European Commission

Revision of Voluntary Agreement on Imaging Equipment

Task 1-7

Final Report

October 2019

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Project website: www.review-imagingequipment.eu

Implements Framework Contract: No. ENER/C3/2015-619 LOT 3

Specific contract no.: ENER/C3/FV 2017-438/16/FWC 2015-619 LOT3/07/SI2.777115

This study was ordered and paid for by the European Commission, Directorate-General for Energy.

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IV. Introduction to report

This is the report for technical assistance to support the process of the revision of the self-regulation measure (Voluntary Agreement) on imaging equipment. As specified in the contract, the study follows the structure of the MEErP methodology in Task 1 to 4. The structure of MEErP in Task 5 to 7 is simplified with regard to identifying improvement potential for energy efficiency. The options for an enhanced contribution of imaging equipment to the objectives of circular economy should be fully investigated, notably with regard to equipment reparability and durability, the design and use of printer cartridges and the use of paper.

Task 1 outlines the product scope including product categorisation, as well as the relevant standards and legislations, including those under development, related to imaging equipment energy consumption, resource efficiency and product design.

Task 2 gives an overview of the imaging equipment market including sales, stock and base data on consumer costs, including stock backcasting and forecasting covered by available data. Furthermore task 2 presents an overview of market trends concerning product design and features, as well as average consumer expenditure data over the product lifetime.

Task 3 presents a detailed overview of use patterns of products and consumables in scope according to consumer use and technological developments. It also provides an analysis of other aspects that affect the energy consumption during the use of these products, such as component technologies. Furthermore, it also touches on aspects that are important for material and resource efficiency such as repair and maintenance, and it gives an overview of what happens to these products at their end of life.

Task 4 reviews the technical aspects of imaging equipment and outlines the current technology levels in terms of average and best available technologies (BAT), as well as which technologies are expected to enter the market (best not yet available technology, BNAT). Besides the effect on energy consumption, the technologies are also reviewed in terms of resource efficiency. This analysis is the basis to define the base case technology, which will be presented and used in subsequent tasks to define the base cases.

Task 5 presents the evaluation of the current Voluntary Agreement, which includes assessment of energy savings, environmental impacts of existing energy efficiency and resource efficiency requirements. The base cases of imaging equipment and consumables and current practices and expected development are presented in order to carry out the evaluation and estimate future impacts if no further action is taken.

Task 6 presents the improvement options in terms of both energy efficiency and resource efficiency potentials for imaging equipment and consumables. It also provides life cycle assessments of the options in order to recommend those with the overall best performance in terms of life cycle costs and environmental impacts.

Task 7 provides conclusions for the appropriateness of the requirements set by the Voluntary Agreement, energy savings achieved and projected, as well as assessment of the improvement potentials, especially in terms of resource efficiency of consumables. It also examines the effectiveness of the VA, makes proposals for its improvement or possible replacement with other policy instrument, and assesses the potential impacts of those changes at the EU level.

1. Task 1: Scope

Task 1 report follows the MEErP methodology and the specific items requested by the European Commission. It includes the following:

1. Product scope: Identification and description of relevant product categories and definition of the product scope and categorisation based on the Voluntary Agreement, existing voluntary schemes and market terms.
2. Legislation: Update of relevant legislation on EU, Member State and third country level. This is presented before test standards (i.e. not following the typical MEErP sequence) as a method to concentrate the relevant test standards to those covering parameters mentioned by EU or third countries' legislations or initiatives.
3. Test standards: Update and description of relevant test and measurement standards on EU, Member State and third country level, including those on resource efficiency aspects.

The review of legislations and test standards include those relevant to the industry's EU Voluntary Agreement v5.2[1].

Voluntary Agreement (VA) is a self-regulation measure adopted by the industry and endorsed by the European Commission based on a participatory exercise (via an assessment carried out together with the Ecodesign Consultation Forum). Self-regulation measures, offered as unilateral commitments by industry, are prioritised by the Ecodesign framework directive whenever they are likely to deliver the policy objectives faster or in a less costly manner than the mandatory implementing measures (Art. 17 of Ecodesign Directive);

The Commission accepted this self-regulation, as an alternative measure to an ecodesign implementing measure, based on an Impact Assessment (IA) completed in 2013[2] and published a communication to the European Parliament and the Council on the voluntary design scheme for imaging equipment[3].

The VA was revised in April 2015 and published the current applicable version v5.2. In April 2018, the revision process has started for the current version.

[1] http://www.eurovaprint.eu/fileadmin/eurovaprint_files/pdfs/VA_version_5.2_April.pdf
[2] https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=SWD:2013:0015:FIN:EN:PDF
[3] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52013DC0023&from=EN

1.1 Product scope

1.1.1 Voluntary Agreement product scope

The current scope of the Voluntary Agreement covers household and office imaging equipment limited to:

- Standard black & white (BW, also called monochrome) format products with maximum speed < 66 A4 images per minute
- Standard colour format products with maximum speed <51 A4 images per minute.

The Voluntary Agreement (VA) covers imaging equipment belonging to one of the following product categories:

- Copiers
- Multifunction Devices (MFDs)
- Printers
- Fax machines

Limited to the following marking technologies:

- Electrophotography (EP)
- Inkjet (IJ), including high performance IJ
- Solid Ink (SI)

See figure below for the different types of imaging equipment in scope of the VA.

Figure 1: Examples of imaging equipment, from top left to bottom right, EP/laser printer[4] inkjet MFD[5], laser MFD including photocopying, scanning and printing functions[6], fax machine[7]

The relevant definitions from the Voluntary Agreement for imaging equipment products are:

Copier: A commercially-available imaging product whose sole function is the production of hard copy duplicates from graphic hard copy originals. 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 copiers or upgradeable digital copiers (UDCs).

