) placed on the market in the three preceding years in each Member State, or alternatively 85% of Waste Electrical and Electronic Equipment (WEEE) generated on the territory of that Member State.

2.2.7.1 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 31). 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 31. 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 32). 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 32. 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.

2.2.7.2 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. Data on cartridge collection is scarce and in occasions contradictory, depending on the source. 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. In Waugh et al (2018) the take-back schemes of some of the main OEMs in the EU market are described (it must be noted that some of these schemes might be slightly different today):

> *Brother*
>
> *Brother offers recycling schemes for both toner and inkjet cartridges. Brother offers three routes for returning used toner cartridges, depending on quantity:*
>
> *-Up to 4 toner cartridges: free postal return. Customers can print out a free postal label and are instructed to pack the empty toner cartridge into the box in which the new toner cartridges arrived.*
>
> *-Between 4 and 12 toner cartridges: free drop off. Customers can order a recycling box with a free postage label to return their cartridges.*
>
> *-More than 12 toner cartridges: free courier collection. Customers can register their details to receive a recycling box to store empty cartridges. Once the box is full, customers can contact Brother to arrange free collection.*
>
> *Brother offers its customers the opportunity to return inkjet cartridges for free by ordering a free postal paid envelope. Customers can return up to five cartridges per envelope.*
>
> *Canon*
>
> *Canon offers recycling schemes for both toner and inkjet cartridges. These schemes are free of charge for genuine Canon cartridges. Both toner and printer cartridges are sent to local hubs for consolidation, before being sent to Canon's recycling facilities - Canon Bretagne S.A.S. in France.*
>
> *Epson*
>
> *Epson offers recycling schemes for both toner and inkjet cartridges through its 'Cartridge Collection & Recycling Programme'. These schemes are free of charge for genuine Epson cartridges. Users who own over 10 Epson printers are requested to register to order cartridge collection boxes, while users with fewer than 10 Epson printers are able to apply online for free return postage labels.*
>
> *HP*
>
> *HP offers recycling schemes for both toner and inkjet cartridges through its 'HP Planet Partners programme'. This scheme is free of charge for genuine HP cartridges and offers different solutions for individual and bulk collections.*

Users returning low volumes of toner cartridges can print postage-paid return labels to return up to four toner cartridges per parcel. Users returning more than 15 toner cartridges can arrange for cartridge collection boxes to be delivered and then collected when full.

Users returning low volumes of inkjet cartridges can apply for postage-paid return envelopes to return up to ten inkjet cartridges per envelope. Users returning more than 100 inkjet cartridges can arrange for cartridge collection boxes to be delivered and then collected when full.

Kyocera

Kyocera offers a take-back system for toner cartridges accessible across the EU via its web portal. This free take-back service takes the form of medium and large boxes delivered to customers and capable of accepting up to 25 and 50 cartridges respectively. It is also possible for smaller users to return single cartridges by generating a return postage label and sending wrapped used units back for processing. This service caters for both unified and toner-only cartridge variants.

Lexmark

Lexmark operates the 'Lexmark Cartridge Collection Programme (LCCP)' and offers different solutions for small, medium and large businesses. Small businesses consuming fewer than 10 toner cartridges per year can apply on-line for free postal labels (toner) or envelopes (inkjet). Medium-sized businesses consuming between 10 and 40 cartridges per year can apply on-line for a free postage-paid Ecobox, which can be filled with used cartridges and then sent back to Lexmark when full. Lexmark also offers customers an Eco Report, summarising the sustainability benefits of the cartridges they have returned.

Large organisations using more than 40 cartridges per year can register to receive a range of container sizes for storing used cartridges. When the container is full, users can scan the container's QR code using a specific Lexmark mobile app, which will notify Lexmark to arrange collection. As for medium-sized businesses, Lexmark offers Eco Reports for large organisations participating in the LCCP, to summarise the sustainability benefits of their cartridge reuse.

Samsung

Samsung operates the 'Samsung Take-back and Recycling (STAR) programme' for retuning used toner cartridges, which began in 2006.

Samsung requires users to register their details and the printer and cartridge type before they are issued with a postage-paid return label, which can be used to return empty Samsung cartridges at no cost.

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.

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:

Brokers: 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 "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.

