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Imaging equipment and its consumables. Preparatory Study for Ecodesign.

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Contents

Abstract

The Commission has decided to work on mandatory regulatory measures under Ecodesign Directive for imaging equipment and its consumables. This Preparatory Study is the first step towards the implementation of such measures. In this document, the current status of the imaging equipment market, user behaviour and technology aspects of this sector have been evaluated.

Issues with environmental relevance have been identified as part of this research. For instance, devices seem to operate under short replacement cycles, despite the willing of consumers of prolonging their lifetime. Prevalent business models and high cost of repair partially explain this short lifetime of printers. Regarding cartridges, the main environmental issues are related to low reuse rates, usually caused by technical barriers introduced during the design phase. Other areas where cartridge environmental performance can improve are related to the optimisation their capacity or on the design of more material efficient configurations.

Environmental and economic assessments of typical products have been carried out. Design options with the potential to reduce the environmental impact have been identified and evaluated. Then, ecodesign measures have been proposed. Improvements can be achieved in greenhouse gas emissions and consumer expenditure with measures aimed at increasing printer lifetime, or tackling the barriers against cartridge reuse, among others.

Executive Summary

Policy context

Imaging equipment is one of the few product groups that has been regulated via a Voluntary Agreement (VA). The current VA –in force since 2015- is focused on devices (printers), dealing with aspects such as energy efficiency, design for recycling, polymer composition, spare part availability and paper recyclability, among others (Eurovaprint, 2015). Imaging equipment is also among the product groups mentioned as a priority by the Circular Economy Action Plan (CEAP20), which establishes 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".

A new VA was proposed by the industry in 2021 (Eurovaprint, 2021) and evaluated by the JRC on behalf of Directorate–General for the Environment (DG ENV). The aim was to ensure that the level of ambition was aligned with the CEAP20, and that it was compliant with the self-regulation guidelines, detailed in Article 17 of the Ecodesign Directive and in European Commission (2016). The EC considered that the VA proposal, despite the improvements introduced, was not compliant with all the self-regulation guidelines of the Ecodesign Directive and that it had not reached the ambitious objectives in terms of circularity mandated by the CEAP20. Therefore, the Commission decided to work on mandatory regulatory measures under the Ecodesign Directive. Consequently, imaging equipment was included in the list of new measures under the Ecodesign and Energy Labelling Working Plan 2022–2024 (European Commission, 2022b). This Preparatory Study is the first step towards the implementation of such mandatory regulatory measures.

Key conclusions

A life cycle environmental and cost assessment has been carried out in this Preparatory Study for the typical products in the market. The environmental hotspots have been identified: raw materials and product manufacturing are the environmental hotspots of both printers and cartridges, suggesting that these are complex products with a wide variety of materials and components, requiring a significant amount of energy to produce and assemble. In contrast with other consumer products regulated under ecodesign, energy use is not an environmental hotspot. The economic assessment has been carried out on a per-page basis. Results show that the cost of producing a page is usually higher in those devices with shorter lifetime, and in those cartridges with lower page yield.

A series of design options with the potential to reduce the environmental impact of devices and cartridges have been identified and evaluated. In the case of printers, extending their lifetime via reparability and durability measures is the option with the highest potential of reducing their environmental. Extending lifetime is also the option with the highest potential of reducing consumer expenditure on devices. For cartridges, using material efficient configurations (single-part rather than integrated solutions) is the option with the highest potential of reducing their environmental impact. Increasing the use of remanufactured cartridges up to a high level of reusability scenario can bring comparable environmental improvements. Improving capacity utilisation of cartridges can also provide significant environmental benefits. Increasing the use of remanufactured cartridges is the option with the highest potential to reduce consumer expenditure on cartridges, followed by the improvement of capacity utilisation.

Main findings and recommendations

With the aim of encouraging the design of the alternatives with the highest potential to reduce environmental impact and consumer expenditure, a series of ecodesign measures have been proposed by the JRC, applicable for both devices and consumables. The main objectives of the measures addressing devices are ensuring that devices last longer and are easier to repair, refurbish and recycle; exploring the untapped potential for improved energy savings in devices; optimizing the consumption of paper; and increasing the use of post-consumer recycled plastic in devices. In the case of consumables, the measures were aimed at improving the capacity utilisation in cartridges; increasing the possibilities to remanufacture cartridges, encouraging the use of material efficient cartridge configurations; and reducing the amount of paper wasted due to performance of cartridges. The measures were presented to stakeholders in an open consultation process and feedback was gathered in writing.

To ensure that devices last longer, a series of measures on reparability were proposed. For instance, design for disassembly requirements; the guaranteed availability of spare parts for a considerable period; the guaranteed availability of software and firmware updates; or mandatory availability of device resetting functions. These measures have been generally supported by stakeholders, and would simply require at this point some level of refinement in the text, to ensure that all relevant priority parts for repair are included in the list of spare parts, and that the mandatory availability period of these priority parts is balanced in terms of the product application, among other aspects.

In addition, to ensure that devices last longer, some measures on durability were proposed. For example, mandatory provisions on software and firmware updates; user access to information on number of pages printed; or minimum durability requirements of key consumables such as print heads or drum units. Based on stakeholder feedback, these measures would require further consideration before implementing them in new regulation. Standard measurements would be needed to ensure that the duty cycle of printers -total amount of pages that devices are able to print- can be compared. Standard measurements would also be essential to establish minimum durability requirements –in pages printed- for key consumables. The measure proposed to increase the recyclability of devices has been widely supported by stakeholders and would simply require some text refinement to clarify verification methods.

To capitalize the remaining untapped potential for improved energy savings in printers, a proposal has been made to include minimum requirements for non-active modes, which are more ambitious than the ones included in Regulation 2023/826[1], both in terms of power consumption and transition time between active and non-active modes. Stakeholders have opposing views on these requirements: while OEMs oppose to stricter minimum requirements, environmental NGOs and national environmental agencies support them. Based on feedback received and on the analysis carried out in the Preparatory Study, the JRC has recommended implementing stricter requirements for imaging equipment than those included in Regulation 2023/826.

Other measures proposed applicable to devices are the mandatory availability of functionality that allows printing on both sides of paper (widely supported by stakeholders with minimum changes needed); and a mandatory minimum percentage of post-consumer recycled plastic for certain components in devices (recommended to change to an information requirement).

With the aim of improving cartridge capacity utilisation, minimum mandatory page yield requirements have been proposed for ink and toner cartridges. Stakeholders have opposing views on the minimum requirements proposed by the JRC: while OEMs consider they are too ambitious and would significantly affect the lower end of the market; environmental NGOs, Member State representatives and national environmental agencies consider that they are not ambitious enough. Some OEMs have made alternative proposals to improve capacity utilisation, in terms of tiered minimum page yield requirements related with product application, and in terms of mandatory placing on the market of high yield cartridges (while not being the only choice available). Considering this level of disagreement, the JRC has recommended to either leave the minimum thresholds as they have been proposed in the Preparatory Study; or to liaise with OEMs, National environmental agencies and NGOs to agree on feasible minimum thresholds for ink and toner cartridges, having different thresholds based on device printing speed.

To increase the possibilities to remanufacture cartridges, a number of proposals have been made by the JRC. For instance, a mandatory measure for OEMs to provide a solution to authorised remanufacturers so that the cartridge chip can be reset at end of life, ensuring that the cartridge retains its key functionality when reused. This proposal has been widely supported by stakeholders. Some text refinement would simply be needed to clarify aspects such as the meaning of 'reasonable and proportional cost', the process of authorisation for remanufacturers, or the verification method. An exemption to this measure was proposed by OEMs: in their view, cartridges sold as part of subscriptions (Printing as a Service), should be exempt, in order to enable the viability of these business models. Cartridge remanufacturers, environmental NGOs, Member State representatives and national environmental agencies opposed to the exemption proposed by OEMs. They considered that exempting cartridges sold in subscriptions could open a loophole and undermine the potential environmental benefits of the mandatory provision of chip resetting functionality.

To facilitate chip resetting operations, the JRC proposed that physical access to the chip shall be ensured without damaging the cartridge, which has been widely supported by stakeholders. Additional proposals to facilitate cartridge remanufacturing are the mandatory compliance with minimum durability and reliability from shocks and drops; the avoidance of design detrimental to cartridge remanufacturability; the or the mandatory inclusion of relevant information for remanufacturing within the cartridge chip. These measures require further liaison

[1] Ecodesign requirements for off mode, standby mode and networked standby consumption

with OEMs and remanufacturers to ensure that the text results in workable requirements compatible with ecodesign principles.

Minimum material efficiency requirements –in pages per gram of cartridge material- have also been proposed, to encourage the design of material efficient cartridge configurations, driving the market from complex integrated solutions to simpler single-part designs. Based on stakeholder feedback, these measures would require further consideration before implementing them in new regulation. Most of OEMs opposed to having minimum requirements on material efficiency, since they consider that they could bring unintended consequences that could be detrimental to consumers and the environment. They explained that single-part cartridges may not always be the best performing environmental solution, since these require heavier and more complex devices, which could undermine the expected benefits of cartridge simplification. Cartridge remanufacturers support the introduction of minimum requirements on material efficiency but disagree on the method proposed by the JRC: they recommend changing the formula of material efficiency, in order to consider the mass and page yield of different components involved in the printing operation. Considering this level of disagreement, the JRC has recommended to carry out additional work with the aim of understanding how to better implement these type of measures. For instance, developing a more detailed environmental assessment of the consequences of switching from integrated to single-part cartridges; initiating the collection of data of key components in the printing system; the definition of an appropriate formula to estimate cartridge material efficiency; or to liaise with stakeholders to agree on feasible minimum requirements.

Additional to the measures proposed by the JRC, some stakeholders recommended the inclusion of other measures. Some of them could be easily implemented in new regulation, such as design requirements on cartridge recyclability –similar to the requirements on device recyclability-; or minimum air quality requirements for devices –using as a basis minimum requirements in currently available ecolabels-.

Other additional measures proposed by environmental NGOs and national environmental agencies would require further work and discussion before being implemented in new regulation. This is the case of minimum energy efficiency requirements in the active mode for devices. The JRC considers that in order to set feasible minimum requirements, it would be necessary to re-assess available data on energy consumption of laser devices to define the most appropriate indicator; or to evaluate how feasible and relevant it is to set minimum requirements on inkjet devices (based on the lack of measurement method today). An energy label on devices has also been proposed. Similarly, it would be necessary to study how feasible it is to establish an energy classification, based on the apparent limited spread on energy efficiency. It would also be essential to decide whether laser and inkjet devices should be classified under the same label or in different labels. Different options regarding the energy classification would need to be evaluated: energy efficiency index, number of energy classes, energy class width, etc. On top of that, it should be studied which other product parameters beyond energy might be of interest to include in an energy label.

A reparability score for devices has also been proposed by national environmental agencies. Such a repair score could be linked to the inclusion of an energy label described above, and would also require further work, related with the selection of parameters relevant for repair on devices; the definition of scoring criteria, weighting factors and aggregation; the definition of assessment and verification methods; and the calibration and testing with real products in the market.

Cartridge remanufacturers have recommended the inclusion of a mandatory reuse target applicable to OEMs, in order to increase cartridge remanufacturing rates. Even though this measure was included in the VA proposal of 2021, it has not been included as a possible measure in this Preparatory Study, due to the nature of ecodesign regulation, applicable only to new products placed on the market. A cartridge reuse target applicable to OEMs would not be verifiable by Market Surveillance Authorities when the product enters the European market. Similarly, remanufacturers have recommended some direct action against cloned and counterfeit cartridges. Although this is acknowledge by the JRC as one of the main issues in the imaging equipment market, affecting both OEMs and remanufacturers, it has been concluded that ecodesign regulation is not the appropriate instrument to address it.

The JRC authors consider that the measures initially proposed were balanced and aimed at improving the environmental performance of devices and cartridges, considering their hotspots and potential for improvement. Feedback received by multiple stakeholders has provided clarity on the feasibility on the measures proposed: while some of them are almost ready for implementation, others require further work or preliminary steps before inclusion. Additional measures proposed by stakeholders have also been considered. In both cases, the

JRC has identified the possible outcomes and next steps for each of these potential ecodesign measures on imaging equipment and its consumables.

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
- The Blue Angel Ecolabel for office equipment with printing functions (DE-UZ 219)
- The Nordic Ecolabelling for Imaging equipment (Nordic Ecollabelling, Version 6.7)
- The EPEAT Ecolabel (Global Electronics Council)., based on the IEEE Standard for Environmental assessment of imaging equipment (IEEE 1680.2)
- The TCO Certified Generation 9, for imaging equipment, Edition 1 (TCO Generation 9).

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:

> <u>Printer</u>*: device intended to apply colourant(s) to a substrate in response to a digital signal.*
>
> <u>Monochrome printer</u>*: a printer only capable of printing black and not configurable to print another colourant.*
>
> <u>Colour printer</u>*: a printer with an operating part to apply ink or toner on a substrate, with a functionality to produce print output containing colours.*
>
> <u>Single-function printer</u>*: printer with an operating part to apply ink or toner on a substrate, having no additional functions such as fax or scan.*
>
> <u>Multi-function printer</u>*: printer with an operating part to apply ink or toner on a substrate, and also providing additional functions such as fax and copy.*
>
> <u>Electrophotographic (EP) printer</u>*: a printer principally using optoelectronic phenomena and electrostatic attraction to move toner to a substrate*
>
> <u>Inkjet (IJ) printer</u>*: a printer with an operating part, for example a print head, 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)
- The Nordic Ecolabelling for remanufactured OEM toner cartridges (Version 5.6)
- The EPEAT (Global Electronics Council)., based on the IEEE Standard for Environmental assessment of imaging equipment (IEEE 1680.2)
- The TCO Certified Generation 9, for imaging equipment, (TCO Generation 9)
- Keypoint 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*

Integrated ink cartridge: cartridge that includes at least an ink containment part and an ink deposition mechanism

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

a) single-part toner cartridge: a toner cartridge that includes only a toner containment part

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

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

Similarly, for ink cartridges:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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, EPEAT (Global Electronics Council). 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):

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

Fuser unit: 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

Transfer unit: 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:

New built: A new cartridge/container

Counterfeit: 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).

> *Remanufactured: 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*
>
> *Refilled: 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:

> *New build compatible (NBC): 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*
>
> *Clones: A New Build Compatible (NBC) that violates patents*
>
> *Virgin Empty: An empty cartridge that has not been remanufactured*
>
> *Bad Virgin Empty: A virgin empty that cannot be remanufactured or one for which there is no market*
>
> *Good Virgin Empty: A virgin empty that can successfully be remanufactured*
>
> *Non-Virgin Empty: An empty cartridge that has previously been remanufactured*
>
> *Bad Non-Virgin Empty: A non-virgin empty that cannot be successfully remanufactured or one for which there is no market*
>
> *Good non-Virgin Empty: 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:

> *Cartridge: 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"*
>
> *Container: 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.*
>
> *Electronic Circuitry: chips, print head, 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:

> *OEM Cartridge/Container: 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.*
>
> *Non-OEM Newbuild Cartridge/Container (NBC): 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.*
>
> *Counterfeit Cartridge/Container: 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:

> *Empty Cartridge/Container: Cartridge/Container that is depleted of the ink or toner and can be refilled, remanufactured, or recycled.*
>
> *Refilled Cartridge/Container: Cartridge/Container resulting from a process where Empty Cartridges/Containers are simply refilled with ink or toner without replacement of components.*

Remanufactured Cartridge/Container: Cartridge/Container resulting from a commercial process where Empty Cartridges/Containers are collected, remanufactured, filled with ink or toner, labelled, and repackaged. Components may be replaced in order to return the Cartridge/Container to working condition and to meet desired functionality requirements, provided that the Cartridge/Container retains all or as much as possible of the original body. The Cartridge/Container shall contain:

a) for toner Cartridges/Containers, greater than 50% by weight of reused parts not counting toner;

b) for ink Cartridges/Containers, greater than 75% by weight of reused parts not counting ink.

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

1.3 Definitions – Circularity concepts

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

Table 1. Circularity aspects in imaging equipment

Circularity Aspect	Definition
Durability	Ability to function as required, under defined conditions of use, maintenance and repair, until a limiting state is reached {EN45552:2020} Individual Cartridge yield: value determined by counting the number of test pages printed between cartridge installation and end of life
Reliability	Probability that a product functions as required under given conditions, including maintenance, for a given duration without limiting event {EN45552:2020}
Repair	Process of returning a faulty product to a condition where it can fulfil its intended use {EN45552:2020}
Upgrade	Process of enhancing the functionality, performance, capacity, or aesthetics {EN45552:2020}
End of life (cartridge)	Phase in a cartridge life cycle when the cartridge can no longer be used for its intended purposes without additional non-customer interaction (ISO/IEC 29142:2021)
Expected cartridge life (cartridge)	Approximate number of pages likely to be printed from a cartridges when ran to cartridge end-of life (ISO/IEC 29142:2021)
Reuse	Process by which a product or its parts, having reached the end of their first use, are used for the same purpose for which they were conceived {EN45552:2020} Reuse of cartridges: operation in which a whole or a component of a cartridge is incorporated in the manufacture or remanufacture of a cartridge, such that the whole or component part is intended to be put into service for the same purpose for which it was conceived (ISO/IEC 29142:2021)
Refill (cartridge)	Operation to replace ink or toner in a costumer's cartridge that does not involve the replacement of refurbishing of worn cartridge components. (ISO/IEC 29142:2021)
Remanufacturing and refurbishing	Industrial process which produces a product from used products or used parts where at least one change is made which influences the safety, original performance, purpose or type of the product. {EN45553:2020}

	Note 1 to entry: The product created by the remanufacturing process may be considered a new product when placing on the market. Refer to the EU Blue Guide [1] for additional information. Note 2 to entry: Refurbishing is a similar concept to remanufacturing except that it does not involve substantial modifications influencing safety, original performance, purpose or type of the product. It is not covered by this standard. Remanufacture of cartridges: operation to replace or clean components and add ink or toner using cartridges from cartridge take-back or collection programs (ISO/IEC 29142:2021)
	Remanufactured Imaging Equipment :Products … which has been returned to a “like new” state of the base model, including energy performance, by the manufacturer, utilizing new and/or reused components from the original equipment manufacturer {Energy Star v3.2}
	Remanufacturer: Cartridge supplier that produces or markets remanufactured cartridges
Recycling	Recovery operation of any kind, by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes excluding energy recovery {EN45555:2019} Recycling of cartridges: reuse, remanufacture or otherwise divert from a solid waste stream
Recovery	Process to divert cartridges and/or cartridge materials from the solid waste stream into productive uses.
Critical Raw Materials	Critical raw material CRM materials which, according to a defined classification methodology, are economically important, and have a high-risk associated with their supply {EN45558:2019}
Post-consumer recycled content	The amount of post-consumer recycled material that goes into the manufacturing of a new product {EN45557:2020}

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

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

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

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

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

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

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

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

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

1.4 Standards

The following standards are directly applicable to imaging equipment and its 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.

- DIN 33870-1 — Office machines - Requirements and tests for the preparation of refilled toner modules for electrophotographical printers, copiers and facsimile machines - Part 1: Monochrome
- DIN 33870-2 — Requirements and tests for the preparation of refilled toner modules for electrophotographical printers, copiers and facsimile machines - Part 2: 4-colour printers
- DIN 33871-1 – Office machines, inkjet print heads and inkjet tanks for inkjet printers – Part 1: Preparation of refilled inkjet print heads and inkjet tanks for inkjet printers.
- DIN 91472 – Remanufacturing – Quality classification for circular processes

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	---

A stakeholder in the cartridge remanufacturing industry highlighted that for new non-OEM cartridges there are no independent and globally/regionally recognized quality standards for measuring performance (other than yield). They add that OEMs have tried in the past to have the ISO29142 standard include performance benchmarks (but have been unable to agree). For remanufactured consumables there are some standards that take into account not only yield but also print quality and environmental aspects (the German DIN standards), as well as Type 1 eco-labels including Blue Angel or Nordic Ecolabelling (described in following sections).

An OEM argued that DIN 33870 are a German self-certification standard that any operator can potentially claim. They add that these standards are 10 years old and therefore obsolete. In their view, it is a criterion on quality that can be hardly measured and verified by an external body. It is not suitable in ensuring the quality of thirdparty cartridges and should not be used in the Preparatory Study to define ecodesign measures. They recommend that it should be replaced by an international recognised standard (ISO/CEN) that is measurable and verifiable and should be developed in cooperation between OEMs and third party remanufacturers.

1.4.1 Other relevant standards

- IEC 60068-2-31:2008. Rough handling shocks, primarily for equipment-type specimens.

  This standard deals with a test procedure for simulating the effects of rough handling shocks, primarily in equipment-type specimens, the effects of knocks, jolts and falls which may be received during repair work or rough handling in operational use.
- EN45552:2020. General method for the assessment of the durability of energy-related products.
- EN45553:2020. General method for the assessment of the ability to remanufacture energy-related products.
- EN 4554:2020. General methods for the assessment of the ability to repair, reuse and upgrade energy-related products.
- EN45555:2019. General methods for assessing the recyclability and recoverability of energy-related products.
- EN45557:2020. General method for assessing the proportion of recycled material content in energy-related products.
- EN45558:2019. General method to declare the use of critical raw materials in energy-related products.

1.5 Legislation and voluntary instruments

Imaging equipment has been regulated with a Voluntary Agreement (VA) under the Ecodesign Directive since 2013. In the Ecodesign and Energy Labelling Working Plan 2022-2024 (European Commission, 2022), the Commission announced the intention to develop regulatory measures for imaging equipment. Other existing relevant legislation and voluntary instruments are also applicable to some aspects of the life cycle of imaging equipment devices and consumables. In particular:

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

1.5.1 Stand by Regulation

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

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

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

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

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

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

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

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

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

The review study[2] (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).

Regulation 2023/826 laying down ecodesign requirements for off mode, standby mode, and networked standby energy consumption of electrical and electronic household and office equipment"[3] aims to revise the thresholds and extend the scope to devices with low voltage power supplies[4], currently excluded from the scope of the regulation. The application of this Regulation should be limited to products corresponding to household and office equipment intended for use in the domestic environment, which, for information technology equipment, corresponds to class B equipment as set out in the EN 55022:2010 standard.

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

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

1.5.2 RoHS Directive

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

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

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

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

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

1.5.3 REACH Regulation

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

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

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

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

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

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

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

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

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

In the context of REACH a cartridge is considered a combination of an article (functioning as a container or a carrier material) and a substance/mixture (ECHA 2017)[5].

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

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

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

1.6 Voluntary schemes

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

1.6.1 The Voluntary Agreement for imaging equipment

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

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

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

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

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

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

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

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

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

1.6.3 Ecolabels

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

Table 5. Scope of Ecolabels regarding devices

Ecolabel	Devices in scope	Devices explicitly excluded from scope
Energy Star v3.2 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 v3.2 product specifications. -Products designed to operate directly on three-phase power -Standalone copiers -Standalone fax machines
Blue Angel (DE-UZ-219) Office equipment with printing functions	Devices which at least: -Offer printing as their primary function -Are capable of producing monochrome colour printouts on standard paper with a grammage of 60-80 g/m2 -Are capable of processing media or a minimum format of DIN A4 and up to a maximum format of DIN A3+ -Work as electrophotographic devices by using toners or as inkjet devices by using inks	-3D printers -Devices not in scope for Energy Star v3.2
Nordic Ecolabelling (Version 6.7) 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 Electronics Council) Imaging equipment	-Copiers -Digital duplicators -Fax machines -Multifunction devices -Printers -Mailing machines -Scanners	Not indicated
TCO Certified Generation 9	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	Not indicated

Imaging equipment	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.	

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

Table 6. Scope of Ecolabels regarding consumables

Voluntary scheme	Consumables in scope	Consumables explicitly excluded from scope
EPEAT – Global Electronics Council Imaging equipment	Toner, toner containers, toner bottles, toner cartridges, waste toner cartridges, ink cartridges, ink heads, ink sticks, ribbon ink, thermal paper, copy paper, imaging units, transfer belts, transfer roller, fusers, drum maintenance units, and other associated items	Not indicated
TCO Certified Generation 9 Imaging equipment	Not indicated	Not indicated
Blue Angel (DE-UZ-177) Remanufactured toner cartridges	Remanufactured ink cartridges and toner cartridges with toner or ink for use in office equipment with an electrophotographic printing function or in inkjet devices. The ink cartridges and toner cartridges may also contain additional parts required for the printing process that can be used on office equipment with printing function.	Not indicated
Nordic Ecolabelling (Version 5.6) 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		X				
	Recyclability						
	Use of renewable materials						
	Durability		X				
	Repairability						
	Reusability			X	X	X	X
	Interoperability						
	Reliability					X	
	Remanufacturability		X				
	Take back systems			X			X
Consumables - Yield	Provision of Yield information				X		
	Mass resource efficiency				X		
	Print capacity			X			
Consumables - Other aspects	Restricted substances		X	X	X		
	Usability of recycled paper						X
	Packaging		X	X			
	Printing performance		X	X	X		
	Emissions to air		X				
	Description of product characteristics			X			
	Product information		X	X			

Aspect is covered in Ecolabel (X)
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 Registry available here
Blue Angel (DE-UZ-219) Office equipment with printing functions	More than 900 models Registry of the labelled models available here
Nordic Ecolabelling (Version 6.7) Imaging equipment	2 brands and 197 models (statistics based on an interview to Nordic Ecolabelling)

EPEAT (Global Electronics Council). 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 Certified Generation 9 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 (DE-UZ-177) Remanufactured toner cartridges	No products labelled Registry of the labelled models available **here**
Nordic Ecolabelling (Version 5.6) Remanufactured OEM toner cartridges	11 license holders and more than 500 models labelled (statistics based on an interview to Nordic Ecolabelling)

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

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

1.6.7 ETIRA Certification label

In 2022, the association of cartridge remanufacturers ETIRA launched their own cartridge certification label[7]. The aim of this label is to differentiate remanufactured OEM cartridges from new OEM and non-OEM cartridges, providing customers with assurance that the cartridge they are purchasing is a remanufactured OEM cartridge that has been correctly placed on the market and remanufactured by an ETIRA member company.

The label is limited to ETIRA members through a qualification process and license agreement. The applicant can apply the certification label not only to their own brand of cartridges, but any brand of cartridges they have produced for a third party that complies with the license requirements.

1.7 Definitions proposal

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

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

1.7.1 Definitions related to devices

Table 11. Definitions related to devices

Concept	Definition
Imaging equipment device (or ‘device’)	Product 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.
Printer	Device intended to apply ink or toner to a substrate in response to a digital signal.
Multi-function printer	Printer with an operating part to apply ink or toner on a substrate, and also providing additional functions such as faxing, scanning or copying.
Copier	A device whose sole function is to produce paper duplicates from paper originals
Scanner	A device whose primary function is to convert paper originals into electronic images
Fax machine (or ‘fax’)	A device whose primary functions are scanning hard copy originals for electronic transmission to remote units and receiving similar electronic transmissions to produce hard copy output
Professional imaging product	A device marketed as intended for producing deliverables for sale, with the following features[8]: 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[9]: g) Paper capacity equal to or greater than 8,000 sheets;

[8] A device should have all features from a) to f) to be considered a Professional imaging product
[9] The basic model without the accessories should not be considered a Professional imaging product

	h) Digital front-end (DFE)[10]; i) Hole punch; j) Perfect binding or ring binding (or similar, such as tape or wire binding, but not staple saddle stitching); k) Dynamic random access memory (DRAM) equal to or greater than 1,024 MB. l) Final-party color certification (e.g., IDEAlliance Digital Press Certification, FOGRA Validation Printing System Certification, or Japan Color Digital Printing Certification, if product is color capable); and m) Coated paper compatibility.
Standard format	Products designed for standard-sized media (e.g., Letter, Legal, Ledger, A3, A4, B4), including those designed to accommodate continuous form media between 210 mm and 406 mm wide. Standard-size products may also be capable of printing on small-format media. a) A3-capable: Standard Format products with a paper path width equal to or greater than 275 mm
Large format	Products designed for A2 media and larger, including those designed to accommodate continuous form media greater than or equal to 406 mm wide. Large-format products may also be capable of printing on standard-size or small-format media.

1.7.2 Definitions related to cartridges

Table 12. Definitions related to consumables and cartridges in general

Concept	Definition
Consumable	A product integral to the functioning of the imaging equipment which, when used to its defined completion, is replaced, refilled, or its content emptied onto an internal printer compartment, during the normal usage and life span of the imaging equipment.
Cartridge	A replaceable unit within a printing system that contains materials intended for deposition onto paper or other physical output media, which must be inserted into or connected to an imaging equipment device during print.
Container	A replaceable unit within a printing system that contains materials intended for deposition onto paper or other physical output media, not intended to be inserted into or connected to an imaging equipment device during print, whose content will be emptied onto an internal printer compartment.
Starter cartridge	A cartridge which is sold together with a printer or multi-function printer.

[10] Definition available in Energy Star v3.2

Table 13. Definitions related to the configuration of cartridges

Concept	Definition
Single part toner cartridge	A toner cartridge that includes only a toner containment part
Two part toner cartridge	A toner cartridge that includes a toner containment part and a developer part and does not include a photoreceptor part
All-in-one toner cartridge	A toner cartridge that includes a toner containment part, a developer part and a photoreceptor part
Single part ink cartridge	A cartridge that includes an ink containment part and does not include an ink deposition mechanism.
Integrated ink cartridge	A cartridge that includes an ink containment part and a ink deposition mechanism

Table 14. Definitions related to the cartridge supplier

Concept	Definition
OEM cartridge	An OEM branded or trademarked cartridge produced by or for the OEM, for use in or with the same OEM's device.
Compatible cartridge (also called 'new built cartridge')	A new cartridge for use with an OEM device, but not produced by or for the device OEM.
Remanufactured cartridge	Cartridge resulting from a commercial process where a used OEM cartridge, in a first or a subsequent cycle, is collected, cleaned, prepared for reuse, refilled, labelled and repackaged. Components may be replaced in order to return the cartridge to working condition and to meet same functionality as the original cartridge.
Refilled cartridge	Cartridge resulting from a process where an empty cartridge is refilled and returned to the original user and involves no relabelling, repackaging or replacement of components or parts.
Cloned cartridge	A compatible cartridge for use with an OEM device, not produced by or for the OEM, and violating some intellectual property (patent, copyright, trademark)
Counterfeit cartridge	A cartridge not produced by an OEM, labelled, packaged or marketed in such a way that is intended to mislead a customer into thinking it is an OEM cartridge

1.7.3 Definitions related to circularity aspects

Table 15. Definitions related to circularity aspects

Circularity Aspect	Definition
Durability	Ability to function as required, under defined conditions of use, maintenance and repair, until a limiting state is reached {EN45552:2020}
Reliability	Probability that a product functions as required under given conditions, including maintenance, for a given duration without limiting event {EN45552:2020}
Repair	Process of returning a faulty product to a condition where it can fulfil its intended use {EN45552:2020}
Upgrade	Process of enhancing the functionality, performance, capacity, or aesthetics {EN45552:2020}
End of life (cartridge)	Phase in a cartridge life cycle when the cartridge can no longer be used for its intended purposes without additional non-customer interaction (ISO/IEC 29142:2021)
Reuse	Process by which a product or its parts, having reached the end of their first use, are used for the same purpose for which they were conceived {EN45552:2020}
Reprocessing	Restoration or modification of the functionality of a product or part Note 1 to entry: Reprocessing may consist of repairing, rework, replacement of worn parts, and/or upgrade of soft-, firm- and/or hardware. (based on the conversation with CEN/CENELEC JTC 10 WG4)
Remanufacturing	Industrial process which produces a product from used products or used parts where at least one change is made which influences the safety, original performance, purpose or type of the product.[11] {EN45553:2020}
Refurbishing	Industrial process to return a used product(s) to its original requirements or to improve a used product(s) within the limits of its original requirements (based on the conversation with CEN/CENELEC JTC 10 WG4) [12]
Recycling	Recovery operation of any kind, by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes excluding energy recovery {EN45555:2019}
Recovery	Process to divert cartridges and/or cartridge materials from the solid waste stream for the purpose of energy recovery.
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}

[11] From EN45553: The product created by the remanufacturing process may be considered a new product when placing on the market. Refer to EU Blue Guide for additional information.

[12] From EN45553: Refurbishing is a similar concept to remanufacturing except that it does not involve changes influencing safety, original performance, purpose or type of the product.

1.8 Scope proposal

Table 16 summarizes the scope proposal for this Preparatory Study.

Table 16. Scope proposal

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

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

The exclusion of professional imaging equipment seems adequate at this point, considering the characteristics of those products, according to the definitions provided by Energy Star v3.2. Professional devices are large machines (at least 180 kg), with default features such as A3 capability, high printing speeds (86 ipm for monochrome and 50 ipm for color), high print resolution and able to support paper with high grammage (minimum of 141 g/m2 when typical office paper grammage is between 70-100 g/m2). They also may have additional features such as hole punch, color certification, digital front-end and paper capacity over 8000 sheets, among others. This combination of features makes significant differences with the typical products used today in households and offices, in terms of performance, functionalities, mass and materials. Consumers and patterns of use of professional devices are also fundamentally different when compared with household and office products. The wide availability of products within the professional sector makes them also unsuitable for the scope of this Preparatory Study.

Digital duplicators and mailing machines are excluded at this point. Their use is intended for professional applications and their use patterns are fundamentally different from household and office products.

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

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

2 Task 2 – Market

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

2.1 Business models

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

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

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

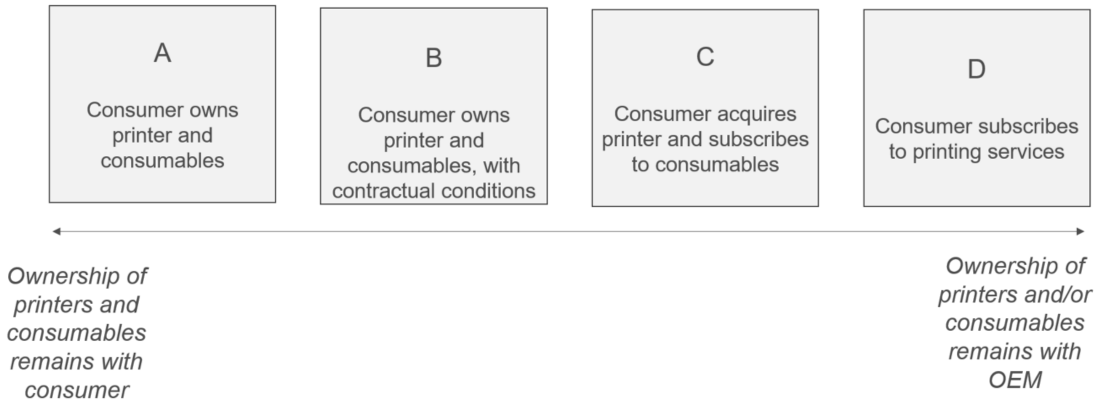


Figure 1. Classification of business models in the imaging equipment sector

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

2.1.1 Ownership of printer and consumables remains with the consumer

<u>Category A: consumer acquires printer and consumables, without contractual agreement</u>

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

<u>Category B: consumer acquires printer and consumables, with contractual agreement</u>

The consumer acquires the printer and establishes a contractual agreement with the OEM, committing to buy and use only their original consumables for a specific period. These business models are often attractive for consumers because printers are offered at a discount or with additional functionality[13]. When the period established in the contract ends, the consumer can choose again between original, compatible or remanufactured consumables. However, during the contract period, the OEM may ensure that the consumer adheres to the contract by blocking the use of non-original consumables. This business model is more common in the B2C sector, although it can also be found in the B2B sector, particularly in small offices.

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

2.1.2 Ownership of printer and/or consumables remains with OEM

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

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

A common subscription service is one where the consumer acquires the printer but not the consumables. In this case, the OEM –or a third party supplier- provides consumables when the consumer needs them. The OEM establishes a collection and delivery system for the new and depleted consumables, often via post. Typically, the consumer will subscribe to print a maximum number of pages over a period. The amount to pay per period will depend on the number of pages the consumer is subscribed to. The printer sends a signal to the OEM to inform that the consumables are running out of ink or toner, to optimise their collection and delivery, ensuring that the user can always print. If the user does not use the amount of pages they are subscribed to in the period, the OEM might offer to roll over them for the next period, or simply to lose them. If the user surpasses the maximum amount subscribed to, the OEM can either prevent them from printing or charge them an additional amount. It is common that the cartridges provided as part of this subscription can only be used with the printer registered in the scheme[14]. If the subcription is cancelled, the OEM may disable the cartridges from working, even if they still have some toner or ink[15]. In some subscription services consumers are prevented from using non-original consumables. In some cases, if cartridges that are not part of the scheme are used, the page counter of the service will continue counting as if the original cartridges were used[16]. Some authors (Dhebar, 2016) consider this type of subscription as a particular case of customer lock-in, because the marketer relies on consumer behaviour inertia: most modern-day consumers are busy and will likely not consider changing to non-original consumables if the marketer sets up an automatic replacement. This option can be found in both the B2C and B2B sectors.

Category D: consumer subscribes to printing services

A different subscription is one where the OEM –or a third party supplier- keeps the ownership of both the printer and the consumables[17]. The consumer (typically a business) will pay depending on the number of pages they print, or the amount of ink or toner they use. Often, installation and maintenance services are included in the agreement. These options are commonly known as Managed Print Services (MPS) and are more common in the B2B sector.

Although categories C and D may still be described as "razor and blade" pricing strategy, under these business some circularity benefits can be expected, related to higher cartridge collection rates. However, as suggested by

[13] https://www.hp.com/us-en/printers/hp-plus.html
[14] https://www.brother.co.uk/about-brother/ecopro-terms-and-conditions
[15] https://images-eu.ssl-images-amazon.com/images/G/02/uk-pc/hp/InstantInk/HP_InstantInk_TandCs.pdf
[16] https://subscription.lexmark.com/en_gb/terms-and-conditions.html
[17] https://readyprint.epson.eu/gb/en/terms-of-use

a stakeholder in the remanufacturing sector, these business models are not circular if the OEMs supplies only new cartridges under the sales contract (which in practice is the most common scenario).

2.1.3 The influence of business models on product circularity

Categories A and B can be more associated with a linear production and consumption system, rather than with a circular one. In both cases, OEMs have the incentive of increasing the sales of their own consumables (new or remanufactured by themselves). Reuse of consumables by other operators is unattractive for OEMs because they compete directly with new original consumables and therefore can reduce their margins. It should also be noted that some OEMs supply remanufactured cartridges and prioritise the supply of remanufactured cartridges when they are available, in place of new production.

In the cases that operate under a “razor and blade” pricing strategy, the business model only works if the consumer, once convinced to purchase the durable product, is locked into the platform (Dhebar, 2016). According to feedback from some remanufacturers, the older the printer, the more likely it is that the consumer will switch to compatible or remanufactured cartridges.

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

This hypothesis is supported by the results of studies such as the one conducted by the French Agency for the Ecological Transition (ADEME), where it is estimated that, while the potential lifetime of a printer is 6 years, the real lifetime of printers is often between 2 and 3 years, after which consumers perceive a printer obsolete (ADEME, 2019). In addition, according to non-governmental organisations, when replacement consumables cost as much as the printer, users often find themselves motivated to discard their appliance in favour of buying a new one after the first set of ink cartridges is used up. These estimations have been compared with results from the user behaviour study in Task 3 of this Preparatory Study.

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

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

2.2 Print volume trends

In this section, data on print volume trends is presented, in terms of total amount of images printed. This data has been supplied by the testing and consulting firm Keypoint Intelligence[18] and comprises the following countries: Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the UK. This represents a combined population of 414 million (in contrast with the total population of 446 million on the whole EU27).

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

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

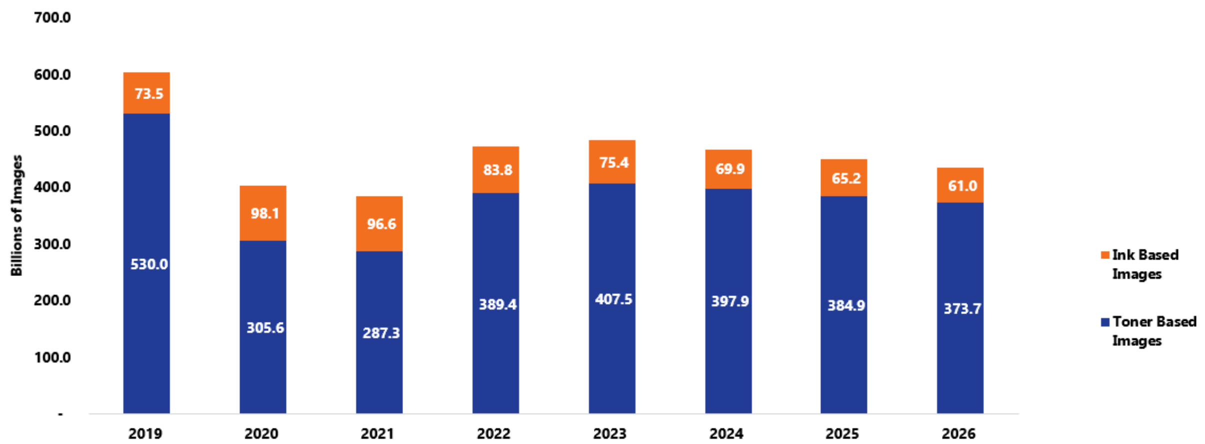


Figure 2. Total images printed by technology
Source: Keypoint Intelligence (2023)

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

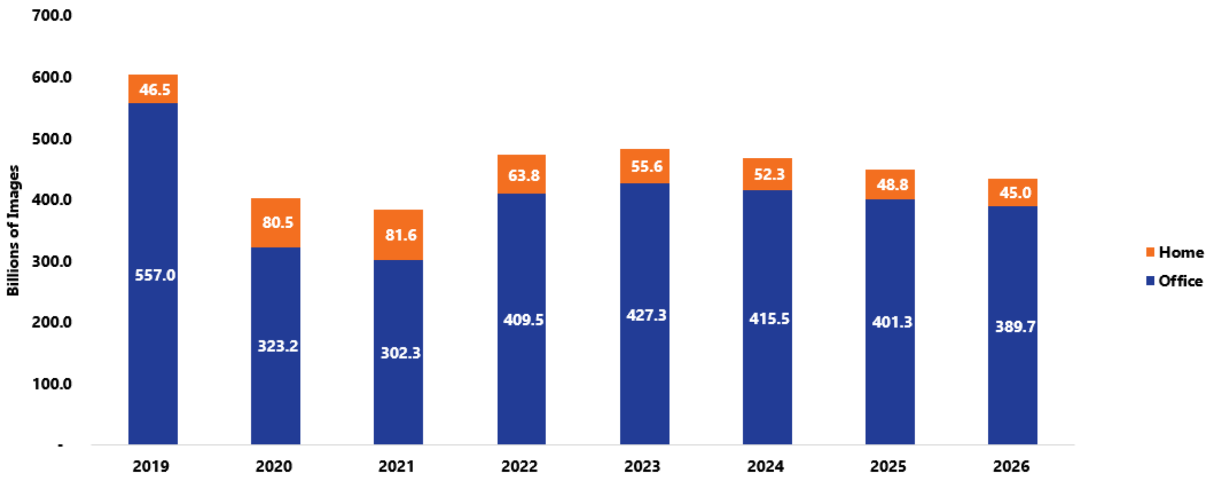


Figure 3. Total images printed by environment
Source: Keypoint Intelligence (2023)

Digital transformation continues to erode home print volume gains from hybrid working, which became more widespread during the COVID19 pandemic. A sharp rise of images printed at home can be observed during years 2020 and 2021 (from 46 billion to around 80 billion), due the high amount of people working from home during

[18] https://keypointintelligence.com/

lockdowns and movement restrictions. The total amount of printed pages returned to lower values (around 63 billion) in 2022, and it is expected to decrease again in the following years.

2.3 The market of printers and multi-function devices

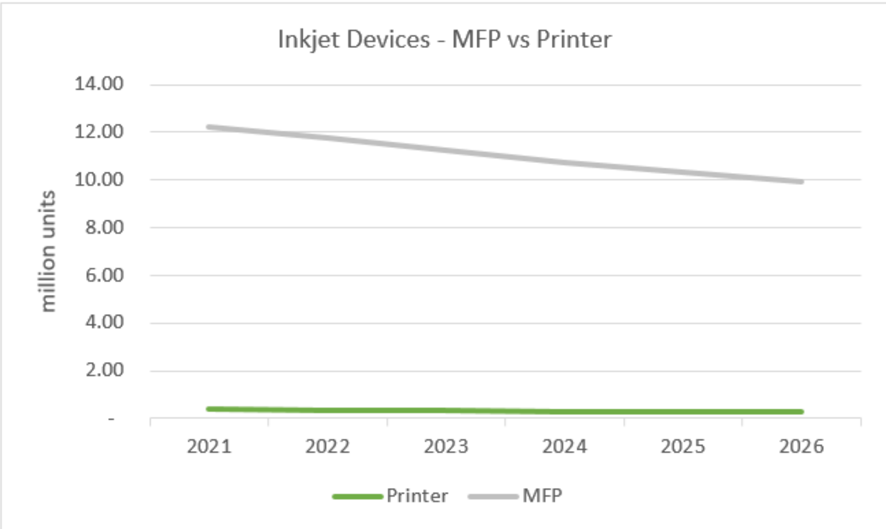
In this section, market data is presented in terms of sales of printers and multi-function printers. These data has been supplied by the market intelligence firm IDC[19] and contains information on 13 EU countries, Norway, Switzerland and the UK. This represents a combined population of 425 million (in contrast with the total population of 446 million on the whole EU27).

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

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

2.3.1 Inkjet devices

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

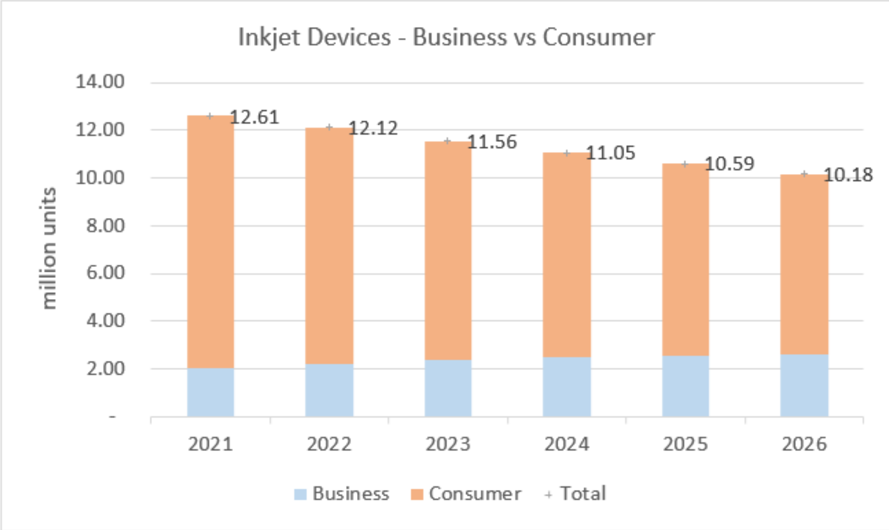


Source: IDC

Figure 4. Sales of inkjet devices in the EU

The overall market of inkjet devices is expected to decrease in the following years, from 12.6 million in 2021 to 10.2 million in 2026, a CAGR of -4.2%. Sales of inkjet devices for business applications will grow and for consumer applications will decrease (Figure 5). In any case, the market of inkjet devices is still expected to be focused on the consumer sector

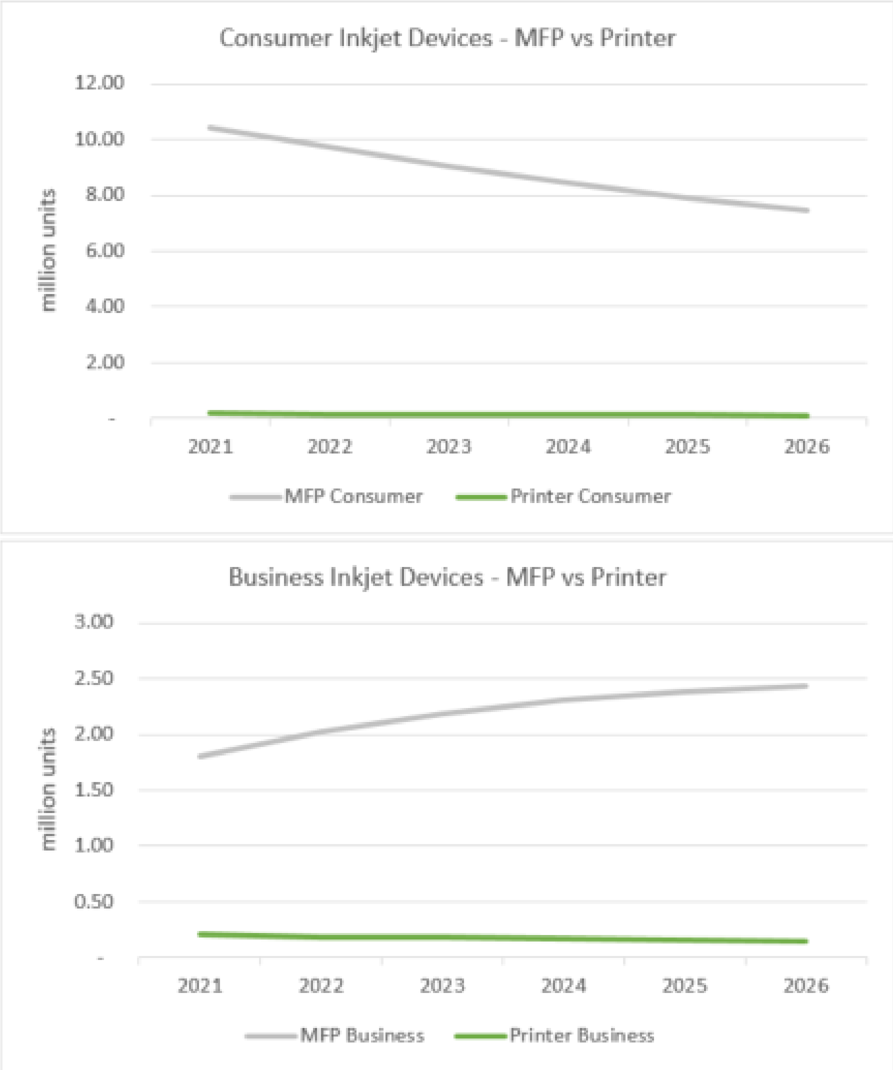
[19] https://www.idc.com/



Source: IDC

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

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



Source: IDC

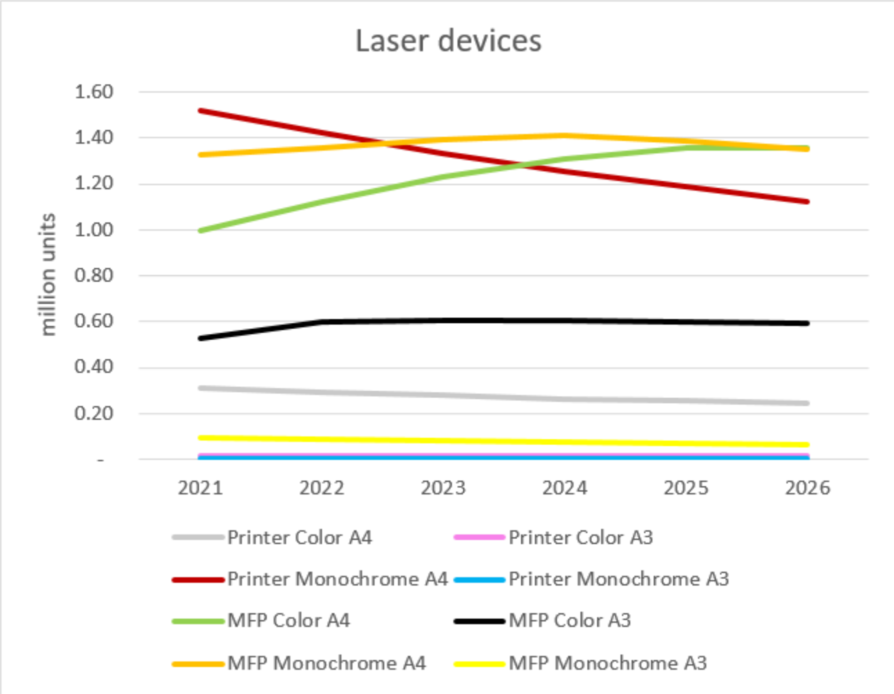
Figure 6. Sales of inkjet devices (business versus consumer, product types)

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

2.3.2 Laser devices

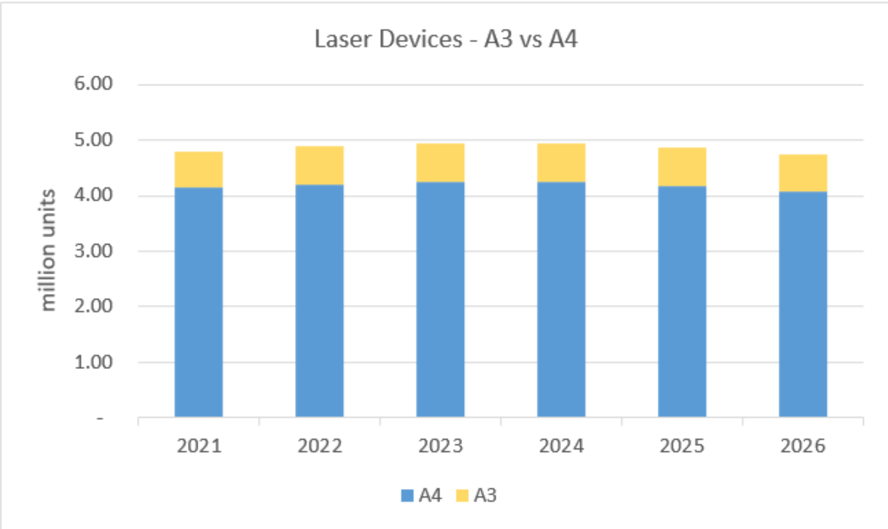
In 2022, nearly 5 million laser printers were sold in the sample of countries under evaluation. In terms of total units sold, the market of inkjet devices is 2.6 times higher than the market of laser devices.

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



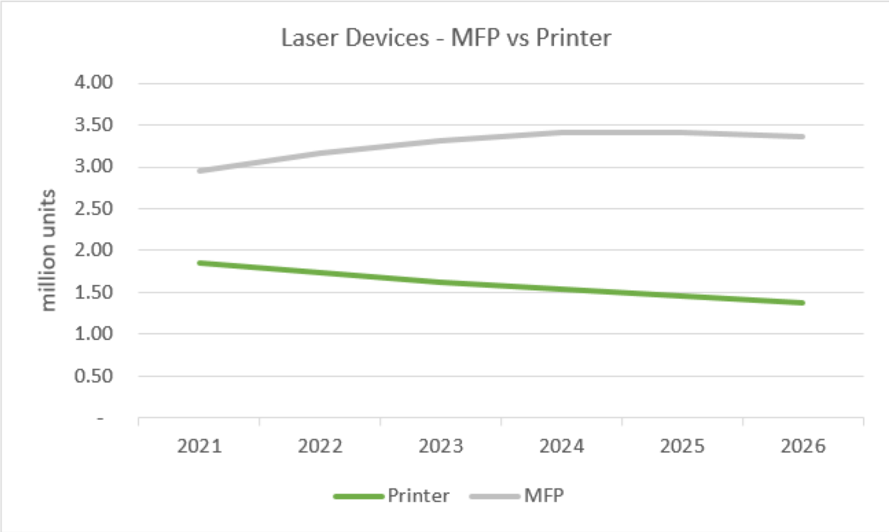
Source: IDC
Figure 7. Sales of laser devices in the EU

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



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

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



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

2.4 The market of scanners, faxes and copiers

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

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

Source: (Huang et al, 2019)

Million units	2020	2025	2030	2035	2040
Scanner	0.88	0.88	0.88	0.88	0.88
Copier	0[20]	0	0	0	0
Fax machines	0	0	0	0	0

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

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

2.5 The market of cartridges

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

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

2.5.1 Ink cartridges

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

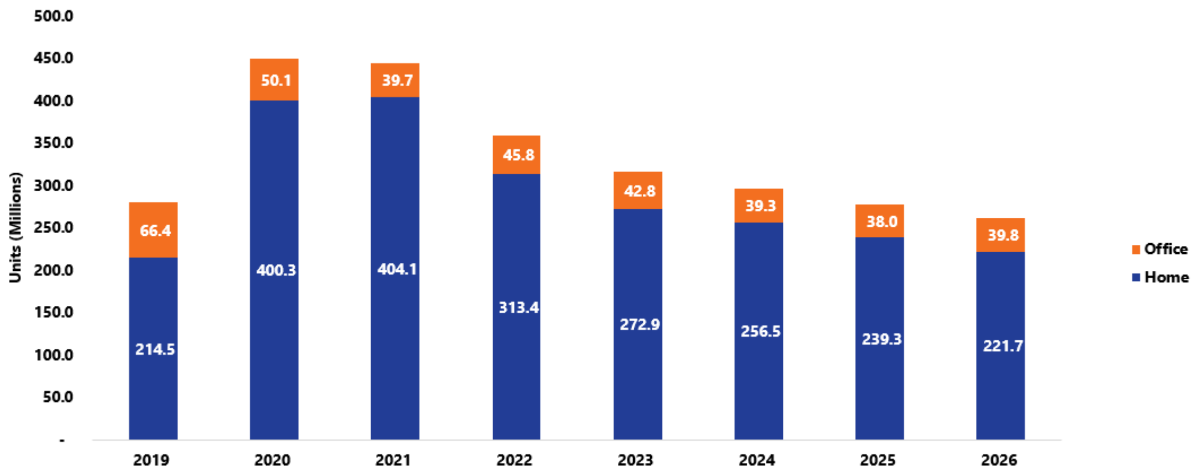


Figure 10. Ink cartridge sales by environment

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

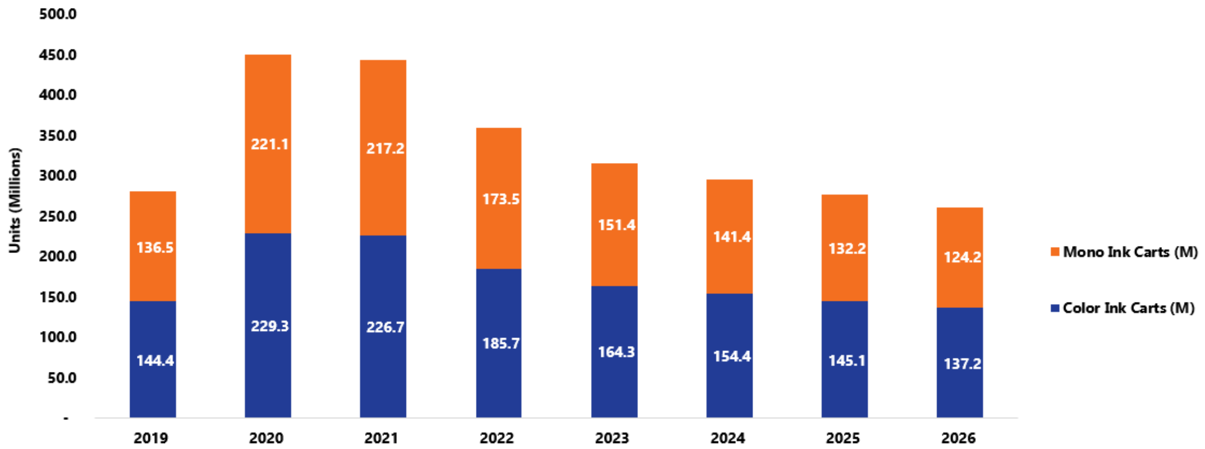


Figure 11. Ink cartridge sales by color type

2.5.2 Toner cartridges

In 2022, nearly 100 million toner cartridges were sold in the sample of countries under evaluation, most of them designated for office environments. The number of units sold suffered a significant decrease in 2020 and 2021 during the COVID19 pandemic, due to lockdowns and the reduced number of people working from offices. Sales increased again in 2022 due to the return to offices, without reaching the levels previous to 2020, reflecting current hybrid working schemes (Figure 12).

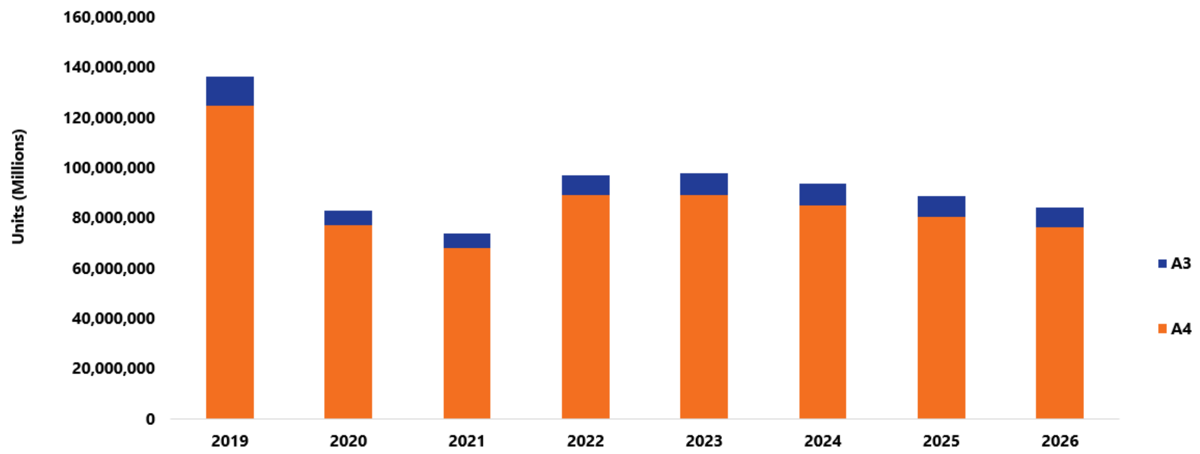


Figure 12. Toner cartridges sales

2.5.3 Remanufactured cartridges

Cartridge remanufacturing is an industrial process whereby empty inkjet or toner cartridges are disassembled and cleaned, refilled, engineered to become as new, and then marketed as own-brand cartridges, competing on the basis of price and quality with new cartridges[21]. The business phenomenon of cartridge remanufacturing is mostly associated with small businesses. The average toner remanufacturing business is equipped to restore for reuse between 8 and 10 different cartridge models through cleaning, parts replacement, filling and testing. Smaller remanufacturers purchase from larger remanufacturers those cartridge models they cannot remanufacture in order to meet their customers' needs[22]. The main aspects of a cartridge remanufacturing business are:

Obtaining the used cartridges (also known as 'empties'). These can be collected from cartridge users, acquired from corporations that bought them for internal use or get them from recycling companies.

Remanufacturing the empties. The empty cartridges must be cleaned, parts inspected for wear and damage, and part replacement, when required. The cartridge must be filled with ink or toner and tested for print quality before packaging it for sale.

Selling remanufactured products. The majority of cartridge remanufacturers sell directly to end users and their companies.

Different business models can be found in the cartridge remanufacturing industry:

Franchises: a new business owner works with an existing company that will do the marketing and prepare the business plan. The franchiser will supply equipment, training and both marketing and technical support.

Total remanufacturers: this is the most common business model. The remanufacturer will remanufacture the products to sell to both the retail and wholesale market.

Remanufacturers/resellers: this model enables the business to choose which cartridge models to remanufacture and which ones to buy from larger remanufacturing companies in order to meet customer's needs.

Total resellers: these companies purchase every cartridge they sell from other remanufacturers. They are able to offer a full line of cartridges from each of the major printer makers without incurring any of the costs of remanufacturing them.

Remanufactured cartridges in Europe have the following market shares, according to the European association of cartridge remanufacturers: toner, between 15-25%; ink, between 5-15%.

[21] https://www.etira.org/about-etira/frequently-asked-questions/
[22] https://www.calameo.com/read/000046992c35719bc443f

2.6 Relevant trends in the imaging equipment market

This section covers other relevant trends in the imaging equipment market. Information has been provided by experts in the industry from IDC[23] and Keypoint Intelligence[24].

2.6.1 Subscription services

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

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

According to Keypoint Intelligence, there are two primary players in the provision of subscription services: HP and Epson, although Brother and Canon also have services available. HP Instant Ink is available in 24 countries across the European Economic Area whereas Epson ReadyPrint reaches 9 countries in the region. Both companies are planning to expand their service to more countries. Keypoint Intelligence estimates that roughly ~3.6 mio subscribers or ~11% of HP machines installed in European homes subscribe to HP Instant Ink. KPI expects the number of Epson subscribers to be far lower than those for HP Instant Ink largely due to the later launch in 2020 (vs. 2013)

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

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

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

2.6.2 Original, remanufactured and refilled cartridges

Most OEMs have a cartridge collection system of some form. Only a few manufacturers offer some kind of remanufacturing before recycling for the supplies placed on the market. Most prefer to go straight to recycling or waste to energy.

Spare parts for supplies are not usually available from manufacturers, rather they are manufactured/remanufactured/repaired within non-patent infringing guidelines.

Chinese company GGImage, which owns Lexmark, Ninestar, Static Control Components, and Geehy Microprocessors is unique in being both an OEM, remanufacturer, aftermarket supplies company, spare parts supplier and microprocessor fabricator.

Many independent and franchised toner remanufacturers have left the market because of legal and profitability concerns. Local remanufacturing, which used to be ubiquitous, through channels such as Cartridge World, have almost completely disappeared. For those remaining, the process has become industrialized. Quality of remanufactured product and availability of empties are major industry issues.

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

Cleaning and refilling of used ink jet cartridges is decreasing in popularity as tank-based devices become commonplace. Toner refilling without remanufacturing is unusual in the EU. Ensuring quality when remanufacturing toner cartridges requires a controlled process.

Specifically on inkjet cartridges, the reverse supply chain for empty ink jet cartridges offers several channels: return envelopes, collection boxes in stores and recycling centres, charitable donation, or waste to landfill or energy. Refilling hardware equipment is available but, is bespoke and limited in availability. Distribution channels, maintenance and training facilities have been dismantled in some countries. As the value of ink jet empties is low, the final destinations for most ink jet empty cartridges to either waste to recycle, energy recovery (incineration) or landfill.

Regarding toner cartridges, the return process for empty laser cartridges differs as they are initially sorted between clones, counterfeits, compatibles and originals. Originals are sorted by brand and type and then sold back to the trade for repair/remanufacturing/refilling. There is an aftermarket for critical parts such as wiper blades, drums, gears, etc. There is significant patent protection litigation surrounding the production of spares and accessories which facilitate the repair, remanufacturing and reuse of toner supplies.

2.6.3 The impact of COVID19 and the rise of teleworking

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

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

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

2.6.4 Supply chain issues

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

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

Similarly in the laser sector, most suppliers are having difficulty in providing devices and cartridges to customers. Some OEMs decided shipping devices and cartridges without microchips to make sure they were able to retain their customers. Others redesigned devices to use less microchips and semiconductors. OEMs feedback in this Preparatory Study highlights that this fits to a very limited case within the EVAP member OEMs' experience. An EVAP member OEM case applies only to its particular model toner products that have a relatively simpler mechanism and does not apply to its any devices. In the particular case, only limited number of the toner products had been shipped without microchips so that the compatible devices, which are high end devices usually used in managed print services, barely keep printing function at the sacrifice of important functions such as detecting remaining toner level. In their view, it is not OEMs' option to ship devices or cartridges without microchips unless in an emergency such as pandemic because microchips are essential parts for designed performance of imaging equipment.

2.6.5 Inflation and economic situation

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

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

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

3 Task 3 – Users

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

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

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

User behaviour aspects have been evaluated differently for household (B2C) and office (B2B) sectors. For B2C, a user behaviour study has been conducted by an external contractor. For B2B, feedback from different stakeholders has been used, including device collectors and refurbishers, and providers of Managed Print Service providers.

3.1 User behaviour in households

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

3.1.1 Objectives of the user behaviour study

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

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

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

- How are consumers using imaging equipment?
- What is the typical printer lifetime?
- How is the business model of the imaging equipment market affecting user behaviour and the circularity of imaging equipment?

- How are relevant design aspects of imaging equipment (e.g. device's lifetime, page yield, durability of the cartridge, printing quality, failure rate, consumable's origin, etc.) affecting consumers' purchase decisions?

3.1.2 Methodology of the user behaviour study

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

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

Based on that, the survey consisted of the following question blocks:

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

<u>Purchase-impacting device features</u>. A central objective of the survey is to identify which product features consumers take into consideration when comparing and purchasing printers or multifunctional printing devices and their consumables.

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

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

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

3.1.2.1 Sociodemographic background indicators

In the first place, a set of sociodemographic indicators were measured to ensure the representativeness of the sample along the following parameters:

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

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

3.1.2.2 Impact of product features on purchase decision

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

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

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

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

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

Table 18. Product features included in survey

Factor	Devices	Consumables
The price of the printer	X	
The (expected) price of the consumables	X	X
Consumer knowledge about the manufacturer (e.g., the reputation of the model/brand/manufacturer, personal past experiences, reviews or ratings)	X	X
Performance and features of the printer (e.g. printing speed, quality, paper formats supported)	X	X
Other product characteristics (printing noise, size/weight of the printer)	X	
The energy consumption of the printer	X	
The expected lifetime of the printer before there is significant performance or usability decrease (e.g., poor printing quality or lack of compatible cartridges)	X	

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

3.1.2.3 Usage behaviour indicators

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

3.1.2.4 Attitudes and awareness indicators

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

Reasons for replacing a device

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

Expected usage length of the printer

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

Printer/consumable failures

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

Circularity of printers and their consumables

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

Printing subscription services

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

3.1.2.5 Survey implementation

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

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

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

The overall final sample size was 800 complete interviews per country.

For the survey, Ipsos drew random samples of respondents from their online access panel network in each of a selection of target countries.

3.1.2.6 Preparation of data for analysis

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

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

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

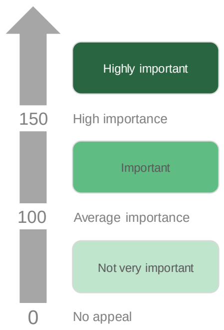
Starting from the raw, unweighted data, the first step was to perform the MaxDiff analysis. This analysis, based on Bayesian hierarchical modelling, was done using dedicated analytical software, resulting in MaxDiff indices for each purchase-impacting factor included in the survey, at respondent level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

The quantitative analysis of the results focused on the core objectives of the survey:

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

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

Figure 13: How to interpret Max-Diff indices. Source (IPSOS 2023).



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

3.1.3 Factors influencing the purchase of imaging equipment and its consumables

The goal of this part of the study was to measure the relative importance of a set of product factors when it comes to their impact on consumers' purchase decisions. The figures below and on the next page show the relative importance of the different factors that could have an influence on the purchase choice of consumers, each time ranked from high to low. The numbers for each factor represent the relative importance score. The difference between any two scores indicates how much more important that factor is found, on average, compared to the other factor (e.g. 100 is twice as important as 50), and a score of 100 in itself indicates that the relevant factor is exactly as likely to be found more as well as less important than other factors (i.e. the closer this score is to 100, the more "average" the importance is compared to other factors).

There are consistencies across imaging equipment/consumables when it comes to the relative importance of various product factors when purchasing them. First, the (expected) price of the consumables (ink cartridges/toner cartridges) is the most important factor for consumers when choosing which printer and which consumable to buy, ranking first for both (Figure 14 and Figure 15).

Second, performance-related factors are overall found more important when buying a printer/consumable than factors related to sustainability. This is highly consistent across printers/consumables.

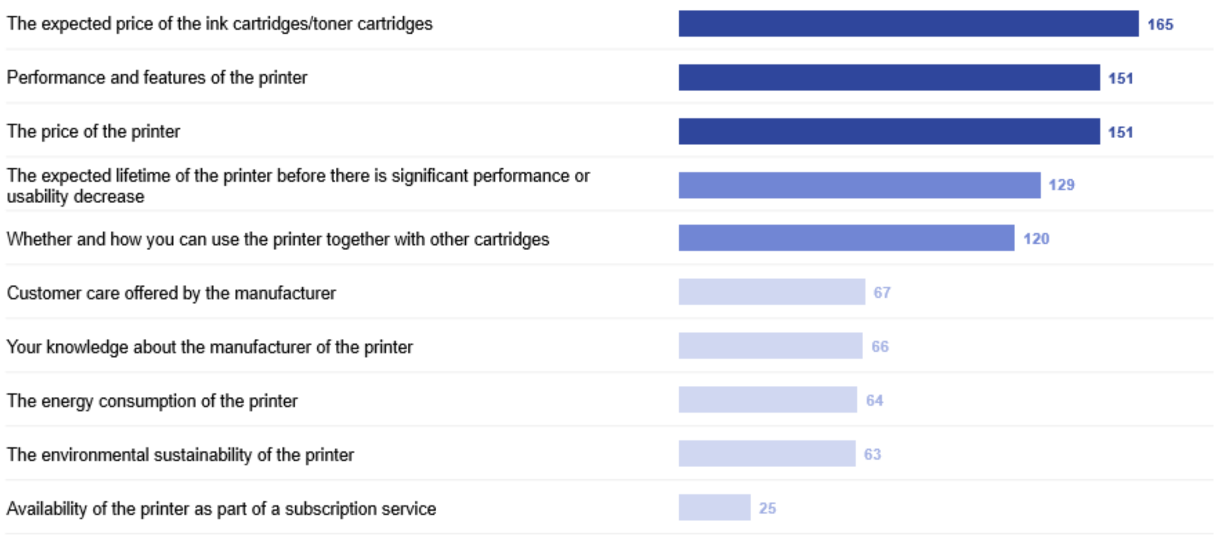


Figure 14. Relative importance of factors when buying a printer

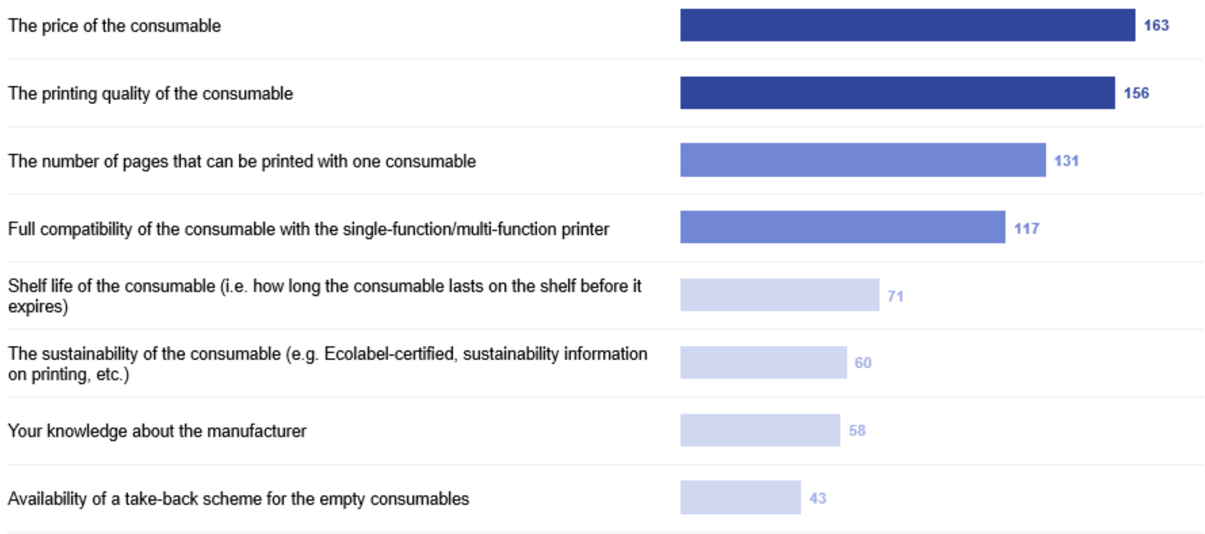


Figure 15. Relative importance of factors when buying a consumable

3.1.4 Usage frequency and intensity

Across the users of printers surveyed, between 42% and 50% of them report using their single and multi-function printers respectively at least once a week, whereas 33% and 31% respectively report using their printers at least once a month (Figure 16). For both types of printer users, just above one in ten reports using their printers on a daily basis

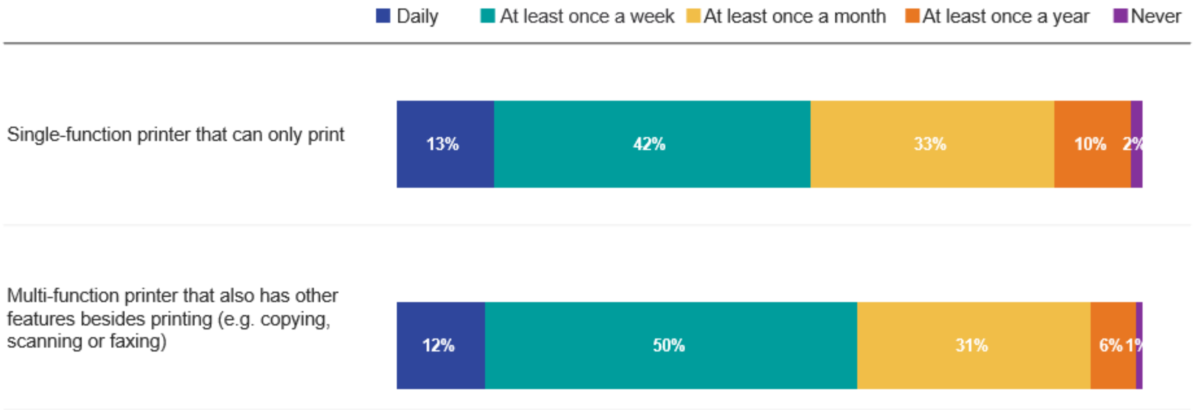


Figure 16. Frequency of printing activities

Consumers who own and regularly use a printer in their household (i.e. at least once a month) on average print about 88 pages per month (median=25 pages per month), with 20% of the users printing 100 pages or more per month. The number of pages printed per month is highest among consumers who are aged 35-49, high educated, and in employment and lowest among consumers aged 18-34 (Figure 17).

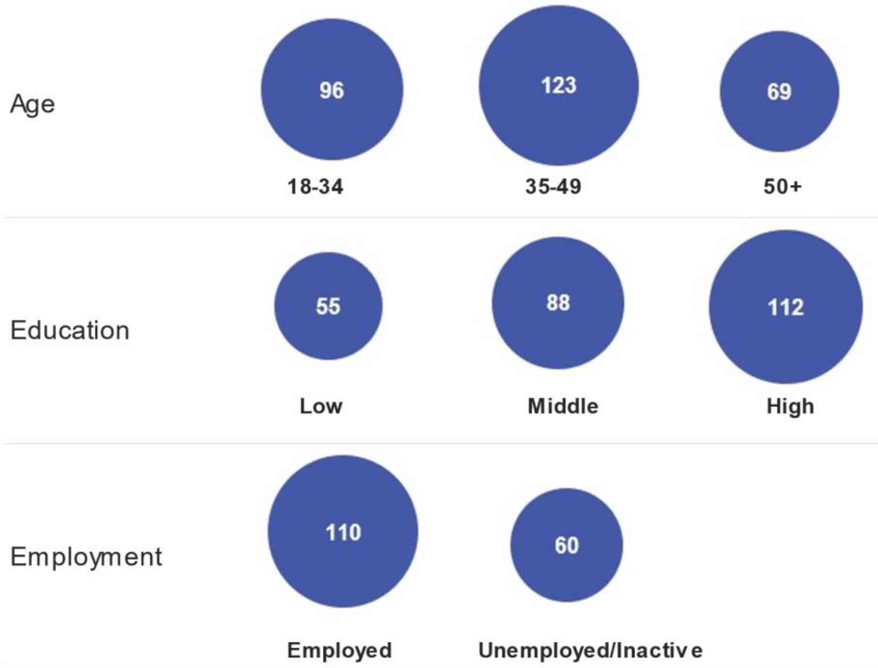


Figure 17. Number of pages printed per month across types of users

Among single-function as well as multi-function printer users, the average number of consumables used every year is 7.7. Twenty-one percent of them report using two or fewer consumables in a year and 12% between three and four consumables. Just about one in ten printer users either uses ten or more consumables every year, or between five and nine consumables every year, respectively. A large number of printer users, however, indicated that they do not know how many consumables they use on average per year (47% of them do not), suggesting that the above figures should be interpreted with caution (Figure 18).

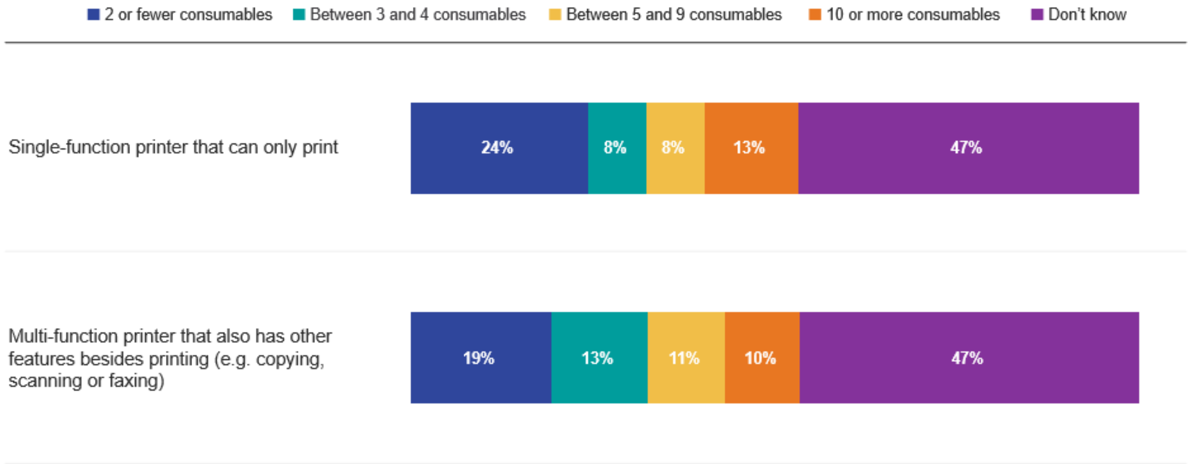


Figure 18. Number of consumables used per year across types of printers

When it comes to consumers' colour printing preferences, 84% and 79% of current single-function and multi-function printer users respectively report printing in black and white (B&W) 50% of the time or more (Figure 19 and Figure 20). The opposite holds for users' preferences printing in colours.

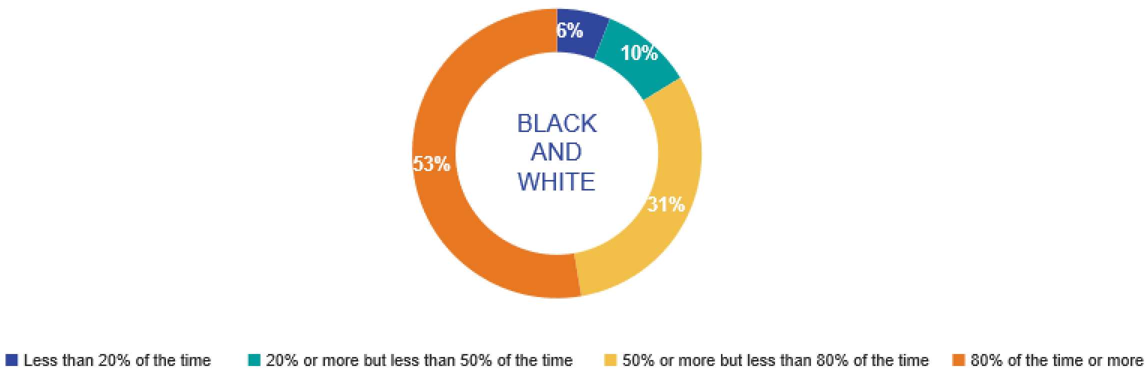


Figure 19. Colour printing preferences, single-function printers

Single-function printer users are more likely than multi-function printer users to print most of the time in black and white, whereas multi-function printer users are more likely than single-function printer users to often print in colours. Most notably, single-function printer users are 11 percentage points more likely than multi-function printer users to report printing in black and white 80% of the time or more.

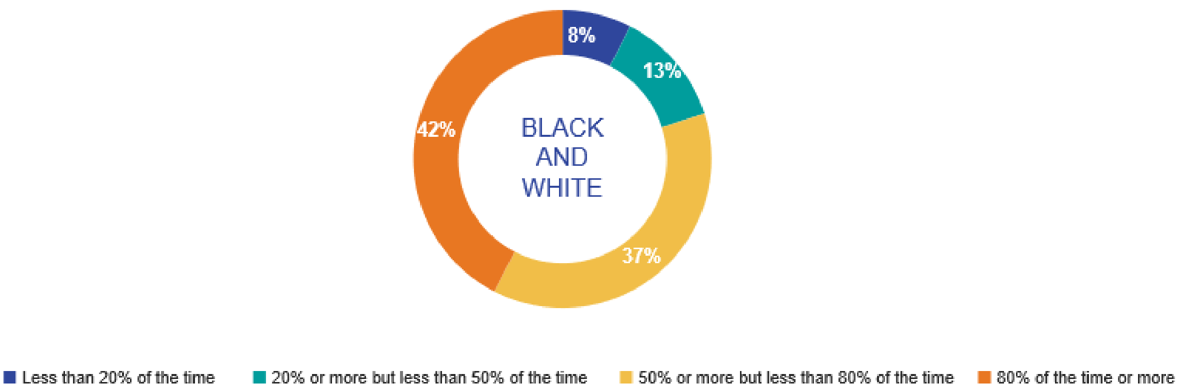


Figure 20. Colour printing preferences, multi-function printers

In terms of preferred paper size formats in which consumers print, more than eight out of ten consumers (84%) print in the standard A4 paper format 80% of the time or more. Of those that do not print in A4 paper format only, some print in A3 paper. Only a minority of consumers prints in these alternative formats more than 40% of the time.

3.1.5 Usage and sustainability attitudes and awareness

In this chapter, consumers' behaviour and attitudes are evaluated in relation to the circularity of their printer/consumables. In particular, this chapter looks at when and why consumers would envisage to replace their single-function/multi-function printers and consumables (and whether different attitudes towards replacement result in different expected use lengths), as well as experienced printer and consumable failures that prompt consumers to replace their equipment before the expected end of life. This chapter also discusses consumers' behaviours regarding the circularity of printers and consumables (such as repairing and sharing schemes).

3.1.5.1 Printer replacement

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

Table 19. Age distribution of printers used by survey respondents

	Single Function Printer	Multi-function Printers
Less than three years	27.81%	37.40%
Between three and five years	32.38%	34.54%
Between five and ten years	28.47%	21.78%
More than ten years	9.46%	5.16%
Don't know	1.87%	1.11%

Survey respondents were also asked to indicate, from a list of possible reasons, what would be important reasons for them to replace their printers, imagining that theirs are still working. Alternatively, respondents could indicate that they intended to keep using their printer until it stops functioning completely.

Approaching four in ten respondents would change their printer before it breaks down if their printer started no longer performing as it used to (37%), followed by almost three in ten respondents who would consider replacing their current printer if the cost of the printer's consumables were too high (28%). Less commonly, consumers would replace their printer if it were no longer compatible with remanufactured/third-party consumables (17%), if there were a better printer on the market (16%), or if there were no longer updates or support available by the manufacturer and/or software providers for the printer (16%). Notwithstanding these reasons for possible printer replacement, 30% of all respondents stated that they intend to keep using their printer until it would break down (Figure 21).

Figure 21. Reasons for replacement of a printer

When asked how long they intend to keep using their printer for, assuming it does not break down or it is not lost/stolen, future owners of single-function and multi-function printers showed a relatively similar response pattern (Figure 22). Among single-function printer users, 14% of them report they would intend using their printer for less than three years, 27% between three and five years, and 34% between five and ten years. Among multi-function printer users, 13% of them report they would intend using their printer for less than three years, 29% of them report they would intend using it between three and five years, and 33% of them between five and ten years. The main difference between the two types of printer owners could be found for long-term expected use length.