Multifunction device (MFD): A commercially-available imaging product, which is a physically-integrated device or a combination of functionally-integrated components that performs two or more of the core functions of copying, printing, scanning, or faxing. The copy functionality as addressed in this definition is considered to be distinct from single sheet convenience copying offered by fax machines. The unit must be capable of being powered

[4] https://www.brother.dk/printers/laser/hl-3170cdw
[5] https://www.canon-europe.com/about_us/press_centre/product_information/all_in_ones/pixma-ts9550-series.aspx
[6] https://www.lexmark.com/en_us/printer/7203/Lexmark-X925de
[7] https://www.brother.dk/fax-machines/fax-2840

from a wall outlet or from a data or network connection. This definition is intended to cover products that are marketed as MFDs or multifunction products (MFPs).

Printer: A commercially-available imaging product that serves as a hard copy output device, and is capable of receiving information from single-user or networked computers, or other input devices (e.g., digital cameras). 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 printers, including printers that can be upgraded into MFDs in the field.

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.

OEM (Original Equipment Manufacturer)[8]: A company that manufactures and commercializes/imports products under its own brand name into the EU single market.

Definitions for the marking technologies in scope (Electrophotography, Inkjet - including high performance-, and Solid Ink) can also be found in the Voluntary Agreement[9].

Consumables such as cartridges are not in scope of the current VA, however they are mentioned in the definitions for "end-users" and "non-OEM cartridge[10]" and there are requirements for cartridges in Part II commitment on resource efficiency, and Part III comments on information requirement for end-users regarding cartridge disposal and treatment as well as yield.

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[8] A stakeholder suggests to update the definition to "manufactures or holds a license" as many products are produces under license. The study team has decided not to follow this suggestion due to consistency with the definition in the VA.

[9] http://www.eurovaprint.eu/fileadmin/eurovaprint_files/pdfs/VA_version_5.2_April.pdf

[10] It is defined by VA as "A toner or ink cartridge not sold by the OEM for use in products that bear the respective OEM's brand name that is a remanufactured cartridge or refilled cartridge."

Voluntary Agreement scope speed limits

As seen above, the scope of the VA is limited by the maximum speed in images per minutes (ipm). The standard black & white (or monochrome) format products should have a maximum speed < 66 A4 images per minute, and standard colour format products should have a maximum speed <51 A4 images per minute.

The monochrome speed limit was based on the industry perspective (EICTA[11]) that semi-professional equipment should be exempted, because according to the preparatory study in 2008[12] that "these products are usually used for high volume printing and applied in professional environments or in large network environments with high job frequency. The functional and performance spectrum including data processing, human and network interfaces as well as the document output (sorting, binding, etc) are optimized for these purposes." This limit was proposed at 86 ipm during the preparatory study, which was aligned with the Japanese Top Runner Program which also exempts products with >85ipm due to the same reason. However, EICTA rejected the stricter and higher speed limit and proposed that monochrome equipment with speed > 65 ipm should be exempted.

The colour equipment speed limit was also based on the exemption proposed. This exemption drew inspiration from the first draft Energy Star specification[13], which distinguishes TEC (Typical Energy Consumption, reference to the test method) colour products at a speed level of 50 ipm, therefore the scope limit was set for products with speed < 51 ipm.

However, the speed limits may have become a less appropriate method for drawing scope as the technology advances and the speed has improved significantly over the last 10 years.

Table 1 illustrates the percentage of standard sized imaging equipment models registered in the US ENERGY STAR database that fall inside and outside of the VA speed requirement scope. It is clear that the VA scope includes a high percentage of mono laser printers and MFDs but slightly fewer colour laser printers and MFDs. Where just speed is considered, all inkjet-based printers and MFDs fall within the scope of the VA. The situation for high performance inkjet products is very different, with the majority of products falling outside of the VA scope.

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[11] Industry association, later renamed to DIGITAL EUROPE.
[12] EuP Preparatory Studies "Imaging Equipment" (Lot 4). Final Report. November 2007-May 2008. Fraunhofer IZM for the European Commission.
[13] https://www.energystar.gov/sites/default/files/specs//Imaging_Equip_V1_Final.pdf

Table 1: ENERGY STAR registered products and VA coverage based on product speed

Product Type	Marking Technology	Colour/ Mono	Percentage of products in/out scope (based on speed limits of <66ipm (mono) and <51ipm (colour))	
			In	Out
Printer	Laser	Mono	85%	15%
MFD	Laser	Mono	85%	15%
Printer	Laser	Colour	71%	29%
MFD	Laser	Colour	70%	30%
Printer	Inkjet	Colour	100%	0%
MFD	Inkjet	Colour	100%	0%
Printer	High Performance Inkjet	Colour	12%	88%
MFD	High Performance Inkjet	Colour	33%	67%

1.1.2 Product categorisation in EU statistical sources

PRODCOM categories

The classification of the products in PRODCOM follows the statistical classification of economic activities in the European Community known as NACE (Nomenclature des activités économiques dans la Communauté Européenne). Products are defined by an eight-digit code in which the first four digits refer to the NACE classification.

There are relatively few PRODCOM codes that relate to domestic and office imaging equipment and associated products within current and potentially extended scope of the voluntary agreement on imaging equipment. The products covered under these categories are listed in Table 2.