2.2.7.3

2.2.7.3 Cartridge reuse

When an ink or toner cartridge has been depleted, it can be refilled or remanufactured (definitions for 'refill' and 'remanufacture' are provided in section 1.3 of this study). By refilling or remanufacturing cartridges, it is possible to reduce the consumption of virgin materials, hence minimising environmental impacts (Huang et al, 2019).

As stated earlier, cartridges cannot be reused indefinitely. The amount of time a cartridge can be reused will depend greatly on their design and on their ability to be remanufactured or refilled. However, 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 and refilled 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. In terms of toner, due to the high value of toner cartridges, they are widely remanufactured (Waugh et al, 2018).

Different cartridge reuse rates have been published recently:

- 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 2.2.7.2.

In contrast to these figures, in Waugh et al (2018), technical and economic potential to reuse cartridges are published.

> *Technical re-use 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.*
>
> *Economic re-use potential refers to the economic business case for undertaking reuse. It may be technically feasible for a cartridge to be remanufactured or refilled, but if the cost of these operations (including any reverse engineering activities required, e.g. software development) is so high that the printer cartridge cannot be sold on the market for a profit, then there is no business case for undertaking re-use activities.*

Table 22. Potential of cartridge reuse

	Technical potential	Economic potential
Toner cartridges	92%	86%
Inkjet cartridges	87%	84%

Source: Waugh et al (2018)

Cartridge reuse needs to be facilitated by an appropriate design. However, in Huang et al (2019) it was highlighted that currently ink and toner consumables are less likely to be designed to facilitate ease of disassembly. In some other cases, some manufacturers may even be actively blocking remanufacturing, due to concerns over leakage and to commercial reasons. Most often, these barriers are introduced at the design phase of printer cartridge production, whereby design decisions are made without the ambition to facilitate or encourage re-use of the product at end-of-life. Examples of barriers to cartridge reuse are provided in Waugh et al (2018) and are described in the following section.

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:

> <u>Collection rate</u>*: estimate of % of cartridges collected through recognised collection processes.*
>
> <u>Viable percentage</u>*: 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.*
>
> <u>Remanufacturing rate</u>*: 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 23.

Table 23. 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%*

2.2.7.3.1 <u>Barriers for cartridge reuse</u>

The presence of electronic circuitry described in section 2.2.3 is commonly cited as a technical barrier for cartridge reuse, particularly for independent remanufacturers. Some of this electronic components -which provide useful functionality for the user- make re-use difficult if they do not include provision for resetting the chip during reuse. Independent remanufacturers without access to or knowledge of the hardware and software systems involved may either have to undertake reverse engineering activities, or replace the relevant microchips with new components. Actors in the industry have highlighted that the increasing technical complexity of, in particular, ink-jet cartridges has created barriers to reuse. The accusation is that such developments are largely driven to frustrate re-use rather than for performance enhancement, and their effect is exacerbated by lack of transparency in technical data (Waugh et al, 2018). According to Aston (2022), some OEMs are employing systems that recognise cartridges with a non-original chip and prevents them from working.

Unexpected firmware updates has also been highlighted as a barrier for cartridge reuse. These updates are sent to imaging equipment after having been placed on the market, and can result in changes to the encryption process between the device and the electronic chip. In some cases, the original OEM chips are able to adapt to these updates and changes to the encryption process, but non-OEM chips cannot adapt. The result is that those chips will no longer function correctly, making remanufactured cartridges unusable (Huang et al, 2019).

Related to this barrier, the Italian Competition Authority has found that the limitations on the use of non-original cartridges are not adequately highlighted on the sales packages (AGCM, 2020). In particular, according to the Authority, the OEM has failed to adequately inform consumers - at the time of purchase - about the presence of this relevant and significant limitation, leading them to believe that they need replacing non-original ink/toner cartridges due to shortages or defects thereof and hence to use only original cartridges. These limitations have been renewed and modified through subsequent printer firmware updates, proposed by the OEM to consumers, once again without properly informing them of the consequences of these updates, neither at the time of their dissemination, nor on its website, nor when information was requested to the assistance centres (AGCM, 2020).

The use of irreversible joining practices (such as gluing, sonic welding or adhesive tapes) has also resulted in a technical barrier for cartridge reuse. Some of these practices require cutting cartridges plastic bodies open to replace worn parts.