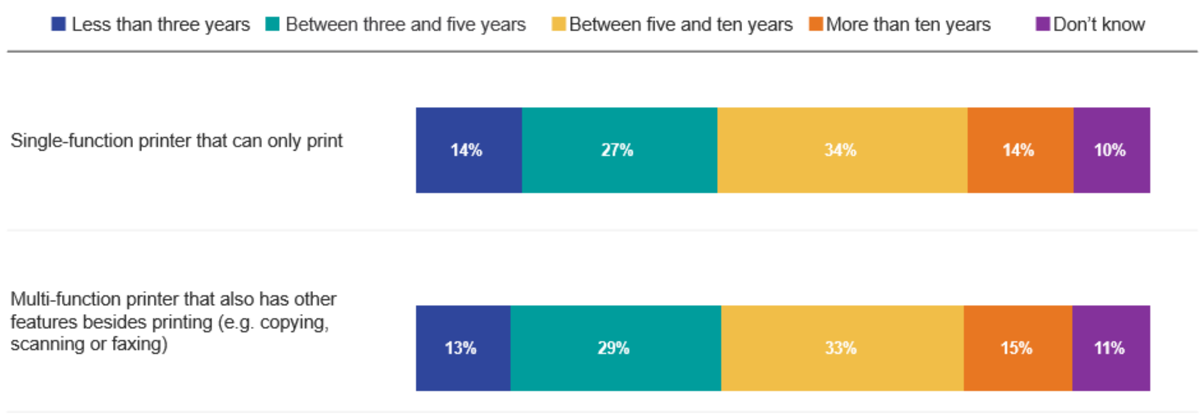


Figure 22. Expected use length

The expected use length of a printer depends on the reasons that consumers see as important to replace that printer before it breaks down. For both types of printers, consumers who report that the availability of a new printer on the market is an important reason to replace a printer are most likely to expect to use their printer for less than three years and for between three and five years (Figure 23 and Figure 24). Single-function printer owners who consider the lack of updates/support by the manufacturer and/or software providers is an important reason to replace their printer are more likely than average to replace their printer after between five and ten years. Multi-function printer owners who consider the decreased printer performance, the lack of software updates and of manufacturer support as important reasons to replace their printer are most likely to replace their printer after between five and ten years. As can be expected, consumers who intend to use a printer until it no longer works (i.e. no reasons to replace their current printer) intend to use their printer the longest. Among single-function printer owners, 28% of those who intend to keep using their printer until it no longer works expect to use their printer for more than 10 years (vs. 14% average). Among multi-function printer owners, 23% of those who intend to keep using their printer until it no longer works expect to use it for more than ten years (vs. 15% average).

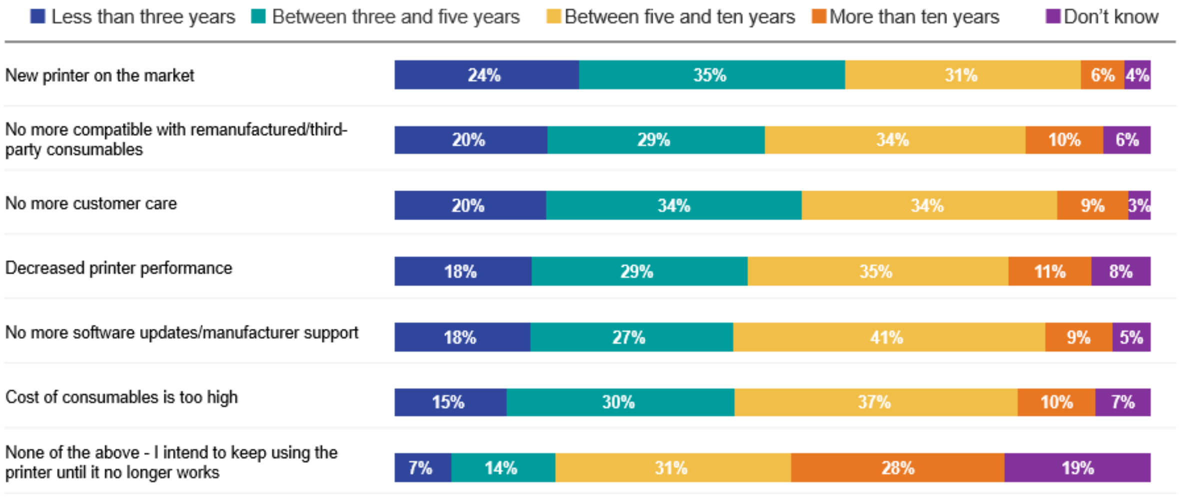


Figure 23. Expected use length per reason of replacement, single function printer

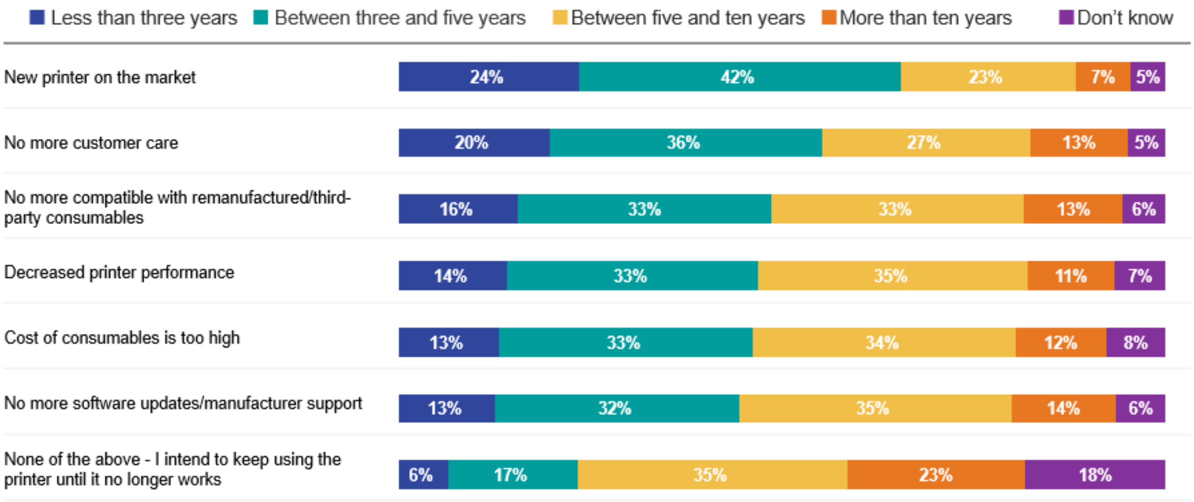


Figure 24. Expected use length per reason of replacement, multi function printer

When asked about the most common printer failures experienced in the past, 35% of all respondents indicate to have had a fault or a problem with a physical component of the printer in the past and 25% indicate to have had a compatibility issue between the printer and cartridges (Figure 25). Two in ten respondents report having had a fault or a problem with the printer's software. Of all respondents, 34% indicate never having experienced printer failures in their household in the past.

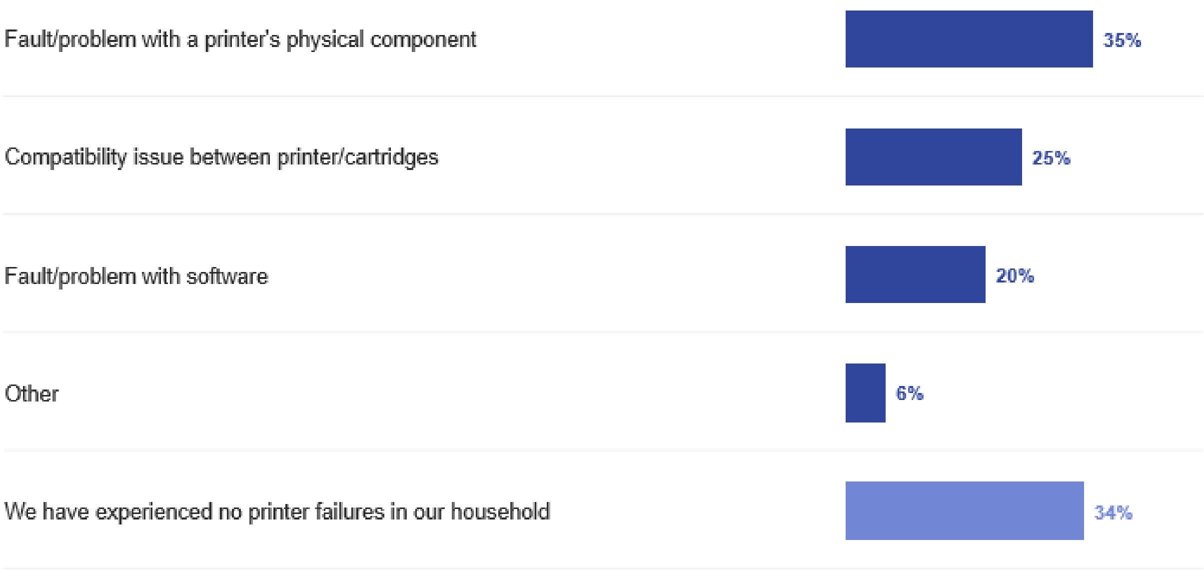


Figure 25. Common printer failures

3.1.6 Cartridge replacement

In this section, aspects related to consumer behaviour when it comes to the replacement of their consumables are evaluated. First, the most common consumable failures and how often they happened in the past, respectively. Then reasons that prompted consumers to replace their consumables before they were empty in the past.

When asked about the most common consumable failures experienced in the past, over four out of ten respondents (43%) indicate never having experienced such failures. As shown in Figure 26, the most commonly reported consumable failure among all respondents is a compatibility issue between the consumable and the printer (21%), followed by a fault when replacing the consumable and a fault with the ink/toner clogging or drying (15% in both cases). Approximately one in ten indicate having experienced a problem with a physical component of the consumable or a problem when refilling the ink tank of the printer (10% in both cases). Less than one in ten indicate having experienced a problem with the toner or ink leaking (7%).

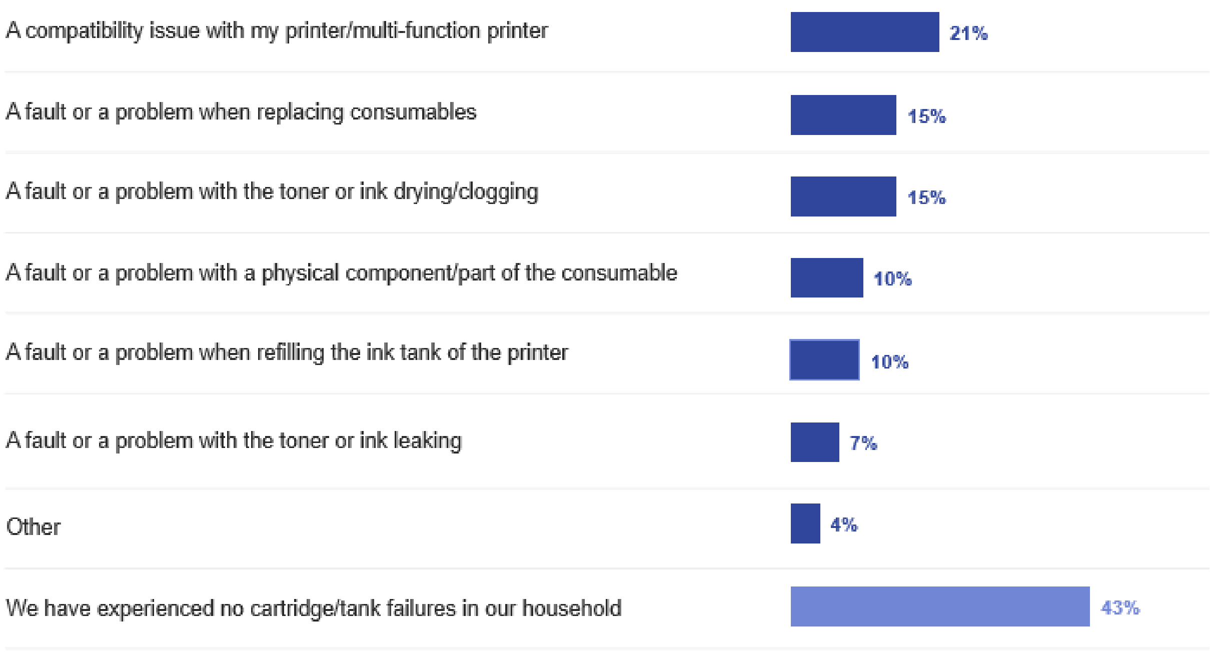


Figure 26. Common consumable failures

More than half of all respondents report they never or hardly ever have to change their consumables before they are empty (22% and 31% respectively). Five percent of all respondents indicate that they always have to replace their printer's consumable before it is empty (Figure 27), whereas approximately three in ten indicate having to sometimes do so (31%).

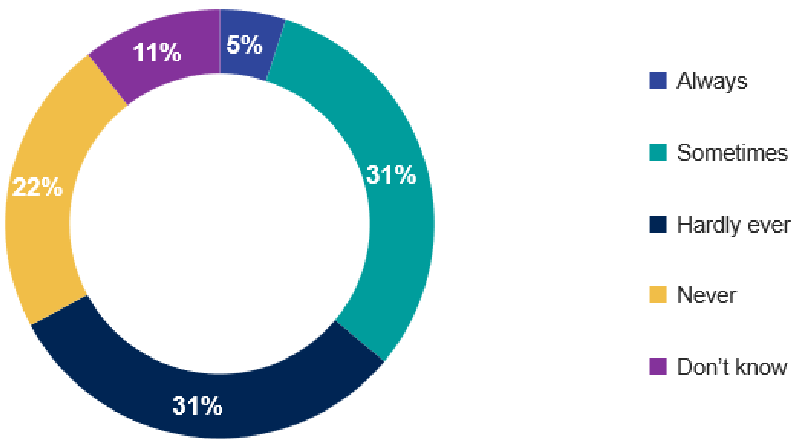


Figure 27. Replacing consumables before they are empty

A correlation is found between the frequency of consumable replacement and consumers' printer usage intensity (in terms of pages printed per month). Indeed, while users with low printer usage intensity profiles are slightly more likely than average to indicate having to always replace their consumables before they are empty, consumers printing 50 pages or more per month are found to be five percentage points more likely than the average to indicate having to sometimes replace their consumables before they are empty.

Among those consumers who indicate having had to replace a consumable in the past before it was empty, the survey enquires about the main reasons that prompted them to do so in the past (Figure 28). Approaching half among these consumers report having been forced or prompted to replace them in the past due to decreased consumable performance (45%), followed by 27% due to incompatibility between the consumable and the printer, and 23% of them due to a technical failure. Of those who replaced consumables in the past before they were empty, 16% of them indicate not having experienced any such consumable failures in the past.

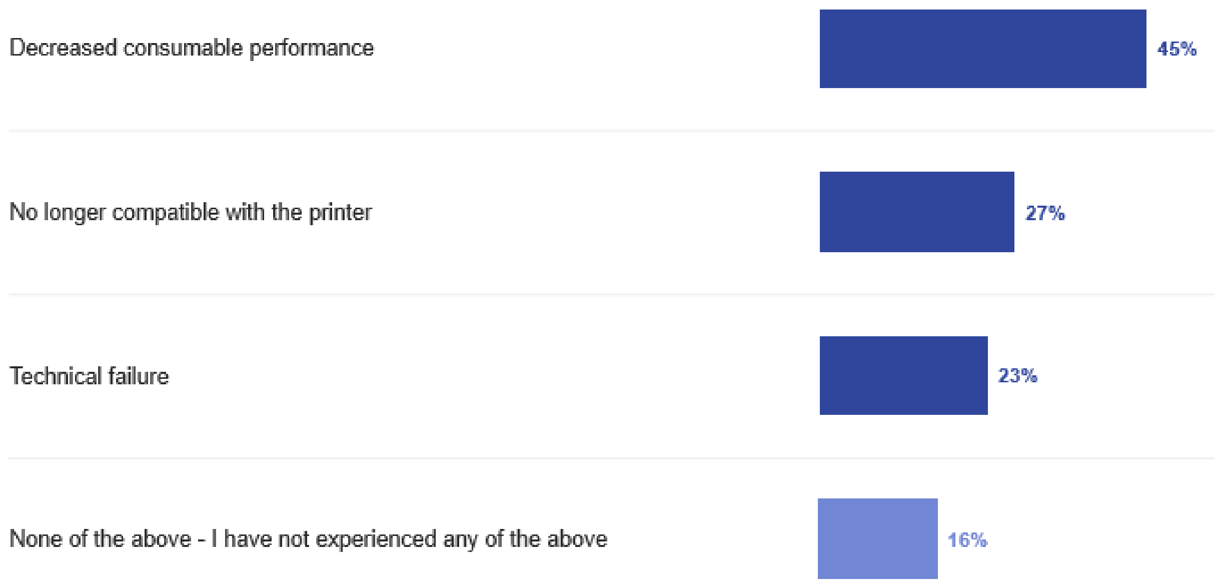


Figure 28. Common consumable replacement reasons

3.1.7 Printers and their consumables in the circular economy

In this section, consumers' behaviours regarding the circularity of printers and consumables are evaluated (such as repairing and sharing schemes). First, consumers' behaviours with regards to repairing their printers and using remanufactured cartridges and reasons why they did not do so in the past. Secondly, consumers' attitudes towards the disposal of printers and consumables no longer in use. Lastly, consumers' use of printing subscription services and reasons why they are/are not using them.

When asked whether they personally repaired their printer, or had it repaired, in the past five years, only slightly over two out of ten (21%) report having done so (Figure 29). Between seven and eight out of ten respondents report not having repaired their printer in the past five years (74%).

Compared to consumers' behaviours towards repairing printers, the use of remanufactured cartridges appears more common among consumers: while a majority still reports never having used remanufactured cartridges over the past five years (53%), just over four in ten consumers report having done so in the past 5 years (41%).

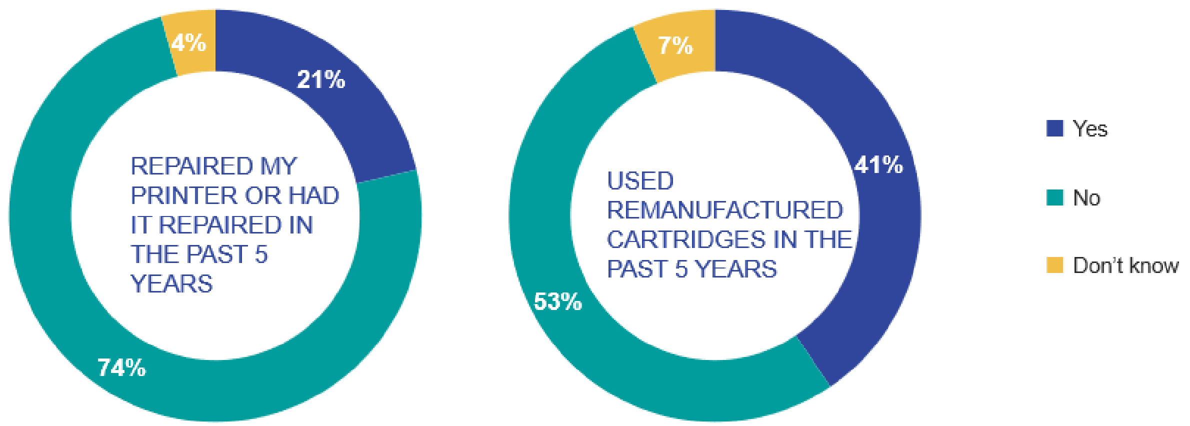


Figure 29. Consumers behaviour regarding repairing printers and using remanufactured cartridges

The main reasons indicated by respondents for not having repaired their printer in the past five years are primarily related to either the overly high price of a printer's repair (30%). For reference, in Cordella et al (2019) was highlighted that, in general, the repair is carried out when its cost is below 30% of the value of the product, for electronic products. Cost reasons are followed by the repair's inconvenience (8%), the non-repairable nature of their printer's model (7%), and not knowing how to repair their printer (7%). Respectively 5% and 6% of these respondents indicate as a reason for not having repaired their printer in the past five years that the manufacturer is not offering repair service or a past bad experience using a repair service (Figure 30).

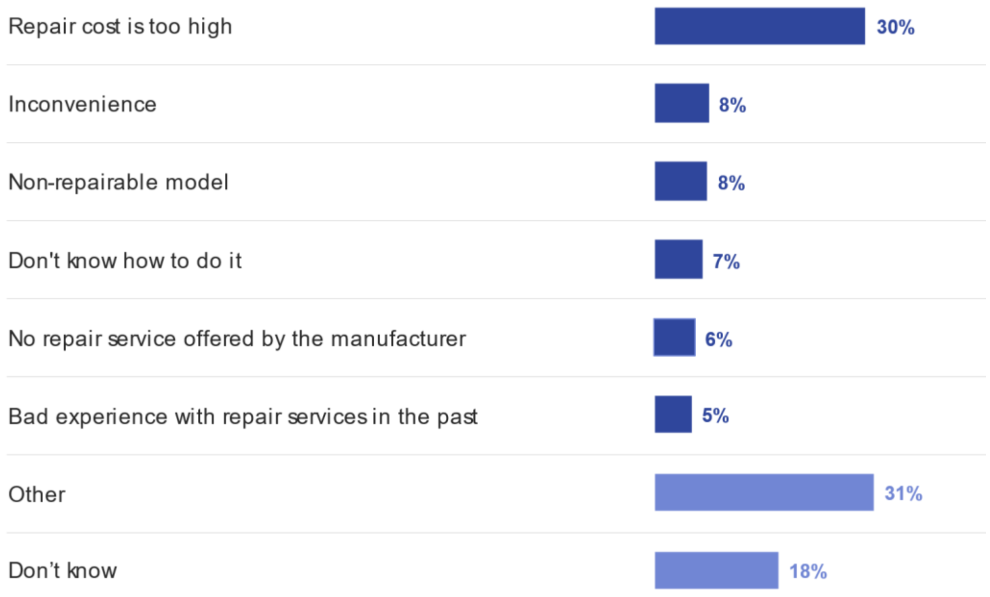


Figure 30. Main reasons for not having repaired printers in the past 5 years

When it comes to the use of remanufactured cartridges, reasons why consumers did not do it in the past are more varied (Figure 31). The main reason indicated for not having done so in the past five years is not knowing enough about remanufactured cartridges (24%), followed by almost 20% either not trusting the manufacturers of remanufactured cartridges or fearing that the printing quality of remanufactured cartridges would be lower than traditional cartridges (19% in both cases). Seventeen percent of these consumers indicate as a reason having had previous bad experiences with remanufactured cartridges, followed by 12% indicating a fear that the number of pages printed with remanufactured cartridges will be lower than with traditional cartridges and a fear that their price would be too high.

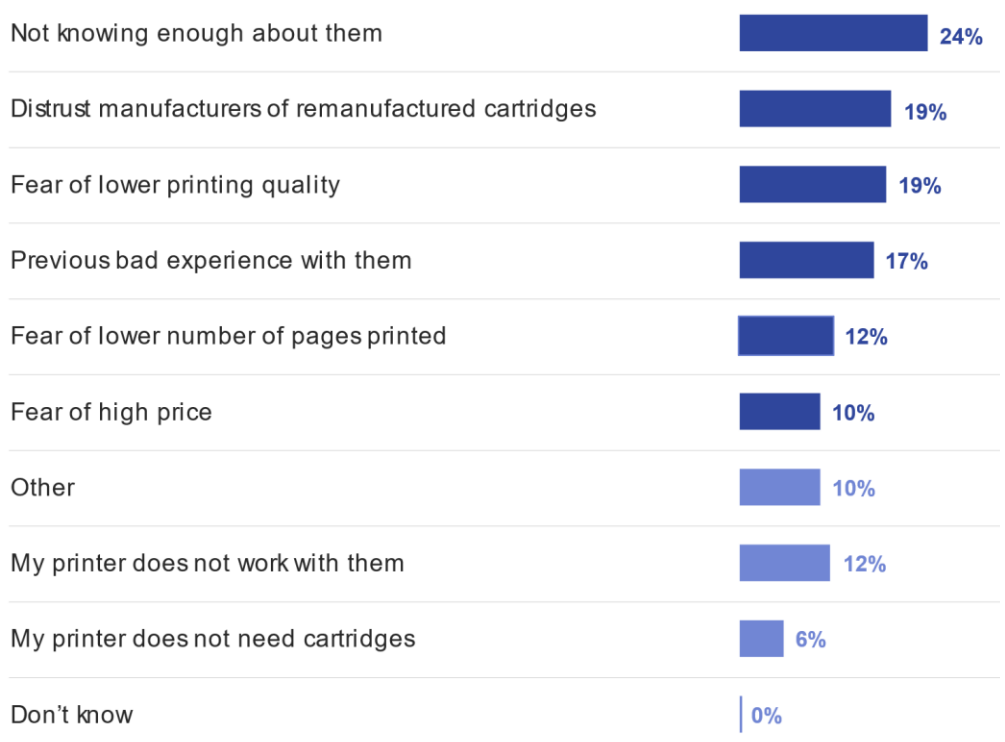


Figure 31. Main reasons for not having used remanufactured cartridges in the past 5 years

Respondents were then asked about how they have disposed of printers they were no longer using in the past (Figure 32). A total of 75% of all respondents reports having selected circular disposal options. The most common of these is recycling them, for example at an IT electronic waste collection point (40%), followed by passing it on to friends or family members (12%), using the manufacturer's or distributor's take-back scheme (8%) using another retailer's take-back scheme (8%), or selling it online (7%). Less than one in ten respondents reports having disposed of their printer into their general-purpose waste bin in the past (9%).

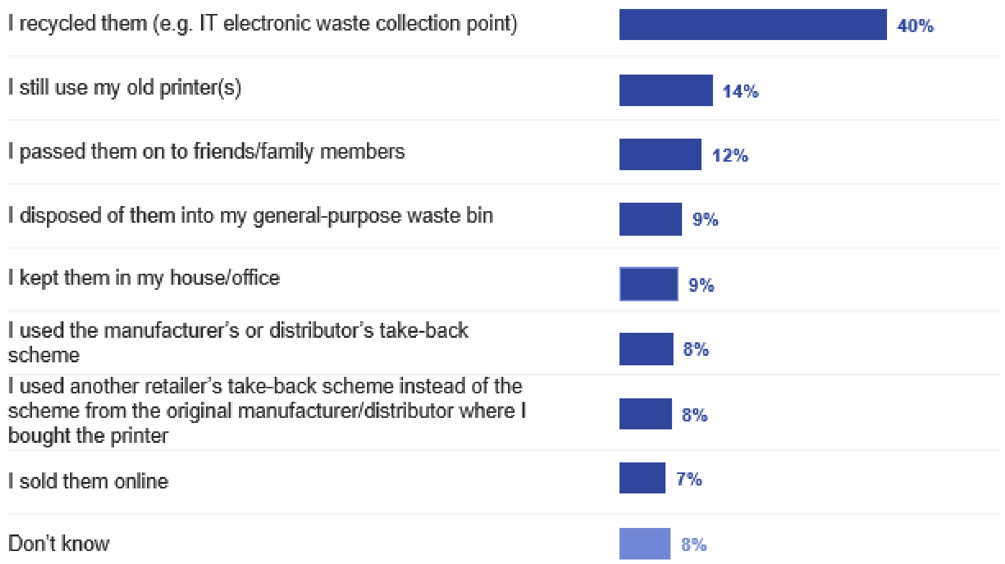


Figure 32. Disposal of printers

Respondents were then asked about how they have disposed of consumables they were no longer using in the past (Figure 33). A total of 71% of all respondents reports having selected circular disposal options. The most common of these is recycling them, for example at an IT electronic waste collection point (45%), followed by using the manufacturer's or distributor's take-back scheme or another retailer's take-back scheme than the original manufacturer's/distributor where the consumables where bought (13% in both cases). Still, just over two out of ten consumers (21%) reports having disposed of their consumables into their general-purpose waste bin in the past, while one out of ten reports having kept them in their house/office (10%).

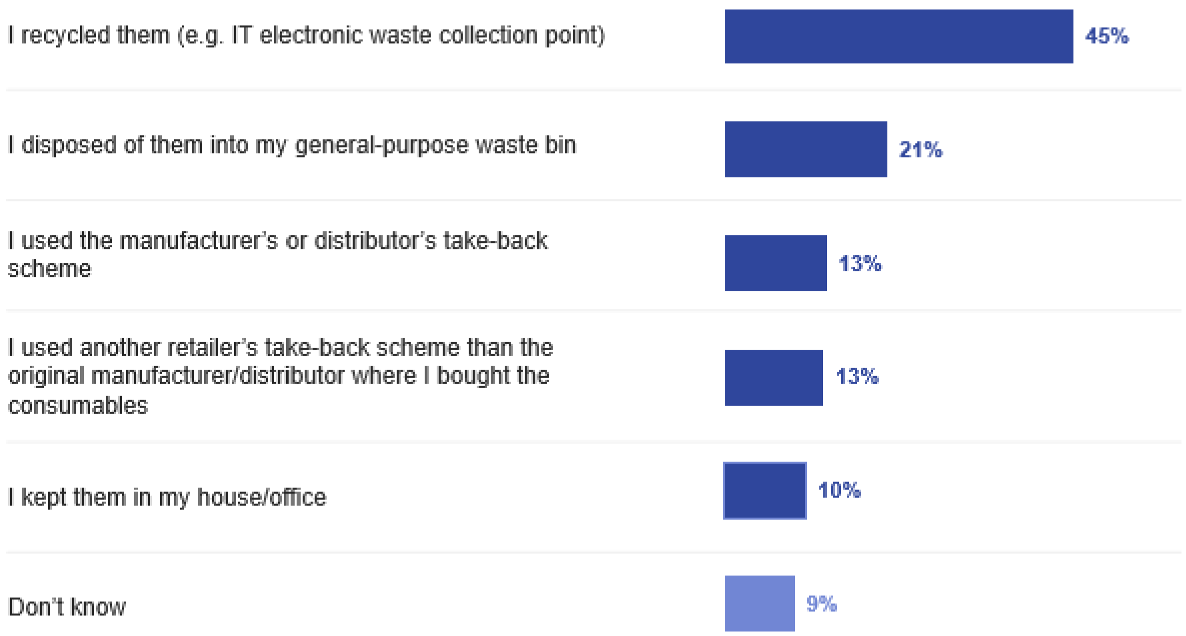


Figure 33. Disposal of consumables

Lastly, respondents were asked about their usage of printing subscription services in the past 12 months (Figure 34). Slightly over seven in ten respondents report not having used a printing subscription service in the past 12 months. Equal splits of the population report having used it for both printer and consumables (12%) and only for consumables (12%).

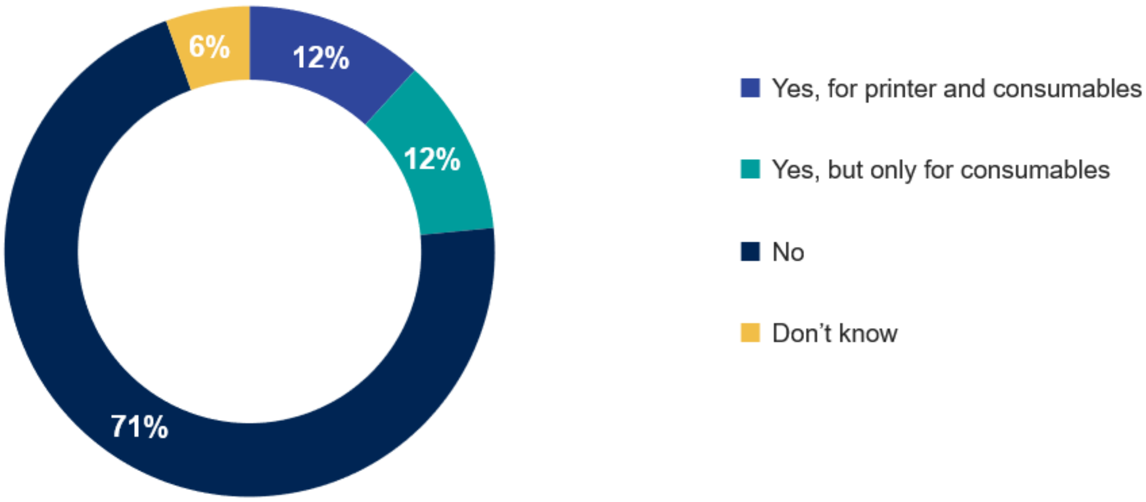


Figure 34. Consumers' usage of printing subscription services

A strong correlation is found between the age of respondents and their likelihood of having used a printing subscription service in the past, such that younger respondents aged 18-34 are least likely to report not having used one in the past (52% vs. 71% average). Younger respondents aged 18-34 are also 11 percentage points more likely than average to have used such a service for both printer and consumables (23% vs. 12% average) and seven percentage points more likely than average to have used such a service for consumables only (19% vs. 12% average). Vice versa, older respondents aged 50 or over are 12 percentage points more likely than average to report not having used a printing subscription service in the past (83% vs. 71% average).

When prompted to think about the reasons why they did *not* use printing subscription services in the past, respondents attribute this choice primarily to either the price of the service being considered too high for their printing needs (42%), or a preference for owning printer/consumables (31%) or similarly a consideration that owning is more appropriate to the household's printing needs (19%), or simply not knowing enough about it (19%). Fewer than one in ten respondents attribute this decision to a rational comparison between costs linked to purchasing/repairing the printer and the printing subscription service's fee (7%) or to a comparison between the purchase price of a printer/consumables and the service's fee (9%). Only 2% of respondents who did not use such services did not do so because of a concern for the environmental impact of such services (Figure 35).

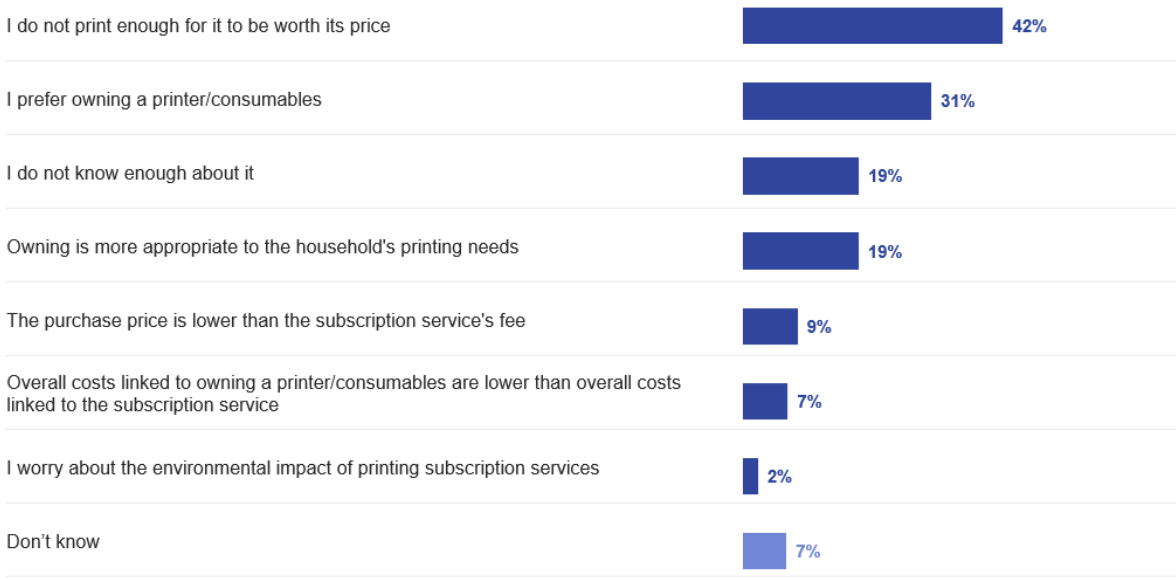


Figure 35. Consumers' reasons for not using printing subscription services

Similarly, respondents who report having used a printing subscription service in the past 12 months were asked about the main seasons why they did so (Figure 36).

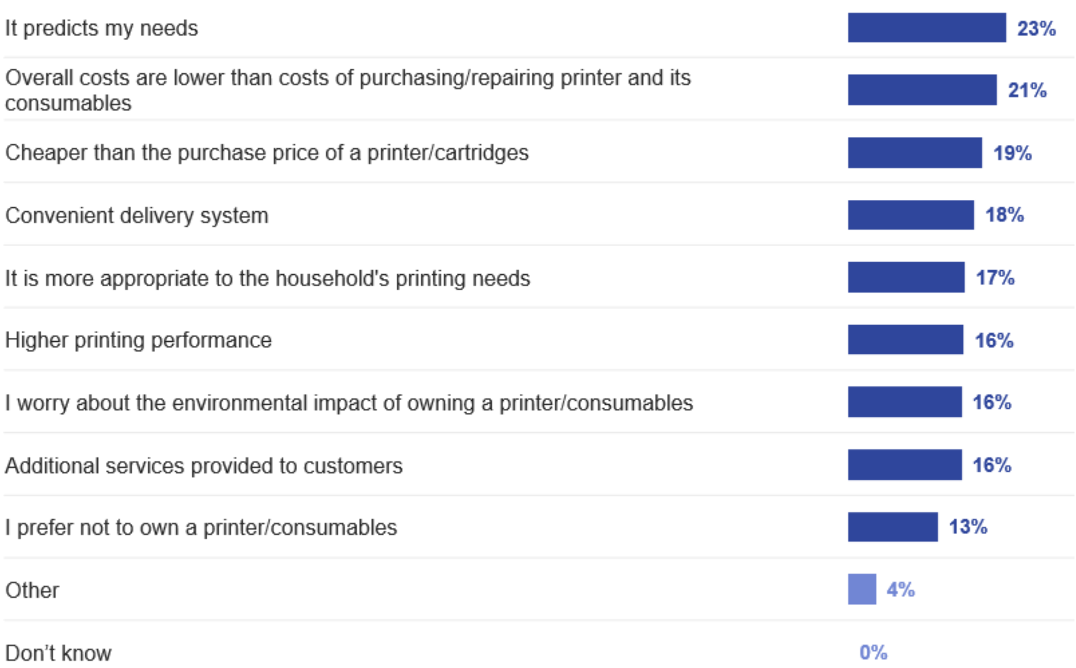


Figure 36. Consumers' reasons for using printing subscription services

3.2 User behaviour in offices

The analysis of the user behaviour in offices is significantly different to the analysis presented in section 3.1, for a variety of reasons. First, the person in charge of purchasing devices and consumables in an office is most likely not the same person who will be using the device. Moreover, printer users in offices generally do not pay for the consumables or the paper used, so usage intensity is potentially higher than in households. It is less likely that users will be aware of their usage intensity, both in terms of printed pages and even more in the case of consumables. Therefore, the user behaviour survey carried out in section 3.1 could only be applied for consumer printers, and the results attained in previous section cannot be extrapolated to office devices and consumables.

In order to understand user behaviour in the office sector, interviews and plant visits have been carried out with stakeholders in the device refurbishing sector –dealing mostly with office equipment- and with providers of monitoring software for Managed Print Service (MPS) contracts. OEMs supplying devices and consumables in the office sector have also contributed to this section.

3.2.1 Purchase of devices and consumables

As described in section 2.1.2 of this Preparatory Study, printers and consumables in the office sector are often purchased via Managed Print Services (MPS), understood as the consolidation and management of an organization's printer needs under a unified program, with equipment and service provided by an outside supplier. Under these contracts, the consumer (typically a business) will pay depending on the number of pages they print, or the amount of ink or toner they use. Often, installation and maintenance services are included in the agreement. When the MPS contract ends, the provider reviews the existing fleet of devices and replaces the ones that have achieved or are close to their technical lifetime, replacing them by new devices.

Keypoint Intelligence highlights a trend in this sector: the replacement of devices is high under MPS contracts. Devices often do not achieve their duty cycle within the period of the contract and are replaced with similar new devices before contract ends under a renewed MPS deal. At the end of the first contract, devices may achieve a second life after refurbishment. At end of second life, devices are often exported out of the country or region.

Refurbishers of office devices also suggest that technical lifetime of devices in the business sector is often not fulfilled due to short replacement cycles. They add that the demand of refurbished printers is higher than the supply. A small percentage of printers placed on the market is refurbished when MPS contracts end. There is no data available on the destination of printers replaced but not refurbished.

Data provided by an OEM provides insight on average age or device replacement, broken down by user segment (Table 20).

Table 20. Average age of device replacement

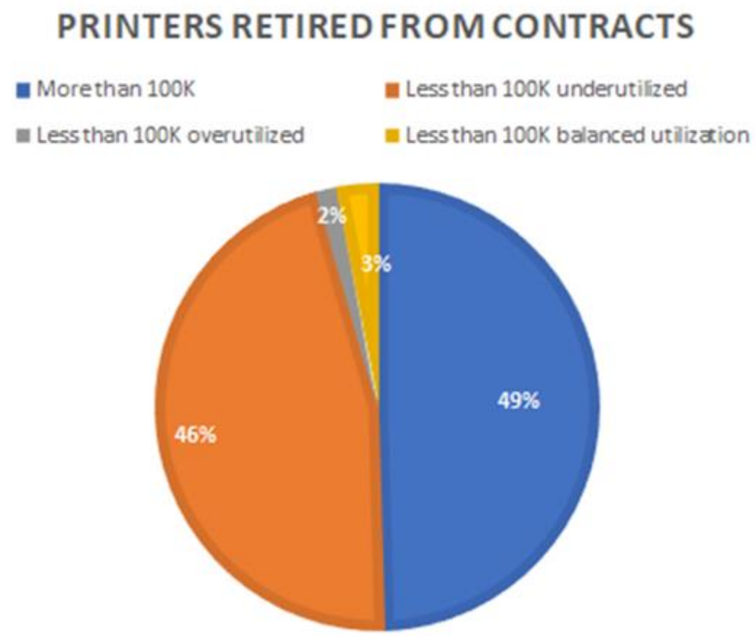
User segment	Average age of replacement (years)
Departmental	6.4
Small workgroup	6.2
Medium workgroup	5.4
Large workgroup	6.5

3.2.2 Usage intensity

A provider of monitoring software for MPS[25] provided information in terms of usage intensity in the business sector. According to their data:

- The average number of printed pages in a 36 months period is 100.000.
- Around 50% of printers under MPS contracts are retired with less than 100.000 pages printed. Most of them (46% of total sample shared by a stakeholder) were underutilized in terms of their regular activity (Figure 37).

[25] Nubeprint



Source: Nubeprint
Figure 37. Printers retired from active contracts

An OEM provided additional data on usage intensity, with a breakdown in terms of the user segment (Table 21).

Table 21. Usage intensity in the business sector

User segment	Average printed pages monthly	36 months extrapolation
Departmental	3412	122823
Small workgroup	917	33027
Medium workgroup	1535	55262
Large workgroup	3108	111882
Average	2382	85744

4 Task 4 – Technologies

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

4.1 Electrophotograpy

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

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

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

> 1-<u>Charging</u>: a high negative voltage of approximately -900V is provided to a charge roller. The charge roller applies a uniform layer of negative charge to the surface of the drum. The resistivity of the photosensitive drum coating allows the charge to remain on the surface.
>
> 2-<u>Exposure</u>: a laser is used to write the image onto the charge surface. The photosensitive coating on the drum becomes conductive when exposed to light. The charges on the surface of the drum exposed to the laser conduct to the base layer (which is connected to a ground). A latent image is created (a near zero volt image with a negative background).
>
> 3-<u>Development</u>: the developer is a mixture of non-magnetic toner and magnetic carrier. As the developer is stirred and the particles rub up against each other, a triboelectric charge is generated between them. The toner becomes negatively charged while the carrier becomes positive. These opposite charges cause the toner to be attracted to the carrier. A magnetic brush carries the attracted toner to the surface of the drum. The toner is attracted to the areas of the drum exposed by the laser. Therefore, the latent image is developed.
>
> 4-<u>Transfer</u>: a sheet of paper passes between the drum and a transfer charge roller that has a high positive voltage applied to it. The negatively charged toner of the developed latent image is attracted to the more positive transfer roller and adheres to the sheet in-between. The charge applied to the back of the sheet causes the paper to cling to the drum. A high negatively voltage is applied to a discharge plate immediately after the transfer charge roller to aid in the separation of the sheet from the drum. More advanced methods of transfer use an intermediate transfer belt system.
>
> 5-<u>Cleaning</u>: after the transfer stage, some toner may be left behind on the surface of the drum. If left there, the background of each successive print would slowly become darker and dirtier. To prevent this, a cleaning blade removes any residual toner from the drum's surface. Some systems recycle this toner back to the developing unit, but mostly the waste toner is collected in a container for disposal.
>
> 6-<u>Erasing</u>: a LED array exposes the drum, bringing this area to near zero volts. This prepares the drum surface for the charging stage of the next print cycle.
>
> 7-<u>Fusing</u>: this is the final stage of the EP process. The most common fusing technology is roll fusing. In this case, the fuser consists of a heat roller, a pressure roller and a cleaning mechanism. When the toner is heated by the heat roller and pressure is applied by the pressure roller, it melts and is pressed into the fibres of the sheet. The toner is bonded to the surface.

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

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

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

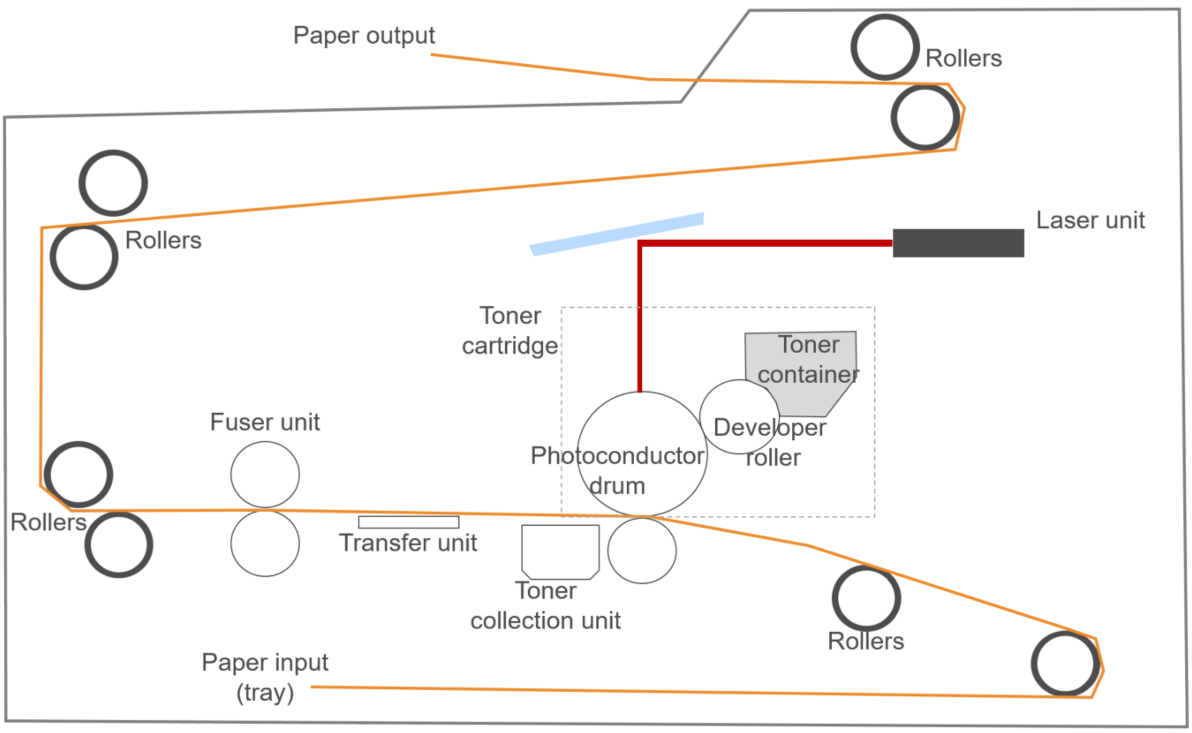
Flash fusing: similar to radiant fusing, in this cases using a xenon-filled flash tube inside a deflector. A power supply charges capacitors, which are then discharged through the flash tube to create instantaneous radiant energy, absorbed by the toner.

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

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

4.1.1 Electrophotographic devices

Electrophotographic (EP) printers are also known as laser printers. They are defined in ISO 29142-1 as a printer principally using optoelectronic phenomena and electrostatic attraction to move toner to a substrate. A schematic description of an EP printer is provided in Figure 38.



Source: JRC, adapted from different sources
Figure 38. Schematic description of EP printer

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

- The photoconductor, also known as ‘drum’, which attracts the toner powder particles and transfers the toner to paper. The drum is a cylinder and can be positioned either next to or inside the toner cartridge. Most photoconductors use an organic material (organic photoconductor, or OPC), although ceramic photoconductors can also be found.
- The developer roller, a cylindrical sleeve used to transfer image forming toner particles. The developer roller can be a part of the printer or located within the cartridge.
- The light source (laser), which imprints the image onto the drum, creating an electrostatic image onto the photoconductor drum.
- The toner cartridge, which holds the toner.
- The waste toner collection unit, which collects the waste toner during the printing process
- The fuser unit, which melts the toner and secures the image to the page.
- The transfer unit, used to transfer the toner image onto paper. It is located after the photoconductor drum and before the fuser unit. It must be noted that not every EP printer contains a transfer unit.
- The internal or external power supplies

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

4.1.2 Toner cartridges

Laser printers use toner as deposition material, which is held in toner cartridges. These cartridges can come in different configurations (Figure 39) and they may consist of a significant number of different components and materials.

-Single-part: comprising only the toner container

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

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

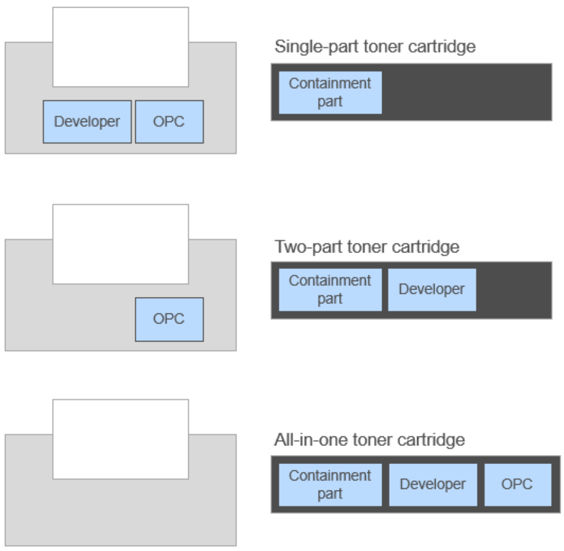


Figure 39. Toner cartridge configurations

A schematic description of a generic monochrome toner cartridge is shown Figure 40.

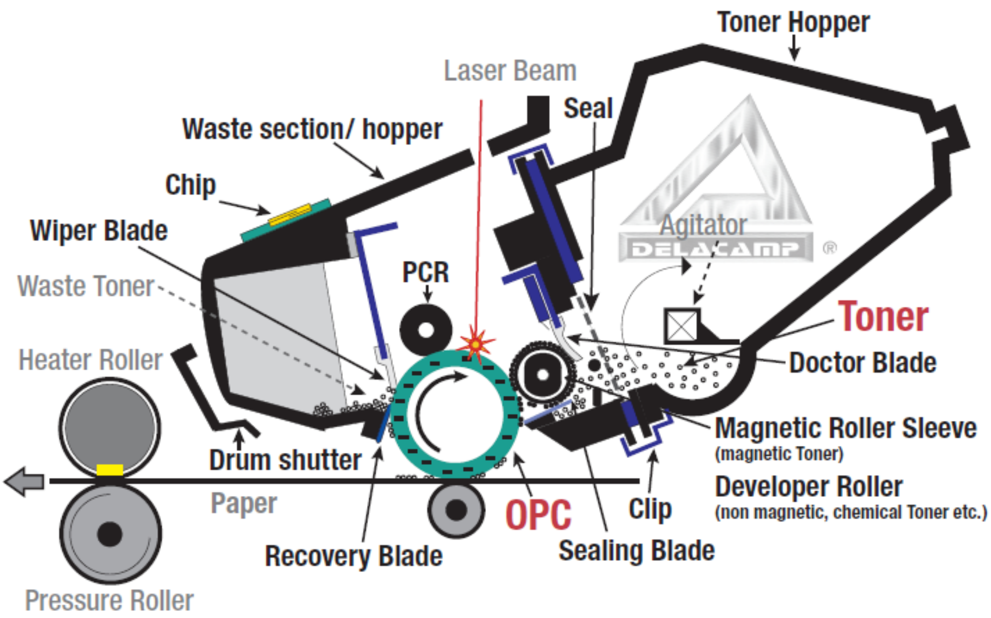


Figure 40. Schematic description of generic monochrome toner cartridge
Source: Delacamp

Some of the main components of a toner cartridge are described above[26] [27] (Josiah et al, 2013):

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

Figure 41, Figure 42 and Figure 43 provide examples of the three toner cartridge configurations describe above.

[26] https://www.farratech.com/how-a-toner-cartridge-works/

[27] https://www.tonerbuzz.com/blog/the-laser-printing-process/

Figure 41. Single part toner cartridge

Figure 42. Two part toner cartridge

Figure 43. All-in-one toner cartridge

In single part toner cartridges, the cartridge is limited only to carrying the toner. The two-part toner cartridges incorporates a toner storage unit and at least a developer part. The all-in-one toner cartridge includes the photoconductor drum as well.

4.2 Inkjet printing

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

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

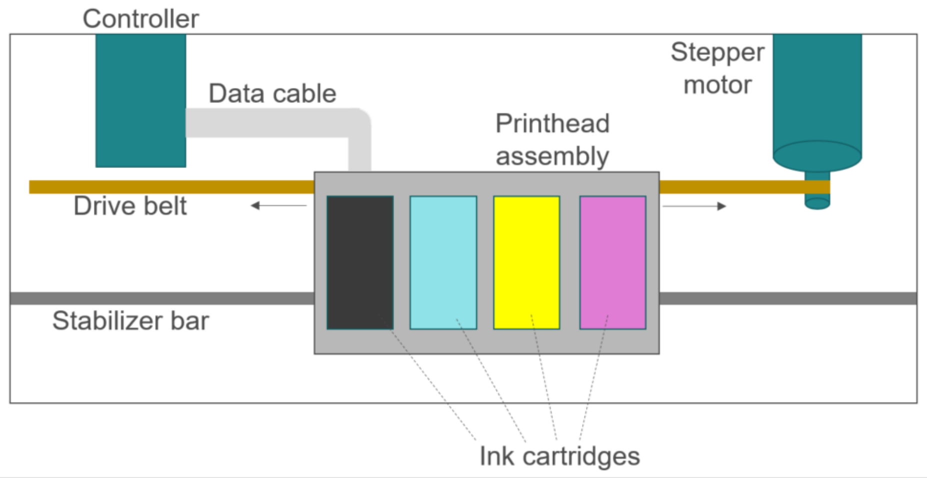
Thermal inkjet is most common in household inkjet printers. A major benefit to using thermal print head technology is the relatively inexpensive print head. Since each colour printed requires a separate print head, and some print devices can contain eight or more colours of ink, thermal technology keeps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

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

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

4.2.1 Inkjet devices

ISO 29142-1 define an inkjet (IJ) printer as a printer with an operating part, for example a print head, to apply ink on a substrate. A schematic description of an inkjet printer is can be seen in Figure 44.



Source: JRC, adapted from Britannica (2022) and other sources[28]
Figure 44. Schematic description of inkjet printer

The main components of an inkjet printer are:

- The print head assembly, which holds the print head and the ink cartridges. The print head contains a series of nozzles used to spray drops of ink onto paper. There is a wide variety of print head designs: print heads designed to be replaced with each cartridge (typically used for low usage); print heads designed to last the life of the product (usually replaced at a service center); and print heads designed to have long life but replaceable by the customer.
- The stepper motor, which moves the print head assembly back and forth across the paper
- The drive belt, used to attach the print head assembly to the stepper motor
- The stabilizer bar, to ensure that movement of the print head assembly is precise and controlled
- The ink collection unit, aiming to collect waste ink during printing
- The controller, electronic circuitry built into the printer to control all the mechanical aspects of the operation, as well as decode the information sent to the printer from the computer. Information is sent to the print head assembly via a data cable.
- Ink cartridges, which hold the ink which can be found in different configurations (Figure 45):
- A set of rollers, which pull the paper from the tray and advance the paper
- The internal and external power supplies

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

4.2.2 Ink cartridges

Inkjet printers use ink as deposition material, which is held in ink cartridges. They can be found in different configurations (Figure 45).

[28] https://computer.howstuffworks.com/inkjet-printer.htm

-Single-part: comprising only the containment part

-Integrated: comprising the containment part and the deposition mechanism

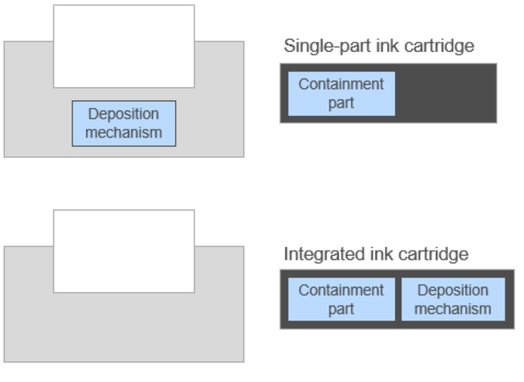


Figure 45. Ink cartridge configurations

Examples of these configurations can be seen in Figure 46 and Figure 47.

Figure 46. Single part ink cartridge

Figure 47. Integrated ink cartridge

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

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

Ink can be either black (monochrome) or coloured (generally cyan, magenta and yellow). Color cartridges can operate in two different ways: an individual cartridge for each color (Figure 48), or three colors included in the same cartridge (Figure 49). Cartridges are often sold in ‘multipacks’, containing one black and one integrated CMY cartridge, or four separate cartridges.

Figure 48. Example of single color cartridge (cyan)

Figure 49. Example of three-color cartridge (cyan, yellow, magenta)

Generally, in printers using cartridges such as in Figure 49, it is not possible to carry on printing when one of the three colors is empty[29]. In those cases, the whole cartridge –even if the rest of the colors are not empty- need to be replaced in order to carry on printing. OEMs explain that when one color runs out, in some cartridges it is possible to continue printing, but it is recommended to replace the cartridge as soon as possible to avoid print head damage[30].

Ink cartridges often contain some electronic circuity, which support a variety of functions (anti-counterfeit, the number of pages printed, etc.) through communication with the device.

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

4.3 Other marking technologies

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

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

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

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

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

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

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

Figure 50. Examples of direct thermal devices

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

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

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

[29] https://support.ldproducts.com/en_us/can-i-print-when-one-printer-cartridge-is-empty-HJz47YJ8P
[30] https://support.hp.com/us-en/document/ish_1929982-1413612-16

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

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

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

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

4.4 Technical aspects affecting environmental performance of devices

In this section, the main technical aspects of devices which affect their environmental performance have been evaluated. The technical aspects evaluated are Energy use, Durability and reliability, Repair and remanufacturing of devices, Emissions to air, Paper use, Noise and Post-consumer recycled content.

4.4.1 Energy use

In this section, different aspects of devices related with energy use are presented. The most common operational modes have been evaluated and their performance compared with currently applicable regulation. Other aspects such as transition times between active and non-active modes or energy efficiency of internal components, have also been investigated.

4.4.1.1 Energy and power consumption in the active mode

The most relevant standard to measure energy performance of imaging equipment devices is Energy Star v3.2. In this standard, definitions related with the active mode are provided:

On Mode, 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.

On Mode, 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).

In Energy Star v3.2, imaging equipment products are classified as Typical Electricity Consumption (TEC) and Operating Modes (OM) products.

- TEC products are devices where the active use the most state relevant, due to their frequency of use. These products are typically used in businesses/office environment and they are usually electro-photographic devices (laser). The active mode of TEC devices has been evaluated in this section.
- OM products are devices which spend a reduced amount of time in the active mode. They spend most of their operating time in low power modes. Therefore, the contribution of the active mode to the overall energy consumption can be considered negliglible. They are typically used in households and they are usually inkjet devices. Non-active modes of OM devices has been evaluated in the following section (4.4.1.2).

In this section, an analysis of the energy consumption of the active mode is conducted, relating it with a relevant parameter such as printing speed.

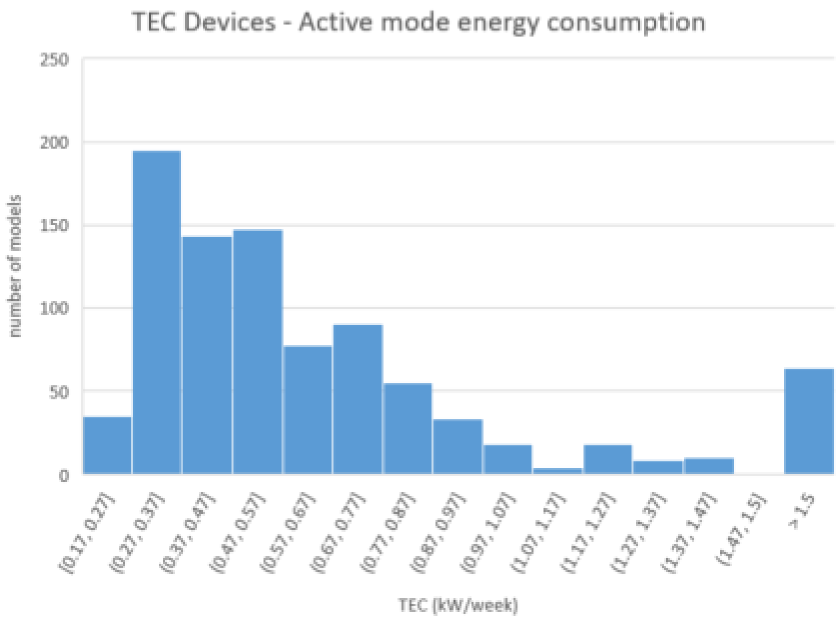


Figure 51. TEC devices – Energy consumption in the Active mode

As can be seen in Figure 51, most of TEC devices registered in Energy Star v3.2 have an energy consumption in the active state between 0.3 and 1 kWh/week. In these devices, energy consumption in the active state is directly related with printing speed (generally measured as the amount of images that a device can print in a minute). Figure 52 shows the relation between printing speed and TEC energy consumption.

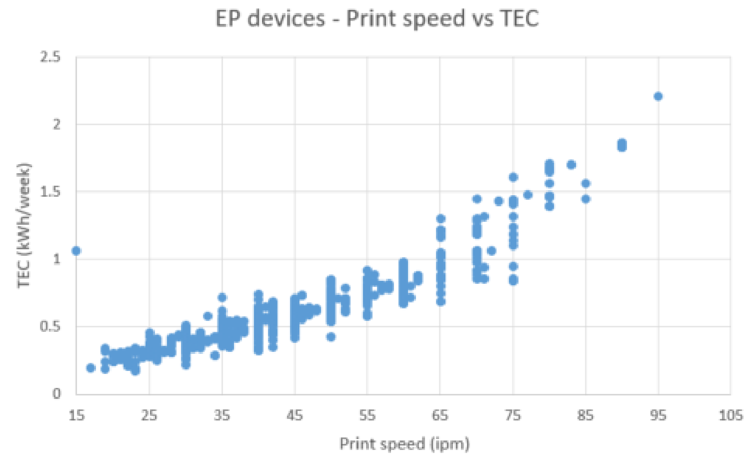
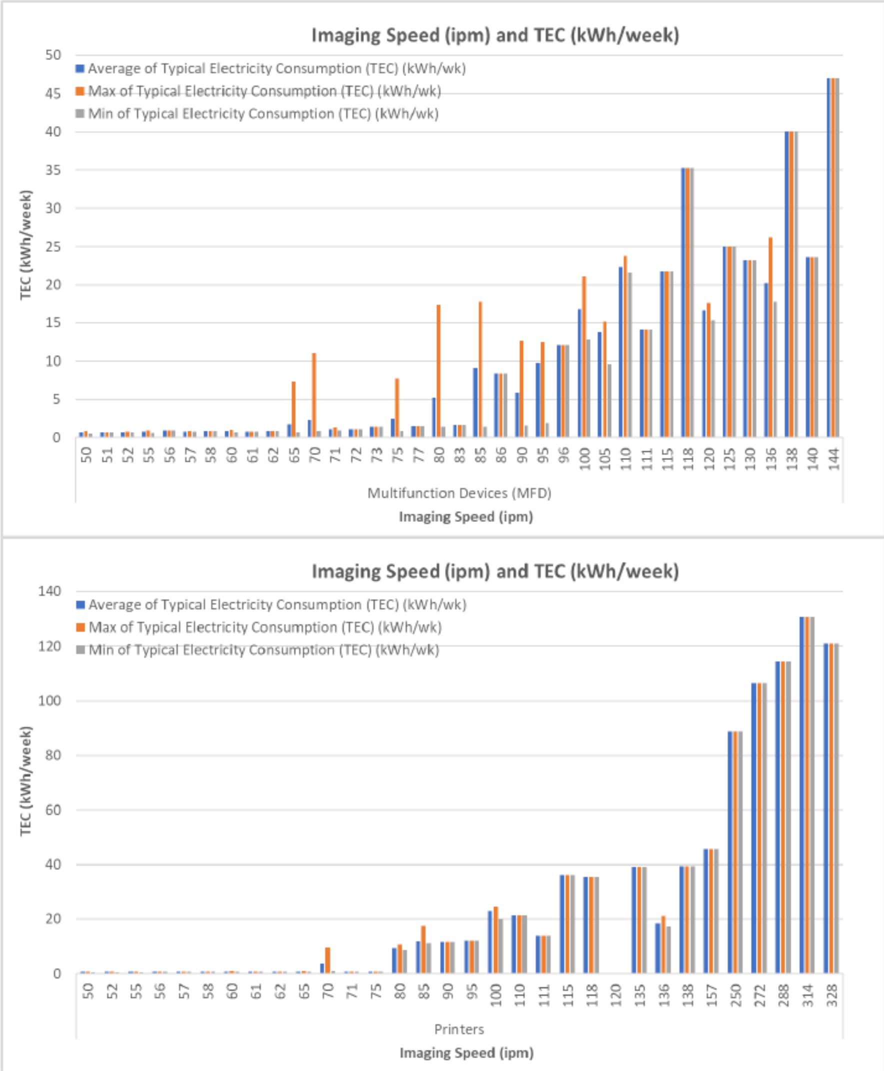


Figure 52. Relation between energy consumption in active mode (TEC) and printing speed

Figure 52 shows there is a clear correlation between printing speed and TEC: devices with higher printing speed consume more energy. Nevertheless, based on feedback from manufacturers, this observation needs to be taken with caution. In their view, generally speaking, devices with higher speeds have higher energy consumption. However, in Figure 52 energy consumption is based on the Energy Star TEC method, which considers a different number of jobs and images per job, for different printing speeds. In essence, the method assumes that devices with higher speeds print more pages. Therefore, TEC (measured in kWh/week) is greatly influenced by printing speed of the device.

In Figure 53 the relation between energy consumption in the active mode (TEC) and printing speed is also evaluated, based on feedback from non-governmental organisations[31]. For each speed (ipm) in the horizontal axis, the average, the maximum and the minimum TEC of products registered in Energy Star v3.2 is shown.

[31] Figure provided by ECOS



Source: provided by ECOS

Figure 53. Printing speed and energy consumption

It can be seen that, for laser printers between 50 and 79 ipm, there is no significant energy increase. A significant increase in energy consumption can be observed in products with imaging speeds higher than 80 ipm. Beyond this threshold, devices between 80 and 100 ipm show values around 10-20 kWh/week. Between 100 and 120 ipm, TEC rises to 20-40 kWh/week. Finally, TEC of devices over 120 ipm can reach values 40-120 kWh/week.

In order to evaluate the effect of the TEC method on the correlation between energy and printing speed, an additional analysis has been carried out (Figure 54).

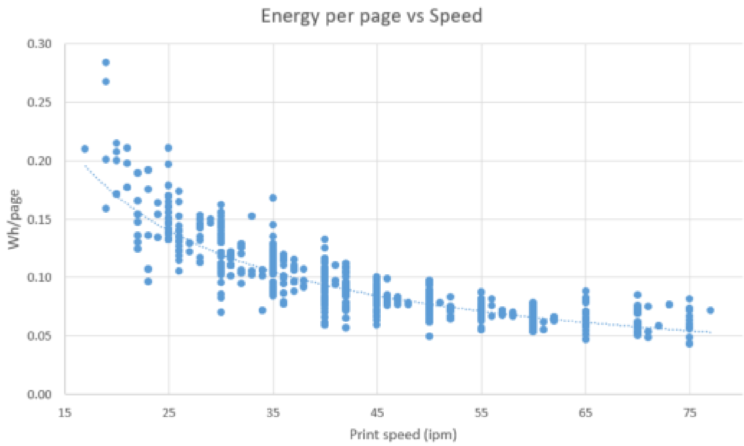


Figure 54. Relation between energy consumption in active mode (per page) and printing speed

In this case, a correlation is also observed, but an opposing trend: printers with higher speeds consume less energy per page.

4.4.1.2 Energy and power consumption in non-active modes

As explained above, non-active operational modes are relevant for OM products (inkjet products), since due to their frequency of use they spend most of their time in these modes. Energy Star v3.2 defines non-active modes as follows:

> *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).
>
> *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.

Printing equipment is also covered by Regulation 2023/826 laying down ecodesign requirements for off mode, standby mode and networked standby energy consumption of electrical and electronic household and office equipment.

As stated in previous sections, the application of this Regulation should be limited to products corresponding to household and office equipment intended for use in the domestic environment, which corresponds to class B equipment as set out in the EN 55022:2010 standard. Class B equipment is designed to be used in a domestic environment and will not cause radio interference with other equipment. In contrast, Class A equipment is used in a domestic environment may cause radio interference with other equipment in its vicinity. Therefore, the latter is out of the scope of such regulation.

Regulation 2023/826 also establishes definitions for non-active modes:

> *Standby mode* means a condition where the equipment is connected to the mains power source, depends on energy input from the mains power source to work as intended and provides only one or more of the following functions, which may persist for an indefinite time:
>
> (a) reactivation function;
>
> (b) reactivation function and only an indication of enabled reactivation function;
>
> (c) information or status display;
>
> *Off mode* means a condition in which the equipment is connected to the mains power source and is not providing any function, or it is in a condition providing only:

(a) an indication of off mode condition;

(b) functionalities intended to ensure electromagnetic compatibility under Directive 2014/30/EU of the European Parliament and of the Council

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;

Regulation 2023/826 states that, unless this is inappropriate for the intended use, printing equipment shall provide one or more of the following conditions:

- Off mode

- Standby mode

- Another condition which does not exceed the applicable power consumption requirements for off mode or standby mode when equipment is connected to the mains power source.

The minimum requirements established in Regulation 2023/826 for those modes are presented in Table 22.

Table 22. Minimum requirements of Regulation 2023/826

Operational mode	Minimum requirement
Standby mode	**<0.5W** (In any condition providing only a reactivation function, or providing only a reactivation function and an indication of reactivation function) **<0.8W** (in any condition providing only information or status display, or providing only a combination of reactivation function and information or status display, or providing only a reactivation function and an indication of enabled reactivation and information or status display)
Networked standby	**<8W** (HiNA equipment[32] or equipment with HiNA functionality[33]) **<7W** (2 years after application of REG) **<2W** (Networked equipment other than HiNA equipment or equipment with HiNA functionality) Not applicable to large format printing equipment
Off mode	**<0.5W** **<0.3W** (2 years after application of REG)

There are slight differences between the operational modes defined in Energy Star v3.2 and Regulation 2023/826. Based on feedback from stakeholders, a table of equivalencies of operational modes between Energy Star v3.2 and Regulation 2023/826 is presented in Table 23.

[32] 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

[33] equipment that has the functionality of a router, network switch, wireless network access point or combination thereof included, but not being HiNA equipment

Table 23. Equivalencies between Energy Star v3.2 and Regulation 2023/826

Energy Star v3.2	**Regulation 2023/826**
Off mode: The power state that the product enters when it has been manually or automatically switched off but is still plugged in and connected to the mains. This mode is exited when stimulated by an input, such as a manual power switch or clock timer to bring the unit into Ready State. When this state is resultant from a manual intervention by a user, it is often referred to as Manual Off, and when it is resultant from an automatic or predetermined stimulus (e.g., a delay time or clock), it is often referred to as Auto-off.	**Off mode:** means a condition in which the equipment is connected to the mains power source and is not providing any function, or it is in a condition providing only: (a) an indication of off mode condition; (b) functionalities intended to ensure electromagnetic compatibility under Directive 2014/30/EU of the European Parliament and of the Council
no direct comparison in Energy Star v3.2	**Standby mode:** means a condition where the equipment is connected to the mains power source, depends on energy input from the mains power source to work as intended and provides only one or more of the following functions, which may persist for an indefinite time: (a) reactivation function; (b) reactivation function and only an indication of enabled reactivation function; (c) information or status display;
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). For products evaluated under the TEC test method, Sleep Mode permits operation of all product features (including maintenance of network connectivity), albeit with a possible delay to transition into Active State. For products evaluated under the OM test method, Sleep Mode permits operation of a single active network interface, as well as a fax connection if applicable, albeit with a possible delay to transition into Active State.	**Networked standby mode**: condition in which the equipment is able to resume a function by way of a remotely initiated trigger from a network connection

Figure 55 shows power consumption of inkjet devices registered under Energy Star v3.2 in their off mode. The most common values are between 0.05 and 0.1W. The average of the database is 0.11W.

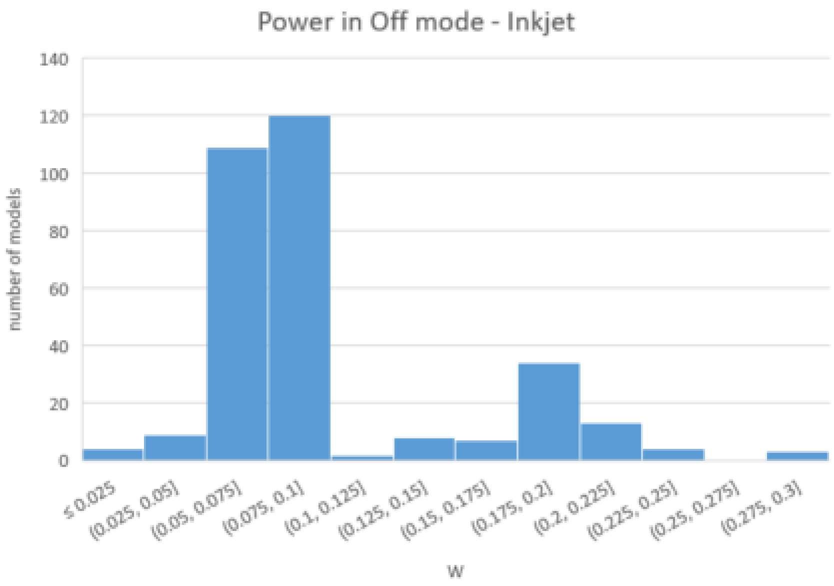


Figure 55: Power in off mode (W) for inkjet printers and MFD registered under Energy Star v3.2
Source: JRC, based on data from Energy Star v3.2 database

Therefore, most of the devices registered in Energy Star v3.2 are below the currently applicable threshold of Regulation 2023/826 (0.5W) and even below the threshold that will be applicable 2 years after the Regulation enters into force (0.3W). Figure 56 shows off-mode power consumption of inkjet devices in Energy Star v3.2 database, with thresholds established in Regulation 2023/826. Nearly all devices in this dataset have power consumption values easily below current and future thresholds.

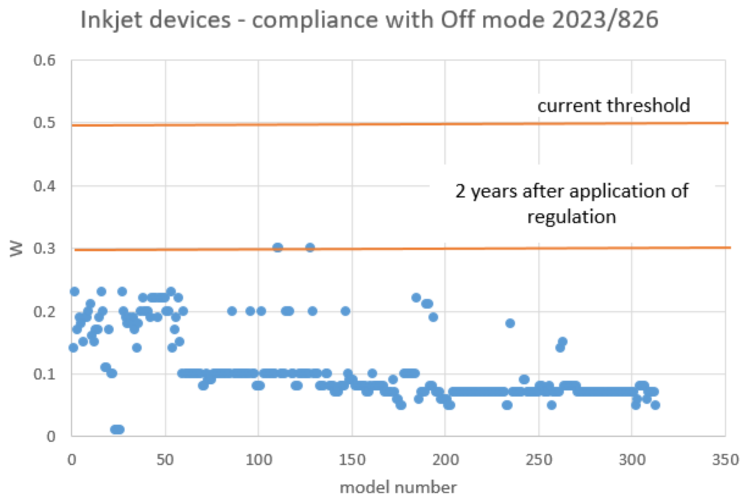


Figure 56. Inkjet devices in Energy Star v3.2 database and off mode thresholds in Regulation 2023/826

Figure 57 shows power consumption of inkjet devices registered under Energy Star v3.2 in their sleep mode. The most common values are between 0.75 and 1.75W. The average of the database is 1.1W.

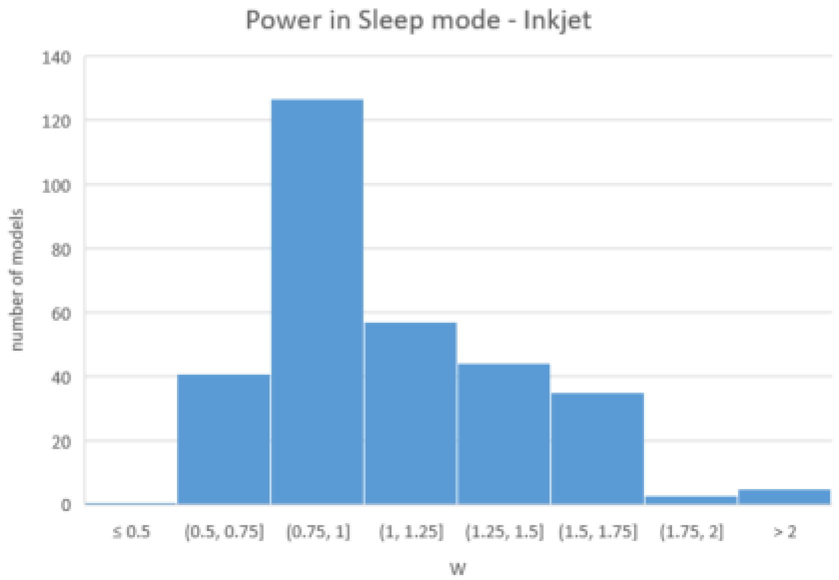


Figure 57. Power in Sleep mode for inkjet printers and MFD registered under Energy Star v3.2

Source: JRC, based on data from Energy Star v3.2 database

Therefore, most of the devices registered in Energy Star v3.2 are below the currently applicable threshold of Regulation 2023/826 (8W for devices that can be classified as HiNA equipment and 2W for the rest). The off-mode performance does not seem to be affected by other performance parameters of the device such as printing speed. Figure 58 shows sleep mode power consumption of inkjet devices in Energy Star v3.2 database, with thresholds established in Regulation 2023/826 for networked standby. Nearly all devices in this dataset have power consumption values easily below current and future thresholds. The 7W and 8W minimum requirements apply both to HiNA equipment and equipment with HiNA functionality. Taking into account the definition of equipment with HiNA functionality, some devices might fall within this category.

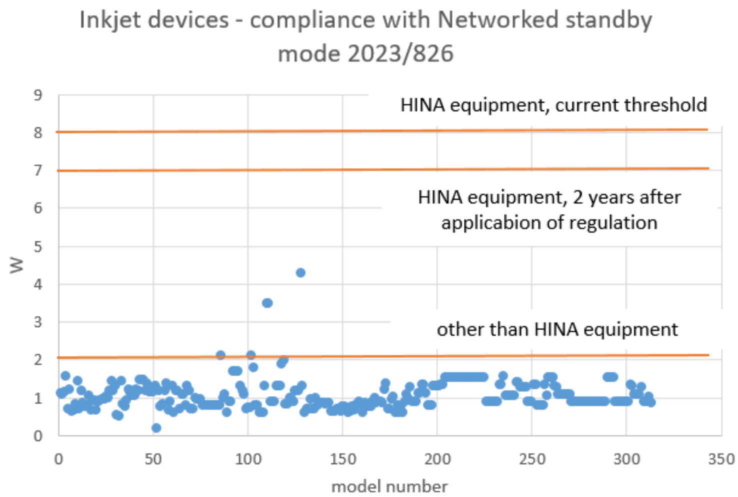


Figure 58. Inkjet devices in Energy Star v3.2 database and networked standby thresholds in Regulation 2023/826

4.4.1.3 Transition between active and non-active modes

Another important parameter affecting the energy consumption of imaging equipment is the automatic transition time from active-ready/mode to sleep mode (also called default time to sleep). This functionality is very relevant for the consumer, considering that imaging equipment devices spend a significant part of their time in non-active modes.

According to the Regulation 2023/826 a power management function, or a similar function, shall be available for all network ports of the networked equipment. The default period of time after which the power management function, or a similar function, switches the equipment automatically into a condition providing networked standby shall not exceed 20 minutes. Moreover, information on this default time to networked standby shall be available on the manufacturer website together with the power consumption in networked standby.

Analysing the Energy Star v3.2 data base, it was found that most of the IJ and EP have a transition to sleep modes. For both categories of products the time to sleep can vary from model to model. The most common transition to sleep period is 4-5 minutes in inkjet devices (Figure 59).

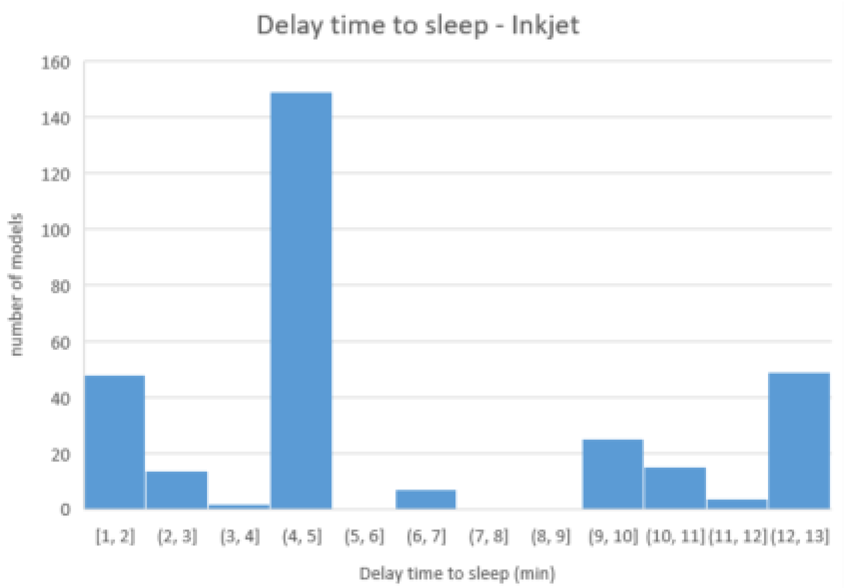


Figure 59. Default delay time to Sleep of inkjet devices
Source: JRC, based on data from Energy Star v3.2 database

Figure 60 shows default delay time to sleep of inkjet devices with the current threshold in Regulation 2023/826. Nearly all devices in this dataset have power consumption values easily below current thresholds.

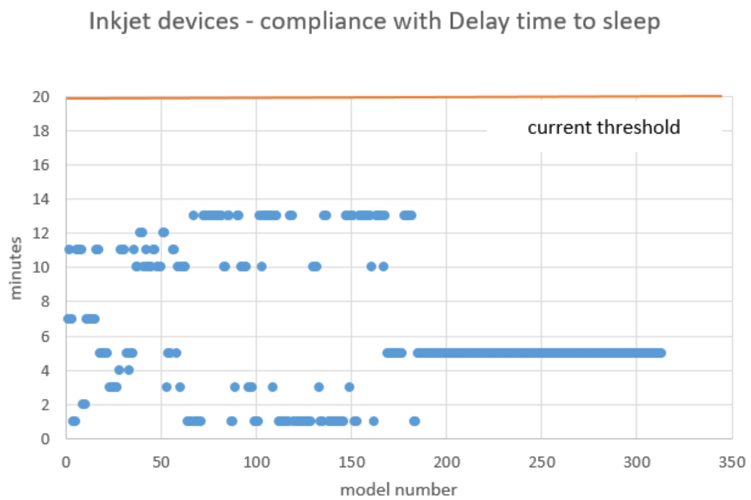


Figure 60. Inkjet devices in Energy Star v3.2 database and default delay time to sleep threshold in Regulation 2023/826

The most common transition to sleep period is 1 minute in laser devices and 4-5 minutes in inkjet devices (Figure 61).

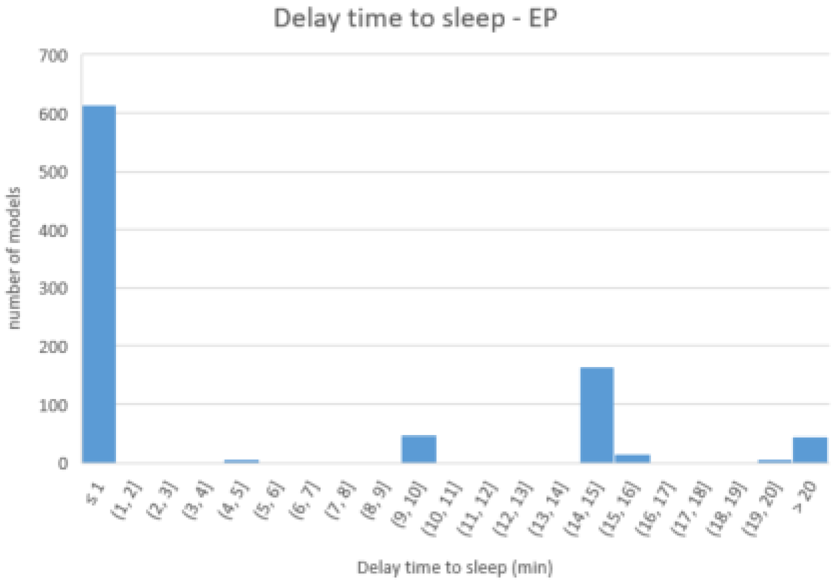


Figure 61. Default delay time to sleep of laser devices

Source: JRC, based on data from Energy Star v3.2 database

Figure 62 shows default delay time to sleep of laser devices with the current threshold in Regulation 2023/826. Nearly all devices in this dataset have power consumption values easily below current and future thresholds.