Table 2: PRODCOM code and description for imaging equipment in scope of current Voluntary Agreement

Product group	PRODCOM code and description
NACE 26.20: Manufacture of computers and peripheral equipment	26.20.16.40
	Printers, copying machines and facsimile machines, capable of connecting to an automatic data processing machine or to a network (excluding printing machinery used for printing by means of plates, cylinders and other components, and machines performing two or more of the functions of printing, copying or facsimile transmission)
	26.20.18.00
	Machines which perform two or more of the functions of printing, copying or facsimile transmission, capable of connecting to an automatic data processing machine or to a network
NACE 28.23: Manufacture of office machinery and equipment (except computers and peripheral equipment)	28.23.21.00
	Photo-copying apparatus incorporating an optical system or of the contact type and thermo-copying apparatus
	28.23.26.00
	Parts and accessories of printers of HS 8443 3
NACE 20.30: Manufacture of paints, varnishes and similar coatings, printing ink and mastics	20.30.22.73
	Organic composite solvents and thinners used in conjunction with coatings and inks; based on butyl acetate
	20.30.22.79
	Organic composite solvents and thinners used in conjunction with coatings and inks (excluding those based on butyl acetate)
	20.30.24.50
	Black printing inks
	20.30.24.70
	Printing inks (excluding black)

Given the broad-brush nature of the PRODCOM codes, they are unlikely to be able to provide an accurate picture of the production quantities of different types of imaging equipment. For example, the first code "26.20.16.40" covers a very wide range of imaging equipment, some of which is unlikely to be covered under the scope of the EU Voluntary Agreement, covering products as diverse as battery operated mobile printers to some types of production printer. In addition, there is some uncertainty around the inclusion of substances used in ink and toner and so it is unclear which PRODCOM codes are relevant for the EU Voluntary Agreement in these instances.

NACE (Statistical classification of economic activities) categories

The NACE codes are also used for statistical classification of economic activities in the European Community[14], which cover more than manufacturing (activities covered by PRODCOM). NACE provides the framework for collecting and presenting a large range of statistical data according to economic activity in the fields of economic statistics (e.g. pro-

[14] Eurostat, Glossary: Statistical classification of economic activities in the European Community (NACE), available from http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Statistical_classification_of_economic_activities_in_the_European_Community_(NACE)

duction, employment, national accounts) and in other statistical domains. Table 3 illustrates the NACE economic activity codes that are relevant for the current (and potentially extended) scope of the voluntary agreement on imaging equipment.

Table 3: NACE economic activity codes relevant to imaging equipment

Section	Division	Group	Class	Description
SECTION C — MANUFACTURING	20	20.3	20.30	Manufacture of paints, varnishes and similar coatings, printing ink and mastics
	26	26.1	26.11	Manufacture of electronic components
		26.2	26.20	Manufacture of computers and peripheral equipment
		26.3	26.30	Manufacture of communication equipment
		26.4	26.40	Manufacture of consumer electronics
		26.7	26.70	Manufacture of optical instruments and photographic equipment
	33	33.1	33.13	Repair of electronic and optical equipment

As with the other classification systems, the NACE economic activity codes do not provide a sufficient level of detail to clearly identify economic activities associated with imaging equipment.

Combined Nomenclature

When goods are imported or exported within the EU they need to be classified according to the Combined Nomenclature (CN)[15]. The CN code is also used in intra-Community trade statistics. The CN is comprised of the Harmonized System (HS) nomenclature, which is managed by the World Customs Organisation (WCO), with further Community subdivisions. Most trading nations around the world use this systematic list of commodities as they form the basis for international trade negotiations. The CN also includes additional notes on CN subdivisions to provide further clarity on what is covered under each code. Each CN subdivision is made up of an eight-digit code number (i.e. the CN code) followed by a description.

Table 4 illustrates the CN codes that are likely relevant for the EU Voluntary Agreement on imaging equipment.

[15] European Commission, Taxation and Customs Union, The Combined Nomenclature, available at https://ec.europa.eu/taxation_customs/business/calculation-customs-duties/what-is-common-customs-tariff/combined-nomenclature_en

Table 4: CN code and description for imaging equipment

CN Product group	CN code and description
8443 Printing machinery used for printing by means of plates, cylinders and other printing components of heading 8442; other printers, copying machines and facsimile machines, whether or not combined; parts and accessories thereof:	8443 19 70
	Other - Other printers, copying machines and facsimile machines, whether or not combined
	8443 31 00
	Machines which perform two or more of the functions of printing, copying or facsimile transmission, capable of connecting to an automatic data-processing machine or to a network
	8443 32
	Other, capable of connecting to an automatic data-processing machine or to a network
	8443 32 10
	Printers
	8443 32 80
	Other
	8443 39 00
	Other - Parts and accessories
3707 Chemical preparations for photographic uses (other than varnishes, glues, adhesives and similar preparations); unmixed products for photographic uses, put up in measured portions or put up for retail sale in a form ready for use:	3707 90 21
	Thermoplastic or electrostatic toner cartridges (without moving parts) for insertion into apparatus of subheadings 8443 31, 8443 32 or 8443 39
3215 Printing ink, writing or drawing ink and other inks, whether or not concentrated or solid:	3215 11 10
	(Printing Ink) (Black 3215 11)- Ink cartridges (without an integrated print head) for insertion into apparatus of subheadings 8443 31, 8443 32 or 8443 39, and incorporating mechanical or electrical components
	3215 19 10
	(Printing Ink) (Other 3215 19) - Ink cartridges (without an integrated print head) for insertion into apparatus of subheadings 8443 31, 8443 32 or 8443 39, and incorporating mechanical or electrical components
	3215 90 20
	(Other 3215 90) Ink cartridges (without an integrated print head) for insertion into apparatus of subheadings 8443 31, 8443 32 or 8443 39, and incorporating mechanical or electrical components; solid ink in engineered shapes for insertion into apparatus of subheadings 8443 31, 8443 32 or 8443 39

The CN codes provide a clear distinction between printers and multi-functional devices but do not allow distinctions to be made between different types of printers or multi-functional devices. For example, whilst it would be possible to distinguish a printer from an MFD it would not be possible to distinguish a laser-based printer from an inkjet printer. In a similar way, they make a distinction between toner and ink cartridges, although toner cartridges refer to those without moving parts thus most likely being containers, not cartridges, therefore not making a distinction between types. The classification of ink cartridges does make this distinction and it is tied up to the imaging equipment products classification. However, they exclude those including a print head which are also found in the EU market.