The rise of sales of counterfeits described in Section 2.2.8 is a market barrier for cartridge reuse. These cartridges are often unsuitable for subsequent reuse, as they may contain toxic or restricted hazardous substances. On top of that, due to their low quality materials and the lack of clarity of potential hazardous substances contained, these cartridges are generally not collected by remanufacturers. Their usual low cost make them apparently more attractive to consumers than legally 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 (Huang et al, 2019). 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. In Aston (2022), the authors state that their research shows third-party inks can offer good value and produce good-quality prints for a fraction of the cost of their premium counterparts.

Potentially related to these claims, in the public sector it is common to find procurement specifications that either explicitly exclude the use of reused cartridges or fail to promote or encourage their usage.

Legal barriers related to copyrights or patents have also been mentioned in Waugh et al (2018). 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.

2.2.7.3.2 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.

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 published by Clover (2022), 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.

2.2.7.3.3 Arguments against cartridge reuse

A variety of arguments have been given, fundamentally by OEMs, 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, OEMs tend to argue that reused cartridges will not perform to the standards of OEM-approved new cartridges. Some OEMs have 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 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.

2.2.7.3.4 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).

The conclusions attained in the different studies seem to be influenced by the role of the authors within the imaging equipment sector. Whereas studies conducted by remanufacturers and/or Universities tend to favour remanufactured cartridges, studies conducted by OEMs tend to favour original cartridges.

Therefore, cartridge print quality –namely the quality of remanufactured cartridges- 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.

2.2.7.4 Cartridge recycling

Although reuse precedes recycling activities in the waste hierarchy, 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).

Cartridge recycling can be divided in the following steps, according to promotional videos published by recyclers:

- 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.

Toner itself is designed to be stable, chemically and mechanically, through a complex chemical composition (Table 24).

Table 24. Chemical composition of toner

Component	% in mass
Polymers	45%
Fe3O4	25%
Carbon black	20%
Additives	5%
Wax	3%
Cellulose/Kaolin	1%
Surfactants	1%

Source: Ruan et al (2018)

The plastic particles in toners are meant to withstand the varying temperature, pressure, and humidity conditions of printers. While the stability of the toners is necessary to obtain a high-quality print, it is a challenge to recycling. The process of recycling involves mechanical dismantling and separation of the components, followed by density separation. In the later stages, recycling is completed using hydrothermal and various metallurgical processes. A review of emerging applications for the recycling of toner can be found in Parthasarathy, 2021.

2.2.7.5 *Cartridges sent to landfill*

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

2.2.8 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.*

The potential presence of toxic chemicals is a concern as well related to low quality compatible cartridges. According to a report published by ETIRA (2021), 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. In an additional study conducted by ETIRA, 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.

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.

2.3 Base cases

Base Cases (BC) should reflect average EU products. The base cases are used as reference for modelling the stock of products together with their environmental and economic impacts and the available improvement design options.

2.3.1 Device base cases

For the definition of the base cases, annual sales published in Huang et al (2019) will be used as a reference (Table 25). It must be noted that these is not the most recent data in terms of device sales. As part of the development of this preparatory study, a market analysis is being conducted in Task 2, where more up to date data in terms of devices sales is being collected. As soon as this new data is available, the preparatory study will be updated accordingly, and if needed, the definition of the base cases as well.

Table 25. Imaging equipment devices sales

Sales in million units	2020	2025	2030	2035	2040
Inkjet printers	0.91	0.86	0.82	0.78	0.74
Inkjet MFP	14.09	13.40	12.74	12.12	11.53
Laser printers	3.64	3.46	3.29	3.13	2.97
Laser MFP	3.98	3.78	3.60	3.42	3.25
Scanners	0.46	0.88	0.88	0.88	0.88
Copiers	0.00	0.00	0.00	0.00	0.00
Faxes	0.00	0.00	0.00	0.00	0.00

Source: Huang et al, 2019

Based on the sales data Table 25, the proposed base cases in Huang et al, (2019) is shown in Table 26.

Table 26. Device base cases proposed in Huang et al (2019)

Base Case	Description
BC1	Monochrome laser multi-function printer, 20 < s < 40
BC2	Colour laser multi-function printer, 20 < s < 40
BC3	Monochrome laser printer, 20 < s < 40
BC4	Colour laser printer, 20 < s < 40
BC5	Colour inkjet multi-function printer, s<20
BC6	Colour inkjet printer, s<20

S: printing speed, in pages per minute

For simplification purposes, in the present study a modification of the list of base cases of Huang et al (2019) will be proposed. In the inkjet sector, the market is clearly dominated by multi-function printers. The base case for inkjet printers will therefore be a MFP. In the laser sector, sales of printers and multi-function printers is expected to have a similar size. However, the performance of laser printers and laser MFPs are very similar. Therefore, one base case (MFP) will be proposed for laser devices as well.