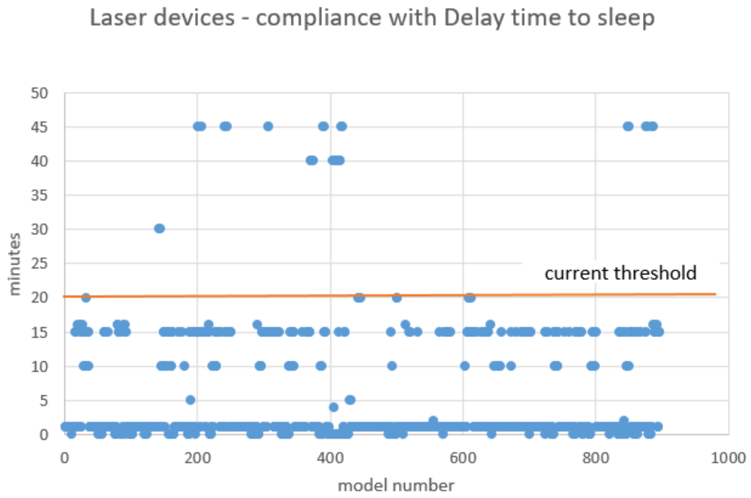


Figure 62. Laser devices in Energy Star v3.2 database and default delay time to sleep threshold in Regulation 2023/826

4.4.1.4 Energy efficiency of internal power supplies

In Regulation 617/2013 on ecodesign requirements for computers and computer servers, an internal power supply (IPS) is defined as a component designed to convert AC voltage from the mains to DC voltage for the purpose of powering the computer or computer server. It has the following characteristics:

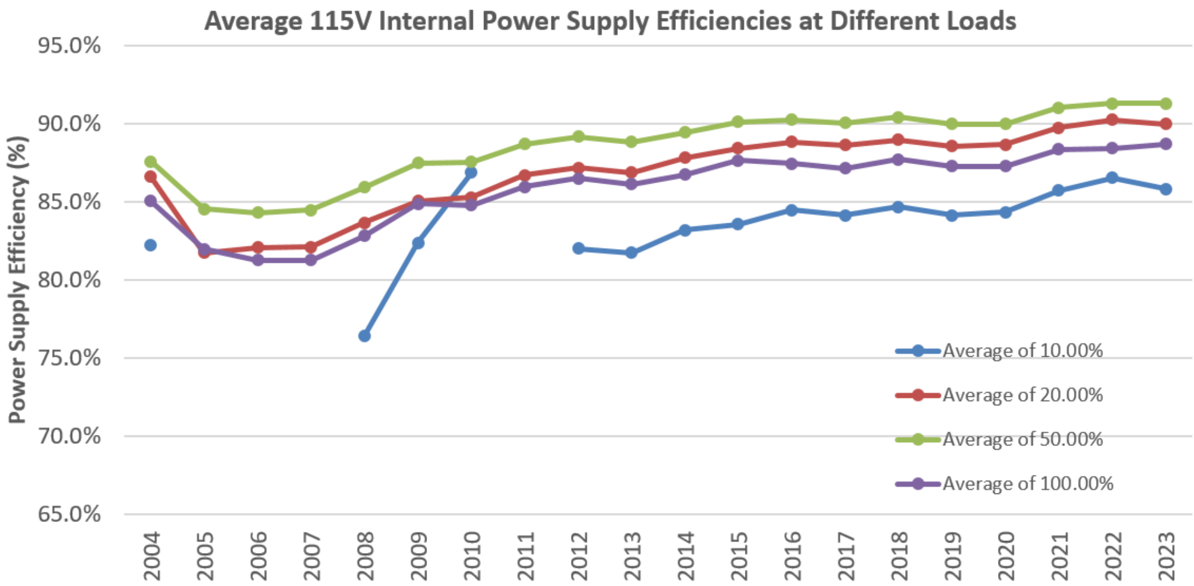
(a) is contained within the computer or computer server casing but is separate from the main computer or computer server board;

(b) the power supply connects to the mains through a single cable with no intermediate circuitry between the power supply and the mains power; and

(c) all power connections from the power supply to the computer or computer server components, with the exception of a DC connection to a display in an integrated desktop computer, are internal to the computer casing.

According to feedback provided by a stakeholder, no major environmental initiative has addressed the issue of IPS efficiency within imaging equipment (except for IPS included in Digital Front Ends). Ecodesign regulations addressing ICT products generally include requirements on IPS, even where the minimum requirements take a duty cycle approach rather than a power demand approach (such as computers). In their view, there is significant additional energy savings available related to internal power supplies.

This figure shows the evolution over time of the energy efficiency of IPSs registered under the 80Plus Programme[35] The efficiency of IPS is different for different power loads, as can be seen in Figure 63. It can also be seen that the efficiency of IPSs has been improving over the past 20 years.



Source: 80Plus registered IPS, provided by ECOS

Figure 63. Average internal power supply efficiencies at different loads

Focusing on 2022 data (products placed on the market in 2022, registered with 80 Plus programme) shows that the average efficiency of IPSs operating at 10% of their capacity is around 87%, whereas the average efficiency at 50% of the load is around 92%. Imaging equipment tend to spend a considerable amount of time in lower power modes, therefore at low load levels on the IPS, which generally provide the lowest efficiency.

The 80 Plus Programme offers six levels of certification (from Standard to Titanium), for IPSs, at increasing levels of energy efficiency. The performance specification requires power supplies in computers and servers to be 80% energy efficient or greater at 20%, 50% and 100% of rated load, with a true power factor of 0.9 or higher (Table 24).

Table 24. Levels of certification of 80 Plus, for 230V EU Internal Non-redundant IPS

	10% of rated load	20% of rated load	50% of rated load	100% of rated load
Standard	-	82%	85% PFC > 0.90	82%
Bronze	-	85%	88% PFC > 0.90	85%
Silver	-	87%	90% PFC > 0.90	87%
Gold	-	90%	92% PFC > 0.90	89%
Platinum	-	92%	94% PFC > 0.90	90%
Titanium	90%	94% PFC > 0.95	96%	91%

[35] https://www.clearesult.com/80plus/program-details-information#80plus-specification

Based on this, there seems to be a potential to improve the energy efficiency of the whole device by using energy efficient IPSs.

4.4.1.5 Average energy and power consumption values of devices

The energy performance of devices registered in Energy Star v3.2 is summarised in Table 25. Compared to the data on energy performance from Huang et al (2019) it can be seen that the values of TEC are now much lower than the previous study (as example average TEC for devices in the 20-40 ipm decreased from more than 60 kwh/week to 40 kWh/week). The main reason is the change in TEC calculation method between ENERGY STAR v.2.0 and v3.2. In revising from v2.0 to v3.2 ENERGY STAR made a significant change to the TEC equation, reducing the number of pages printed during the test by a factor of four. As a result, v2.0 and v3.0 TEC values are not comparable.

Table 25. Energy performance for different categories of devices

Source: JRC elaboration from Energy Star v3.2 Database (September 2022)

Device	Marking Technology	Speed (ipm)	Average TEC (kWh/week)	BAT TEC (kWh/week)	Average Sleep mode (W)	Average Off mode (W)	Average default delay time to sleep (min)
MFD	EP	28-32	0.39	0.34			3.5
MFD	EP	48-52	0.69	0.60			6.9
MFD	EP	70-72	1.12	0.92			7.4
Printer	EP	28-32	0.37	0.30			3.5
MFD	Inkjet	20-40			1.1	0.1	7.3
Printer	Inkjet	20-40			1.02	0.15	5.0

Based on feedback from OEMs, the Energy Star v3.2 TEC evaluation method does not allow for comparison of products with different speeds, as the TEC limit, number of jobs printed during the test and number of pages per job are calculated according to the product speed. Therefore, averaging TEC values for products with significantly different speeds does not provide relevant information. In Table 25, narrow speed ranges have been selected in the EP devices in order to provide average values of TEC. Although these values will not be used to define base cases in this Preparatory Study, they can be used as a reference to ensure that TEC values proposed as base cases are in the right order of magnitude.

As shown in previous studies (Huang et al. 2019) laser printers spend most of their time in networked standby (sleep) or off mode and spent very little time in active state (i.e. performing jobs) at households but also at offices (Figure 64).

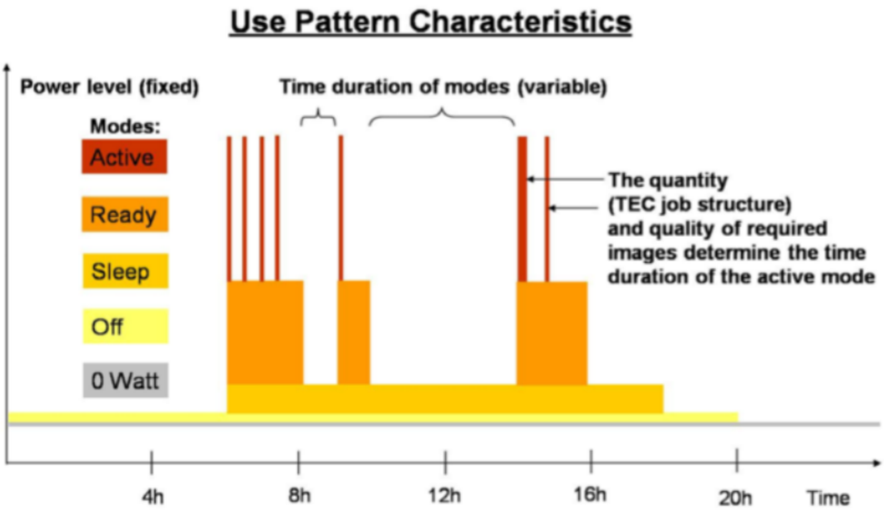


Figure 64: Schematic description of use pattern factors during the course of a day

The example in Table 26, although anecdotic and based on the power specification of a single device[36] and assumptions on time duration of modes, aims to highlight where the main saving opportunities are. In particular, it shows the important power gaps between the ready state mode (85W) and the sleep (16.8W) and deep sleep (1.1W).

In this context, ensuring a short default transition time between active and non-active modes can provide significant energy savings with a relatively low impact on the printing performance. The main reasons for the relative high consumption in ready mode are the display units kept on and the fusing unit kept ready at high temperature (through the fusing unit heater).

Table 26. Example of power and energy consumption in different modes for a laser printer

Mode	Power (W)	Time (hours)	Energy consumption (kWh/year)
Active – Printing	770 W	0.4 h	16.0
Active – Printing in quite mode	430 W	0.2 h	4.5
Active - Ready	85 W	1.4 h	6.2
Sleep	16.8 W	6 h	5.2
Deep sleep	1.1 W	60 h	3.4
Power off	0.04 W	100 h	0.2
Total			35.6

The example in Table 27 shows how, on the contrary, the power use (and energy consumption) in active mode is less relevant for inkjet devices, characterised by a less energy intensive process. Energy consumption for inkjet printers seems to be mostly related to the energy consumption in sleep mode. As above, the example is based on the specific power configurations of a device placed on the market[37] .

[36] https://www.brother.ee/printers/laser-printers/mfc-l9670cdn#specifications
[37] https://www.epson.eu/en_EU/products/printers/inkjet/consumer/ecotank-l1250/p/30220

Table 27. Example of power and energy consumption in different modes for an inkjet printer

Mode	Power (W)	Time (hours)	Energy consumption (kWh/year)
Printing	12 W	0.5 h	0.5
Ready	3 W	4.5 h	0.7
Sleep	0.7 W	114 h	4.1
Power off	0.2 W	48 h	0.5
Total			5.8

A similar exercise was carried out in Saidani et al (2022) with an inkjet printer, although the results are not comparable (in that study, total energy consumption is significantly higher). This is related to different assumptions in the distribution of time allocated to each of the operational modes.

4.4.2 Durability and reliability

The purpose of this section is to evaluate how the durability and reliability concepts relate with imaging equipment lifetime; understand how lifetime is measured in this sector; and to characterize devices in terms of their typical lifetime.

- Durability is the ability of a product (or of a part of a product) to function as required, under defined conditions of use, maintenance and repair, until a limiting state is reached.
- Reliability is probability that a product functions as required under given conditions, including maintenance, for a given duration without limiting event.

Both durability and reliability can be expressed in units appropriate to the part or product concerned: calendar time, operating cycles, distance run, etc. (EN45552).

Therefore, reliability represents the assessment of a probability of duration from first use to first failure or in-between failures; whereas durability is the whole expected time for this same period and not a probability. Durability can be considered the most likely maximum normal use of a product until the transition from a limiting state to end of life. The reliability of a product is directly related to its probability of failure under given normal environmental and operating conditions. Increasing the durability and reliability of energy-related products can contribute to a reduction in the quantity of raw materials used and energy required for the production/disposal of energy-related products and consequently reduces adverse environmental impacts.

Durability and reliability are directly related with product lifetime. According to Laitala et al (2021), increasing product lifetime is one of the most effective environmental strategies, and has the potential to slow down the production and consumption cycle and thus prevent waste and reduce emissions from product and transport, and save energy.

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

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

Printers are products were the difference between technical lifetime and functional lifetime appears to be significant, based on published bibliography. Domestic printers –generally inkjet devices- are products usually not subject to significant stress in terms of frequency of use and are not placed in hostile environments, so they can technically last for a considerable number of years. However, according to HOP (2017), it is considered that the average lifetime of an inkjet printer is around 3 years (a period which could be increased 2 additional years if reparability was adequately promoted). Similar conclusions are made in ADEME (2019), where the authors consider that the potential lifetime of a printer is 6 years. Their hypothesis is that lifetime of printers is generally not fulfilled. Additionally, according to non-governmental organisations, around 80% of printers are replaced by users within the first 3-4 years after purchase[38], estimating that around 500,000 tonnes of e-waste is produced from discarded imaging equipment in the EU every year (with just 2% being reused in new products). In Bakker et al (2014), it was pointed out that the median lifetime of imaging equipment showed a decreasing trend by 11%[39], as happened to other ICT products during the same period.

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

<u>The number of printed pages</u>. Lifetime of the device will be directly affected by the intensity of use in terms of printed pages. Two parameters should be taken into account regarding the number of printed pages:

a) The actual number of printed pages by the device at a given point. It is relevant to highlight that currently there is a lack of common measurement method on how imaging equipment devices count the actual number of printed pages.

b) The maximum number of pages that a device can potentially print (aspect also known as duty cycle, which could also be approximated to device durability). As above, there is neither a common measurement method on how imaging equipment devices measure duty cycle[40].

The absence of measurement methods makes lifetime comparisons between different imaging equipment devices not possible nowadays.

<u>Engine cycles</u>. To overcome the absence of measurement methods on number of printed pages, this parameter is suggested by a stakeholder as a valid substitute to measure printer lifetime. The engine cycle counter exists in all printers (although in the most recent ones the manufacturer hides it by relegating it to an "internal" use). In some OEMs it is known as “service counter”. Manufacturers set maintenance policies based on engine cycles.

4.4.2.1 Device durability in the business sector

Printers in the business sector –generally laser devices- are usually devices with higher performance and value and subject to more intense frequency of use. Therefore they are generally designed to last longer and withstand tougher conditions.

Devices in the business sector are often run under Managed Print Service contracts. Usually, when MPS contracts end, the whole fleet of devices installed is replaced with new devices, without considering the available lifetime of the installed devices, as pointed out in section 3.2.1. A provider of monitoring software for MPS contracts indicates that almost 75% of printers in their active contracts have an age of 2 years or less, whereas only 6% have an age of 4 years or more (Figure 65).

[38] https://ecostandard.org/news_events/when-empty-promises-wont-do-why-regulation-is-needed-to-end-built-in-obsolescence-of-printers/

[39] Between the years 2000 and 2005

[40] https://insights.ricoh.co.uk/streamlining-processes/understand-the-duty-cycle-of-your-printer

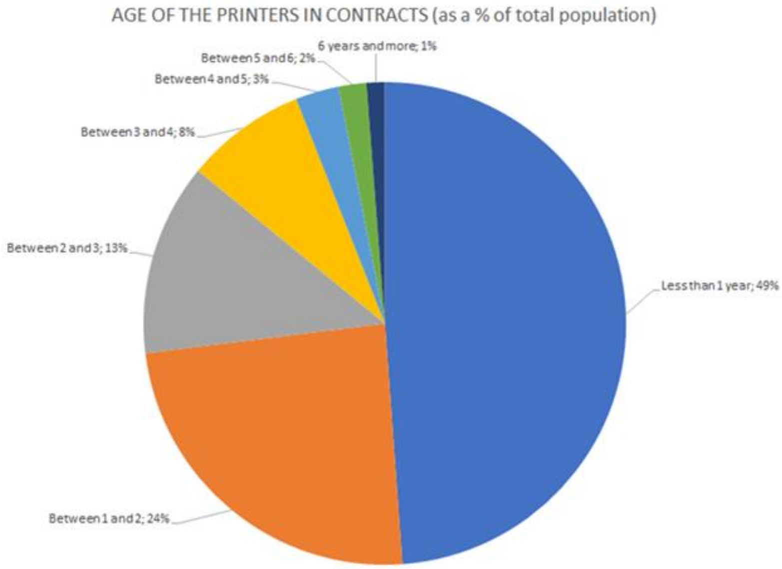


Figure 65. Age of printers in active MPS contracts
Source: Nubeprint

Data was also provided by an OEM in terms of the total number of pages printed by devices at replacement (Table 28). It can be seen that the average age of printers at replacement is around 6 years, with slight variations depending on the application.

Table 28. Average pages printed at replacement

Application	Average pages printed at replacement (2022)	Average age of printers at replacement (2022)	Average monthly print (pages)
Departmental	383,200	6.4	3,412
Small workgroup	81,961	6.5	917
Medium workgroup	109,839	5.4	1,535
Large workgroup	348,662	6.2	3,108

Additional to the data presented in Table 28, it is also relevant to understand the percentage of the duty cycle consumed at that age. In other words, to understand how many pages a device can still print when it is replaced (data presented in Figure 37 already suggested that half of printers under MPS contracts are retired with less than 100.000 pages printed, which is less than their typical duty cycle). Data provided by an OEM provides insight on the percentage of the duty cycle consumed by devices under MPS contracts (Table 29).

Table 29. Duty cycle consumed by devices under MPS contracts

	<1 year	1-3 years	3-5 years	5-7 years	7-10 years	>10 years
Departmental	0.9%	3.4%	6.8%	15.0%	25.0%	24%
Small workgroup	5.8%	21.4%	26.3%	21.7%	21.0%	26.1%
Medium workgroup	1.3%	5.5%	12.6%	19.1%	23.5%	56.0%
Large workgroup	0.9%	4.2%	9.0%	16.4%	24.0%	33.1%

As can be seen, devices that have been in use for more than 10 years have only consumed between 24% -56% of their technical capacity. Replacing these devices early would be underutilizing their available lifetime potential. As seen in Table 28, the average age of devices when they are replaced in the business sector is around 6 years. At that age, devices have usually only consumed between 15-22% of their duty cycle.

This practice of early replacement of devices in businesses seems to be declining, based on feedback provided by an OEM. According to their data, average lifetime of printers in active MPS contracts has raised from 3.2 years in 2018 up to 3.9 years in 2023. Evaluating the age of printers in active contracts (2023 first quarter), 60% of devices were older than 3 years, with 28% between 1-3 years and 12% between 0-1 years.

When devices are replaced, they are often sent for refurbishing operations (either by the OEM or by authorised operators), which have been addressed in section 4.4.3 of this Preparatory Study.

Device refurbishing operations have been visited as part of the development of this Preparatory Study and interviews were held with managers of these plants. In terms of device lifetime in the business sector, refurbishers of office devices have provided some relevant information:

- Average lifetime of devices collected at the end of their use in the business sector is between 4 and 6 years (which is aligned with data provided by OEMs and providers of MPS monitoring software).
- In organisations with large budgets, devices are replaced every 3-4 years, usually when MPS contracts expire (which agrees with feedback provided by Keypoint Intelligence).
- Assemblies and key components such as fusers, transfer units or drums often have 70% of remaining lifetime when they are discarded.
- In terms of the capacity of the refurbishing process to increase device lifetime, they estimate that a 4-year old device with 85% of remaining lifetime can be refurbished up to its initial conditions. A device can be refurbished up to 3 times. Its technical lifetime can be estimated between 12-14 years.

Based on the data presented in this section (both current practices in terms of early replacement and technical potential highlighted by refurbishers), there seems to be room to increase printer lifetime in the business sector.

4.4.2.2 Device durability in the domestic sector

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

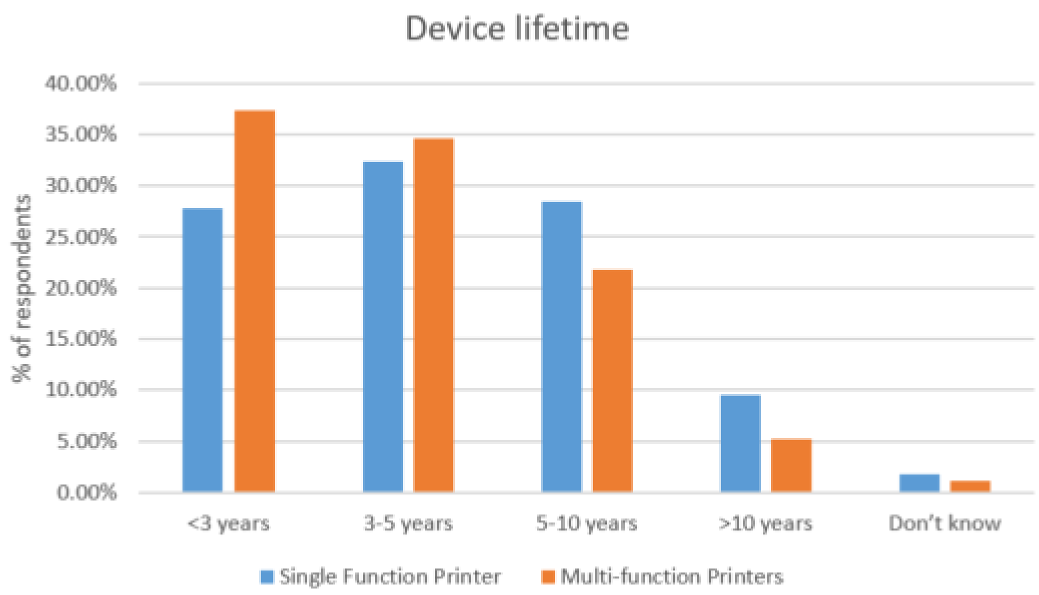


Figure 66. Device lifetime in the domestic sector based on user behaviour survey

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

Real device lifetime presented in Figure 66 can be compared with expected device lifetime shown in Figure 67. Most of users of single-function and multi-function printers intend to use their device between 5-10 years before they buy a new one (around 33% of respondents). Between 25-30% of respondents intend to use their device between 3-5 years, whereas 15% of them intend to use it for more than 10 years.

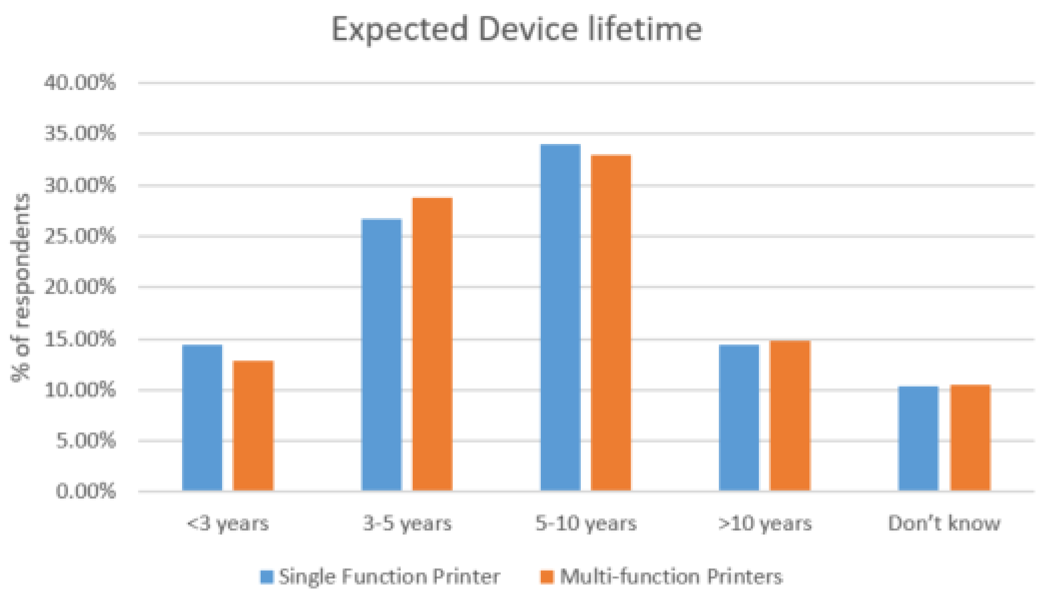


Figure 67. Expected device lifetime in the domestic sector based on user behaviour study

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

Results from the user survey of this Preparatory Study (Task 3) confirm that most of the respondents have the intention of using their printers between 5 and 10 years, although the average age of installed printers in households is lower, around 4 years. Nearly 70% of respondents have experienced some sort of printer failure, but only 21% have had their printer repaired (Figure 25 and Figure 29). The main reason for not repairing the printer is the cost of repair (Figure 30). As it was highlighted in Bovea et al (2017) for other household ICT equipment such as laptops, mobile phones or video cameras, the main reason for not repairing devices is the perception from the consumer that it is not worth doing so, because for the same (or similar) price it is possible to have a new device.

On top of that, almost 1/3 of respondents would consider replacing their printer if the cost of the original cartridges becomes too expensive, pushing consumers to purchase another brand printer that has cheaper cartridges (Figure 21). These aspects suggest that there is room to increase printer lifetime in the domestic sector.

4.4.3 Repair and remanufacturing of devices

The purpose of this section is to evaluate the main parameters that can help to characterize the ability of a device to be repaired or remanufactured.

- Repair is defined as the process of returning a faulty product to a condition where it can fulfil its intended use (EN45554).
- Remanufacturing is an 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).

In both cases (repair and remanufacturing) the product is modified at some extent. The EU Blue Guide (European Commission, 2022) provides clarifications on when a modified product must be considered a new product[44]. According to the conditions defined in the EU Blue Guide, a repaired product must not be considered a new product, but a remanufactured products must be.

In section 4.4.2 device durability in the business and household sectors has been evaluated. It has been observed that there is potential to increase device lifetime in both sectors. One of the possible strategies to increase device lifetime is by improving the conditions to repair or remanufacture them.

From an environmental point of view, it is generally beneficial to repair defect products so that they remain in use longer (Pini et al, 2019). Specifically on printers, Boldoczki et al (2020) showed that preparation for reuse activities provided environmental improvements in 5 out of 6 impact categories evaluated, in comparison to replacing the printer by a new one. Consumers are also willing to pay more for products with better reparability (Cerulli-Harms et al, 2018). However, as pointed out in Proske (2022), increasing device lifetime by repair does not always necessarily reduce the environmental impact, either because they do not address the main issue for the obsolescence of the product, or because more material and energy intensive processes are needed to conduct the repair.

Repair in the imaging equipment sector is usually associated with the activities aimed at fixing typical device failures (such as the ones listed in Figure 25). Repair can be carried out either by authorised operators or by the providers of Managed Print Service contracts, which usually include maintenance. After repair, the device is returned to a condition where it can fulfil its initial purpose, but it is not considered as new.

Remanufacturing in the imaging equipment sector is usually associated with collection, cleaning and component substitution operations necessary to place the device again in the market as new. Often, remanufacturing operations are undertaken by the same OEMs who placed the device on the market in the first place. These operations consist in collecting devices and transporting them to remanufacturing facilities, where they will undertake a process similar to the above[45]:

- Disassembly of key components and cleaning of dirty parts
- Testing of key components and re-assembly
- Replacement of components that are worn or with significant technical lifetime loss
- Upgrading firmware and software
- Conducting quality checks
- Packaging for storage and transport

[44] If a product is considered new, it must comply with the provisions of applicable legistlation at that time.
[45] https://gmtechnology.net/greenline/

Although repair and remanufacturing have different meanings, the ability of a device to be repaired or remanufactured can be characterized by similar parameters: priority parts, ease of disassembly, priority part provision policy or cost, among others. Sabbaghi et al (2016) conclude that barriers against product repair include spare parts not being readily available, the cost of spare parts, lack of the required repair tools, time-consuming repairs, the complexity of repair processes and lack of repair manuals.

From the environmental and social point of view, it is sensible to try to increase devices lifetime. Waste streams can be reduced by extending the service life of devices by repair. As a general rule, repair is more material efficient than recycling and has positive effects at local level for jobs and value creation (Ritthoff et al, 2023). In Kerr et al (2001) it was concluded that refurbishing can reduce resource consumption and waste generation over the life cycle of an imaging equipment device (between 23% and 65% savings in emissions of CO_2eq., for instance). It was also concluded that products designed for disassembly and remanufacturing can deliver much greater savings that can be achieved through the remanufacturing of a product that was not designed with this intention. In Liao et al (2021) it was also concluded that environmental benefits can be expected as part of printer refurbishing operations.

4.4.3.1 Priority parts

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

Table 30: Statistic on consumer printers failures. Source: Open Repair Alliance (2021)

Failure type	Percentage of total failures evaluated
Paper feed	25%
Ink cartridge	17.5%
Print head cleaning	9.6%
Power supply/connectors	7.4%
Print head failure	6.1%
Software	5.9%
Print quality	5.9%
Internal damage	5.5%
Paper output	5.3%
Scanner	2.6%
Other failures	9%

The design of imaging equipment can affect the ability to maintain its functional state but also the ability to maintain and repair/refurbish the device and fulfil the expected lifetime. In this context, priority parts are those that typically fail during the normal use of a product. In Cordella et al (2019), it is stated that a priority part has to be functionally important. Therefore, priority parts are usually those targeted to be provided as spare parts by environmental schemes. In this section, a review of priority part lists in different schemes is presented.

In their proposal of a reviewed Voluntary Agreement, Eurovaprint (2021) identified the list of replaceable spare parts presented in Table 31.

Table 31. Priority parts in Eurovaprint (2021)

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

The EU GPP Criteria (Kaps et al. 2020) also identified a list of priority parts, divided between core level (minimum compliance) and comprehensive level (Table 32).

Table 32. Priority part in Kaps et al (2020)

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

Blue Angel (DE-UZ-219) provides a list of spare parts (Table 33) and classifies them by technology (inkjet vs electro-photographic devices) and by target group (to consumers and to professional repairers).

Table 33. Priority parts in Blue Angel (DE-UZ-219)

	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

In their study "Methods and standards for assessing the reparability of electrical and electronic devices", Ritthoff et al (2023) proposed a methodology to assess how reparable electrical and electronic devices are. To test the methodology, the authors conducted a comprehensive analysis of aspects affecting the reparability of inkjet and laser printers. This analysis was conducted on 6 inkjet printers and 4 laser printers. Although the sample of devices is small, their results can provide useful information on the current status of device reparability. In Ritthoff et al (2023), a list of priority parts is proposed, differentiating between inkjet and laser devices (Table 34).

Table 34. Priority parts in Ritthoff et al (2023)

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

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

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

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

Toner and ink collection units

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

Inkjet printers need to manage a similar issue for waste ink. They have collection units or ink pads designed to collect any residual ink from the print-heads. Similarly to what happens in toner devices, a sensor monitors the status of the deposit or is estimated based on its use[46]. After a specific threshold, the device halts the printing processes when the waste ink collection unit is full (or estimated to be full). Again, this is to avoid damaging the device if ink were to get into the main body of the printer. The collection units needs to be emptied or replaced to bring the device back to the functional state.

In some cases, waste collection units are designed for a single use. According to an OEM, emptying and reusing the waste collection unit could lead to toner or ink being spilled inside the product, which could result in reduced print quality[47]. An additional reason provided by OEMs is that recommending to return the waste toner to the manufacturer for proper recycling prevents the toner from being improperly deposited in the waste stream (as opposed to the customer emptying the toner in the trash and reusing the container).

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

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

Print heads (inkjet devices)

There are two main design philosophies in inkjet print head design: fixed-head and disposable head. The fixed-head design provides an inbuilt print head within the device that is designed to last for the life of the printer. The print head 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 (integrated ink cartridge). Fixed print-head designs are available in consumer products, but are more likely to be found on professional, high-end printers and large format printers.

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

Drum unit (laser devices)

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

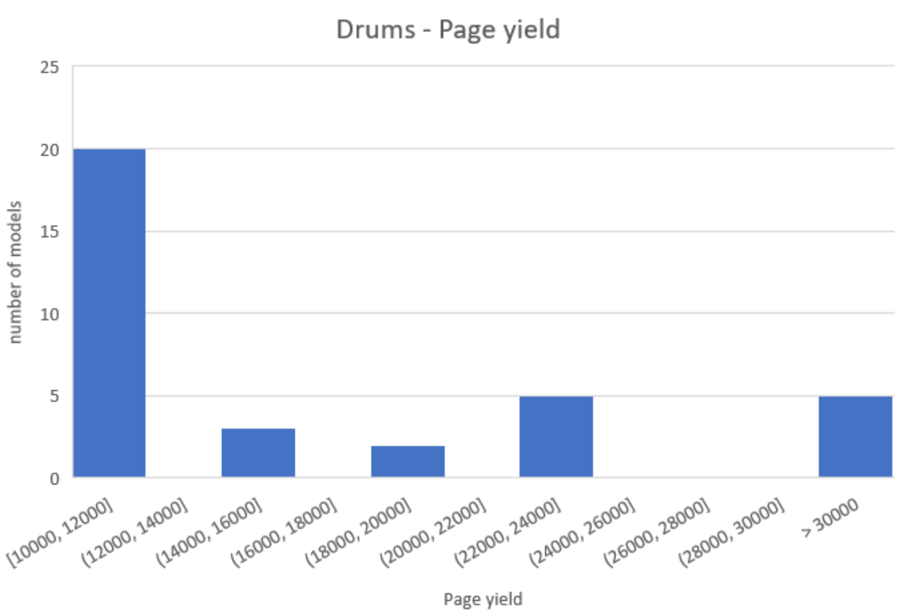
Laser printers and their consumables vary across printer models. Some printers only need you to replace the toner cartridge, and others require that the user regularly replace both the toner cartridge and the drum unit. The drum can be provided as a separate consumable with a specific lifespan specification. Drums units are reported to be typically replaced after the use of 3-4 toners[48] (e.g. 12.000 pages).

This estimation is aligned with data provided by a stakeholder regarding the durability of drum units (Figure 68). Most of drums in this database provide between 10.000 and 12.000 pages, with just a few units providing more than 30.000 pages.

[46] https://support.printerpotty.com/2021/waste-counter-reset-what-does-myths

[47] 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

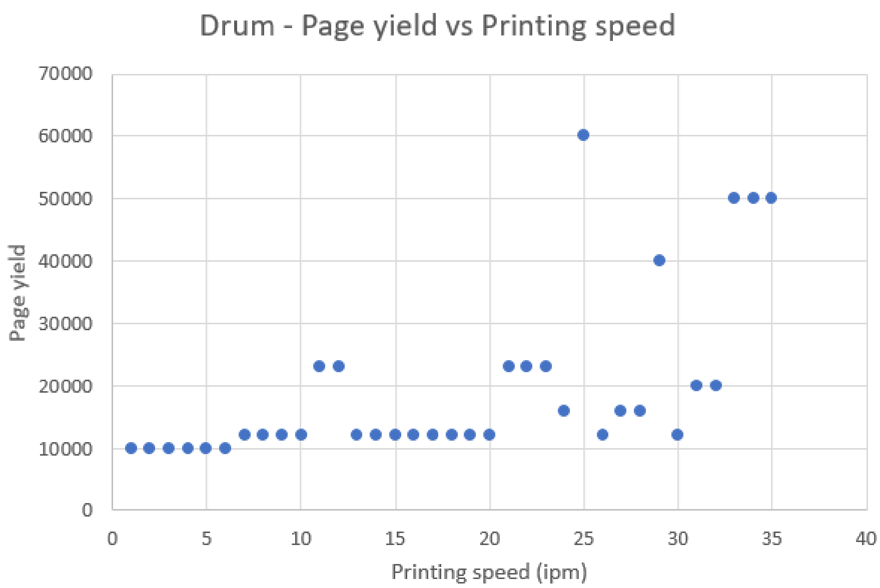
[48] https://www.ldproducts.com/blog/whats-the-difference-between-a-toner-cartridge-and-a-drum-unit/



Source: Consumentenbond.nl

Figure 68. Page yield of drum units

The same data is represented together with device printing speed, to observe whether there is a relationship between page yield of drum unit and speed (Figure 69).



Source: Consumentenbond.nl

Figure 69. Page yield of drum units and device printing speed

As can be seen in Figure 69, devices with lower printing speeds have drums with lower page yield.

Fuser unit (laser devices)

The fuser unit is an end-user replaceable component, which fits into an imaging equipment product and which consists of a pair of heated rollers that fuse toner onto output media. Fusers are reported to need replacement every 75,000 - 300,000 pages depending on the printer model[49]. 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;

[49] https://www.metrofuser.com/post/symptoms-of-bad-fuser

- 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

A stakeholder highlights that lifetime of fuser units can be extended through enhanced durability: increasing the thickness of the fluorocarbon polymer coating on the upper fuser roller can significantly increase the life of the component.

Transfer unit (laser devices)

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

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

4.4.3.2 Ease of disassembly of priority parts

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

In Rithoff et al (2023), ease of disassembly of printers is measured using disassembly time as an indicator. The authors conducted disassembly operations on 6 inkjet printers and 4 laser printers. Time to reach access to priority parts was measured. Table 35 presents disassembly times for some priority parts in inkjet printers.

Table 35. Disassembly time in inkjet printers

Priority part	Disassembly time
Print head	0.33 - 90 min
Feed roller document feeder	1 - 3 min
Internal power supply unit	0.16 - 25 min
Ink sponge	0.5 - 27 min
Total disassembly of devices	8.5 - 118.5 min

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

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

Table 36 presents disassembly times for some priority parts in laser printers.

Table 36. Disassembly time in laser printers

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

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

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

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

4.4.3.3 Spare part provision

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

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

The duration of the availability of spare parts is also a relevant aspect. If a spare part cannot be obtained any more after a short time the product has been placed on the market, this severely limits the reparability of devices.

Currently, the duration of the availability of spare parts depends, among other things, on sales. Therefore, this duration can be flexible in time, without guarantee from the OEM, and changed by the manufacturer depending on market conditions (Rithoff et al, 2023). Therefore, it is not possible for consumers today to know for how long the availability of spare parts will be guaranteed for the model they purchase.

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

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

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

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

4.4.3.4 Software and firmware updates

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

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

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

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

4.4.3.5 Cost of repair

The cost of repair services can vary significantly from one country to another, since repair is a labour intensive activity subject to regional labour costs. Figure 70 shows average labour costs per hour (EUR/h) per employee in full-time equivalents for the repair of computers and personal and households goods, in selected EU countries (Schischke et al, 2021).

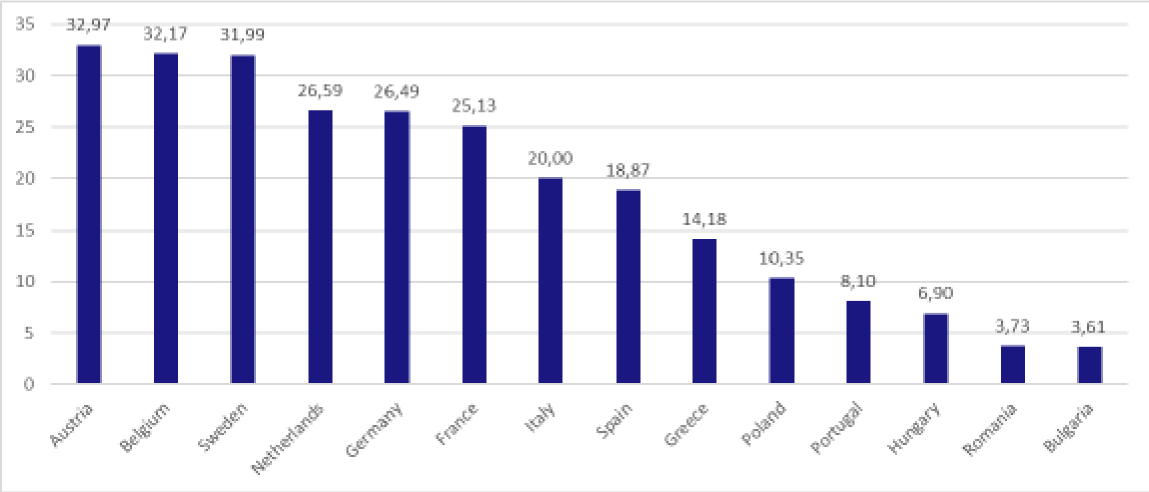


Figure 70. Average labour costs for the repair of computers and personal household goods (EUR/h)

As seen in Figure 30, the cost of repair is a fundamental issue affecting the likelihood of a printer to be repaired. Research indicates that consumers are willing to pay approximately between 19% and 30% for the repair of household appliances, compared to the replacement price of new ones (Laitala et al, 2021).

4.4.4 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. The purpose of this section is to conduct a brief bibliography review of the typical emissions to air of printers, and to evaluate the air emission thresholds proposed in currently available voluntary schemes.

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 (2011), 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 37).

Table 37. Air emissions rates in voluntary schemes

		Emission rates (mg/h)						
		TVOC	Benzene	Styrene	Unidentified single substances VOC	Ozone	Dust	Ultra-fine particles
Blue Angel (DE-UZ-219)	Colour	18	<0.05	1.8	0.9	3.0	4.0	2023: $3.0*10^{11}$ 2025: $2.5*10^{11}$
	Monochrome	10	<0.05	1.0	0.9	1.5	4.0	2023: $3.0*10^{11}$ 2025: $2.5*10^{11}$
Nordic Ecolabelling (Version 6.7)	Colour	18	<0.05	1.8	0.9	3.0	4.0	n/c
	Monochrome	10	<0.05	1.0	0.9	1.5	4.0	n/c
EPEAT (Global Electronics Council)	Colour	18	<0.05	1.8	n/c	3.0	4.0	n/c
	Monochrome	10	<0.05	1.0	n/c	1.5	4.0	n/c

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

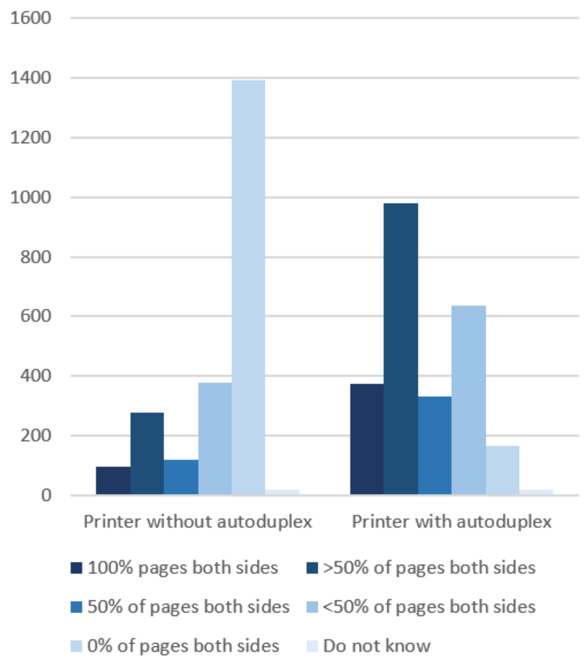
4.4.5 Paper use

The use of paper is one of the environmental hotspots throughout the life cycle of printers, according to the conclusions from Huang et al (2019). The consumption of paper contributes to the device's total consumption of resources. The purpose of this section is to evaluate the functionalities available in printers today that can help to reduce the use of paper, as well as the approaches followed in currently available voluntary schemes.

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

Printers without duplex imaging capability can also print in both sides of paper, but they require manual operation of the user (taking the sheet of paper and putting it again into the paper input tray). This reduces the frequency in which the user prints in both sides of paper, contributing to the generation of paper waste. According to data provided by a stakeholder[56], the percentage of users printing in both sides of paper increases significantly when the printer has autoduplex capability.

[56] consumentenbond.nl



Source: survey conducted by Consumentenbond.nl
Figure 71. Number of users printing in both sides of paper

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

In Blue Angel (DE-UZ-219), the inclusion of default duplex printing is mandatory for all professional devices and for color and monochrome devices with speeds higher than 19 and 24 ipm, respectively. This requirement is equivalent to the one included in Energy Star v3.2. Similarly, in TCO Certified Generation 9, the inclusion of default duplex printing is mandatory for all printers, without specifying a minimum threshold on printing speed.

N-up printing is the ability to print multiple pages on a single sheet of paper, and is a printer feature that can also contribute to the reduction of paper consumption. The default availability of this function is included in voluntary schemes such as Blue Angel (DE-UZ-219), TCO Certified Generation 9 and GPP Criteria on Imaging Equipment.

Recycled paper can have substantially lower environmental impacts than virgin paper, so the ability of printers to use recycled paper can help to reduce the environmental impact of paper consumption. Recycled paper can already be used in many devices on the market. The default ability of using recycled paper is included in voluntary schemes such as Blue Angel (DE-UZ-219), TCO Certified Generation 9 and GPP Criteria on Imaging Equipment.

Paper use is related as well with printing quality. Devices and cartridges able to deliver quality printouts without failures will use less paper. This topic will be addressed in more detail in section 4.5.7 of this Preparatory Study.

4.4.6 Noise

Noise produced by imaging equipment devices has an effect on end-users, particularly when confined to a closed areas such as offices. The purpose of this section is to evaluate approaches followed in currently available voluntary schemes to tackle noise emissions.

Noise is relevant for this product group as larger products such as MFDs may create irritating noise to end-users while in operation. Some of the short and long term effects are (Kaps et al, 2020):

- It creates annoyance to the receptors due to sound level fluctuations.
- Physiological features like breathing amplitude, blood pressure, heart-beat rate, pulse rate, blood cholesterol are affected.
- Noise has negative impacts on cognitive performance. For attention and memory, a 5 dB(A) reduction in average noise level results in approximately a 2-3 % improvement in performance.

- It causes pain, ringing in the ears, feeling of tiredness, thereby effecting the functioning of human system.
- It affects sleepiness by inducing people to become restless and lose concentration during their activities.

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

- The A-weighted sound power level LWA must be determined according to ISO 7779. Devices capable of colour printing must be tested in both monochrome mode (LWA,M) and colour mode (LWA,F).
- Noise measurements must be conducted without optional peripheral devices.
- A4 size paper of grammage 60 g/m² to 80 g/m² must be used for test operations.
- The four-page Adobe Reader file from the Office Test Suite according to B.1 of ISO/IEC 24734 must serve as test pattern.
- Only one-sided printing must be measured.
- The noise measurement must only be conducted during repetitive printing operation cycles. The measurement time interval must include at least three complete outputs of the four-page test pattern (12 pages). The interval must begin after the printing preparation.

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

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

The requirements included in GPP Criteria for Imaging Equipment are equivalent to the ones proposed in Blue Angel (DE-UZ-219) for this product group.

4.4.7 Post-consumer recycled content

Inclusion of recycled content material in products is a measure that is linked to the decoupling of economic development from natural resource use and reduction of material dependencies. The purpose of this section is to evaluate approaches followed in currently available voluntary schemes to address post-consumer recycled content.

According to TCO Certified Generation 9, the manufacturing of recycled plastics, if 100% recycled content is achieved, can reduce the energy consumption up to 60%, compared to virgin plastics. Less raw materials are required to produce recycled plastics, which can lead to a reduced carbon footprint. Every metric ton of recycled plastic produced can result in up to 1-3 metric tons of CO_2 savings, compared to virgin plastics.

Recycled content in devices is covered in some of the voluntary schemes evaluated (Table 38).

Table 38. Post-consumer recycled content in devices in voluntary schemes

Voluntary scheme	Requirements
Blue Angel (DE-UZ 219)	The proportion of PCR plastics in the overall plastic mass of a base unit must be at least 5%[57] Devices must contain at least 5g of PCR plastic from 01.01.2021 All devices for which an application is made for the Blue Angel (DE-UZ-219) for the first time from 01.01.2023 must contain 1% PCR plastic or reused plastics or a combination of both measured against the total plastic mass All devices for which an application is made for the Blue Angel (DE-UZ-219) for the first time from 01.01.2024 must contain 5% PCR plastic or reused plastics or a combination of both measured against the total plastic mass
Nordic Ecolabelling (Version 6.7)	At least one part > 25 g must contain re-used plastic part or post-consumer and pre-consumer re-cycled plastic.
EPEAT (Global Electronics Council)	Any product containing plastic parts whose combined weight exceeds 100 g shall contain at least 5 g of postconsumer recycled plastic. Product containing 5 kg of plastic or less shall contain on average a minimum of 10% postconsumer recycled plastic. Product containing more than 5 kg of plastic shall contain on average a minimum of 5% postconsumer recycled plastic Product shall contain on average a minimum of 25% postconsumer recycled plastic, calculated as a percentage of total plastic (by weight) in the product
TCO Certified Generation 9	The following information for the typical product configuration of the certified product (including any external power supply) must be reported: Percentage of post-consumer recycled plastics by weight versus the total weight of all plastics. Percentage of identified post-consumer recycled materials (plastic and non-plastic) by weight versus the product weight
GPP Criteria for Imaging Equipment	The percentage of postconsumer recycled plastic content, calculated as a percentage of total plastic (by weight), must be declared. The percentages must be provided in increments of x <1%, 1% ≤ x < 5%, 5% ≤ x < 10%, 10% ≤ x < 15%, 15% ≤ x < 20% and beyond (in 5% intervals).

Available bibliography confirms the potential environmental benefits of using post-consumer recycled plastics. In Meyer et al (2016), for instance, the authors state that post-consumer recycled content plastic has significant environmental benefits over the use of virgin materials, especially due to reductions in resource extraction, refining and manufacturing. Karvinen (2015) estimates that if the plastic cover of a base station contains 100% recycled PC, emissions and primary energy demand of plastics production are reduced by 86%. Substituting 30% of virgin PC by recycled PC reduces the environmental impacts of plastic production by 23%.

4.4.8 Preliminary objectives of policy options on devices

Based on the data gathered in sections 4.4.1 to 4.4.7, preliminary objectives of policy options applicable to devices can already be proposed. They can be summarized as:

- Ensuring that devices last longer and are easier to repair, refurbish and recycle
- Explore the untapped potential for improved energy savings in devices
- Optimize the consumption of paper
- Increase the use of post-consumer recycled plastic in devices

[57] Excluding printed circuit boards, labels, cable, plug, electronic components and optical components

These objectives will be used as a basis for the definition of base cases and design options in Task 5 and Task 6, as well as for the proposal of ecodesign measures in Task 7.

4.5 Technical aspects affecting environmental performance of cartridges

In this section, the main technical aspects of cartridges which affect their environmental performance have been evaluated. The technical aspects evaluated are Electronic circuitry, Page yield, Cartridge material efficiency, The cost of printing, Compatibility, Shelf life, Print quality, End of life of cartridges and Legal aspects related to cartridges.

4.5.1 Electronic circuitry

Some cartridges have electronic circuitry, commonly known as chips. These components are typically mounted on a small circuit board and support communication between the cartridge and the device, through either direct contact or radio frequency connections. The purpose of this section is to identify the main uses of electronic circuitry in cartridges, their advantages and potential risks.

An example of chip mounted on a toner cartridge can be seen in Figure 72.

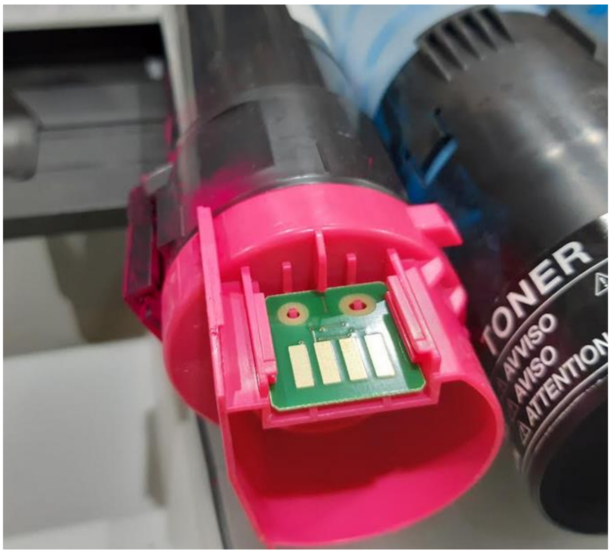


Figure 72. Chip in toner cartridge

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

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

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

The purpose of the chip is an aspect under debate in the imaging equipment industry. Some OEMs use chips to enable cartridge authentication against counterfeit cartridges. They may also be used as a data security feature[58]. However, one stakeholder in the remanufacturing industry suggested that placing security on the consumable is not necessary, since the only possible access to data is through the device. Moreover, there are cartridges in the market without chip, proving the same level of printing quality, without data security issues. On top of that,

[58] https://h20195.www2.hp.com/v2/GetDocument.aspx?docname=4AA7-9396ENW

responding to global chip shortages in 2022, some OEMs that usually included chips in their cartridges, provided chip-free versions for a while[59].

An environmental NGO added that ensuring the security of IT devices is important, although they have not been able to identify how malevolent actors could remotely access the hardware connection between the imaging equipment to steal users' data from the imaging equipment. They add that it is unclear why the chip on the cartridge needs to contain writable memory that needs to be reset. Cartridge chips essentially serve as information storage devices equipped with EEPROM memory, and do not possess the capability to make decisions regarding the data they hold; it's the printer firmware that undertakes decision-making tasks. For cartridges equipped with a chip, OEMs preload (write) it with data including some form of identification (ID) to operate in a designated printer or set of printers. The chip usually houses a unique ID such as a serial number along with additional data related to cartridge/printer function for utilization by the printer firmware such as the yield of the cartridge. When the ink/toner is used, the printer calculates how much ink/toner is left in the cartridge from the original page yield. When the chip is first read, the firmware checks the cartridge ID. Most modern printers now use encrypted codes. In the case of encrypted chip cartridges, encryption keys are generated utilizing data clusters in memory and are preloaded onto the chip to ensure secure data transmission between the printer and chip. The use of encrypted codes causes problems for remanufacturing because the encryption keys need to be copied (often taken from used OEM chips). This then allows OEMs to update the printer firmware to block any cartridge chips that have copied keys.

The concern from the cartridge remanufacturing industry is that the greater use of electronics in printer cartridges has also resulted in barriers to reuse for independent remanufacturers. Some of these electronic components make reuse difficult if they do not include provision for resetting the chip during reuse (Waugh et al, 2018). The location of the chip within the cartridge is also an important aspect. These topics will be covered in more detail in section 4.5.11.2 on barriers for cartridge reuse.

Cartridges without chips may be seen as an option to avoid cartridges being blocked by firmware updates, or having reduced functionality after their first use. However, according to feedback from stakeholders, the use of chips in cartridges is essential in order to achieve higher reuse cycles and higher empty collection rates. Both these aspects require more specific information on the cartridge: about its page yield, the remanufacturer, installation and removal date, etc. This information can be provided by the chip, which shares its information with the printer and with any monitoring tool, which can be used to track whether the cartridge prints the expected volume of pages or how many times it has been reused, among other aspects. OEMs add that it is not an option for them to ship devices or cartridges without chips unless in an emergency such as pandemic because they are essential parts for designed performance of imaging equipment.

4.5.2 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. It can be understood as the printing capacity of a cartridge and is a common metric to benchmark cartridges. Page yield is also a very relevant aspect for consumers (Figure 15).

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, which contributes to the generation of waste. Optimising the use of materials, simplifying cartridge design can help to increase the number of pages that can be printed with a single cartridge. Consequently, this can reduce the total amount of cartridges that are manufactured and therefore, managed at end of life (Kaps et al, 2019).

In the EU market, consumers can find cartridges with very different page yield. Small inkjet cartridge inkjet consumables may have page yields of less than 300 pages whereas high volume printing devices can print up to tens of thousands of pages. OEMs also offer cartridges with low and high page yield for the same device.

The purpose of this section is to evaluate different aspects related to page yield: how it is measured, page yield of different types of cartridges and typical page yield of cartridges in the market today.

[59] https://www.therecycler.com/posts/canon-goes-chip-free/

4.5.2.1 Measured versus real page yield

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

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

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

A stakeholder provided feedback regarding measured versus real page yield[60]. A study was conducted by this stakeholder including 370,871 cartridges used by 51 customers on 5,244 devices. This analysis was limited to ink cartridges of two OEMs (anonymised as A and B). The results from this study highlighted that on average, cartridges from OEM A performed 64% of their published yield, whereas cartridges from OEM B performed 78% of their published yield (showing also that the discrepancies between measured and real page yield can also vary between OEMs).

Some websites provide useful guidelines in terms of page coverage and page yield[61], as well as examples of the amount of pages that the user can expect to print with a cartridge based on different use patterns.

4.5.2.2 Page yield of different types of cartridges

A starter cartridge is a cartridge which is sold together with a printer or multi-function printer. These cartridge generally offer lower page yield than standard cartridges, although their external appearance might be very similar or exactly the same. According to data provided by Consumentenbond, around 66% of printers placed on the market come with some sort of starter cartridge.

Figure 73 shows ink cartridges with different design of the inner compartments that results in different page yields. The sponge in the inner compartments contains the ink used to print. Cartridges A and B are two different ink monochrome cartridge models with different exploitation of the inner available volume. Cartridge A makes use of the full available volume, whereas cartridge B includes additional inner compartments to reduce the total amount of ink. Cartridge B is likely a starter cartridge. With the same amount of material, Cartridge A makes a more efficient use of resources.

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

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

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

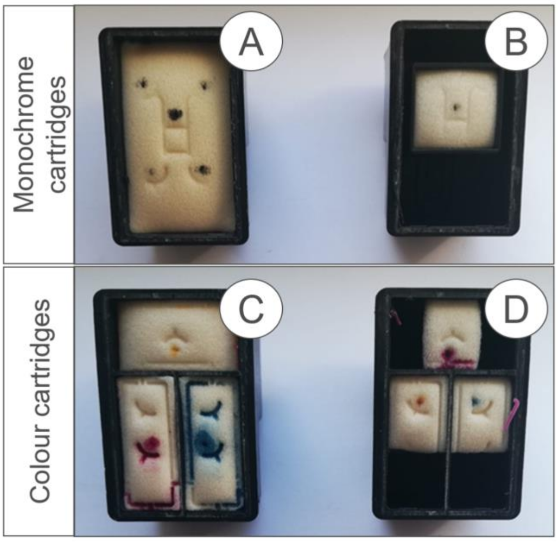


Figure 73. Monochrome and colour cartridges with different page yield

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

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

Beyond starter cartridges (which are sold together with the printer), cartridges are also sold with higher page yields, often commercialized as "standard" cartridges or "XL" cartridges (alternative commercial naming can be found, such as "high capacity", "extra-high capacity", etc.). Often these cartridges have the same external shape and size, and they are simply filled up to a lower percentage of capacity.

In inkjet printers, color cartridges can be designed in different ways. One option is to have each color (cyan, magenta, yellow) in a different compartment within the printer. Therefore, an individual cartridge will be required for each color (Figure 74).

Figure 74. Example of printer with individual cartridges for each color

In other cases, there are only two compartments in the printer, one for the monochrome cartridge and another one for the color cartridge. In this case, the color cartridge will contain the three required colors (yellow, magenta, cyan) inside (Figure 75).

Figure 75. Example of printer with one cartridge for monochrome and another cartridge for the three colors

A stakeholder[62] provided data from ICRT (International Consumer Research and Testing) on this topic, a database containing information on 305 inkjet devices from different OEMs. 84 of those use a system similar to the one in Figure 75, where one cartridges holds the three colors together. According to this database, these type of cartridges provide significant less yield than cartridges such as the one in Figure 74, as can be seen in the histograms of Figure 76 and Figure 77.

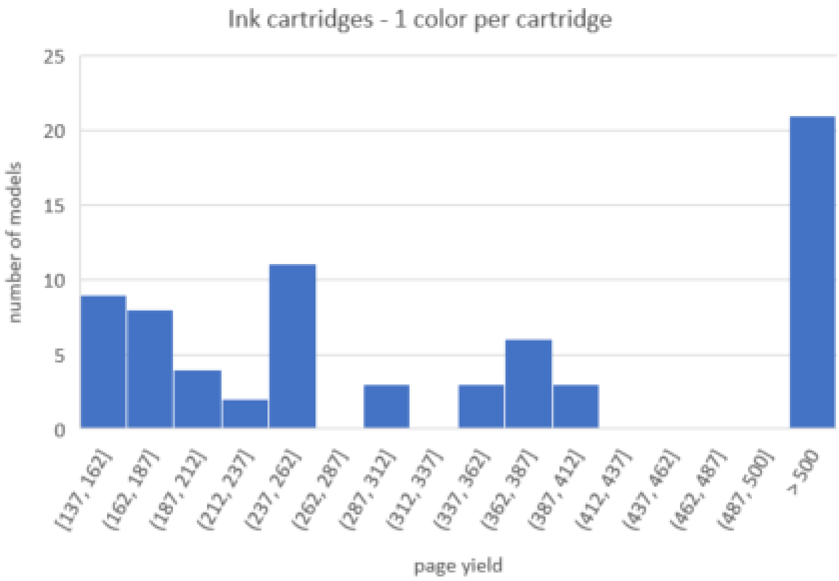


Figure 76. Page yield of cartridges with 1 color per cartridge

[62] Consumentenbond.nl

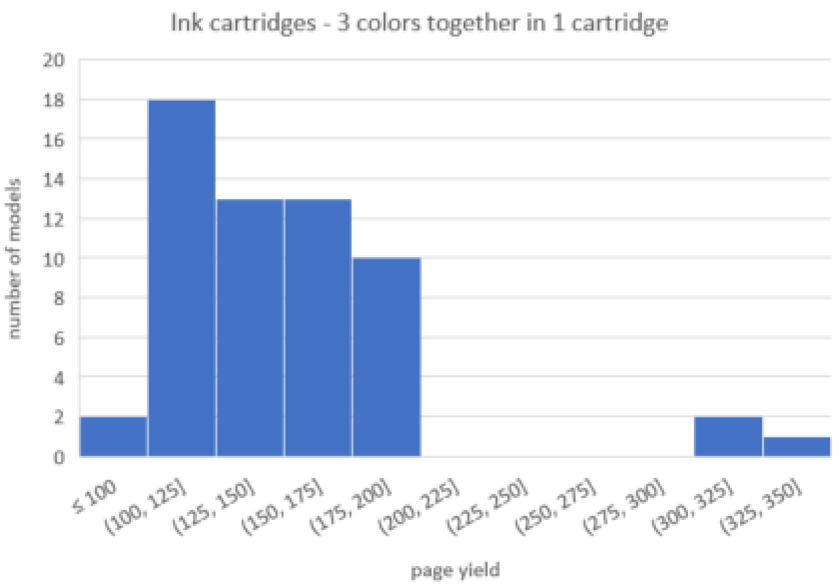


Figure 77. Page yield of cartridges with 3 colors together

4.5.2.3 Available page yield at cartridge end of life

Full capacity of cartridges is often not used due to early discarding of the cartridge. Feedback from a stakeholder indicates that by default, printers show the message of “toner/ink low” at or before 20% level. This is useful information for the user because it allows them to purchase a new one before the cartridge is completely empty. However, the most usual behaviour at that point is to replace the cartridge, or in any case before the printer stops printing. Another stakeholder adds that it should be made clear that the message “toner/ink” low does not mean that the cartridge need to be replaced immediately.

The authors of the Preparatory Study carried out visits to cartridge collection and remanufacturing facilities, mainly focusing on different types of toner cartridges. Feedback received during these visits confirmed this trend. Many of the empty cartridges collected by these operators are in practical terms not empty of toner or ink. This is due to users under MPS contracts requesting cartridge replacements before needed, or due to device replacements that contain cartridges with available page yield. Some of these operators collect available toner on those end of life cartridges and commercialize it as original remanufactured toner[63].

In order to increase the usage of available cartridge page yield, a stakeholder[64] carried out a study involving 4750 printers and copiers under an MPS monitoring software. During an initial period of 6 months, the software was used to track the behaviour of the user as to when the cartridges in the device were replaced: an average 14% of toner was wasted. The study also showed that other printer consumables such as drums (21%), fusers (17%) and transfer units (18%) were replaced earlier than required. In the next phase of the study, the information obtained through the MPS was used to influence the behaviour of when users should replace the cartridges. For instance, the shipment of new cartridges was based on remaining days, opposite to use remaining percentage. As a result of these measures, a reduction of waste of 85% was achieved.

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

4.5.2.4 The effect of cleaning cycles on page yield of ink cartridges

In ink cartridges, ink passes through small passageways towards the print heads. To ensure the printer is in good operating condition, these passageways need to be free of obstructions. Small clogs occur sometimes on inkjet printers, as the print heads are exposed to air. Therfore, ink cartridges need to be cleaned periodically in order to maintain performance. This process is carried out via cleaning cycles (also known as cleaning runs). Some

[63] https://gmtechnology.net/remanufactured-consumables/
[64] https://www.nubeprint.com/

OEMs provide information on their websites about cleaning cycle functions[65]. The main function of cleaning cycles is to keep print heads from clogging or drying out[66].

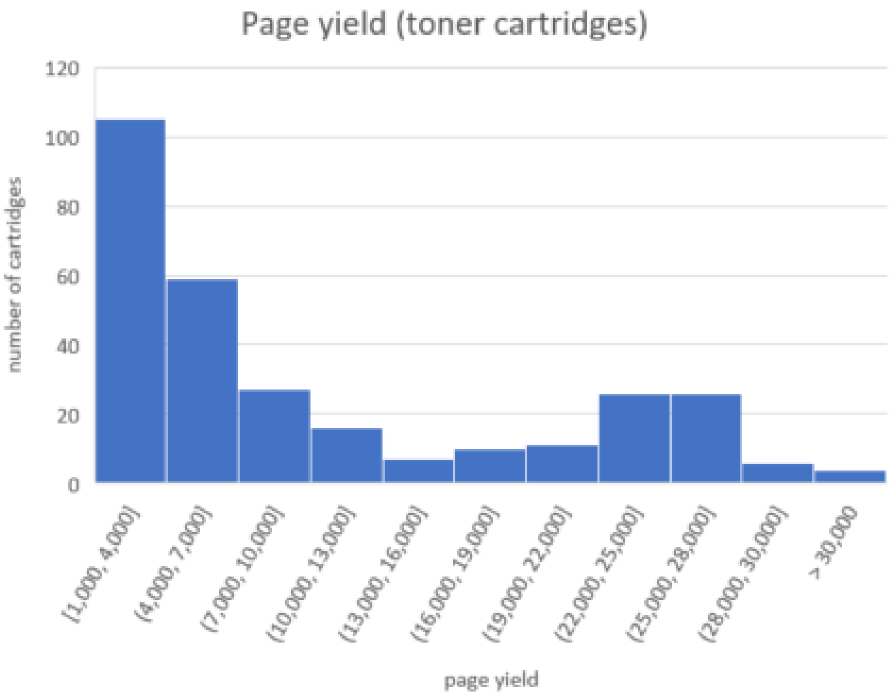
During cleaning cycles, printers shoot ink through the passageways that lead to the print heads, breaking up dried ink along the way. Ink is also applied to the print heads with a wiper blade. Some printers have also suction pumps that play an important role in the cleaning cycle. They suck air through the ink passageways after the print heads have been moistened (these are only used when a severe ink clog has been detected).

Some consumers' organisations claim that some printers use much more ink than others in cleaning cycles[67], affecting significantly cartridge page yield. A stakeholder[68] has provided data to explain this issue. They have carried out page yield tests, printing continuously (until the cartridge is empty) or printing intermittently (a small number of pages during a set number of weeks), in order to evaluate the influence of cleaning cycles (which only take place during the intermittent test). The results of these tests indicated that, in intermittent use, many models delivered half or less of their ink to the page, and a few managed no more than 20-30%. As a result, consumers were getting less number of pages than declared on the packaging. This "excess ink use" is of great influence on the cartridges that contain a few ml of ink.

4.5.2.5 Page yield in ETIRA database

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

In Figure 78, a histogram representing number of toner cartridges for different ranges of page yield is presented.



Source: ETIRA

Figure 78. Page yield of toner cartridges

As can be seen in Figure 78 35% of the toner cartridges provide 4000 pages or less, whereas 21% of cartridges provide 22000 pages or more.

65 https://www.hp.com/us-en/shop/tech-takes/how-to-clean-printhead

66 http://www.247inktoner.com/blog/post/2012/01/31/What-does-the-cleaning-cycle-do-on-an-inkjet-printer.aspx

67 https://www.consumerreports.org/printers/the-high-cost-of-wasted-printer-ink/

68 Consumentenbond.nl

In Figure 79, a histogram representing the number of ink cartridges for different ranges of page yield is presented.

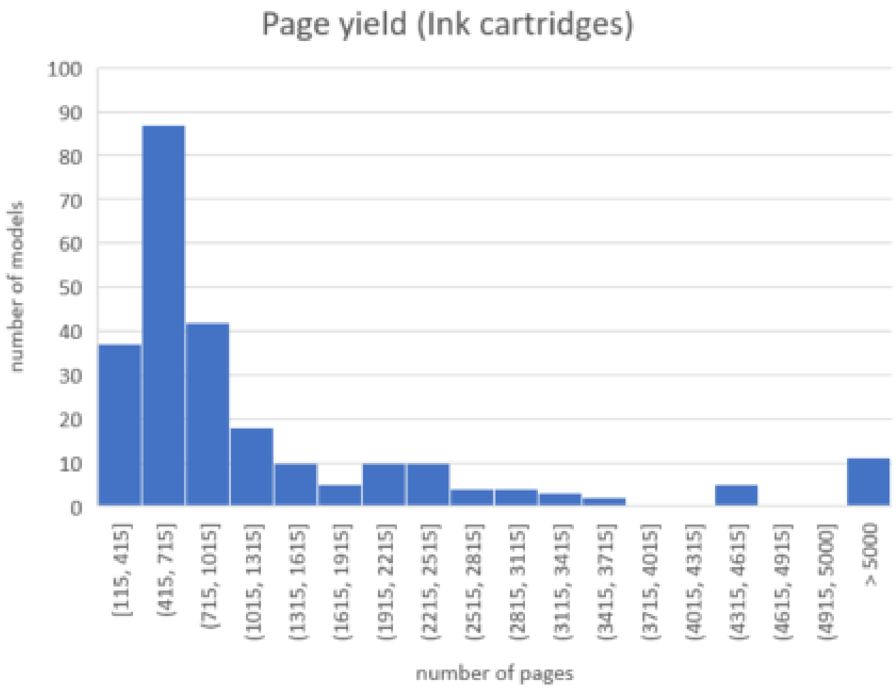


Figure 79. Page yield of ink cartridges

As can be seen in Figure 79, 50% of the ink cartridges provide 700 pages or less, whereas 4% of cartridges provide 5000 pages or more.

Based on the analysis of this database, it appears that both markets of ink and toner cartridges are biased towards lower yield products. Considering that the external dimensions and shape of cartridges are often very similar or the same, this suggests that cartridge capacity utilisation is not optimised. The analysis carried out in section 4.5.3 on cartridge material efficiency can help to confirm this trend.

4.5.3 Cartridge material efficiency

Material efficiency encompasses a range of strategies that support the reduction of material consumption and waste production from a product's life cycle perspective (Cordella et al, 2021). It can also be understood as a metric which refers to decreasing the amount of a particular material needed to produce a specific product.

The purpose of this section is to understand how material efficiency of cartridges has been addressed in currently available voluntary schemes, and to evaluate whether these approaches are appropriate for this Preparatory Study. In addition, it also aims at characterizing cartridges in the market today based on typical material efficiency values, considering different typologies of cartridges.

4.5.3.1 Material efficiency in voluntary schemes

The purpose of cartridges is to produce printed pages. Therefore, a definition of material efficiency should consider the amount of material used to produce a specific number of pages. A way to express material efficiency of cartridges is the ratio between the number of printed pages and the mass of cartridges consumed. This is the approach followed in GPP criteria (Kaps et al, 2020), also used in previous preparatory studies in this product group (Huang et al., 2019):

$$Material\ efficiency = \frac{Page\ yield}{Cartridge\ mass}$$

It must be noted that OEMs consider that the material efficiency proposal in the GPP Criteria is flawed in that it favours consumables that minimize weight when installed in the printer and ignores consumable packaging and the material needed to enable that consumable within the printer. For instance, tank based printers have the tank and tubes to move the ink to the print head. The reliability requirements of having these in the printer may lead to greater and more exotic materials which can result in greater environmental impact than the consumables used over a five (or more) year life span for some consumers.

A slightly different approach is followed in Nordic Ecolabelling (Version 6.7) for imaging equipment. Cartridge material efficiency is defined as:

$$Material\ efficiency = \frac{Cartridge\ mass}{Page\ yield}$$

Minimum thresholds were also proposed in Nordic Ecolabelling (version 6.7) in terms of material efficiency.

4.5.3.2 Material efficiency based on Keypoint Intelligence data

For the development of this Preparatory Study, the JRC contracted Keypoint Intelligence to provide information on typical page yield and material efficiency of cartridges in the market today. Keypoint Intelligence was asked to measure material efficiency as defined in Kaps et al (2019), in pages per gram of material.

In this analysis, Keypoint Intelligence examined cartridges from different OEMs, representing the top sale cartridges in the installed base of devices. Only original cartridges were examined. Page yields were taken from manufacturer databases. Empty cartridges were individually weighed in order to estimate material efficiency. Table 39 shows the results of these analysis, in terms of material efficiency of typical ink cartridges in the market.

Table 39. Material efficiency of ink cartridges (Keypoint Intelligence)

Unit: pages/gram	Standard format		XL format	
	Monochrome	Color	Monochrome	Color
Integrated	11	8	17	11
Single part	26	19	40	30

Material efficiency of ink cartridges is between 8-17 pages per gram for integrated ink cartridges and 19-40 pages per gram for single part ink cartridges. Single part cartridges tend to be more material efficient than integrated. XL cartridges tend to be more material efficient than standard ones. Monochrome cartridges tend to be slightly more material efficient than colour ones (Figure 80).

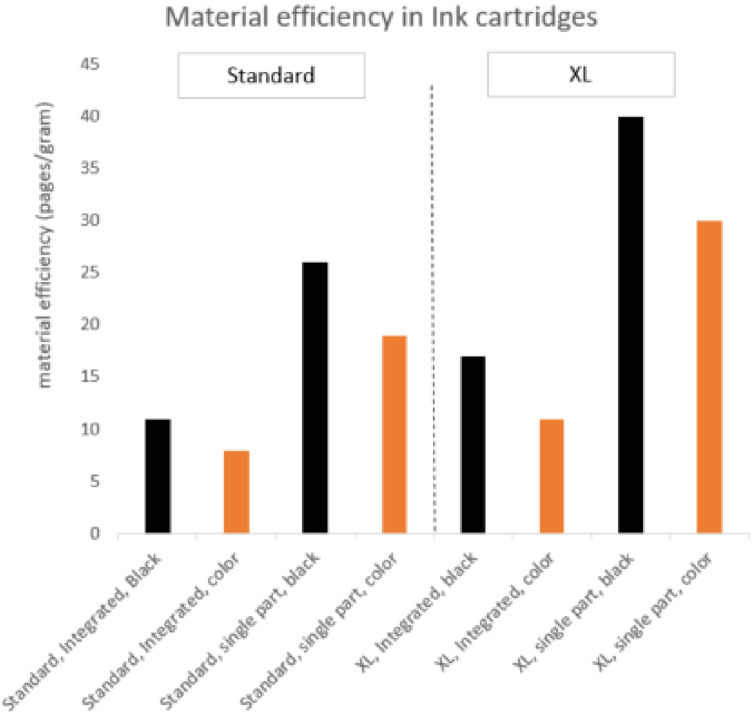


Figure 80. Material efficiency of ink cartridges

Table 40 shows material efficiency of typical toner cartridges in the market for copiers or MFPs.

Table 40. Material efficiency of toner cartridges for copiers and MFPs (Keypoint Intelligence)

Unit: pages/gram	Standard format		XL format	
	Monochrome	Color	Monochrome	Color
Integrated	5.5	5.5	8.2	6
Single part	97	85	57.8	48.5

Material efficiency of toner cartridges for copiers or MFPs is between 5.5-8.2 pages per gram for integrated toner cartridges and 48.5-97 pages per gram for single part toner cartridges. Single part toner cartridges tend to be more material efficient than integrated ones. Monochrome cartridges tend to be slightly more material efficient than colour ones. In contrast with ink cartridges, XL cartridges are less material efficient than standard cartridges (Figure 81).

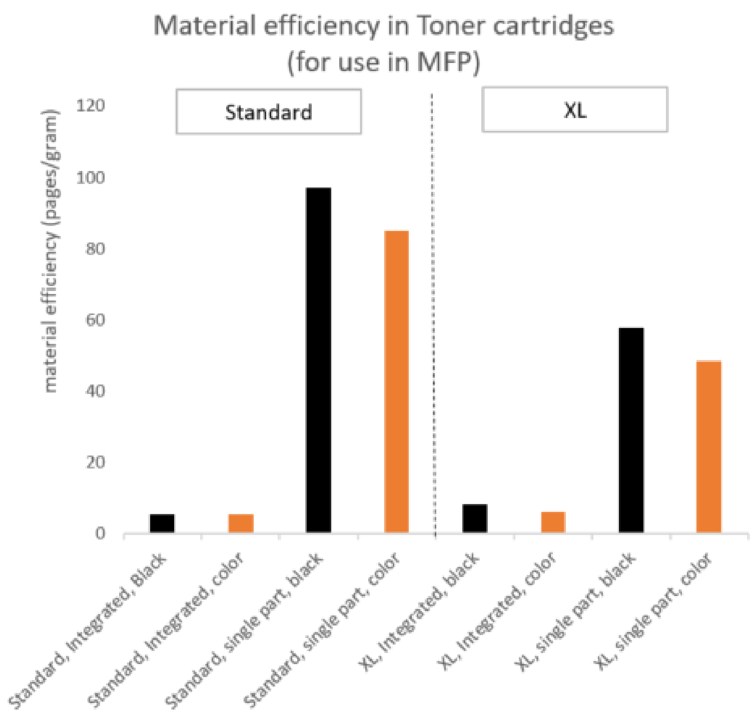


Figure 81. Material efficiency of toner cartridges for use in MFP

Table 41 shows material efficiency of typical toner cartridges in the market for printers.

Table 41. Material efficiency of toner cartridges for printers (Keypoint Intelligence)

Unit: pages/gram	Standard format		XL format	
	Monochrome	Color	Monochrome	Color
Integrated	6.3	6.4	11.1	8.8
Single part	55	45.7	41.6	42.3

Material efficiency of toner cartridges for printers is between 6.3-11.1 pages per gram for integrated toner cartridges and 41.6-55 pages per gram for single part toner cartridges. Single part toner cartridges tend to be more material efficient than integrated ones. Monochrome cartridges tend to be slightly more material efficient than colour ones. In contrast with ink cartridges, XL cartridges are less material efficient than standard cartridges (Figure 82).

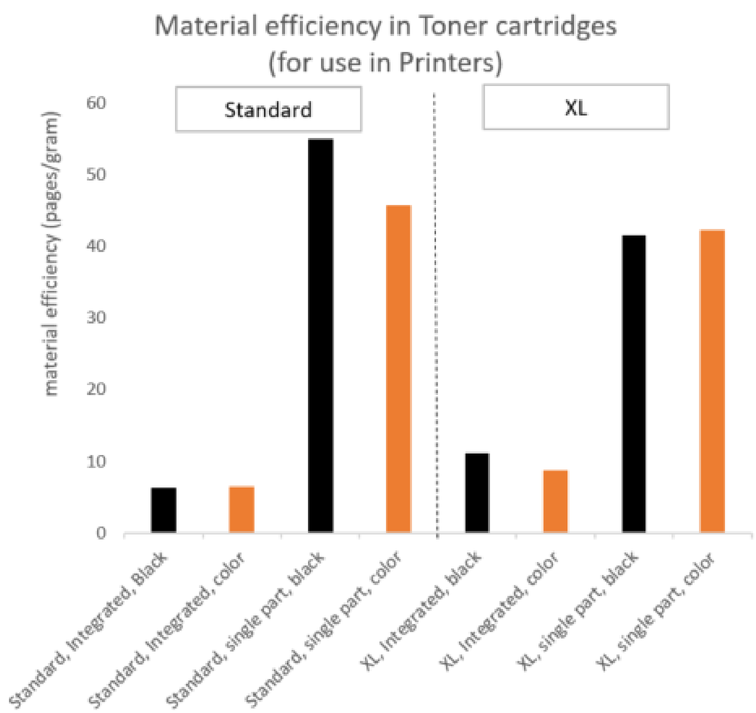


Figure 82. Material efficiency of toner cartridges for use in printers

Comparing Table 40 and Table 41, it can be seen that material efficiency of toner cartridges for use in MFPs tend to be more material efficient than toner cartridges for use in printers.

According to Keypoint Intelligence, each brand has a different approach to how it uses integrated and single part cartridges. In general terms, the market is moving away from integrated cartridges towards single-part products. Regarding starter cartridges, they are typically serve to prime, low-cost inkjet printers and achieve a market price point. Their popularity is in decline as the market moves to tank-based devices.

4.5.3.3 Material efficiency of toner cartridges based on ETIRA database

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

In Figure 83, cartridge empty mass is represented versus page yield. A slight correlation can be observed between these two parameters (higher yields require larger cartridges, therefore higher mass of empty cartridge).

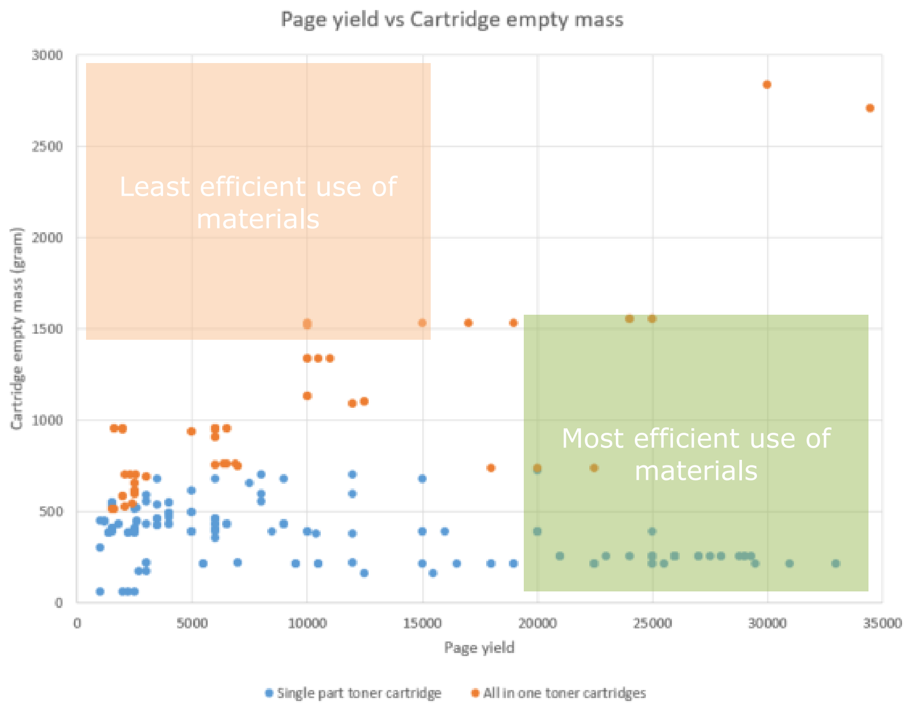


Figure 83. Page yield versus cartridge mass of toner cartridges

Red and green rectangles show the areas of least and most efficient use of materials (these are simply and indication for the chart and not a specific threshold). In terms of material use, the most efficient cartridges are those providing high page yields with low mass. In opposition, the least efficient are those providing low page yields with high mass.

In Figure 83, it can also be seen that cartridges with the same empty weight (for instance, around 250 grams), provide very different levels of page yield (between 2,500 and 30,000 pages). Two examples of this situation have been provided in Table 42 and Table 43. Data has been anonymised but it corresponds to real cartridges in the market.

Table 42. Example of cartridges with same empty mass and different page yield

Cartridge model	Page yield	Mass of empty cartridge (grams)	Material efficiency (pages per gram)
Cartridge X1	3,000	430	6.97
Cartridge X2	6,500	430	15.11
Cartridge X3	9,000	430	20.93

As can be seen in Table 42, the same cartridges (of 430 grams) are able to provide significantly different number of pages (3000, 6500 and 9000), which results in material efficiency values between 6.97 and 20.93.

Table 43. Example of cartridges with same empty mass and different page yield

Cartridge model	Page yield	Mass of empty cartridge (grams)	Material efficiency (pages per gram)
Cartridge Y1	1,500	385	3.89
Cartridge Y2	2,500	385	6.49
Cartridge Y3	5,000	385	12.98
Cartridge Y4	10,000	385	25.97
Cartridge Y	20,000	385	51.94

Similarly, Table 43 shows cartridges weighing 385 grams, providing page yields between 1500 and 20000 pages, resulting in material efficiency values between 3.89 and 51.94.

This data suggests that toner cartridges are, on occasions, placed on the market with different fill levels of toner, potentially to provide different price points to the customer. This also suggests that some toner cartridges are placed on the market with a fill level of 1/3 of their capacity (Table 42) or even less than 1/10 of their capacity (Table 43).

In Figure 84, page yield versus material efficiency of toner cartridges is represented in a scatter diagram. Cartridges are classified between all-in-one toner cartridges (in red) and single-part and double-part toner cartridges (in blue).

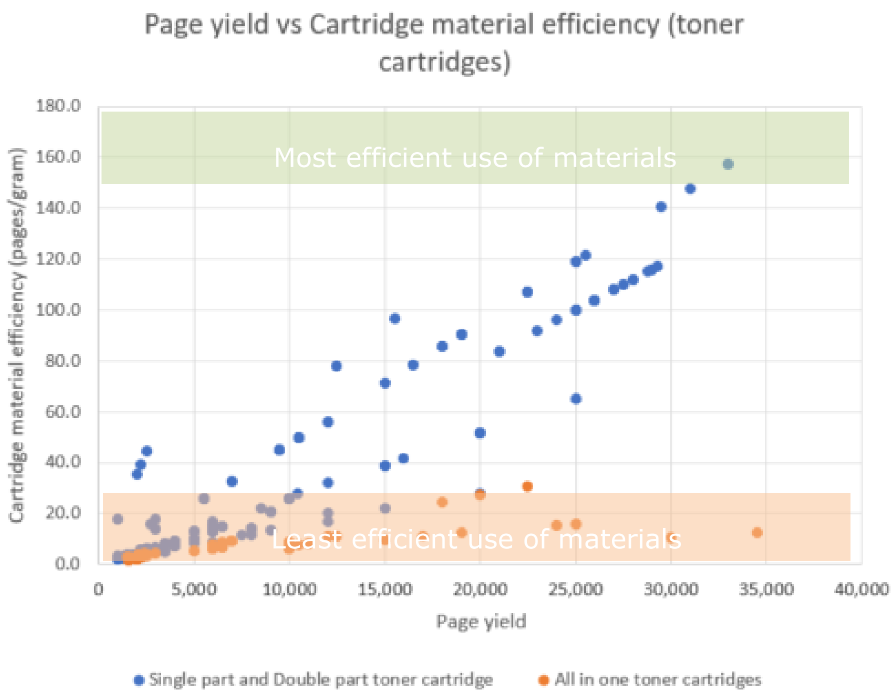


Figure 84. Page yield versus material efficiency of toner cartridges

Red and green rectangles show the areas of least and most efficient use of materials (these are simply and indication for the chart and not a specific threshold).

As can be seen in Figure 84, there seems to be a clear correlation between page yield and material efficiency, particularly for single-part and double-part toner cartridges. In general, from ETIRA database it can be interpreted that cartridges with higher yield are able to achieve higher material efficiency levels, particularly for single-part and double-part cartridges. There is a clear separation between all-in-one toner cartridges and single-part/double-part cartridges in Figure 84. All-in-one toner cartridges tend to provide less pages per gram of cartridge material, since they contain both the photoreceptor and the developer part (they have less volume available to store toner). This agrees with data provided by Keypoint Intelligence (Figure 81 and Figure 82).

4.5.3.4 Material efficiency of ink cartridges based on ETIRA database

In Figure 85, cartridge empty mass is represented versus page yield. A slight correlation can be observed between these two parameters (higher yields require larger cartridges, therefore higher mass of empty cartridge).