1.1.3 Consumables categorisation and definitions[16]

Consumables are not in scope as individual products in the current VA, however they are included in some definitions. Furthermore, as mentioned, several VA requirements address cartridge design (requirement 5.4.1), use (requirement 6.6.2) and disposal (requirement 6.3). Cartridges are defined as those produced by or recommended by the OEM for use in imaging equipment products in scope, but non-OEM cartridges are also meant to be used by imaging equipment products (requirement 5.4.2). It is therefore recommended to include a definition of consumables in the VA and consider include them in the scope.

Cartridges design are quite different depending on their application, i.e. whether they are for inkjet or for laser printing, and that is why some voluntary schemes like the US EPEAT[17], the Blue Angel[18], the Nordic Swan Ecolabel[19] and the Korea Ecolabel[20] make a distinct categorisation accordingly. Also, some of the schemes make an additional distinction for containers, which are basically holders of ink and toner without integrated electronic components and which are therefore very different design wise and simpler to dispose once they reach their end of life. It thus recommended to follow this approach of distinguishing containers for ink and toners from cartridges for ink and toner in the VA, in particular if cartridges and containers are to be included in the scope of the VA, which would improve the effectiveness of the requirements.

Consumables can include[21] containers, cartridges, drum units, fuser units and transfer units, more detailed descriptions of all the consumables are presented in the Task 4, however, in this study, the focus is on containers and cartridges as consumables.

Specific definitions[22] below have been drafted for the proposals of the ongoing revision of the EU Green Public Procurement (GPP) criteria for imaging equipment[23]. These definitions can be used to elaborate on the potential categorisation of consumables in a revised VA:

- **Container:** An end-user replaceable product that holds ink or toner and that fits onto or into or is emptied into an imaging equipment product. Containers do not

[16] The Current VA is under revision and the definitions may change.
[17] http://www.epeat.net/about-epeat/
[18] https://www.blauer-engel.de/en/blue-angel/who-is-behind-it
[19] http://www.nordic-ecolabel.org/about/
[20] http://el.keiti.re.kr/enservice/enpage.do?mMenu=2&sMenu=1
[21] A stakeholder has raised the point that it is not relevant to include a definition of "consumable" that includes items such as drum and fuser units as this is not relevant for the VA. The stakeholder states that a limited definition of "consumable" could be included in the VA but the same effect is already achieved by the most recent definition of "cartridge" proposed by the OEMs. The study team does not change this definition because we are assessing consumables in the study and thereby needs a clear definition of these.
[22] A stakeholder has raised the point that they are missing a clear definition of new builds and remanufactured consumables.
[23] Revision of the EU Green Public Procurement (GPP) Criteria for Imaging Equipment. Technical report. Draft final criteria. JRC, Viegand Maagøe and Tenvic. February 2018.

contain integrated components or moving parts (other than simple rollers) integral to the imaging product's function.

- **Cartridge:** An end-user replaceable product, which fits into or onto an imaging equipment product, with printing-related functionality that includes integrated components (e.g. a drum unit or electronic chip) or moving parts integral to the imaging equipment's function beyond holding the ink or toner material.

It is important to note that the proposed definition for consumables in GPP introduces an artificial boundary between container and cartridges. In reality, there will be crossover in the market, where e.g. certain products usually considered as containers could also include an electronic chip. However, the definitions capture the majority of the cases, and provide the general understanding of differences between containers and cartridges. See Figure 2 for ink and toner containers and cartridges.

Figure 2: Ink and toner containers (left), and toner and ink cartridges (right)

Furthermore, during the GPP study it became evident that along energy consumption during use, the most important life cycle environmental hotspot of imaging equipment products is the use and disposal of consumables. This is because imaging equipment products have become very efficient, in some cases the use of consumables surpasses the energy consumption in terms of significance. It is therefore important to set requirements for their use and disposal, which are harmonised with the ongoing adoption of the Circular Economy package in Ecodesign.

However, a stakeholder has stated that the definitions of a container and a cartridge are not aligned with the users' and industries' common understanding. The stakeholder believes that the users recognize replaceable products, which fits into a machine as "Cartridges", regardless of it has complex components or not. Hence, the stakeholder suggested to use these definitions:

- Cartridge: An end-user replaceable product, which fits into or onto an imaging equipment product
- Container: An end-user product that holds ink or toner and is emptied into an imaging equipment product

Regardless the choice of definitions it is important that the definitions are aligned across different initiatives, so the VA and GPP use the same definitions.

1.1.4 Summary

Whilst each existing EU statistical classification codes provides some insight into imaging equipment categorization, none of the statistical sources discussed above provides a perfect solution. For each of the statistical categorization systems, there is often a large degree of ambiguity in terms of which category a particular type of imaging equipment would fit within. This ambiguity would result in a significant amount of uncertainty if the statistical categorization approaches is used to derive savings from the revised Voluntary Agreement on imaging equipment. Other data sources, such as those published by market research organisations or as part of other environmental initiatives may provide enhanced data that is more targeted towards imaging equipment.

It is recommended to include definitions and categorisation from the GPP study[23], or similar, of consumables such as ink and toner containers, and ink and toner cartridges into the VA. As the VA requirements do address cartridges, definitions and categories could help understanding of the requirements and this approach aligns with multiple national and international labelling scheme, and lastly their use and disposal have been identified by previous studies as the most important life cycle environmental hotspot of imaging equipment.

1.2 Legislation

This section summarises the scope and the requirements found in legislation and initiatives at EU, Member State and third country level.

1.2.1 EU legislation

Ecodesign Standby Regulation (EC) No 1275/2008

In 2008 the European Commission implemented a horizontal regulation on standby and off mode power demand ((EC) No 1275/2008) which covered a broad range of products including some imaging equipment[24]. In 2013 the Commission published the Ecodesign Regulation (EC) No 801/2013 which is an amending regulation introducing requirements for networked standby into the existing Regulation (EC) No 1275/2008[25]. In addition to

[24] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:339:0045:0052:en:PDF
[25] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013R0801&from=EN

changes around the power demand requirements in various power states, the revised regulation also included an amended product scope. Some of these amendments in scope concern imaging equipment.