Scanners, copiers and faxes are expected to have negligible sales between 2020 and 2040, so no base cases will be included for those devices.

Based on this, the proposed list of base cases for the present study is shown in Table 27.

Table 27. Base cases proposal for imaging equipment devices

Base Case (1)	Description	Typical use
BC1Dev	Colour laser multi-function printer, 20 < s < 40	Laser office multi-function printer
BC2Dev	Colour inkjet multi-function printer, s<20	Inkjet home printer

(1) the base cases proposed in the present study are subject to the availability of market and user behaviour data. When this data becomes available, the list of base cases may be increased or updated

In terms of energy consumption, the base cases performance values applied Huang et al, (2019) are described in Table 28. Regarding the specific value applied, in the case of BC1Dev the study team considers the TEC value applied by Huang et al. (2019) needs to be revised. The average TEC reported by Huang et al. (2019) (1.8 and 2.1 kWh/week) is by far higher than the average TEC for the same range products currently registered under the US Energy Star Programme (around 0.4 kWh/week for both base cases). This difference does not seem to be plausible, considering the high level of market uptake of Energy Star products[12]. Further evidence will be collected during the preparatory study (e.g. Task 2 on Market Analysis). In this context, as preliminary proposal, the study team considers that the US Energy Star average TEC, with a 20% correction factor, could be used for establishing a preliminary base case, as for the following formula:

BC1Dev TEC= Average Energy Star BC1Dev TEC + 0.2 * Average Energy Star TEC BC1Dev

Regarding the BC2Dev, the sleep state and state baseline scenario established by Huang et al. (2019) is fully in line with the average performance of Energy Star products currently certified as described in Table 13.

Table 28. Device base cases and energy consumption

Base Case	Description	Energy (3)	Power (3)	
		Average TEC (1) (kWh/week)	Sleep state (W) (2)	Standby/off (W) (2)
BC1Dev	Colour Laser MFP, 20 < s ≤ 40	1.8 (in Huang et al. (2019)) 0.5 (JRC proposal)	n/a	n/a
BC2Dev	Colour Inkjet MFP, s ≤ 20	n/a	1.1	0.1

(1) Energy consumption of laser printers is more significant on active state, so it is measured with the TEC approach

(2) Energy consumption of inkjet printers is more significant on low power modes, so it is measured with the OM approach

(3) Energy consumption and power data is subject to updates, as soon as more recent data becomes available for the present study

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 considered that the average lifetime of an inkjet printer is around 3 years. However, this time could be increased 2 additional years if reparability was adequately promoted.

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

[12] While more evidence needs to be collected for the EU market, EPA reported a market penetration for energy star products of 90% for Energy Star compliant multifunctional devices and printers. See: https://www.energystar.gov/sites/default/files/asset/document/2019%20Unit%20Shipment%20Data%20Summary%20Report_0.pdf

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.

Printer lifetime is an aspect that will be evaluated as part of Task 3 (Users). Lifetime estimations will be made based on recent consumer data from a survey and used to define the base cases. This data is not available at this point. In the meantime, in terms of lifetime, the proposed base cases can be seen in Table 29:

Table 29. Device base cases and expected lifetime

Base Case	Description	Expected lifetime (years)
BC1Dev	Colour Laser MFP, 20 < s ≤ 40	5
BC2Dev	Colour Inkjet MFP, s ≤ 20	3

In terms of cartridges associated to each of the base cases, a summary is presented in Table 30. The selection of the type of cartridges is based on sales data presented in Huang et al, (2019), pg 102. As in the case of devices, for the definition of typical cartridges, it must be noted that this is the most recent published data in terms of device sales. As part of the development of this preparatory study, a market analysis is being conducted in Task 2, where more up to date data in terms of cartridges sales is being collected. As soon as this new data is available, the preparatory study will be updated accordingly, and if needed, the definition of the base cases as well.

Table 30. Device base cases and associated cartridges

Base Case	Description	Type of cartridge (1)
BC1Dev	Colour Laser MFD, 20 < s ≤ 40	Two part toner cartridge (colour)
BC2Dev	Colour Inkjet MFD, s ≤ 20	Single part ink cartridge (colour)

(1) The selection of cartridge type is subject to changes, as soon as market data on cartridges is available for the present study.