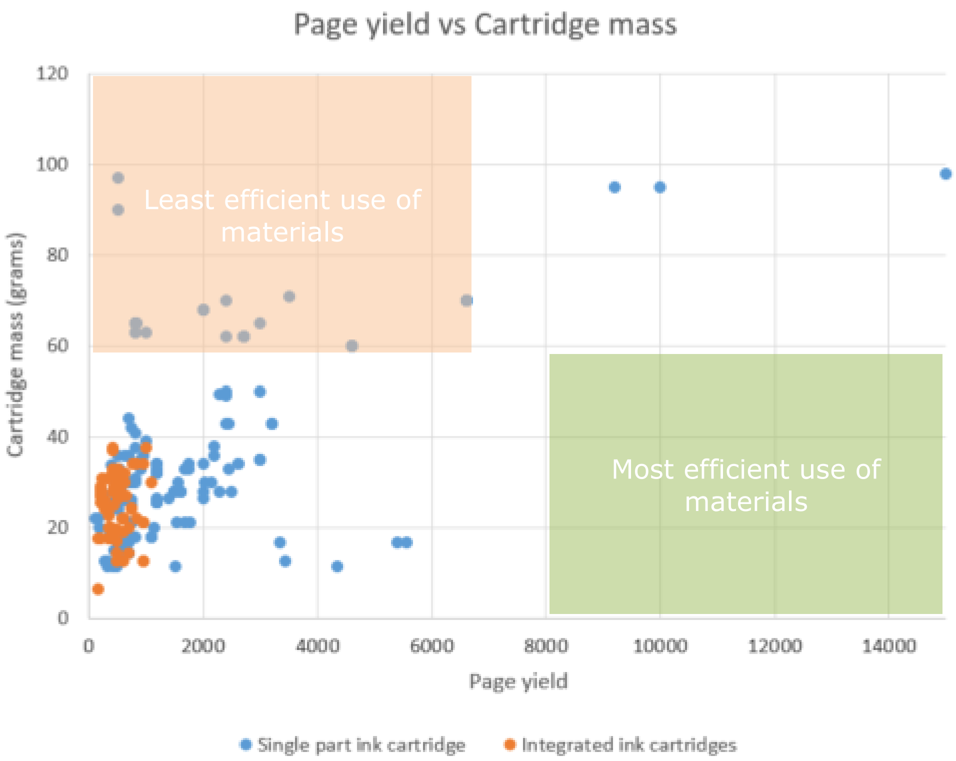


Figure 85. Page yield versus cartridge mass of ink cartridges

Red and green rectangles show the areas of least and most efficient use of materials (these are simply an indication for the chart and not a specific threshold). In terms of material use, the most efficient cartridges are those providing high page yields with low mass. In opposition, the least efficient are those providing low page yields with high mass.

The different fill level aspect explained in toner cartridges can also be observed in ink cartridges (Figure 85). Cartridges with very similar mass (around 20 grams, for instance) are able to provide significantly different levels of page yield (between 100 and 3500 pages).

In Figure 86, page yield versus material efficiency of ink cartridges is represented in a scatter diagram. Cartridges are classified between integrated ink cartridges (in red) and single-part ink cartridges (in blue).

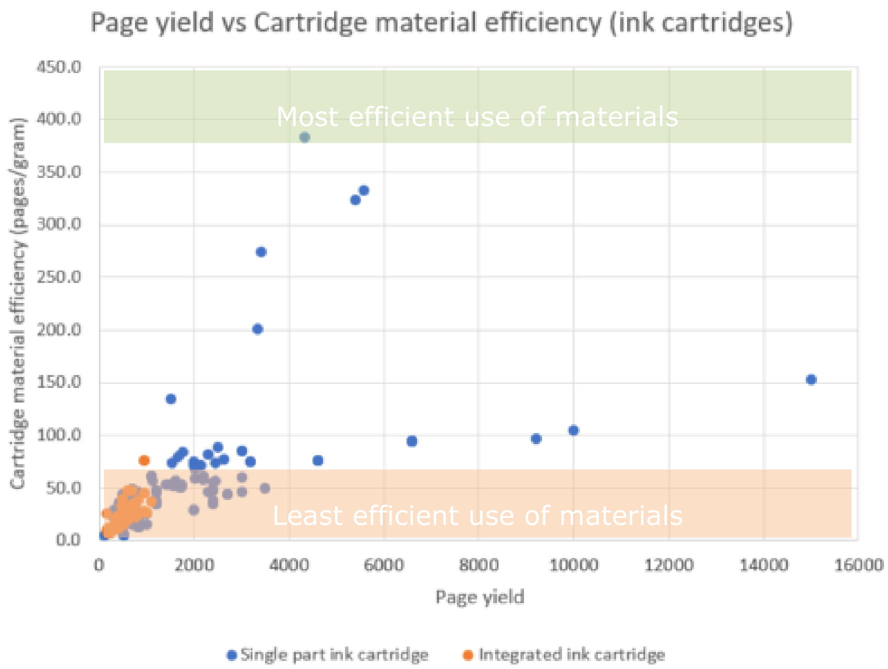


Figure 86. Page yield versus material efficiency of ink cartridges

Red and green rectangles show the areas of least and most efficient use of materials (these are simply and indication for the chart and not a specific threshold).

As can be seen in Figure 86, there seems to be a correlation between page yield and material efficiency. There is a clear separation between integrated ink cartridges and single-part ink cartridges in Figure 86. Integrated ink cartridges tend to provide 1000 pages or less. Within that range, material efficiency of integrated and single-part ink cartridges is similar. Only single-part ink cartridges seem to provide 1000 pages or more. Beyond 1000 pages, a wide range of material efficiency can be found, between 20 pages per gram and nearly 400 pages per gram.

4.5.4 The cost of printing

The cost of printing is a very relevant aspect for consumers. As highlighted in the user behaviour study of Task 3, the most important factor for consumers when buying a printer is the expected price of the ink/toner cartridges, even above the purchase price of the printer (Figure 14). On top of that, almost 1/3 of them would consider replacing their current printer if the cost of the cartridges were too high (Figure 21). The purpose of this section is to estimate the cost of printing with different types of cartridges.

To evaluate the cost of printing with different types of cartridges, a stakeholder[69] provided data from International Consumer Research and Testing[70] (ICRT), containing information on 394 devices (and their associated cartridges) from different OEMs. This database contains information on purchase price of cartridges and page yield, among many other parameters. Page yield values in this dataset are not the declared values with OEMs, but the number of pages resulting from their own testing. Tests are conducted for different printing types (monochrome text, color and full A4 photos). They also differentiate between cartridges sold as “standard” capacity and “XL” capacity.

Figure 87 shows the cost of printing with standard ink cartridges. As can be seen, it is cheaper to print with cartridges that provide higher yield. It is also significantly more expensive to print full A4 pictures than monochrome text.

[69] Consumentenbond.nl
[70] https://www.international-testing.org/index.html

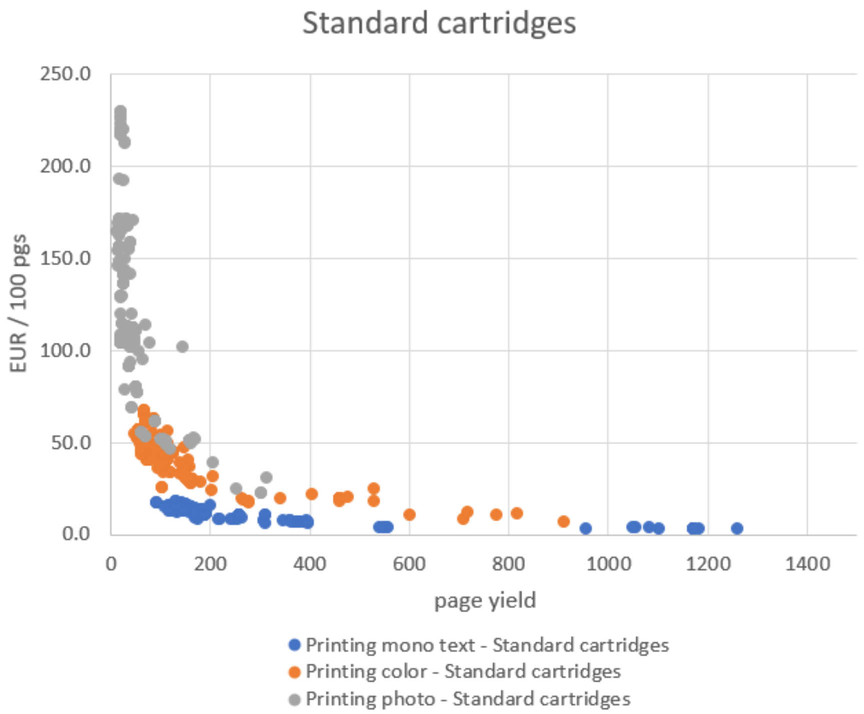


Figure 87. The cost of printing with ink standard cartridges

Figure 88 shows the cost of printing with ink XL cartridges. Again, it is cheaper to print with cartridges that provide higher yield. If standard and XL cartridges are compared, it can be observed that generally it is cheaper to print with XL cartridges.

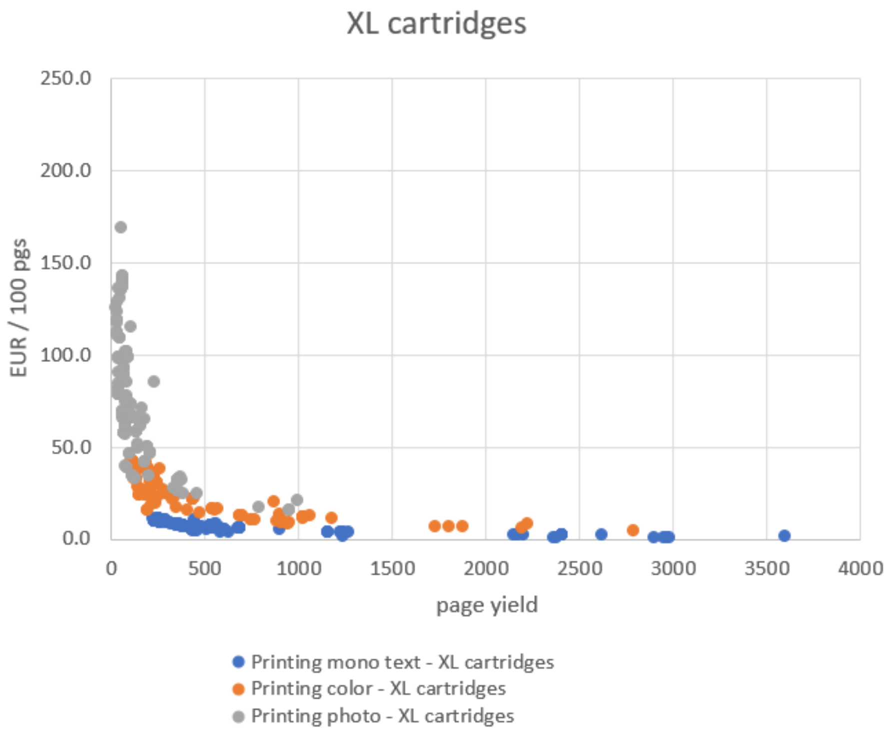


Figure 88. The cost of printing with ink XL cartridges

Figure 89 shows the cost of printing with standard toner cartridges. In this case, only the cost of printing monochrome text is shown, due to lack of data for other modes of printing. As can be seen, it is generally cheaper with cartridges providing higher yield.

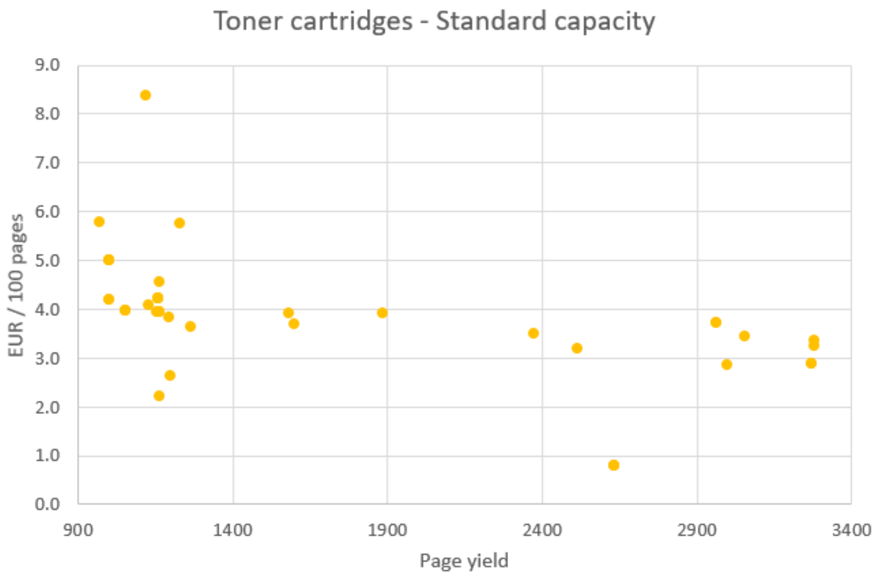


Figure 89. The cost of printing with toner standard cartridges

Figure 90 shows the cost of printing with XL toner cartridges. Again, it is generally cheaper to print with cartridges providing higher yield. If standard and XL cartridges are compared, it can be observed that generally it is cheaper to print with XL cartridges

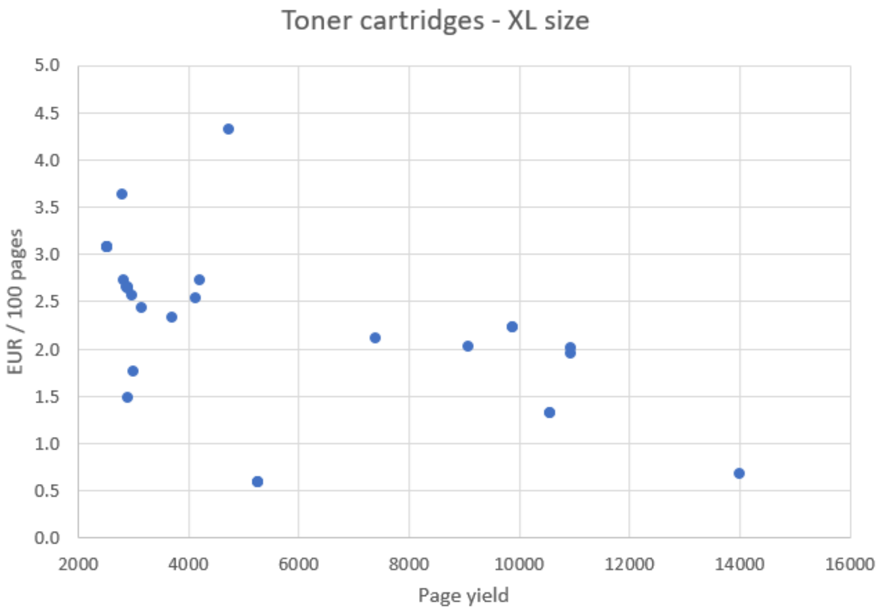


Figure 90. The cost of printing with toner XL cartridges

4.5.5 Compatibility

The market of cartridges is characterized by the availability of a really wide range of models. According to stakeholders from cartridge collection sector, there are currently more than 25000 single cartridge models. Many of these cartridges are very similar in their design, with slight differences often not easy to identify.

Based on the feedback received by some stakeholders in the cartridge remanufacturing sector, the design of cartridges and other consumables is usually changed across several models and generation of printers, resulting in a proliferation of cartridge models linked to specific printer models. The purpose of this section is to provide some examples of these practices and to evaluate their potential consequences from the environmental point of view.

Figure 91 shows five cartridges that share the same core design. However, they contain small plastic features (highlighted in the image with yellow rectangles) that make them slightly different between them. The function of these small plastic features appears to be matching each of those cartridge models with a specific printer model (making them, at the same time, incompatible with the rest of printer models).

Source: Bioservice[71]

Figure 91. Cartridges with slight differences in their design (example 1)

A similar situation can be observed in Figure 92. This figure shows the caps of two toner cartridges (A and B). For proper installation into the printer, the cap needs to fit into a specific area within the printer. The cartridges contain slight design differences (highlighted in yellow). With the introduction of these design differences, each cartridge is only compatible with a specific printer model.

Source: Bioservice

Figure 92. Cartridges with slight differences in their design (example 2)

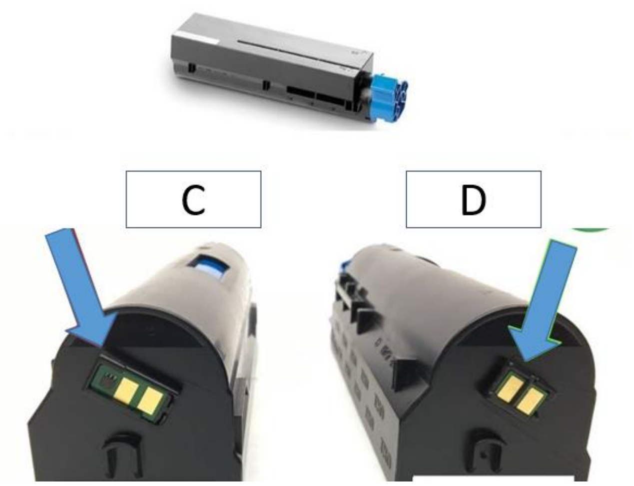
These slight differences in cartridge design can be observed across multiple cartridge configurations. In Figure 93, it can be seen that a large format single-part toner cartridge can have multiple different caps. Each of those caps has different design features, making the cartridge compatible with a limited number of printers.

[71] https://www.bioservice.es/

Source: Bioservice

Figure 93. Cartridges with slight differences in their design (example 3)

Another example can be seen in Figure 94. In this case, cartridges C and D share the same core, the only difference being the shape of the chip holder.



Source: Bioservice

Figure 94. Cartridges with slight differences in their design (example 4)

The examples provided in Figure 91, Figure 92, Figure 93 and Figure 94 indicate that there is a wide range of variability in the design of cartridges, even between very similar models. The purpose of these small design changes between similar cartridge models is unclear, since they do not seem to provide critical functionality. These differences do not appear to be product improvements or innovations. Based on feedback from stakeholders, these design variations have been purposefully included to limit printer and cartridge compatibility.

OEMs explain that they create a variety of competitive service offerings consisting of the printer and cartridge combination to offer the best solution and pricing for the customers' needs, so it becomes necessary to differentiate the design of the cartridge to avoid quality and trade related issues.

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

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

4.5.6 Shelf life

Cartridge shelf life is the estimated length of time a cartridge will last in its sealed package. The purpose of this section is to define shelf life and the main aspects contributing to longer shelf lives.

This aspect is potentially more relevant for 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 print heads can also dry out. Different factors contribute to the eventual deterioration of a printer cartridges, such as storage location, storage temperature, storage position, use of a sealed package, etc. (Figure 95). On occasions they will also include warranty dates.

Source: LD Products[72]
Figure 95. 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[73].

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. As long as the toner cartridge is appropriately stored and managed, it can last several years[74]. In any case, manufacturers still provide warranty and expiration dates.

[72] https://www.ldproducts.com/blog/do-printer-cartridges-expire/

[73] https://cash4toners.com/does-printer-ink-expire/

[74] https://cash4toners.com/how-long-does-printer-toner-last/

4.5.7 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. The purpose of this section is to understand how print quality has an effect on the environmental performance of cartridges, and to characterize different types of cartridges in terms of print quality.

DIN 33870-1 and DIN 33870-2 define the quality requirements for the remanufacturing process of toner modules and appropriate test methods. These standards are used as a reference for various voluntary schemes regarding printing performance of consumables. This is the case of the GPP criteria in their Technical Specification 20 on Consumable quality (Kaps et al, 2020), as well as Blue Angel (DE-UZ-219) and Nordic Ecolabelling (Version 6.7)

Print quality is a recurring theme when comparing OEM and remanufactured 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 print heads 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.

In Du et al (2023), the authors state that the performance of the remanufactured consumables is the same as that of original brands but with a higher failure rate. 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.

According to a study published by the consumer organization Which?[75], 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.

Feedback provided by a consumer organisation says that data from their members, 74% of surveyed consumers in Belgium, Italy, Portugal, and Spain combined have relied on alternative cartridges (non-OEM) and 40% of surveyed consumers recently used recycled/remanufactured cartridges or from a refilling service. The main reasons for not opting for the alternative cartridges are: fear that they could damage the printer, satisfaction

[75] https://www.which.co.uk/news/article/is-cheap-printer-ink-any-good-amWMI5s3L4Nd

with the original ones, misinformation from the manufacturer, and perception of a lower printing quality. According to recent test results from their British member Which?, most third-party brands of cartridges are of good quality, meet printing needs and are at times of superior print quality of original brands, whhile costing less (even 4 times lower price) .

In contrast, other sources[76] indicate that 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. Additionally, in a survey conducted in the UK asking 1531 people about their printing habits, 22% of people believed that 3rd party cartridges would damage their printer and 17% that they would invalidate their printer warranty[77].

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[78]. However, no test reports are available on the association's website. They also point out that print quality is a subjective term, and that customers may have different quality requirements for different types of outputs.

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

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

4.5.8 End of life of cartridges

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

- Prevention
- Preparing for reuse
- Recycling
- Recovery
- Disposal

In the following sections, each of those aspects of the waste hierarchy will be described, focusing on its applicability to cartridges. Therefore, the purpose of the following sections is to describe in detail different aspects related to cartridge waste prevention, cartridge collection, cartridge remanufacturing, cartridge recycling and cartridges sent to landfill and incineration.

4.5.9 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

[76] https://www.tonerbuzz.com/blog/toner-cartridges-genuine-oem-vs-compatible-vs-remanufactured/

[77] https://www.cartridgepeople.com/info/blog/home-printing-statistics#:~:text=According%20to%20our%20results%2C%2027,using%20their%20printer%20every%20week

[78] https://www.etira.org/cartridge-remanufacturing/quality-first/

generation of waste. 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[79] (115 EUR).

There are several examples of this technology in the market today[80] [81] [82] [83]. According to feedback from a stakeholder, in 2022, 13% of printers sold were tank models. OEMs confirm that some companies have their business model based on shifting towards cartridges-less printer models. According to OEMs offering this technology, the system features a large ink tank that the user fills with the included ink bottles instead of cartridges (Figure 96).

Figure 96. Examples of re-fillable tanks

One of the disadvantages of this technology is that the ink may dry up when left unused, leading to clogged tubes or cartridge nozzles[84]. Remanufacturers add that imaging equipment devices cannot be properly treated at end of life if some toner or ink remains inside. Therefore, tank systems would need to be designed with disassembly in mind, so that residual ink or toner is kept out of machine steams. They also consider that tank systems may not be environmentally beneficial if print head replacement is not easy and affordable.

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

4.5.10 Cartridge collection

Cartridge collection is key at end of life to ensure that the materials can be prepared for reuse or recycled, and to reduce the amount of material sent to recovery or disposal. In Denmark, for instance, it was estimated that 0.5% of the total waste generated is material which is misplaced (not sorted and collected appropriately). 2% of that misplaced waste is related to ink cartridge waste, which accounts for a total of 249 tonnes per year. When this type of waste is not sorted and collected and is sent to treatments such as incineration, it can have significant negative impacts on resource depletion (Bigum et al, 2017).

In this section, the main aspects related to cartridge collection are summarised.

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

- Lexmark began reclaiming material in 1991 through the Lexmark Cartridge Collection Program (LCCP). This program allows customers to return cartridges free of charge, with the purpose of reusing or

[79] https://www.which.co.uk/news/article/is-cheap-printer-ink-any-good-amWMl5s3L4Nd
[80] https://www.hp.com/es-es/shop/product.aspx?id=1TJ12A&opt=BHC&sel=PRN
[81] https://www.epson.eu/en_EU/for-home/ecotank
[82] https://www.canon.es/printers/refillable-ink-tank-printers/
[83] https://www.brother-usa.com/inkvestment-tank

[84] https://www.ldproducts.com/blog/is-the-epson-ecotank-really-worth-the-money/

recycling them. Individual customers may use a postal box which can fit up to 5 cartridges. Companies can request a container. According to Lexmark[85], the LCCP collected 4689 tons of cartridge materials in 2021. According to the company, nearly 40% of the total toner cartridges shipped worldwide were returned through the LCCP.

- Brother[86], for their operations in Europe, have been collecting and remanufacturing toner cartridges since 2004, and have publicly available webpages and a portal site for recycling consumables and products, providing information on how to return used toner cartridges, drum units, ink cartridges and products, how to use their recycling services and order collection boxes etc. They provide recycling services in 30 countries with a variety of schemes depending on country, customer convenience and quantity of cartridges, giving customers the option of postal return or bulk collection – free of charge. Brother utilizes the collection channels in place in respective countries (in compliance with the WEEE Directive) and cartridges are returned to their two European remanufacturing facilities, both accredited as zero waste to landfill and carbon neutral. Cartridges are primarily remanufactured, and anything that cannot be directly reused is recycled

- Canon[87] has been collecting and recycling used ink cartridges since 1996. As of the end of 2021, Canon's collection program was operational in 35 countries and regions worldwide, and the total volume of cartridges that had been collected up to the end of 2021 reached 2616 tons. Both toner and printer cartridges are sent to local hubs for consolidation, before being sent to Canon's recycling facilities.

- Epson[88] have established collection and recycling programmes for cartridges that consist of either single returns (via post) or bulk returns (via box collection). Programmes vary across our European markets, according to local legislation and our recycling partners. The collection scheme works differently depending on the type of cartridge (inkjet, toner, large format) and the number of devices owned by the user.

- HP[89] provides take-back programs in 77 countries and territories worldwide through a global network of reuse and recycling vendors. HP provides free ways to recycle used Original HP Ink and Toner Cartridges and Samsung toner cartridges. Home and commercial customers can return Original HP Ink and Toner Cartridges for free to more than 18,500 authorized sites worldwide. Free pickup and mail-back options are available in most countries.

- Kyocera[90] offer a number of ways to return used cartridges to their recycling partners, depending on customer location. They provide boxes of different sizes to customers, depending on the type and size of cartridges being returned.

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

Public administrations may provide different solutions as well for the collection of empty cartridges. Municipalities may offer mobile or fix drop-off points where users can bring their depleted toner and ink cartridges. Information is given in terms of location of fix points and time availability of mobile points[91].

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:

[85] https://csr.lexmark.com/pdfs/2021-CSR-Report.pdf
[86] https://download.brother.com/pub/com/en/csr/pdf/sus-2022-en.pdf
[87] https://global.canon/en/csr/report/pdf/canon-sus-2022-e.pdf
[88] https://epsonemear.a.bigcontent.io/v1/static/A14510-brochure-lores-en-INT Epson_Europe%E2%80%99s_Sustainability_Report_2021_-_2022_digital?12
[89] https://h20195.www2.hp.com/v2/GetDocument.aspx?docname=c08228880
[90] https://www.kyoceradocumentsolutions.com/en/ecology/process/toner.html
[91] https://www.barcelona.cat/cuidembarcelona/es/reciclar/res/RM0030

<u>Brokers</u>: companies with business models based primarily –or exclusively- on the collection and sale of empty ink and toner cartridges. In some cases, firms differentiate "brokers" from "collectors" with the former being only interested in gathering cores for sale and the latter collecting all empties.

<u>Remanufacturers</u>: 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.

<u>Dealers</u>: 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.

<u>Dealer-Remans</u>: 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.

<u>Virgin OEM core</u>. 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.

<u>Remanufactured OEM core.</u> 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.

<u>New build core</u>. 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 remains

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.
- 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.

Finally, it needs to be taken intou account that cartridge collection rates are also influenced by how the cartridge was sold in the first place. Cartridges supplied as part of subscription and service models have significantly higher collection rates that cartridges sold individually (around 3 times higher, according to rough estimations from a stakeholder).

4.5.11 Cartridge reuse

When an ink or toner cartridge has been depleted, depending on the characteristics of the cartridge, it can be refilled or remanufactured. The process of refilling consists simply in filling the cartridge again with ink or toner, without carrying out any modifications on the empty cartridge.

The process of cartridge remanufacturing is more complex, and a description can be found in Lindahl et al (2006). Toner cartridges are sent by consumers, usually stored in boxes, which can hold multiple cartridges. When the box arrives, it is unpacked and undergoes a combined manual operation where the product is simultaneously identified, inspected and sorted. The cartridges are sorted according to whether they have been used only one time (virgin) or have been remanufactured before (non-virgin). They are also sorted based on the status of the core.

The sorting is done in case there is an over-supply of cores. In this case, the best (i.e. virgin) are designated for remanufacturing, while the remaining cores are placed in reserve. Another reason is for capacity management: when there is a demand peak, it is only the virgin cores that can be used, enabling more rapid remanufacturing and thereby a higher remanufacturing volume. Non-virgin cartridges are used in situations of over-capacity, due to the increased time it takes to remanufacture the cartridges.

After the sorting operation, the cores are stored in inventory waiting for a remanufacturing order. When the order arrives, the cores are sent to a disassembly operation. From this point, some of the parts are sent to a cleaning operation, while others are sent to machining operations to be reprocessed and, in some cases, cleaned. Some of the parts are also sent to recycling/landfills, and new components are used to replace the discarded. The reason for the discarding is either that the components are broken, or due to a policy at the company to always replace the components. After all parts have gone through reprocessing operations, they are reassembled with the new components. After reassembly, they are tested and packed before they are placed in the finished goods inventory.

The concept of remanufacturability has been defined as a product property, which can be used to describe the possibility and ability of a product to be remanufactured (Zhang et al, 2021). In the context of this Preparatory Study, cartridge remanufacturability has been understood as the potential to be remanufactured of a cartridge.

Cartridge reuse comprises both the ability of being refilled and/or the ability of being remanufactured. Based on conclusions from previous studies, with cartridge reuse it is possible to reduce the consumption of virgin materials, hence minimising environmental impacts (Huang et al, 2019). Reusing cartridges can also contribute to reducing consumer expenditure.

4.5.11.1 Cartridge reuse rates and potential for reuse

Cartridges cannot be reused indefinitely. The number of times a cartridge can be reused will depend greatly on their design and on their ability to be remanufactured or refilled. 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".

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

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

- In Huang et al (2019), it is estimated that 15-20% of all cartridges in the EU are reused as a cartridge after first use, including OEM and non-OEM cartridges
- In Waugh et al (2018), it is estimated that 20% of toner and 13% of ink cartridges are remanufactured in the EU
- The cartridge remanufacturing[92] industry estimate that around 15%–20% of printer cartridges are remanufactured within the European Union and a further 10%–12% are from outside the EU
- Non-governmental organisations[93] estimate that remanufacturing rates in Europe are around 10%

The low reuse rate figures are significantly influenced by low collection performance described in section 4.5.10.

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

> *Collection rate: estimate of % of cartridges collected through recognised collection processes.*
>
> *Viable percentage: estimate of % collected/purchased by anticipated Signatories and considered viable for reuse. Takes into account cartridge lifecycles e.g. end of life of cartridges. Also takes into account market factors; Signatories won't remanufacture what they can't sell.*
>
> *Remanufacturing rate: estimate reflecting loss due to damaged cartridges or loss in production process.*

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

Reuse rate = Collection rate x Viable percentage x Remanufacturing rate

The agreed figures for collection rate, viable percentage and remanufacturing rate, for toner and ink cartridges, are presented in Table 44.

[92] https://www.therecycler.com/posts/ecolabelling-to-incorporate-reuse/

[93] https://www.coolproducts.eu/wp-content/uploads/2021/06/ECOS-eNGO-Comments-on-Imaging-Equipment-December-2020.pdf

Table 44. Collection rates, viable percentages and remanufacturing rates estimated for the VA 2021 proposal

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

In contrast to these figures, in Waugh et al (2018), technical potential to reuse cartridges are proposed (Table 45). Technical reuse potential refers to the ability of a printer cartridge to technically be processed for reuse. For example, the use of adhesives may make it impossible to disassemble a printer cartridge without damaging the components beyond repair. If a printer cartridge cannot technically be remanufactured or refilled, the only end-of-life options will be recycling, energy recovery, and landfill.

Table 45. Potential of cartridge reuse

	Technical reuse potential
Toner cartridges	92%
Inkjet cartridges	87%

Source: Waugh et al (2018)

Regarding the technical potential for reuse, OEMs state that whilst it might be high for the first time reuse, it significantly declines for second and third time reuse. In their view, these rates look much higher than reality.

4.5.11.2 Barriers for cartridge reuse

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

<u>Design-related barriers</u>

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

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

   As explained in section 4.5.1, chips provide functionality such as page count, which is useful for the consumer. In some cases, when the cartridge is refilled, the chip blocks the use of the cartridge unless a reset operation is carried out. This resetting is on occasions very complex or even not possible for independent remanufacturers. The complexity of the resetting operations has increased over the past years. In other occasions[94], chips use serial numbers to identify whether a cartridge has already been used with that printer model. If a serial number has already been used in the first life of the cartridge, the printer will not allow its use as a remanufactured cartridge. Stakeholders in the remanufacturing industry point out that such developments are largely driven to frustrate reuse, rather than for enhancing the performance of the cartridge.

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

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

[94] https://www.youtube.com/watch?v=ZKu9qkZG0QE&t=10s

On occasions, these software/firmware updates change to the encryption process between the device and the chip. Legal non-OEM cartridges –such as remanufactured cartridges- sometimes cannot adapt to these changes, making them unusable (Huang et al, 2019). These software updates are often sent without the knowledge of consumers, who then are forced to use original cartridges only[95] [96] [97].

c) *The use of irreversible joining practices*

Some cartridges are designed with irreversible joining practices –such as gluing, adhesive tapes and welding- that prevent the access to components key for remanufacturing[98]. Some of these practices require cutting cartridges plastic bodies open to replace worn parts.

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

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

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

As described in section 4.5.5 of the Preparatory Study, cartridges have external design features to facilitate their installation into the device. Often new printer models are placed on the market with small changes in terms of functionality, but with relevant changes regarding cartridge compatibility. These new devices have new design features which essentially make them incompatible with existing cartridges in the market. Superfluous design features need to be added to new cartridges, in order to make them compatible with new device models (see examples in Figure 91, Figure 92, Figure 93 and Figure 94). As a result, the market is filled with a wide variety of very similar models of devices and cartridges, which provide very similar –or the same- functionality, but incompatible between them.

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

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

Some cartridges contain parts that are fragile and key for their performance, such as photoreceptors in all-in-one cartridges. On occasions, these components are located in exposed areas without protection (Figure 97).

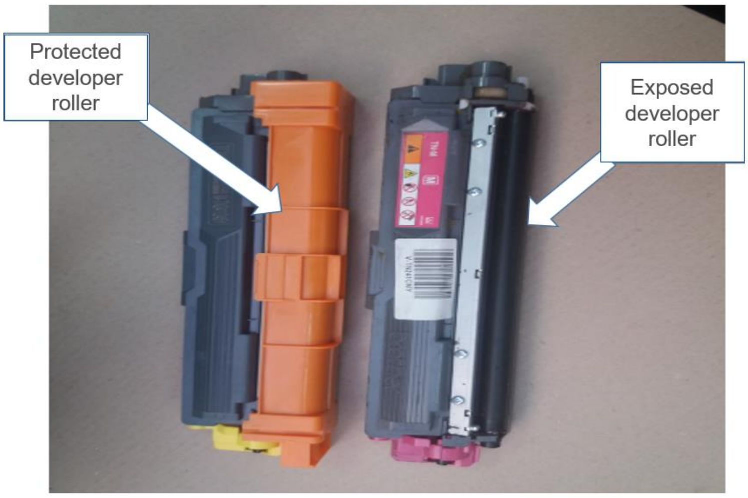


Figure 97. Examples of cartridges with protected and exposed developer roller

95 https://www.theguardian.com/money/2023/may/10/how-can-hp-block-me-from-using-a-cheaper-printer-cartridge

96 https://www.therecycler.com/posts/hp-customers-upset-over-new-firmware-update/

97 https://www.xataka.com/perifericos/drama-hp-sus-impresoras-su-ultima-actualizacion-bloquea-no-se-utilizan-cartuchos-oficiales

98 OEMs explain that these practices are mostly likely used to prevent the leakage of toner or ink

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

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

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

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

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

i) *The design of cartridges with low capacity*

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

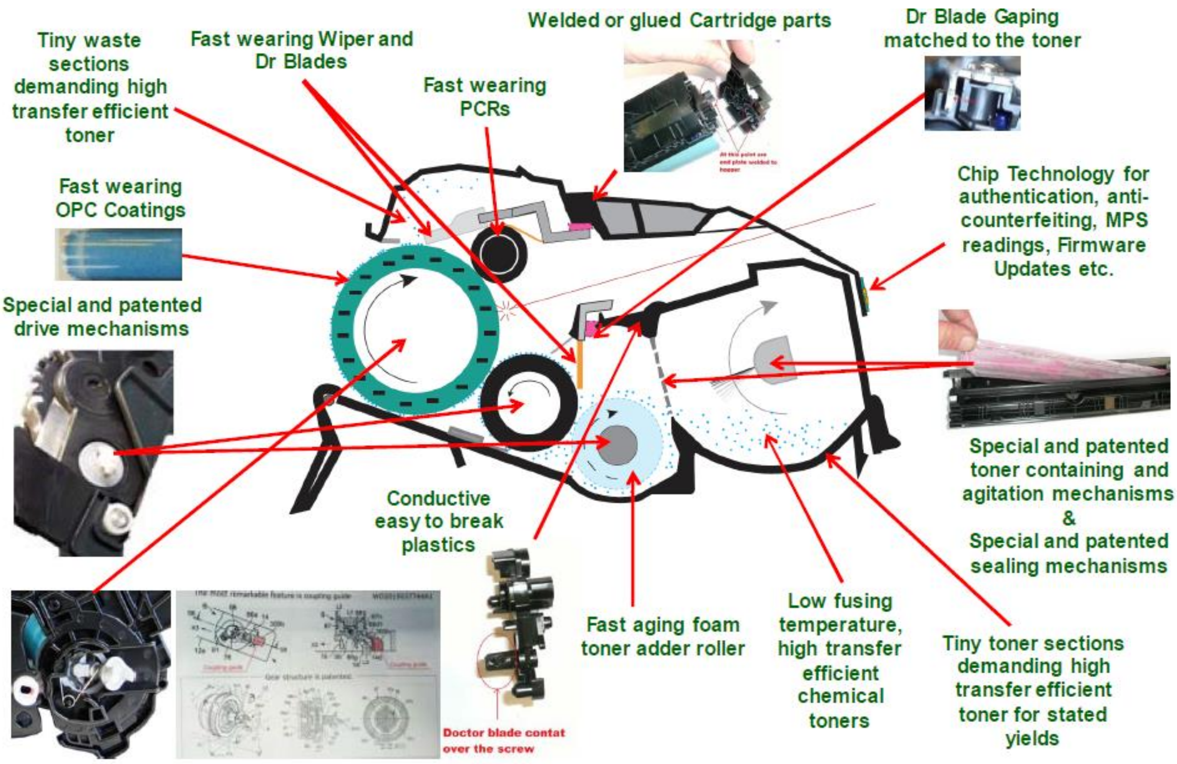
j) *The lack of information on cartridge life condition, model identification or device compatibility*

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

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

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

In addition to barriers identified above, a stakeholder from the remanufacturing industry contributed to this Preparatory Study with a graphic description of the most common barriers that remanufacturers find today in toner cartridges (Figure 98). Most of these barriers can be associated with the classification provided in a) to k).



Source: Delacamp

Figure 98. Summary of design-related barriers in toner cartridges

Other barriers

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

l) The sales of counterfeit cartridges

The rise of sales of counterfeits described in Section 4.5.14 is a market barrier for cartridge reuse. These cartridges are often unsuitable for subsequent reuse, as they contain toxic or restricted hazardous substances. They tend to be manufactured with lower quality materials, which reduces the cost of manufacturing. Their usual low price make them more attractive to consumers than legally remanufactured cartridges, displacing them from the market.

m) Published claims about poor quality of remanufactured cartridges

Published claims about poor quality issues with reused consumables has also been highlighted as a marketing barrier for reuse, together with the propagation of inaccurate claims about printer warranties, stating that they might be voided using non-original cartridges[99]. These claims can have an impact on the sales of remanufactured cartridges since consumers may fear that they will not perform appropriately. As stated in Dhebar (2016), the intent of this stratagem might be to incentivise the user to consume only the original brand.

n) Contractual bindings

Contractual aspects between OEMs and customers can operate as a barrier for cartridge reuse. Some printing subscription schemes available in the market today are an example of this. In some of these services[100] [101] [102] [103], the device will work with original supplies only. If the printer gets damaged, the cartridge may not be used in a different printer. In some other cases[104] the device may only work with

[99] https://www.hp.com/us-en/shop/tech-takes/are-off-brand-ink-cartridges-as-good-as-name-brand
[100] https://www.epson.eu/en_EU/readyprint
[101] https://instantink.hpconnected.com/uk/en/l/v2
[102] https://www.brother.co.uk/ecopro
[103] https://www.lexmark.com/en_gb/services/lexmark-oneprint.html?cid=web-emea-gb-cust-SUBSCRIPTION-toner-finder
[104] https://www.hp.com/us-en/printers/hp-plus.html

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

o) Closed collection programmes for used cartridges

Some OEMs provide collection schemes in which the cartridge is sold at a discount in exchange for the customer's agreement that the cartridges will be used only once and returned only to OEM for remanufacturing or recycling[105]. These cartridges will stop working after reaching the end of the rated life established by the OEM. This can be a barrier for reuse since it limits the access to third party operators to the collection of used cartridges. If the OEM is not able to collect all cartridges that are placed on the market under these scheme, waste will be generated, since independent operators will not be able to remanufacture them.

p) Copyrights or patents

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

4.5.11.3 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 Bergling 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

[105] https://www.lexmark.com/en_gb/supply/14428/Lexmark-C-MC3224-3326-3426-Black-Return-Programme-1-5K-Print

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 released by Clover[106], a company whose main business is cartridge remanufacturing, a life cycle assessment is conducted to compare remanufactured toner cartridges with equivalent OEM cartridges. Based on the environmental indicators evaluated, both black and color remanufactured cartridges were found to exhibit lower environmental impacts compared to their OEM counterparts in all significant impact categories evaluated. For instance, black and colour remanufactured cartridges had 53% and 49% less carbon footprint than OEM cartridges, respectively.

In Miyoshi et al (2022), the circularity of toner containers is evaluated using Life Cycle Simulation (LCS), focusing on component remanufacturing and the effect of circularity on life cycle cost and CO_2 emissions. The authors conclude that CO_2 emissions are reduced by 42% if the toner container is reused, compared with using a new container. The printing quality of the new and reused containers is assumed the same

In Fraunhofer Umsicht (2019), a study conducted by the Fraunhofer Institute for Environmental and Energy Technology for Interseroh, the authors evaluate the environmental savings of reprocessing and reusing toner cartridges. According to their results, reusing a single cartridge saves 4.49 kg of greenhouse gas emissions compared to new production. In addition, 9.39 kg of primary resources are saved per cartridge. In comparison, recycling a cartridge saves 0.41 kg of greenhouse gas emissions and 1.94 kg of resources.

In Chung et al (2013), a study conducted in the University of British Columbia (Canada), a comparison is made between original and remanufactured cartridges in terms of their environmental, economic and social impacts. Different printing qualities are assumed for each cartridges: remanufactured cartridges need 11% more paper to accomplish the same task. Considering this, the authors conclude that remanufactured cartridges impose a smaller toll on the environment based on material resources, greenhouse gas emissions, and waste generation.

4.5.11.4 Arguments against cartridge reuse

A variety of arguments have been given against cartridge reuse, mainly related to the factors below (Waugh et al, 2018):

- Print quality considerations.
- Unfavourable life cycle impacts.
- Non-adherence to safety, health, environmental and related issues.
- Infringement of intellectual property or brand distortion.
- Alternative printing technologies.
- Other generic issues.

In terms of print quality and the related unfavourable life cycle impacts, some organisations tend to argue that reused cartridges will not perform to the standards of OEM-approved new cartridges. In Waugh et al (2018), one OEM claimed that for highest quality demands, up to 150% more pages are required using an average remanufactured cartridge, though a 50% excess is typical over the range of quality uses envisaged. It must be noted that not every OEM considers different printing quality results between new and remanufactured cartridges: according to Waugh et al, 2018, Lexmark places the same quality guarantees on its new and remanufactured (toner cartridges). Based on direct feedback from the OEM, Brother’s remanufactured toner cartridges are also the same quality and follow exactly the same rigorous checks as new 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

[106] https://www.cloverimaging.com/lca

(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.

4.5.11.5 Cartridge reuse in published bibliography

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.

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.

In recent years original cartridge manufacturers have commissioned 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.

Table 46. Summary of studies where environmental performance of original and reused cartridges are compared

Year	Reference	Peer-reviewed	Publisher	Page yield of reused versus new	Best environmental performance
2002	Berglind et al (2002)	N	University of Kalmar	=	Reused cartridge
2004	First Environment (2004)	N	First Environment for HP	-12%[107]	not conclusive
2008	Gell (2008)	N	UK Cartridge Remanufacturing Association	=	Reused cartridge
2008	Ferrari (2008)	N	Universita di Modena e Reggio Emilia, for SAPI	+21%	Reused cartridge
2010	Kara (2010)	N	UK Centre for Remanufacturing and Reuse	=	Reused cartridge
2011	Four Elements (2011)	N	OEM (HP)	-15%	New cartridge
2013	Chung et al (2013)	N	University of British Columbia	-11%	Reused cartridge
2014	Krystofik et al (2014)	Y	The International Journal of Life Cycle Assessment	=	Reused cartridge
2014	Four Elements (2014)	N	OEM (HP)	-23%	New cartridge
2018	Badurdeen et al (2018)	Y	Journal of Cleaner Production	n/a	Reused cartridge
2019	Fraunhofer Umsicht (2019)	N	Fraunhofer Institute for Environmental and Energy Technology for Interseroh	n/a	Reused cartridge
2019	Four elements (2019)	N	OEM (HP)	-38%	New cartridge
2021	Four Elements (2021)	N	OEM (HP)	-8%	New cartridge
2022	Clover (2022)	N	Clover	n/a	Reused cartridge
2022	Miyoshi et al (2022)	Y	29th CIRP Life Cycle Engineering Conference	=	Reused cartridge

Printing quality –translated as total number of pages printed- is a parameter that influences environmental assessments and the related conclusions. In four of the studies presented, the larger paper consumption associated with remanufactured cartridges caused more favourable results for new cartridges. In contrast, despite this extra paper use, remanufactured cartridges were still the best option according to Chung et al (2013).

Cartridge print quality is a key factor when assessing whether remanufacturing is the most appropriate option from environmental perspective. Based on the analysis of bibliography, there seems to be discrepancies between

[107] The reused cartridge evaluated can print 12% less pages than the original one. The same principle is applied for the rest of rows in this table.

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.

4.5.12 Cartridge recycling

Cartridge recycling can be divided in the following steps:

- Cartridge collection, usually through a take-back scheme
- Transport to a recycling facility
- Manual sorting of cartridges, to remove packaging elements and sort them by cartridge type
- Optical sorting of cartridges
- Automatic disassembly, to separate different materials such as precious metals, foams and plastics.
- Plastic shredding, where different types of plastics are also separated
- Addition of plastic materials from other sources (such as discarded bottles), to create the final resin used to manufacture new cartridges.

Recycling activities are widely described in OEM's Corporate Sustainability Reports:

- In 2007 Lexmark established a recycling plant in Juarez, Mexico, to provide customers a place to return their empty laser cartridges for responsible end-of-life reuse or recycling[108]
- Brother[109] collects end-of-life toner cartridges and remanufactures them at the Brother Group's recycling sites into toner cartridges having the same quality as brand new products, then delivered to customers again. In FY2021, the Brother Group as a whole remanufactured 2.78 million toner cartridges.
- In a similar way, Canon[110], in order to maximize the value brought about by resource recycling, pursues product-to-product recycling. Canon collects cartridges post-use and making them into products with good-as-new quality. Currently, Canon has five sites conducting recycling, in Japan, Europe (two sites), the United States, and China (Canon, 2022).
- Epson[111] states that following collection, from most of the EU countries, all treatment and recycling is managed by CloseTheLoop in Belgium.
- HP[112] states that 10,300 tonnes of Original HP and Samsung toner cartridges were recycled, and that 84% of materials recovered were used in other products. Moreover, 1,500 tonnes of Original HP Ink Cartridges were recycled, with 67% of materials recovered used in other products.
- Kyocera[113] states that they have been working on collection and reuse of toner containers since 1998. Empty toner containers sent from customers are collected at a collection center and then transported to a recycling plant. After separating the cassettes into individual components, the polymers in the toner cassette are separated and then granulated and prepared for reuse as "recyclate" which can be added to brand new materials to manufacture a variety of products.

4.5.13 Cartridges sent to landfill and incineration

Printer cartridges constitute an important part of electronic waste, mainly due to their limited operational life, resistance to degradation after disposal, and environmental and economic challenges in recycling/reuse, as seen in previous sections. When disposed in landfills, they cause soil and water pollution leading to a multitude of health hazards (Parthasarathy, 2021).

There are no comprehensive studies analysing the amount of waste sent to landfill or incineration from discarded cartridges in the EU. The conclusions of the available studies are summarised below:

108 https://csr.lexmark.com/pdfs/2021-CSR-Report.pdf
109 https://download.brother.com/pub/com/en/csr/pdf/sus-2022-en.pdf
110 https://global.canon/en/csr/report/pdf/canon-sus-2022-e.pdf
111 https://epsonemear.a.bigcontent.io/v1/static/A14510-brochure-lores-en-INT-Epson_Europe%E2%80%99s_Sustainability_Report_2021_-_2022_digital?12
112 https://h20195.www2.hp.com/v2/GetDocument.aspx?docname=c08228880
113 https://www.kyoceradocumentsolutions.com/en/ecology/process/toner.html

- In Huang et al (2019) it is published that 60-70% of all cartridges end up on landfills or are 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 Denmark, around 249 tonnes of ink cartridge waste is generated every year, as part of residual waste (Bigum et al, 2017)
- In a study conducted by the non-governmental organisation ECOS[114], 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 of every day on a global scale. Each cartridge contains about eight percent of unused toner by weight, amounting to the release of 6000 tons of carbon powder into the environment

4.5.14 Legal aspects related to cartridges

Ecodesign aims at implementing technical requirements to improve the environmental performance of products, focusing on significant environmental aspects. Despite not being strictly technical issues, some legal issues have been identified within this product group 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.

Compatible consumables were estimated to account for 21.1% of the global printing consumables demand in 2019 and expected to grow up to 22.8% in 2024 (Du et al, 2023). The average annual growth rate of compatible consumables remained around 9% between 2014 and 2018. Therefore, the growing expansion of the market share of compatible consumables brings a great concern for both original brand manufacturers and remanufacturers.

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.*

[114] https://ecostandard.org/news_events/when-empty-promises-wont-do-why-regulation-is-needed-to-end-built-in-obsolescence-of-printers/

- *Newbuild/clone low prices (in many cases due to government subsidies) seriously impact market viability of remanufactured cartridges. They also reduce the value of and the incentive to collect empty cartridges.*
- *Many remanufacturers have been compelled to sell newbuild cartridges and some newbuild companies sell remans. Some companies have an incentive to confuse the issues to encourage the EU to enable newbuild cartridges rather than remanufactured cartridges.*
- *While some newbuild/clone companies invest in R&D, it is primarily to circumvent IP as opposed to add performance, improve customer experience, or reduce the environmental impact.*
- *Clones are simply newbuild cartridges that disregard OEM IP to produce the lowest price and get to market faster. Unfortunately, it can take technical knowledge and inspection to separate NBCs from clones.*
- *Counterfeiting is about deceiving customers into thinking they are buying an OEM cartridge. Counterfeiters need to source cartridges. While newbuilds/clones are generally the cheapest and therefore preferred by counterfeiters, remans will be used if the price difference is sufficient. When available, counterfeiters use a 3rd party chip configured to be recognized by the system as an OEM original. Therefore, authentication of chips is required to protect the OEM brand and consumers.*

In Waugh et al (2018) views from different members of the industry are also presented:

- *In response to increased market pressure from compatible cartridges, OEMs will continue to shift to print service business models. This may adversely affect remanufacturers, for example through their ability to collect core and access to customers who are tied to OEMs.*
- *There was a strong view that South-East Asian imports of compatible cartridges would put remanufacturers under severe pressure unless the imports are subject to the same stringent manufacturing and quality requirements as local production.*
- *A number of OEMs and third party refillers raise the issue of consumables which do not meet EU health and safety considerations being used in cloned and compatible cartridges. These issues largely originate from suppliers outside the EU. There are concerns that, for example, toners or inks contain substances not approved for use in the EU; or that the conditions under which these substances are made and placed into consumables do not conform to workplace conditions acceptable to the EU. Such short-cuts are likely associated with cost-cutting, thus presenting unfair cost advantages in addition to the health concerns.*

Cartridge collectors and remanufacturers from ETIRA shared with the authors of the Preparatory Study different examples of counterfeit cartridges packaging containing symbols mimicking environmental labels and compliance with other EU regulation such as RoHS. The packaging of these cartridges seemed undistinguishable from original cartridges for a non-expert in the market. The packaging did not contain information either about the supplier of the cartridge.

The potential presence of toxic chemicals is a concern as well related to low quality compatible cartridges. According to ETIRA[115], In October 2019 industry media reported that several newbuilt non-OEM cartridges had been found to contain excessive levels of Decabromodiphenylether (DecaBDE), a halogenated flame retardant that, because of its health risks, had been prohibited in the EU since 2008 in electronics above certain levels, and fully prohibited in many other products. The original OEM equivalent did not contain DEcaBDE. It was observed that four of those non-OEM cartridges had DecaBDE levels ranging from 2,000 mg/kg to 17,000 mg/kg, although only 1,000 mg/kg of (0.1% w/w). The wider group of polybrominated diphenyl ethers (PBDE) is also only allowed at levels lower than 0.1% w/w according to the RoHS Directive 2011/65/EU.

The Italian remanufacturing association PACTO also highlighted the issue of false “remanufactured origin” claims for products placed on Italian market in the context of the application of mandatory Green Public Procurement Criteria.

[115] https://www.etira.org/posts/etira-commissioned-tests-find-hazardous-decabde-in-more-newbuilt-non-oem-cartridges/

4.5.15 Preliminary objectives of policy options on cartridges

Based on the data gathered in sections 4.5.1 to 4.5.14, preliminary objectives of policy options applicable to cartridges can already be proposed. They can be summarized as:

- Improving the capacity utilisation in cartridges
- Increasing the possibilities to remanufacture cartridges
- Encouraging the use of material efficient cartridge configurations
- Reducing the amount of paper wasted due to performance of cartridges

These objectives will be used as a basis for the definition of base cases and design options in Task 5 and Task 6, as well as for the proposal of ecodesign measures in Task 7.

4.6 Base cases

In this section, base cases (BC) for devices and cartridges have been proposed. 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 (Task 5).

Base cases reflect average EU products and not real specific ones. Due to the technical differences, market relevance, applications and users of the imaging equipment and consumables in the scope, multiple base cases are proposed for each product category identified.

4.6.1 Device base cases

The definition of the device base cases have considered market data described in Task 2 of this Preparatory Study. The market of consumer inkjet devices is dominated by the sales of multi-function printers (MFP) with 12 million units sold in 2022 in Western Europe (IDC, 2023). The trend for these devices is downwards but it is still expected to be the highest seller in the short-term. In contrast, around 0.35 million units of single-function inkjet printers were sold in 2022 (3% of market), with a very slight decrease expected in the following years (IDC, 2023).

In the laser printer sector, the highest sales in 2022 corresponded to printers A4 Monochrome devices, with 1.4 million and a downward trend and shift toward multi-function devices. Multi-function printers A4 monochrome achieved 1.3 million sales, with multi-function printers A4 monochrome showing the fastest-growing market, expected to be the dominant devices in the short-term. With 0.6 million, multi-function printers A3 colour are the most common device with A3 capability. Single-function printers with A4 capability and color have a downward trend and less than 0.3 million sales in 2022.

Considering market data, and relevant performance parameters such as printing speed, color/monochrome printing and A4/A3 capability, device base cases are proposed in Table 47.

Table 47. Device base cases proposal

Device Base Cases	Use	Description	Speed (ipm)
Device1	Small office	Laser A4 color	26
Device2	Small office	Laser A4 mono	42
Device3	Large office	Laser A4 color	52
Device4	Large office	Laser A4 mono	70
Device5	Large office	Laser A3 color	80
Device6	Large office	Laser A3 mono	90
Device7	Household	Inkjet A4 color	15

4.6.1.1

4.6.1.1 Materials used in device base cases

The bill of materials of the device base cases are presented in Table 48. This data has been provided by OEMs in support of the development this Preparatory Study.

Table 48. Bill of materials of device base cases

	Steel	Stainless Steel	Aluminium	Other metal	Glass	Plastics	Paper & wood	Rubber	Assembled circuit	Others	Total Weight (kg)
Device 1	11.4	0.7	0.4	0.7	0.9	15.8	1.7	0.1	1.7	1.5	34.9
Device 2	7.8	0.2	0.2	0.5	0.7	11.9	1.8	0.2	1.1	0.7	25.1
Device 3	17.4	0.6	0.6	1.1	1.2	22.3	5.0	0.3	3.5	2.7	54.7
Device 4	8.0	0.2	0.2	0.7	1.0	13.8	2.5	0.3	1.4	1.3	29.5
Device 5	60.9	3.4	1.9	2.0	2.2	38.1	6.2	0.7	3.3	5.8	124.6
Device 6	125.6	4.6	2.3	4.5	2.2	45.7	11.4	0.7	4.8	7.8	209.6
Device 7[116]	1.2	0.1	0.0	0.0	0.7	5.2	0.1	0.1	0.5	0.7	8.6

4.6.1.2 Energy and power consumption of device base cases

In this section, the base cases proposed are characterised in terms of energy and power consumption. Data used in this section has been obtained from the analysis of Energy Star v3.2 database of registered products and with the contribution of device manufacturers. Energy and power consumption of device base cases can be seen in Table 49.

[116] An alternative bill of materials for an inkjet printer can be found in Grzesik et al (2012)

Table 49. Energy and power consumption of device base cases

Devices	Energy Average TEC (kWh/week)	Power Sleep state (W)	Power Off (W)	Default delay time to sleep (minutes)
Device1	0.43	n/a	n/a	5.7
Device2	0.54	n/a	n/a	6.2
Device3	0.69	n/a	n/a	10.6
Device4	1.04	n/a	n/a	11.2
Device5	1.67	n/a	n/a	16.5
Device6	1.86	n/a	n/a	27.6
Device7	n/a	1.10	0.10	10

In order to have a comparable figure for inkjet devices, assumptions have been made regarding the time spent in different operational modes (Table 50).

Table 50. Power and time spent in different operational modes for inkjet devices

	Printing	Ready	Sleep	Off
Power (W)[117]	12	3	1.1	0.1
Time (hours/week)	0.21[118]	0.42 [119]	13.37	154[120]

Based on that, the estimated energy consumption of Device7 is 0.03 kWh/week.

It has also been assumed that the internal power supplies of the base cases are classified as Standard 80 Plus[121] in terms of energy efficiency.

4.6.1.3 Lifetime of device base cases

In order to characterize the typical lifetime of devices, data from different sources has been used.

In the case of laser devices, literature review and data gathered in stakeholder consultation and from visits to refurbishing plants have been used to define the typical lifetime (see more in section 4.4.2):

- Data provided by an OEM suggests that devices are replaced after a period between 5.4 and 6.5 years, depending on the intended use. It has been assumed that Device1 and Device2 correspond to Small Workgroup type of use; Device 3 and Device4 to Medium Workgroup; and Device 5 and Device 6 to Large Workgroup (see Table 28)

In the case of inkjet devices, data from the existing literature and the consumer survey conducted in Task 3 have been considered:

- In Huang et al. (2019) a typical lifetime of 5 years was applied to inkjet devices, based on the inputs of the stakeholders, although technical evidence collected in the preparatory study suggested 4 years.

117 Average inkjet device in the market
118 Assuming 88 pages/month (see Task 3) and 1 minute per page
119 Assuming 5 pages per document printed and 10 minutes delay time to sleep
120 Assuming 22 hours/day is off
121 https://www.clearesult.com/80plus/program-details#program-details-table

- According to the consumer behaviour survey presented in Task 3, the most common age of single-function consumer printers is between 3-5 years. The highest percentage of multi-function printers in use are between 0-3 years.
- According to the interviews with stakeholders and evidence collected, the refurbished market for consumer inkjet printers is negligible and does not have a significant impact on the lifetime of this product category.
- Based on the evidence above, a lifetime of 4 years is considered a reasonable assumption for Device7.

Based on the data above, the lifetime of device base cases can be seen in Table 51.

Table 51. Lifetime of device base cases

Devices	Description	Average lifetime, 1st use (years)	Lifetime, after refurbish (years)	Average frequency of use (pages/month)	Average printed pages (in lifetime)
Device1	Small office, laser A4 color	6.5	1.0	917	82,530
Device2	Small office, laser A4 mono	6.5	1.0	917	82,530
Device3	Large office, laser A4 color	5.4	1.0	1,535	117,888
Device4	Large office, laser A4 mono	5.4	1.0	1,535	117,888
Device5	Large office, laser A3 color	6.2	1.0	3,108	304,307
Device6	Large office, laser A3 mono	6.2	1.0	3,108	304,307
Device7	Household, inkjet A4 color	4	0.0	88[124]	4,224

4.6.1.4 Reparability of device base cases

In section 4.4.3 an analysis is made on reparability of devices. Reparability is a semi-qualitative aspect of a product that cannot be directly measured and characterized with a specific value. However, it can be characterized with aspects such as:

- Spare part provision
- Duration of availability of spare parts
- Delivery time of spare parts
- Cost of spare parts
- Provision of relevant information of repair
- Availability of software and firmware updates

For the characterization of the base cases, information from Ritthoff et al (2023) has been used. In that study, a repair score methodology is proposed for printers. For each of the indicators above, four categories are defined from A-D (A being the best and D being the worst). In this Preparatory Study, it is proposed to use these categories to characterize device base cases and Best Available Technologies. It has been assumed to use category B in

[124] Results from user behaviour study in Task 3

Ritthoff et al (2023) for each of the indicators to define device base cases. As a result, the characteristics of the base cases can be seen in Table 52. Those characteristics are common for the 7 base cases proposed.

Table 52. Reparability of device base cases

Reparability aspect	Characteristics of Base Cases (Device1 – Device7)
Disassembly	High complexity
Spare part provision	A limited list of spare parts, available for professional repairers and authorised services
Duration of availability of spare parts	Medium term availability of spare parts (2-10 years)
Delivery time of spare parts	5-14 working days
Provision of relevant information of repair	Basic information available
Availability of software and firmware updates	Availability of software and firmware updates between 2-10 years after the placing on the market of the last unit of a product model

4.6.1.5 Manufacturing and refurbishing of devices

The energy required to manufacture and assemble printers and multi-function devices is presented in Table 53. This secondary data has been obtained from bibliography review.

Table 53. Energy consumption for product manufacturing

Source: EPA[125]

Device	Energy consumption for product manufacturing (kWh/kg)
MFD color	34.55
Printer monochrome	52.43
MFD monochrome	43.12
Average	48.21

4.6.1.6 Paper use in device bases

As described in section 4.4.5, the availability in devices of functionality such as duplexing capability can contribute to reduce the amount of waste paper.

In the environmental analysis, the "paper use" parameter will be used to evaluate the potential benefit of having duplexing capability. Therefore, only wasted paper will be included in the analysis, and not the paper actually produced as output (since it is obvious that more impact will be generated by devices which print more sheets

[125] https://www.epa.gov/sites/default/files/2018-02/documents/lca_mfd_printer.pdf

of paper). In other words, the paper output satisfactorily produced by the device is not considered an environmental impact. Only paper waste is considered relevant for the environmental assessment.

It has been assumed that all laser base cases (Device1-Device6) have duplexing capability. For the inkjet base case (Device7), it has been assumed that it does not have duplexing capability (Table 54).

Table 54. Paper use in device base cases

Base case	Duplexing capability	Number of documents printed (in lifetime)[126]	Printing frequency of both sides[127] (%)	Paper waste in lifetime (number of A4 sheets)	Paper waste in lifetime[128] (kg)
Device1	Available	16506	58%	13997	9.3
Device2	Available	16506	58%	13997	9.3
Device3	Available	23578	58%	19994	15.6
Device4	Available	23578	58%	19994	15.6
Device5	Available	60861	58%	51610	35.8
Device6	Available	60861	58%	51610	35.8
Device7	Not available	845	20%	1348	1.7

4.6.1.7 Post-consumer recycled plastic in device base cases

There is currently no available data on the average amount of post-consumer recycled plastic in devices placed on the market in the EU. Therefore, for the environmental evaluation of devices it has been assumed that the average percentage of post-consumer recycled plastic is 0%.

4.6.1.8 Purchase price of device base cases

Table 55 shows purchase price of the device base cases defined in this section. Data has been obtained from various sources (Huang et al, 2019 and Consumentenbond.nl).

[126] Assuming an average document length of 5 pages
[127] Weighted average from Consumentenbond.nl (Figure 71)
[128] Assuming that an A4 sheet weight approximately 5 grams

Table 55. Purchase price of device base cases

Base Case	Purchase price (EUR)
Device1	430
Device2	510
Device3	513
Device4	456
Device5	757
Device6	757
Device7	160

4.6.2 Cartridge base cases

The definition of cartridge base cases has been done considering market data presented in Task 2 of the Preparatory Study. In terms of configurations described in Task 1, it has been assumed that cartridge base cases are all-in-one (for toner) or integrated (for ink). Summary of cartridge base cases can be seen in Table 56.

Table 56. Cartridge base cases

Base Case	Description
Cartridge1	Toner cartridge for A4 device (all-in-one)
Cartridge2	Toner cartridge for A3 device (all-in-one)
Cartridge3	Ink cartridge for A4 device (integrated)

The base cases do not represent a specific cartridge in the market, but a theoretical one that aims to represent the average product on market in terms of material use, emissions and functional performance within its segment.

4.6.2.1 Materials used in cartridge base cases

The bill of materials of the cartridge base cases are presented in Table 57. This data has been provided by OEMs in support of the development this Preparatory Study.

Table 57. Cartridge base cases bill of materials

	Steel	Stainless Steel	Aluminium	Other metal	Glass	Plastics	Paper & wood	Rubber	Assembled circuit board	Others
Cartridge 1	18.32%	0.31%	2.27%	0.27%	0.00%	55.67%	6.53%	0.98%	0.25%	15.40%
Cartridge 2	3.51%	6.13%	3.54%	0.77%	0.00%	85.25%	0.17%	0.03%	0.29%	0.30%
Cartridge 3	0.00%	0.84%	0.00%	0.00%	0.00%	97.05%	0.98%	0.31%	0.08%	0.75%

4.6.2.2 Page yield

To define page yield of cartridges, data provided from cartridge manufacturers and remanufacturers has been used.

According to data provided by ETIRA (Figure 78), most of the toner cartridges in the sample have a page yield between 1000 and 4000 pages. Feedback from a toner cartridge manufacturer suggests that the weighted average page yield of their production for A4 devices is 15291 pages. For Cartridge1, an intermediate value between these will be chosen: 7500 pages.

According to data provided by ETIRA, there is a significant number of models providing between 22.000 and 28.000 pages, most likely corresponding to cartridges used in A3 devices. Feedback from a toner cartridge manufacturer suggests that the weighted average page yield of their production for A3 devices is 29471 pages. For Cartridge2, an intermediate value between these will be chosen: 25000 pages.

To define page yield of Cartridge3, data from Figure 79 has been used. It has been assumed that page yield is 300 pages.

The page yield of the cartridge base cases is summarized in Table 58.

Table 58. Page yield of cartridge base cases

Base Case	Description	Page yield
Cartridge1	Toner cartridge for A4 device	7500
Cartridge2	Toner cartridge for A3 device	25000
Cartridge3	Ink cartridge for A4 device	300

4.6.2.3 Material efficiency of cartridge base cases

In order to understand the material efficiency of cartridges in the market, the JRC contracted Keypoint Intelligence to carry out an investigation on this topic. The rational of this test, conducted on real cartridges on the market, has been described in section 4.5.3.2 of this Preparatory Study.

From the analysis of Keypoint Intelligence data, it can be seen that lower material efficiency values correspond to standard, integrated/all-in-one cartridges, ranging between 6-11 pages per gram for toner cartridges, and 8-11 pages per gram for ink cartridges. It has been assumed that cartridge base cases are between those ranges, both for toner and ink. Based on this analysis, material efficiency of cartridge base cases are proposed in Table 59.

Table 59. Material efficiency of cartridge base cases

Base Case	Description	Material efficiency (pages/gram)
Cartridge1	Toner cartridge for A4 device	6.3 [129]
Cartridge2	Toner cartridge for A3 device	11.1 [130]
Cartridge3	Ink cartridge for A4 device	11.0 [131]

For reference, Cartridge1 and Cartridge2 material efficiency can be seen in Figure 99, and Cartridge3 in Figure 100, together with cartridges from ETIRA database.

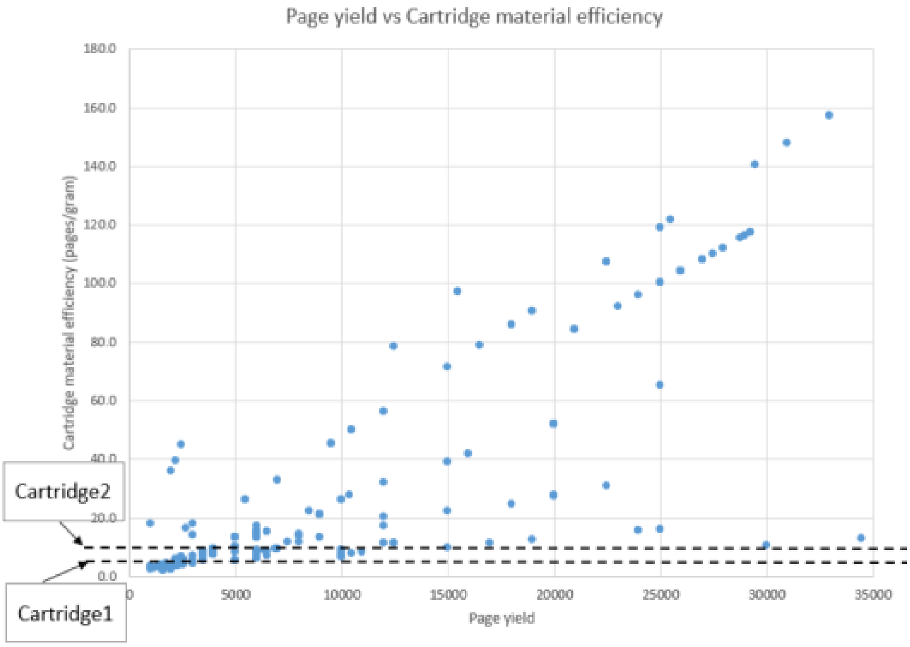


Figure 99. Material efficiency of toner cartridge base cases, in comparison with cartridges in ETIRA database

[129] Keypoint Intelligence data: Standard, integrated, black toner cartridge, for use in Printer
[130] Keypoint Intelligence data: XL, integrated, black toner cartridge, for use in MFP
[131] Keypoint Intelligence data: Standard, integrated, black ink cartridge

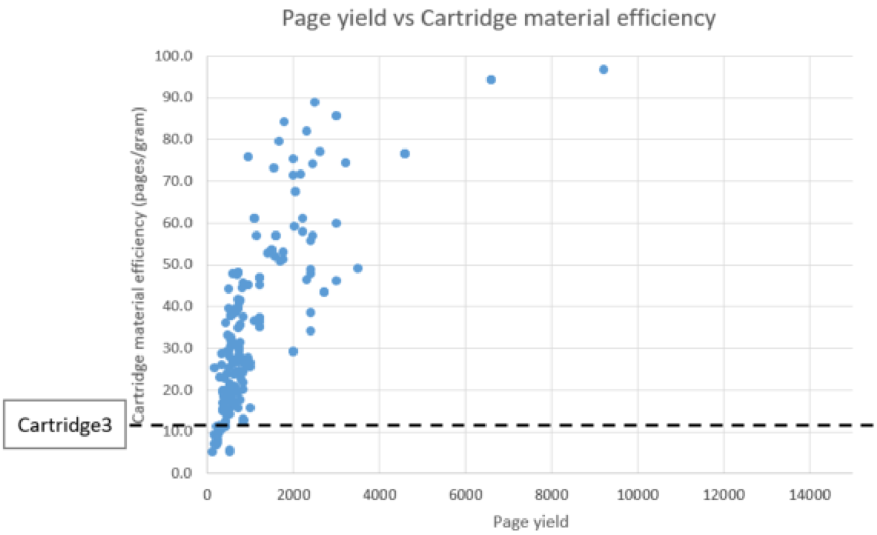


Figure 100. Material efficiency of ink cartridge base cases, in comparison with cartridges in ETIRA database

4.6.2.4 Reusability of cartridge base cases

In section 4.5.11, a detailed description of different aspects of cartridge reuse has been carried out. Reusability is a semi-qualitative aspect that cannot be directly measured, for which it is complex to assign a specific value (similar to the case of printer reparability). Therefore, cartridge base cases have been defined using a series of qualitative parameters.

It is proposed that the list of parameters to characterize cartridge base cases is the list of barriers for cartridge reuse identified in section 4.5.11.2 of this Preparatory Study, a) to k). Therefore, a cartridge base case may be defined as a cartridge with the following characteristics:

> *The cartridge base case is a cartridge with a chip that cannot be reset by third party operators when the cartridge is empty. It uses irreversible joining practices such as gluing and welding in some components. It uses non-durable materials that can be broken during the remanufacturing process. Some fragile components are exposed. It is compatible with a limited number of printer models of the same OEM.*

Since reusability is a semi-qualitative aspect, the authors of this Preparatory Study propose not to use a specific figure to characterize it. In contrast, it is suggested to define three levels of reusability (low, medium and high), which will be related to the characteristics of the cartridges. In each of those categories, cartridges will be assumed to be reused a different number of times (Table 60)

Table 60. Categories of cartridge reusability

Reusability level	Ink cartridge	Toner cartridge
Low	0	0
Medium	0.5	1
High	1	2

Based on the description of the base case provided in this section, and on current reuse rates summarized in section 4.5.11 of this Preparatory Study, it will be assumed that cartridge base cases are, on average, in the Low category of reusability level. This does not mean that every cartridge in the market today has low reusability. It is an attempt to reflect the current average situation of cartridge reusability in the EU, considering current low reuse rates.

4.6.2.5 Paper use of cartridge base cases

As described in section 4.5.7, the printing quality of cartridges has an effect on the amount of wasted paper. Cartridges with the ability of producing output with low failure rates generate less waste.

In the environmental analysis, the “paper use” parameter will be used to evaluate the benefit of reduced failure rates. Therefore, only wasted paper will be included in the analysis, and not the paper actually produced as output (since it is obvious that more impact will be generated by cartridges which print more sheets of paper). As in the case of devices, the paper output satisfactorily produced by the cartridge is not considered an environmental impact. Only paper waste is considered relevant for the environmental assessment.

For this, assumptions have been made based on failure rates of cartridges. For all cartridge base bases, a 2% failure rate is proposed (Table 61).

Table 61. Failure rates in cartridges, to estimate paper wasted in base cases

Base case	Failure rate (1)	Paper wasted in lifetime[132] (kg)
Cartridge1	2%	0.38
Cartridge2	2%	1.25
Cartridge3	2%	0.02

(1) Percentage of unusable sheets of paper.

4.6.2.6 Manufacturing and remanufacturing of cartridges

The energy required to manufacture and remanufacture cartridges is presented in Table 62. Data has been provided by a stakeholder in the cartridge remanufacturing business.

Table 62. Energy required to manufacture and remanufacture cartridges

Energy consumption of cartridge manufacturing	9.01 kWh/kg [133]
Energy consumption of cartridge remanufacturing	1.32 kWh/kg [134]
Mass of substituted components at cartridge remanufacturing	7% [135]

4.6.2.7 Cost per page of cartridge base cases

In section 4.5.4 of the Preparatory Study, the cost of printing has been evaluated, considering different types of OEM cartridges. This data will be used to define the cost per page of cartridge base cases (Table 63).

[132] Assuming that an A4 sheet of paper weighs approximately 5 grams
[133] Secondary data provided by SAPI (Ecoinvent)
[134] Primary data provided by SAPI
[135] Primary data provided by SAPI

Table 63. Cost per page of cartridge base cases

Base case	Type of cartridge	Page yield	Correlation page yield-cost per page
Cartridge1	Toner for A4 device, standard size, all-in-one	7500	Cost per page = 221*Yield$^{-0.564}$
Cartridge2	Toner for A3 device, XL size, all-in-one	25000	Cost per page = 90*Yield$^{-0.451}$
Cartridge3	Ink for A4 device, standard size, integrated	300	Cost per page = 560*Yield$^{-0.739}$

In this Preparatory Study, it has been assumed that printing with remanufactured cartridges is 40% cheaper than with original ones.

The estimated cost of printing with each of the cartridge base cases can be seen in Figure 101, Figure 102 and Figure 103.

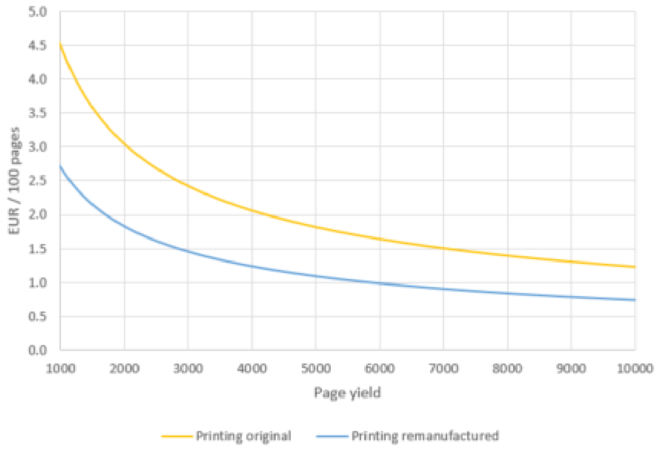


Figure 101. Estimated cost of printing with toner cartridges for A4 device (Cartridge1)

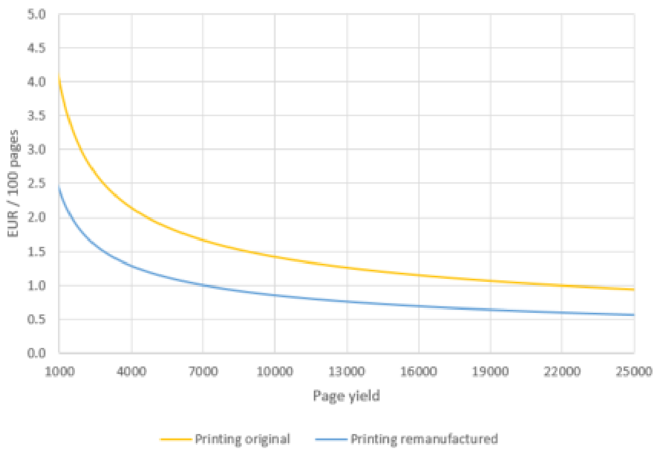


Figure 102. Estimated cost of printing with toner cartridges for A3 device (Cartridge2)

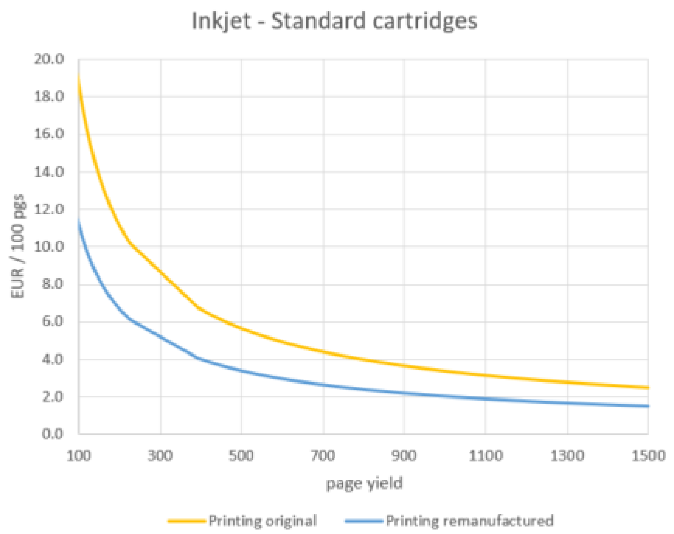


Figure 103. Estimated cost of printing with ink cartridges (Cartridge3)

Printing with remanufactured cartridges is generally cheaper than with OEM cartridges, due to the lower purchase price of remanufactured ones. According to Huang et al (2019), printing with remanufactured cartridges is between 25-83% cheaper than with original cartridges, depending on the device under evaluation. In Waugh et al (2018), it is estimated that reused cartridges are between 30-70% cheaper than new ones, depending on region and other factors. According to the ETIRA, printing with remanufactured cartridges is between 20-30% cheaper than the OEM equivalents[136].

4.7 Best Available Technologies

4.7.1 Devices Best Available Technologies

In this section, the Best Available Technologies (BAT) on devices have been presented. For each of the aspects covered in section 4.6 on Base Cases, the BAT has also been identified. The BATs have been used in Task 6 of this Preparatory Study to propose design options with the potential to improve the environmental performance of the base cases.

4.7.1.1 Energy and power consumption

In section 4.4.1, an analysis has been made of average energy and power consumption of MFDs and printers, for different ranges of printing speeds. This analysis is used to define the base cases of this Preparatory Study. For the identification of the Best Available Technologies regarding energy and power consumption, it has been assumed that they correspond to the best 10% percentile (Table 64).

[136] https://www.etira.org/about-etira/frequently-asked-questions/

Table 64. Energy and power consumption of device BAT

	Speed (ipm)	BAT TEC (kWh/week)	BAT Power Sleep state (W)	BAT Power Off (W)	BAT Default time to sleep (minutes)
Small office, laser A4 color	26	0.29	n/a	n/a	1
Small office, laser A4 mono	42	0.45	n/a	n/a	1
Large office, laser A4 color	52	0.54	n/a	n/a	1
Large office, laser A4 mono	70	0.88	n/a	n/a	1
Large office, laser A3 color	80	1.39	n/a	n/a	1
Large office, laser A3 mono	90	1.83	n/a	n/a	16
Household, inkjet A4 color	15	n/a	0.61	0.07	5

Additionally, laser devices BAT have a switch that immediately turns the device in standby mode. They also have a clearly displayed energy saver programme like in the picture below:

- The availability of an easy to reach function allowing the machine to enter the Sleep mode in an easy and quick way, by pressing a simple button (Energy Saver)[137] (see Figure 104)
- The availability of an ECO Night Sensor that can detect darkness and automatically turn off this product's power. If ECO Night Sensor[138] is enabled and detects darkness in a room after the lights are turned off, the sensor automatically turns the power off and reduces the power consumption of this product to 1W or less.

Figure 104: Example of Energy Saver Functionality

It has also been assumed that the internal power supplies of the Best Available Technologies are classified as 80 Plus Titanium[139] in terms of energy efficiency.

[137] http://ppbwiki.rz-berlin.mpg.de/uploads/Main.CanonImageRunnner/manual/uk_iRADV_500i_Manual/contents/1T0002183321.html

[138] http://support.ricoh.com/bb_v1oi/pub_e/oi_view/0001057/0001057280/view/manual/int/0052.htm

[139] https://www.clearesult.com/80plus/program-details#program-details-table

4.7.1.2 Lifetime

In section 4.4.2.1 of the Preparatory Study, data provided by stakeholders on device lifetime in the business sector has been presented. According to this feedback, a 4-year old device with 85% of remaining lifetime can be refurbished up to its initial conditions. A device can be refurbished up to 3 times. Its technical lifetime can be estimated between 12-14 years. It has be assumed that lifetime of the BAT in the office environment (laser printers) is 14 years.

As described in 4.4.2.2, there is a gap between actual device lifetime of domestic printers (between 3-5 years) and the expected lifetime by consumers before replacing it (between 5-10 years). Moreover, according to the user survey a 5% of the respondents declared to have a printer older than 10 years. For the characterization of the BAT, it has been assumed that consumer expectations in terms of device lifetime are fulfilled. Therefore the BAT of inkjet printers is considered 10 years.

4.7.1.3 Reparability

In this Preparatory Study, it is proposed to use the categories defined in Ritthoff et al (2023) to characterize device base cases and Best Available Technologies. It has been assumed that the 1st category in Ritthoff et al (2023) for each of the indicators is the one that most accurately reflects device Best Available Technologies. As a result, the characteristics of the BATs can be seen in Table 65.

Table 65. Reparability of Best Available Technologies

Aspect	Inkjet devices	Laser devices
Disassembly	Characteristics of Best Available Technology: - Repair feasible with basic tools - Use of removable fasteners - The number of work steps required to disassembly a priority part is ≤ 70% of the mean value	Characteristics of Best Available Technology: - Repair feasible with basic tools - Use of removable fasteners - the number of work steps required to disassembly a priority part is ≤ 70% of the mean value
Spare part provision	A comprehensive list of spare parts, available to end-users and professional repairers	A comprehensive list of spare parts, available to end-users and professional repairers
Duration of availability of spare parts	Long term availability of spare parts (10 years)	Long term availability of spare parts (14 years)
Delivery time of spare parts	2 working days for consumables 2 working days for other priority parts	2 working days for consumables 4 working days for other priority parts
Provision of relevant information of repair	Comprehensive information available for users and repairers	Comprehensive information available for users and repairers
Availability of software and firmware updates	Long term availability of software and firmware updates (10 years after the placing on the market of the last unit of a product model)	Long term availability of software and firmware updates (14 years after the placing on the market of the last unit of a product model)

Restoring of factory settings and resetting passwords	Restoring factory settings and resetting passwords is possible with the help of a function integrated in the device	Restoring factory settings and resetting passwords is possible with the help of a function integrated in the device

4.7.1.4 Paper use

In terms of paper use it has been assumed that the Best Available Technology is a device that contains both duplexing capability and n-up printing, in order to reduce the amount of wasted paper.

4.7.2 Cartridges Best Available Technologies

In this section, the Best Available Technologies (BAT) on cartridges have been presented. For each of the aspects covered in section 4.6 on Base Cases, the BAT has also been identified. The BATs have been used in Task 6 of this Preparatory Study to propose design options with the potential to improve the environmental performance of the base cases.

4.7.2.1 Material efficiency

Based on data from Keypoint Intelligence presented in section 4.5.3.2, the Best Available Technology for toner cartridges in terms of material efficiency is 97 pages per gram, achieved by a standard, single part, black cartridge, for use in a MFP (Figure 105).

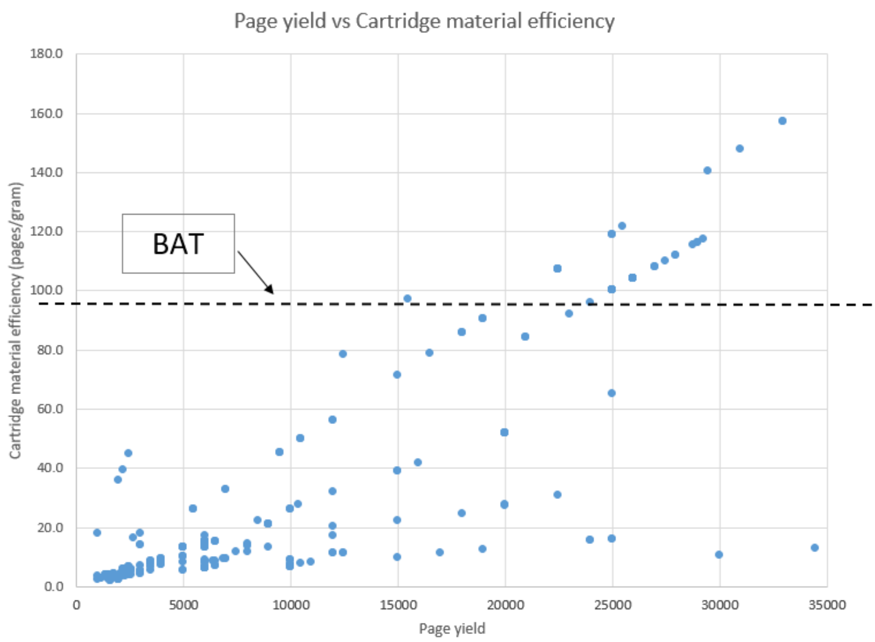


Figure 105. Material efficiency of Best Available Technologies of toner cartridges

As can be seen, some of the toner cartridges in ETIRA database have higher material efficiency values than the BAT indicated by Keypoint Intelligence data. It can be interpreted that any cartridge beyond that value (97 pages per gram) is among the BATs of toner cartridges.