The requirements of Regulation (EC) No 1275/2008 only apply to products that are intended primarily for use in the domestic environment, i.e. EMC Class B IT equipment[26].

The definition of 'information technology equipment' and 'domestic environment' is identical to EN55022 or EN55032 covering essential requirements of the EMC Directive. This includes products intended for use in offices and other areas not being homes. All products designated EN55022/EN55032 EMC Class A, especially commercial and industrial products, are normally not in the scope of the regulation.

In terms of imaging equipment, this means that products that are unlikely to be used in a domestic environment will not be covered under the standby regulation. However, for many imaging equipment products there is no clear line between "domestic" and "non-domestic" products as even some relatively high specification imaging equipment may be used in domestic premises. During the standby regulation review study, which was completed in 2017, it was found that several common office MFD models were defined as Class A, even though they were clearly office equipment, but these were not subject to standby requirements of the regulation.

The Ecodesign Regulation (EC) No 801/2013 on networked standby includes exemptions from requirements on power consumption in networked standby (HiNA and non-HiNA) for imaging equipment meeting the following definitions:

- "large format printing equipment" means printing equipment designed for printing on A2 media and larger, including equipment designed to accommodate continuous-form media of at least 406 mm width, for which "printing equipment" means equipment that generates paper output from electronic input. Printing equipment may have additional functions and may be marketed as a multifunctional device or multifunctional product.

Large format printers are therefore exempted from the network standby requirements.

The Ecodesign Regulation includes a range of power demand and power management requirements that are applicable to imaging equipment. These requirements are listed in Table 5 and Table 6 together with the scope and exemptions.

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[26] https://ec.europa.eu/energy/sites/ener/files/documents/Guidance%20document_Lot%2026_Networked%20Standby_clean%20FIN.pdf

Table 5: Ecodesign standby/off mode requirements relevant to imaging equipment

Requirement Area	Scope	Power Demand Requirement (W)	Information or status display Allowance (W)	Exemp-tions
Standby Power Demand	All imaging equipment for domestic use	0.5	0.5	None
Off Mode Power Demand		0.5[27]	0	

Table 6: Ecodesign networked standby requirements relevant to imaging equipment with the scope and exemptions

Requirement Area	Scope	Implementation Date and Requirement		
		January 2015	January 2017	January 2019
Network Standby Requirements	HiNA[28] Equipment	12W	8W	8W
	Other Networked Equipment	6W	3W	2W
	Exemptions	Printing equipment with a power supply of a rated power larger than 750 W and large format printing equipment	Large format printing equipment	Large format printing equipment

The EU Ecodesign Regulation on standby power demand also includes a wide range of power management requirements (requirement details in Commission Regulation 1275/2008). This regulation is currently under revision, proposal for a revised regulation was made with the intent to include several new product groups.

Ecodesign External Power Supplies Regulation (EC) No 278/2009

In 2009, the European Commission adopted a Regulation on the energy efficiency of EPS[29]. The Commission is currently at the stage of reviewing this Regulation, proposal for a revised regulation was made and aims to align with US DOE (Department of Energy) Rule-making requirements.

The current Ecodesign EPS Regulation is limited in scope to single voltage EPS with rated output powers below 250W. Most, but not all, EPS shipped with imaging equipment would likely fall within scope of the current Ecodesign Regulation on EPS. It should be noted that

[27] In Consultation Forum held in December 2017 for standby regulation, it is proposed that revised off mode requirement should not exceed 0.3 W.
[28] High Network Availability
[29] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009R0278&from=EN

most non-domestic imaging equipment products are shipped with internal power supply (IPS) units rather than EPS.

The Ecodesign Regulation on external power supplies (EPS) includes no-load condition electric power demand and average active efficiency for all external power supplies (EPS) with an output of less than 250 W and supplying only one output voltage at a time. The EPS Regulation only applies to EPS that are intended to be used to power household and office electrical and electronic equipment (requirement details in Commission Regulation No. 278/2009). This regulation is therefore also relevant for a broad range of imaging equipment[30].

EU Directive 2014/35/EU – Low Voltage Directive[31]

The revised Low Voltage Directive (LVD) came into force on the 20th of April 2016. The LVD ensures that electrical equipment that operates within certain voltage limits, provides a high level of protection. The LVD Directive covers all health and safety risks of electrical equipment operating with a voltage of between 50 and 1000 volts for alternating current and between 75 and 1500 volts for direct current. Consumer goods with a voltage below 50 for alternating current or 75 for direct current are covered by the General Product Safety Directive (GPSD) (2001/95/EC).

Most imaging equipment products fall under the scope of the LVD Directive.

EU Directive 2012/19/EU – The WEEE Directive[32]

The Waste Electrical and Electronic Equipment (WEEE) Directive implements the principle of "extended producer responsibility" where producers of EEE are expected to take responsibility for the environmental impact of their products at the end of life. As such, the WEEE Directive aims to reduce environmental impacts through setting targets for the separate collection, reuse, recovery, recycling and environmentally sound disposal of WEEE.

As EEE, imaging equipment products fall under the scope of the WEEE Directive.

Moreover, the FAQ document on the WEEE Directive issued by the European Commission in April 2014[33], has clarified that most printer cartridges fall within the scope of the Directive. Specifically, those which meet the definition of EEE given in Article 3(1)(a), meaning those that need electric current or electromagnetic fields to operate. Those merely

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[30] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32009R0278
[31] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014L0035&from=EN
[32] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012L0019&from=EN
[33] http://ec.europa.eu/environment/waste/weee/pdf/faq.pdf

consisting of ink and a container without electric parts are out of scope, defined as "container" above. According to the European Commission[34], these are found on the EU market and can be classified as ink 'Supertank' systems[35], toner cartridges separated from the print-head[36] and toner 'cartridge-less' systems[37].