The bill of materials of the BC1Dev and BC2Dev are presented in Table 31. They are based on data provided by stakeholders to Huang et al (2019).

Table 31. Device base cases bill of materials

Material breakdown (1)	BC1Dev (grams)	BC2Dev (grams)
Bulk Plastics	11.5	8.4
TecPlastics	10.2	3.9
Ferro	27.7	8.0
Non-ferro	3.0	0.8
Coating	0.0	0.0
Electronics	6.3	3.3
Miscellaneous	9.6	4.3

(1) Material categories are based from EcoReport tool (European Commission, 2013)

Source: Huang et al (2019)

2.3.2 Cartridge base cases

The selection of cartridge base cases is related to the definition of device base cases. BC1Dev is assumed to use two part toner cartridges. BC2Dev is assumed to use single part ink cartridge (Table 30). Based on this, cartridge base cases are proposed in Table 32.

Table 32. Cartridge base cases proposed in present study

Base case	Description
BC1Car	Two part toner cartridge (colour)
BC2Car	Single part ink cartridge (colour)

BC1Car is composed fundamentally of a containment part, with the deposition mechanism located in the device. BC1Car is commonly known as well as an ink 'container'. BC2Car is composed of a containment part and a developer part, with the organic photoconductor (OPC) drum located in the device. A schematic illustration of single part ink cartridges and two part toner cartridges can be seen in Figure 33 and Figure 34, respectively.

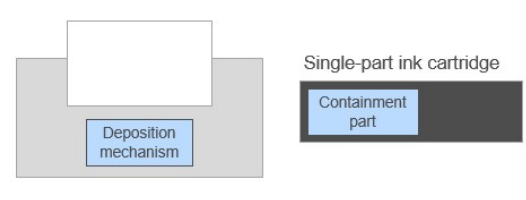


Figure 33. Single part ink cartridge (BC1Car)

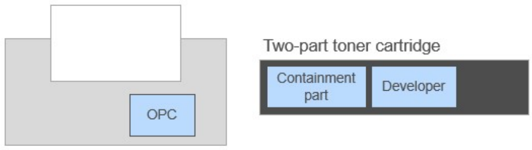


Figure 34. Two part toner cartridge (BC2Car)

For the definition of the base cases in terms of page yield, the proposals made in Huang et al (2019) will be taken as a reference (page 191). In that report, average, maximum and minimum page yields are provided for different types of cartridges. For the base cases in the present study, average page yields will be considered. Then, additional data is provided in charts presenting pages/gram of material versus page capacity (pages 193-194 of Huang et al, 2019). Material efficiency of the base cases in the present study will be taken from this data. A summary of the proposed cartridge base cases can be seen in Table 33.

Table 33. Cartridge base cases and page yield

Base case	Description	Page yield (number of pages) (1)	Material efficiency (pages/gram of material) (2)
BC1Car	Two part toner cartridge (colour)	7646	6
BC2Car	Single part ink cartridge (colour)	384	7

(1) Source: Huang et al (2019), page 191

(2) Source: Huang et al (2019), pages 193-194

For cartridge base cases, an average factor for reusability will be defined. This factor should reflect how likely a cartridge may be reused, based on its technical characteristics. Reusability is a semi-qualitative factor that cannot be directly measured, for which it is complex to assign a specific value. Therefore, estimations from Table 23 will be used to estimate cartridge reusability. Collection rates will not be taken into account since they cannot be addressed (they cannot be improved) with ecodesign regulation. 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 34.

Table 34. Cartridge base case reusability

Base case	Description	Reusability (%)
BC1Car	Two part toner cartridge (colour)	38%
BC2Car	Single part ink cartridge (colour)	48%

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 2.2.6 (print quality) and 2.2.7.3.3 (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 both Base Cases, a 3% failure rate is proposed (out of 33 prints, 1 paper sheet is unusable).

Table 35. Printing quality (failure rate)

Base case	Description	Failure rate (1)
BC1Car	Two part toner cartridge (colour)	3%
BC2Car	Single part ink cartridge (colour)	3%

(1) Percentage of unusable sheets of paper

The bill of materials of the proposed cartridge base cases can be seen in Table 36. They are based on data provided by stakeholders to Huang et al (2019).