For ink cartridges, the BAT in terms of material efficiency is 40 pages per gram, achieved by a XL, single part, black cartridge (Figure 106).

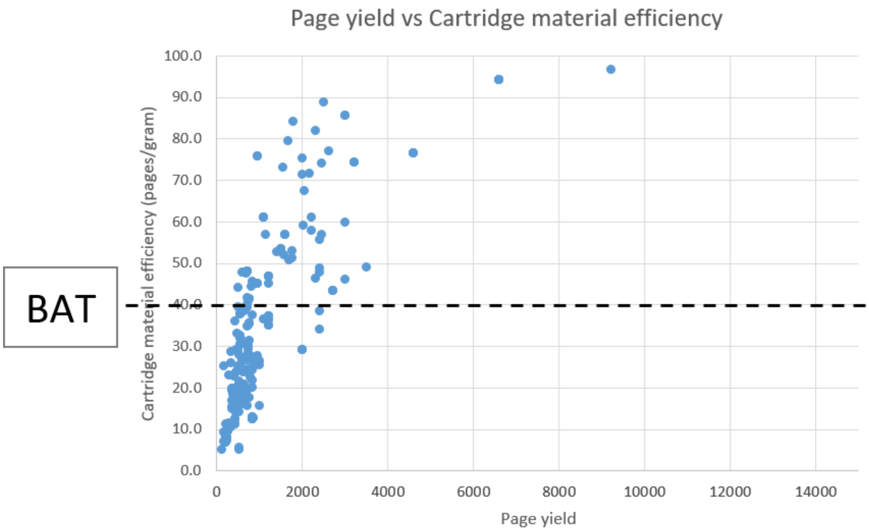


Figure 106. Material efficiency of Best Available Technologies of ink cartridges

As can be seen, some of the ink cartridges in ETIRA database have higher material efficiency values than the BAT indicated by Keypoint Intelligence data. A possible interpretation could be that any cartridge beyond that value (40 pages per gram) is among the BATs of ink cartridges.

4.7.2.2 Reusability

In this Preparatory Study, it is proposed that the list of indicators to characterize cartridge Best Available Technologies is the list of barriers for cartridge reuse identified in section 4.5.8.1 of this report, a) to k). Therefore, a cartridge BAT may be defined as a cartridge with the following characteristics:

> *The cartridge Best Available Technology is a cartridge with a chip that can be reset by third party operators when the cartridge is empty. The location of the chip is easily accessible. It does not use irreversible joining practices. Durable materials are used and fragile components are protected. It is compatible with a wide range of printer models of the same OEM.*

Based on the description of the Best Available Technology provided in this section, and on technical potential reuse rates summarized in section 4.5.11 of this Preparatory Study, it has been assumed that cartridge Best Available Technologies are, on average, in the High category of reusability level.

Table 66. Cartridges Best Available Technologies reusability

Base case	Reusability level	Average number of reuses
Cartridge1	High	2
Cartridge2	High	2
Cartridge3	High	1

The aim of this approach is not to suggest that every cartridge in the market should be reusable the number of times indicated in Table 66, but to show the improvement potential in terms of reusability when comparing the base case and the BAT, taking into account the qualitative descriptions provided.

4.7.2.3 Paper use

In terms of paper use, considering that a 3% failure rate was assumed by the JRC for the base cases in section 4.6.2.5, a 1% failure rate is proposed for the cartridge Best Available Technologies.

4.7.2.4 Cartridge monitoring and traceability

Cartridge traceability has been mentioned by some stakeholders as an aspect that could contribute significantly to increase the amount of cartridges that are reused. Knowing who the original manufacturer was, how many times the cartridge has been remanufactured for reuse and who did the remanufacturing is valuable information for the remanufacturers, in order to determine whether or not the cartridge can be remanufactured for one more use cycle.

A stakeholder in the Managed Print Services sector suggests that, as part of cartridge traceability strategy, the following data should be registered in the chip after every cycle of use:

- ID of remanufacturer
- Date of remanufacturing
- ID of manufacturer
- Serial number
- Compliance with regulation 2019/1020 on product market surveillance

With a proper cartridge and monitoring system, collectors of empty cartridges would have access to the data above online, making it easier to diagnose the quality of the empty cartridge and anticipating its destination.

Moreover traceability can be a way to avoid counterfeiting in the remanufacturing sector. An interesting example comes from Italy where the collection company Ecorecuperi, in collaboration with the association Pacto, has developed a traceability system based on blockchain technology, aiming to track the placing on the market of remanufactured cartridges from the collection of empty cartridges up to their deliver to the final users[140].

It is worth noting that currently existing subscription services require the use of monitoring technology, no matter if they are installed in a large corporate office or in a household.

4.8 Best Not Available Technologies

4.8.1 Easy to access page counter

As explained in section 4.4.2 printers' technical lifetime are often not fulfilled in terms of the amount of pages they can print. A potential solution to tackle these issues, proposed by a stakeholder, is to include an easy-to-access page counter. Although page counting functionality is already available in all printers, easy user access to this information is not common. This page counter should be available for users in the display –if the printer has a display- or in any other location of the printer accessible for the user.

Ideally, this page counter shall show the number of pages printed, relative to the total number of pages that the device is able to produce (its technical lifetime). That way, the user could be aware at each point of the remaining available life of the device, potentially avoiding the removal of printers with significant lifetime still available.

4.8.2 Cartridge standardization

As described in section 4.5.5, there seems to be a wide range of single product models in the cartridge market, often very similar between them in design, but only compatible with a limited number of printer models, due to the addition of superfluous design features. In section 4.5.11.2, this has been described as a barrier to cartridge reuse.

This strategy goes in the opposite direction of cartridge standardization. Designing cartridges with the aim of making them compatible with the highest amount of printer models could contribute significantly to increase cartridge reuse rates, and ultimately to the reduction of waste.

Printers that have similar functionality or performance could share the same design features that allow the use of a wider number of models today. The aim of this strategy would be to avoid the introduction of design features in printers or in cartridges that do not add relevant functionality, and that avoid their interchangeability.

140 https://www.ecorecuperi.it/tracciabilita_delle_cartucce/

5 Task 5 – Environment and Economics

The aim of this section is to assess the environmental and economic impacts associated with different base cases of devices and cartridges described in Task 4.

5.1 Life cycle assessment of device base cases

The environmental assessment consists in a Life Cycle Assessment (LCA) study conducted using an updated version of EcoReport Tool (Caldas et al, 2021), with data collected in Tasks 1-4 of this Preparatory Study.

5.1.1 Goal, functional unit and system boundaries

The goal of this LCA study is to evaluate the environmental impacts of the device base cases proposed in section 4.6.1 of this Preparatory Study. The environmental hotspots of devices will be identified, as well as the potential areas of improvement. Based on those, design options will be proposed and evaluated in Task 6 of this Preparatory Study.

The Functional Unit (FU) is a quantified description of the performance of the product systems, for use as a reference unit (Weidema et al., 2004) and forms the baseline for comparing product substitutions (Guinée, 2002). In general, the FU is not simply a product or quantities of materials, it is also related to the function or performance of the product.

Although it was not defined explicitly, the FU in Huang et al (2019) was the product itself: “the production and use of a device for a given number of years”. This approach has some advantages, such as the simple direct comparison between different products. However, it also has some drawbacks: the products performing better in terms of environment are the lighter/simpler in terms of technology and performance. On top of that, this approach does not take into account, for instance, that a large A3 multi-function device will produce a significantly higher number of pages during its lifetime, compared to a household inkjet single-function printer. In other words, it can be expected that the overall environmental impact of the A3 MFD will be higher, but the performance and overall output will also be higher.

In order to take this into account, it has been decided to compare the device base cases in terms of an equivalent number of pages. Therefore, the FU of this LCA study is:

The production of 1 printed page with each of the device base cases

A graphical representation of the FU selected can also be seen in Figure 107. Device5 and Device6 produce a significantly higher number of pages in their lifetime, compared to Device7, for instance. Consequently, the overall impacts of Device5 and Device6 will be higher, using as a reference the product itself (as in Huang et al, 2019). In contrast, as proposed in this Preparatory Study, using as a FU “the production of 1 printed page” allows to compare the devices on equivalent terms.

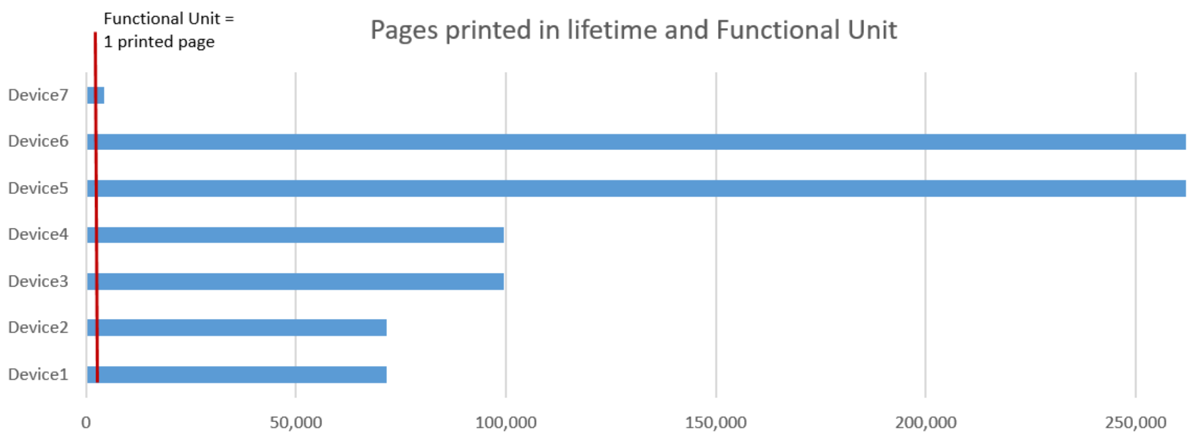


Figure 107. Pages printed in lifetime and Functional Unit for the LCA study

A list of potential FU to evaluate the impact of a printer was presented in Bousquin et al (2012). A different number of pages could also have been used as a FU (for instance, “the production of 100,000 pages”). Alternatively, a time-related FU could have been used as well (“the use of a device for 5 years”). However, the authors consider that presenting results on a "per page" basis can help to understand in a simpler way the environmental impact incurred by each of the devices.

The system boundaries of the LCA study are described in Figure 108 (devices without refurbishing) and Figure 109 (devices with refurbishing). In both systems, the first life cycle stages (raw materials, manufacturing & assembly, transport from manufacturing location to EU, and use) are common. Then, in the system without refurbishing, the device is transported from the place of use to the end of life site, and then undergoes the end of life treatment.

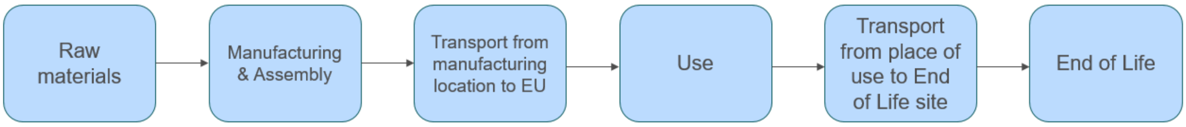


Figure 108. System boundaries of device base cases without refurbishing

In contrast, in the system with refurbishing, after use the device is transported to the refurbishing site, parts are replaced, energy is consumed in the refurbishing process and the use of the device is extended for a period of time, before being transported from the place of use to the end of life site.

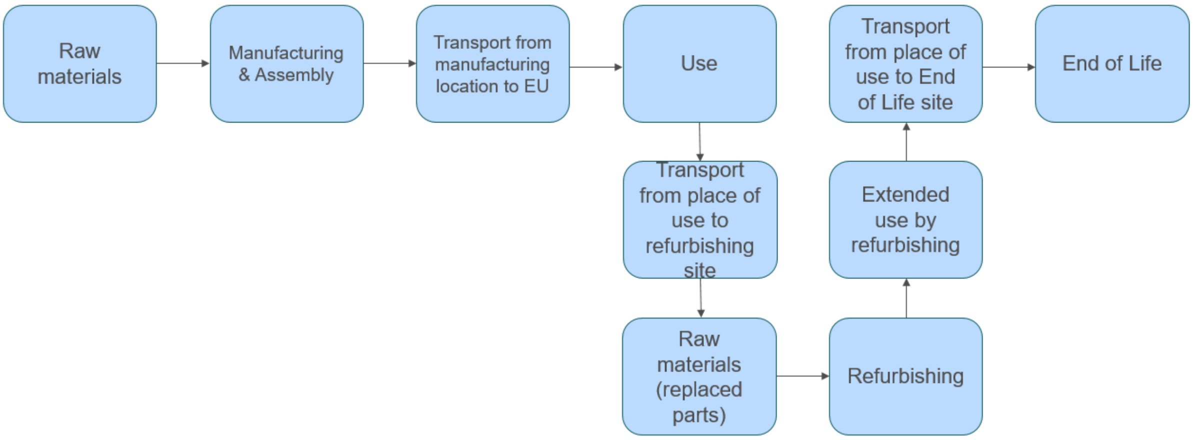


Figure 109. System boundaries of device base cases with refurbishing

The description of each of the life cycle stages can be seen in Table 67.

Table 67. System boundaries of device base cases

Life cycle stage	Description
Raw materials (for manufacturing)	Materials needed to manufacture the device
Manufacturing & Assembly	Energy needed to manufacture the different components and assembly the device
Transport	- From manufacturing location to EU (road + ship) - From place of use to refurbishing centre (road) - From place of use to end of life site (road)
Use	Energy and resources consumed during lifetime of the device: - Electricity consumption in different operational modes - Paper use
Raw materials (for refurbishing)	Materials needed to refurbish the device
Refurbishing	Energy needed to refurbish the device
End of life	Recyclability rate of materials

5.1.2 Impact categories and indicators

In the environmental assessment carried out in this section, results have been provided on 17 impact categories, as developed for the Environmental Footprint methods (Table 68).

Table 68. Impact categories evaluated

Impact categories	Unit of measure
Climate change, total	kg CO_2 eq
Ozone depletion	kg CFC-11 eq
Human toxicity, cancer	CTUh
Human toxicity, non-cancer	CTUh
Particulate matter	disease incidence
Ionising radiation, human health	kBq U_{235} eq
Photochemical ozone formation, human health	kg NMVOC eq
Acidification	mol H+ eq
Eutrophication, terrestrial	mol N eq
Eutrophication, freshwater	kg P eq
Eutrophication, marine	kg N eq
Ecotoxicity, freshwater	CTUe
Land use	pt
Water use	m^3 water eq. of deprived water
Resource use, minerals and metals	kg Sb eq
Resource use, fossils	MJ
Primary energy consumption	MJ

A detailed description of the interpretation of those impact categories can be found in Commission Recommendation 2021/2279 on the use of Environmental Footprint methods to measure and communicate the life cycle environmental performance of products and organisations[141]. For simplification purposes, in the following sections results have been presented in a graphical style only for one of the impact categories in Table 68 (Climate Change, total). Results for the remaining impact categories can be seen in Annex I.

5.1.3 Inventory data

The inventory data used for the environmental assessment of the device base cases is described in Table 69.

[141] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32021H2279

Table 69. Inventory data used for device base cases

Life cycle stage	Inventory data
Raw materials (for manufacturing)	Table 48
Manufacturing & Assembly	Table 53
Transport	- From manufacturing location to EU (600 km road + 12,000 km ship)[142] - From place of use to refurbishing centre (100 km road for laser devices, 50 km road for inkjet devices) - From place of use to end of life site (20 km road)
Use	Lifetime: Table 51 Electricity consumption: Table 49 Paper use: Table 54[143]
Raw materials (for remanufacturing)	Laser devices: 1 repair / lifetime. Spare parts needed to refurbish the device: 20% of device mass Inkjet devices: 0 repairs / lifetime
Refurbishing	Assumed as 10% of product manufacturing
End of life	Assumed a recyclability rate of 50%

5.1.4 Life cycle impact assessment

The results from the environmental assessment of device base cases are presented using as a reference (functional unit) the production of one printed page. In this section, graphical results are presented and commented for Climate Change. The results of the remaining impact categories are available in Table 138 to Table 144 of Annex I.

Figure 110 shows the impact of the device base cases on Climate Change, expressed as grams of CO_2 equivalent per page printed. The main findings from this assessment are summarized below:

- Comparing base cases between each other, the one with the highest impact is Device7 (household inkjet A4 color), with 47 gCO2eq/page; and the one with the lowest impact is Device4 (large office, laser A4 mono), with 9 gCO2eq/page.
- Although Device7 is the lightest device (less impact on absolute terms on materials production and manufacturing), the low number of pages produced after its lifetime (around 4200) is the cause for the high impact per page.

[142] The manufacturing location has been assumed to be in Asia. The road distance between the manufacturing location and the shipping origin is assumed as 300 km. The shipping distance between origin and destination in the EU has been estimated as 12,000 km. The road distance between the shipping destination and the point of sale has been assumed as 300 km. Road transport assumed with "Articulated lorry transport, Euro 5, Total weight>32 t diesel driven". Ship transport assumed with "Transoceanic ship, containers heavy fuel oil driven, cargo consumption mix, to consumer 27.500 dwt payload capacity".

[143] To estimate paper waste, it has been assumed that the average document length is 5 pages and that the average paper sheet weighs 5 grams

- The life cycle stages with the highest contribution to the impact are raw materials and product manufacturing. This can probably be attributed to the fact that imaging equipment devices are complex products with a wide variety of materials and components, which require a significant amount of energy to produce and assemble. The environmental relevance of the manufacturing stage was also observed in Grzesik et al (2012).
- Use (accounting for electricity use and paper wasted) and refurbishing (assuming 1 refurbishing per lifetime) stages have a smaller contribution to the impact on climate change. Distribution and end of life are negligible. A negative value can be observed regarding the end of life, related to the avoided impact due to the recycling of materials: it has been assumed that 50% of materials are sent to recycling at end of life; and by recycling, the use of virging materials is avoided (this is represented in LCA methodology by a negative impact).

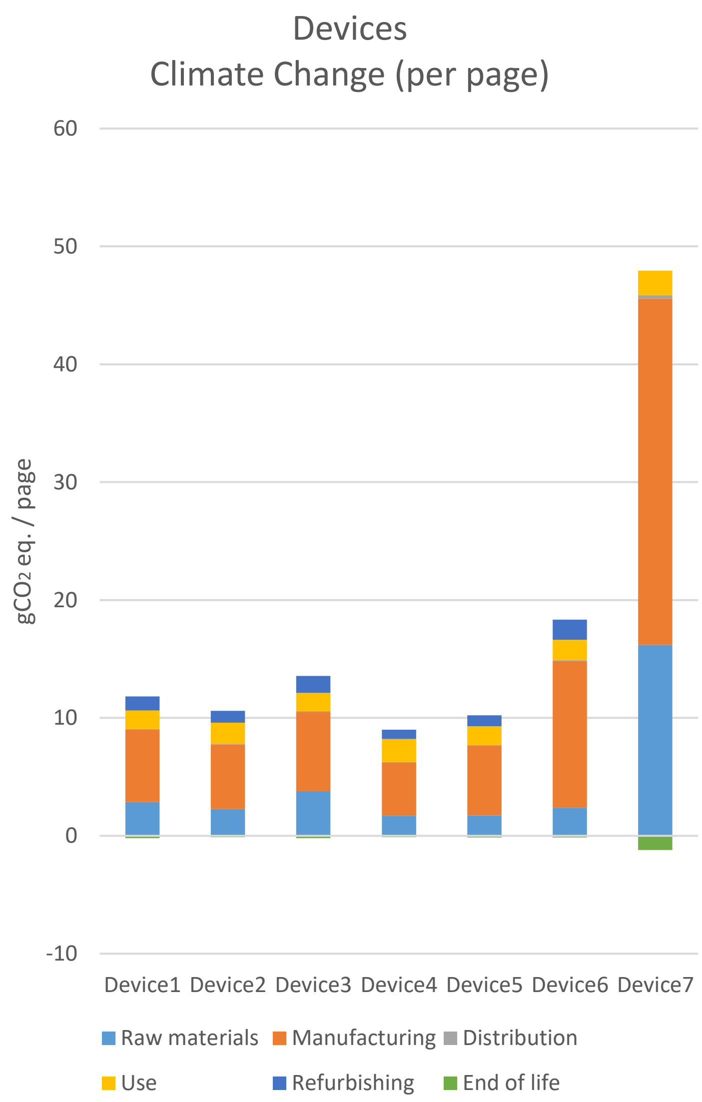


Figure 110. Device base cases – Impact on Climate change

The results on climate change can also be seen in Table 70.

Table 70. Device base cases – Impact on Climate change (gCO2eq./page)

	Raw materials	Manufacturing	Distribution	Use	Refurbishing	End of life	Total
Device1	2.87	6.12	0.06	1.58	1.19	-0.20	11.63
Device2	2.26	5.49	0.05	1.80	1.00	-0.13	10.47
Device3	3.80	6.72	0.07	1.54	1.43	-0.19	13.37
Device4	1.69	4.52	0.04	1.96	0.79	-0.11	8.89
Device5	1.72	5.92	0.06	1.59	0.94	-0.15	10.08
Device6	2.39	12.44	0.10	1.69	1.72	-0.15	18.19
Device7	16.19	29.37	0.30	2.08	0.00	-1.19	46.75

5.2 Life cycle assessment of cartridge base cases

5.2.1 Goal, functional unit and system boundaries

The goal of this LCA study is to evaluate the environmental impacts of the cartridge base cases proposed in section 4.6.2 of this Preparatory Study. The environmental hotspots of cartridges will be identified, as well as the potential areas of improvement. Based on those, design options will be proposed and evaluated in Task 6 of this Preparatory Study.

Following a similar reasoning as described in section 5.1.1, the Functional Unit (FU) of this LCA study is:

The production of 1 printed page with each of the cartridge base cases

The environmental impact of the cartridges will be expressed on a "per page" basis.

The system boundaries of the LCA study are described in Figure 111 (cartridges without remanufacturing) and Figure 112 (cartridges with remanufacturing). In both systems, the first life cycle stages (raw materials, manufacturing & assembly, transport from manufacturing location to EU, and use) are common. Then, in the system without remanufacturing, the cartridge is transported from the place of use to the end of life site, and then undergoes the end of life treatment.

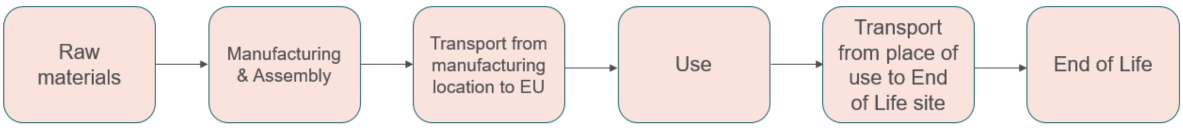


Figure 111. System boundaries of cartridge base cases without remanufacturing

In contrast, in the system with remanufacturing, after use the cartridge is transported to the remanufacturing site, components are replaced, energy is consumed in the remanufacturing process and the use of the cartridge is extended for a period of time, before being transported from the place of use to the end of life site.

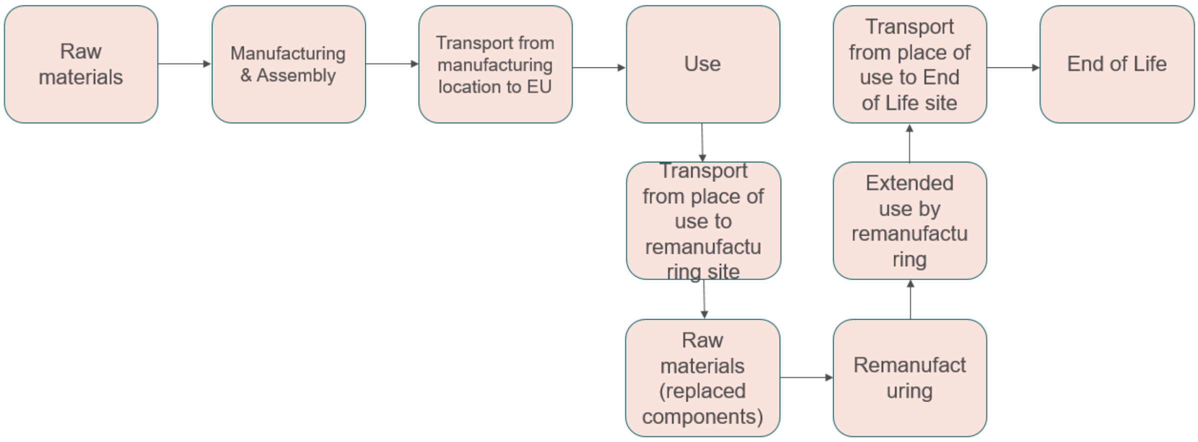


Figure 112. System boundaries of cartridge base cases with remanufacturing

The description of each of the life cycle stages can be seen in Table 71.

Table 71. System boundaries of cartridge base cases

Life cycle stage	Description
Raw materials (for manufacturing)	Materials needed to manufacture the cartridge
Manufacturing & Assembly	Energy needed to manufacture the different components and assembly the cartridge
Transport	- From manufacturing location to EU (road + ship) - From place of use to remanufacturing centre (road) - From place of use to end of life site (road)
Use	Resources consumed during lifetime of the cartridge: - Paper waste
Raw materials (for remanufacturing)	Materials needed to remanufacture the cartridge
Remanufacturing	Energy needed to remanufacture the cartridge
End of life	Recyclability rate of materials

5.2.2 Impact categories and indicators

The impact categories and indicators selected to evaluate the environmental impact of the cartridge base cases are the same as in section 5.1.2 for the device base cases.

5.2.3 Inventory data

The inventory data used for the environmental assessment of cartridge base cases is described in Table 72.

Table 72. Inventory data used for cartridge base cases

Life cycle stage	Description
Raw materials (for manufacturing)	Bill of materials: Table 57 Material efficiency: Table 59
Manufacturing & Assembly	Table 62
Transport	- From manufacturing location to EU (600 km road + 12,000 km ship)[144] - From place of use to remanufacturing centre (500 km road) - From place of use to end of life site (20 km road)
Use	Page yield: Table 58 Reuse cycles: 0 (Table 60) Paper use: Table 61[145]
Raw materials (for remanufacturing)	Table 62
Remanufacturing	Table 62
End of life	Assumed a recyclability rate of 50%

5.2.4 Life cycle impact assessment

The results from the environmental assessment of cartridge base cases are presented using as a reference (functional unit) the production of one printed page. In this section, graphical results are presented and commented for Climate Change. The results of the remaining impact categories are available in Table 145, Table 146 and Table 147 of Annex I.

Figure 113 shows the impact of the cartridge base cases on Climate Change, expressed as grams of CO_2 equivalent per page printed over lifetime. The main findings from this assessment are summarized below:

- Comparing base cases between each other, the one with the highest impact is Cartridge1 (toner cartridge for A4 device, all-in-one), with 0.97 gCO2eq/page; and the one with the lowest impact is Cartridge3 (ink cartridge for A4 device, integrated), with 0.60 gCO2eq/page.
- Although Cartridge1 is lighter than Cartridge2 (less impact on absolute terms on materials production and manufacturing), the lower number of pages provided (page yield of 7500) is the cause for the high impact per page.
- The life cycle stages with the highest contribution to the impact are raw materials and product manufacturing. This suggests that cartridges are also complex products with a wide variety of materials and components, which require a significant amount of energy to produce and assemble.

[144] The manufacturing location has been assumed to be in Asia. The road distance between the manufacturing location and the shipping origin is assumed as 300 km. The shipping distance between origin and destination in the EU has been estimated as 12,000 km. The road distance between the shipping destination and the point of sale has been assumed as 300 km.

[145] To estimate paper waste, it has been assumed that the average document length is 5 pages and that the average paper sheet weighs 5 grams

- Use (accounting for paper wasted) stage and end of life have a smaller contribution to the impact on climate change. Distribution is negligible and remanufacturing has no impact, since it has been assumed that the cartridge base cases are not remanufactured.

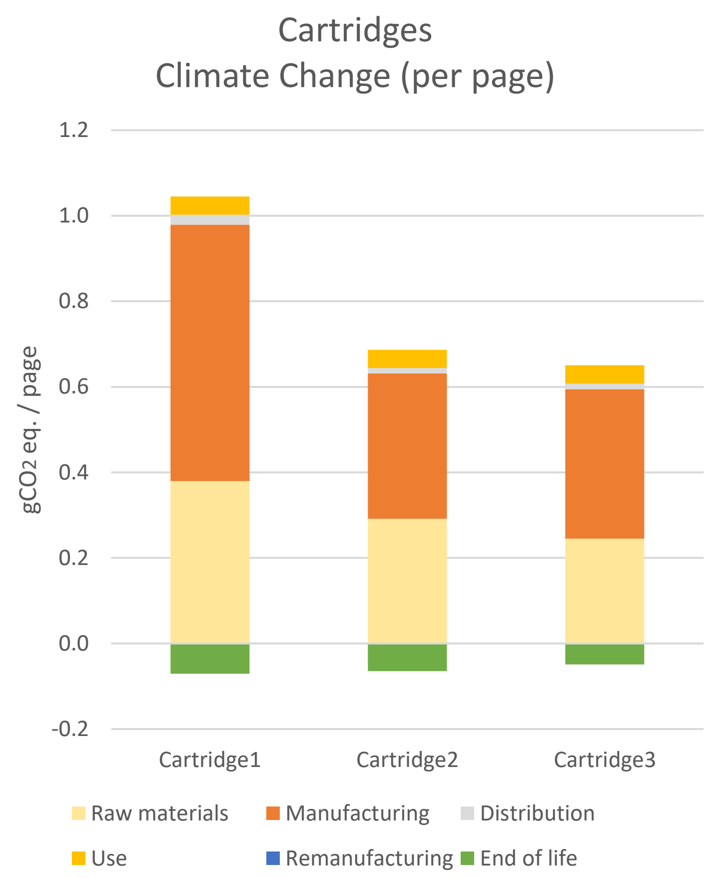


Figure 113. Cartridge base cases – Impact on climate change

The results on Climate change can also be seen in Table 73.

Table 73. Cartridge base cases – Impact on climate change (gCO2eq / page)

	Raw materials	Manufacturing	Distribution	Use	Remanufacturing	End of life	Total
Cartridge1	0.38	0.60	0.02	0.04	0.00	-0.07	0.97
Cartridge2	0.29	0.34	0.01	0.04	0.00	-0.06	0.62
Cartridge3	0.25	0.35	0.01	0.04	0.00	-0.05	0.60

5.3 Life cycle costing of device base cases

In this section, the life cycle costing (LCC) of the device base cases has been presented.

For each base case, the LCC has been estimated as follows (Table 74):

Life Cycle Cost = (Purchase price + Use + Refurbishing) / Pages printed in lifetime

Table 74. Life cycle costing of device base cases

	Data and assumptions
Purchase price	Purchase price of device base cases has been estimated in Table 55.
Use (electricity + paper)	Electricity expenditure has been estimated taking into account the electricity consumption of each device (Table 49) and electricity cost of 0.25 EUR/kWh[148]). Paper expenditure represents the cost of wasted paper, as explained in 4.6.1.6. It has been assumed that each sheet of paper costs 0.01 EUR.
Refurbishing (refurbishing + transport)	Refurbish expenditure represents the cost of refurbishing the device (once in the base cases). Repair costs in the EU have been presented in Figure 70 (assuming 30 EUR/h as an average). It has been assumed that each refurbishing events takes a total of 3 hours. Transport expenditure represents the cost to the user of transporting the device to the refurbishing centre (one event in the base case) and to the recycling centre at end of life (also one event). Transport distances have been estimated in Table 69. The cost of transport by car has been estimated as 0.10 EUR/km.

The LCC of the device base cases can be seen in Figure 114. The main findings of this analysis are summarized below:

- The base case with the highest cost (per page) is Device7 (household inkjet A4 color) with 4 EUR/100 pages. In contrast, the cost of printing 100 pages with Device5 is 0.50 EUR.
- The high cost of printing with Device7 is again related to the low number of pages produced over its lifetime (around 4200).
- In devices printing lower number of pages across their lifetime (such as Device7, Device1, and Device2), the stage with the highest contribution to the LCC is the purchase price. In devices printing a high number of pages (such as Device5 or Device6), the purchase price is less relevant, having similar importance than the use stage.

[148] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Electricity_price_statistics

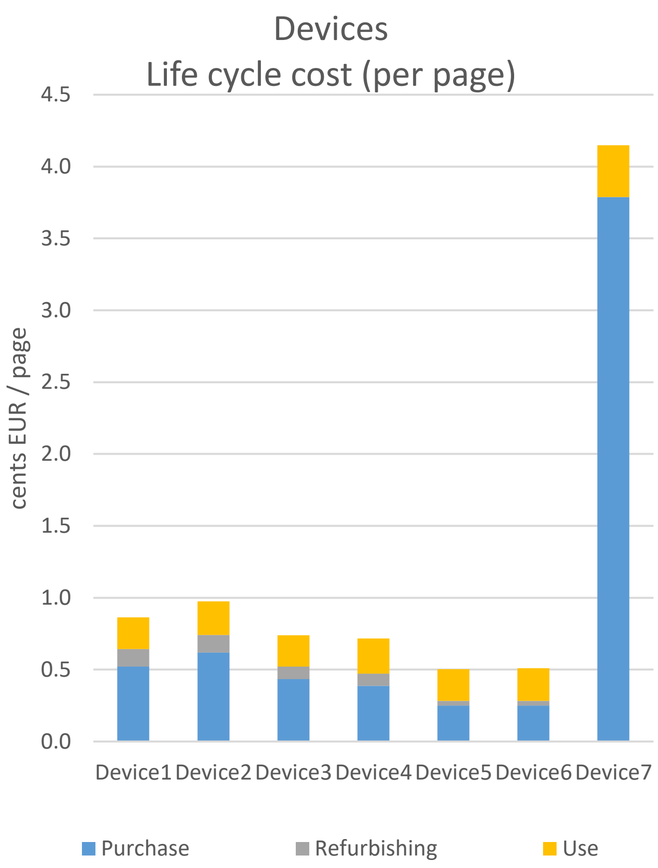


Figure 114. Life cycle costing of device base cases

Table 75. Life cycle costing of device base cases (cents EUR/page)

	Purchase	Refurbishing	Use	Total
Device1	0.52	0.12	0.22	0.86
Device2	0.62	0.12	0.23	0.97
Device3	0.44	0.09	0.22	0.74
Device4	0.39	0.09	0.24	0.72
Device5	0.25	0.03	0.22	0.50
Device6	0.25	0.03	0.23	0.51
Device7	3.79	0.00	0.36	4.15

5.4 Life cycle costing of cartridge base cases

In this section, the life cycle costing (LCC) of the cartridge base cases will be presented.

For each base case, the LCC has been estimated as follows (Table 76):

Life Cycle Cost = (Printing cost + Paper expenditure) / Pages printed in lifetime

Table 76. Life cycle costing of cartridge base cases

	Data an assumptions
Printing cost	The cost of printing with each cartridge has been estimated using data from Table 63, which includes regression analysis between cartridge page yield and cost per page, based on data provided by stakeholders.
Paper expenditure	Paper expenditure represents the cost of wasted paper, as explained in 4.6.2.5 It has been assumed that each sheet of paper costs 0.01 EUR.

The LCC of the cartridge base cases can be seen in Figure 114. The main findings of this analysis are summarized below:

- The highest cost of printing a page corresponds to Cartridge3, which is over 8 cents EUR/page, whereas the lowest cost is with Cartridge2 (less than 1 cents EUR/page). This is related with the total amount of pages that can be printed with each cartridge (much lower with Cartridge3).
- The highest contribution to the overall cost is the cost of printing. The cost of wasted paper is negligible.

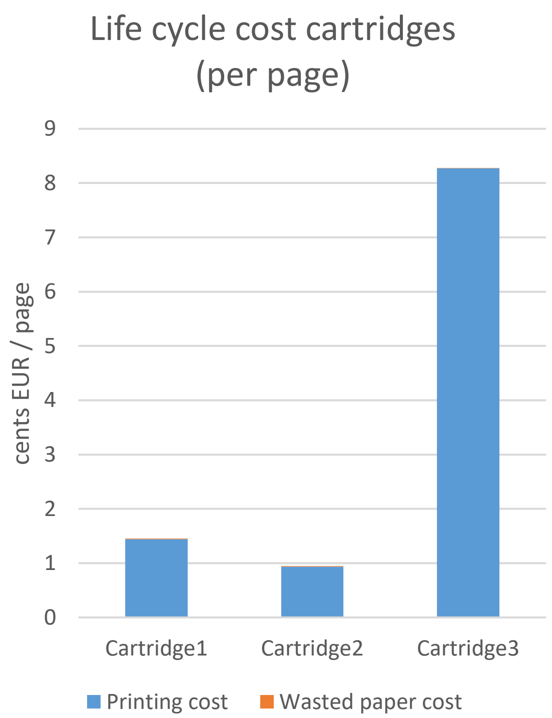


Figure 115. Life cycle costing of cartridge base cases

Table 77. Life cycle costing of cartridge base cases (centsEUR/page)

	Printing cost	Wasted paper cost	Total
Cartridge1	1.44	0.01	1.45
Cartridge2	0.93	0.01	0.94
Cartridge3	8.27	0.01	8.28

6 Task 6 - Design options

In Task 6 of the Preparatory Study, a variety of design options are presented, which have the potential to improve the environmental performance of devices and cartridges, based on data gathered in Task 4. These design options are based on the identified Best Available Technologies for each product. The goal of this section is to estimate the potential environmental benefit of implementing different design options individually.

6.1 Design options for devices

Based on preliminary objectives of policy options identified in section 4.4.8, different design options have been identified for devices, as described in Table 78[149].

Table 78. Objectives of ecodesign measures and definition of design options for devices

Objectives	Design Options
Ensure that devices last longer and are easier to repair, refurbish and recycle	Device 1.1 to Device 7.1 Device with extended lifetime
Explore untapped potential for improved energy savings in devices	Device 1.2 to Device 7.2 Device with reduced energy consumption
Optimize the consumption of paper	Device 1.3 to Device 7.3 Device with reduced paper consumption
Increase the amount of post-consumer recycled plastic in devices	Device 1.4 to Device 7.4 Device with increased use of post-consumer recycled plastic

Details for the each design option is provided in the following sections.

6.1.1 Device with extended lifetime

Technical lifetime of devices is a key aspect that can influence significantly their environmental performance. Due to their comparatively short use-time and their environmental impact caused mainly by the raw materials and assembly stages, a longer use-time would seem to have great potential for reducing their overall environmental impact.

Lifetime of devices can be increased, for instance, by enhancing their ability to be repaired or refurbished. An analysis has been carried out on device lifetime, repair and refurbish in sections 4.4.2 and 4.4.3 of this Preparatory Study. The main findings of those sections are summarized below:

- In the business sector, the average first use of devices (when they are replaced) is between 4-7 years, according to data from different sources
- Feedback received from experts in the device refurbishing industry suggests that office devices (generally laser) can last up to 12-14 years
- In the business sector, the total number of pages that a device can print (known as duty cycle) is often not fulfilled after this first use (see Table 29, Table 28 or Figure 37)

[149] For clarification, Device 1.1 means the Device 1, for which the Design Option 1 is applied. Device 1.2 is Device 1, for which the Design Option 2 is applied, and subsequently.

- In the consumer sector, there is a gap between expected and actual use of devices in terms of lifetime (see Figure 67)

Based on that, there seems to be a potential to extend average device lifetime, both for laser and inkjet technologies. Since this option is applicable to every device base case, seven design options have been defined. The system boundaries of devices with extended lifetime by remanufacturing can be seen in Figure 109. Aspects described in Peters (2016) have been taken into account to ensure that LCA methodological aspects of refurbished products are considered with a coherent approach. In Table 79, the key aspects changing from the device base cases are described.

Table 79. Key parameters changing from baseline in design options on extended device lifetime

Design option	Reference Base case (baseline)	Average lifetime (years)	Average printed pages (in lifetime)	Refurbishing events (in lifetime)	Spare parts needed to refurbish the device (%)	Mass of device (kg)	Transport distance, from place of use to repair centre (km)	End of life (% to recycling)
Device1.1	Device1	9.8[150]	107,289[151]	2	40%	38.4	75	75%
Device2.1	Device2	9.8	107,289	2	40%	27.6	75	75%
Device3.1	Device3	8.1	149,202	2	40%	60.2	75	75%
Device4.1	Device4	8.1	149,202	2	40%	32.5	75	75%
Device5.1	Device5	9.3	393,063	2	40%	137.0	75	75%
Device6.1	Device6	9.3	393,063	2	40%	230.6	75	75%
Device7.1	Device7	6.0	6,336	1	20%	9.4	25	75%

In this section, it has been assumed that lifetime is extended by 50% of the lifetime assumed for the baseline. The average number of printed pages has also increased accordingly. By extending the lifetime of the device (for instance, from 7.5 years to 9.8 years in Device1), the total amount of pages printed by the device increases significantly (from 82,000 to 107,000, again in Device1).

The baseline assumed that one refurbishing event was carried out during the device lifetime for laser devices, and no refurbishing was carried out for inkjet devices. In the Design Options proposed in this section, 2 refurbishing events are carried out for laser devices, and 1 for inkjet devices.

Extending the lifetime of an appliance usually has some benefits in terms of environmental impact (associated to a reduction in the impact per year of stages such as materials production or manufacturing) but also trade-offs, related with the increased use of materials (for replacement parts) and energy (for refurbishing). As already pointed out in section 4.4.3, increasing device lifetime by repair does not always necessarily reduce the environmental impact, because more material and energy intensive processes may be needed to conduct the repair. A holistic evaluation is necessary to confirm that increasing lifetime via repair and refurbish is the most appropriate action.

Therefore, as it was done in Cheung et al (2018) or Pini et al (2019), the replacement of faulty parts in refurbishing activities, and the related energy use, has also been considered in the analysis of lifetime extension. Due to lack of data, no specific components have been considered to be replaced, but simply a proportion of the total mass

[150] Lifetime in total, considering first use and after refurbish
[151] Printed pages in total, considering first use and after refurbish

of the device. Accordingly, 40% of the mass of the laser device has been assumed to be replaced, and 20% of the inkjet device.

Due to the higher complexity of a more repairable device, it has been assumed that the mass of the design options in this section is 10% higher than the baseline (which indirectly will also affect manufacturing and transport impacts).

Designing with reparability considerations may also have a positive effect on product disassembly, which can contribute to increasing recyclability rates. Therefore, the percentage of devices sent to recycling has been increased from 50% in the baseline to 75% in the design options.

The purchase price of more reparable devices has been assumed to increase by 10%.

Lifetime of devices may be extended by the following design changes, among others:

- Designing devices with disassembly processes in mind, facilitating access to priority parts described in section 4.4.3.1
- Providing spare parts for a significant amount of time after the product has been placed on the market
- Providing repair information to users and repairers
- Ensuring that the user can get software and firmware updates for a significant amount of time after the product has been placed on the market
- Providing easy access to information on the lifetime of devices (pages printed versus duty cycle) to users

Results in this section are presented in Table 80 for Climate Change. Reference values (baseline for each base case) can be found in Table 70.

- Extending the lifetime of the device increases the impact of the Refurbishing stage: when a device is refurbished, more virgin materials are consumed as spare parts. On top of that, additional energy needs to be consumed to refurbish the device.
- Extending the lifetime of the device reduces the impact per page of the rest of life cycle stages. For instance, the impact caused by Raw materials is 'shared' among a higher number of pages (the same happens with the rest of stages). This is in line with the results observed in Proske (2022) in a similar study on smartphones: the longer the lifetime of the device, the lower the contribution of raw materials and assembly.
- Extending lifetime of devices reduces the overall impact on Climate Change of every device evaluated, between 3-17%, depending on the device. This environmental benefits of device refurbishing are aligned with the benefits shown in the refurbishing of other ICT products such as laptops (Atescan et al, 2023).

Table 80. Device with extended lifetime – Impact on Climate change (gCO2eq./page)

	Raw materials	Manufact uring	Distributio n	Use	Refurbishi ng	End of life	Total	Total (reduction versus baseline)
Device1.1	2.43	5.18	0.05	1.59	2.01	-0.25	11.01	-5%
Device2.1	1.91	4.65	0.04	1.80	1.70	-0.16	9.94	-5%
Device3.1	3.30	5.84	0.06	1.54	2.49	-0.25	12.98	-3%
Device4.1	1.47	3.93	0.03	1.96	1.37	-0.14	8.62	-3%
Device5.1	1.46	5.04	0.05	1.59	1.59	-0.20	9.55	-5%
Device6.1	2.03	10.59	0.09	1.69	2.93	-0.20	17.14	-6%
Device7.1	11.87	21.54	0.22	2.08	4.53	-1.33	38.91	-17%

Table 81 shows the results of this design option in terms of Life cycle cost. Reference values (baseline for each base case) can be found in Table 74.

- Extending the lifetime of the device reduces the Purchase price of the device (per page). Although the actual cost of the device is 10% higher, it is used for a longer period, and therefore it is used to produce a higher number of pages. Essentially, by extending the lifetime the user is making a better use of the initial investment.
- Extending the lifetime of the device increases the costs related to Refurbishing and Maintenance, since more money is spent in refurbishing in the design options presented in this section.
- Extending the lifetime of the device reduces the overall expenditure of devices between 4% and 7%, depending on the device. Extending the lifetime of the device compensates the extra costs incurred in refurbishing.

Table 81. Device with extended lifetime – Life cycle cost (cents EUR/page)

	Purchase	Refurbishing & Maintenanc e	Use	Total	Total (reduction versus baseline)
Device1.1	0.44	0.15	0.22	0.81	-6%
Device2.1	0.52	0.15	0.23	0.91	-7%
Device3.1	0.38	0.11	0.22	0.71	-5%
Device4.1	0.34	0.11	0.24	0.69	-4%
Device5.1	0.21	0.04	0.22	0.47	-6%
Device6.1	0.21	0.04	0.23	0.48	-6%
Device7.1	2.78	0.83	0.36	3.96	-4%

6.1.2 Device with reduced energy consumption

Based on the analysis carried out in section 4.4.1.2 of the Preparatory Study, non-active operational modes have a significant role in overall power and energy consumption. Typical power consumption of non-active modes are below currently applicable thresholds of Regulation 2023/826 (Figure 56 and Figure 58). Therefore, there seems to be a potential to improve overall energy consumption of devices, by setting power consumption thresholds that are stricter than the ones established by Regulation 2023/826.

There seems to be potential as well to save energy by setting stricter requirements on the transition between active and non-active modes, both in laser and inkjet devices (Figure 60 and Figure 62).

Finally, as described in section 4.4.1.4 there seems to be a potential to improve the energy efficiency of the device by improving the energy efficiency of the internal power supply (IPS). The 80 Plus Programme provides different categories depending on the energy efficiency of the IPS at different loads[154].

In this section, the potential environmental improvement potential has been evaluated, with the definition of seven design options. For each of those design options, it has been assumed that there is potential to reduce the average energy consumption of devices with a combination of the following design changes:

- Reduced power consumption of non-active operational modes
- Reduced time from active to non-active operational modes
- Improved energy efficiency of IPS

There is no data available on the potential to reduce energy consumption of devices by setting the above design changes. In Saidani et al (2022), it was assumed that by reducing the power consumption of different operational modes of devices, it is possible to reduce annual yearly consumption of printers by 35%. Taking a more conservative approach, it has been assumed in this Preparatory Study that with the combination of measures listed above, it is possible to reduce overall energy consumption of devices by 20%. In Table 82, the key parameters changing from baseline in design options on reduced energy consumption are presented.

Table 82. Key parameters changing from baseline in design options on reduced energy consumption

Design option	Energy Consumption baseline (kWh/year)	Energy Consumption Design option (kWh/year)
Device1.2	22.36	17.89
Device2.2	28.08	22.46
Device3.2	35.88	28.70
Device4.2	54.08	43.26
Device5.2	86.84	69.47
Device6.2	96.72	77.38
Device 7.2	1.76	1.41

Results in this section are presented in Table 83 for Climate Change. Reference values (baseline for each base case) can be found in Table 70.

[154] https://www.clearesult.com/80plus/program-details#program-details-table

- Reducing energy consumption of devices reduces the impact of the use stage. It has been assumed that there are no changes required in the components used, so reducing energy consumption of devices has no effect on the rest of stages.
- Since the overall contribution of the use stage is low (see Figure 110), the effect of reducing energy consumption can only provide improvements between 1% and 3%, depending on the device.

Table 83. Device with reduced energy consumption - Climate change (gCO2eq./page)

	Raw materials	Manufact uring	Distributio n	Use	Refurbishi ng	End of life	Total	Total (reduction versus baseline)
Device1.2	2.87	6.12	0.06	1.41	1.19	-0.20	11.46	-1%
Device2.2	2.26	5.49	0.05	1.58	1.00	-0.13	10.26	-2%
Device3.2	3.80	6.72	0.07	1.38	1.43	-0.19	13.20	-1%
Device4.2	1.69	4.52	0.04	1.71	0.79	-0.11	8.65	-3%
Device5.2	1.72	5.92	0.06	1.42	0.94	-0.15	9.91	-2%
Device6.2	2.39	12.44	0.10	1.49	1.72	-0.15	18.00	-1%
Device 7.2	16.19	29.37	0.30	1.94	0.00	-1.19	46.61	-0.3%

Table 84 shows the results of this design option in terms of Life cycle cost. Reference values (baseline for each base case) can be found in Table 78

- Reducing energy consumption of devices reduces the cost related to the use stage. If devices consume less energy, users will need to pay less in their electricity bills.
- Since electricity consumption is not the main aspect contributing to the life cycle cost of a device (see Figure 114), the design options presented in this section provide improvements between 0.2 and 2%, depending on the device.

Table 84. Device with reduced energy consumption - Life cycle cost (centsEUR/page)

	Purchase	Refurbishing & Maintenance	Use	Total	Total (reduction versus baseline)
Device1.1	0.52	0.12	0.21	0.85	-1%
Device2.1	0.62	0.12	0.22	0.96	-1%
Device3.1	0.44	0.09	0.21	0.73	-1%
Device4.1	0.39	0.09	0.23	0.70	-2%
Device5.1	0.25	0.03	0.21	0.49	-2%
Device6.1	0.25	0.03	0.22	0.50	-2%
Device7.1	3.79	0.00	0.35	4.14	-0.2%

6.1.3 Device with reduced paper consumption

The availability of duplexing capability contributes to the reduction of paper waste. To evaluate the benefits of including duplexing capability, one design option has been defined (applicable only to Device7, which is the only device assumed not to have this functionality in the base case).

Table 85. Key parameters changing from baseline in design options on reduced paper waste

Design option	Reference base case (baseline)	Number of documents printed (in lifetime)	Printing frequency of both sides (%)	Paper waste in lifetime (number of A4 sheets)	Paper waste in lifetime (kg)
Device7.3	Device7	845[155]	58%	716	0.9

For the design option on reduced paper waste, it has been assumed that by including duplexing functionality in the inkjet device, the printing frequency on both sides of paper will increase from 20% (base case) to 58% (same printing frequency as laser devices with duplexing functionality).

Results in this section are presented in Table 86 for Climate Change. Reference values (baseline for each base case) can be found in Table 70.

- Reducing paper waste of devices with the introduction of duplexing capability reduces the impact of the use stage. It has been assumed that there are no changes required in the components used, so this design option has no effect on the rest of stages.
- Since the overall contribution of the use stage is low (see Figure 110), the effect of reducing paper waste can only provide improvement of 1%.

Table 86. Device with reduced paper waste – Climate change (gCO2eq./page)

	Raw materials	Manufact uring	Distributio n	Use	Refurbishi ng	End of life	Total	Total (reduction from baseline)
Device7.3	16.19	29.37	0.30	1.43	0.00	-1.19	46.10	-1%

Table 87 shows the results of this design option in terms of Life cycle cost. Reference values (baseline for each base case) can be found in Table 78.

- Reducing paper waste of devices reduces the costs related to the use stage. If devices are able to produce documents in both sides of paper sheets, less paper will be used, so users will need to buy less paper.
- Since paper use is not the main aspect contributing to the life cycle cost of a device (see Figure 114), the design option presented in this section provide improvement of 4%.

Table 87. Device with reduced paper waste – Life cycle cost (centsEUR/page)

	Purchase	Refurbishing & Maintenance	Use	Total	Total (reduction versus baseline)
Device7.3	3.79	0.00	0.21	4.00	-4%

[155] Assuming an average document length of 5 pages

6.1.4 Device with increased use of post-consumer recycled plastic

The use of post-consumer recycled plastic can help to reduce the environmental impact of the product, essentially reducing the need of using virgin material. Data on the use of post-consumer recycled (PCR) plastic has been presented in section 4.4.7 of the Preparatory Study.

The purpose of this section is to evaluate the environmental benefit of increasing the percentage of post-consumer recycled plastic in devices. For that, the design options in Table 88 are proposed.

Table 88. Key parameters changing from baseline in design options on increased post-consumer recycled plastic

Design option	Reference Base case (baseline)	Post-consumer recycled plastic (%)
Device1.4	Device1	75%
Device2.4	Device2	75%
Device3.4	Device3	75%
Device4.4	Device4	75%
Device5.4	Device5	75%
Device6.4	Device6	75%
Device 7.4	Device7	75%

Results in this section are presented in Table 89 for Climate Change. Reference values (baseline for each base case) can be found in Table 70.

- Increasing the amount of post-consumer recycled plastic reduces the impact of the Raw materials life cycle stage[156]. It has no effect on the rest of stages.
- The improvement on Raw materials production has an effect of 1%-3% on the overall impact of devices.

[156] Virgin plastic: "Acrylonitrile Butadiene Styrene (ABS) emulsion polymerisation, bulk polymerisation or combined processes production mix, at plan"
Recycled plastic: "Recycled Acrylonitrile Butadiene Styrene (ABS) fossil-fuel based"

Table 89. Device with increased use of post-consumer recycled plastic – Climate change (gCO2eq./page)

	Raw materials	Manufact uring	Distributio n	Use	Refurbishi ng	End of life	Total	Total (reduction versus baseline)
Device1.4	2.63	6.12	0.06	1.58	1.19	-0.20	11.38	-2%
Device2.4	2.08	5.49	0.05	1.80	1.00	-0.13	10.29	-2%
Device3.4	3.55	6.72	0.07	1.54	1.43	-0.19	13.12	-2%
Device4.4	1.54	4.52	0.04	1.96	0.79	-0.11	8.74	-2%
Device5.4	1.55	5.92	0.06	1.59	0.94	-0.15	9.91	-2%
Device6.4	2.18	12.44	0.10	1.69	1.72	-0.15	17.99	-1%
Device 7.4	14.57	29.37	0.30	2.08	0.00	-1.19	45.13	-3%

Table 90 shows the results of this design option in terms of Life cycle cost. Reference values (baseline for each base case) can be found in Table 78.

Increasing the amount of post-consumer recycled plastic has no effect on the Purchase price of the device, or in the Refurbishing or Use stages. Therefore, there are no consequences in terms of cost related to these design measures.

Table 90. Device with increased use of post-consumer recycled plastic - Life cycle cost (cents EUR/page)

	Purchase	Refurbishing & Maintenance	Use	Total	Total (reduction versus baseline)
Device1.4	0.52	0.12	0.22	0.86	0%
Device2.4	0.62	0.12	0.23	0.97	0%
Device3.4	0.44	0.09	0.22	0.74	0%
Device4.4	0.39	0.09	0.24	0.72	0%
Device5.4	0.25	0.03	0.22	0.50	0%
Device6.4	0.25	0.03	0.23	0.51	0%
Device 7.4	3.79	0.00	0.36	4.15	0%

6.1.5 Summary of assessment of design options for devices

Figure 116 shows the improvement potential of the design options proposed, in terms of Climate change (per page produced over lifetime).

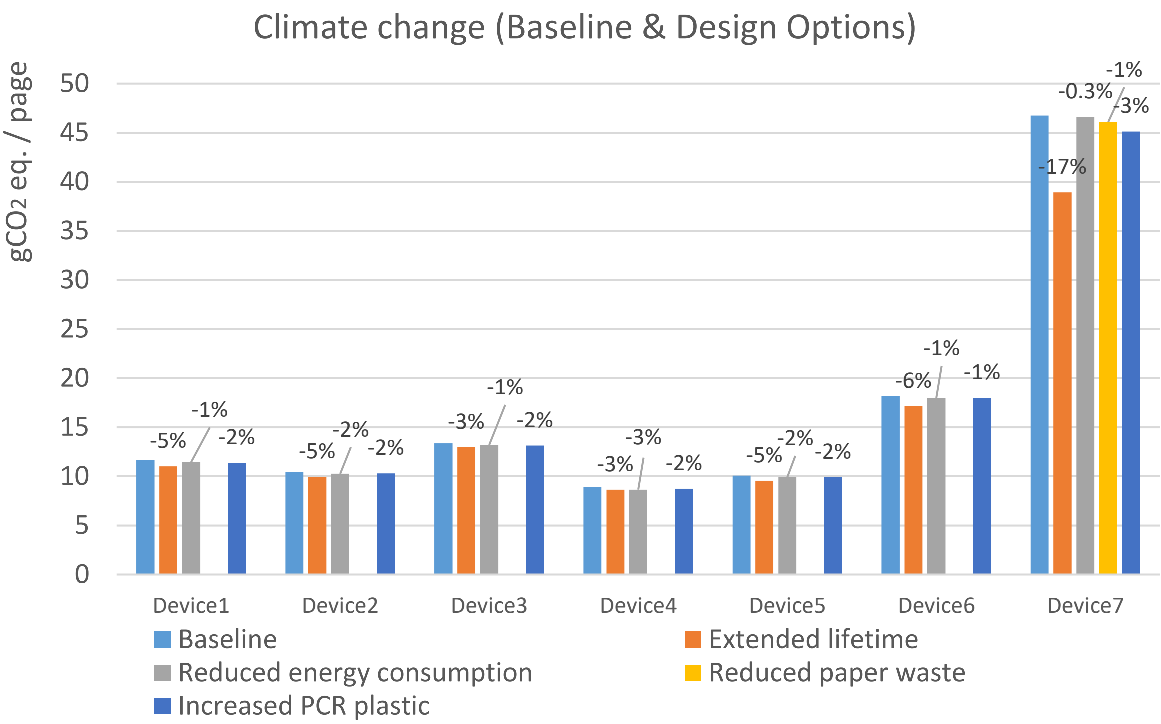


Figure 116. Improvement potential of design options – Climate change

- The design option with the highest potential of reducing the environmental impact of devices is the extension of their lifetime, with improvements between 3% and 17%.
- Reducing energy consumption, reducing paper waste or increasing the amount of PCR plastic have similar effects on the overall impact of devices (between 1%-3%).

Figure 117 shows the improvement potential of the design options proposed, in terms of Life cycle cost (per page produced over lifetime).

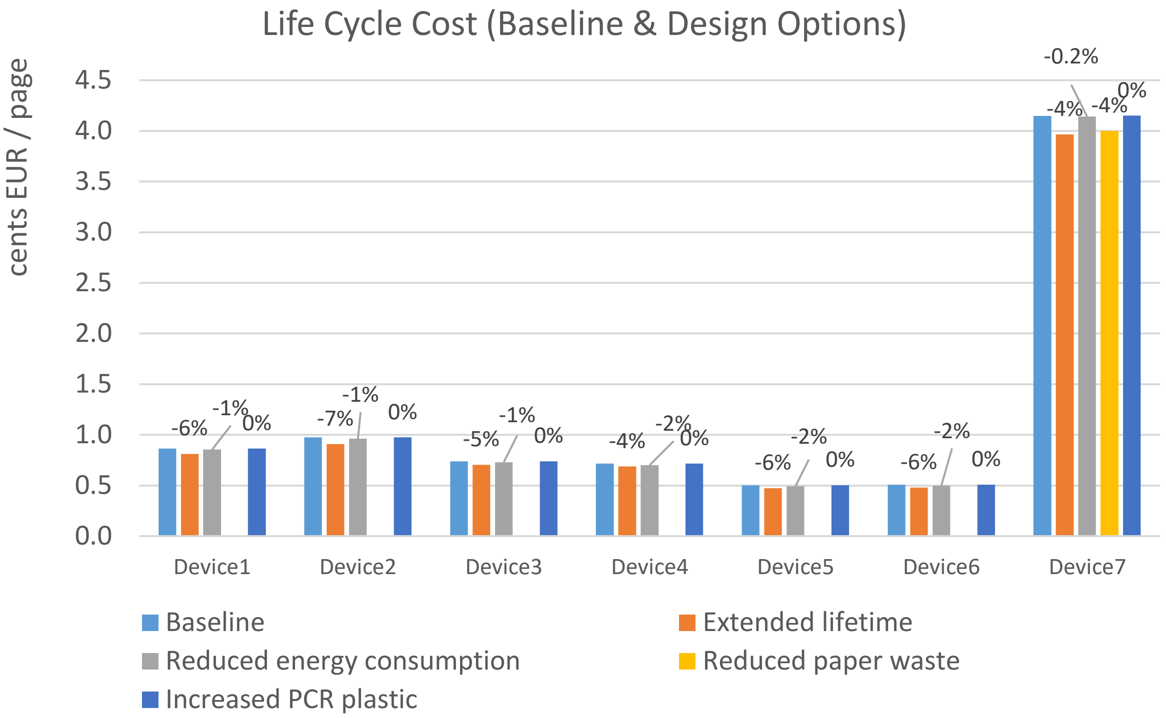


Figure 117. Improvement potential of design options – Life cycle cost

- The design option with the highest potential of reducing the life cycle cost of devices for users is the extension of their lifetime, with improvements between 4% and 7%.
- Reducing energy consumption and reducing paper waste have similar effects on the overall impact of devices (1%-4%).
- Increasing the amount of PCR plastics has no effect on life cycle cost for consumers.

6.2 Design options for cartridges

Based on preliminary objectives of policy options identified in section 4.5.15, different design options have been identified for devices, as described in Table 91.

Table 91. Objectives of ecodesign measures and definition of design options for cartridges

Objectives	Design Options
Improve capacity utilisation in cartridges	Cartridge 1.1 to Cartridge 3.1 Cartridge with improved capacity utilisation
Encourage the use of material efficient cartridge configurations	Cartridge 1.2 to Cartridge 3.2 Cartridge with improved material efficiency configuration
Increase the possibilities to remanufacture a cartridge	Cartridge 1.3 to Cartridge 3.3 Cartridge with enhanced remanufacturability
Reduce the amount of paper wasted due to performance of cartridges	Cartridge 1.4 to Cartridge 3.4 Cartridge with reduced failure rate

Details for the each design option category is provided in the following sections.

6.2.1 Cartridge with improved capacity utilisation

Cartridge capacity utilisation is related with page yield. A higher page yield means that the cartridge will last longer, for a given frequency of use. In section 4.5.2 of the Preparatory Study, an analysis has been conducted on cartridge page yield. Some of the findings from that section are summarized below:

- There are many cartridge models in the market providing low page yield: less than 4000 pages in toner cartridges (see Figure 78) and less than 400 pages in ink cartridges (Figure 79). Many of those are starter cartridges.
- Data shown in Figure 83 suggests that there are cartridges in the market with low fill levels (same mass of empty cartridge with significantly different page yield).
- Feedback gathered in section 4.5.11.2 on cartridge reuse indicates that cartridges with low capacity are less likely to be reused.
- It is generally cheaper to print with cartridges with higher page yield (see Figure 87 to Figure 90)

Based on that, there seems to be potential to increase average page yield of cartridges placed on the EU market. The purpose of this section is to evaluate the potential environmental improvement of increasing page yield of cartridge base cases. For that, the design options in Table 92 are proposed. In Cartridge1.1, Cartridge2.1 and Cartridge3.1, it has been assumed that page yield is increased by 25% compared to the baseline.

Table 92. Key parameters changing from baseline in design options on increased page yield

Design option	Page yield baseline (number of pages)	Page yield design option (number of pages)
Cartridge1.1	7500	9375
Cartridge2.1	25000	31250
Cartridge3.1	300	375

Cartridge page yield may be increased via the following design changes (among others):

- Avoiding the use of internal compartments (as shown in Figure 73)
- Making use of the entire available volume (or higher percentages), avoiding the situations described in Table 42 and Table 43.

Results in this section are in Table 93 for Climate Change. Reference values (baseline for each base case) can be found in Table 73.

- Improving capacity utilisation increases the impact of the use stage: since more pages are produced by each cartridge, proportionally more paper waste will be generated.
- Improving capacity utilisation reduces the impact of the rest of life cycle stages. For instance, the impact caused by Raw materials is 'shared' among a higher number of pages (the same happens with the rest of stages).
- Improving capacity utilisation has an overall positive effect between 18%-19%, depending on the cartridge type.
-

Table 93. Cartridge with improved capacity utilisation – Climate change (gCO2eq./page)

	Raw materials	Manufact uring	Distributio n	Use	Remanufa cturing	End of life	Total	Total (reduction versus baseline)
Cartridge1 .1	0.30	0.48	0.02	0.04	0.00	-0.06	0.79	-19%
Cartridge2 .1	0.23	0.27	0.01	0.04	0.00	-0.05	0.51	-19%
Cartridge3 .1	0.20	0.28	0.01	0.05	0.00	-0.04	0.49	-18%

Table 94 shows the results of this design option in terms of Life cycle cost. Reference values (baseline for each base case) can be found in Table 77.

Table 94. Cartridge with improved capacity utilisation – Life cycle costing (centsEUR/page)

	Printing cost	Paper cost	Total	Total (reduction versus baseline)
Cartridge1.1	1.271	0.01	1.281	-12%
Cartridge2.1	0.845	0.01	0.855	-10%
Cartridge3.1	7.014	0.01	7.024	-15%

The cost of printing a page is reduced when page yield increases (as seen in section 4.5.4). This is reflected in the life cycle costing of these design options, with overall improvements between 10%-15%, depending on the cartridge.

6.2.2 Cartridge with enhanced remanufacturability

Ink and toner cartridges may be remanufactured a number of times (between 3 and 4, according to feedback from experts). In section 4.5.11 of the Preparatory Study, an analysis has been conducted on cartridge remanufacturing. Some of the findings from that section are summarized below:

- Current remanufacturing rates are low (between 10%-20%), according to data from different sources
- The technical potential of remanufacturing cartridges is high (more than 85%) according to previous studies
- Published research suggests there is an environmental benefit in cartridge remanufacturing (see Table 46)
- Current low remanufacturing rates and low collection rates are caused by multiple design-related barriers, as described in section 4.5.11.2

Based on that, there seems to be potential to enhance the remanufacturability of cartridges. The purpose of this section is to evaluate its potential environmental improvement. For that, the design options in Table 95 are proposed.

Table 95. Key parameters changing from baseline in design options on cartridges with enhanced remanufacturability

	Design option	Reference Base case (baseline)	Mass of empty cartridge (grams)	Reuse cycles	Mass of substituted components at remanufacturing (%)	Transport distance, from place of use to remanufacturing centre (km)
Medium level	**Cartridge1.2**	Cartridge1	1250	1	7%	300
	Cartridge2.2	Cartridge2	2365	1	7%	300
	Cartridge3.2	Cartridge3	29	0.5	3.5%	300
High level	**Cartridge1.3**	Cartridge1	1310	2	14%	150
	Cartridge2.3	Cartridge2	2477	2	14%	150
	Cartridge3.3	Cartridge3	30	1	7%	150

From the methodological perspective, enhancing the remanufacturability of cartridges is a similar case to the lifetime extension of devices described in 6.1.1. Reusing a cartridge is, in essence, increasing its lifetime (by remanufacturing it.

Increasing cartridge lifetime by remanufacturing may not necessarily reduce its environmental impact. It will depend on the additional material and energy required in the remanufacturing process. A holistic evaluation is necessary to confirm that increasing cartridge lifetime via remanufacturing is the most appropriate action.

Therefore, the replacement of faulty components in remanufacturing activities, and the related energy use, has also been considered in the analysis of increased use of remanufactured cartridges. As in the case of devices, due to lack of data, no specific components have been considered to be replaced during remanufacturing, but simply a proportion of the total mass of the cartridge.

Cartridge1.2, Cartridge2.2 and Cartridge3.2 are design options representing a medium level scenario in terms of use of remanufactured cartridges. In this case, it has been assumed that toner cartridges are, on average, reused 1 time, and ink cartridges 0.5 times. The mass of substituted components at cartridge remanufacturing is 7%, as indicated in Table 62. It has also been assumed that the average distance to the remanufacturing centre is lower than in the baseline, due to higher availability of remanufacturing locations.

Cartridge1.3, Cartridge2.3 and Cartridge3.3 are design options representing a high level scenario in terms of use of remanufactured cartridges. In this case, it has been assumed that toner cartridges are, on average, reused 2 times, and ink cartridges 1 time. The mass of substituted components at cartridge remanufacturing is 14%, (two times the mass of 1 reuse cycle). It has also been assumed that the average distance to the remanufacturing centre is lower than in the baseline and in medium reusability, due to higher availability of remanufacturing locations.

A cartridge which is easier to remanufacturer might be more bulky or require additional components and fasteners. Therefore, tt has been assumed that the mass of the design options in this section is 5% higher than the baseline for the medium reusability scenario, and 10% higher for the high reusability scenario (which indirectly will also affect manufacturing and transport impacts).

Cartridge remanufacturing rates may be increased via design changes in cartridges, addressing the technical barriers presented in section 4.5.11.2 of the Preparatory Study. For instance:

- Using chips that can be easily reset after first use of the cartridge (or by OEMs providing chip resetting functionality at end of life)
- Making relevant data for reuse available in chips (such as number of reuse cycles, manufacturer, remanufacturer)
- Avoiding the deployment of software updates that prevent the use of remanufactured cartridges

- Limiting the use of irreversible joining practices
- Placing key components (such as chips) in easily accessible areas (to facilitate replacement or re-setting)
- Encouraging compatibility between cartridges and printers
- Protecting fragile components such as photoreceptors (avoiding damage during transport and collection)
- Using robust materials and durable design
- Better utilisation of cartridge capacity

Results in this section are presented in Table 96 for Climate Change. Reference values (baseline for each base case) can be found in Table 77.

- Increasing the use of remanufactured cartridges increases the impact of the Remanufacturing stage, since energy and materials are used to remanufacture the cartridges.
- Increasing the use of remanufactured cartridges reduces the impact on the rest of life cycle stages. When cartridges are reused, they are able to provide a higher number of pages over their lifetime. When they are reused more times, they provide even more pages over their lifetime. Therefore, the impact caused by each of the life cycle stages is shared among a larger number of pages.
- Overall, in a medium reusability scenario, the environmental improvements related to climate change are between 24%-39%. In a high reusability scenario, between 36%-56%[157]. The impacts caused by energy and materials consumed during the Remanufacturing stage are compensated by the reduced impact in the rest of stages.

Table 96. Cartridge with enhanced remanufacturability – Climate change (gCO2eq./page)

		Raw materials	Manufacturing	Distribution	Use	Remanufacturing	End of life	Total	Total (reduction versus baseline)
Medium	Cartridge1.2	0.20	0.31	0.01	0.0425	0.06	-0.04	0.59	-39%
	Cartridge2.2	0.15	0.18	0.01	0.0435	0.04	-0.04	0.38	-38%
	Cartridge3.2	0.17	0.24	0.01	0.0411	0.02	-0.03	0.45	-24%
High	Cartridge1.3	0.14	0.22	0.01	0.0425	0.08	-0.03	0.46	-53%
	Cartridge2.3	0.11	0.12	0.01	0.0290	0.03	-0.03	0.27	-56%
	Cartridge3.3	0.13	0.19	0.01	0.0408	0.04	-0.03	0.38	-36%

Table 97 shows the results of this design option in terms of Life cycle cost. Reference values (baseline for each base case) can be found in Table 81.

In the reusability scenarios presented (medium and high), it has been assumed that after their first life (after the initial page yield has been depleted), the cartridges will be commercialized as remanufactured cartridges. As an example, Cartridge1.2 is assumed to be used 7500 pages as original and 7500 additional pages as remanufactured (only 1 reuse cycle). Similarly, Cartridge 1.3 is assumed to be used 7500 as original and 22500 as remanufactured (the equivalent to 3 reuse cycles).

Increasing the use of remanufactured cartridges reduces the cost of printing (per page), since remanufactured cartridges tend to be cheaper than original (as seen in in section 4.6.2.7). This is reflected in overall reductions between 33-50% in the medium reusability scenario, and between 50-67% in the high reusability scenario.

[157] Very similar environmental improvements were estimated in Lindahl et al (2016) on the remanufacturing of toner cartridges.

Table 97. Enhanced remanufacturability of cartridges - Life cycle costing (centsEUR/page)

		Printing cost	Paper cost	Total	Total (reduction versus baseline)
Medium	Cartridge1.2	0.72	0.01	0.73	-50%
	Cartridge2.2	0.47	0.01	0.48	-50%
	Cartridge3.2	5.52	0.01	5.53	-33%
High	Cartridge1.3	0.48	0.01	0.49	-67%
	Cartridge2.3	0.31	0.01	0.32	-67%
	Cartridge3.3	4.14	0.01	4.15	-50%

6.2.3 Cartridge with improved material efficiency configuration

Cartridge material efficiency has been defined as the ratio between page yield and mass of empty cartridge (expressed as pages per gram of material). An analysis of cartridge material efficiency has been carried out in section 4.5.3 of the Preparatory Study. Some of the findings from that section are summarized below:

- There are several cartridge models in the market with low material efficiency (see Figure 84 and Figure 85)
- Single-part cartridges tend to be more material efficient than integrated/all-in-one cartridges (see Figure 80 to Figure 84)

Based on that, there seems to be potential to increase average material efficiency of cartridges placed on the EU market, encouraging cartridge configurations with higher material efficiency. The purpose of this section is to evaluate the potential environmental improvement of increasing material efficiency of cartridge base cases, shifting from all-in-one/integrated configurations to single-part configurations. For that, the design options in Table 98 are proposed.

Table 98. Key parameters changing from baseline in design options on increased material efficiency

Design option	Material efficiency base case (pages/gram)	Material efficiency design option (pages/gram)
Cartridge1.4	6.3	41.6 [158]
Cartridge2.4	11.1	57.8 [159]
Cartridge3.4	11.0	30 [160]

As can be seen in Table 98 and Figure 118 and Figure 119, the design options proposed have material efficiency values corresponding with XL, single part cartridges.

[158] Keypoint Intelligence data: XL, single part, black toner cartridge, for use in Printer
[159] Keypoint Intelligence data: XL, single part, black toner cartridge, for use in MFP

[160] Keypoint Intelligence data: XL, single part, black ink cartridge

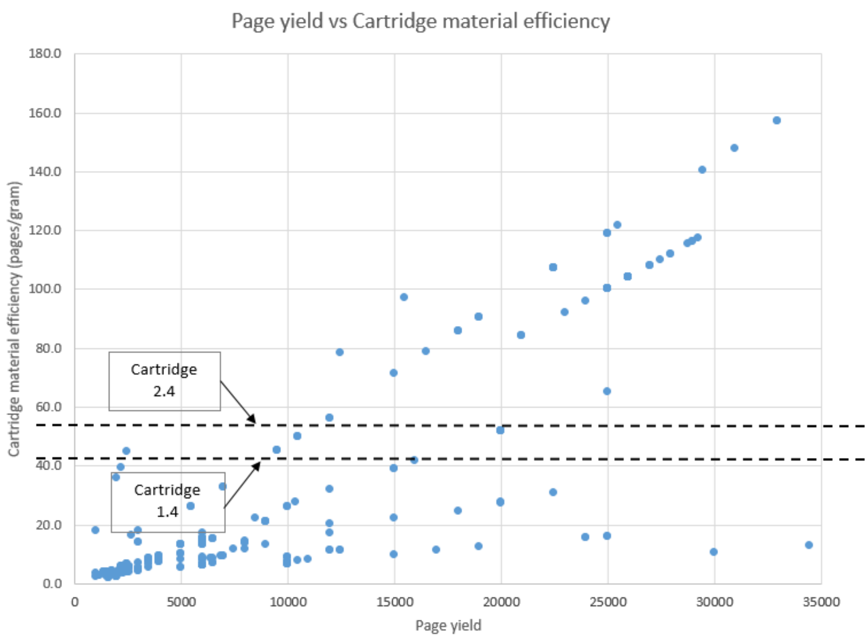


Figure 118. Design Options proposed in terms of increased material efficiency for toner cartridges

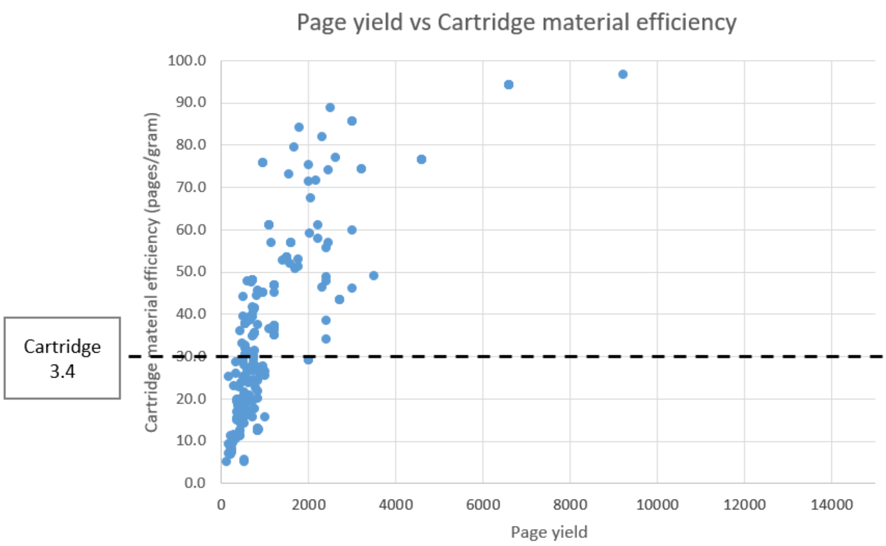


Figure 119. Design Options proposed in terms of increased material efficiency for ink cartridges

Cartridge material efficiency may be increased by switching from integrated/all-in-one configurations to single-part configurations. In Figure 120 and Figure 121, a schematic description of toner and ink cartridge configurations can be seen. In all-in-one toner cartridges, the containment part, the developer part and the photoconductor (the drum) are within the cartridge; whereas in single-part toner cartridges comprise only the containment part.

However, this does not mean that the developer part and the photoreceptor are not needed: they are simply installed permanently in the printer. The potential advantage of printers using single-part toner cartridges is that the drum and the developer part tend to be more durable (last more pages) than when they are included in the cartridge. In all-in-one cartridges, when the containment part is empty of toner, the three cartridge elements need to be replaced. In single-part cartridges, drums tend to last between 3 and 4 times longer than their associated cartridges.

-**Single-part**: comprising only the toner container

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

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

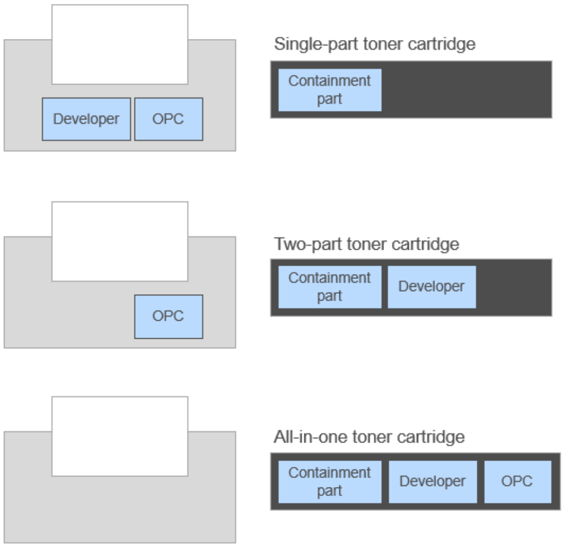


Figure 120. Schematic description of toner cartridge configurations

The same happens when comparing single-part and integrated ink cartridges. In this case, when an integrated cartridge is empty, both the container and the print head need to be replaced. In contrast, in single-part cartridges, only the containment part is replaced, with the print head remaining in the printer.

-**Single-part**: comprising only the containment part

-**Integrated**: comprising the containment part and the deposition mechanism

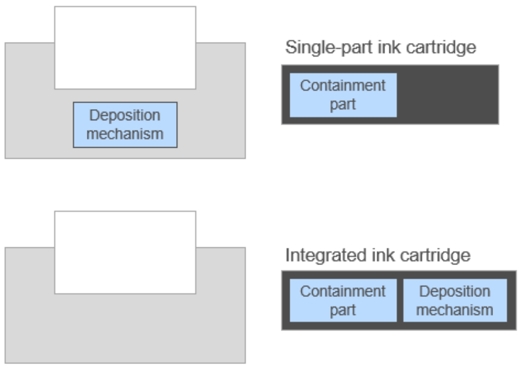


Figure 121. Schematic description of ink cartridge configurations

All these aspects have been taken into account during the environmental assessment of the design options in this section.

Results in this section are presented in Table 86 for Climate Change. Reference values (baseline for each base case) can be found in Table 77.

Table 99. Cartridge with improved material efficient configuration – Climate change (gCO2eq./page)

	Raw materials	Manufacturing	Distribution	Use	Remanufacturing	End of life	Total	Total (reduction versus baseline)
Cartridge1.4	0.14	0.22	0.01	0.04	0.00	-0.03	0.38	-61%
Cartridge2.4	0.11	0.13	0.01	0.04	0.00	-0.03	0.27	-56%
Cartridge3.4	0.10	0.14	0.01	0.04	0.00	-0.02	0.27	-55%

By switching to single-part cartridges, less amount of material is used in the cartridge, reducing the impact on Raw materials and Manufacturing. The drum and additional components still need to be manufactured and placed on the printer. The fact that this component will last longer –more pages- when it is inside the printer provides the additional environmental benefits. The potential benefits are between 55%-61%, depending on the type of cartridge.

Table 100 shows the results of this design option in terms of Life cycle cost. Reference values (baseline for each base case) can be found in Table 81.

Table 100. Cartridge with improved material efficient configuration – Life cycle costing (centsEUR/page)

	Printing cost	Paper cost	Total	Total (reduction versus baseline)
Cartridge1.4	1.442	0.01	1.452	0%
Cartridge2.4	0.935	0.01	0.945	0%
Cartridge3.4	8.272	0.01	8.282	0%

In this assessment, it has been assumed that the cost of printing is influenced by the number of pages provided by the cartridge, as detailed in section 4.6.2.7 (higher page yield means lower cost per page). In design options Cartridge1.1, Cartridge2.1 and Cartridge 3.1, it has been assumed that the only design change being developed is related to cartridge configuration (from integrated/all-in-one to single-part). No changes in page yield have been assumed for these design options. The authors acknowledge that this is a simplification from what would possibly happen in the real market: changing cartridge configuration would result in an increase in page yield. However, the intention of these design options was to evaluate the consequences of changing only cartridge configuration (changing only material efficiency), without increasing page yield. This is the reason why there is no change in the cost of printing with Cartridge1.1, Cartridge2.1 or Cartrige3.1.

6.2.4 Cartridge with reduced failure rate

Cartridge printing quality may have a significant effect on paper waste. Cartridges that fail more often (delivering low quality printouts) will generate more paper waste. An analysis has been carried out on printing quality in section 4.5.7 of the Preparatory Study. The main findings of that section are summarized below:

- Studies conducted by OEMs suggest that original cartridges provide more usable pages than non-original cartridges
- Cartridge remanufacturers highlight that printing quality of remanufactured cartridges is comparable to the original cartridges
- Printing quality has been highlighted in previous studies (Huang et al, 2019; Waugh et al, 2018) as an aspect that could improve the market situation for both original and reused cartridges (avoiding the entrance on the EU market of low quality clones or counterfeits).

Based on that, there seems to be a potential to address the printing quality of cartridges, by reducing their failure rates, in order to reduce the amount of paper waste. The purpose of this section is to evaluate the potential environmental improvement of reducing failure rates of base cases. For that, the design options in Table 101 are proposed, where failure rate 1% is assumed instead of 2% from base case.

Table 101. Key parameters changing from baseline in design options on reduced paper waste

Design Option	Reference base case (baseline)	Failure rate	Paper wasted in lifetime[161] (kg)
Cartridge1.5	Cartridge1	1%	0.19
Cartridge2.5	Cartridge2	1%	0.63
Cartridge3.5	Cartridge3	1%	0.01

Results in this section are presented Table 102 for Climate Change. Reference values (baseline for each base case) can be found in Table 77.

Table 102. Cartridge with reduced paper waste – Improvement versus baseline – Climate change

	Raw materials	Manufact uring	Distributio n	Use	Remanufa cturing	End of life	Total	Total (reduction versus baseline)
Cartridge1 .5	0.38	0.60	0.02	0.02	0.00	-0.07	0.95	-2%
Cartridge2 .5	0.29	0.34	0.01	0.02	0.00	-0.06	0.60	-3%
Cartridge3 .5	0.25	0.35	0.01	0.03	0.00	-0.05	0.58	-3%

- Reducing the amount of paper waste has a benefit on the use stage. If cartridges are able to produce outputs with reduced failure rate, the impact cause by waste paper will be reduced.
- The overall benefit of reducing the amount of paper waste is between 2%-3%, depending on the cartridge

Table 103 shows the results of this design option in terms of Life cycle cost. Reference values (baseline for each base case) can be found in Table 81.

Table 103. Cartridge with reduced paper waste – Improvement versus baseline – Life cycle costing

	Printing cost	Paper cost	Total	Total (reduction versus baseline)
Cartridge1.5	1.442	0.005	1.447	-0.3%
Cartridge2.5	0.935	0.005	0.940	-0.5%
Cartridge3.5	8.272	0.005	8.277	-0.1%

When less paper is wasted, the user needs to expense less in replacing that paper. This is reflected in the life cycle costing results of these design options, with savings between 0.1% and 0.5% over cartridge lifetime.

6.2.5 Summary of assessment of design options for cartridges

Figure 122 shows the improvement potential of the design options proposed for cartridges, in terms of Climate change (per page produced over lifetime).