Because of the difference of implementation across Member States, the timeline for implementation after this clarification by the European Commission has been different. According to ETIRA[38], although this FAQ document was published in 2014, some Member States have provided specific guidelines on the inclusion of cartridges in the scope until 2017/2018.

EU Regulation 1907/2006/EC – REACH Regulation[39]

The Regulation on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) addresses chemicals, and their safe use, and aims to improve the protection of human health and the environment through a system of Registration, Evaluation, Authorisation and Restriction of Chemicals. The REACH Regulation places greater responsibility on industry to manage the risks from the chemicals they manufacture, import and market in the EU. Companies are required to demonstrate how substances can be used safely and risk management measures must be reported to users. The REACH Regulation also establishes procedures for collecting and assessing information on the properties and hazards of substances and requires that companies register their substances in a central database. The entries in the database are then assessed to determine whether the risks of the substances can be managed. The REACH Regulation allows for some chemicals to be determined "substances of very high concern (SVHC)" due to their large potential negative impacts on human health or the environment. The European Chemicals Agency must be notified of the presence of SVHCs in certain products and the use of SVHCs may then be subject to prior authorisation. Substances can also be banned were risks are deemed to be unmanageable. As such, REACH encourages substitution of the most dangerous chemicals when suitable alternatives have been identified.

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[34] Study on the implementation of product design requirements set out in Article 4 of the WEEE Directive. The case re-usability of printer cartridges. Final report. January 2018.
[35] Ink reservoirs as containers or bottles that can be refilled externally using ink supplied in low cost, which are significantly cheaper than cartridges.
[36] Restricted only to carrying the tone, simplifying the construction and material impact of the cartridge.
[37] Where the cartridge as a replaceable element has disappeared completely. E.g. a manufacturer has replaced the cartridge by a refillable toner reservoir replenished from simply-packaged toner refills.
[38] European Toner & Inkjet Remanufacturers' Association aisbi/ivzw. Activity report 2017-2018
[39] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02006R1907-20140410&from=EN

As REACH applies to all chemical substances defined in Article 3 contained in articles placed on the market, such is the case of imaging equipment products.

EU Directive 2011/65/EU – RoHS Directive[40]

The Restriction of Hazardous Substances (RoHS) Directive aims to reduce hazardous substances from electrical and electronic equipment (EEE) that is placed on the EU market. A number of hazardous substances are listed in the Directive along with maximum concentration values that must be met. The RoHS Directive does contain some exemptions where it has been decided that it may not be possible to manufacture some products without the use of one or more of the banned substances.

1.2.2 Member State and third countries legislations and initiatives

Blue Angel

The Blue Angel[41], a German based eco-label, includes specifications for many products and services on the EU market. The eco-label includes detailed specifications for several key pieces of information technology equipment.

The Blue Angel criteria are developed by a multi stakeholder group consisting of government bodies, environmental and consumer associations, trade unions, industry and academia. There are two Blue Angel specifications that are relevant for this review study of the Voluntary Agreement on imaging equipment: The Blue Angel on imaging equipment (RAL-UZ 205)[42] and the Blue Angle on "Remanufactured Toner Modules" (RAL-UZ 177)[43].

In order to be considered within scope of the current Blue Angel specification on imaging equipment products need to offer printing as their primary function, are capable of producing monochrome or colour printouts (4-colour-printing) on standard paper with a grammage of 60 to 80 g/m2, are capable of processing media or a minimum format of DIN A4 and up to a maximum format of DIN A3+, and work as electrophotographic devices (LED or laser technology) by using toners or as inkjet devices by using inks (or gels, or waxes). As well as including imaging products in scope, the Blue Angel specification also includes additional components in scope including:

- Consumable Materials
- Photoconductor Drums
- Packaging

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[40] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32011L0065&from=EN
[41] https://www.blauer-engel.de/en/blue-angel/who-is-behind-it
[42] https://www.blauer-engel.de/en/products/electric-devices/drucker-und-multifunktionsgeraete
[43] https://www.blauer-engel.de/en/products/paper-printing/tonermodule

The Blue Angel categorisation process is based on technical attributes of the products. Products are categorised based on:

- Colour capability
- Marking technology
- Consumable type

Unlike ENERGY STAR v2.0 specification (most recent specification in effect, though v3.0 has been published), the Blue Angel eco-label does not include detailed specific definitions for each type of imaging equipment in scope. The Blue Angel specification does include a number of different definitions for key issues in the areas of:

- Stakeholders (i.e. user, manufacture or distributor)
- Device designs (i.e. basic description)
- Primary Functions
- Printing and Printing Technologies
- Device Parts
- Materials and operating materials
- Operation Modes
- Time-related Definitions
- Power Consumption

The Blue Angel criteria on imaging equipment (RAL-UZ 205) contains a broad range of requirements across multiple environmental category areas. In particular, the Blue Angel specification addresses:

- Energy efficiency
- Lifetime extension
- Recyclability
- Long-life and recyclable design
- Hazardous material content
- Particle emissions
- Noise emissions

The Blue Angle has also developed a set of criteria on "Remanufactured Toner Modules" (RAL-UZ 177). The remanufactured toner module criteria include requirements on the following areas:

- Collection and disposal
- Documentation of collection process
- Remanufacturing process

- Requirements for housing parts
- Heavy metal content
- Azo Colorant content
- Emissions
- Quality

The full details of each set of criteria can be viewed on the Blue Angel website.

Nordic Swan Ecolabel

The Nordic Swan Ecolabel is the official eco-label of the Nordic countries (Denmark, Norway, Sweden, Finland and Iceland)[44]. Nordic Swan scheme includes specification for over 60 product groups, including imaging equipment.

The Nordic Swan specification (v6.5) for imaging equipment was implemented in June 2013 and has an effective end date of the 31st of December 2020[45]. There is no planned revision in 2019, and it is thus very likely that the criteria document will be prolonged 12 to 24 months after effective end date[46].