Table 36. Cartridge base cases bill of materials

Material breakdown (1)	Mass (g)	
	BC1Car	BC2Car
Bulk Plastics	339	33
TecPlastics	86	1
Ferro	179	1
Non-ferro	58	0
Coating	10	0
Electronics	3	0
Miscellaneous	132	9
Deposition material	166 (2)	20 (3)

(1) Material categories are based from EcoReport tool (European Commission, 2013)

(2) Toner

(3) Ink

Source: Huang et al (2019)

2.4 Best Available Technologies

In this section, proposals for Best Available Technologies (BAT) in the imaging equipment sector will be made. These BAT will be presented for both devices and cartridges, and for different factors.

2.4.1 Devices Best Available Technologies

Best Available Technologies (BAT) in devices can be related to a variety of factors, such as energy consumption and reparability.

In terms of energy, the BAT may be considered as a device within the 10% best performing products according to Energy Star v3.2. Following this approach, the proposed BATs for devices can be seen in Table 37.

Table 37. Best Available Technologies for devices in terms of energy

BAT	Description	Energy (3)	Power (3)	
		Average TEC (1) (kWh/week)	Sleep state (W) (2)	Standby/off (W) (2)
BAT1Dev	Colour Laser MFP, 20 < s ≤ 40	0.29	n/a	n/a
BAT2Dev	Colour Inkjet MFP, s ≤ 20	n/a	0.7	0.07

(1) Energy consumption of laser printers is more significant on active state, so it is measured with the TEC approach

(2) Energy consumption of inkjet printers is more significant on low power modes, so it is measured with the OM approach

(3) Energy consumption and power data is subject to updates, as soon as more recent data becomes available for the present study

(4) BAT are expressed in relation to the Base Cases previously defined

In terms of lifetime, the BAT may be considered as a device with the ability to function as required, for a period of time which is among the leaders in the market. The potential lifetime of devices has been studied in reports such as HOP (2017) and ADEME (2019). Based on those studies, the proposed BATs for devices can be seen in Table 38:

Table 38. Best Available Technologies for devices in terms of lifetime

BAT	Description	Expected lifetime (years)
BAT1Dev	Colour Laser MFP, 20 < s ≤ 40	10
BAT2Dev	Colour Inkjet MFP, s ≤ 20	6

Source: HOP (2017); ADEME (2019)

In terms of compatibility with remanufactured cartridges the following aspects are considered relevant:

- Use of user-resettable electronic circuitries (if any) for functionality as toner level / page counting
- Long term compatibility of the device with cartridges from previous generations

2.4.2 Cartridges Best Available Technologies

Best Available Technologies (BAT) in cartridges can be related to a variety of factors, such as page yield, material efficiency, reusability and waste avoidance.

In terms of page yield, the BAT will be a cartridge with the ability to increase significantly both the average number of page capacity and the material efficiency of the proposed base cases. Based on that, the proposed Best Available Technologies can be seen in Table 39. They are based on page yield and material efficiency data published in Huang et al (2019).

Table 39. Cartridge Best Available Technologies and page yield

BAT	Description	Page yield (number of pages)	Material efficiency (pages/gram of material)
BAT1Car	Two part toner cartridge (colour)	17000	14
BAT2Car	Single part ink cartridge (colour)	2300	29

(1) Source: Huang et al (2019), page 191

(2) Source: Huang et al (2019), pages 193-194

In terms of reusability, the BAT will be a cartridge with no technical features that limit their remanufacture. Features that the BAT cartridge in terms of reusability might have are:

- Design for disassembly feasible with reusable fasteners / joining techniques, common tools

- Use of re-settable electronic circuitries (if any) for functionality as toner level / page counting

- Absence of internal empty compartments

- High capacity in terms of ink/toner volume

- Long term compatibility of the cartridge with new imaging equipment devices placed on the market

To define the BATs for cartridges, the technical potential in reusability estimated in Waugh et al (2018) will be used (Table 40).

Table 40. Cartridge Best Available Technologies and reusability

BAT	Description	Reusability (%)
BC1Car	Two part toner cartridge (colour)	92%
BC2Car	Single part ink cartridge (colour)	87%

Source: Waugh et al (2018)

In terms of printing quality, for both BATs, a 1% failure rate is proposed (out of 100 prints, 1 paper sheet is unusable).

Table 41. Printing quality (failure rate)

Base case	Description	Failure rate (1)
BC1Car	Two part toner cartridge (colour)	1%
BC2Car	Single part ink cartridge (colour)	1%

(1) Percentage of unusable sheets of paper

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