[161] Assuming that an A4 sheet of paper weighs approximately 5 grams

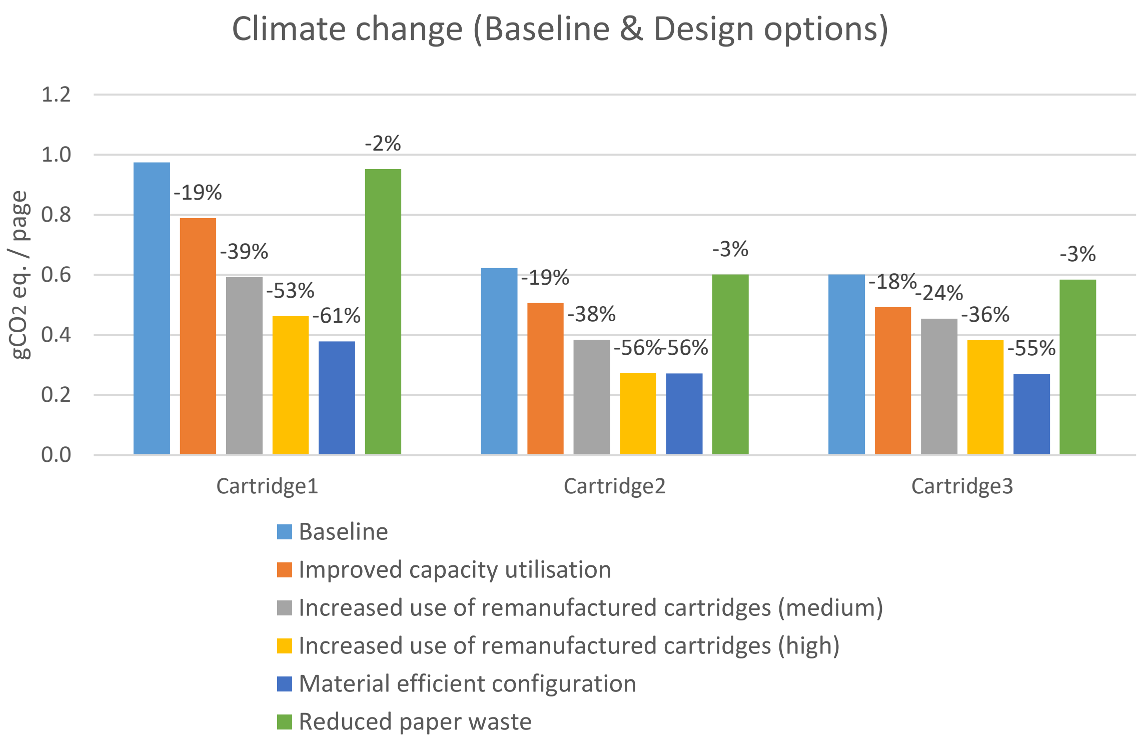


Figure 122. Improvement potential of design options for cartridges – Climate change

- The design option with the highest potential of reducing the environmental impact of cartridges is the use of material efficient cartridge configurations (single-part cartridges), with estimated improvements between 55%-61%.
- Increasing cartridge reusability (in a high reusability scenario) provides also significant environmental benefits to the use of material efficient configurations, around 36%-53%.
- A medium reusability scenario also provides environmental benefits between 24%-39%.
- Increasing the capacity utilisation of cartridges (increasing their average page yield) may reduce their environmental impact between 18%-19%.
- The benefit of reducing the amount of paper waste is around 2%-3%.

Figure 123 shows the improvement potential of the design options proposed, in terms of Life cycle cost (per page produced over lifetime).

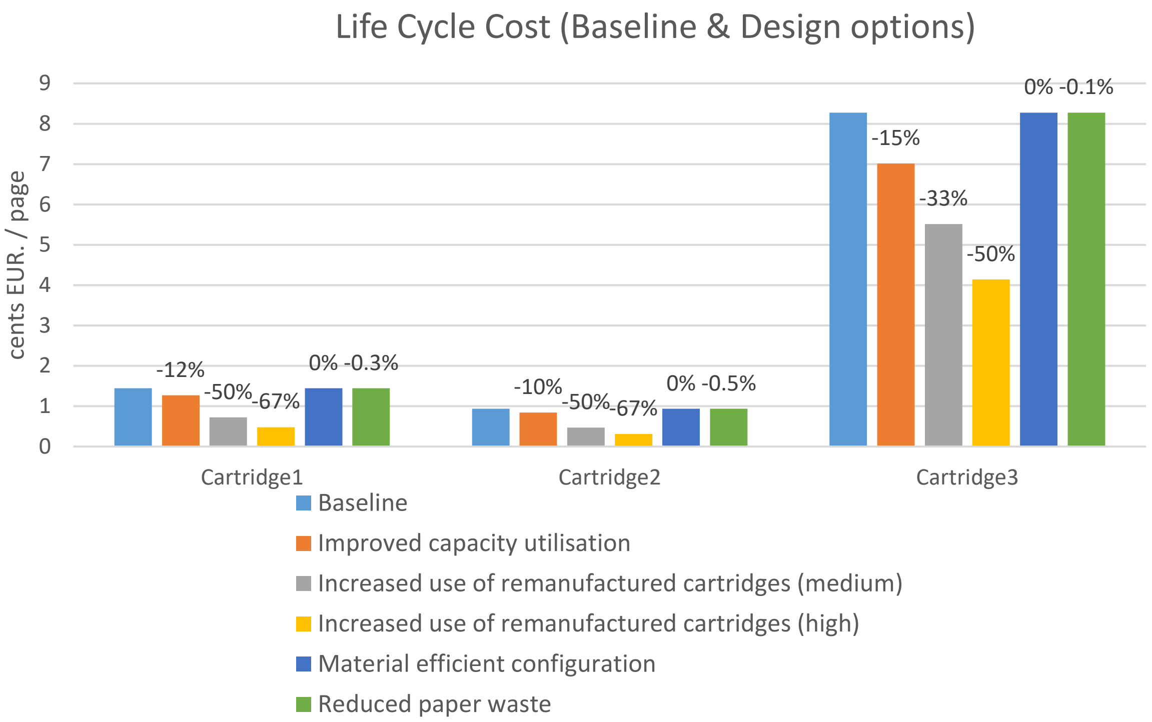


Figure 123. Improvement potential of design options for cartridges – Life cycle costing

- The highest opportunities for reducing consumer expenditure of cartridges are provided by increasing reusability scenarios (both medium and high), with improvements between 33-50% in the medium reusability and 50-67% in the high reusability.
- Increasing the capacity utilisation of cartridges –increasing page yield- can also reduce consumer expenditure, between 10%-15%.

6.3 Sensitivity analysis

In the context of a Life Cycle Assessment study, a sensitivity analysis is a method of testing how the results change when you vary one or more input parameters or assumptions (for instance, the functional unit, the system boundaries, data sources or assumptions).

In Tasks 5 and 6, the environmental performance of different products (printers and cartridges) has been evaluated, using as an input a variety of data from different sources. For some key parameters, assumptions have been made by the authors. The purpose of this sensitivity analysis is to evaluate how the results vary when these assumptions are changed.

For devices, a sensitivity analysis will be carried out, considering different lifetime extensions. For cartridges, two aspects will be evaluated in this section: different levels of reuse and different levels of material efficiency.

6.3.1 Device lifetime extension

In section 6.1.1, the environmental benefits of extending the lifetime of devices has been evaluated. For that, it has been assumed that, after refurbishing, the life of the device is extended, on average, by 50%. In this section, different lifetime extensions are checked: 30% and 75%. The results of this analysis can be seen in Figure 124.

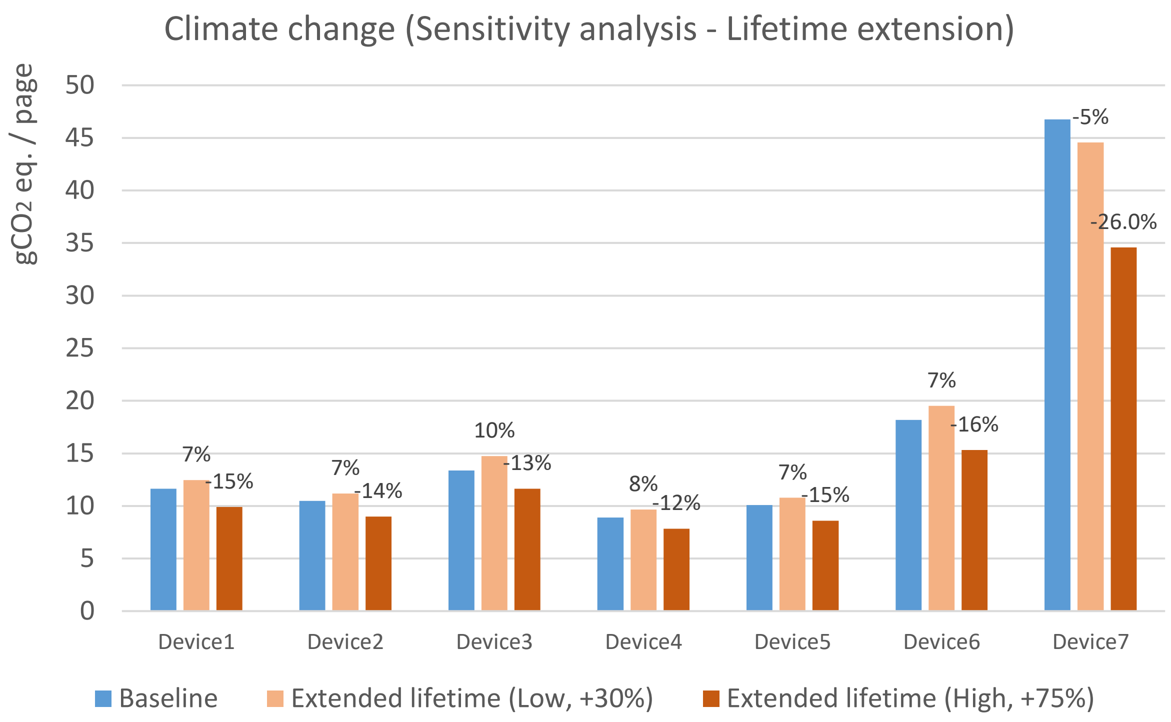


Figure 124. Sensitivity analysis – Device lifetime extension

In section 6.1.1 it was concluded that extending the lifetime of the device by 50% provides overall impact reductions for all base cases (see Table 80). However, as can be seen in Figure 124, extending device lifetime does not always provide environmental benefits.

If lifetime is only extended by 30%, the impact is higher than the baseline in 6 out of 7 of the base cases evaluated. This is because the extra energy and materials required to refurbish the device are not compensated by the additional lifetime obtained. In contrast, if lifetime is extended by 75%, the impact is lower than the baseline in 7 out of 7 of the base cases evaluated.

From this analysis, it can be concluded that refurbishing printers to extend their lifetime is beneficial for Climate change, only if lifetime is extended for a significant amount of time. This also shows that lifetime extension is a key parameter in this Life Cycle Assessment.

6.3.2 Cartridge reuse rates

In section 6.2.2 the environmental benefits of increasing the use of remanufactured cartridges has been evaluated. For that, it has been assumed that, in a medium reusability scenario, cartridges are reused on average 1 time; and in a high reusability scenario, 3 times. In this section, different levels of reused are checked. In this case, it has been considered that ink cartridge are less likely to be remanufactured than toner cartridges (Table 104).

Table 104. Sensitivity analysis – Cartridge reuse rates

Level of reuse	Cartridge base case	Number of reuses (average)
Marginal	Toner cartridge for A4 device	0.25
	Toner cartridge for A3 device	0.25
	Ink cartridge for A4 device	0.10
Low	Toner cartridge for A4 device	0.50
	Toner cartridge for A3 device	0.50
	Ink cartridge for A4 device	0.25

The results of this analysis can be seen in Figure 125.

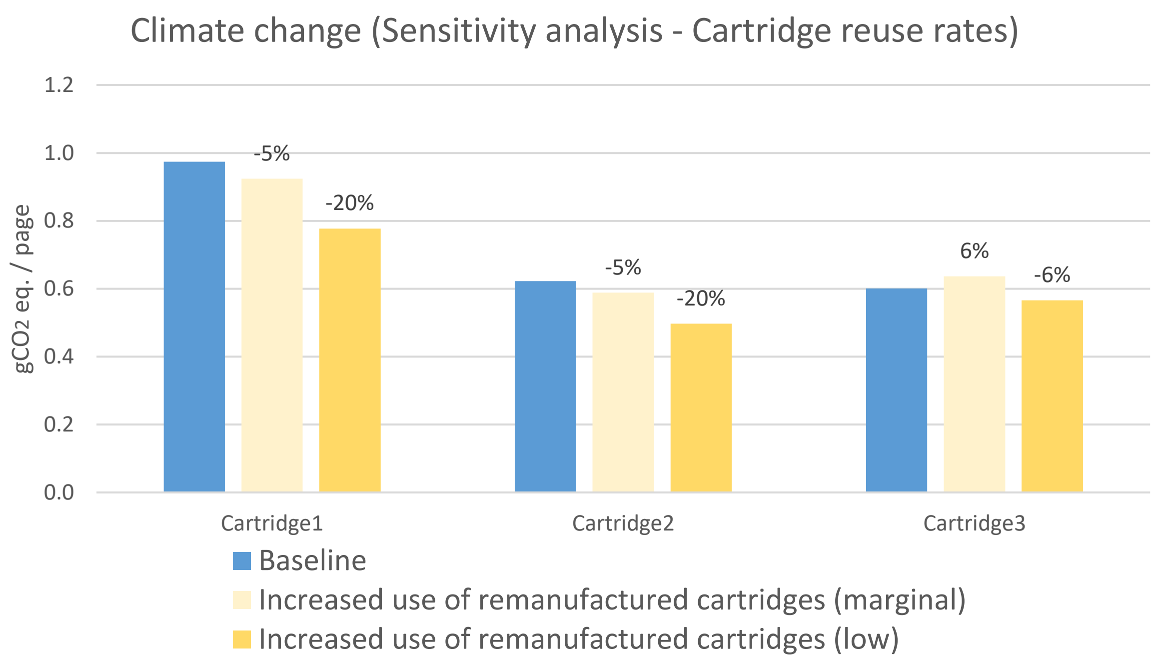


Figure 125. Sensitivity analysis – Cartridge reuse rates

In section 6.2.2 it was concluded that increasing the use of remanufactured cartridges provided overall environmental reductions for all base cases, both in a medium and in a high reusability scenario. However, as can be seen in Figure 125, increasing the use of remanufactured cartridges does not always provide environmental benefits.

In a low reusability scenario (0.5 reuses for toner cartridges, and 0.25 reuses for ink cartridges), environmental benefits between 6% and 20% can be obtained. However, in a marginal reusability scenario (0.25 reuses for toner cartridges and 0.1 reuses for ink cartridges), only 2 out of 3 of the base cases show environmental improvements. If ink cartridges are only reused, on average, 0.1 times, then the extra pages provided do not compensate the additional materials and energy consumed during remanufacturing.

From this analysis, it can be concluded that remanufacturing cartridges is beneficial for Climate change, only if they are reused for a minimum amount of times. This also shows that cartridge reuse rates is a key parameter in this Life Cycle Assessment.

6.3.3 Cartridge material efficiency

In section 6.2.3, the environmental benefits of improving the material efficiency of catridges have been evaluated. For that, it has been assumed that different cartridge configurations have different values of material efficiency. In this section, an alternative (intermediate) material efficiency value has been checked (Table 105).

Table 105. Sensitivity analysis – Cartridge material efficiency

Design option	Material efficiency base case (pages/gram)	Material efficiency design option (pages/gram)	Material efficiency sensitivity analysis (pages/gram)
Toner cartridge for A4 device	6.3	41.6	23.9
Toner cartridge for A3 device	11.1	57.8	34.4
Ink cartridge for A4 device	11.0	30	20.5

The results of this analysis can be seen in Figure 126.

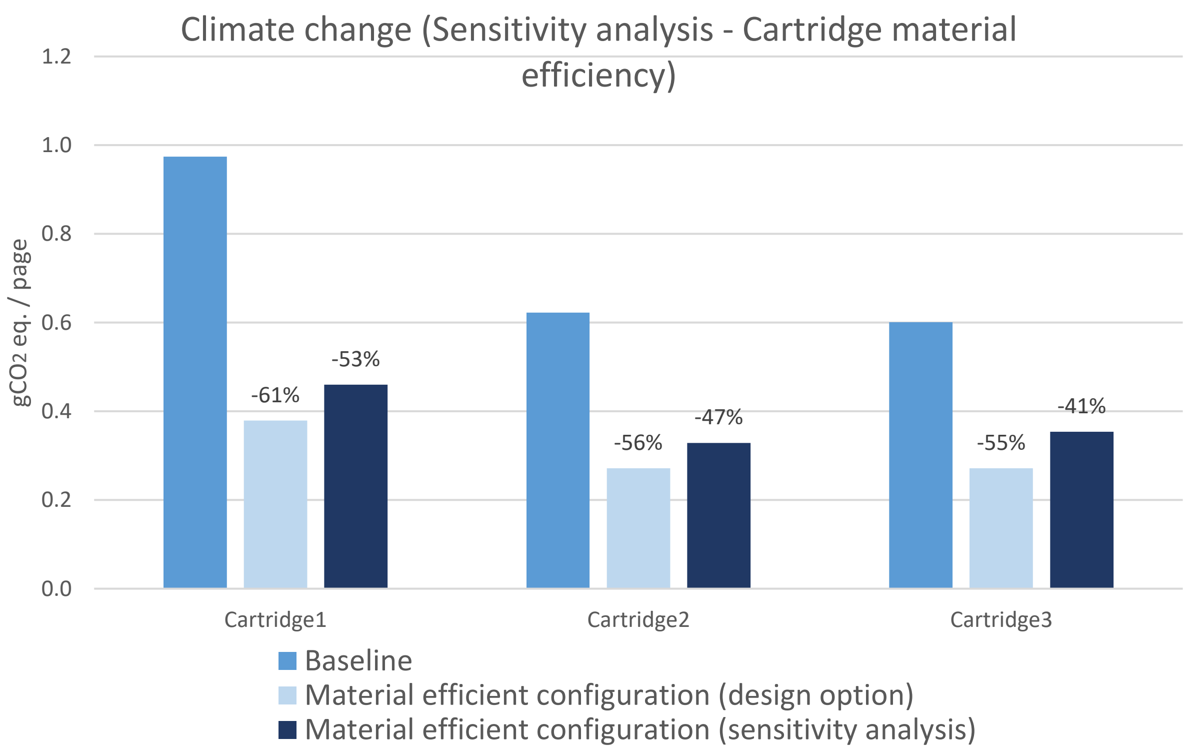


Figure 126. Sensitivity analysis – Cartridge material efficiency

In section 6.2.3 it was concluded that improving material efficiency of cartridges provided overall environmental reductions for all base cases (between 55-61%). This conclusion can be confirmed with the findings of the sensitivity analysis: assuming lower material efficiency than in the design options of section 6.2.3, significant environmental improvements can still be expected for the three base cases (41-53%).

7 Task 7 – Policy options

In this section, ecodesign measures that may be applicable to devices and cartridges have been proposed by the JRC authors. The proposal of these measures is based on the information gathered in Tasks 1-4, as well as on the environmental an economic assessment carried out in Tasks 5 and 6.

Ecodesign measures in this section are presented individually. Each measure is described following the schema below:

- Applicability: the device or cartridge type affected by the ecodesign measure
- Content of the measure: a preliminary text proposal for the ecodesign measure
- Relevance and feasibility: main reasons that justify the inclusion of the ecodesign measure
- Assessment and verification: an indication on how the ecodesign measure might be assessed and verified by market surveillance authorities
- Feedback from stakeholders: a summary of the feedback received from stakeholders

It is important to highlight that the measures proposed by the JRC in this section are the version that was presented in the 3rd TWG Meeting held in October 2023. They were not modified based on stakeholder feedback. All feedback provided by each stakeholder has been added after each proposal. This facilitates understanding what was proposed from the JRC authors, and every stakeholder's view on each of the proposals.

An overview of the feedback received, further work required, next steps and potential outcome related to each measure has been proposed in Section 8 of the Preparatory Study.

It is also worth noting that every proposal made in the following sections would be applicable to all new products placed on the EU market[162].

7.1 Ecodesign measures for devices

In section 4.4.8, preliminary objectives of policy options on devices were identified. In this section, areas for ecodesign measures are proposed and developed.

Table 106. Objectives, Design options and Areas for measures (Devices)

Objectives of measures	Design options	Areas for measures
Ensure that devices last longer and are easier to repair, refurbish and recycle	Device 1.1 to Device 7.1 Device with extended lifetime	7.1.1. Reparability of devices 7.1.2 urability of devices 7.1.3 Recyclability of devices
Explore untapped potential for improved energy savings in devices	Device 1.2 to Device 7.2 Device with reduced energy consumption	7.1.4 Reducing energy consumption of devices
Optimize the consumption of paper	Device 1.3 to Device 7.3 Device with reduced paper consumption	7.1.5 Paper use optimization in devices
Increase the amount of post-consumer recycled plastic in devices	Device 1.4 to Device 7.4 Device with increased use of post-consumer recycled plastic	7.1.6 Post-consumer recycled content of devices

Individual ecodesign measures associated to each of the above objectives and areas are described in the following sections.

[162] A remanufactured product is also a new product

7.1.1 Reparability of devices

As described in section 4.4.2 and section 4.4.3, there is room to extend the technical lifetime of devices via reparability measures. Reparability is also a relevant aspect for consumers: nearly 70% of respondents have experienced some sort of printer failure, but only 21% have had their printer repaired (Figure 25 and Figure 29). The main reason for not repairing their device is cost (Figure 30).

The potential environmental benefit of extending the lifetime of devices has been estimated in section 6.1.1: reductions in Climate change impact can be achieved between 3% and 17%, depending on the device type.

The potential consumer expenditure benefit has been estimated in section 6.1.1: reductions in cost per page between 4% and 7%, depending on the device type.

The first step to define measures to increase the reparability of devices is to define a list of priority parts for repair. In section 4.4.3.1, different lists of priority parts for repair from different sources have been presented. The most comprehensive list is the one provided by Blue Angel (DE-UZ 219), which differentiates between laser and inkjet devices, as well as parts to be provided for users and professional repairers (Table 107). Therefore, this is the list of priority parts that will be used as a reference for the definition of ecodesign measures.

Table 107. Priority parts for repair

	For consumers	For professional repairers
Laser 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	Ink collection tank / excess ink reservoirs (including 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 (including sponges)

Feedback from stakeholders

The association of manufacturers support the proposed list of priority parts for repair. They noted that some details, including specific exemptions, would need to be included in any regulatory proposal such as printheads and excess ink reservoirs designed to last the lifetime of the equipment.

Cartridge remanufacturers suggest that chips should be included in the list of priority parts for professional cartridge remanufacturers.

One national environmental agency suggested that all kind of electronic displays –especially smaller displays- shall be made replaceable and therefore should be included in the list of prioirity parts.

Another environmental agency recommended adding the following parts to the list:

- For inkjet printers, professional repairers: internal power supply unit.
- For laser printer, professional repairers: drive motor for paper transport, separation rollers and pads.
- For laser printer, consumers: closing lid

One NGO consider that the list of priority parts to make available to consumers is too restrictive. While they understand there might be some spare parts that necessitate the involvement of a professional repairer for safety reasons (e.g. for some professional laser devices), most of the spare parts listed in the table should be made available to consumers too. Smaller devices targeted at home users and smaller offices are designed to have basic maintenance (such as exchange of consumables) done by the end-user. They also noted that, for laser printers, many of the listed spare parts (e.g. drum, laser unit, fuser unit, toner collection unit) are considered consumables and are currently available on consumer-oriented websites. They also suggest to consider the potential effect of the material efficiency requirements proposed in 7.2.2 which could restrict integrated or all-in-one cartridges. They consider that integrated/all-in-one cartridges are restricted, other consumables such as the drum should eventually be made available to consumers too (and not only to professional repairers).

7.1.1.1 Design for disassembly of priority parts

Applicability: Laser & Inkjet devices

Content of the measure:

Priority parts for professional repairers shall comply with the following requirements:

- Fasteners shall be removable
- Process for replacement shall be feasible with commercially available tools
- Process for replacement shall be able to be carried out in a workshop environment
- Process for replacement shall be able to be carried out by a generalist

Priority parts for consumers shall comply with the following requirements:

- Fasteners shall be removable
- Process for replacement shall be feasible with commercially available tools
- Process for replacement shall be able to be carried out in a use environment
- Process for replacement shall be able to be carried out by a layman

Relevance and feasibility

Technical lifetime of devices is often not fulfilled, both in household and office sector. Designing devices with reparability in mind –ensuring that priority parts are easily accessible, removable with commonly available tools, in the relevant environment, without damaging the device- can help to increase average printer lifetime.

Assessment and verification

This measure shall be verified with the provision of the following information, in a repair manual with the device and on a free access website:

- Exploded view of device
- Illustration of how parts can be accessed, replaced and reassembled (indication of required tools, fasteners location, etc.)

Feedback from stakeholders

The association of manufacturers considered that the authors of the Preparatory Study had leveraged approach from other regulations –particularly, mobile phones and tablets- which may not transfer easily to imaging equipment. The product scope of mobile phones and tablets regulation is quite limited and homogenous in terms of design. The imaging equipment portfolio on the other hand is very broad and diverse. In their view, this may require a more detailed consideration and proposal (although no specifics were provided). They added that terms such as 'generalist', 'layman' or 'workshop environment' would have to be defined.

A national environmental agency recommended that, when stating that spare parts should be replaceable with the use of commonly available tools, it should also be ensured that it is without permanent damage to the device.

7.1.1.2 Availability of priority parts and delivery time

<u>Applicability</u>: Laser & Inkjet devices

<u>Content of the measure:</u>

Priority parts shall be available for consumers and/or professional repairers for a minimum period of 10 years after placing the last unit of the model on the market.

Priority parts shall be available for consumers and/or professional repairers in less than 10 working days after having received the order

<u>Relevance and feasibility</u>

As highlighted in section 4.4.3.3, there are significant differences in terms of availability of spare parts for printers in the EU market today. This availability can vary between a wide range of spare parts available for some printers, and no parts at all for others. It is not possible for consumers today to know which parts, and for how long their availability will be guaranteed.

Providing certainty to consumers on the availability of spare parts and their delivery time, can help to encourage printer repair and increase average lifetime.

<u>Assessment and verification</u>

This measure shall be verified with an indication by the manufacturer of the list of spare parts which are available for repair, together with their delivery time, in a repair manual provided with the device and on a free access website.

<u>Feedback from stakeholders</u>

The association of manufacturers exposed that the authors of the Preparatory Study may have leveraged the minimum period of 10 years from ecodesign regulations for white goods without any real basis relative to imaging equipment, nor to the exisiting timeframe of 7 years in ecodesign regulations for other ICT equipment and also in line with Blue Angel DE-UZ 219.

Manufacturers consider that 7 years is appropriate for printers as with other ICT products. Also, given the breadth and diversity of the imaging equipment portfolio, applying a single timeframe to the entire portfolio is a gross oversimiplification (the appropriate period of spare part provision is not the same for a 50 EUR consumer inkjet printer and a 9,000 EUR enterprise laserjet multifunction device). In their view, a single timeframe is not a reasonable approach.

Manufacturers argue that requirements to maintain parts when they are not needed leads to significant waste and is contrary to the objective of material efficiency. Parts are typically manufactured at the same time as the printers, because during that period the factories are set up to manufacture those parts. Manufacturers therefore need to predict the numbers of spare parts that will be used in the lifetime of those products. The longer the period in which spare parts must be provided, the greater the variability in those estimates and the greater the potential for waste.

Manufacturers also consider that a separate spare part availability period should be established for remanufactured/refurbished devices. Blue Angel DE-UZ 219 has set a spare parts availability period of 5 years from the placing on the market device for remanufactured/refurbished devices. The requirement to ensure the availability of spare parts for remanufactured/refurbished devices should fall on the remanufacturer/refurbisher (the original manufacturer has no control or visibility over how long remanufacturing/refurbishing of devices will continue).

An individual device manufacturer provided additional feedback in the same terms. This OEM also considered that 10 years is excessive for a guarantee and suggest aligning with Blue Angel and EPEAT requirements that are between 5 and 7 years. They argue that user behavior will drive this aspect. As they see it, it is the OEM best interest for machines to last and print as long as possible. They highlight that as long as users are still printing with the devices, OEMs will continue to support them.

This OEM adds that material suppliers will not supply very low volumes for 10 years, so these will need to be purchased years in advance, leading to large inventory (plus insurance stock) that will need to be stored for years (and potentially not used), therefore scrapped. In their view, this would offset environmental impact of customers keeping devices longer.

7.1.1.3 Availability of information on repair, maintenance and price of spare parts

Applicability: Laser & Inkjet devices

Content of the measure:

The list of spare parts and the procedure for ordering shall be publicly available on a free access website managed by the OEM, at least 2 years after the placing on the market of the first unit of a model, and until the end of the period of availability of spare parts.

Repair instructions shall be available for consumers on a free access website for the priority parts targeted for them.

Repair and maintenance information shall be available for professional repairers 2 years after the placing on the market of the first unit of a model and until the period of availability of the spare parts.

In order to have access to repair and maintenance information, OEMs may ask the professional repairer to meet certain conditions, similar to other products under Ecodesign regulation (technical competence, insurance, etc.)

Access to repair and maintenance information shall be made at a reasonable and proportionate cost for professional repairers.

Once registered, professional repairers shall have access to repair and maintenance information within one working day after requesting it.

Repair and maintenance information shall include: device identification, disassembly map or exploded view, technical manual of instructions for repair, list of necessary repair and test equipment, component and diagnosis information, wiring and connection diagrams, diagnostic fault and error codes, instructions for installation of relevant software and firmware including reset software, information on how to access data records of reported failure incidents stored on the device

Information on the price of spare parts shall be available on a free access website. A minimum requirement on spare part pre-tax price (as a fraction of the product purchasing price) shall be considered.

Relevance and feasibility

As indicated in section 4.4.3.3, manuals provided by OEMs today contain little or no information on repair. Moreover, the cost of some of the priority parts can be a big percentage of the initial purchase price of the device (up to 86% in some examples).

Providing relevant information on repair, and ensuring the price of spare parts is reasonable, can help to encourage printer repair and increase average lifetime.

Assessment and verification

This measure shall be verified with a provision of a repair manual with the device and on a free access website, including as a minimum the information indicated in this section.

Feedback from stakeholders

The association of manufacturers consider that the list of repair information elements which shall be provided is not applicable to all imaging equipment product models because the product portfolio is very broad and diverse. In their view, any such regulatory requirement must include "if/as applicable" and be limited to information that is necessary to complete repairs. They add that the listed information will not always be relevant or necessary and it makes no sense to force OEMs to create information where it has no value. They recommend to limit requirements to applicable information and that which is necessary to complete repairs.

The association of manufacturers is strongly opposed to the proposal to set spare part prices as a fraction of the printer purchasing price, and recommend deleting this proposal. They do not think that the Ecodesign Directive allows for setting of prices. They consider this as extremely challenging to implement for a variety of reasons:

(a) This favours more expensive printers

(b) What if the printer is sold at a discount or if the manufacturer wants to change printer price throughout the printer lifespan?

(c) Would manufacturers have to provide a special price for each customer based on what they paid? – if products are sold indirectly manufacturers don't know what they paid;

(d) Would someone who buys a part on day 1 have to get the same price as a person who buys 15 years later?

Another individual manufacturer suggested that, in addition to Blue Angel and EPEAT, alignment with R2R laws in NY and CA in the US should be taken into account. They also consider that regulating price of spare parts should be out of scope for an Ecodesign regulation, and wonder about the meaning of "reasonable and proportionate" cost.

They add that a clear disctinction between spare parts requirements for the B2B and B2C market should be made, because consumers have different expectations than professional users. The scope and definitions of spare parts needs to be clarified. In terms of the list of spare parts and the procedure that shall be publicly available on a free access website, they ask for clarification whether it applies to "all spare parts" or the "priority list".

An NGO asks for clarification on the availability of repair information to consumers. They explain that the JRC recommends to provide access to repair and mantainance information after 2 years from the placing on the market, while under the Ecodesign Regualtion for smartphones and tablets, this requirement applies (for both information and spare parts availability) as of 1 month after the date of placement of the market.

7.1.1.4 Availability of resetting functionality

Applicability: Laser & Inkjet devices

Content of the measure:

The device shall have software functionality that allows resetting to initial factory settings.

Restoring factory settings shall be possible with the help of a software function, either integrated in the device or accessible on a free access website.

Relevance and feasibility

Factory reset may be necessary to return devices before a fault occurred.

Having this feature reduces the probability that a device with a fault that can be fixed by resetting it is discarded prematurely.

Assessment and verification

This measure shall be verified with an indication from the manufacturer on the availability of resetting functionality in the user manual, provided with the device and on a free access website. Instructions on how to reset the device to factory settings shall also be included in the user manual.

Feedback from stakeholders

The association of manufacturers consider that this requirement would need to be properly considered and defined. In their view, it should be limited to settings that have been changed by the user and the reset would be back to the default settings as shipped from the factory. Some data such as page counter information, usage data should not be resettable without proper diagnosis and repair. Resetting this data could result in disabling of ink and toner cartridges and a loss of data needed to identify when wear parts need to be replaced. In some cases with office/managed products the settings are set by service personnel to prevent faults (requiring repairs and environmental impact) and should not be easily resettable by unqualified users.

An environmental NGO makes a proposal that contradicts the above. They consider that the key to encouraging more reuse of cartridges lies in the ability of users to reset the firmware in the printer and not just on the cartridge. Therefore, an ecodesign requirement could be written that allows users to reset the printer when a remanufactured cartridge is installed. The remanufactured cartridge would then appear to the printer as if it is an unused cartridge. In their view, this should be accompanied by a requirement that stops any code being written to the chip which limits the ability to refill or remanufacture the cartridge (as written in 7.1.2.1 Software and firmware updates). They suggest the following wording, which could be incorporated in measure 7.1.1.4:

> *Imaging equipment must contain functionality that allows users to clear any stored data about a previously used cartridge. OEMs may provide a warning to users that resetting the firmware before a cartridge has been refilled or remanufactured may result in unreliable remaining ink/toner levels and could result in damage to the printer that would not be covered under warranty*

7.1.2 Durability of devices

In section 7.1.1, a series of measures to increase device lifetime via reparability have been proposed. Making a device more reparable is a strategy to increase its lifetime, but not the only one, or – some cases – not the most appropriate one. For instance, in the case of key components that get easily worn out or damaged during operation, it is not enough to ensure that they can be easily replaced; it must be ensured that these components provide a minimum performance for a considerable period (ensure a minimum durability). Therefore, complementary to the measures to extend the lifetime of devices via repair, a series of measures to increase the durability of devices has been proposed.

7.1.2.1 Software and firmware updates

Applicability: Laser & Inkjet devices

Content of the measure:

Updated software and firmware shall be provided for a minimum period of 10 years after the placing on the market of the last unit of a product model.

Software and firmware updates shall include printer drivers, operating systems of printers and/or security software.

Software and firmware updates shall not have the effect of changing the device or cartridge performance.

Software and firmware updates shall not prevent the refilling and remanufacturing of cartridges or the use of third party cartridges.

Relevance and feasibility

As highlighted in section 4.4.3.4, software obsolescence can be prevented with guaranteed availability of printer software and firmware, for a specific and long enough period. Providing software and firmware updates for a significant period reduces the probability that a device is discarded due to incompatibility with a new or updated operating system.

On top of that, around ¼ of consumers indicate that they have experienced a compatibility issue between the printer and cartridge, often caused by a software or firmware update (Figure 25). A similar percentage experienced cartridge-related failures on compatibility (Figure 26). Ensuring that software and printer updates do not affect the performance of third party cartridge can help to reduce early discarding of cartridges.

Assessment and verification

This measure shall be verified with an indication from the manufacturer on the procedure to update software and firmware in the user manual, provided with the device and on a free access website. A declaration shall be provided from the manufacturer in the user manual, guaranteeing that software and firmware updates will not change the device or cartridge performance, nor prevent the use of third party cartridges.

Feedback from stakeholders

The association of manufacturers consider that this proposal is problematic in a number of ways:

(a) First sentence - "updated software" - if a requirement to update software is going to be included it must specify the types of updates that are required. Manufacturers support the wording currently used in the Displays Implementing Measure: "the latest available version of the firmware shall be available for a minimum period of [x] years after placing on the market..."

(b) First sentence - 10 years after placing on the market of the last unit of a product model. The printer market is very broad and diverse. Setting a single period for maintaining software applicable to all printers does not make sense. Maintaining software is complex and expensive and the complexity and cost increase significantly over longer time periods.

(c) The third sentence requires that the software/firmware update shall not change the device or cartridge performance. The whole purpose of a software/firmware update is to change something in the printer. The ability to make changes using software/firmware updates is both necessary and desirable. It would also not be workable to simply state that only positive changes are permitted because changes to software/firmware involve complex interactions such that this would be extremely hard to assess and enforce.

(d) Fourth sentence. Manufacturers support the view that software/firmware updates should not prevent the use of remanufactured/refilled cartridges that maintain the original and unmodified electronic circuitry. However, OEMs cannot be responsible for something they do not design or place on the market and may not even be aware of or have access to i.e. third party chips. Making OEMs responsible for the functioning of third party chips would require OEMs to carry out tests on every single third party chip on the market over an undefined period of time regardless of quality and regardless of whether they even have access to or are aware of the existence of those chips. This would, in effect, make it impossible for OEMs to produce software and firmware updates. The proposal in 7.2.3.1 provides an OEM solution (complementary to OEMs' own remanufacturing) to ensure that cartridges can be remanufactured with key functionalities (including cartridge acceptance) using the original circuitry. This is consistent with Ecodesign and can be verified to market surveillance authorities by the OEMs. In fact, for this reason, with the proposal in 7.2.3.1 the fourth sentence in 7.1.2.1 is not necessary because the proposal in 7.2.3.1 would provide a legally required solution for acceptance of refilled/remanufactured cartridges.

An individual OEM does not consider regulating firmware availability for 10 years as an advantage to drive circular economy and reduce the overall environmental footprint of the imaging equipment industry. Regarding the concern about firmware updates not changing functions, they argue that functions are modified all the time, and that in most cases, this is the point of firmware updates: to drive improvements and field fixes, including security updates. In terms of software and firmware updates not preventing the use of third party cartridges, this manufacturer argues that OEMs cannot be responsible for something they do not design or place on the market and may not even be aware of or have access to.

A national environmental agency recommends that firmware, drivers, security updates and operating software shall be made available, to prevent software-based obsolescence, with the following conditions:

(a) The timeframe for the availability of these updates and software should be aligned to the timeframe for the availability of spare parts.

(b) Firmware, drivers, security updates, and operating software shall never have the effect of changing the product's performance in such a way, that it no longer meets the minimum requirements or to prevent the use of third party cartridges or remanufactured cartridges.

An environmental NGO strongly support the proposed measures guaranteeing sofware updates availability and believe that software updates should not have the effect of preventing the refilling, use and remanufacturing of any cartridge: OEM, third party and remanufactured cartridges. Another environmental NGO agrees with this approach and recommends the following change in the content of the measure:

No existing or updated software or firmware updates shall prevent the refilling and remanufacturing of cartridges by altering the cartridge chip, nor shall any software or firmware updates prevent the use of refilled or remanufactured cartridges in imaging equipment

A Member State representative adds that (spare) part pairing should not be allowed. This would also follow from requirements on the possibility to use refilled or remanufactured cartridges.

7.1.2.2 Warnings and messages about cartridges

Applicability: Laser & Inkjet devices

Content of the measure:

Messages with inflammatory terminology toward the use of remanufactured cartridges shall not be given to users.

Inflammatory terminology may include –but not limited- claims about printing quality of remanufactured cartridges or potential security risks on the use of remanufactured cartridges.

Relevance and feasibility

Ensuring that non-inflammatory terminology toward the use of remanufactured cartridge is given to consumers would help to increase cartridge reuse rates.

Assessment and verification

A verification of correct installation message when remanufactured cartridges are installed in the device.

Feedback from stakeholders

The association of manufacturers consider that the term "inflammatory terminology" is unclear. In the context of a regulation OEMs need clarity to ensure that they can design compliant products. They add that it would be wrong and counterproductive to prohibit OEMs from providing messages to users that install cartridges in printers such as to inform the customer as to the type of cartridge they have installed or that a cartridge has been reset using an OEM solution in accordance with measure 7.2.3.1. Therefore, if such an obligation is to be included in the regulation then it will be extremely important to provide clarity to OEMs so that they can design printer firmware. They recommend to review this measure and provide clear criteria so that OEMs have certainty on messages that are not permitted. Any requirements must take into account the reasonable interests of the OEM as manufacturer of the printer and the need to provide information to users.

Another individual manufacturer agrees with the general approach but wonders who would decide what is 'inflammatory' and what is not. Therefore, they suggest to have a clear definition section of the terminology. They add that they would still want to provide messages to their customers when they are not using an original cartridge.

7.1.2.3 Access to information on number of pages printed

Applicability: Laser & Inkjet devices

Content of the measure:

Devices shall have a function that provides information to the user to compare the number of pages printed versus the device duty cycle.

Relevance and feasibility

Most of multi-function printers currently in use are less than three years (37% of respondents), or between three and five years (35%), which suggests a quick replacement rate.

The replacement of devices is high as well under MPS contracts. Devices often do not achieve their duty cycle within the period of the contract and are replaced with similar new devices before the contract ends under a renewed MPS deal, as indicated in section 4.4.2.1.

Providing the user with information on the percentage of the technical lifetime actually used at any time would help to make the most environmentally conscious decisions in terms of device replacement, potentially contributing to extend the average lifetime of devices.

Assessment and verification

This measure shall be verified with an indication from the manufacturer on how to access this information in the user manual, provided with the device or on a free access website.

Feedback from stakeholders

The association of manufacturers consider that this proposal would be counter-productive and should not be included in regulation. They argue that there is no recognized standard for measuring device duty cycle. This depends on many factors such as temperature, humidity, type of paper used, print coverage, use of 3rd party consumables, etc. They add that some products are designed to be used in a range of environmental conditions that are not always consistent and stable. Each OEM will have a different methodology for setting the duty cycle. This may create unrealistic expectations of the printer life and is unlikely to have a significant impact on product lifespan. Any declared lifetime would be a minimum value and would be inaccurate for a majority of users, possibly leading high-usage customers to want to replace devices unnecessarily.

Another individual manufacturer explains that the number of pages printed is already available in devices. However, they typically do not claim a lifetime for the printer. In their product information file, they use wording such as:

> *These products are modular in design so that any component that fails may be replaced. With proper care and routine maintenance, the product will have an indefinite life.*

They add that printer lifetime is affected by many conditions, depending on the environment it is used in and the media type that is used by the customer. Any declared lifetime would be a minimum value and would be inaccurate for a majority of users. This theoretical approach would not work in practice.

An environmental NGO state thaty they currently have no data on the possible impact of providing consumers with access to information on number of pages printed. However, an assessment conducted by one of their members on inkjet printers, page counters (where the page count is not freely accessible to the user) are causing premature obsolescence. For instance, the waste ink pad is considered full after an undisclosed number of pages printed, after which the device stops working. The ink pad is not easily accessible, even though it seems that it could be designed to be so; and the internal counter can only be reset by the manufacturer. Sending the printer out for repair is often as expensive as a new device and thus for many printers, this issue leads to it being discarded.

A national association of cartridge remanufacturers supports the proposal. They consider that all printers already measure the number of pages they print and are produced with an expected life cycle and monthly duty cycle. However, evidence shows that the average effective printer life is extremely short and that the contract sales business model has resulted in printers being retired long before their technical lifetime. They add that if every device would have a page counter, this will avoid unnecessary early retirements and strengthen the market for secondary printers.

7.1.2.4 Durability of key consumables of laser devices

Applicability: Laser devices

Content of the measure:

Key consumables in laser devices shall last, as a minimum, the number of pages indicated in Table 108.

Table 108. Minimum durability of key consumables of laser devices (number of pages)

	Fuser unit	Transfer unit	Waste toner unit	Drum unit
24 months after entry into force of this regulation	50,000	50,000	20,000	10,000
36 months after entry into force of this regulation	57,500	57,500	23,000	11,500
48 months after entry into force of this regulation	62,500	62,500	25,000	12,500

Information on minimum durability of the above components shall be provided in the technical specification of the device, in number of pages.

Relevance and feasibility

Fuser units, transfer units, waste toner units and drum units are key consumables in laser devices which often need to be replaced during the lifetime of the device. Ensuring a minimum lifetime in each of those components might help to close the gap between real and technical lifetime of devices.

In section 7.2.2.1 and 7.2.2.2, minimum ecodesign measures for cartridges in terms of material efficiency have been proposed, aiming to drive the market from all-in-one/integrated configurations to single-part solutions (containers). There is a slight risk in this strategy: according to feedback from NGOs, some OEMs might be incentivised to make other components (eg. Fusers, Drums) “the consumables”. To avoid that certain components are designed to be frequently replaced, or to discourage lower lifetimes than today, minimum durability requirements are proposed.

The thresholds proposed are based on available data on typical lifetime of consumables (section 4.4.3.1), and assuming a reasonable maximum number of replacements of each consumable across lifetime. The initial minimum requirements are increased by 15% and 25%, 36 months and 48 months after the regulation enters into force.

Providing the user with information on the technical lifetime of key components in terms of pages would help them make the right purchase decisions, as well as understanding the percentage of technical lifetime actually used at any time.

Assessment and verification

This measure shall be verified with the provision of information on the page yield of each of the above components, when they are present in the device. This information shall be available in the product documentation sheet.

Feedback from stakeholders

The association of manufacturers consider that this proposal is problematic in a number of ways:

(a) The draft Preparatory Study sets one standard applicable to all printers. However, the imaging equipment market includes a very wide range of products from 50 EUR inkjet printers to 9,000 EUR multifunction office printers. In addition, for each printer within the product range, the user profiles can differ enormously in terms of numbers of pages printed per month. Setting a single standard for all printers is likely to result in wasted resources, for example, if a 12,000 page drum is required for printers where most users print less than 6,000 pages in the printer lifetime.

(b) It needs to be considered how durability would be measured. There are a great many variables that differ for different technologies and products.

(c) If durability criteria are set then sufficient time would have to be allowed for redesign cycles. Redesigning parts is complex and resource intensive and manufacturing timelines also need to be considered. It is simply not possible to redesign and manufacture parts within one year.

(d) Compatibility with existing products would have to be considered. If the durability requirements require redesign then OEMs cannot be certain of being able to produce consumables meeting the requirements that are compatible with existing printers. That would require redesign of printer, making the whole process more complex. While, with sufficient time, new printer models could be made to comply, the new consumables would likely not be compatible with the printers in the installed base. If OEMs are prohibited from supplying consumables for those printers then those printers would become prematurely obsolete with the consequent environmental impact. As written, the association is extremely concerned that this requirement would result in numerous unintended consequences and have a negative impact from an environmental perspective.

Therefore, the association of manufacturers consider that it is best to leave minimum durability to the market. However, if the Commission feels that there should be regulation, some sort of tiered system based on speed/price/usage should be considered and manufacturers would need to be closely involved in setting appropriate thresholds. Any threshold would have to set clear criteria for measuring durability and sufficient periods for redesign provided. Any requirements should only be applicable to new printer models.

Another individual manufacturer adds that setting minimum durability for consumables such as the waste toner bottle would force redesigns (forcing OEMs to design larger printers) for negligible environmental benefits. They also wonder how this measure would apply in printers that use all-in-one cartridges (where the drum is not in the printer, but in the cartridge).

A Member State representative wonders whether there is practical experience with the verification of minimum page yields proposed by the JRC in Table 108.

An environmental NGO states that the minimum page yield of waste toner units proposed by the JRC is too low, when compared to the required durability of other key consumables such as drum units. They add that waste toner units are essentially a plastic hopper and a wiper blade. A basic search of waste toner units shows that some have capacities over 100,000 pages, suggesting that the size of the hopper is the determining factor in page yield and not the wiper blade. To reduce the use of waste toner units, it would be preferable to link their minimum page capacities to the page yield of the other key consumables such as cartridges or drum units (or the duty cycle). That way, measures could be tailored to different types of imaging equipment and minimize the number of waste toner units used.

7.1.2.5 Durability of key consumables of inkjet devices

Applicability: Inkjet devices

Content of the measure:

Key consumables in inkjet devices shall last, as a minimum, the number of pages indicated in Table 109.

Table 109. Minimum durability of key consumables of inkjet devices (number of pages)

	Ink collection unit	Print head unit
24 months after entry into force of this regulation	10,000	10,000
36 months after entry into force of this regulation	11,500	11,500
48 months after entry into force of this regulation	12,500	12,500

Information on minimum durability of the above components shall be provided in the technical specification of the device, in number of pages.

Relevance and feasibility

Ink collection units and print heads are key components in inkjet devices which often need to be replaced during the lifetime of the device. Ensuring a minimum lifetime in each of those components might help to close the gap between real and technical lifetime of devices.

In section 7.2.2.1 and 7.2.2.2, minimum ecodesign measures for cartridges in terms of material efficiency have been proposed, aiming to drive the market from all-in-one/integrated configurations to single-part solutions (containers). As explained above, there is a slight risk in this strategy: according to feedback from NGOs, some OEMs might be incentivised to make other components (eg. Print heads) "the consumables". To avoid that certain components are designed to be frequently replaced, or to discourage lower lifetimes than today, minimum durability requirements are proposed.

The thresholds proposed are based on available data on typical lifetime of consumables (section 4.4.3.1), and assuming a reasonable maximum number of replacements of each consumable across lifetime. The initial minimum requirements are increased by 15% and 25%, 36 months and 48 months after the regulation enters into force.

Providing the user with information on the technical lifetime of key components in terms of pages would help them make the right purchase decisions, as well as understanding the percentage of technical lifetime actually used at any time.

Assessment and verification

This measure shall be verified with the provision of information on the page yield of each of the above components, when they are present in the device. This information shall be available in the product documentation sheet.

Feedback from stakeholders

The feedback from the association of manufacturers is equivalent to the one provided in 7.1.2.4.

An environmental NGO states that the minimum page yield of ink collection units is too low. As with the waste toner units, ink collection units are basic components that just collect waste ink. There are ink collection units available with capacities over 100,000 pages. Some ink collection units include chips that must be reset if the product is to be remanufactured. As such, it is important that ink collection units last as long as possible. It would be preferable to match the capacity of the ink collection unit to the page yields of the ink cartridges/containers designed for us in each model of imaging equipment. That way imaging equipment that is designed for heavy use would be required to have much larger ink collection units than small domestic inkjet printers.

7.1.3 Recyclability of devices

A series of measures to improve the recyclability of devices have also been proposed, in order to complement the measures to improve reparability and durability of devices.

7.1.3.1 Design for recyclability of devices

Applicability: Laser & Inkjet devices

Content of the measure:

Plastic parts weighing more than 25g or measuring more than 50cm2 shall be marked by material type, according to ISO 11469.

Plastic parts weighing more than 100g shall be manually separable into recyclable plastic streams with commonly available tools.

Devices shall use commonly used fasteners for joining components, subassemblies, chassis and enclosures.

Plastic casing parts weighing more than 100g shall consist of one single polymer or a polymer blend

All plastic casing parts shall only consist of up to 4 separable polymers or polymer blends

Large-sized casing parts shall be designed in a way that the contained plastics can be used for the production of high-quality durable devices by applying available recycling techniques

The use of coatings shall be reduced to a minimum, unless it can be demonstrated that it does not alter recyclability.

The device shall be designed in a way that joining, fastening or sealing techniques do not prevent access to the following components in a non-destructive method, and that the extraction method can be carried out using non-proprietary and commonly available tools: printed circuit boards greater than 10 cm2, ink and toner cartridges, plastic containing brominated flame retardants, electronic displays greater than 100 cm2, external electric cables, electrolyte capacitors containing substances of concern.

Information on how to access and dismantle such components shall be available to professional repairers, documenting the sequence of dismantling operations.

Relevance and feasibility

Ensuring that key components with valuable materials can be easily accessed would help to increase the amount of valuable materials recovered at device end of life.

Ensuring that materials included in devices can be easily identified and separated, avoiding contamination that hinders recycling processes, would help to divert devices from landfilling and incineration, increasing recycling rates.

These measures may have a dual objective, since they would also benefit device reparability.

Assessment and verification

This measure shall be verified with the provision of the following information on a free access website:

- Exploded view of device
- Illustration of how parts can be accessed and dismantled (indication of tools needed, disassembly steps)

Feedback from stakeholders

The association of manufacturers does not object to the substantive requirements but does object to the assessment and verification. In their view, the appropriate way to evidence compliance is through WEEE disassembly instructions which are already produced by and available from manufacturers. Indeed, an exploded view would not seem to act as evidence of compliance of the specific requirements.

A national environmental agency finds it challenging, and possibly confusing, that there are different requirements for plastic parts and plastic casing. They consider that the Waste Directive should address the question of what constitutes recyclable waste streams. They suggest that for both component groups, requirements are set for the plastic parts to be able to be included in recyclable plastic streams, and possibly further specify what is meant recyclable plastic streams.

An environmental NGO support this measure but consider that the requirements need to be more robust. They recommend that wording from the Commission Regulation (EU) 2023/1670 on smartphones and tablets should be adopted to increase robustness:

> *(1) Manufacturers, importers or their authorised representatives shall, without prejudice to Article 15(1) of Directive 2012/19/EU of the European Parliament and of the Council (2), make available, on a free access website, the dismantling information needed to access any of the products components referred to in Annex VII, point 1, of Directive 2012/19/EU.*
>
> *(2) The information referred to in point (1) shall include the sequence of dismantling steps, tools or technologies needed to access the targeted components.*
>
> *(3) The information referred to in point (1) shall be available until at least 15 years after the placing on the market of the last unit of a product model*

They add that thresholds on the proportions of pollutants and impurities have not been suggested in this measure. In their view, taking this into account is essential to ensure a healthy recycling ecosystem.

7.1.4 Reducing energy consumption of devices

As described in section 6.1.2, there is some room to reduce the energy consumption of devices via energy efficiency measures. The potential environmental benefit of reducing the energy consumption of devices has been estimated in section 6.1.2: reductions in Climate change impact can be achieved between 1% and 2%, depending on the device type.

The potential consumer expenditure benefit has been estimated in section 6.1.1: reductions in cost per page between 1% and 2%, depending on the device type.

<u>Setting minimum requirements on energy efficiency</u>

Typically, the reduction of energy consumption of products is addressed in ecodesign by setting minimum mandatory energy efficiency requirements in the active mode of the product (such as in Regulation 2019/2023 on Washing machines and Washer dryers; or in Regulation 2019/2023 on Dishwashers, among others), which usually need to be complied with in tiered periods. Often, energy efficiency is calculated as a function of a relevant performance parameter of the appliance (capacity, in the examples provided).

The environmental assessment of devices showed that the use phase (the energy consumption of the device) is not the environmental hotspot in this product group (see Figure 110). This is because devices spend more time in non-active modes (such as off, sleep,) than in active modes (printing). Therefore, setting a minimum requirement on the active mode would be tackling an aspect of the product that has little contribution to the overall impact, particularly for inkjet devices.

From the methodological point of view, setting minimum requirements on energy in the active mode would be currently feasible for laser devices. There is a widely accepted measurement method (TEC) that could be used either directly to set minimum requirements on energy consumption (min kWh/week), or indirectly, translating it into energy consumed per page (min Wh/page). However, setting minimum requirements on energy in the active mode would be currently not feasible for inkjet devices because there is no widely accepted measurement method. Energy Star v3.2 follows the OM method for inkjet devices, aimed at power consumption of non-active modes (off, sleep). The definition of a new alternative measurement method for energy consumption of devices was considered out of the scope of this Preparatory Study.

It must be noted that setting minimum requirements on energy efficiency of devices would require significant resources and investment from OEMs in terms of testing and provision of information. It could also drive OEMs to focus on design changes (for instance, changes in the printer electric motor) that are not particularly meaningful considering the environmental assessment of the products.

Based on the reasons provided above, setting minimum requirements in the active mode was not considered appropriate for imaging equipment devices.

<u>An energy label for printers</u>

An energy labelling scheme is meaningful if there are significant differences between devices in terms of energy use. This does not seem to be the case for imaging equipment devices (see Figure 53). Moreover, different labels might be necessary for laser and inkjet devices, considering their significant differences in terms of energy use (as described in section 4.4.1), creating confusion for consumers. Therefore, energy labelling was not considered appropriate for imaging equipment devices either.

Other measures on energy efficiency

In order to capitalize the remaining untapped potential for energy efficiency of these products, a series of measures focused on non-active modes and internal power supplies have been identified, based on stakeholder feedback. These measures are not expected to require significant design changes and/or investment to OEMs, and could help to obtain the currently available improvements in terms of energy efficiency. They are described in the following sections.

7.1.4.1 Power consumption of non-active modes

Applicability: Laser & Inkjet devices

Content of the measure:

Non-active modes of laser and inkjet devices shall have a power consumption compliant with the requirements described in Table 110

Table 110. Minimum requirements of Regulation 2023/826 and proposed minimum requirements for printers under ecodesign

Operational mode	Conditions	Minimum requirement of Regulation 2023/826	Minimum requirements proposed (ecodesign for imaging equipment)
Standby mode	In any condition providing only a reactivation function, or providing only a reactivation function and an indication of reactivation function	<0.5W	**<0.3W**
	In any condition providing only information or status display, or providing only a combination of reactivation function and information or status display, or providing only a reactivation function and an indication of enabled reactivation and information or status display	<0.8W	**<0.4W**
Networked standby	HiNA equipment or equipment with HiNA functionality	<8W	**<4W**
	HiNA equipment or equipment with HiNA functionality, 2 years after application of Regulation	<7W	**<4W**
	Networked equipment other than HiNA equipment or equipment with HiNA functionality Not applicable to large format printing equipment	<2W	**<1W**
Off mode	Off mode	<0.5W	**<0.3W**
	Off mode, 2 years after application of Regulation	<0.3W	**<0.2W**

Relevance and feasibility

Most of devices registered in Energy Star are already compliant with power consumption limits established in Regulation 2023/826.

In the proposal made, power consumption minimum requirements of Regulation 2023/826 are reduced by 50% in ecodesign for imaging equipment. In the proposal, no yearly tiers have been included, although they might be considered if the requirement means a significant challenge for manufacturers.

Ensuring that devices have lower power consumption in non-operational modes -which is where devices spent most of their technical lifetime- would contribute to reduce overall energy consumption of devices.

Assessment and verification

This measure shall be verified following the same methods described in Annex IV of Regulation 2023/826 laying down ecodesign requirements for off mode, standby mode, and networked standby energy consumption of electrical and electronic household and office equipment.

Feedback from stakeholders

The association of manufacturers supports the view that energy requirements for printers in scope of the Imaging Equipment Regulation should be contained in that regulation. Therefore, Regulation 2023/826) should be amended so that it no longer applies to that Imaging Equipment. This is the approach taken so far when a vertical measure is introduced. In addition, the concepts and wording from Regulation 2023/826 should be carried over to the Imaging Equipment Regulation. Manufacturers are currently implementing the requirements of Regulation 2023/826 and it would create unnecessary costs and administrative burden to force manufacturers to carry out an implementation to different standards just because of the transition to an Imaging Equipment Regulation.

However, manufacturers disagree with the minimum requirements proposed in Table 110. They argue that simply reducing the minimum limits of Regulation 2023/826 seems quite arbitrary. They remind that a large proportion of the imaging equipment portfolio (those classified as Class A in EN 55022:2010 standard) are out of scope of Regulation 2023/826. In their view, it is not clear how the authors determined that TEC products already comply with the Regulation 2023/826 limits, as that data is not available on the Energy Star database. However, they recognise that most of the proposed limits are feasible. Other specific comments on the limits proposed are listed below:

(a) The proposed <1W limit for networked standby for networked equipment other than HiNA equipment or equipment with HiNA functionality is not realistic, particularly for office equipment that is not in scope of Regulation 2023/826. We recommend maintaining the 2W limit.

(b) An analysis of actual data would be required in order to propose a tiered approach with a limit <2W for networked standby and <0.2W for off mode.

As a summary from manufacturers' point of view on this measure, they recommend to carry across the existing requirements from Regulation 2023/826/EU into the Imaging Equipment Regulation and exclude imaging equipment from the scope of 2023/826/EC.

A Member State representative also recommends to align power consumption requirements of non-active modes with Regulation 2023/826.

A national environmental agency supports the introduction of stricter power consumption minimum requirements, beyond the horizontal thresholds set by Regulation 2023/826. Off mode and standby consumption are relevant energy consumption modes for inkjet devices. Data from Energy Star database show that a relevant share of inkjet devices on market is already fulfilling these more ambitious thresholds. Nevertheless, the proposal of the same threshold for laser devices should be further supported by data on feasibility, otherwise removed.

7.1.4.2 Reducing the time between active and non-active modes

Applicability: Laser & Inkjet devices

Content of the measure:

The device shall automatically switch from active/ready modes to a non-operational mode (standby, networked standby or off mode) in 10 minutes or less.

Relevance and feasibility

Most of devices registered in Energy Star are already compliant with transition to non-operational modes established in Regulation 2023/826. There is room to introduce slightly stricter requirements. As in the measure described above, in the proposal for ecodesign of imaging equipment, the time to achieve a low consumption power mode has been reduced to 50% of the time proposed in Regulation 2023/826.

Ensuring that laser devices have lower transition times to non-operational modes would contribute to reduce overall energy consumption of devices.

Assessment and verification

This measure shall be verified following the same methods described in Annex IV of Regulation 2023/826 laying down ecodesign requirements for off mode, standby mode, and networked standby energy consumption of electrical and electronic household and office equipment.

Feedback from stakeholders

The association of manufacturers clarify that the product behavior in question is referred to as "delay time to sleep or off" in the Energy Star specification and "power management to standby/off or networked standby" in regulations 1275/2008 and 2023/826. They explain that Regulation 2023/826 includes a 20 minute default period to power management for both standby/off and networked standby. They wonder on what basis the authors are proposing a 50% reduction in this limit, as it seems rather arbitrary. Manufacturers question the amount of energy saved with this measure.

Manufacturers note that Regulation 2023/826 allows the user to disable this functionality and wonder if the measure proposed would also include this allowance. They add that it is important to note that OEMs are currently implementing changes to printer functionality to comply with the requirements of Regulation 2023/826. They must proceed with those changes given the uncertainty surrounding the imaging equipment regulation. If the imaging equipment regulation then requires additional changes that will impose a further implementation process on OEMs within a short space of time. Without compelling analysis and evidence of important environmental benefits imposing further administrative and cost impact on OEMs seems inappropriate. Further, unassessed or unnecessary requirements should not be included because they limit product development options and make devices less convenient to use, potentially driving unwanted user behaviours.

An individual OEM adds that this measure is more aggressive than Regulation 2023/826, and that it would require additional effort by OEMs, and potentially could affect customer productivity. They recommend to carry across the existing requirements from Regulation 2023/826/EU into the Imaging Equipment Regulation and exclude imaging equipment from the scope of 2023/826/EC.

A national environmental agency states that laser printers have relevant energy consumption to keep the device in an active ready-state mode (e.g. to keep fuser at high temperature). The measure 7.1.4.2 aims to address this issue by mandating a power management function that switch the equipment, after a specific period (10 minutes proposed by JRC) in stand-by or off-mode, according to the approach from the Commission Regulation (EU) 2023/826. They consider that a more ambitious period (i.e. 1 minute) could be appropriate for the intended use of the printers, due to the following reasons:

(a) The majority of laser devices in the market have a transition period of 1 minute (see Figure 61).

(b) According to the Regulation (EU) 2023/826, the user still have the option to disactivate/change the setting of the energy management system.

(c) Strict requirements have been already applied for other product groups[163]

An environmental NGO fully supports the inclusion of power management enabling times that are more suitable for imaging equipment than those included in the horizontal Networked Standby Ecodesign Regulation (2023/826).

[163] e.g. for drip filter household coffee machines storing the coffee in an insulated jug, a maximum of five minutes is set

7.1.4.3 Efficiency of internal power supply units

Applicability: Laser devices

Content of the measure:

Internal power supplies installed in the device shall have a minimum efficiency of:

- 90% when operating at 10% of rated load
- 92% when operating at 50% of rated load
- 89% when operating at 100% of rated load

The efficiency of internal power supplies installed in the device shall be provided in the technical specifications document.

Relevance and feasibility

Most of power supply units registered in 80Plus already have high efficiency levels (70% are Gold or higher).

Ensuring that internal power supplies used in laser devices have a minimum energy efficiency would contribute to reduce overall energy consumption of devices.

Assessment and verification

This measure shall be verified with the provision of the energy efficiency of internal power supplies in the product documentation sheet. Measurements shall be made using the Generalized Test Protocol for Calculating the energy efficiency of internal AC/DC and DC/DC power supplies. Revision 6.7.2.

Feedback from stakeholders

The association of manufacturers highlight that there are no internal power supply efficiency requirements for imaging equipment today and there never have been any. There are many product level energy efficiency requirements and meeting these require efficient power supplies. They argue that the 80Plus standard was developed for computing products whose power behavior is significantly different than printing products. It is not a standard which can simply be applied to another product category.

Manufacturers also wonder how much energy would be saved with the proposed requirements. Printer power supplies are optimized for efficiency at low load levels (networked standby/sleep). Those load levels are much lower than 10% load. In simple terms, printer power supplies do not operate at 10% load and therefore setting requirements based on 10% load is pointless. They believe the proposal is misguided, unnecessary, would not save significant energy, and would impose a significant new testing and administrative burden.

An individual OEM states that they have a significant concern with this proposed requirement, for the following reasons:

(a) Printer power supplies spend a large amount of time in sleep (very low power state), and are optimized for this. The 80plus program looking at power states between 10% and 100% does not address this.

(b) Most all of the low and mid-range supplies do not include any active power factor correction which would be required to achieve these high power factor values over a wide load range.

(c) Adding active power factor correction to low and mid-range supplies would result in a complete redesigning investment and cause a large cost increases for those supplies.

Therefore, manufacturers recommend to remove this measure.

An environmental NGO welcomes the inclusion of draft requirements on the internal power supply efficiency of imaging equipment. Requirements on the internal power supply efficiency of imaging equipment has been missing in every major environmental initiative focusing on this product type. Given that internal power supply efficiency is addressed for most other types of information technology products, it is appropriate to now include them for imaging equipment.

7.1.4.4 Availability of manual switch to off-mode

Applicability: Laser & Inkjet devices

Content of the measure:

Devices shall have a function that allows the user to manually switch from an active/ready mode to a non-operational mode (standby, networked standby or off mode).

Relevance and feasibility

Providing the user with the possibility of manually switching to a non-operational modes would contribute to reduce overall energy consumption of devices.

Assessment and verification

This measure shall be verified with an indication on how to access the manual switch of off mode and shall be included in the user manual, provided with the device and on free access website.

Feedback from stakeholders

The association of manufacturers support this measure, except that it should not be applicable to remanufactured or refurbished devices.

An environmental NGO also support the requirement for imaging equipment to include a manual switch, allowing users to manually place a product in a lower power mode.

7.1.5 Paper use optimization in devices

As described in section 4.4.5, there is room to reduce the amount of paper waste generated by devices via functionality such as autoduplex or n-up printing.

The potential environmental benefit of reducing paper waste of devices has been estimated in section 6.1.3: reductions in Climate change impact can be achieved around 1%, depending on the device type.

The potential consumer expenditure benefit has been estimated in section 6.1.3: reductions in cost per page are around 4%, depending on the device type.

Considering this, a series of possible ecodesign measures have been proposed to reduce the amount of waste paper generated by devices. They are described in the following sections.

7.1.5.1 Duplexing capability

Applicability: Laser & Inkjet devices

Content of the measure:

Devices shall have as a standard feature the capability of printing on both sides of paper (autoduplex, or duplexing capability)

Relevance and feasibility

Providing the user with the possibility of printing on both sides of paper would help to reduce overall paper consumed during device lifetime.

Assessment and verification

This measure shall be verified with an indication on how to use duplexing capability. This should be included in the user manual, provided with the device and on a free access website.

Feedback from stakeholders

The association of manufacturers support this measure, but recommend duplex requirements to be aligned with the Energy star and Blue Angel ecolabel requirements:

-Automatic duplexing required for laserjet products with print speed >19ipm for color and >24ipm for mono

Manufacturers explain that these requirements have been defined as they are because these are the products where duplexing actually saves energy. For low print volume products (most inkjets and home laserjet) and some products for special applications such as photo printers, adding duplex (adding materials materials) would increase carbon emissions more than duplex printing would save. They add that the proposed requirement would force OEMs to prematurely obsolete many models.

A national environmental agency supports this measure. They suggest to complement this measure with setting it as the default option, when applicable.

An environmental NGO consider that the analysis in section 6.1.3 is only based on an inkjet printer and does not show the full potential of duplexing in higher speed electrography products. They add that Energy Star includes auto-duplexing requirements on standard sized laser printers and MFDs over certain speeds. This approach was chosen in Energy Star because users who buy higher speed printers are likely to print more – and so the benefits of auto-duplexing become more relevant. They suggest that the Ecodesign Regulation should ensure that 100% of the higher speed product types on the EU market have auto-duplexing.

7.1.5.2 N-up printing capability

Applicability: Laser & Inkjet devices

Content of the measure:

Devices shall have as a standard feature the capability of printing several pages of a document on one sheet of paper (n-up printing)

Relevance and feasibility

Providing the user with the possibility of printing several pages of a document on a single sheet of paper might help to reduce overall paper consumed during device lifetime.

Assessment and verification

This measure shall be verified with an indication on how to use n-up printing capability be included in the user manual, provided with the device and on free access website.

Feedback from stakeholders

The association of manufacturers fully support this measure.

7.1.6 Post-consumer recycled content of devices

The potential environmental benefit of reducing the energy consumption of devices has been estimated in section 6.1.4: reductions in Climate change impact can be achieved between 1% and 3%, depending on the device type.

Considering this, a series of possible ecodesign measures have been proposed to increase the amount of post-consumer recycled content of device. They are described in the following sections.

7.1.6.1 Post-consumer recycled plastic in devices

Applicability: Laser & Inkjet devices

Content of the measure:

Plastic parts weighing more than 100g shall contain a minimum of 50% PCR plastic.

The overall percentage of PCR plastic used in the device shall be provided in the user manual.

Relevance and feasibility

Ensuring that a minimum amount of PCR plastic is used in the device would help to increase the average amount of recycled content in devices.

Assessment and verification

Manufacturers shall provide information specifying the percentage of PCR plastic in applicable components, calculated in accordance with *EN 45557:2020. General method for assessing the proportion of recycled material content in energy-related products.*

Currently there is no product-specific standard to calculate the amount of post-consumer recycled plastic in devices. If this measure is included in regulation, a product-specific standard shall be developed.

Feedback from stakeholders

The association of manufacturers explain that, in practice, it is very difficult for companies to obtain PCR plastic of the right type and performance characteristics in sufficient and reliable quantities. As chemical regulations applicable to plastics continue to tighten they anticipate that the problems in securing a sufficient and reliable supply will continue and may cause severe restrictions on unavailability over an extended period.

They note that the most ambitious voluntary ecolabels currently require 5%, but being voluntary the impact on OEMs if unable to source sufficient PCR plastic is lower that it would be under a mandatory regulatory requirement. In their view, mandatory requirements should not be set unless they are consistently achievable across the whole market. Manufacturers highlight that other Ecodesign Regulations in the ICT sector do not contain PCR content requirements. They consider it would seem inconsistent to single out imaging equipment for different treatment.

If any mandatory PCR requirements are set it is important they that are applied to new printing platforms to avoid disruption from having to incorporate PCR into existing supply chains and redesign existing products to accomodate the differences in working with PCR.

Manufacturers agree on the need for development of a product-specific standard for assessing recycled material content and believe this must preceed any regulatory requirement for post-consumer recycled plastic content.

Another individual OEM states that the measure proposed is simply not possible to achieve. Some parts >100g have specialty materials that do not have PCR alternates, such as POM, PPS or PET. They add that if PCR requirements are necessary, it would be better to specify a minimum realistic percentage of PCR plastic per device, and align with other ecolabels. In terms of standards, they highlight that IEEE 1680.2 sets a standard for calculation of PCR content, containing the calculation method and parts to be included/excluded from the calculation.

A national environmental agency recommends, in order to be in line with the waste hierarchy, to extend the requirement for a minimum use of PCR plastic so that the use of reused components also fulfills the requirement. Their proposal would be as follows:

> *Plastic parts weighing more than 100g shall contain a mini-mum of 50% PCR plastic. To meet this requirement reused plastic parts can be used as well*

Another national environmental agency proposes, as an alternative to the minimum percentage of PCR plastic, an information requirement on PCR content in relevant plastic parts, for instance in the product information sheet. They add that it is very complex to determine the content of recycled plastic due to the complexity of supply chains. It is therefore important to consider the possibilities for verification. For instance, a certification scheme.

An environmental NGO welcomes the inclusion of PCR plastic requirements for imaging equipment. However, they reiterate that recycled content must be measured with robust methodologies. Techniques such as pyrolysis and gasification should not be accepted for calculation of recycled content. Additionally, recycled content must only come from post-consumer recycling.

7.2 Ecodesign measures for cartridges

In section 4.5.15, preliminary objectives of policy options on cartridges were identified. In this section, areas for ecodesign measures are proposed and developed.

Table 111. Objectives and areas for measures (Cartridges)

Objectives of measures	Design options	Areas for measures

Improve capacity utilisation of cartridges	Cartridge 1.1 to Cartridge 3.1 Cartridge with improved capacity utilisation	7.2.1 - Capacity utilisation of cartrides
Encourage the use of material efficient configurations	Cartridge 1.2 to Cartridge 3.2 Cartridge with improved material efficiency configuration	7.2.2 – Material efficiency of cartridges
Increase the possibilities to remanufacture a cartridge	Cartridge 1.3 to Cartridge 3.3 Cartridge with enhanced remanufacturability	7.2.3 – Remanufacturability of cartridges
Reduce the amount of paper wasted due to performance of cartridges	Cartridge 1.4 to Cartridge 3.4 Cartridge with reduced failure rate	7.2.4 – Paper use optimization in cartridges

Individual ecodesign measures associated to each of the above objectives and areas are described in the following sections.

7.2.1 Capacity utilisation of cartrides

As described in section 4.5.2, there is room to increase the capacity utilisation of cartridges, by measures aimed at increasing their minimum page yield.

The potential environmental benefit of making a better utilisation of cartridge capacity has been estimated in section 6.2.1: reductions in Climate change impact can be achieved between 18% and 19%, depending on the cartridge type.

The potential consumer expenditure benefit has been estimated in section 6.2.1: reductions in cost per page between 10% and 15%, depending on the device type.

7.2.1.1 Page yield of ink cartridges

Applicability: Ink cartridges

Content of the measure:

- Ink cartridges shall have a minimum page yield of 300 pages (Tier 1, 24 months after entry into force of this regulation)
- Ink cartridges shall have a minimum page yield of 350 pages (Tier 2, 36 months after entry into force of this regulation)
- Ink cartridges shall have a minimum page yield of 400 pages (Tier 3, 48 months after entry into force of this regulation)

Information on page yield shall be provided in the product packaging and in the technical specification of the product, in total number of pages that the cartridge can print.

This measure shall also be applicable to ink cartridges included in the purchase price of a device, and to external containers.

Relevance and feasibility

Establishing a minimum requirement on cartridge page yield would help to increase the average page yield of cartridges in the market. For the proposal of this minimum requirement, the database of cartridges provided by ETIRA in the context of this Preparatory Study has been used. Figure 127 shows the three tiers proposed (300, 350 and 400 pages, respectively).

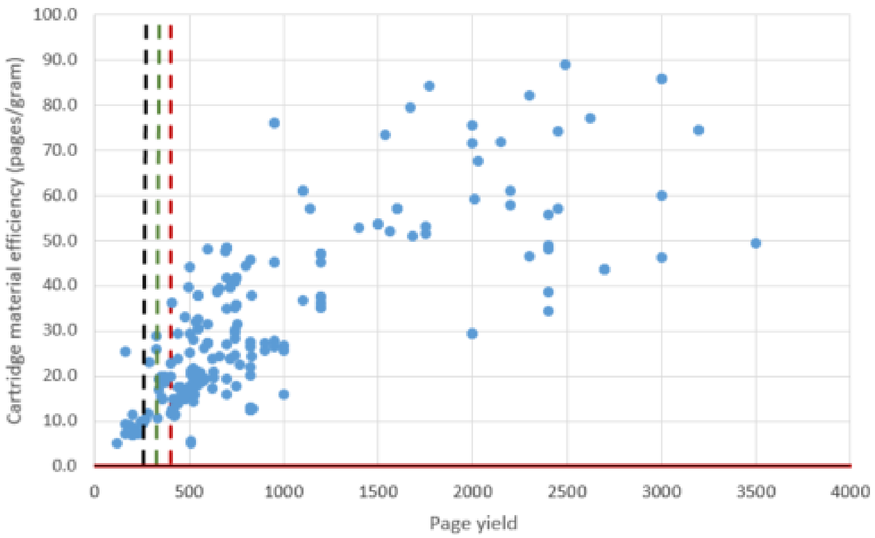


Figure 127. Minimum requirement on page yield of ink cartridges

Table 112 is an estimation of the possible consequences on the market of establishing minimum requirements on cartridge page yield. Using the database of cartridges provided by ETIRA as a reference, setting a minimum requirement of 300 pages would make not compliant 8% of the cartridges in the database. This percentage would increase to 11% and 13% with the following tiers proposed.

Table 112. Compliant ink cartridges with minimum requirements on page yield, using ETIRA database

	Tier 1 (300 pages)	Tier 2 (350 pages)	Tier 3 (400 pages)
Compliant (%)	92%	89%	87%
Not compliant (%)	8%	11%	13%

Setting a minimum requirement on page yield of ink cartridges could also have the following consequences:

- Ensuring that ink cartridges have a minimum page yield of 300 pages would help to reduce the amount of starter cartridges with low page yield.
- Increasing average page yield of cartridges would help to reduce the number of cartridges placed on the market which have low fill levels, shifting the market from Standard to XL or High Capacity cartridges.
- Increasing average page yield would reduce the cost of printing for consumers, since generally the cost per page is lower in cartridges with higher page yield.
- Providing the consumer with clear information on the number of pages that the cartridge can print would help them make the right purchase decision.
- Increasing average page yield of cartridges would contribute to increase cartridge reuse rates.
- As explained in section 4.5.6, cartridges have a specific shelf life, in the case of ink cartridges, related with issues such ink drying and clogging. This aspect needs to be taken in to account when proposing minimum mandatory requirements. Too ambitious minimum requirements could be detrimental and increase faults related to drying and clogging.

Assessment and verification

This measure shall be verified with the provision of page yield information on the packaging and in the product documentation sheet. The latest version of the applicable standard to measure page yield of ink cartridges shall be used (see Table 2).

Feedback from stakeholders

The association of manufacturers explains that the imaging equipment market is a diverse market with a range of designs, technologies and products. Printers range from ~20-80 pages per minute and customers print between ~5 pages per month and 5000 pages per month with wide variations in print volumes within the installed base for each printer model. OEMs provide a range of cartridges designed to suit customers' needs and ensure affordability.

According to OEMs, setting minimum page yield requirements is likely to have negative environmental impacts and negative impacts on the affordability and lifecycle costs for customers. It is important to understand that customers typically (and partially for affordability reasons) make decisions based on cost of purchase rather than cost per page. OEMs are strongly of the view that providing a range of cartridge yields for customers to choose the best option for them is the most environmentally efficient solution. In the case of subscription and service models, customers pay per page or per month and, as a result, do not make an upfront investment in the cartridge. Under these business models OEMs supply the optimal capacity cartridges and seek to recover their investment through the service or subscription payments.

OEMs provide additional specific comments on the proposals on cartridge page yield:

> (i) With a wide range of customer print volumes for each printer model, setting a required minimum page yield is likely to result in some customers being forced to buy more ink/toner than they need with the result that the ink/toner is likely to be wasted. For toner, for low end momochrome devices the minimum yields proposed could result in a 15+ year life based on lower useage customer[164]
>
> (ii) Forcing customers to buy higher yield cartridges than they need will result in customers having old ink/toner that may deteriorate and cause damage to the printer requirement printer repairs with the consequent environmental impact, cost and disruption. This is likely to be exacerbated by the separate proposal of forcing OEMs to move away from all-in-one/integrated printhead cartridges (measures 7.2.2.1 and 7.2.2.2). A key benefit of those technologies is that costly printer repairs can be avoided by refreshing key parts when the cartridge is changed or by changing the cartridge.
>
> (iii) OEMs consider that the analysis in Table 112 and Table 115 is misleading because it estimates percentages of products (SKUs) and not units sold and most cartridges are sold at the lower page yields. They consider that the underlying data from the ETIRA database is flawed. This resuts in the impact on lower end products being significantly underestimated. In addition, forcing customers to buy higher yield cartridges would increase the price and there would be fewer empties for remanufacturers and likely at a higher cost. It is wrong to assume that increasing page yields will increase reuse. In particular, increasing page yields will not change customer behaviour in relation to reuse.
>
> (iv) It is possible that if only high yield cartridges are available that could drive unwanted behaviour by customers such as deciding to replace their printer rather than buy a new cartridge. This may especially be the case for printers already in the installed base. If customers can no longer buy cartridges with a yield and price point that were available when they purchased their printer they are likely to blame the manufacturer and this may drive unwanted behaviours from a sustainability perspective, such as replacing their printer.

In summary, regarding minimum requirements on page yield, manufacturers consider that it is best left to the market. However, if the Commission feels that there should be regulation on page yield, some sort of tiered system based on speed/price/usage should be considered and manufacturers would need to be closely involved in setting appropriate thresholds.

Alternatively, if the Commission would prefer a more simple approach a solution could be to require that a cartridge with the yield set out in section 7.2.1.1 is available on the market while not being the only or minimum choice available[165].

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[164] In other words, according to OEMs, with the minimum thresholds proposed by the JRC, cartridges used by consumers with low usage profile would last more than 15 years.

[165] For instance, if the new regulation establishes a minimum yield of 400 pages, in this case the OEM would be obliged to provide a cartridge with at least those pages, although they would also be allowed to commercialized cartridges with lower yield, for instance 200 pages

They consider that the proposed minimum page yields are appropriate for >150 EUR printers but low users of <100 EUR printers will encounter issues and create increased waste. They point out that a significant part of ink cartridges currently in the market would be not compliant with the proposed minimum requirements. Therefore, they made a proposal in terms of minimum page yield of ink cartridges (Table 113).

Table 113. Minimum page yield of ink cartridges (OEM proposal)

Price of device (EUR)	Minimum page yield (pages)
< 100 EUR	100
100 – 149 EUR	150
150 – 199 EUR	300
200 – 400 EUR	400
> 400 EUR	1500

The same OEM provides an alternative, which is to require OEMs to provide a minimum high yield cartridge offering (while not being the only or minimum choice available) as in Table 114.

Table 114. Minimum high yield of ink cartridges (OEM proposal)

Price of device (EUR)	Minimum high yield monochrome (pages)	Minimum high yield monochrome (color)
< 100 EUR	400	300
100 – 149 EUR	600	400
150 – 199 EUR	800	600
200 – 400 EUR	1500	1000
> 400 EUR	5000	3000

Another individual OEM states that the metrics for compliance (Table 112) are flawed because the database of cartridges is extremely limited. Moreover, they question that the minimum requirements is against all cartridges, from low-end all the way to A3. They consider that if the data was segmented to look at low-end products separately, the proposed limits would impact a significant portion of that market. This is unfairly biased against consumer products. They add that consumers do not want high capacity toner cartridges due to the cost and upfront payment.

In terms of the information requirement to provide page yield on the product packaging, OEMs wonder if this could be done by using a QR code.

In contrast with OEMs, a national environmental agency consider that the proposed minimum requirements regarding page yield are unambitious for both ink and toner cartridges. This can be seen from the compliance rates which are already at a high level for tier 3 (87 % for ink cartridges and 87 % for toner cartridges). They suggest that the proposed tier 3 requirements are used for the first tier 1 to 2 years after adoption of the regulation, and that more ambitious requirements are set in a second tier 3-4 years after the adoption of the regulation. The second tier could be for instance set at a compliance rate at 70 - 80 %. In addition, they propose that information about page yield should be available on the energy label (if implemented) and in product information online.

A Member State representative agrees that the minimum requirements proposed are not ambitious. They add that the requirements on page yield should explicitly include cartridges placed on the market together with the device (starter cartridges).

An environmental NGO supports the inclusion of minimum page yield for ink cartridges. However, they think that additional material efficiency savings could be achieved by relating the minimum page yield to the speed of the imaging equipment. That is, higher minimum page yields could be developed for higher speed products.

7.2.1.2 Page yield of toner cartridges

Applicability: Toner cartridges

Content of the measure:

- Toner cartridges shall have a minimum page yield of 1500 pages (Tier 1, 24 months after entry into force of this regulation)
- Toner cartridges shall have a minimum page yield of 1750 pages (Tier 2, 36 months after entry into force of this regulation)
- Toner cartridges shall have a minimum page yield of 2000 pages (Tier 3, 48 months after entry into force of this regulation)

Information on page yield shall be provided on the product packaging and in the technical specification of the product, in total number of pages that the cartridge can print.

This measure shall also be applicable to toner cartridges included in the purchase price of a device, and to external containers.

Relevance and feasibility

As in the case of ink cartridges, establishing a minimum requirement on toner cartridge page yield would help to increase the average page yield of cartridges on the market. For the proposal of this minimum requirement, the database of cartridges provided by ETIRA in the context of this Preparatory Study has been used. Figure 128 shows the three tiers proposed (1500, 1750 and 2000 pages, respectively).

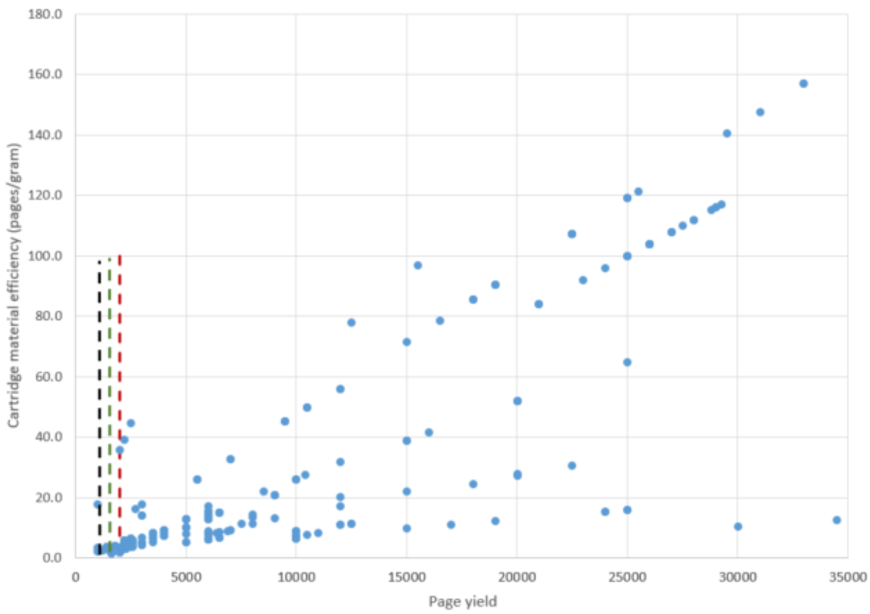


Figure 128. Minimum requirement on page yield of toner cartridges

Table 115 is an estimation of the possible consequences on the market of establishing minimum requirements on cartridge page yield. Using the database of cartridges provided by ETIRA as a reference, setting a minimum requirement of 1500 pages would make not compliant 9% of the cartridges in the database. This percentage would increase to 10% and 14% with the following tiers proposed.

Table 115. Compliant toner cartridges with minimum requirements on page yield, using ETIRA database

	Tier 1 (1500 pages)	Tier 2 (1750 pages)	Tier 3 (2000 pages)
Compliant (%)	91%	90%	86%
Not compliant (%)	9%	10%	14%

Setting a minimum requirement on page yield of toner cartridges would have similar consequences to the ones described for ink cartridges:

- Ensuring that toner cartridge have a minimum page yield of 1500 pages would help to reduce the amount of starter cartridges with low page yield.
- Increasing average page yield of cartridges would help to reduce the number of cartridges placed on the market which have low fill levels.
- Increasing average page yield would reduce cost of printing for consumers, since generally cost per page is lower in cartridges with higher page yield.
- Providing the consumer with clear information on the number of pages that the cartridge can print would help them make the right purchase decision.
- Increasing average page yield of cartridges would contribute to increase cartridge reuse rates.
- As in the case of ink cartridges, toner cartridges also have a specific shelf life, which needs to be taken in to account when proposing minimum mandatory requirements. Too ambitious minimum requirements could be detrimental and increase faults related to ageing of toner.