The scope of the Nordic Swan imaging equipment specification extends to the following product types:

- Copiers
- Digital duplicators
- Facsimile machines (Fax machine)
- Multifunction devices (MFD)
- Printers
- Scanners

In addition to the main product groups listed above the Nordic Swan also includes consumable products and material in scope including:

- OPC (Optical Photosensitive Conductor) kits
- Drums
- Toner powder
- Toner cartridges

[44] http://www.nordic-ecolabel.org/about/
[45] http://www.nordic-ecolabel.org/product-groups/group/?productGroupCode=015
[46] Information provided by Product Development Manager of Nordic Swan Specification in October 2018

The Nordic Swan includes the following product definitions which are aligned with the definitions used by the Voluntary Agreement V5.2 on imaging equipment:

- Copier - A commercially-available imaging product whose sole function is the production of hard copy duplicates from graphic hard copy originals. 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 copiers or upgradeable digital copiers (UDCs).
- Digital duplicator - A commercially-available imaging product that is sold in the market as a fully-automated duplicator system through the method of stencil duplicating with digital reproduction functionality. 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 digital duplicators.
- Facsimile machine (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.
- Multifunction device (MFD) - A commercially-available imaging product, which is a physically-integrated device or a combination of functionally-integrated components, that performs two or more of the core functions of copying, printing, scanning, or faxing. The copy functionality as addressed in this definition is considered to be distinct from single sheet convenience copying offered by fax machines. 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 MFDs or multifunction products (MFPs).
- Printer - A commercially-available imaging product that serves as a hard copy output device, and is capable of receiving information from single-user or networked computers, or other input devices (e.g., digital cameras). 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 printers, including printers that can be upgraded into MFDs in the field.
- Scanner - A commercially-available imaging product that functions as an electro-optical device for converting information into electronic images that can be stored, edited, converted, or transmitted, primarily in a personal computing environment. 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 scanners.

The Nordic Swan imaging equipment environmental requirements are largely harmonised with the Blue Angel eco-label but also with the ENERGY STAR label (on energy related impacts); the categorisation approach is also harmonised.

As well as having a detailed environmental specification for imaging equipment, the Nordic Swan has also developed a specification for remanufactured OEM toner cartridges (v5.4)[47].

The Nordic Swan remanufactured OEM toner cartridge specification was implemented in June 2012 and has an effective end date of December 2022. An evaluation of these criteria took place in 2017, which concluded that the criteria is still valid and relevant. Thus, there is no revision planned for next year[48].

The scope is limited to toner cartridges with no further categorization.

The Nordic Swan criteria are closely linked to those found in the Blue Angel, meaning that if a product is already registered with Blue Angel then it is relatively straightforward to also apply for a Nordic Ecolabel licence.

The Nordic Swan criteria on imaging equipment includes requirements on:

- Energy efficiency
- Disassembly
- Ensuring cartridges are not designed to prevent re-use
- Ability to use remanufactured cartridges
- Take back system for consumables
- Marking of plastics in casings and their components
- Single plastic casing parts in casings and their components
- Limitations on different types of plastic in small parts
- Chlorinated polymer restrictions
- Flame retardants restrictions
- Phthalates in external power cable
- Chemicals used during production
- Plastic materials in packaging
- Re-cycled material in packaging
- Availability of spare parts
- Duplex printing

[47] http://www.nordic-ecolabel.org/product-groups/group/?productGroupCode=008
[48] Information provided by Product Development Manager of Nordic Swan Specification in October 2018

- Consumable page yield efficiency
- Chemical Emissions
- Noise Emissions
- Product quality

The Nordic Swan criteria on remanufactured toner cartridges includes requirements on:

- Hazardous material restrictions in toner
- Working conditions
- Chlorinated polymer restrictions
- Plastic materials in packaging
- Minimum weight recycled parts
- Take-back system
- Waste from production
- Production quality
- Print quality
- Measurable yield

The full details of each set of criteria can be viewed on the Nordic Swan website.

ENERGY STAR

ENERGY STAR is a US programme on energy efficiency of a broad range of products. An agreement between the Government of the United States of America and the European Community on the coordination of energy-efficient labelling programs for office equipment was effective between June 2001 and February 2018, which included imaging equipment. The current effective version of the ENERGY STAR specification for imaging equipment (ENERGY STAR v2.0) was developed during 2011 to 2013 with implementation of the specification occurring in January 2014 in the US[49] and May 2014 in the EU[50].

The ENERGY STAR v2.0 specification will be retired on the 10th October 2019, with the new ENERGY STAR v3.0 specification effective from the 11th October 2019. Manufacturers have been able to register products to the new ENERGY STAR v3.0 specification since the 28th December 2018.

The ENERGY STAR v3.0 specification includes some key changes over the current ENERGY STAR v2.0 specification including:

- Removal of copiers and fax machines from scope due to low sales volumes

[49] https://www.energystar.gov/products/office_equipment/imaging_equipment/partners
[50] EU ENERGY STAR website was shutdown following the expiration of the EU-US agreement on 20th February 2018

- Inclusion of a "Professional Imaging Products" category
- Inclusion of a Professional Digital Front-end (DFE) category
- Increasing the efficiency requirements of single voltage External Power Supplies (EPS) to match the Level VI requirements in the International Efficiency Marking Protocol [51]
- More ambitious requirements for TEC Imaging Equipment products that are shipped with a Digital Front End (DFE)
- Inclusion of default recovery time requirements for TEC products to help ensure that products have a quick wake-up from Sleep Mode
- Extension of default delay time requirements to all Imaging Equipment products (both TEC and OM)
- Reduced maximum delay times to sleep that can be set by the user
- Slightly more stringent Automatic Duplexing Requirements for all TEC MFDs and Printers (i.e. removal of optional accessory option)
- Duplexing requirement harmonized in line with Blue Angel, by requiring duplexing by default over the current speed bins.
- Reduction of the additional energy allowance given for products capable of supporting output to A3 size media
- Addition of a small extra allowance for Wi-Fi functionality in TEC products
- Energy efficiency requirements for TEC products that will only be met by between 24% to 29% (depending on speed and type) of the most efficient products in the ENERGY STAR dataset
- No proposed decrease in sleep mode base power demand requirements for OM products due to low savings potentials
- Removal of additional sleep mode power demand allowances for scanner units in OM MFD products (allowance, at same level as in ENERGY STAR v2.0 combined into base allowance)
- Removal of additional sleep mode power demand allowances for internal disk drives in OM products
- Proposal to reduce off mode requirements to 0.3W to align with the findings of the European Commission Network Standby review study.