<u>Assessment and verification</u>

This measure shall be verified with the provision of page yield information on the packaging and in the product documentation sheet. The latest version of the applicable standard to measure page yield of ink cartridges shall be used (see Table 2).

<u>Feedback received from stakeholders</u>

The feedback received in this section is equivalent to the one received in section 7.2.1.1.

Additionally, and individual OEM highlight that the proposed minimum page yields are appropriate when looking at the average page volume of an average user, but half of users print below the average, and many well below. Therefore, in their view the current proposals would result in unintended outcomes: unused or expired toner; potential cartridge or printer failures resulting in repair or replacement and cost to customers. They also made a specific proposal in terms of minimum page yield for toner cartridges. The measure would be to require that a cartridge with the yield set out in Table 116 is available on the market while not being the only or minimum choice available (a minimum high yield).

Table 116. Minimum high yield available in the market (OEM proposal)

Device type	Printing speed	Minimum high yield
Monochrome printer	< 42 ipm	2000
	42 ipm – 70 ipm	8000
	> 70 ipm	30000
Color printer	< 26 ipm	1200
	26 ipm – 52 ipm	4500
	> 52 ipm	13000

This OEM consider that minimum page yields must account for these low usage customers or will also create unintended consequences, such as incompletely used cartridges, damage to printers and premature printer replacements.

7.2.2 Material efficiency of cartridges

As described in section 4.5.3, there is room to increase the material efficiency of cartridges, by measures aimed at shifting from integrated/all-in-one to single-part configurations.

The potential environmental benefit of shifting to material efficient configurations has been estimated in section 6.2.3: reductions in Climate change impact can be achieved between 55% and 61%, depending on the cartridge type.

Considering this, a series of possible ecodesign measures have been proposed to improve the material efficiency of cartridges. They are described in the following sections.

7.2.2.1 Material efficiency of ink cartridges

Applicability: Ink cartridges

Content of the measure:

- Ink cartridges shall have a minimum material efficiency of 10 pages per gram of empty cartridge (Tier 1, 24 months after entry into force of this regulation)
- Ink cartridges shall have a minimum material efficiency of 12.5 pages per gram of empty cartridge (Tier 2, 36 months after entry into force of this regulation)
- Ink cartridges shall have a minimum material efficiency of 15 pages per gram of empty cartridge (Tier 3, 48 months after entry into force of this regulation)

Cartridge material efficiency shall be measured as:

$$Material\ efficiency = \frac{Page\ yield}{Cartridge\ mass\ (empty)}$$

Relevance and feasibility

Establishing a minimum requirement on cartridge material efficiency would incentivise the design of cartridge configurations that are more material efficient, as well as discouraging low fill levels. This measure can be seen as complementary to the proposal of setting minimum page yield.

For the proposal of this minimum material efficiency requirement, the database of cartridges provided by ETIRA in the context of this Preparatory Study has been used. Figure 129 shows the three tiers proposed (10, 12.5 and 15 pages per gram, respectively).

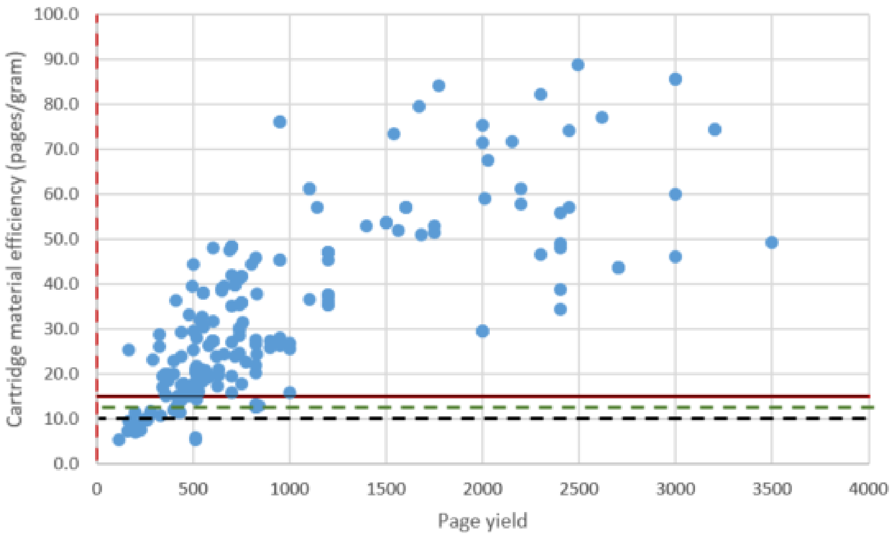


Figure 129. Minimum requirement on material efficiency of ink cartridges

Table 117 is an estimation of the possible consequences on the market of establishing minimum requirements on cartridge page yield. Using as a reference the database of cartridges provided by ETIRA, setting a minimum requirement of 10 pages/gram would make not compliant 6% of the cartridges in the database. This percentage would increase to 10% and 16% with the following tiers proposed.

Table 117. Compliant ink cartridges with minimum requirement on material efficiency, using ETIRA database

	Tier 1 (10 pages/gram)	Tier 2 (12.5 pages/gram)	Tier 3 (15 pages/gram)
Compliant (%)	94%	90%	84%
Not compliant (%)	6%	10%	16%

Setting a minimum requirement on material efficiency of ink cartridges could have the following consequences:

- A shift might be observed from integrated to single-part cartridge configurations (a market trend which has been observed already, as highlighted in section 4.5.3.2). Single-part cartridge configurations are more material efficient than integrated ones. They also tend to provide higher page yields.
- There is a slight risk that, if the market is driven towards single-part solutions (with print heads located in the device), some manufacturers are incentivised to commercialize replaceable print heads, encouraging lower lifetimes. To discourage this, minimum durability requirements on key components have been proposed in section 7.1.2.5.

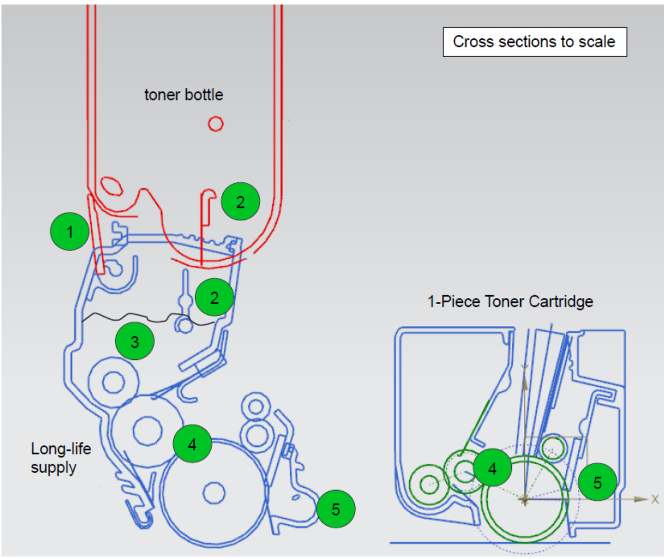
Assessment and verification

This measure shall be verified with the provision of information on the calculation of material efficiency of cartridge (including page yield and mass of empty cartridge) in the product documentation sheet.

Feedback from stakeholders

The association of manufacturers recommends to remove this proposal. They explain that printers and cartridges are a system and need to be analysed together considering whole lifecycle impacts. As already noted, the imaging equipment market involves a complex interaction between different technologies, products types/performance and customers use profiles. They disagree with the JRC proposal to set a single minimum requirement for all products.

Manufacturers are very concerned that this approach and this proposed criterion will have unintended and negative consequences for the environment and for consumers. A key concern is that pushing manufacturers to move away from all-in-one/integrated cartridges would necessitate putting more material into printers. In their view, this is likely to result in greater use of resources rather than fewer. An OEM provided a diagram of the whole printing system, for both a singe-part and an all-in-one toner cartridge, to exemplify the additional mass needed in the single-part solution (Figure 130).



1-Toner delivery system

2-Toner sensing systems

3-Toner reservoir

4-Drum and developer roller

5-Waste toner system

Figure 130. Comparison of printing system in single-part (left) and all-in-one (right) cartridges

In addition, where faults/failures occur (such as a result of forcing customers to buy cartridges with a yield much higher than they need) the waste of resources is likely to be exacerbated by customers having to carry out printer repairs with a much greater resource impact when under current product configurations the issue could have been dealt with by replacing the all-in-one or integrated cartridge with a much lower resource impact, cost and disruption to the customer.

They add that if the Commission proceeds to try and implement these criteria, it would be important to provide exemptions for cartridges used in current systems designed for all-in-one/integrated cartridges, otherwise the Commission would cause a huge printer obsolescence issue.

Manufacturers also argue that for lower-end colour and monochrome devices, there is a minimum amount of material that is required to manufacture a cartridge to hold the necessary components. The proposed material efficiency requirements could ban sale of cartridges for those products.

They consider that the data in Table 118 significantly underestimates the impact because it focuses on the number of SKUs rather than the number of products sold. Again, this measure would have a significant and disproportionate impact on lower end products.

Manufacturers point out that all-in-one cartridges are the most efficient approach to delivering the low usage needs of the consumer and small-medium business market. Moving multi-part cartridges would add significant mass to the printer, which would mean larger, more expensive devices.

Manufacturers recommend to review the conclusion presented in the Preparatory Study that states that single-part cartridges tend to provide higher yield. In their view, this is a flawed conclusion. There may be a corellation, but not causation. Single-part cartridges are typically present in larger, more expensive machines, which are sold to higher-end users that print more and require a larger yield cartridge. The yield is higher due to customer need, not because of any inherent property of single-part cartridges. In fact, holding machine size the same, there is less room for toner in a single-part architecture because of the additional mechanism required in the printer to deliver the toner between the cartridge and developer parts.

In essence, the association of manufacturers recommends to remove this proposal from the Preparatory Study in light of the complexity and the high likelihood of unintended consequences. However, if the Commission wishes to further investigate requirements of this nature, the Preparatory Study would need to be revised with a sufficient number of real base cases and assessing in detail from a system perspective.

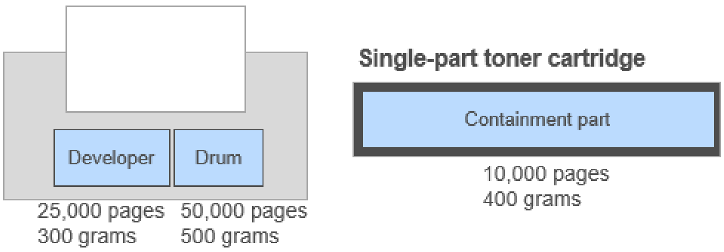
An individual OEM added that integrated cartridges are beneficial to maintain the quality of the system, because the customer refreshes components periodically that impact print quality (such as the print head), helping to prolong printer lifetime. In their view, preventing the use of integrated cartridges would increase the complexity of the print system and increase the environmental impact. They consider that material efficiency is redundant with minimum page yields and can easily lead to worse system environmental performance and therefore it is not an effective requirement to drive environmental improvements.

In contrast with OEMs, the association of cartridge remanufacturers support the inclusion of minimum requirements on cartridge material efficiency. However, they disagree with the approach described in 7.2.2.1. In their view, the calculation of material efficiency should also consider the mass of the rest of cartridge components: the drum, the developer or the print head (when applicable). They consider that all units involved in the image development process need to be replaced at some point and are thus consumables (the only difference is the number of pages after which they are consumed). In their view, not taking into consideration the mass of these components would bring wrong biased results. They conclude that by evaluating the material efficiency across all individual components, it is possible to get a more accurate assessment of the environmental impact and resource usage of the imaging development process.

Remanufacturers propose to use the formula below to calculate the material efficiency of printing:

$$Material\ efficiency = \frac{Pages\ MAX\ of\ empty\ consumable\ with\ highest\ page\ yield}{Sum\ of\ the\ weight\ in\ grams\ of\ all\ empty\ consumables\ involved}$$

An example is provided below to clarify the two different approaches: Option A (JRC proposal) and Option B (Remanufacturers proposal). In the example, a hypothetical single-part toner cartridge is considered (400 grams and 10,000 pages). The associated drum weighs 500 grams and provides 50,000 pages; and the developer weighs 300 grams and provides 25,000 pages.



With Option A, material efficiency would be calculated as follows:

$$\text{Material Efficiency} = \frac{10{,}000}{400} = 25\ pg/gr$$

As can be seen, with the JRC proposal, only the mass of the empty cartridge (400 grams) and its page yield (10,000 pages) are considered.

With Option B, material efficiency would be calculated as follows:

$$\text{Material Efficiency} = \frac{50{,}000}{500+2x300+5x400} = 16.1\ pg/gr$$

With the proposal from remanufacturers, the maximum number of pages of the consumable with the highest yield is considered (the drum, with 50,000 pages). Then, the total mass of consumables to achieve that yield is considered as well (1 drum, 500 grams; 2 developers, 300 grams; 5 cartridges, 400 grams).

A national environmental agency supports the inclusion of minimum requirements on page yield, but considers that the proposed limits are not ambitious enough. They suggest that the proposed tier 3 requirement for ink cartridges is used for the first tier 1 to 2 years after adoption of the regulation, and that a more ambitious requirement is set in a second tier 3-4 years after the adoption of the regulation. The second tier could for instance be set at a compliance rate in line with the one used in tier 3 for toner cartridges. In addition, they propose that information about the material efficiency of cartridges should be available on the energy label (if implemented) and in product information online.

Another national environmental agency disagrees with the definition of material efficiency proposed in 7.2.2.1. They consider that the formula is misleading. It is about the yield of ink/toner per cartridge weight, which is meant to show when the cartridges are not fully filled, which is not visible to the outside. However, the weight of the cartridge can easily be manipulated in other ways to achieve a better value while still maintaining a low fill level.

An environmental NGO support the inclusion of minimum material efficiency requirements. However, they consider the the requirements should be linked to the speed of the imaging equipment, because higher speed imaging equipment generally uses higher yield cartridges. They add that the proposed cartridge material efficiency requirements are not ambitious enough, since they only appear to impact a small number of relatively low yield cartridges.

7.2.2.2 Material efficiency of toner cartridges

Applicability: Toner cartridges

Content of the measure:

- Toner cartridges shall have a minimum material efficiency of 5 pages per gram of empty cartridge (Tier 1, 24 months after entry into force of this regulation)
- Toner cartridges shall have a minimum material efficiency of 6.5 pages per gram of empty cartridge (Tier 2, 24 months after entry into force of this regulation)
- Toner cartridges shall have a minimum material efficiency of 8 pages per gram of empty cartridge (Tier 3, 24 months after entry into force of this regulation)

$$Material\ efficiency = \frac{Page\ yield}{Cartridge\ mass\ (empty)}$$

Relevance and feasibility

Establishing a minimum requirement on cartridge material efficiency would promote cartridge configurations that are more material efficient, as well as discouraging low fill levels. This measure can be seen as complementary to the proposal of setting minimum page yield (on one hand, a minimum number of pages is ensured; on the other, appropriate fill levels and configurations are promoted).

For the proposal of this minimum requirement, the database of cartridges provided by ETIRA in the context of this Preparatory Study has been used. Figure 131 shows the three tiers proposed (5, 6.5 and 8 pages per gram, respectively).

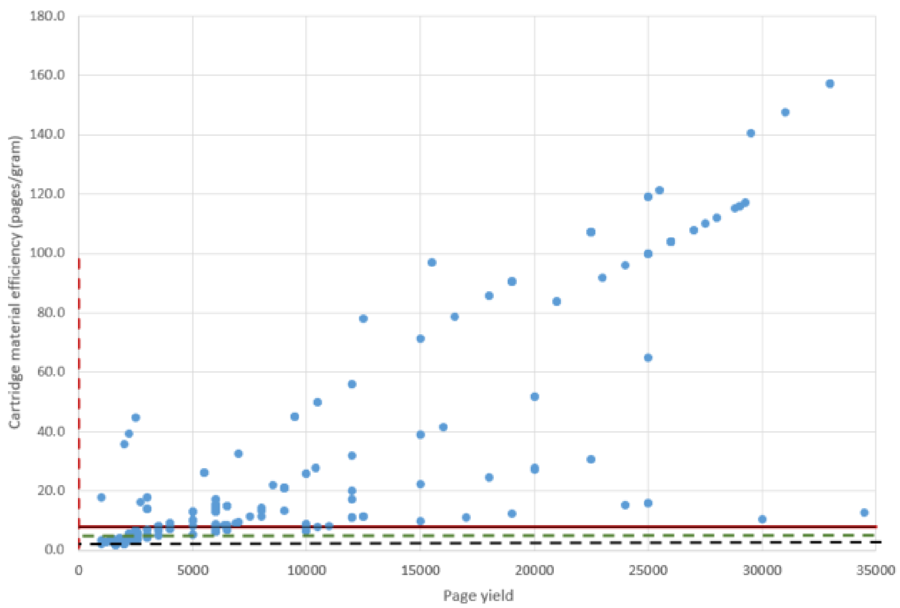


Figure 131. Minimum requirement on material efficiency of toner cartridges

Table 118 is an estimation of the possible consequences on the market of establishing minimum requirements on cartridge page yield. Using as a reference the database of cartridges provided by ETIRA, setting a minimum requirement of 5 pages/gram would make not compliant 19% of the cartridges in the database. This percentage would increase to 28% and 36% with the following tiers proposed.

Table 118. Compliant toner cartridges with minimum requirement on material efficiency

	Tier 1 (5 pages/gram)	Tier 2 (6.5 pages/gram)	Tier 3 (8 pages/gram)
Compliant (%)	81%	72%	64%
Not compliant (%)	19%	28%	36%

Setting a minimum requirement on material efficiency of toner cartridges could have the following consequences:

- A shift from all-in-one to single-part cartridge configurations (a market trend which has been observed already). Single-part cartridge configurations are more material efficient than all-in-ones. They also tend to provide higher page yields.
- As in the case of inkjet, there is a slight risk that, if the market is driven towards single-part solutions (with drums located in the device), some manufacturers are incentivised to commercialize replaceable drums, encouraging lower lifetimes. To discourage this, minimum durability requirements on key components have been proposed in section 7.1.2.4.

Assessment and verification

This measure shall be verified with the provision of Information on the calculation of material efficiency of cartridge (including page yield and mass of empty cartridge) in the product documentation sheet.

Feedback received from stakeholders

The feedback received in this section is equivalent to the one received in section 7.2.2.1.

An individual OEM added that for the base cases considered, the proposed efficiency specifications work well. However, in the lower end of the market, all-in-one cartridges are the most environmentally efficient system according to their analysis. Moving away from integrated cartridges requires more material to be added to the printers than is removed from the cartridge(s). That has a greater environmental impact. They propose dropping the material efficiency metrics, as they could lead to design decisions that would negatively impact overall system material efficiency.

7.2.2.3 Printing with one or more empty cartridges

Applicability: Ink cartridges

Content of the measure:

In printers that use more than one cartridge (e.g. black and multi-colour) printing in monochrome shall not be impeded when one or more of the colour cartridges are empty.

Relevance and feasibility

Impediment of printing with one cartridge when another cartridge in the printer is empty can lead to replacement (waste) of cartridges that may no longer be used or needed by the user.

Assessment and verification

This measure shall be verified with information in the product documentation that printing is not impeded when one cartridge is emptied.

Feedback from stakeholders

The association of manufactuers explain that the issues vary according to the design of the printing system, however, generally printing and servicing (spitting tiny amounts of ink to stop the printhead drying out) is necessary to maintain the health of the printhead. In systems with semi-permanent or permanent printheads this requirement could result in no ink being available for printhead maintenance for long periods. This, in turn, could result in damage to the color printhead beyond the ability to recover when ink/toner is replaced and again available for servicing. In order to accomodate this additional design constraint in new printer models it is likely that manufacturers would have to add additional material to the printer. In their view, the environmental impact of doing so is likely to significantly outweight any benefits achieved by this requirement. Their recommendation is that this should be enabled as a customer choice, where printing in black after colour fades will not cause damage to the printing system.

An environmental NGO points out that this requirement should refer to empty colors, rather than empty cartridges. Multi-colour cartridges should continue to work even when one color is empty.

7.2.3 Remanufacturability of cartridges

As described in section 4.5.11, there is room to enhance the remanufacturability cartridges.

The potential environmental benefit of increasing the use of remanufactured cartridges has been estimated in section 6.2.2: reductions in Climate change impact can be achieved between 38% and 60%, depending on the cartridge type.

The potential consumer expenditure benefit has been estimated in section 6.2.2: reductions in cost per page between 27% and 64%, depending on the cartridge type.

Considering this, a series of possible ecodesign measures have been proposed to increase the reusability of cartridges. They are described in the following sections.

7.2.3.1 Chip resetting functionality

Applicability: Toner & Ink cartridges with chip

Content of the measure:

Cartridges shall be designed in a way that the chip can be reset by registered professional remanufacturers so that they will print with key functionality.

Chip resetting may be provided either by resetting and reusing the original chip present in the cartridge, or by supplying a replacement chip.

Chip resetting functionality may be provided to any registered professional remanufacturer (with technical competence, with insurance) who requests it, at a reasonable and proportional cost.

Chip resetting functionality may be provided in less than 5 working days.

Key functionality refers to:

- Cartridge acceptance
- Calibration
- Clean and align print heads
- No blocking data collection agents
- Single installation message without use of inflammatory terminology
- Functioning ink or toner level gauge and/or approximate page count remaining, if provided with the original cartridge

Relevance and feasibility

Providing chip resetting functionality to registered professional remanufacturers would help to increase cartridge reuse rates.

Assessment and verification

This measure shall be verified with instructions for authorised operators on how to access chip resetting functionality, provided in the product documentation sheet and on free access website.

Feedback from stakeholders

This measure was developed by the JRC based on a proposal from OEMs. Therefore OEM support it in general terms. However, they explain that their proposal was framed as an obligation for manufacturers to make available a solution while leaving it to the manufacturers as to how this is done (resetting and chip replacement were included as examples). They recommend that any regulatory requirement must specify the outcome and not the technological solutions so as to encourage innovation (therefore, the 3rd sentence in the JRC proposal above should be removed). In their view, OEMs should be encouraged to offer their own branded remanufactured cartridges and compete in the remanufactured cartridge market.

OEMs agree that information on the solutions would need to be available to remanufacturers, but they suggest that this information is shared on a 1:1 basis between OEMs and remanufacturers to avoid the disclosure of competitively sensitive information. They add that if the concept of a registered professional is to be included, that would need to be carefully defined.

In terms of cost of the resetting solution for remanufacturers, OEMs propose to leave this to the market and not setting specific limits, although they would agree to use language similar to that used in other Ecodesign Regulation: “reasonable and proportionate fees”. OEMs do not consider it necessary to set specific delivery times for the chip resetting functionality, since once the solution is in place, resetting a chip is likely to take a few seconds.

In the view of OEMs, this solution would encourage the collection and reuse of empty OEM cartridges (the only ones that are feasible to reuse). Remanufacturers that collect those empty OEM cartridges would be able to reuse them without being dependent on the supply of third party chips.

Remanufacturers agree in general terms with this proposal of licensing the resetting of the chip to professional operators. However, most of them consider that it is not enough with making mandatory the provision of chip resetting functionality, but suggest that the chip be provided by OEMs as a spare part at a proportional cost. They consider that used chips can be regarded as faulty parts because they no longer work, unless they are reset.

Remanufacturers also consider that terms such as “reasonable and proportionate” should be clearly defined in regulation, to avoid OEMs setting prohibitive fees. In the view of remanufacturers, information on the price of spare chips and resets shall be available on a free access website for registered professional remanufacturers. Remanufacturers propose that cartridge chip resetting should allow that cartridges originally sold as part of a subscription can be remanufactured and sold individually. They add that cartridge chip resetting should allow for upgrading: it should be possible to remanufacture a low capacity starter cartridge as a high capacity cartridge.

A national environmental agency supports the proposal of mandatory chip resetting functionality, available to independent remanufacturers. However, they consider that the resetting of the chip should always be preferred. They point out that technically full-functioning chips should not be discarded. They add it should also be considered the inclusion of cartridge chips in the mandatory list of spare parts (as recommended by remanufacturers). Another national environmental agency supports this proposal in general terms, when they point out that chips shall not prevent the refill of the cartridge.

An environmental NGO fully support the need to ensure that chips can either be reset or replaced to facilitate fully functional remanufactured consumables. However, they are concerned that the current proposal would not be workable in practice. They believe that all Ecodesign requirements should be verifiable by market surveillance agencies in the EU, and they do not believe that the current draft requirement on chip resetting would be verifiable. They add that the draft requirement calls for chips to be resettable by “registered professional remanufacturers” but it is unclear for them where remanufacturers would be required to be “registered”.

7.2.3.1-a Exemption to chip resetting functionality for cartridges sold in subscriptions

OEMs proposed that cartridges sold as part of subscription and service models (PaaS) should be exempt from compliance with the requirement described in 7.2.3.1. To account for that, OEMs propose to include a clause similar to the paragraph above:

> *The requirement to provide a solution for remanufacturing with key functionality would not apply to subscription and service models cartridges as long as the manufacturer of those cartridges provides a convenient, free-of-charge collection or return solution to independent remanufacturers that collect those cartridges and the manufacturer collects the cartridges with a view to reuse/recycling in accordance with lifecycle thinking*

OEMs explain that subscriptions are beneficial for circularity because collection rates of subscription cartridges are higher than the collection rates of regular cartridges –cartridges sold individually-, the quality of material collected is higher, and because it allows them to supply high yield cartridges without payment upfront. They add that subscriptions are beneficial for consumers in terms of affordability, since it is cheaper to print with high yield cartridges on a per-page basis.

OEMs point out that, in order make the subscription model economically viable, they need to be able to use technological controls –chips that block empty cartridges- that protect their upfront investment. OEMs add that without the use of these technological controls, unscrupulous parties could collect full, or near-full cartridges provided to a customer -for which the OEM has not been yet compensated- and then reset them and resell them for use in any printer.

OEMs argue that the first operator able to collect the cartridges coming off subscriptions should not become the owner nor have the right to sell them.

With such an exemption, OEMs acknowledge that remanufacturers would collect cartridges that were sold as part of a subscription and that they wiould not be able to reuse them. To overcome this issue, OEMs propose a mandatory requirement to provide a convenient, free-of-charge collection or return solution to remanufacturers that collect those cartridges.

OEMs add that, in terms of market today, the volumes of cartridges sold as subscriptions are relatively small given the share of the market represented by those programs and the collection rates achieved by OEMs.

Remanufacturers oppose to the exemption. They argue that while the collection rates of such cartridges may in some cases be higher, their reuse rate is much lower than cartridges sold individually. They add that OEMs still can collect payment of their subscription fee without the need to block the chip.

Remanufacturers explain that, as of today, no OEM has a relevant percentage of collection of their own cartridges (most empties are returned by postal mail), and that most cartridges are collected by third parties (a well-established industry that has been around for over 30 years). They add that empty cartridge collection is not for free but has a cost. They believe that OEMs want their cartridges back free of charge by using the known and established 3rd party collection systems, in order to reduce costs on individual collection.

Remanufacturers also point out that collecting cartridges on an individual basis by postal mail does not appear the most appropriate solution from environmental point of view, and that it might also be illegal in some countries, since transporting hazardous waste requires the transport company to possess waste transport licenses to execute such activity.

Remanufacturers explain that very few OEMs prepare a small portion of cartridges for reuse. Therefore, with such an exemption most of OEMs would merely recycle some of the cartridge materials, resulting in low cartridge reuse rates. The rest of the materials would be incinerated.

Remanufacturers do not agree with OEMs reasoning that the first operator able to collect subscription cartridges should not become the owner. In their view, after running empty, a user should be free to choose what to do with it. They add that it is not up to the OEM to determine what a user may do with his used cartridge.

Remanufacturers suggest that all collected cartridges should be considered waste, should have gone through patent exhaustion and should be free to be prepared for re-use by every genuine professional remanufacturer.

Some remanufacturers conclude that the prevailing idea behind the exemption on subscription cartridges is to avoid the chance of reusing them by third party operators.

In terms of market, remanufacturers highlight that it is not appropriate to include such as exemption because subscriptions are the most important and growing section on the market.

One Member State representative opposes to the exemption. They consider that including an exemption for cartridges sold in subscriptions would open a loophole.

One national environmental agency opposes to the exemption. They believe that ecodesign requirements should apply to products and not to specific business models. The aim should be to facilitate remanufacturing as much as possible, by ensuring the highest technical feasibility of chip resetting, independently from the business model applied.

They consider that, even without the exemption, OEMs would still be free to establish their take-back systems under subscription services and make sure that they are economically attractive. They add that there is no direct link between subscription and cartridge reuse/remanufacturing. The fact that the cartridges are sent back does not mean that they are going to be remanufactured. They conclude that this exemption would make market surveillance very complex, because cartridges that are technically equivalent should be distinguished by MSA based on their business model.

One environmental NGO did not explicitly support or oppose to the exemption, but provided some insight on the alleged environmental and consumer expenditure benefits of PaaS models. They explain that the main advantages of PaaS models is that they always have ink in stock, new cartridges are delivered on time, and the costs are clear. Ink subscriptions are generally more economical than standard ink cartridges for occasional print in colour, but usually more expensive for black and white printing.

Despite these advantages with PaaS, this NGO highlights that users always depend on the manufacturer's offering. For instance, they have to compulsorily accept updates, and for some models even accept that the manufacturer may block the use of non-original cartridges any time in the future, even after the end of the subscription. Therefore, if the manufacturer stopped supplying ink cartridges, users would no longer be able to use the device, leading to premature obsolescence and causing a heavier environmental impact than the benefits derived from the ink subscription.

This NGO explains that, despite subscription cartridges contain more ink and toner than regular cartridges, this should not be taken as evidence that these models provide better environmental results. From a technical point of view, subscription cartridges are identical to the regular cartridges, in terms of size and materials. The only difference is the amount of ink or toner (higher in subscription cartridges). In fact, this demonstrates that regular cartridges could be filled to a higher level.

Additional issues identified by this NGO on PaaS models are the following:

(a) Some manufacturers start to impose restriction on the type of documents that can be printed, due to the amount of ink required. For instance, some printers currently restrict the size for photo quality prints, as photo prints cost a lot of ink.

(b) Users tend to print more pages with PaaS models than with purchased cartridges, in turn having a potential negative impact on the environment.

7.2.3.2 Relevant information stored in chip

Applicability: Toner & Ink cartridges with chip

Content of the measure:

Cartridges containing chips shall be designed in a way that the chip can store at least the following information:

- Serial number
- ID of original manufacturer
- ID of operator(s) that have remanufactured the cartridge
- Dates of remanufacturing operations
- Compliance with regulation 2019/1020 on product market surveillance

Relevance and feasibility

Providing cartridge remanufacturers with relevant information for reuse would help to increase cartridge reuse rates, as well as the quality of remanufactured cartridges. It would also help to reduce the amount of chips that are discarded after one use and therefore the consumption of raw materials to produce new chips.

Assessment and verification

This measure shall be verified with instructions for authorised operators on how to access and update relevant data for reuse, provided in the product documentation sheet and on free access website.

Feedback from stakeholders

The association of manufacturers understand the desire for more data about the life and history of a cartridge but important considerations from their point of view are the following:

(i) What is the purpose of the data?

(ii) Confidentiality/security/privacy concerns?

(iii) Who should be able to read it?

(iv) How should they be able to read it?

(v) How would IDs be issued and maintained? Does this only apply to cartridges remanufactured using the solution set out in 7.2.3.1?

In their view, this measure may not be possible to implement on existing models and therefore should at most only be required for new models of printing systems. OEMs consider that this is a complex issue and that it needs further consideration and discussion before being included in regulation.

Remanufacturers agree in general terms with this proposal. They suggest that the national WEEE registration number of the original manufacturer and the operator(s) that have remanufactured the cartridge should be added.

A Member State representative highlight that it is also important that the information stored in the chip can be read-out with “common available tools”, i.e. without the need for proprietary hardware or software.

7.2.3.3 Physical access to chip via disassembly

Applicability: Toner & Ink cartridges with chip

Content of the measure:

Cartridges containing chips shall be designed in a way that the chip is easily accessible with the aim of chip substitution or resetting, with the use of commonly available resetting tools, without permanent damage to cartridge.

Relevance and feasibility

Ensuring that the chip can be easily accessed with the use of commonly available tools, without damaging the cartridge, would help to increase cartridge reuse rates.

Assessment and verification

This measure shall be verified with instructions for authorised operators on how to access the chip without permanent damage to the cartridge, provided in the product documentation sheet and on free access website.

Feedback from stakeholders

The association of manufacturers support this measure in terms of the wording in "Content of the measure". Resetting of the original chip is the best solution for cartridge reuse. As long as the cartridge chip is accessible to enable the resetting then that objective is served. They point out that there is a trade off between making a chip easily accessible for replacement and reducing risk of damage in collection and handling. The regulation should optimise for preventing damage so as to enable reuse via resetting.

The association of cartridge remanufacturers strongly welcome this measure.

7.2.3.4 Functionality of device when disconnected from the Internet

Applicability: Laser & Inkjet devices

Content of the measure:

It shall be possible to use the main functionalities of the device without being connected to the Internet.

Relevance and feasibility

This measure has the main objective of increasing cartridge reuse rates, but is applicable to devices (laser and inkjet).

On occasions, software and firmware updates affect the performance of third party cartridges. If the user has the possibility to disconnect the device from the Internet, it is possible for them to still use third party cartridges, avoiding the risks associated to software and firmware updates.

This measure could also have a positive effect of reducing energy consumption during use phase.

Assessment and verification

This measure shall be verified with instructions on how to disconnect the device from the Internet, included in the user manual, provided with the device and on free access website.

Feedback from stakeholders

The association of remanufacturers consider that this measure is not necessary to increase the use of remanufactured cartridges if measure 7.1.2.1 (Software and firmware updates) is written as proposed by them. Therefore, they recommend to take their proposal in 7.1.2.1 and to remove 7.2.3.4.

An environmental NGO consider that it is very important for consumers to be able to use printers also when the device is disconnected from the internet. This ensures that products are not discarded prematurely because they do not meet consuemrs expectations.

7.2.3.5 Resistance to shocks and drops

Applicability: Toner & Ink cartridges

Content of the measure:

Cartridges shall be designed in a way that they comply with specifications of a standard drop test. The cartridges should retain full functionality after 20 drops.

Relevance and feasibility

Collection, transport and storage are processes that can severely damage empty cartridges. If key components of cartridges such as developers are exposed (see Figure 97), there is a high risk that they will become non-reusable during reverse logistics operations.

Ensuring that the cartridge can withstand drops would help to reduce damages during collection, transport and storage operations, contributing to higher collection and reuse rates. Some OEMs are already conducting such tests to ensure that a higher proportion of cartridges can be reused.

Assessment and verification

This measure shall be verified with documentation that proves compliance with standard drop test. Measurements shall be made *with IEC 60068-2-31 Environmental testing. Rough handling shocks, primarily for equipment-type specimens.*

Feedback from stakeholders

The association of manufacturers consider that, tor this measure to be meaningful the conditions of the tests must be specified (for instance, full or empty cartridge; in packaging or not; onto what type of surface; from which height, etc.). OEMs also wonder why 20 drops was selected and which are the pass/fail criteria. In their view, it is also important to note that the ability to pass stringent drop criteria would be become more challenging with the proposal to progressively reduce the material to pages ratio. These are potentially conflicting design criteria. If cartridges are weakened, packaging has to be strengthened; then there materials impact may be unchanged or worsened.

OEMs point out that, if the goal is to reduce damage to empties to support reuse, then this requires a comprehensive assessment of collection systems and how to prevent damage (noting that this cannot be done through EcoDesign). In their view, the answer is not to arbitrarily create a drop test requirement that may or may not improve the quality of empties and is likely to increase the amount of material used. Therefore, they suggest to remove this measure until a comprehensive assessment has been carried out, appropriate design changes developed, aligned with other regulatory requirements, and a suitable transition period granted.

Another individual OEM highlights that IEC 60068-2-31 only deals with product robustness to handling while being serviced. It specifically does not involve transportation which is the concern that the JRC is trying to mitigate. They consider that this requirement seems misplaced because making cartridges more robust would add mass, cost and carbon footprint. Alternately, OEMs could instead create better handling procedures when remanufacturing cartridges to reduce scrap. They recommend that instead of legislating the solution, legislate the requirement and let OEMs figure out the best way to achieve the goal.

An environmental NGO points out that it it is important to clarify the conditions of the test, whether it should be carried out with or without the protective packaging.

7.2.3.6 Cartridge joining techniques

Applicability: Toner & Ink cartridges

Content of measure:

The cartridge shall be designed in a way so that it can be opened for remanufacturing or refilling without damaging it to a point where it cannot be reused.

Relevance and feasibility

Ensuring that the cartridge can be easily dismantled without permanent damage can help to increase cartridge reuse rates.

Assessment and verification

This measure shall be verified by checking that no permanent joining techniques have been used in components that need to be dismantled to remanufacture or refill the cartridge.

Feedback from stakeholders

The association of manufacturers consider that this proposal, as written, is vague, subjective and problematic to implement and enforce. Manufacturers require certainty in order to design and place products on the market. They wonder how a determination would be made at the design stage as to whether a cartridge can be opened without damaging it to the point where it cannot be reused. They also wonder if the cartridge can be refurbished without disassembling it, it should be excluded from the scope of this case.

They add that OEMs cannot know or take into account all current and future remanufacturing techniques when they design a product. It is important to note that this criterion is potentially in conflict with the requirements to ensure more robust cartridges (drop tests) and to reduce cartridge material. Reversible joining techniques are likely to require significantly more materials. It is also important to consider which products the requirement would have to apply to. In most cases it would not be possible to redesign cartridges for existing printer models. This criterion is likely to result in bigger cartridges with more material that would not be compatible with existing printer models. If enforced on cartridges for existing printer models it could therefore result in a significant printer obsolescence issue.

Therefore, OEMs recommend that this proposal should be reconsidered and would require input from remanufacturers and OEMs to find workable requirements.

The association of cartridge remanufacturers fully support this measure. In their view, cartridge construction techniques must always allow opening and remanufacturing operations without permanent and irreversible damage to the cartridge.

In general terms, a national environmental agency agrees with this measure, when they point out that a cartridge shall not contain a mechanism that prevents the full refill.

7.2.3.7 Logos and badges

Applicability: Toner & Ink cartridges

Content of the measure:

Cartridges shall not contain trademark logos or badges in areas that are fragile and/or critical for the remanufacturing process.

Relevance and feasibility

In order to commercialize remanufactured cartridges, remanufacturers might need to remove OEM logos and/or badges in cartridges, to avoid trademark-related issues.

Ensuring that no logos or badges are placed in key areas of the cartridge would reduce damages caused to the cartridge in the attempt to remove them, increasing cartridge reuse rates.

Assessment and verification

This measure shall be verified with visual inspection, ensuring that cartridges do not contain logos and badges on previously identified key areas for reuse.

Feedback from stakeholders

The association of manufacturers point out that the proposal, as written, is vague and very problematic to implement and enforce. Manufacturers require certainty in order to design and place products on the market. They explain that it would not be possible for them to determine at the design stage which parts are to fragile or critical for any remanufacturing process used in the future. They add that it would not be possible to assess all current and future products to give manufacturers upfront design criteria.

Manufacturers point out that logos are important from a brand and trademark perspective but also for the purpose of anti-counterfeiting measures. They consider that legitimate uses of trademarks should not be undermined by the regulation. If the logos or badges can be covered (e.g. by using stickers), or if it can be removed by scraping it, and still can be remanufactured, such logos or badges should be out of scope of this proposal.

OEMs recommend that this proposal should be reconsidered and would require input from remanufacturers and OEMs to find workable requirements.

Remanufacturers highlight that removing OEM logos on consumables may not be cost effective or energy efficient. Moreover, if the logos are removed, it might be difficult to distinguish the cartridge from a non-original one. They recommend that OEM logos do not need to be removed in remanufactured products; and suggest to add a label to clearly indicate to the user that it is a remanufactured product.

7.2.3.8 Information requirements on remanufacturing

Applicability: Toner & Ink cartridges

Content of the measure:

Information shall be provided to consumers regarding the possibilities to remanufacture or refill cartridges. If the cartridge cannot be remanufactured or refilled, this should be clearly indicated in the product packaging or instructions.

Information shall be provided to consumers on how to facilitate the remanufacturing or refilling of cartridges, indicating where and how to return it or dispose it.

Cartridges commercialized as remanufactured shall provide information on the latest date and place of remanufacturing, as well as contact data of the operator which carried out the remanufacturing.

Relevance and feasibility

Only 26% of consumers tend to use take-back schemes when their cartridges are empty (see Figure 33). This percentage could be improved if clear information is provided on how and where to return empty cartridges.

When a consumer purchases a remanufactured cartridge, they often lack information on the remanufacturing process and operator. As highlighted in Figure 31, the main reasons for not using remanufactured cartridges are: not knowing enough about them; distrust manufacturers of remanufactured cartridges; and fear of lower printing quality with remanufactured cartridges.

On top of that, on occasions, in order to be considered for public tenders, cartridges are commercialized as remanufactured -with the use of logos and badges, for instance- when they actually are clones or counterfeits.

Ensuring that cartridges commercialized as remanufactured need to provide relevant information -such as the place and date of the remanufacturing process- could provide consumers with more confidence about the expected quality of the cartridge. It could also help to reduce clones and counterfeits being commercialized as remanufactured cartridges.

Assessment and verification

This measure shall be verified with the provision of relevant information on remanufacturing process in the product packaging, including as a minimum: name of remanufacturer, a commercial address and date of remanufacturing.

Feedback from stakeholders

The association of manufacturers agrees that there is a problem with newbuild/clone cartridges being marketed as remanufactured. This is already an unfair commercial practice and consider that merely requiring more information is unlikely to have any impact: if some companies are prepared to falsely state that a cartridge is remanufactured then they will equally falsify information about the place and date of remanufacturing. Although OEMs understand the concern behind this requirement, they do not think it is appropriate to include in ecodesign because authorities already have powers to carry out market surveillance and enforcement.

Regarding the first sentence of this measure, manufacturers consider that requiring information on whether or not a cartridge can be remanufactured seems problematic to achieve. It may be technically possible to refill newbuild/clone cartridges but to OEMs' knowledge; independent remanufacturers cannot use them in their processes and they end up being disposed of. In relation to collection programs, companies should not be required to promote each others collection programs. They recommend to require cartridge manufacturer to provide information on its take back program and inform if no take-back program is available.

The association of remanufacturers support the ability of tracking and tracing the remanufacturing of a cartridges. However, they point out that some companies remanufacture for 3rd parties, or under so called "white brand". In those cases the name of the actual remanufacturer is business secret, which has standard business data protection under regular national and EU trade laws. The product can still be traced back to the remanufacturer and production date, as it will carry a coding that allows retroactive identification of the actual remanufacturer, remanufacturing date/batch number, etc. Remanufacturers consider that a universal obligation to publish the date and place of information, as well as contact data of the operator is overly stringent. They recommend that a packaging identifies the brand and marketing company and a tracking code that allows identification of the date of place and batch number of the last remanufacturing operation.

Regarding the first sentence of this measure, a Member State representative highlights that remanufacturing or refilling (of new empties) should always be possible. The option of including clear indication that a cartridge cannot be refilled or remanufactured opens a large loophole.

7.2.4 Paper use optimization in cartridges

The quality of printing with original and remanufactured cartridges, as well as its influence on paper consumption, have been discussed in section 4.5.7.

In section 6.2.4, the potential environmental benefits of reducing paper waste have been estimated: reductions in Climate change impact can be achieved between 2% and 3%, depending on the cartridge type.

The potential consumer expenditure benefit has been estimated in section 6.2.4: reductions in cost per page between 0.1% and 0.5%, depending on the device type.

Considering this, a measure has been proposed to reduce paper waste associated to cartridges.

7.2.4.1 Quality of remanufacturing process

Applicability: Toner & Ink cartridges commercialized as "reused", "remanufactured"

Content of the measure:

Cartridges commercialized as remanufactured shall be compliant with minimum requirements in terms of quality of remanufacturing process, as established by international standards

Relevance and feasibility

As highlighted in Figure 31, one of the main reasons for not using remanufactured cartridges is fear of lower printing quality with remanufactured cartridges.

Ensuring that remanufactured cartridges are compliant with minimum quality requirements on the remanufacturing process would help to avoid the placing on the market of low performance remanufactured cartridges, as well as increase the confidence of consumers in remanufactured cartridges.

It would also help reduce the amount of paper wasted due to unusable outputs.

An option regarding this measured could be to link it with measure 7.2.3.1 (provision of chip resetting functionality to professional remanufacturers). For instance, the OEM could be required to make available means for remanufacturing (including resetting) to remanufacturers that comply with the standards.

Assessment and verification

This measure shall be verified with documentation that proves compliance with relevant standards on quality of remanufacturing process:

- DIN 33870-1 — Office machines - Requirements and tests for the preparation of refilled toner modules for electrophotographical printers, copiers and facsimile machines - Part 1: Monochrome DIN 33870-2 — Requirements and tests for the preparation of refilled toner modules for electrophotographical printers, copiers and facsimile machines - Part 2: 4-colour printers
- DIN 33871-1 – Office machines, inkjet print heads and inkjet tanks for inkjet printers – Part 1: Preparation of refilled inkjet print heads and inkjet tanks for inkjet printers.
- DIN 33871-2 - Office machines, inkjet print heads and inkjet tanks for inkjet printers - Part 2: Requirements on compatible ink cartridges (4-colour system) and their characteristic features

<u>Feedback from stakeholders</u>

The association of manufacturers consider that OEMs should not be required to certify their cartridges to DIN standard if their remanufactured cartridges are warranted to have the same quality as original OEM cartridges. In their view, the DIN 33870 standards are not sufficient to claim equivalent quality to an OEM cartridge and do not guarantee print quality, durability or reliability comparable to an OEM cartridge.

OEMs explain that if third party remanufacturers are to produce cartridges to standards equivalent to OEM standards then they should carry out these additional tests:

1) Environmental Performance Testing: OEMs evaluate their new and remanufactured cartridges not only under standard temperature and humidity conditions but also in high temperature/high humidity and low temperature/low humidity environments to guarantee optimal performance across diverse settings. This is imperative as not all customers are office or home based. There are many customers who require machines to be used in different environmental conditions, such as; hospitals, laboratories, agriculture etc. where strict environmental conditions need to be managed.

2) Indoor Air Quality Testing (IAQ): Electronic devices emit substances into the indoor air. To minimize adverse environmental and health impacts, new and remanufactured toner cartridges should undergo rigorous IAQ testing. This would ensure that emission rates of the entire system (cartridge, paper and device), even with a different toner, do not exceed those of the original toner design, regardless of the absolute level of emissions.

3) Packaging Assurance Testing (Vibration and Drop): Proper packaging is crucial to prevent damage during the distribution process. This can include measures such as container vibration protection, damping performance, and resonance effect assessment. Implementing these safeguards will significantly reduce waste caused by transport-related damages and avoid unnecessary CO2eq emissions of damaged cartridges transport.

4) Shelf Life/Storage Assurance Testing: further clarification is required on the aims and objectives of shelf life and storage assurance to ensure consumer satisfaction and environmental conservation.

5) Yield Testing: in accordance with ISO/IEC standards (ISO/IEC19752, ISO/IEC19798) is paramount to aligning with industry norms and ensuring transparency in product performance.

6) Archivability Testing: if the OEM cartridge is certified for archivability then remanufactured cartridges should be tested to the same standards as used by OEM.

Original manufacturers recommend that, as currently proposed, this requirement should not apply to OEM remanufactured cartridges because DIN 33870 is a German standard and not international self certification standard which does not guarantee quality. They suggest the creation of a new appropriate international standard – to become developed by an International or European Organization for Standardization (ISO/CEN) potentially including the other standards and tests noted above. OEMs and third party remans would need to be invited to work together on such a new more suitable, verifiable international standard.

The association of remanufacturers endorses a strict requirement for remanufactured cartridge quality. They consider that an obligation to comply with such a standard should apply equally to all remanufactured cartridges on the EU market.

Remanufacturers note that the DIN standards proposed by the JRC in 7.2.4.1 require that the cartridge core was a new or remanufactured OEM (not a non-OEM newbuilt cartridge). Thus by definition, remanufactured non-OEM cartridges (clones) cannot claim DIN-compliance. Remanufacturers point out that it should be avoided that as a result, only remanufactured OEM cartridges would need to comply with the DIN criteria, while OEM cartridges and newbuilt non-OEM cartridges and remanufactured newbuilt non-OEM cartridges do not need to comply. They recommend that regulation could use wording similar to “internationally recognized standards comparable to DIN 33870-1, 33870-2 and 33871-1”.

7.3 Comparison of ecodesign measures

In sections 7.1 and 7.2, individual ecodesign measures that may be applicable to devices and cartridges have been proposed, without establishing a priority in terms of their potential to reduce the environmental impact of products.

In Tasks 5 and 6, an environmental and economic assessment of Base Cases and Design Option has been carried out. Ecodesign measures presented in sections 7.1 and 7.2 can be compared and prioritised based on the results of such assessments (Table 119 and Table 120).

Table 119. Summary of ecodesign measures on devices

Areas	Measures	Climate change improvement potential (gCO2eq./page)	Consumer expenditure improvement potential (cEUR/page)
Reparability	Design for disassembly of priority parts	0.3 – 7.8 (3-17%)	0.03 – 0.18 (4-7%)
	Availability of priority parts and delivery time		
	Availability of information on repair		
	Availability of resetting functionality		
Durability	Software and firmware updates		
	Warnings and messages about cartridges		
	Access to information on number of pages printed		
	Durability of key consumables of laser devices		
	Durability of key consumables of inkjet devices		
Recyclability	Design for recyclability of devices		
Energy efficiency	Power consumption of non-active modes	0.14 - 0.25 (0-3%)	0.01 (0-2%)
	Reducing the time between active and non-active modes		
	Efficiency of internal power supply units		
	Availability of manual switch to off-mode		
Paper use	Duplexing capability	0.65 -1%	0.15 -4%
	N-up printing capability		
PCR plastic	Post-consumer recycled plastic in devices	0.15 - 1.6 (1-3%)	0 0%

Table 120. Summary of ecodesign measures on cartridges

Areas	Measures	Climate change improvement potential (gCO2eq./page)	Consumer expenditure improvement potential (cEUR/page)
Capacity utilisation	Page yield of ink cartridges	0.11 – 0.19 (18-19%)	0.09 – 1.26 (10-15%)
	Page yield of toner cartridges		
Material efficiency	Material efficiency of ink cartridges	0.33 – 0.60 (55-61%)	0 0%
	Material efficiency of toner cartridges		
	Printing with one or more empty cartridges		
Remanufacturability	Chip resetting functionality	0.15 – 0.51 (24-56%)	0.47 – 4.13 (33-67%)
	Relevant information stored in chip		
	Physical access to chip		
	Functionality of device when disconnected from the Internet		
	Resistance to shocks and drops		
	Cartridge joining techniques		
	Logos and badges		
	Information requirements on remanufacturing		
Paper use	Quality of remanufacturing process	0.02 (2-3%)	0.005 (0.1-0.5%)

7.4 Scenario analysis

The objective of this section is to set up a stock model (up to 2040) and calculate the impact of different policy scenarios in terms of Climate change (CO2eq) and consumer expenditure (million EUR), depending on the market evolution of imaging equipment. The policy scenarios presented in this section will be based on the ecodesign measures proposed in sections 7.1 and 7.2.

In the following sections, different scenarios will be proposed for devices and cartridges.

7.4.1 Scenario analysis for devices

The stock of devices has been estimated using the following input data:

- Sales of devices (Section 2.3 of the Preparatory Study)
- Lifetime of device base cases (Section 4.6.1.3)
- Reference Weibull[166] parameters (Baldé, 2015)

The estimated stock of laser and inkjet devices for the period 2023-2040 can be seen in Figure 132 and Figure 133, respectively. The stock of laser devices remains stable around 35 million units, favoured by a stable total sales over the period, as seen in section 2.3.2. The stock of inkjet devices is expected to decrease in the period evaluated, due to a decrease in the sales of inkjet devices at a 4.2% yearly rate (section 2.3.1) and reduced lifetime (section 4.4.2.2) of 4 years of average.

[166] The Weibull distribution is a probability distribution commonly used to measure failure rates. Its form is similar to an exponential distribution, which models a fixed failure rate, except that a Weibull distribution allows for a failure rate that changes over time in a particular fashion. https://www.weibull.com/basics/lifedata.htm

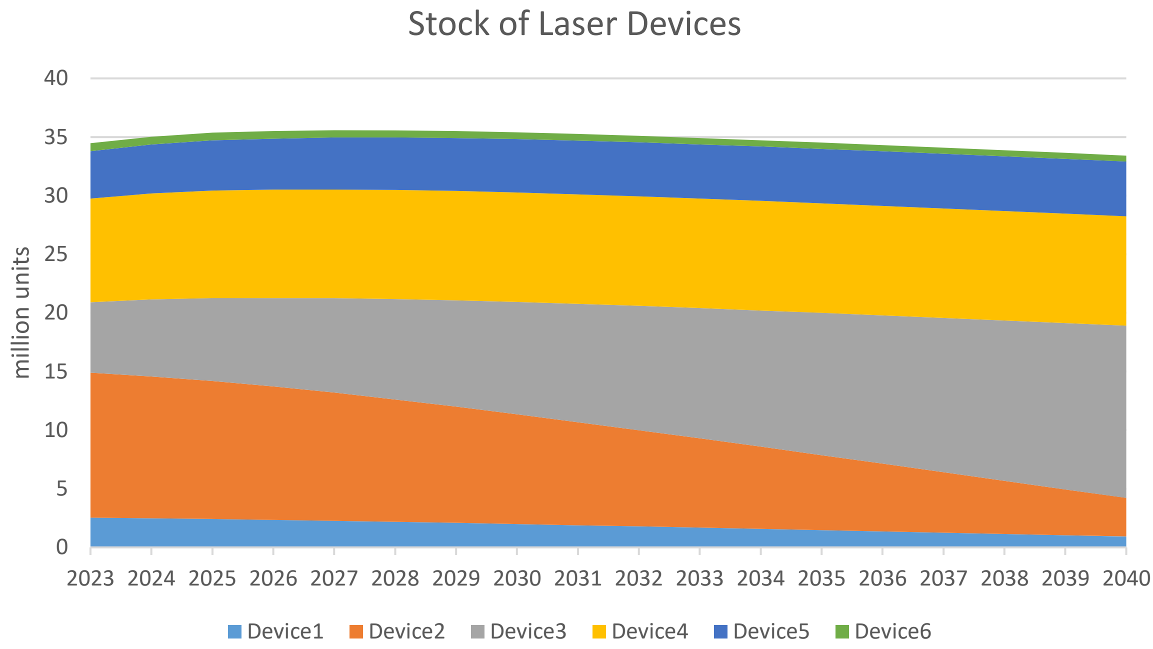


Figure 132. Estimated stock of laser devices 2023-2040

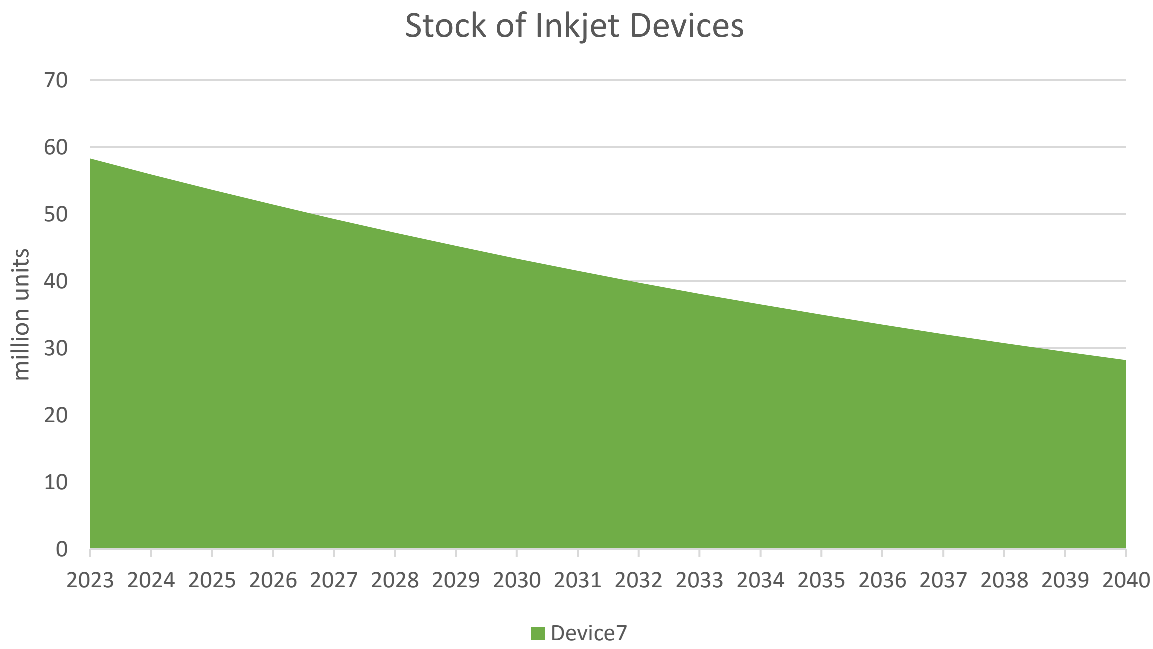


Figure 133. Estimated stock of inkjet devices 2023-2040

The scenario analysis presented in the following sections has been carried out considering sales and stock data of devices, with their associated cartridge use. Environmental impacts and consumer expenditure of base cases described in Task 5 have also been used as an input. Improvement potential of different design options described in Task 6 have also been considered.

In the Scenario Business as Usual (BAU) it has been assumed that there is no change in the status quo. No regulation is implemented in the imaging equipment sector. The market of devices is mainly represented by the base cases described in Task 5 of the Preparatory Study.

The impact on Climate Change of the Scenario BAU can be seen in Figure 134. The estimated emissions in 2023 are 9.8 MTCO2eq. These emissions are expected to decrease down to 9.4 MTCO2eq in 2040. The largest contributor to the overall emissions in 2023 is Device7 (household inkjet device). Its relevance is expected to decrease over time, due to its decrease in sales (4.2% yearly reduction). It has been estimated that in 2040 the largest contributor to overall emissions will be Device3 (large office, laser A4 color).

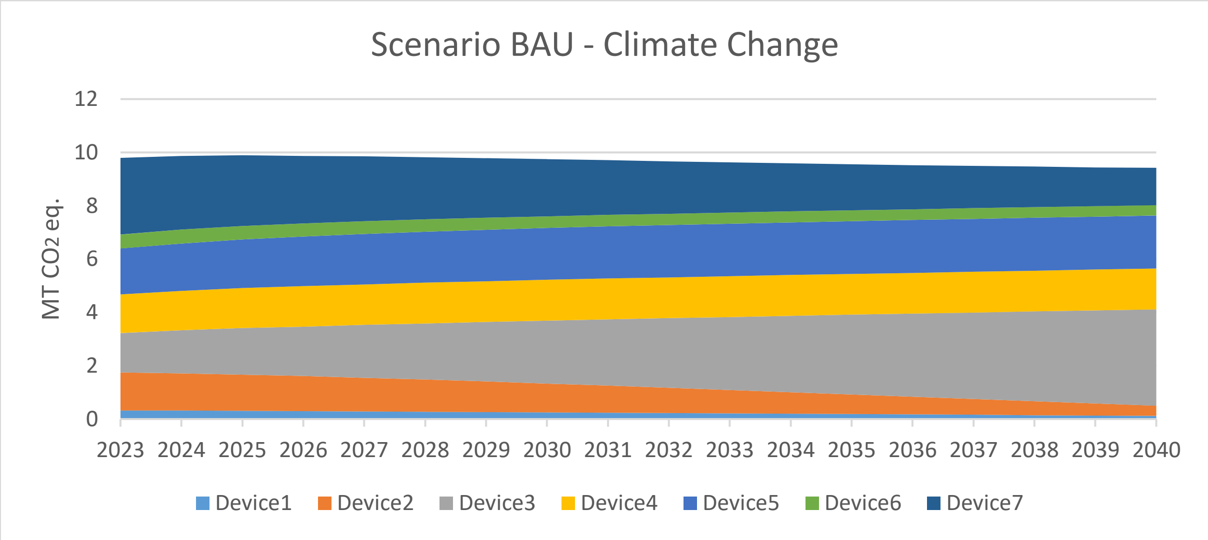


Figure 134. Scenario BAU – Impact on Climate Change of devices

The impact on Consumer expenditure of the Scenario BAU can be seen in Figure 135. The estimated consumer expenditure in 2023 is 71.1 million EUR. This expenditure is expected to decrease down to 60.1 million EUR in 2040. The largest contributor to the consumer expenditure in 2023 is Device7 (household inkjet device). It has been estimated that in 2040 the largest contributor to consumer expenditure will be Device3 (large office, laser A4 color).

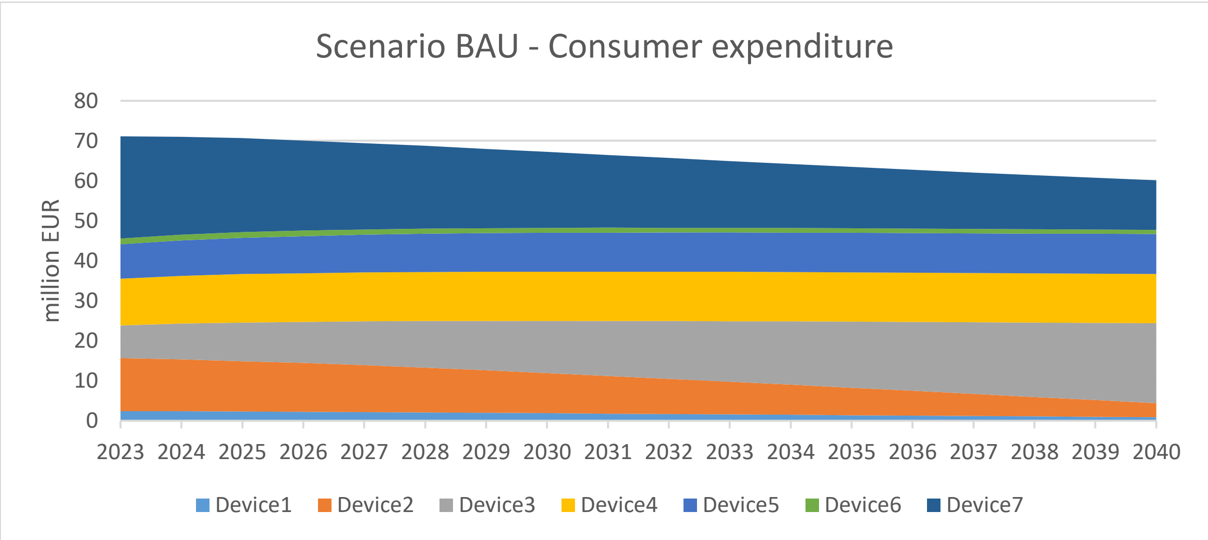


Figure 135. Scenario BAU – Impact on Consumer expenditure of devices

As an alternative to the Scenario BAU, the scenarios described in Table 121 are proposed.

Table 121. Scenarios proposed for devices

Scenario	Description	Ecodesign measures and timeline
Scenario BAU	Business as Usual	No ecodesign measures
Scenario 1	Energy efficiency	Ecodesign measures described in 7.1.4 enter into force in 2026

Scenario 2	Reparability, recyclability and durability	Ecodesign measures described in 7.1.1 and 7.1.2 enter into force in 2026
Scenario 3	Resource conservation	Ecodesign measures described in 7.1.6 and 1.1 enter into force in 2026
Scenario 4	Combination of different ecodesign measures	Ecodesign measures to reduce paper waste enter into force in 2026 Ecodesign measures to extend lifetime enter into force in 2027 Ecodesign measures to increase amount of PCR plastic enter into force in 2028 Ecodesign measures to reduce energy consumption enter into force in 2029

In Scenario 1 it is assumed that energy efficiency of devices is improved by implementing more ambitious requirements on non-active modes (standby, off, transition time) and more efficient components such as internal power supplies.

In Scenario 2 it is assumed that average lifetime of devices is increased with the implementation of reparability and durability measures. Scenario 2 can be associated with an increase in subscription services for devices, since these business models are incentivised by durable and reparable devices. Scenario 2 can also represent a strategy change in business and public administrations of increasing the useful lifetime of devices, rather than their early replacement.

In Scenario 3 it is assumed that less resources are consumed, by reducing the amount of paper waste and by increasing the use of post-consumer recycled plastic.

Scenario 4 is a combination of the three scenarios above. It represents the improvement potential of different strategies combined: optimising energy efficiency, reducing paper waste and increasing plastic recycled content, making full use of devices lifetime or promoting subscription services for devices, among others. In this scenario, it is assumed that the different strategies will be implemented in a staggered manner.

The impact on Climate change of the different scenarios proposed can be seen in Figure 136. Considering Scenarios 1, 2 and 3, the one with the highest improvement potential is Scenario 2, which assumes that reparability and durability measures enter into force in 2026. The improvement potential of Scenario 2 is 7.2 MTCO2eq in the evaluated period. The combination of the three scenarios (Scenario 4) could bring a reduction of 9.2 MTCO2eq.

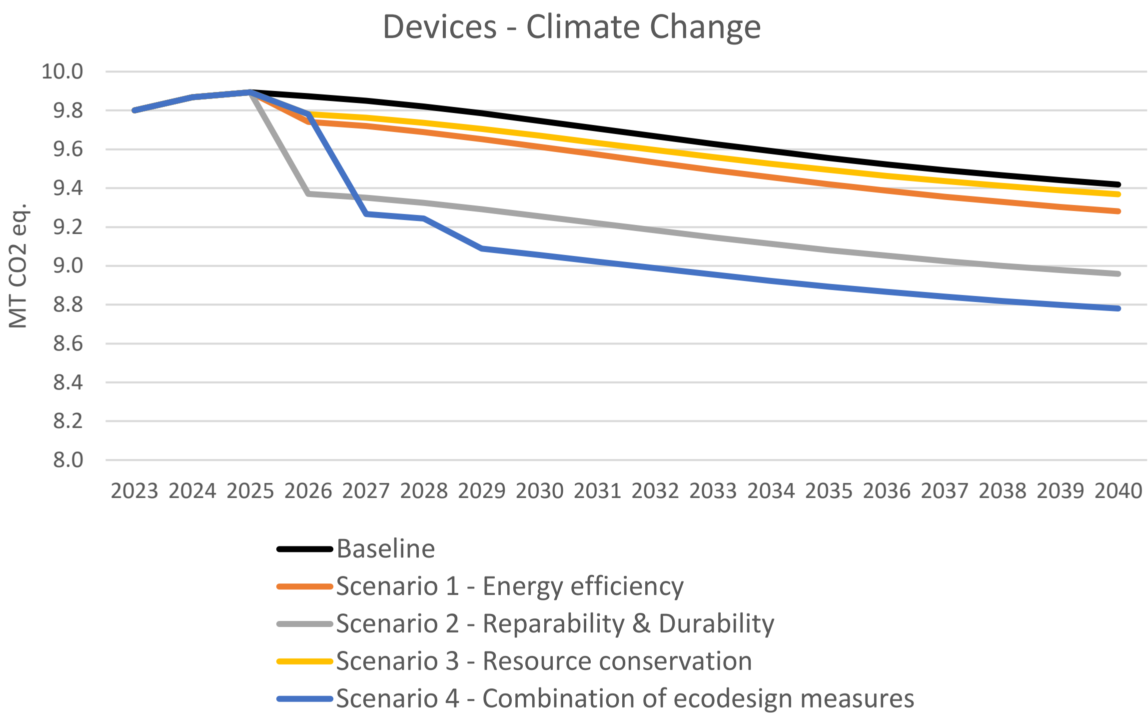


Figure 136. Scenarios for devices – Climate change

The impact on Consumer expenditure of the different scenarios proposed can be seen in Figure 137. Considering Scenarios 1, 2 and 3, the one with the highest improvement potential is again Scenario 2, which assumes that reparability and durability measures enter into force in 2026. The improvement potential of Scenario 2 is 48.2 million EUR in the evaluated period. The combination of the three scenarios (Scenario 4) could bring a reduction of 63 million EUR.

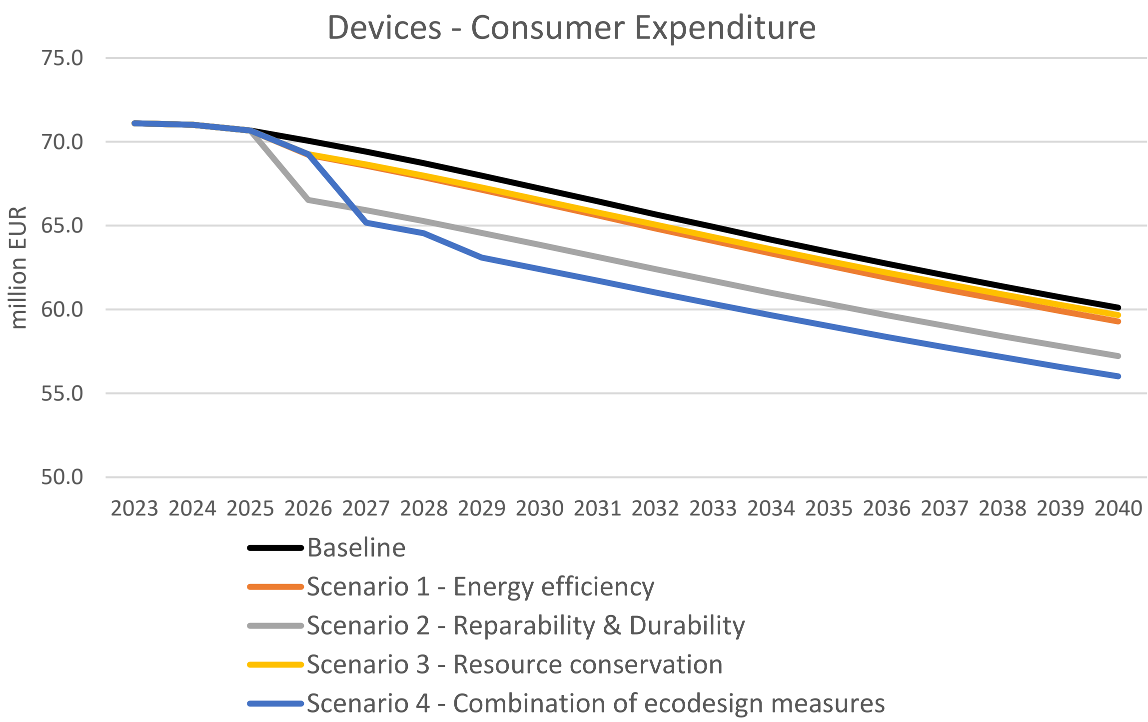


Figure 137. Scenarios for devices – Consumer expenditure

In Table 122 the improvement potential of Climate change and Consumer expenditure of the different scenarios are summarized.

Table 122. Improvement potential of scenarios for devices

Scenario	Description	Improvement potential Climate change (MTCO2eq.)	Improvement potential Consumer expenditure (million EUR)
Scenario BAU	Business as Usual	0	0
Scenario 1	Energy efficiency	2.0	12.5
Scenario 2	Reparability and durability	7.2	48.2
Scenario 3	Resource conservation	1.0	9.1
Scenario 4	Combination of different ecodesign measures[167]	9.2	63.0

7.4.2 Scenario analysis for cartridges

In the Scenario Business as Usual (BAU) it has been assumed that there is no change in the status quo. No regulation is implemented in the imaging equipment sector. The market of cartridges is mainly represented by the base cases described in Task 5 of the Preparatory Study.

The impact on Climate Change of the Scenario BAU can be seen in Figure 138. The estimated emissions in 2023 are 0.59 MTCO2eq. These emissions are expected to increase up to 0.63 MTCO2eq in 2040. The largest contributor to the overall emissions across the period 2023-2040 is Cartridge1 (toner cartridge A4).

[167] In Scenario 4, strategies are assumed to be implemented at different years than in Scenarios 1, 2 and 3. Therefore, the estimated savings of Scenario 4 are not the addition of the savings of Scenarios 1, 2 and 3.

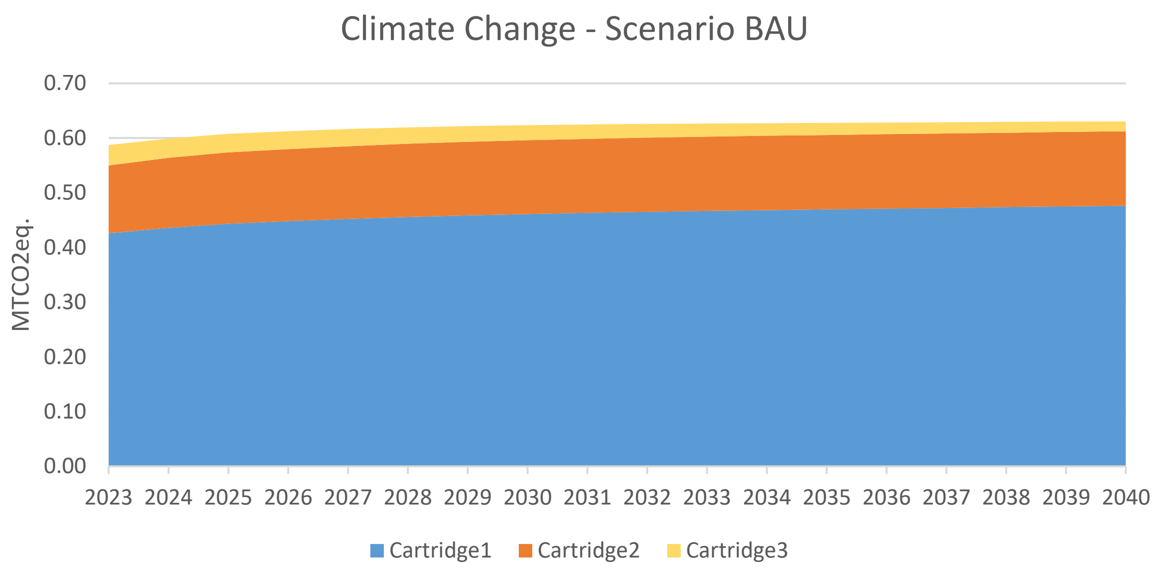


Figure 138. Scenario BAU – Impact on Climate Change of cartridges

The impact on Consumer expenditure of the Scenario BAU can be seen in Figure 139. The estimated consumer expenditure in 2023 is 133 million EUR. This expenditure is expected to decrease down to 116 million EUR in 2040. The largest contributor to the consumer expenditure across the period 2023-2040 is Cartridge1 (toner cartridge A4).

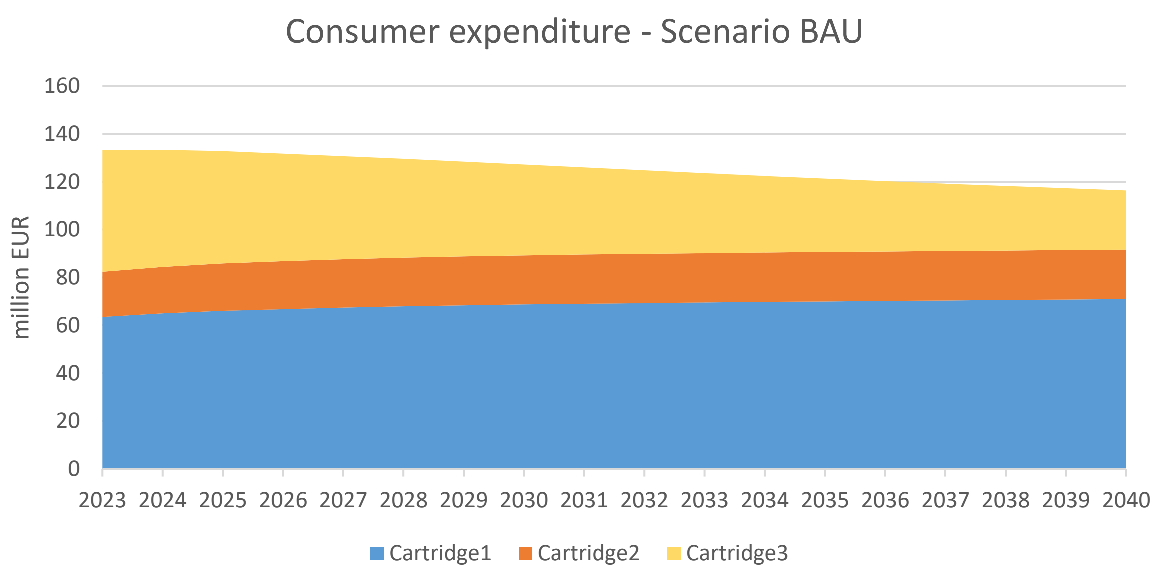


Figure 139. Scenario BAU – Impact on Consumer expenditure of cartridges

As an alternative the Scenario BAU, the scenarios described in Table 123 are proposed.

Table 123. Scenarios proposed for cartridges

Scenario	Description	Ecodesign measures and timeline
Scenario BAU	Business as Usual	No ecodesign measures
Scenario 1	Capacity utilisation	Ecodesign measures described in 1.1.1.1 and 1.1.1.1 enter into force in 2026

Scenario 2	Material efficient configuration	Ecodesign measures described in 7.2.2.1 and 7.2.2.2 enter into force in 2026
Scenario 3	Remanufacturing	Ecodesign measures described in 7.2.3 enter into force between 2027 and 2030
Scenario 4	Reduced paper waste	Ecodesign measures described in 7.2.4 enter into force in 2026
Scenario 5	Combination of different ecodesign measures	Ecodesign measures to reduce paper waste enter into force in 2026 Ecodesign measures to improve capacity utilisation enter into force in 2027 Ecodesign measures to increase the use of remanufactured cartridges enter into force between 2028 and 2030 Ecodesign measures to increase the sales of material efficient configurations enter into force in 2029

In Scenario 1 it is assumed that the capacity utilisation of cartridges in the market is improved, so the average page yield of cartridges increases. This could mean that cartridge OEMs reduce the sales of standard capacity cartridges and increase the sales of high capacity or XL cartridges. This could also mean the inclusion of starter cartridges with higher capacities. In a way, Scenario 1 represents as well a rise in subscription services for cartridges, since these tend to include cartridges with higher capacity.

In Scenario 2 it is assumed that the material efficiency of cartridges (in pages/gram) increases, without increasing average page yield. In essence, this could mean that cartridge OEMs reduce the sales of integrated/all-in-one configurations and increase the sales of single-part solutions. Scenario 2 can also represent a rise in sales of products such as printers with tanks and external containers (described in section 4.5.9), which tend to have higher material efficiencies.

In Scenario 3 it is assumed that remanufacturing rates of cartridges increase significantly, due to design changes in printers and cartridges. This could mean that cartridge OEMs change their current strategy of prioritising recycling towards reuse and remanufacturing. In Scenario 3 OEMs and remanufacturers would compete on cartridge collection and remanufacturing. Scenario 3 represents as well a rise in subscription services for cartridges, since these tend to have higher capacities and be designed for easier collection and reuse.

In Scenario 4 it is assumed that the amount of paper wasted by remanufactured cartridges is reduced, by mandatory compliance with quality measurement standards.

Scenario 5 represents a combination of the four scenarios above. It represents the improvement potential of different strategies combined: increasing sales of cartridges with optimised capacity, increasing sales of single-part solutions, prioritising remanufacturing over recycling, promoting subscription services or increasing sales of tank-based printers, among others. In this scenario, it has been assumed that each of the strategies are implemented in a staggered manner.

The impact on Climate change of the different scenarios proposed can be seen in Figure 140. Considering Scenarios 1, 2, 3 and 4, the one with the highest improvement potential is Scenario 3, which assumes increases in the use of remanufactured cartridges between 2026 and 2028. The improvement potential of Scenario 3 is 6.6 MTCO2eq in the evaluated period. The combination of the four scenarios (Scenario 5) could bring a reduction of 7.3 MTCO2eq.

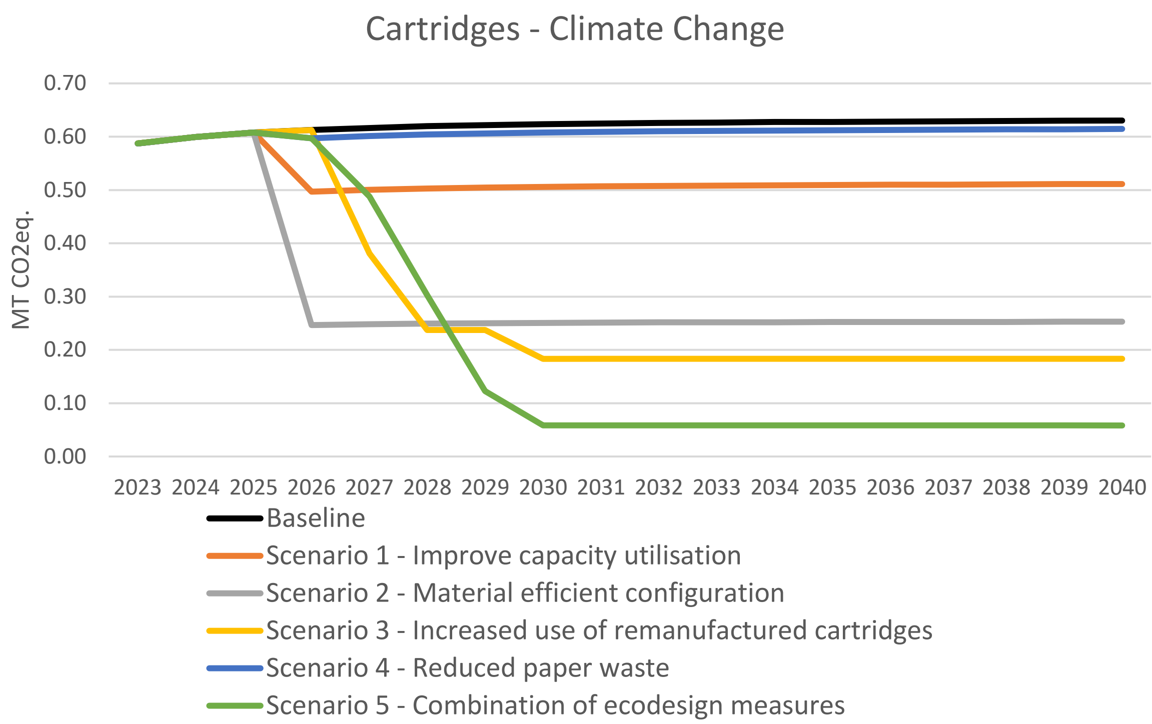


Figure 140. Scenarios for cartridges – Climate change

The impact on Consumer expenditure of the different scenarios proposed can be seen in Figure 141. Considering Scenarios 1, 2, 3 and 4, the one with the highest improvement potential is again Scenario 3, which assumes that reparability and durability measures enter into force in 2026. The improvement potential of Scenario 2 is 1207.8 million EUR in the evaluated period. The combination of the three scenarios (Scenario 4) could bring a reduction of 1110 million EUR.

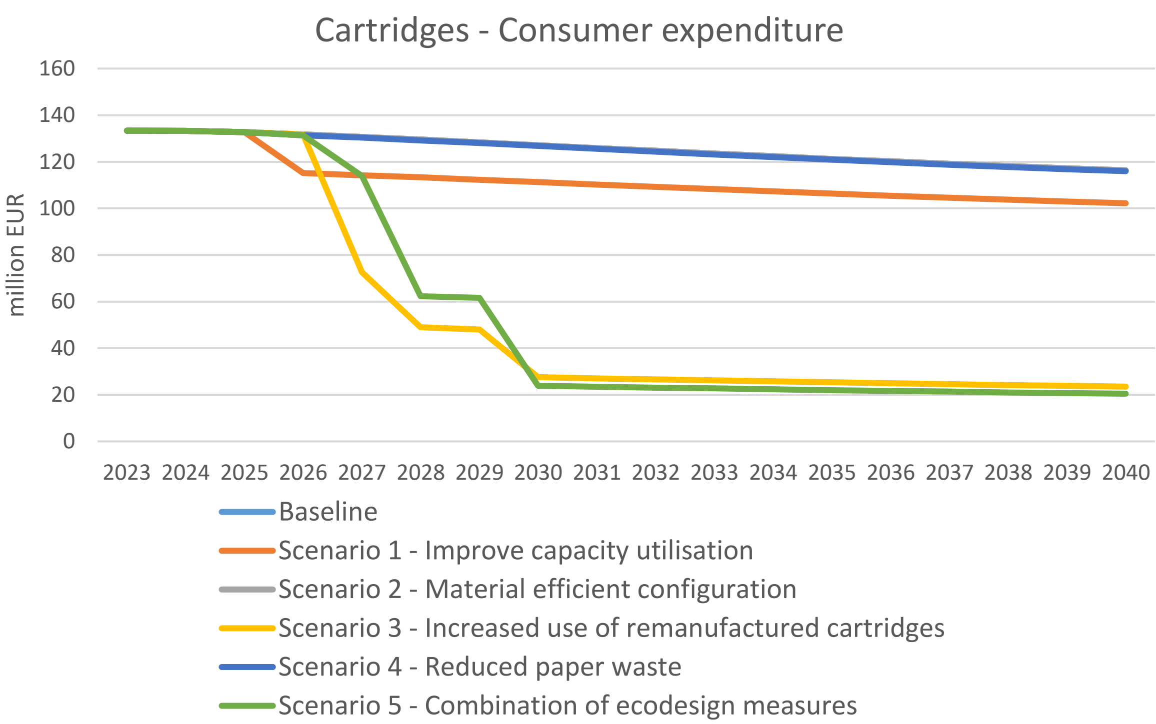


Figure 141. Scenarios for cartridges – Consumer expenditure

In Table 124, the improvement potential of Climate change and Consumer expenditure of the different scenarios are summarized.

Table 124. Improvement potential of scenarios for cartridges

Scenario	Description	Improvement potential Climate change (MTCO2eq.)	Improvement potential Consumer expenditure (million EUR)
Scenario BAU	Business as Usual	0	0
Scenario 1	Capacity utilisation	1.8	229.8
Scenario 2	Material efficient configuration	5.6	0.0
Scenario 3	Remanufacturing	5.9	1275.6
Scenario 4	Reduced paper waste	0.2	5.5
Scenario 5[168]	Combination of different ecodesign measures	7.3	1110.0

7.5 Socio-economic analysis

In this section, a qualitative socio-economic analysis is carried out, with the aim of indicating the potential consequences of introducing ecodesign measures on imaging equipment products. This evaluation will take into account the perspective of device and cartridge manufacturers, device refurbishers, cartridge remanufacturers and retailers. This socio-economic analysis can be considered a preliminary version of the higher level analysis that will be carried out as part of an impact assessment by the European Commission at a later stage in the policy-making process.

In terms of new products, the printer and copier global market share[169] is led by HP (25%), followed by Canon (18%), Brother (11%), Epson (10%) and Kyocera (8%). Regarding consumables, the EU market of new cartridges is mostly shared between HP (27%), Samsung (16%), Brother (16%), Canon (9%), Kyocera (8%) and Ricoh (6%), according to data in Huang et al (2019).

With regards to refurbished or remanufactured products, the refurbished printers market size is estimated to be valued at 1236 million EUR globally in 2023. The adoption of refurbished printers is likely to advance at a CAGR of 8% during the following 10 years[170]. The EU cartridge remanufacturing sector is mostly comprised by small companies (most of them with an annual turnover of less than 2 million EUR), according to data in Waugh et al (2018). The European organisation of cartridge remanufacturers estimates that there are approximately 2000-3000 professional cartridge remanufacturers in Europe[171] and that their worth is over one billion EUR to the European economy each year[172].

[168] In Scenario 5, strategies are assumed to be implemented at different years than in Scenarios 1, 2, 3 and 4. Therefore, the estimated savings of Scenario 5 are not the addition of the savings of Scenarios 1, 2, 3 and 4.

[169] https://www.tonerbuzz.com/blog/printer-market/
[170] https://www.futuremarketinsights.com/reports/refurbished-printers-market
[171] https://www.etira.org/cartridge-remanufacturing/key-facts/
[172] https://www.etira.org/about-etira/frequently-asked-questions/

Efficient supply networks have motivated many firms in China and other developing countries to produce and sell compatible cartridges. Furthermore, the emergence of compatible consumables has intensified competition in the global printing consumables market. Due to their low price, compatible consumables have quickly occupied a part of the printing consumables market (Du et al, 2023).

Implementing mandatory ecodesign measures on imaging equipment devices and cartridges can have impacts of different level for the stakeholders describe above. For instance, the implementation of ecodesign measures to reduce energy consumption of devices may have a minor product cost increase for OEMs, in order to achieve minimum power requirements on standby, off-modes and transition times between active and non-active modes. This cost is considered minor because most of the devices in the market seem to comply easily with current ecodesign thresholds of Regulation 2023/86 (see Figure 56 to Figure 61). Ensuring a minimum energy efficiency on specific components such as internal power supplies could also have a minor to moderate cost increase to OEMs. No significant impact of these measures is expected on device refurbishers or retailers.

Implementing ecodesign measures to increase device lifetime via reparability and durability requirements may have a considerable impact on OEMs. A production cost increase can be expected related to compliance with requirements such as design for disassembly, which would require redesigning some components, to achieve certain level of modularity, changes in joining techniques, etc. The management of spare part provision can also affect production costs, since OEMs would need to plan how many spare parts might be needed for a certain period. Ensuring availability of spare parts would mean increases in costs related to stocking and transport operations. Increasing product lifetime could also mean that OEMs and retailers sell less new units, because devices last longer in operation. Implementing reparability and durability could promote subscription and service contracts.

Remanufacturing and refurbishing generates benefits to society by employing both non-skilled and experienced labour, and creates economic benefits due to the lower price of remanufactured products (Singhal et al, 2020). Remanufacturing is considered a dynamic and varied production environment: blue-collar workers require more initial training and skills, with the long-term benefit of a broader skill set and higher work satisfaction. In addition, retired and laid-off factory workers would be in high demand, providing the experience in disassembling and reassembling products that they helped build years before[173]. In a study carried out in UK, it was estimated that increasing remanufacturing of products by 50% could create 312,000 jobs[174]. In Pini et al (2019) it was also shown that preparation for reuse activities in electronic equipment can contribute to the creation of jobs. Specific examples of companies in the remanufacturing sector which have contributed to the creation of local jobs are available online[175]

Increasing the opportunities to repair and refurbish devices could boost the creation of businesses dedicated to device collection, repair and refurbishing, contributing to employment creation within the EU. These businesses would need to make significant investments on common replacement components –such as fuser units, drums, etc. – as well as repair tools and equipment. The refurbishing business could also grow within OEMs. Some businesses are reluctant about remanufacturing and refurbishing due to fear of own product cannibalization. However, as stated in Guide et al (2010), some OEM managers believe that new, remanufactured and repaired equipment do not compete for the same fixed market share, but rather allow OEMs to reach market segments that they could not serve by offering only new equipment. Entering the remanufacturing sector can help OEMs embrace state-of-the-art manufacturing process (by learning new techniques, investing in personnel or improving material traceability), and to gather valuable data for product improvements in design and function, enhancing after-sales activities[176] [177].

Ecodesign measures aimed at resource conservation –such as reducing paper waste or increasing the use of recycled content material- can have a minor cost increase on OEMs in product manufacturing to achieve minimum requirements on PCR plastic content, for instance. Ensuring that every device has autoduplex functionality can have a moderate cost increase on OEMs as well. From the perspective of refurbishers, it is not expected that products with additional functionality will be more complex to repair. In contrast, it might increase repair opportunities, since it might be more commercially viable to refurbish devices with additional functionality (such as autoduplex).

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[173] https://si2partners.com/resources/circular-economy-importance-remanufacturing-productivity/
[174] https://green-alliance.org.uk/wp-content/uploads/2021/11/Levelling_up_through_circular_economy_jobs.pdf
[175] https://journals.openedition.org/factsreports/6709
[176] https://earthshine-group.com/downloads/Norsk_Ombruk_Final.pdf
[177] https://www.nibusinessinfo.co.uk/content/advantages-and-disadvantages-remanufacturing

The implementation of ecodesign measures to improve cartridge capacity utilisation can have a considerable impact on OEMs and retailers. It may reduce their possibility of placing cartridges in the market which are half-filled or less, affecting the possibility of selling cartridges at low price points. It also limits the possibilities of commercializing devices with starter cartridges that have low capacity (starter cartridges may still be possible, but they would need to comply with minimum page yield requirements). These measures could promote subscription and service contracts, since these type of business models rely on the use of cartridges with higher capacity.

Optimising cartridge capacity would have a considerably positive impact on the cartridge remanufacturing industry, since it is more commercially viable to remanufacture cartridges with higher capacity.

Implementing ecodesign measures to promote material efficient cartridge configurations can have a significant impact on some OEMs and retailers, notably those with the higher percentage of sales based on all-in-one or integrated configurations. These OEMs would need to implement design changes in their cartridges to ensure compliance with minimum material efficiency requirements, or to change their strategy towards single-part configurations. OEMs selling mostly tank-based solutions would be not affected by these measures.

Increasing the amount of single-part cartridges in the market would also increase opportunities for remanufacturing, since these cartridges tend to have a higher capacity, which is more commercially viable for remanufacturers. These higher opportunities for remanufacturing could mean employment creation within the EU.

Ecodesign measures aimed at increasing the amount of remanufactured cartridges in the market can have a considerable impact on OEMs. The need for design changes that ensure easy disassembly of certain components could lead to one-off increases in manufacturing costs. The need for testing (to ensure resistance to shocks and drops) can also lead to extra costs, as does the need to put in place the infrastructure that provides chip resetting functionality to registered remanufacturers. Increasing cartridge remanufacturing can also have the effect on OEMs of selling less new units, since more remanufactured cartridges will be available on the market.

Implementing mandatory measures to increase remanufacturing could incentivise OEMs to change their strategies from prioritising the recycling of cartridges to prioritising collection and remanufacturing. Some OEMs are reluctant to introduce remanufactured products because they fear new products sales cannibalization. In contrast, there are companies where managers believe that selling remanufactured products serves to expand market share (Guide et al, 2010).

Increasing the possibility to remanufacture cartridges could boost the creation of businesses dedicated to cartridge collection and remanufacturing, contributing the employment creation within the EU. These businesses would need to make significant investments on replacement components as well as remanufacturing tools and equipment.

Implementing measures aimed at reducing paper waste could have a considerable impact on cartridge remanufacturers, which would need to incur in testing costs to ensure that the remanufacturing processes are compliant with minimum quality requirements.

As described in section 4.5.14, the cartridge European market is greatly affected by increased sales of non-legal compatible cartridges, usually known as clones and counterfeit cartridges, often manufactured outside of the EU. These cartridges are sold at significantly lower prices through a combination of reduced quality materials and lower manufacturing standards, particularly in their health and safety aspects. Clones and counterfeits are usually not remanufactured due to these low quality materials, so they contribute greatly to the generation of waste as well. The presence of clones and counterfeit cartridges in the market is an issue that affects both OEM and remanufactured cartridges.

Although this is not strictly an ecodesign-related issue, it cannot be simply disregarded. Implementing ecodesign measures will likely increase production costs for OEMs, who will need to comply with additional requirements. Unless compliance with ecodesign and other European legislation is reinforced and ensured, implementing new ecodesign measures could make cartridge OEMs and remanufacturers more vulnerable to cloning and counterfeiting. As stated in Huang et al (2019), enforcement of existing EU legislation (including WEEE, RoHS, patent rights and compliance with product market surveillance) on producers of cloned consumables would help to alleviate the negative impacts of these products.

8 Overview, JRC recommendations and next steps

8.1 Regulation, market and environmental issues

Imaging equipment is one of the few product groups that has been regulated via a Voluntary Agreement (VA). The current VA –in force since 2015- has been focused on devices, dealing with aspects such as energy efficiency, design for recycling, polymer composition, spare part availability and paper recyclability, among others (Eurovaprint, 2015). Imaging equipment is also among the product groups mentioned as a priority in the Circular Economy Action Plan (CEAP20), which established in March 2020 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 industry proposed a new VA in 2021 (Eurovaprint, 2021) and it was evaluated by the JRC on behalf of Directorate–General for the Environment (DG ENV). The aim of the evaluation was to ensure that the level of ambition was aligned with the CEAP20, and that it was compliant with the self-regulation guidelines, detailed in Article 17 of the Ecodesign Directive and in European Commission (2016). The JRC considered that the VA proposal, despite the improvements introduced, was not compliant with all the self-regulation guidelines of the Ecodesign Directive and that it had not reached the ambitious objectives in terms of circularity mandated by the CEAP20. Therefore, the Commission decided to work on mandatory regulatory measures under the Ecodesign Directive. Consequently, imaging equipment was included in the list of new measures under the Ecodesign and Energy Labelling Working Plan 2022–2024 (European Commission, 2022b). This Preparatory Study is the first step towards the implementation of such mandatory regulatory measures.

The total number of pages printed is expected to decline in the following years, due to digitalisation of activities and more environmentally conscious consumers. Despite this decline in pages printed, a considerable number of inkjet and laser devices were still sold in the EU in 2022 (12 million and 5 million, respectively). Combined sales of laser devices –commonly used in offices- are expected to remain stable in the following years, whereas the sales of inkjet devices –typically used in households- are expected to decline at a 4.2% yearly rate. The estimated stock of devices in operation today is around 95 million combined. Laser and inkjet devices use cartridges to hold the deposition material used for printing (toner in the case of laser and ink in inkjet devices). In 2022, around 359 million ink cartridges and 100 million toner cartridges were sold in the EU.

One of the particularities of this sector is that it generally operates under what is usually known as a "razor-and-blade" pricing strategy: the device is generally sold at a low cost, with margins made through the price of the consumables. The foregone profits from the printer sales on the printer sale can be recouped through the latter sales of original cartridges. Another market trend observed over the last few years is the rise of subscription and service contracts. Under these contracts, consumers subscribe to printing services rather than purchasing the devices and/or the cartridges, which remain under the property of the OEM. Only a few percent of printers today in the EU are on a subscription service, although the expectation is that they will grow in the following years.

Domestic printers are devices that consumers replace fast. The average age of printers in households is 4 years, even though their average frequency of use is not high (less than 90 pages per month) and that the intention of most of consumers is to use them for a period between 5 and 10 years. One of the main reasons for this fast replacement of printers is the high cost of repair, compared to the price of a new device. Almost 70% of consumers reported having some sort of technical issue with the printer, but only 21% had it repaired. 30% of them were discouraged because it was too expensive.

In businesses, where devices are generally provided as part of a printing service, it has been observed that replacement rates are also high. Printers rarely fulfil their technical lifetime within the period of the service, and are often replaced with similar new devices under renewed deals. Assemblies and key components of devices such as drums often have 70% of remaining lifetime when they are discarded. The average age sof laser devices in active contracts is between 3-6 years. When they are replaced, they are between 5-7 years old, although they could last up to 12-14 years with proper remanufacturing.

Printers could stay in service for longer periods if they were designed with reparability in mind, and the study points out that there is some room for improvement. Currently, it is not possible for consumers to know for how long the availability of spare parts will be guaranteed. The cost of individual components is sometimes a high percentage of the price of the whole device. The availability of printer software is neither guaranteed

Energy consumption of printers seems a less relevant aspect in comparison with other ICT products, since most of the time they remain in non-active operational modes. The power consumption of those modes is in most of devices in the market below the current minimum requirements of Regulation 2023/826 on standby and off modes.

The cost of printing is highly determined by the device and cartridge technology, and it is a very relevant aspect for consumers. Ink has been reported to be particularly expensive[178]. In fact, the cost of printing is the most important factor for consumers when choosing which printer and which consumable to buy. Almost 1/3 of consumers would consider replacing their current printer if the cost of the consumables were too high.

Another relevant aspect of cartridges is the amount of pages they can print, a parameter known as page yield. As a general rule, the lower the page yield, the earlier it will need to be replaced, contributing to the generation of waste. The current market of cartridges seems to be skewed towards low yield cartridges, particularly in the case of inkjet technology. Cartridges with the same external shape and volume are often sold with different page yields, in order to offer different purchase price points to consumers. However, this suggests that their capacity utilisation is often not optimised (some cartridges might be filled at 50%, 30% or even less of their available volume). In addition printers are often supplied with a cartridge included in the purchase price –this is usually known as a starter cartridge- which tends to provide a very limited number of pages. OEMs have explained that low yield cartridges are necessary to address the lower end users in the market.

Different cartridge configurations can be found on the market. Broadly speaking, there are cartridges that have a containment part to hold toner or ink, bundled with other key elements for printing, such as drums or print heads. These cartridges are generally known as integrated in the case of inkjet or all-in-one in the case of laser. In contrast, single-part cartridges only have the containment part, with the key elements for printing located in the device. Taking into account the number of pages that a cartridge can provide per gram of cartridge material (a parameter named 'cartridge material efficiency'), there are considerable differences between cartridge configurations. Typically, single-part cartridges tend to be more material efficient than integrated/all-in-one solutions. The market of cartridges today seems to be skewed towards lower material efficiency cartridges, although it has been shifting towards single-part products lately. OEMs have also explained that integrated cartridges are necessary to address the lower end users in the market and to facilitate longer printer lifetimes.

Waste prevention and preparation for reuse precedes recycling in the Waste Hierarchy set out in the European Waste Framework Directive, and is generally considered a better solution from environmental point of view. However, nowadays cartridge OEMs prioritise collection and recycling of materials, rather than preparation for reuse and remanufacturing. Cartridge reuse rates are between 5-25%, whereas the technical potential to reuse them is estimated around 90%. Reuse rates are low due to technical barriers introduced during the design phase and to poor collection rates. On occasions, these barriers may have been introduced on purpose to facilitate the customer lock-in that enables the razor-and-blade pricing strategy.

One of the most common barriers is the use of chips (electronic circuitry used to capture useful information for the user) that cannot be reset when the cartridge is empty, making it unusable. Software and firmware updates are sometimes sent to printers connected to the Internet, preventing them from printing if they are using non-original remanufactured cartridges. The use of irreversible joining techniques –that hinder the disassembly of components- and the lack of information on cartridge condition at end of life are also identified as barriers against reuse. Despite the presence of these barriers, 41% of consumers report having used remanufactured cartridges, which shows they have a market relevance, possibly due to their significant lower cost of printing when compared with original cartridges. The main reason for not having used them is not knowing enough about remanufactured cartridges, followed by lack of trust in the suppliers of remanufactured cartridges or fearing of lower printing quality.

A life cycle environmental and cost assessment has been carried out in this Preparatory Study for the typical products in the market. The environmental hotspots have been identified: raw materials and product manufacturing are the environmental hotspots of both printers and cartridges, suggesting that these are complex products with a wide variety of materials and components, requiring a significant amount of energy to produce and assemble. In contrast with other consumer products regulated under ecodesign, energy use is not an environmental hotspot. Results of the economic assessment show that the cost of producing a page is usually higher in those devices with shorter lifetime, and in those cartridges with lower page yield.

[178] https://www.bbc.com/news/technology-57941625

A series of design options with the potential to reduce the environmental impact of devices and cartridges have been identified and evaluated. In the case of printers, extending their lifetime via reparability and durability measures is the option with the highest potential of reducing their impact on climate change. Extending lifetime is also the option with the highest potential of reducing consumer expenditure on devices. For cartridges, using material efficient configurations (single-part rather than integrated solutions) is the option with the highest potential of reducing their environmental impact. Increasing the use of remanufactured cartridges can bring comparable environmental improvements. Improving capacity utilisation of cartridges can also provide significant environmental benefits. Increasing the use of remanufactured cartridges is the option with the highest potential to reduce consumer expenditure on cartridges, followed by the improvement of capacity utilisation.

8.2 JRC proposal of ecodesign measures

In sections 7.1 and 7.2, a series of possible ecodesign measures on devices and cartridges have been proposed by the JRC. These measures were presented to every stakeholder in the 3rd Technical Working Group in October 2023. All stakeholders had 7 weeks to review the measures and provide written feedback on the feasibility of those measures.

In the following sections, an overview of the feedback from stakeholders on each of the measures is given. In this case, feedback will be presented in four 'groups of stakeholders':

- OEMs
- Cartridge remanufacturers
- Environmental NGOs and Consumer organisations
- Member States representatives and National Environmental Agencies

The purpose of this grouping is to understand the discrepancies between different groups of interest. This needs to be taken with caution since, when grouping, the opinion of a small number of stakeholders has been taken as the opinion of the whole group. Then, the opinion of each group has been classified in four 'levels of agreement':

1. Support
2. Support – Minor changes needed
3. Oppose – Measure needs to be reviewed
4. Oppose – Remove measure

The classification in 'levels of agreement' is a subjective exercise from the JRC authors. Although the authors have tried to follow a consistent approach, on occasions feedback received could have been classified in two different levels (level 2 and 3, particularly). The classification is based on the written feedback received after the 3rd TWG Meeting Group only.

This classification has been used to identify measures where the agreement between stakeholders is complete, or easily achieavable; and the measures where the views of stakeholders are conflicting or opposing. Based on this, possible outcomes or next steps for each measure have also been recommended by the authors of the Preparatory Study.

8.2.1 Increasing lifetime of devices

With the aim of increasing the lifetime of devices, a list of priority parts for repair and four measures on Reparability were proposed (Table 125).

Table 125. Level of agreement on Device reparability measures

Section	Measure	OEMs	Cartridge remanufacturers	Environmental NGOs & Consumer organisations	Member States & National Environmental agencies
7.1.1	Priority parts for repair	Support- Minor changes needed	Support- Minor changes needed	Support- Minor changes needed	Support- Minor changes needed
7.1.1.1	Design for disassembly of prioirity parts	Support- Minor changes needed	No comment	No comment	Support- Minor changes needed
7.1.1.2	Availability of priority parts and delivery time	Oppose - Measure needs to be reviewed	No comment	No comment	No comment
7.1.1.3	Availability of information on repair, maintenance and price of spare parts	Oppose - Measure needs to be reviewed	No comment	Support- Minor changes needed	No comment
7.1.1.4	Availability of resetting functionality	Support- Minor changes needed	No comment	Support- Minor changes needed	No comment

There is nearly full agreement between stakeholders on the **List of priority parts for repair** (7.1.1). Next steps should be aimed at refining the list to accommodate the requests of different stakeholders. Possible additions to the list are the following:

- Inkjet printers, professional repairers: internal power supply, displays
- Laser printers, professional repairers: drive motor for paper transport, separation rollers, pads, displays
- Laser printers, consumers: closing lid
- Cartridges, professional remanufacturers: chip

The measure on **Design for disassembly of priority parts** (7.1.1.1) has been generally supported (or not commented) by stakeholders. Next steps should be aimed at working with OEMs to refine the text, so that it applies more specifically to the imaging equipment sector. Terms such as 'generalist', 'layman' or 'workshop enviroment' could be defined. Additionally, the text should ensure that disassembly can be carried out 'without permanent damage to the device'.

The measure on **Availability of priority parts and delivery time** (7.1.1.2) would require further consideration. OEMs oppose to different aspects proposed by the JRC. In their view the following changes should be considered:

- Changing the availability of spare parts from 10 to 7 years.
- Having different availability periods for devices of different speeds.
- Setting different availability of spare parts for remanufactured/refurbished devices (5 years).

Similarly, the measure on **Availability of information on repair, maintenance and price of spare parts** (7.1.1.3) would require some review. It would be useful to liaise with OEMs to agree on the relevant and necessary information for repair and maintenance of devices. The Commission should consider removing the reference to the price of spare parts as a fraction of the purchase price of the device. Moreover, according to the OEMs, reducing the period of first availability of repair information for consumers, from 2 years to 1-2 months, should also be considered.

The measure on **Availability of resetting functionality** (7.1.1.4) is generally supported (or not commented) by stakeholders. Next steps should be aimed at refining the text, so that resetting is limited to changes made by the user, and the reset is back to default settings as shipped from factory.

Furthermore, with the aim of increasing the lifetime of devices, five measures on Durability were proposed (Table 125).

Table 126. Level of agreement on Device durability measures

Section	Measure	OEMs	Cartridge remanufacturers	Environmental NGOs & Consumer organisations	Member States & National Environmental agencies
7.1.2.1	Software and firmware updates	Oppose - Measure needs to be reviewed	No comment	Support- Minor changes needed	Support- Minor changes needed
7.1.2.2	Warnings and messages about cartridges	Support- Minor changes needed	No comment	No comment	No comment
7.1.2.3	Access to information on number of pages printed	Oppose - Remove measure	Support	Support- Minor changes needed	No comment
7.1.2.4	Durability of key consumables of laser devices	Oppose - Measure needs to be reviewed	No comment	Oppose - Measure needs to be reviewed	No comment
7.1.2.5	Durability of key consumables of inkjet devices	Oppose - Measure needs to be reviewed	No comment	Oppose - Measure needs to be reviewed	No comment

The measure on **Software and firmware updates** (7.1.2.1) requires further consideration on some of its aspects according to OEMs. A key aspect where stakeholders have opposing views is whether software and firmware updates should prevent the use of third party cartridges. With the available information at this point, the JRC is unable to identify which option would bring the most efficient solution.

Additional considerations on this measure are the following:

- The first sentence in 7.1.2.1 could be refined as suggested by OEMs: "*The latest available version of the firmware shall be available for a minimum period of X years after placing on the market*"
- Having different availability periods for devices of different speeds.
- Removing third sentence in 7.1.2.1 ("Software and firmware updates shall not have the effect of changing the device or cartridge performance")
- Stakeholders overall support the view that software/firmware updates should not prevent the use of remanufactured/refilled cartridges that maintain the original and unmodified electronic circuitry

The measure on **Warnings and messages about cartridges** (7.1.1.2) is generally supported by stakeholders, and would simply require some refining in the text, providing a clear definition of 'inflammatory terminology'.

Stakeholders have opposing views on the the proposal on **Access to information on number of pages printed** (7.1.2.3). In order to be able to implement this measure effectively, a standard measurement on the durability of devices (the estimated number of pages that they can print in their lifetime, also known as 'duty cycle') would be essential. Therefore, a possible outcome at this point is to first include only a page counter, and then initiate the development of a standard measurement for device duty cycle.

Similarly, the measures on the **Durability of key consumables of laser and inkjet devices** (7.1.2.4 and 7.1.2.5, respectively) require further work before being implemented:

- In order to implement such as measure, it would be essential to initiate the development of a standard measurement of the durability of key consumables such as drums, fuser units, transfer units, waste toner units, print heads and ink collection units.
- Once the methods are developed, it would be important to liaise with OEMs and NGOs to agree on relevant minimum requirements of these key consumables, having different level of ambition for different device speeds.
- To reconsider the timing ambition of the tiered approach (delay the entering into force to allow for device redesigns).

8.2.2 Improving the recyclability of devices

With the aim of increasing the amount of material in devices which is used for recycling, one measure on Recyclability was proposed (Table 127).

Table 127. Level of agreement on Device recyclability measures

Section	Measure	OEMs	Cartridge remanufacturers	Environmental NGOs & Consumer organisations	Member States & National Environmental agencies
7.1.3.1	Design for recyclability of devices	Support- Minor changes needed	No comment	Support- Minor changes needed	Support- Minor changes needed

The measure on **Design for recyclability of devices** (7.1.3.1) is generally supported by stakeholders. Additional work at this point would be to reconsider the verification method, as suggested by OEMs; and to refine the text, taking input from NGOs and National Environmental Agencies.

8.2.3 Reducing energy consumption of devices

With the aim of reducing the energy consumption of devices, four measures were proposed in terms of device energy efficiency (Table 128).

Table 128. Level of agreement on Device energy efficiency measures

Section	Measure	OEMs	Cartridge remanufacturers	Environmental NGOs & Consumer organisations	Member States & National Environmental agencies
7.1.4.1	Power consumption of non-active modes	Oppose - Remove measure	No comment	Support- Minor changes needed	Support- Minor changes needed
7.1.4.2	Reducing the time between active and non-active modes	Oppose - Remove measure	No comment	No comment	Support- Minor changes needed
7.1.4.3	Efficiency of internal power supplies	Oppose - Remove measure	No comment	Support	No comment
7.1.4.4	Availability of manual switch to off-mode	Support- Minor changes needed	No comment	Support	No comment

Stakeholders have opposing views on the measure on **Power consumption of non-active modes** (7.1.4.1) and **Reducing the time between active and non-active modes** (7.1.4.2). Whereas OEMs recommend to use Regulation 2023/826 as a basis for minimum requirements; NGOs and National Environmental Agencies support having stricter requirements. Based on feedback received and on the analysys carried out in section 4.4.1.2, the JRC would recommend at this point to set stricter requirements than those established in Regulation 2023/826, as proposed in Table 110. A tiered approach could be followed in order to allow for device redesigns.

Stakeholders also have opposing views in the measure on **Efficiency of internal power supplies** (7.1.4.3). Considering that this proposal came from a single stakeholder (not particularly supported by any other stakeholder), as well as the strong opposition and rationale provided by OEMs, the JRC would recommend at this point not to include such a measure in new regulation.

The measure on the **Availability of manual switch to off mode** (7.1.4.4) is generally supported by stakeholders. The only additional work at this point would be to refine the text proposed, so that the measure does not apply to remanufactured devices.

8.2.4 Optimizing paper use in devices

With the aim of optimizing the use of paper in devices, two measures were proposed (Table 129).

Table 129. Level of agreement on Device paper use measures

Section	Measure	OEMs	Cartridge remanufacturers	Environmental NGOs & Consumer organisations	Member States & National Environmental agencies
7.1.5.1	Duplexing capability	Support- Minor changes needed	No comment	Support- Minor changes needed	Support- Minor changes needed
7.1.5.2	N-up printing capability	Support	No comment	No comment	No comment

The measure on **Duplexing capability** (7.1.5.1) is generally supported by stakeholders. Minor additional work at this point would be to consider refining the text, so that this measure is aligned with Energy Star and Blue Angel requirements in terms of scope (applicable to devices beyond a certain speed).

The measure on **N-up printing capability** (7.1.5.2) is generally supported by stakeholders.

8.2.5 Increasing post-consumer recycled content in devices

With the aim of increasing the amount of recycled content in devices, one measure was proposed in terms of Device PCR content (Table 130).

Table 130. Level of agreement on Device PCR content measures

Section	Measure	OEMs	Cartridge remanufacturers	Environmental NGOs & Consumer organisations	Member States & National Environmental agencies
7.1.6.1	Post-consumer recycled plastic in devices	Oppose - Remove measure	No comment	Support- Minor changes needed	Support- Minor changes needed

Stakeholders have opposing views on the measure on **Post-consumer recycled plastic in Devices** (7.1.6.1). Given the absence of a widely accepted method to measure recycled content, and the scarcity of recycled material in the market, one possible outcome would be to reconsider changing this measure to an information requirement on PCR content of devices.

8.2.6 Enhancing capacity utilisation of cartridges

With the aim of enhancing the capacity utilisation of cartridges, two measures were proposed in terms of Cartridge page yield (Table 131).

Table 131. Level of agreement on Cartridge page yield measures

Section	Measure	OEMs	Cartridge remanufacturers	Environmental NGOs & Consumer organisations	Member States & National Environmental agencies
7.2.1.1	Page yield of ink cartridges	Oppose - Measure needs to be reviewed	No comment	Support- Minor changes needed	Oppose - Measure needs to be reviewed
7.2.1.2	Page yield of toner cartridges	Oppose - Measure needs to be reviewed	No comment	Support- Minor changes needed	Oppose - Measure needs to be reviewed

OEMs recommend not to include minimum requirements in terms of **Page yield of ink cartridges and toner cartridges** (7.2.1.1 and 7.2.1.2, respectively). Alternatively, they propose to require that a cartridge with the yield set out in section 7.2.1.1 and 7.2.1.2 is available on the market while not being the only or minimum choice available (a 'minimum high yield'). The JRC would not recommend this approach due to their low level of ambition.

If a minimum requirement on page yield is considered, stakeholders have opposing views in terms of the thresholds proposed. Whereas OEMs consider that the level of ambition of the thresholds proposed is too high; environmental NGOs, Member State representatives and National environmental agencies believe that the thresholds proposed are not ambitious enough. Considering this level of disagreement, two possible outcomes are possible:

- Leave the minimum thresholds as they are currently in 7.2.1.1 and 7.2.1.2
- Liaise with OEMs, National environmental agencies and NGOs to agree on feasible minimum thresholds for ink and toner cartridges, having different thresholds based on device printing speed.

8.2.7 Encouraging material efficient cartridge configurations

With the aim of encouraging material efficiency cartridge configurations, three measures were proposed in terms of Cartridge material efficiency (Table 132).

Table 132. Level of agreement on Cartridge material efficiency measures

Section	Measure	OEMs	Cartridge remanufacturers	Environmental NGOs & Consumer organisations	Member States & National Environmental agencies
7.2.2.1	Material efficiency of ink cartridges	Oppose - Remove measure	Oppose - Measure needs to be reviewed	Support- Minor changes needed	Oppose - Measure needs to be reviewed
7.2.2.2	Material efficiency of toner cartridges	Oppose - Remove measure	Oppose - Measure needs to be reviewed	Support- Minor changes needed	Oppose - Measure needs to be reviewed
7.2.2.3	Printing with one or more empty cartridges	Support- Minor changes needed	No comment	Support- Minor changes needed	No comment

Stakeholders generally oppose to the measures on **Material efficiency of ink and toner cartridges** (7.2.2.1 and 7.2.2.2, respectively), for different reasons.

- OEMs argue that there are multiple unintended negative consequences on the market and the environment if this proposal is implemented as currently proposed. They also ask for a more detailed environmental analysis of the potential consequences of encouraging the design of single-part cartridges.
- Cartridge remanufacturers support the idea of having minimum material efficiency requirements, but disagree on the approach proposed. They recommend changing the formula of material efficiency, in order to consider the mass and the page yield of different components involved in printing.
- National environmental agencies support the idea of having minimum material efficiency requirements, but disagree on the level of ambition, which they consider too low.

Considering this level of disagreement between stakeholders, the JRC considers that there is a risk in implementing these measures as currently proposed. Therefore, the following additional work is recommended:

- Carry out a more detailed environmental assessment of the potential consequences of encouraging the design of single-part cartridges.

- If the results of this analysis confirms the environmental benefits of single-part cartridge congiruations, initiate the collection of mass and yield data of components such as print heads, drums and developers
- Re-assess database with new data and formula considering the mass of the whole printing system
- Liaise with OEMs, Cartridge remanufacturers, NGOs and National Environmental agencies to agree on feasible thresholds on Cartridge material efficiency

Stakeholders generally agree on the measure on **Printing with one or more empty cartridges** (7.2.2.3). Some text refinement would still be needed, so that this measure is enabled as a customer choice, where printing in black after colour fades will not cause damage to the printing system.

8.2.8 Increasing the amount of remanufactured cartridges

With the aim of increasing the amount of remanufactured cartridges, eight measures were proposed in terms of Cartridge remanufacturability.

Table 133. Level of agreement on Cartridge remanufacturability measures

Section	Measure	OEMs	Cartridge remanufacturers	Environmental NGOs & Consumer organisations	Member States & National Environmental agencies
7.2.3.1	Chip resetting functionality	Support- Minor changes needed	Support- Minor changes needed	Support- Minor changes needed	Support- Minor changes needed
7.2.3.1	Exemption of chip resetting functionality to cartridges in subscriptions	Support	Oppose - Remove measure	Oppose - Remove measure	Oppose - Remove measure
7.2.3.2	Relevant information stored in chip	Oppose - Measure needs to be reviewed	Support- Minor changes needed	No comment	Support- Minor changes needed
7.2.3.3	Physical access to chip via disassembly	Support	Support	No comment	No comment
7.2.3.4	Functionality of device when disconnected from the Internet	Oppose - Remove measure	No comment	Support	No comment
7.2.3.5	Resistance to shocks and drops	Oppose - Remove measure	No comment	Oppose - Measure needs to be reviewed	No comment
7.2.3.6	Cartridge joining techniques	Oppose - Measure needs to be reviewed	Support	No comment	Support
7.2.3.7	Logos and badges	Oppose - Measure needs to be reviewed	Oppose - Measure needs to be reviewed	No comment	No comment
7.2.3.8	Information requirements on remanufacturing	Oppose - Measure needs to be reviewed	Support- Minor changes needed	No comment	Support- Minor changes needed

The measure on **Chip resetting functionality** (7.2.3.1) is generally supported by stakeholders. Only some text refinement would be needed at this point, taking into account input from different stakeholders:

- Remove the second sentence ("*Chip resetting may be provided either by resetting and reusing the original chip present in the cartridge, or by supplying a replacement chip*"), since any regulatory requirement should specify the outcome and not the technological solution.
- Provide clarity on the meaning of 'reasonable and proportionate' costs
- Ensure that chip resetting allows also for page yield upgrade
- Provide clarity on the registration process of professional remanufacturers
- Provide clarity on the verification method proposed

Stakeholders have opposing views on the **Exemption of chip resetting functionality to cartridges in subscriptions** (7.2.3.1-a). Whereas OEMs consider that the exemption is necessary to enable printing subscription schemes; cartridge remanufacturers, Environmetnal NGOs, Member States and National Environmental Agencies consider that including such an exemption would undermine significantly the potential benefits of measure 7.2.3.1. The JRC is aligned with this view.

There are also conflicting views around the measure on **Relevant information stored in chip** (7.2.3.2). Whereas OEMs consider that this needs further review due to the technical complexities involved; Cartridge remanufacturers encourage the introduction of the measure due to the potential benefits on cartridge remanufacturability. In order to accommodate the requests of different stakeholders, the following actions could be taken:

- Consider adding other relevant data to the list, such as the National WEEE registration number of the original manufacturer and subsequent remanufacturers.

- Refine the text to ensure that the data stored in the chip can be read with commonly available tools
- Apply a tiered approach to allow for cartridge redesigns

The measure on **Physical access to the chip via disassembly** (7.2.3.3) is generally supported by stakeholders and would not need any changes at this point.

Stakeholders have opposing views on the measure on **Functionality of the device when disconnected from the Internet** (7.2.3.4). Whereas OEMs consider that it is not necessary as their purpose is covered by other measures; NGOs still consider it relevant for customer expectations. The JRC would be aligned with NGOs in this case.

The measure on **Resistance to shocks and drops** (7.2.3.5) does not seem ready for implementation based on feedback received. A possible outcome could be to initiate the development of a standard measurement to ensure that cartridges are resistant to shocks and drops during collection and storage operations.

The measure on **Cartridge joining techniques** (7.2.3.6) requires further work before being implemented effectively. Although supported by cartridge remanufacturers and National environmental agencies, it requires significant refinement based on feedback from OEMs. A possible outcome would be to liaise with OEMs and cartridge remanufacturers to agree on wording of workable requirements.

Similary, the measure on **Logos and badges** (7.2.3.7) requires further work before being implemented effectively. A possible outcome would be to liaise with OEMs and cartridge remanufacturers to agree on wording of workable requirements.

The measure on **Information requirements on remanufacturing** (7.2.3.8) is generally supported by stakeholders, with a slight opposition from OEMs. The text would still need to be modified taking into account the following aspects:

- Remove the first sentence to avoid a loophole on cartridge remanufacturing ("*Information shall be provided to consumers regarding the possibilities to remanufacture or refill cartridges. If the cartridge cannot be remanufactured or refilled, this should be clearly indicated in the product packaging or instructions*")
- Remove the mandatory provision of information on manufacturing location and contact data
- Add a mandatory provision of a tracking code that allows identification of the data of place and batch number of the last remanufacturing operation
- Add a mandatory provision of information on manufacturer take-back program; and to make it mandatory to inform the consumer if no take-back program is available

8.2.9 Reducing paper waste due to performance of cartridges

With the aim of reducing the amount of paper wasted due to performance of cartridges, one measure was proposed in terms Cartridge print quality.

Table 134. Level of agreement on Cartridge print quality measures

Section	Measure	OEMs	Cartridge remanufacturers	Environmental NGOs & Consumer organisations	Member States & National Environmental agencies
7.2.4.1	Quality of remanufacturing process	Oppose - Measure needs to be reviewed	Support- Minor changes needed	No comment	No comment

Stakeholders have opposing views regarding the measure on **Quality of remanufacturing process** (7.2.4.1). A possible outcome at this point is to initiate the development of a standard measurement to ensure the printing quality of all cartridges (original and remanufactured).

8.3 Additional ecodesign measures proposed by stakeholders

After the 3rd TWG Meeting in October 2023, several additional ecodesign measures, not initially proposed by the JRC, were suggested by stakeholders for consideration. This section provides a summary of these additional measures, in terms of which group of stakeholders requested it, the rationale for inclusion; as well as the potential outcome or next steps of these additional measures.

8.3.1 Additional measures on devices

Stakeholders proposed five additional measures related with imaging equipment devices (Table 135).

Table 135. Additional measures on devices proposed by stakeholders

	Additional Measures	OEMs	Cartridge remanufacturers	Environmental NGOs & Consumer organisations	Member States & National Environmental Agencies
Devices	Minimum Energy efficiency requirements for Printers			Requested	Requested
	Energy Label for Printers			Requested	Requested
	Repair Score for Printers				Requested
	Minimum air quality requirements for printers			Requested	Requested
	Common charging connection in devices			Requested	

The rational for inclusion of those measures, as well as the potential outcome and next steps, are described in the following sections.

8.3.1.1 Minimum energy efficiency requirements for devices

In section 7.1.4, the JRC proposed not to include a **Minimum requirement on Energy in the Active mode** for devices.

The association of manufacturers supports this conclusion, stating that developing new approaches or methodologies for addressing energy efficiency are out of scope of the Preparatory Study. However, other stakeholders disagree with this approach.

One national environmental agency considers that a measure on maximum Active State TEC, specifically for laser printers, should be further investigated, considering that the Energy Star method is largely applied in the market and developed in consultation with stakeholders.

One environmental NGO agrees with the conclusions of section 7.1.4 that in use energy contributes a relatively small amount to the overall environmental impacts of imaging equipment. However, they point out that data presented in the Preparatory Study suggests that the estimated energy use may be too low as it is based on Energy Star data. They highlight that Energy Star has been effective in increasing the energy efficiency of imaging equipment over the years. However, not all imaging equipment meets these requirements. In their view, the lack of a comprehensive approach to energy use in Ecodesign may encourage more inefficient products to enter the EU market. They think that the Energy Star requirements should be used as a basis for developing energy efficiency targets, especially for thermal products.

Further work would be required at this point in order to propose minimum requirements, such as:

- Study the feasibility of minimum requirements on energy in the active mode of laser devices. This could potentially involve re-assessing Energy Star data on Typical Electricity Consumption (TEC) for laser devices. It could also involve the use of an alternative indicator to TEC (kWh/week), such as energy consumed per page (kWh/page)
- Study the feasibility of minimum requirements on energy in the active mode for inkjet devices. In this case, this could involve the development of a method that estimates their energy in the active mode, currently not available for inkjet devices.
- Based on the above, the proposal of thresholds, potentially in a tiered approach, to identify the worst performing products in the market in terms of energy in the active mode.

8.3.1.2 Energy label for devices

In section 7.1.4, the JRC proposed not to include an **Energy label for devices**. Some stakeholders disagree with this approach.

A national environmental agency highlights that, if a minimum energy efficiency requirement on TEC is considered, an Energy Label for laser printers should be considered as well. In their view, establishing an energy label would ensure that information on energy performance is accessible to consumers through the label and EPREL. In the absence of an energy label, information on TEC could be required in instruction manuals for end-users, and free access websites of manufacturers, importers, or authorised representatives, as foreseen for standby parameters according to the regulation 2023/826.

A Member State representative disagrees with the JRC authors when they say that different energy labels for laser and inkjet devices would confuse consumers. This representative considers that the label could be the same, only the calculation method for energy efficiency and reparability index would differ. They also note that without energy label, products would not be included in the product database EPREL, which is a valuable tool.

An environmental NGO regrets the proposed rejection of an Energy Label for imaging equipment, as this will result in significant savings foregone. Not developing an Energy Label for imaging equipment will also result in consumers and institutional purchasers having less information about the environmental performances of imaging equipment they wish to procure. They disagree with the JRC authors when they say that there is not sufficient difference in the energy consumption of devices for an energy label to be meaningful. They consider that there is still considerable divergence between products employing the same functionality, but even more divergence between products providing similar levels of functionality but via different technology solutions. For example, there are considerable differences in energy use between inkjet and laser-based products even where these products provide similar levels of functionality. In their view, it would be a simple process to estimate the time inkjets spend printing so that it is in line with the laser printers. This would allow easy comparisons between the different product types. They add that consumers and institutional purchasers need to be able to compare products to choose the most environmentally preferable option.

According to the same NGO, the EU Energy Label, and the accompanying EPREL database is an important tool to facilitate environmental conscious purchasing of products but also to support market surveillance activities in the EU. The EU Energy label is being used to communicate a wide range of environmental information, beyond energy use. For example, the Energy label for Washing Machines communicates energy use, water use, noise emissions and technical features (load and duration). There is a wide range of environmental impacts associated with imaging equipment and its consumables that should be communicated via an energy label.

They conclude that the proposed Ecodesign Regulation could result in manufacturers designing products solely for the EU market (given that they won’t need to make all the other environmental improvements for all markets). Environmental initiatives, such as Energy Star, have encouraged the shift to more efficient imaging equipment over many years. There is no guarantee that new imaging equipment models will be energy efficient without an environmental initiative dictating efficiency. This necessitates the development of either Ecodesign measures which focus on overall imaging equipment energy efficiency and/or the development of an Energy Label for this product group.

Further work would be required at this point to propose an energy label, such as:

- Study the feasibility of an energy label for laser and inkjet devices, based on the spread of product energy efficiency
- Assess whether laser and inkjet devices should be classified under the same label or in different labels
- Evaluate different options regarding the energy classification: energy efficiency index, number of energy classes, energy class width, etc.
- Study which other product parameters beyond energy might be of interest to include in an energy label

8.3.1.3 Reparability score for devices

The JRC did not include a proposal for a **Reparability score for devices**. Some stakeholders have requested to reconsider this option.

A national environmental agency considers that the inclusion of an Energy label could be beneficial also from the point of access of information (i.e. through the use of EPREL) and could potentially complement the energy efficiency information with material efficiency information (e.g. reparability scoring).

They suggest that disassembly depth and other reparability related parameters should be considered as a basis for the calculation of a repair scoring shown on a label or in other product information. Different options for disclosing the score should be considered:

1) In case the repair scoring is adopted under the current Directive 2009/125/EC, it should be shown as part of the Energy Label, as it happens for the recently approved regulation for smartphones and tablets.

2) In case of regulation adopted under the new ESPR framework, the repair scoring system could be implemented as a dedicated reparability label (similarly to what happens for the French Repair Index)

Another national environmental agency strongly supports the implementation of a repair score as mandatory information for consumers on a label. They suggest taking as a basis the study from Ritthoff et al (2023). However, the underlying data would still have to be adapted accordingly.

An environmental NGO is concerned that in the absence of an energy label, other important information on the resource and material efficieny of devices will not be provided to consumers. Taking the example of the energy label for smartphones and tablets, besides information about energy efficiency, the label also contains important details about repairability, reliability and durability.

Further work would be required at this point to propose a repair score for printers, based on the methodology developed in Cordella et al (2019), similar to the work that was carried out by Ritthoff et al (2023) for printers and by Spiliotopoulos et al (2022) for smartphones and tablets:

- Selection of priority parts (potentially using the list already defined in section 7.1.1)
- Selection of scoring paramerters which are most relevant for imaging equipment devices
- Definition of scoring criteria for the selected parameters
- Definition of weighting factors, aggregation, assessment and verification
- Calibration of the reparability scoring system, with the use of real products in the market

8.3.1.4 Minimum air quality requirements for devices

The JRC did not propose any measure regarding **Minimum air quality for devices**. A national environmental agency highlighted that, although the topic of air emissions was addressed in section 4.4.4, it did not result in a specific measure in Task 7. They consider that emissions such as volatile organic substances, ozone or ultrafine particles should be kept as low as possible in order to maintain good indoor air quality.

An environmental NGO explain that Blue Angel ecolabel already includes requirements addressing substance emissions from printers, including volatile organic compounds (VOCs), ozone, and fine and ultrafine particles. They suggest that this issue should be addressed, as it is likely to be a concern for some users, especially where imaging equipment is used in poorly ventilated areas.

A possible outcome to address this could be to include a measure on minimum air quality for devices in the regulation, using the same thresholds proposed in Blue Angel (DE-UZ-219), already presented in Table 37.

8.3.1.5 Common charging connection in devices

An environmental NGO explains that the USB Power Deliver (PD) Revision 3.1 specification enables up to 240W of power to be delivered over full featured **USB Type-C cables and connectors**. They add that most inkjet printers will not use more than 240W of power even during active printing. As such, the Commission could consider applying the common charger specification to inkjet printers. This could reduce the need for additional cables and power supplies.

A possible outcome could be to include in the regulation a measure on mandatory availability of USB Type-C cables and connectors for inkjet devices below a specific threshold, to be agreed with OEMs.

8.3.2 Additional measures on cartridges

Stakeholders proposed seven additional measures related to cartridges (Table 136).

Table 136. Additional measures on cartridges proposed by stakeholders

	Additional Measures	OEMs	Cartridge remanufacturers	Environmental NGOs & Consumer organisations	Member States & National Environmental Agencies
Cartridges	Cartridge reuse target at OEM level		Requested		
	Action against cloned and counterfeit cartridges		Requested		
	Recyclability of cartridges		Requested		Requested
	Mandatory take-back system for cartridges and other consumables			Requested	Requested
	Centralized collection of cartridges		Requested		
	Refilled or remanufactured cartridges at a non-discriminatory price				Requested
	A labelling system on the material efficiency of cartridges				Requested

The rational for inclusion of those measures, as well as the potential outcome and next steps, are described in the following sections.

8.3.2.1 Cartridge reuse target

In the VA proposal of 2021 (Eurovaprint, 2021), a **Cartridge reuse target** was included. The JRC did not include a reuse target as a possible measure in the Preparatory Study on ecodesign. Some stakeholders disagree with this approach.

The association of remanufacturers regrets that the JRC proposals did not include a reuse target for cartridges. They recommend an EU-wide compulsory reuse target of at least 50% for toner and 35% for inkjet for all products put on the EU market, both with annual increase rates. In their view, the targets must be an obligation on each manufacturer that supplies cartridges on the EU market.

According to cartridge remanufacturers, the circular potential of consumables is extremely high if compared with other IT equipment. In addition, due to the short life span of a cartridge (real usage period), the potential to reuse it at least 3 or more times is quite high. They add that currently cartridges are part of a larger group of IT products with an overall 65% collection target under the WEEE Directive. Thus, by collecting other products in the IT group, Member States can meet their WEEE Directive collection target without a single cartridge being collected. Moreover, a mere collection target may not help to support cartridge reuse, because remanufacturing by 3rd parties may not be counted under collection. Therefore, a compulsory (preparation for-) reuse target should be included instead, only for cartridges.

It is important to highlight that Ecodesign Directive “seeks to achieve a high level of protection for the environment by reducing the potential environmental impact of energy-related products”. Therefore, it applies to specific products and not to businesses or organisations. The Ecodesign Directive “provides for the setting of requirements which the energy-related products covered by implementing measures must fulfil in order to be placed on the market”. Therefore, any requirement applicable to a product must be measurable and verifiable before the product enters the EU market.

A cartridge reuse target such as the one proposed by the association of cartridge remanufacturers does not fulfil the above characteristics. It would be applicable to OEMs and not to specific products, making it incompatible with main ecodesign objectives. Moreover, compliance with the requirement would not be measurable nor verifiable by Market Surveillance Authorities when the product is placed on the market (since a cartridge reuse target would need be measured, for instance annually, at an OEM level).

Therefore, a cartridge reuse target was considered not suitable for ecodesign regulation and the JRC did not include any measures related to this in the Preparatory Study.

To overcome this, another remanufacturing association recommended amending the requirements under the WEEE Directive so that a separate and distinct reuse target is set –beginning at 30% but thereafter increasing to 50% by 2030. They add that the WEEE Directive Review is a more appropriate instrument for this type of measure.

8.3.2.2 Action against cloned and counterfeit cartridges

In section 4.5.14 some of the issues of cloned and counterfeit cartridges have been described. Some stakeholders request that direct **Action against cloned and counterfeit cartridges** is taken as part of ecodesign regulation.

A national association of remanufacturers highlights that the proposals do not address the main obstacle to reducing the environmental impact of printng, as they do not clarify how large volumes of polluting and non-compliant non-OEM single-use consumables will be banned from the EU market. They add that tens of thousands of these products enter the EU every day and are one of the main causes of low cartridge reuse rates, as they are unhealthy, cheap, are not reused and many violate basic human rights.

This association of remanufacturers highlights that emphasis should be placed on the importance of stopping or severely restricting the import of Single Use Cartridge (SUC) and New Build Cartridges, which contribute to the continued introduction of new plastics into the European territory. They add that reusing a cartridge as many times as possible, followed by recycling the materials that make up the cartridge, is a key factor in reducing the overall environmental footprint of printing.

To overcome this issue, the association remanufacturers recommends:

- To start an assessment of compliance regarding clones and counterfeits offered on the EU market
- To impose an immediate import moratorium at European customs level for products that use forced/slave labour.
- To prohibit the import of products without correct CE marking with notifying body.

As explained above, it is important to highlight that Ecodesign Directive "seeks to achieve a high level of protection for the environment by reducing the potential environmental impact of energy-related products". Therefore, theEcodesign regulation is not the appropriate tool to determine whether a product is compliant with other applicable regulation (such as Market Surveillance or WEEE Directive), nor to determine if a product has infringed IP rights.

Ecodesign is able to tackle the issue of clones and counterfeits indirectly, by setting minimum performance requirements that address some of the aspects that characterize clones and counterfeits. The following proposed measures could reduce the entrance on the EU market of poor quality non-remanufacturable cartridges (if appropriate resources on market surveillance accompany them):

- Measures 7.2.3.1, 7.2.3.2 and 7.2.3.3 on chip resetting functionality, relevant information stored in chip and physical access to chip.
- Measure 7.2.3.5 on resistance to shocks and drops.
- Measure 7.2.3.6 on cartridge joining techniques
- Measure 7.2.3.8 on information on remanufacturing.

8.3.2.3 Recyclability of cartridges

The JRC did not include any measure on the **Recyclability of cartridges**, equivalent or similar to the measure in 7.1.3.1 on Recyclability on devices. Some stakeholders disagree with this approach.

A cartridge remanufacturer argues that a measure on the recyclability of cartridges should be added. They suggest the following:

> *Plastic parts weighing more than 5g or measuring more than 15cm2 shall be marked by material type, according to ISO 11469.*
>
> *Plastic parts weighing more than 5g or measuring more than 15cm2 shall consist of one single polymer or polymer blend without any flame retardants.*

A national environmental agency considers that the same way as for laser and inkjet devices, there should be requirements for the plastic parts to be marked by material type, and thereby be able to be included in the recyclable plastic stream.

A possible outcome could be the inclusion of a measure on Recyclability of cartridges, similar to measure 7.1.3.1 on Recyclability of devices.

8.3.2.4 Mandatory take-back system for cartridges and other consumables

A national environmental agency suggested that **Take-back systems for cartridges should be mandatory**.

An environmental NGO adds that not all cartridge take-back programmes are equal in terms of their environmental performance. Some cartridge take-back schemes prioritise energy recovery of plastics rather than remanufacturing of the cartridges. They consider that users of cartridge take-back schemes must be provided with information on the end-of-life process for their returned cartridges. This could encourage users of printer consumables to favour cartridge take-back schemes which prioritise remanufacturing over recycling or energy recovery.

An environmental NGO highlights that the Preparatory Study has shown that there are several other types of consumables used by printers beyond cartridges (e.g. waste toner cartridges, print heads, transfer belts, transfer roller, fusers, drum units and drum maintenance units). These other consumables must also be considered to reduce overall environmental impacts and therefore have a mandatory take-back system.

A possible outcome could be the inclusion of a measure on mandatory take-back systems for cartridges and other consumables such as drums, print heads, transfer belts, etc., for consumables beyond a specific page yield threshold, to be agreed with OEMs.

8.3.2.5 Centralized collection of cartridges

The association of cartridge remanufacturers highlights that an **efficient and secure empty cartridge collection system should be mandatory**. In their view, collection must be efficient, avoiding any losses or damages. Individual shipments and individual collection systems cannot be the rule. They add that such schemes may not even be legal (if performed by a non-authorized collector like the regular postal services) and do not provide the best solution. They suggest that collection systems must be generic. For example collection in a building, with customers using several brands each having their own different collection operator, is extremely inefficient.

A national association of cartridge remanufacturers adds that collection must be aimed at increasingly implementing and improving circular economy and reuse systems with a preference for 'zero km' collection and production. They add that legislative simplification should serve to decrease environmental impacts by favouring circularity and direct transport to cartridge remanufacturing plants. Furthermore, it must ensure a 'single fair market' by offering both OEMs and independent collectors equal opportunities, leaving the empties available for all to re-use, and it must ensure compliance with the EU waste hierarchy.

They also consider that exports of empty cartridges as waste outside the EU should be banned. Currently, large volumes of unsorted used cartridges are shipped outside the EU. A significant percentage ends up in landfills in third countries. Only a small part is used to recycle the material base. These cartridges are no longer available for reuse in the EU and generate further waste on the planet.

As expressed in previous sections, it is important to highlight that Ecodesign Directive “seeks to achieve a high level of protection for the environment by reducing the potential environmental impact of energy-related products”. It applies to specific products and not to businesses or organisations. Therefore, it is not possible with ecodesign to mandate how a product will be collected at end of life.

8.3.2.6 Refilled or remanufactured cartridges available at non-discriminatory price

In section 4.5.4 the cost of printing with different types of devices was described. Related with this topic, a national environmental agency considered that **refilled and/or remanufactured cartridges should be made available for a reasonable non-discriminatory price**.

However, setting minimum prices on products is out of scope of the Ecodesign Directive.

8.3.2.7 A labelling system on the material efficiency of cartridges

In section 6.2.3 the potential benefits of encouraging the design of material efficient cartridge configurations was presented. In section 7.2.2.1 and 7.2.2.2, specific mandatory measures have been proposed by the JRC.

Based on this, a national environmental agency suggested **a labelling system on the material efficiency of catridges**, with scoring and different classes (A-G) could also be set up to inform consumers on this aspect of the cartridges on the market.

Feedback from stakeholders indicates that further work is still required to implement relevant mandatory measures on cartridge material efficiency. Therefore, a labelling system on the material efficiency of cartridges is not feasible at this point.

8.3.3 Other additional measures

Stakeholders proposed three additional measures not specifically related with devices or cartridges (Table 136).

Table 137. Additional measures proposed by stakeholders

	Additional Measures	OEMs	Cartridge remanufacturers	Environmental NGOs & Consumer organisations	Member States & National Environmental Agencies
Other measures	Standardization in parts of printers/cartridges			Requested	
	Online platforms and fulfilment service providers			Requested	
	Critical Raw Materials				Requested

The rational for inclusion of those measures, as well as the potential outcome and next steps, are described in the following sections.

8.3.3.1 Standardization of parts in devices and cartridges

In section 4.5.5 some of the issues of cartridge compatibility have been described. Some stakeholders have requested that ecodesign should tackle those issues.

An environmental NGO suggest that a better development of standardized parts for devices is required to allow a more efficient use of resources. The PROMPT project suggests that “Standardisation of parts and/or their interfaces might improve the access to spare parts and thus enhance reparability. Also, when a part is standardized, the costs per part are likely to decrease through economies of scale. In general, it is recommended to standardize parts which have the same function across all manufacturers.

This NGO adds that a standardisation of parts such as cartridges, external power supplies and power cables, paper cassettes, and ink collection tanks and excess ink reservoirs (including sponges) could increase their robustness and ensure that they can be used in several devices. The use of standardised wear/spare parts in different devices also supports the long-term availability of these parts, so that replacement is ensured in the event of a defect. In addition, the subsequent upgradeability of devices with newly developed wear parts would be supported. Standardisation should be developed as far as possible within manufacturers’ product lines, but also cross-manufacturers.

8.3.3.2 Online platforms and fulfilment service providers

An environmental NGO highlight that a major concern regarding the effectiveness and compliance with the eco-design measures of imaging equipment and its consumables in the European market lies in the critical role of online platforms and fulfilment service providers, who must actively ensure adherence to environmental and consumer protection regulations. However, both the Digital Services Act (DSA) and the Ecodesign for Sustainable Products Regulation (ESPR), are currently deficient to tackle this issue. In their view, the DSA lacks clear liability allocation for online platforms without an economic operator in the EU, leaving a legal loophole despite the active role these platforms often play. The ESPR allows third-country businesses to place non-compliant products on the market, as the introduced measure to designate a responsible person in the EU comes with limited obligations and fails to establish a liable economic operator for non-compliant online sales on the EU market.

They suggest that online platforms must check whether there is a liable actor in the EU who guarantees compliance with the eco-design measures on imaging equipment. Furthermore, online platforms must check whether the obligations of manufacturers and distributors are being met (e.g. energy label availability, comprehensive information for consumers, provision of spare parts, etc.) before a product is put online for sale. Fulfilment service providers must be subject to similar obligations. If no such checking obligations are set, massive amounts of illegal products will keep on being imported into the EU market.

8.3.3.3 Critical Raw Materials

A national environmental agency proposes to consider the feasibility of setting information requirements for content of critical raw materials in components. Such a requirement could be inspired from the information requirement regarding critical raw materials in regulations (EU) 2019/424 for servers and data storage products and (EU) 2023/1670 for smartphones and slate tablets.

9 Annex I

Table 138. Environmental assessment of Device1

		Raw materials	Manufacturing	Distribution	Use	Remanufacturing	End of life	Total
Climate change, total	kg CO2 eq / page	0.003	0.006	0.000	0.002	0.001	0.000	0.012
Ozone depletion	kg CFC-11 eq / page	2.1E-11	2.3E-12	1.3E-17	4.4E-11	4.3E-12	-2.9E-13	7.1E-11
Human toxicity, cancer	CTUh / page	6.9E-12	1.0E-12	1.4E-14	6.8E-13	1.5E-12	-3.2E-12	6.9E-12
Human toxicity, non-cancer	CTUh / page	6.6E-11	2.0E-11	2.6E-13	8.1E-12	1.5E-11	-3.2E-12	1.1E-10
Particulate matter	disease incidence / page	1.4E-10	2.0E-10	2.7E-11	9.4E-11	4.8E-11	-1.1E-11	5.0E-10
Ionising radiation, human health	kBq U235 eq / page	1.1E-04	2.6E-03	1.7E-07	5.0E-04	2.8E-04	-8.7E-06	3.5E-03
Photochemical ozone formation, human health	kg NMVOC eq / page	7.0E-06	1.0E-05	1.2E-06	6.3E-06	2.4E-06	-7.4E-07	2.6E-05
Acidification	mol H+ eq / page	1.2E-05	1.9E-05	1.7E-06	8.0E-06	4.3E-06	-1.3E-06	4.3E-05
Eutrophication, terrestrial	mol N eq / page	2.5E-05	3.7E-05	4.9E-06	2.2E-05	8.7E-06	-2.5E-06	9.5E-05
Eutrophication, freshwater	kg P eq / page	3.0E-08	1.2E-08	1.3E-10	1.0E-07	7.2E-09	-2.1E-09	1.5E-07
Eutrophication, marine	kg N eq / page	2.4E-06	3.5E-06	4.5E-07	2.4E-06	8.3E-07	-2.4E-07	9.3E-06
Ecotoxicity, freshwater	CTUe / page	0.018	0.028	0.001	0.007	0.006	-0.003	0.058
Land use	Pt / page	0.011	0.026	0.000	0.215	0.005	0.151	0.409
Water use	m3 water eq. of deprived water / page	0.000	0.002	0.000	0.001	0.000	0.000	0.003
Resource use, minerals and metals	kg Sb eq / page	1.8E-07	1.6E-09	1.3E-11	1.3E-09	3.5E-08	-1.0E-08	2.0E-07
Resource use, fossils	MJ / page	0.044	0.106	0.001	0.029	0.019	-0.006	0.193
Primary energy consumption	MJ / page	0.044	0.110	0.001	0.030	0.020	-0.006	0.198

Table 139. Environmental assessment of Device2

	Unit (per page)	Raw materials	Manufacturing	Distribution	Use	Remanufacturing	End of life	Total
Climate change, total	kg CO2 eq	0.002	0.005	0.000	0.002	0.001	0.000	0.010
Ozone depletion	kg CFC-11 eq	1.7E-11	2.0E-12	9.5E-18	4.4E-11	3.6E-12	-3.0E-13	6.7E-11
Human toxicity, cancer	CTUh	2.4E-12	9.1E-13	1.1E-14	7.1E-13	5.6E-13	-8.7E-13	3.7E-12
Human toxicity, non-cancer	CTUh	5.3E-11	1.8E-11	1.9E-13	8.8E-12	1.2E-11	-2.2E-12	9.1E-11
Particulate matter	disease incidence	1.1E-10	1.8E-10	2.0E-11	1.0E-10	4.0E-11	-6.1E-12	4.4E-10
Ionising radiation, human health	kBq U235 eq	8.4E-05	2.3E-03	1.2E-07	5.9E-04	2.5E-04	-6.4E-06	3.3E-03
Photochemical ozone formation, human health	kg NMVOC eq	5.6E-06	9.0E-06	9.0E-07	6.7E-06	2.0E-06	-5.3E-07	2.4E-05
Acidification	mol H+ eq	9.2E-06	1.7E-05	1.2E-06	8.7E-06	3.5E-06	-8.2E-07	3.9E-05
Eutrophication, terrestrial	mol N eq	2.0E-05	3.4E-05	3.6E-06	2.4E-05	7.3E-06	-1.8E-06	8.6E-05
Eutrophication, freshwater	kg P eq	2.5E-08	1.1E-08	9.8E-11	1.0E-07	6.1E-09	-1.8E-09	1.4E-07
Eutrophication, marine	kg N eq	1.9E-06	3.2E-06	3.3E-07	2.5E-06	7.0E-07	-1.8E-07	8.4E-06
Ecotoxicity, freshwater	CTUe	0.014	0.025	0.001	0.008	0.005	-0.002	0.051
Land use	pt	0.010	0.024	0.000	0.216	0.004	0.123	0.377
Water use	m3 water eq. of deprived water	0.000	0.002	0.000	0.001	0.000	0.000	0.003
Resource use, minerals and metals	kg Sb eq	1.4E-07	1.4E-09	9.4E-12	1.3E-09	2.8E-08	-6.6E-09	1.6E-07
Resource use, fossils	MJ	0.034	0.096	0.001	0.033	0.016	-0.004	0.175
Primary energy consumption	MJ	0.034	0.099	0.001	0.034	0.017	-0.004	0.179

Table 140. Environmental assessment of Device3

	Unit (per page)		Raw materials	Manufacturing	Distribution	Use	Remanufacturing	End of life	Total
Climate change, total	kg CO2 eq		0.004	0.007	0.000	0.002	0.001	0.000	0.013
Ozone depletion	kg CFC-11 eq	kg CO2 eq / page	2.0E-11	2.5E-12	1.4E-17	4.4E-11	4.2E-12	-5.8E-13	7.0E-11
Human toxicity, cancer	CTUh	kg CFC-11 eq / page	4.7E-12	1.1E-12	1.6E-14	6.7E-13	1.0E-12	-1.8E-12	5.7E-12
Human toxicity, non-cancer	CTUh	CTUh / page	9.1E-11	2.2E-11	2.8E-13	8.0E-12	2.0E-11	-3.9E-12	1.4E-10
Particulate matter	disease incidence	CTUh / page	2.0E-10	2.1E-10	3.0E-11	9.3E-11	6.0E-11	-1.2E-11	5.8E-10
Ionising radiation, human health	kBq U235 eq	disease incidence / page	1.4E-04	2.9E-03	1.8E-07	4.8E-04	3.1E-04	-1.1E-05	3.8E-03
Photochemical ozone formation, human health	kg NMVOC eq	kBq U235 eq / page	9.4E-06	1.1E-05	1.4E-06	6.2E-06	3.0E-06	-8.8E-07	3.0E-05
Acidification	mol H+ eq	kg NMVOC eq / page	1.6E-05	2.0E-05	1.8E-06	7.9E-06	5.2E-06	-1.4E-06	5.0E-05
Eutrophication, terrestrial	mol N eq	mol H+ eq / page	3.3E-05	4.1E-05	5.4E-06	2.2E-05	1.1E-05	-3.0E-06	1.1E-04
Eutrophication, freshwater	kg P eq	mol N eq / page	4.3E-08	1.4E-08	1.5E-10	1.0E-07	1.0E-08	-3.2E-09	1.7E-07
Eutrophication, marine	kg N eq	kg P eq / page	3.2E-06	3.9E-06	4.9E-07	2.4E-06	1.0E-06	-2.9E-07	1.1E-05
Ecotoxicity, freshwater	CTUe	kg N eq / page	0.022	0.031	0.001	0.007	0.008	-0.004	0.065
Land use	pt	CTUe / page	0.018	0.029	0.000	0.216	0.006	0.182	0.451
Water use	m3 water eq. of deprived water	Pt / page	0.000	0.002	0.000	0.001	0.000	0.000	0.004
Resource use, minerals and metals	kg Sb eq	m3 water eq. of deprived water / page	2.5E-07	1.7E-09	1.4E-11	1.3E-09	5.0E-08	-1.5E-08	2.8E-07
Resource use, fossils	MJ	kg Sb eq / page	0.055	0.117	0.001	0.028	0.023	-0.007	0.217
Primary energy consumption	MJ	MJ / page	0.055	0.121	0.001	0.029	0.023	-0.007	0.222

Table 141. Environmental assessment of Device4

	Unit (per page)		Raw materials	Manufacturing	Distribution	Use	Remanufacturing	End of life	Total
Climate change, total	kg CO2 eq		0.002	0.005	0.000	0.002	0.001	0.000	0.009
Ozone depletion	kg CFC-11 eq	kg CO2 eq / page	1.6E-11	1.7E-12	7.8E-18	4.5E-11	3.3E-12	-2.8E-13	6.5E-11
Human toxicity, cancer	CTUh	kg CFC-11 eq / page	2.0E-12	7.5E-13	8.6E-15	7.4E-13	4.8E-13	-7.9E-13	3.2E-12
Human toxicity, non-cancer	CTUh	CTUh / page	3.9E-11	1.5E-11	1.5E-13	9.4E-12	9.3E-12	-1.4E-12	7.1E-11
Particulate matter	disease incidence	CTUh / page	8.3E-11	1.4E-10	1.6E-11	1.1E-10	3.1E-11	-4.2E-12	3.8E-10
Ionising radiation, human health	kBq U235 eq	disease incidence / page	6.4E-05	1.9E-03	9.9E-08	6.6E-04	2.0E-04	-5.4E-06	2.8E-03
Photochemical ozone formation, human health	kg NMVOC eq	kBq U235 eq / page	4.2E-06	7.4E-06	7.3E-07	6.9E-06	1.6E-06	-4.2E-07	2.0E-05
Acidification	mol H+ eq	kg NMVOC eq / page	6.8E-06	1.4E-05	9.8E-07	9.2E-06	2.7E-06	-6.3E-07	3.3E-05
Eutrophication, terrestrial	mol N eq	mol H+ eq / page	1.5E-05	2.8E-05	2.9E-06	2.5E-05	5.7E-06	-1.4E-06	7.4E-05
Eutrophication, freshwater	kg P eq	mol N eq / page	1.9E-08	9.2E-09	8.0E-11	1.1E-07	4.6E-09	-1.4E-09	1.4E-07
Eutrophication, marine	kg N eq	kg P eq / page	1.4E-06	2.6E-06	2.7E-07	2.6E-06	5.4E-07	-1.4E-07	7.3E-06
Ecotoxicity, freshwater	CTUe	kg N eq / page	0.011	0.021	0.000	0.009	0.004	-0.002	0.043
Land use	pt	CTUe / page	0.008	0.019	0.000	0.217	0.004	0.117	0.366
Water use	m3 water eq. of deprived water	Pt / page	0.000	0.002	0.000	0.001	0.000	0.000	0.003
Resource use, minerals and metals	kg Sb eq	m3 water eq. of deprived water / page	1.0E-07	1.2E-09	7.6E-12	1.4E-09	2.0E-08	-2.1E-09	1.2E-07
Resource use, fossils	MJ	kg Sb eq / page	0.026	0.079	0.000	0.036	0.013	-0.003	0.150
Primary energy consumption	MJ	MJ / page	0.026	0.082	0.000	0.036	0.013	-0.003	0.154

Table 142. Environmental assessment of Device5

	Unit (per page)		Raw materials	Manufacturing	Distribution	Use	Remanufacturing	End of life	Total
Climate change, total	kg CO2 eq		0.002	0.006	0.000	0.002	0.001	0.000	0.010
Ozone depletion	kg CFC-11 eq	kg CO2 eq / page	1.4E-11	2.2E-12	1.3E-17	4.4E-11	2.9E-12	-2.7E-13	6.3E-11
Human toxicity, cancer	CTUh	kg CFC-11 eq / page	8.5E-12	9.8E-13	1.4E-14	6.8E-13	1.8E-12	-4.3E-12	7.7E-12
Human toxicity, non-cancer	CTUh	CTUh / page	3.7E-11	2.0E-11	2.5E-13	8.2E-12	9.4E-12	-1.8E-12	7.3E-11
Particulate matter	disease incidence	CTUh / page	8.9E-11	1.9E-10	2.6E-11	9.4E-11	3.7E-11	-9.7E-12	4.3E-10
Ionising radiation, human health	kBq U235 eq	disease incidence / page	7.1E-05	2.5E-03	1.6E-07	5.0E-04	2.7E-04	-4.0E-06	3.4E-03
Photochemical ozone formation, human health	kg NMVOC eq	kBq U235 eq / page	4.2E-06	9.7E-06	1.2E-06	6.3E-06	1.8E-06	-5.1E-07	2.3E-05
Acidification	mol H+ eq	kg NMVOC eq / page	7.4E-06	1.8E-05	1.6E-06	8.0E-06	3.3E-06	-1.1E-06	3.7E-05
Eutrophication, terrestrial	mol N eq	mol H+ eq / page	1.5E-05	3.6E-05	4.8E-06	2.2E-05	6.6E-06	-1.7E-06	8.3E-05
Eutrophication, freshwater	kg P eq	mol N eq / page	1.7E-08	1.2E-08	1.3E-10	1.0E-07	4.6E-09	-1.4E-09	1.4E-07
Eutrophication, marine	kg N eq	kg P eq / page	1.4E-06	3.4E-06	4.4E-07	2.4E-06	6.3E-07	-1.6E-07	8.1E-06
Ecotoxicity, freshwater	CTUe	kg N eq / page	0.013	0.027	0.001	0.007	0.005	-0.003	0.050
Land use	pt	CTUe / page	0.008	0.026	0.000	0.216	0.004	0.123	0.377
Water use	m3 water eq. of deprived water	Pt / page	0.000	0.002	0.000	0.001	0.000	0.000	0.003
Resource use, minerals and metals	kg Sb eq	m3 water eq. of deprived water / page	9.8E-08	1.5E-09	1.2E-11	1.3E-09	2.0E-08	-4.2E-09	1.2E-07
Resource use, fossils	MJ	kg Sb eq / page	0.027	0.103	0.001	0.029	0.016	-0.004	0.172
Primary energy consumption	MJ	MJ / page	0.027	0.107	0.001	0.030	0.016	-0.004	0.177

Table 143. Environmental assessment of Device6

	Unit (per page)		Raw materials	Manufacturing	Distribution	Use	Remanufacturing	End of life	Total
Climate change, total	kg CO2 eq		0.002	0.012	0.000	0.002	0.002	0.000	0.018
Ozone depletion	kg CFC-11 eq	kg CO2 eq / page	1.5E-11	4.6E-12	2.1E-17	4.4E-11	3.4E-12	-4.9E-13	6.7E-11
Human toxicity, cancer	CTUh	kg CFC-11 eq / page	1.1E-11	2.1E-12	2.4E-14	6.9E-13	2.5E-12	-5.7E-12	1.1E-11
Human toxicity, non-cancer	CTUh	CTUh / page	5.3E-11	4.2E-11	4.2E-13	8.5E-12	1.5E-11	-5.2E-13	1.2E-10
Particulate matter	disease incidence	CTUh / page	1.3E-10	4.0E-10	4.5E-11	9.7E-11	6.5E-11	-8.7E-12	7.2E-10
Ionising radiation, human health	kBq U235 eq	disease incidence / page	9.7E-05	5.3E-03	2.7E-07	5.4E-04	5.5E-04	3.2E-06	6.5E-03
Photochemical ozone formation, human health	kg NMVOC eq	kBq U235 eq / page	5.9E-06	2.0E-05	2.0E-06	6.5E-06	3.2E-06	-5.8E-07	3.7E-05
Acidification	mol H+ eq	kg NMVOC eq / page	1.0E-05	3.8E-05	2.7E-06	8.3E-06	5.9E-06	-1.3E-06	6.4E-05
Eutrophication, terrestrial	mol N eq	mol H+ eq / page	2.1E-05	7.6E-05	8.0E-06	2.3E-05	1.2E-05	-2.0E-06	1.4E-04
Eutrophication, freshwater	kg P eq	mol N eq / page	2.6E-08	2.5E-08	2.2E-10	1.0E-07	7.7E-09	-2.0E-09	1.6E-07
Eutrophication, marine	kg N eq	kg P eq / page	2.0E-06	7.2E-06	7.3E-07	2.4E-06	1.1E-06	-1.9E-07	1.3E-05
Ecotoxicity, freshwater	CTUe	kg N eq / page	0.017	0.057	0.001	0.008	0.009	-0.003	0.088
Land use	pt	CTUe / page	0.014	0.054	0.000	0.216	0.008	0.279	0.571
Water use	m3 water eq. of deprived water	Pt / page	0.000	0.004	0.000	0.001	0.000	0.000	0.006
Resource use, minerals and metals	kg Sb eq	m3 water eq. of deprived water / page	1.4E-07	3.2E-09	2.1E-11	1.3E-09	2.9E-08	4.0E-09	1.8E-07
Resource use, fossils	MJ	kg Sb eq / page	0.036	0.216	0.001	0.031	0.029	-0.005	0.310
Primary energy consumption	MJ	MJ / page	0.036	0.225	0.001	0.032	0.030	-0.005	0.319

Table 144. Environmental assessment of Device7

	Unit (per page)		Raw materials	Manufacturing	Distribution	Use	Remanufacturing	End of life	Total
Climate change, total	kg CO2 eq		0.016	0.029	0.000	0.002	0.000	-0.001	0.047
Ozone depletion	kg CFC-11 eq	kg CO2 eq / page	2.7E-10	1.1E-11	6.3E-17	8.4E-11	0.0E+00	-2.0E-13	3.6E-10
Human toxicity, cancer	CTUh	kg CFC-11 eq / page	2.2E-11	4.9E-12	6.9E-14	1.1E-12	0.0E+00	-6.7E-12	2.1E-11
Human toxicity, non-cancer	CTUh	CTUh / page	3.7E-10	9.8E-11	1.2E-12	1.2E-11	0.0E+00	-1.4E-11	4.7E-10
Particulate matter	disease incidence	CTUh / page	7.7E-10	9.4E-10	1.3E-10	1.5E-10	0.0E+00	-3.4E-11	2.0E-09
Ionising radiation, human health	kBq U235 eq	disease incidence / page	5.6E-04	1.2E-02	8.0E-07	5.5E-04	0.0E+00	-3.4E-05	1.4E-02
Photochemical ozone formation, human health	kg NMVOC eq	kBq U235 eq / page	3.9E-05	4.8E-05	5.9E-06	1.0E-05	0.0E+00	-3.0E-06	1.0E-04
Acidification	mol H+ eq	kg NMVOC eq / page	6.4E-05	8.9E-05	8.0E-06	1.2E-05	0.0E+00	-4.0E-06	1.7E-04
Eutrophication, terrestrial	mol N eq	mol H+ eq / page	1.4E-04	1.8E-04	2.4E-05	3.7E-05	0.0E+00	-1.0E-05	3.7E-04
Eutrophication, freshwater	kg P eq	mol N eq / page	1.6E-07	6.0E-08	6.5E-10	2.0E-07	0.0E+00	-2.7E-09	4.1E-07
Eutrophication, marine	kg N eq	kg P eq / page	1.3E-05	1.7E-05	2.2E-06	4.0E-06	0.0E+00	-9.6E-07	3.5E-05
Ecotoxicity, freshwater	CTUe	kg N eq / page	0.100	0.134	0.003	0.010	0.000	-0.014	0.233
Land use	pt	CTUe / page	0.034	0.126	0.001	0.406	0.000	0.112	0.679
Water use	m3 water eq. of deprived water	Pt / page	0.000	0.010	0.000	0.001	0.000	0.001	0.012
Resource use, minerals and metals	kg Sb eq	m3 water eq. of deprived water / page	9.4E-07	7.5E-09	6.2E-11	2.2E-09	0.0E+00	-6.7E-08	8.8E-07
Resource use, fossils	MJ	kg Sb eq / page	0.256	0.511	0.004	0.039	0.000	-0.031	0.779
Primary energy consumption	MJ	MJ / page	0.256	0.530	0.004	0.040	0.000	-0.031	0.798

Table 145. Environmental assessment of Cartridge1

	Unit (per page)		Raw materials	Manufacturing	Distribution	Use	Remanufacturing	End of life	Total
Climate change, total	kg CO2 eq		3.8E-04	6.0E-04	2.3E-05	4.3E-05	0.0E+00	-7.1E-05	9.7E-04
Ozone depletion	kg CFC-11 eq	kg CO2 eq / page	2.3E-12	2.2E-13	4.3E-18	2.6E-12	0.0E+00	-5.7E-13	4.6E-12
Human toxicity, cancer	CTUh	kg CFC-11 eq / page	5.7E-13	1.0E-13	5.2E-15	3.1E-14	0.0E+00	-1.8E-13	5.2E-13
Human toxicity, non-cancer	CTUh	CTUh / page	3.7E-12	2.0E-12	9.1E-14	3.1E-13	0.0E+00	-4.9E-13	5.6E-12
Particulate matter	disease incidence	CTUh / page	4.1E-11	1.9E-11	1.0E-11	3.9E-12	0.0E+00	-7.4E-12	6.7E-11
Ionising radiation, human health	kBq U235 eq	disease incidence / page	1.3E-05	2.5E-04	5.8E-08	7.9E-06	0.0E+00	-3.1E-06	2.7E-04
Photochemical ozone formation, human health	kg NMVOC eq	kBq U235 eq / page	1.7E-06	9.8E-07	4.6E-07	2.9E-07	0.0E+00	-3.8E-07	3.1E-06
Acidification	mol H+ eq	kg NMVOC eq / page	2.5E-06	1.8E-06	6.2E-07	3.2E-07	0.0E+00	-5.2E-07	4.7E-06
Eutrophication, terrestrial	mol N eq	mol H+ eq / page	5.9E-06	3.7E-06	1.8E-06	1.0E-06	0.0E+00	-1.3E-06	1.1E-05
Eutrophication, freshwater	kg P eq	mol N eq / page	2.0E-08	1.2E-09	4.4E-11	6.0E-09	0.0E+00	-4.8E-09	2.3E-08
Eutrophication, marine	kg N eq	kg P eq / page	6.2E-07	3.5E-07	1.7E-07	1.1E-07	0.0E+00	-1.4E-07	1.1E-06
Ecotoxicity, freshwater	CTUe	kg N eq / page	7.0E-03	2.7E-03	2.6E-04	2.0E-04	0.0E+00	-1.9E-03	8.3E-03
Land use	pt	CTUe / page	4.6E-03	2.6E-03	5.3E-05	1.2E-02	0.0E+00	7.4E-03	2.7E-02
Water use	m3 water eq. of deprived water	Pt / page	2.4E-04	2.0E-04	6.2E-07	2.2E-05	0.0E+00	-5.2E-05	4.1E-04
Resource use, minerals and metals	kg Sb eq	m3 water eq. of deprived water / page	5.3E-09	1.5E-10	4.4E-12	6.2E-11	0.0E+00	3.0E-11	5.5E-09
Resource use, fossils	MJ	kg Sb eq / page	8.6E-03	1.0E-02	2.9E-04	8.3E-04	0.0E+00	-1.9E-03	1.8E-02
Primary energy consumption	MJ	MJ / page	8.6E-03	1.1E-02	2.9E-04	8.3E-04	0.0E+00	-1.9E-03	1.9E-02

Table 146. Environmental assessment of Cartridge2

	Unit (per page)		Raw materials	Manufacturing	Distribution	Use	Remanufacturing	End of life	Total
Climate change, total	kg CO2 eq		2.9E-04	3.4E-04	1.3E-05	4.3E-05	0.0E+00	-6.5E-05	6.2E-04
Ozone depletion	kg CFC-11 eq	kg CO2 eq / page	1.6E-12	1.3E-13	2.4E-18	2.6E-12	0.0E+00	-3.9E-13	3.9E-12
Human toxicity, cancer	CTUh	kg CFC-11 eq / page	4.0E-12	5.6E-14	2.9E-15	3.2E-14	0.0E+00	-1.6E-12	2.5E-12
Human toxicity, non-cancer	CTUh	CTUh / page	2.9E-12	1.1E-12	5.0E-14	3.1E-13	0.0E+00	-4.0E-13	4.0E-12
Particulate matter	disease incidence	CTUh / page	3.4E-11	1.1E-11	5.6E-12	3.9E-12	0.0E+00	-7.5E-12	4.7E-11
Ionising radiation, human health	kBq U235 eq	disease incidence / page	1.0E-05	1.4E-04	3.2E-08	7.9E-06	0.0E+00	-3.3E-06	1.6E-04
Photochemical ozone formation, human health	kg NMVOC eq	kBq U235 eq / page	1.2E-06	5.6E-07	2.5E-07	2.9E-07	0.0E+00	-3.0E-07	2.0E-06
Acidification	mol H+ eq	kg NMVOC eq / page	2.1E-06	1.0E-06	3.4E-07	3.2E-07	0.0E+00	-5.5E-07	3.3E-06
Eutrophication, terrestrial	mol N eq	mol H+ eq / page	4.3E-06	2.1E-06	1.0E-06	1.0E-06	0.0E+00	-1.0E-06	7.4E-06
Eutrophication, freshwater	kg P eq	mol N eq / page	1.4E-08	6.9E-10	2.4E-11	6.1E-09	0.0E+00	-3.2E-09	1.7E-08
Eutrophication, marine	kg N eq	kg P eq / page	4.4E-07	2.0E-07	9.2E-08	1.1E-07	0.0E+00	-1.0E-07	7.3E-07
Ecotoxicity, freshwater	CTUe	kg N eq / page	5.1E-03	1.5E-03	1.4E-04	2.1E-04	0.0E+00	-1.5E-03	5.6E-03
Land use	pt	CTUe / page	2.4E-04	1.5E-03	2.9E-05	1.3E-02	0.0E+00	1.3E-02	2.7E-02
Water use	m3 water eq. of deprived water	Pt / page	1.7E-04	1.2E-04	3.4E-07	2.3E-05	0.0E+00	-3.9E-05	2.7E-04
Resource use, minerals and metals	kg Sb eq	m3 water eq. of deprived water / page	7.7E-09	8.7E-11	2.4E-12	6.2E-11	0.0E+00	-9.2E-10	7.0E-09
Resource use, fossils	MJ	kg Sb eq / page	6.2E-03	5.9E-03	1.6E-04	8.4E-04	0.0E+00	-1.5E-03	1.2E-02
Primary energy consumption	MJ	MJ / page	6.2E-03	6.1E-03	1.6E-04	8.4E-04	0.0E+00	-1.5E-03	1.2E-02

Table 147. Environmental assessment of Cartridge3

	Unit (per page)		Raw materials	Manufacturing	Distribution	Use	Remanufacturing	End of life	Total
Climate change, total	kg CO2 eq		2.5E-04	3.5E-04	1.3E-05	4.3E-05	0.0E+00	-4.9E-05	6.0E-04
Ozone depletion	kg CFC-11 eq	kg CO2 eq / page	1.8E-12	1.3E-13	2.5E-18	2.6E-12	0.0E+00	-4.5E-13	4.1E-12
Human toxicity, cancer	CTUh	kg CFC-11 eq / page	6.2E-13	5.8E-14	3.0E-15	3.2E-14	0.0E+00	-2.2E-13	5.0E-13
Human toxicity, non-cancer	CTUh	CTUh / page	2.1E-12	1.2E-12	5.2E-14	3.1E-13	0.0E+00	-4.2E-13	3.2E-12
Particulate matter	disease incidence	CTUh / page	3.0E-11	1.1E-11	5.9E-12	3.9E-12	0.0E+00	-5.8E-12	4.5E-11
Ionising radiation, human health	kBq U235 eq	disease incidence / page	3.5E-06	1.5E-04	3.3E-08	8.0E-06	0.0E+00	-7.7E-07	1.6E-04
Photochemical ozone formation, human health	kg NMVOC eq	kBq U235 eq / page	1.2E-06	5.7E-07	2.6E-07	2.9E-07	0.0E+00	-2.8E-07	2.1E-06
Acidification	mol H+ eq	kg NMVOC eq / page	1.7E-06	1.1E-06	3.6E-07	3.2E-07	0.0E+00	-3.9E-07	3.1E-06
Eutrophication, terrestrial	mol N eq	mol H+ eq / page	4.2E-06	2.1E-06	1.1E-06	1.0E-06	0.0E+00	-9.6E-07	7.4E-06
Eutrophication, freshwater	kg P eq	mol N eq / page	1.6E-08	7.1E-10	2.5E-11	6.1E-09	0.0E+00	-3.7E-09	1.9E-08
Eutrophication, marine	kg N eq	kg P eq / page	4.4E-07	2.0E-07	9.6E-08	1.1E-07	0.0E+00	-1.0E-07	7.4E-07
Ecotoxicity, freshwater	CTUe	kg N eq / page	4.1E-03	1.6E-03	1.5E-04	2.1E-04	0.0E+00	-9.9E-04	5.0E-03
Land use	pt	CTUe / page	5.0E-04	1.5E-03	3.0E-05	1.3E-02	0.0E+00	-8.1E-05	1.4E-02
Water use	m3 water eq. of deprived water	Pt / page	1.7E-04	1.2E-04	3.6E-07	2.3E-05	0.0E+00	-3.8E-05	2.7E-04
Resource use, minerals and metals	kg Sb eq	m3 water eq. of deprived water / page	2.4E-09	8.9E-11	2.5E-12	6.2E-11	0.0E+00	-5.6E-10	2.0E-09
Resource use, fossils	MJ	kg Sb eq / page	6.0E-03	6.1E-03	1.7E-04	8.4E-04	0.0E+00	-1.4E-03	1.2E-02
Primary energy consumption	MJ	MJ / page	6.0E-03	6.3E-03	1.7E-04	8.4E-04	0.0E+00	-1.4E-03	1.2E-02

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