The ENERGY STAR v3.0 specification covers a wide range of domestic and office-based imaging equipment.

The ENERGY STAR v3.0 specification for imaging equipment includes detailed definitions for products in scope of the current Voluntary Agreement:

[51] https://www.regulations.gov/document?D=EERE-2008-BT-STD-0005-0218

- **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 an MFD.
- **Facsimile (Fax) Machine**: A product whose primary functions are (1) to scan paper originals for electronic transmission to remote units, and (2) to receive electronic transmissions for conversion to paper output. A fax machine may also be capable of producing paper duplicates. Electronic transmission is primarily over a public telephone system, but may also be via a computer network or the Internet. This definition is intended to cover products that are marketed as fax machines.
- **Multifunction Device (MFD)**: A product that performs the core functions of a Printer and Scanner. 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).

The ENERGY STAR v3.0 specification includes definitions for other types of imaging equipment, such as scanners, digital duplicators and mailing machines, which are not covered under the scope of the current Voluntary Agreement:

- **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.
- **Digital Duplicator**: A product sold as a fully-automated duplicator system through the method of stencil duplicating with digital reproduction functionality. This definition is intended to cover products that are marketed as digital duplicators.
- **Mailing Machine**: A product whose primary function is to print postage onto mail pieces. This definition is intended to cover products that are marketed as mailing machines.

The ENERGY STAR v3.0 specification also includes a definition for "Professional Imaging Products" which, in virtually all cases (i.e. only colour printers with colour speeds at 50ipm where colour speed matches monochrome speed), would not fall in scope of the current Voluntary Agreement:

- **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 color, color product speed equal to or greater than 50 ipm;
e) Print resolution of 600 x 600 dots per inch or greater for each color;
f) Weight of the base model greater than 180 kg; and

Five of the following additional features for color 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) Third-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.

The ENERGY STAR v3.0 specification for imaging equipment also includes detailed complementary definitions for the marking technologies (i.e. the type of technology used to place an image on the output media), the media format sizes (i.e. the size of the paper or other media that can be used with the imaging equipment product), power modes and additional functionalities found in imaging equipment. The definitions of the various marking technologies in the ENERGY STAR v3.0 specification are:

- Direct Thermal (DT): 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.
- Dye Sublimation (DS): A marking technology characterized by the deposition (sublimation) of dye onto print media as energy is supplied to heating elements.
- Electro-photographic (EP): A marking technology characterized by the illumination of a photoconductor in a pattern representing the desired output image via a light source, development of the image with particles of toner using the latent image on the photoconductor to define the presence or absence of toner at a given location, transfer of the toner to the final print media, and fusing to cause the output to

become durable. For purposes of this specification, Color EP products simultaneously offer three or more unique toner colors, while Monochrome EP products simultaneously offer one or two unique toner colors. This definition includes Laser, Light Emitting Diode (LED), and Liquid Crystal Display (LCD) illumination technologies.

- Impact: 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. This definition includes Dot Formed Impact and Fully Formed Impact.
- Ink Jet (IJ): A marking technology characterized by the deposition of colorant in small drops directly to the print media in a matrix manner. For purposes of this specification, Color IJ products offer two or more unique colorants at one time, while Monochrome IJ products offer one colorant at a time. This definition includes Piezoelectric (PE) IJ, IJ Sublimation, and Thermal IJ. This definition does not include High Performance IJ.
- High Performance IJ: 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.
- Solid Ink (SI): A marking technology characterized by ink that is solid at room temperature and liquid when heated to the jetting temperature. This definition includes both direct transfer and offset transfer via an intermediate drum or belt.
- Stencil: A marking technology characterized by the transfer of images onto print media from a stencil that is fitted around an inked drum.
- Thermal Transfer (TT): A marking technology characterized by the deposition of small drops of solid colorant (usually colored waxes) in a melted/fluid state directly to print media in a matrix manner. TT is distinguished from IJ in that the ink is solid at room temperature and is made fluid by heat.

Of the above marking technologies, only Electrophotography (EP), Inkjet (IJ), high performance IJ and Solid Ink (SI) are covered under the current Voluntary Agreement scope.

The ENERGY STAR v3.0 specification includes a detailed categorization process but with two main overarching categories of called "TEC" (Typical Electricity Consumption) and "OM" (Operational Mode). Most, but not all, thermal based imaging equipment (i.e. those that use significant amounts of heat to deposit an image) are defined as TEC products and products that use no, or little heat, are classed as OM products. There are exceptions to this general rule however. Further sub-categories of product types are defined underneath these two overarching categories of "TEC" and "OM" based on other technical features such as imaging speed.

The ENERGY STAR v3.0 specification does not include any upper limits on imaging speed (i.e. the speed which products can print, copy or scan), meaning that high speed products can obtain ENERGY STAR certification. The scope of the current Voluntary Agreement is restricted to mono imaging equipment with imaging speeds below 66 A4 images per minute (ipm) and colour imaging equipment with imaging speeds below 51 A4 ipm.

The definition does not extend the scope of product types covered under ENERGY STAR, as many products meeting the proposed definition are already ENERGY STAR qualified. However, the inclusion of a professional imaging equipment category within ENERGY STAR allows for a clearer delineation between office-based products and products used for commercial printing. This delineation could serve to be useful within a revised Voluntary Agreement (VA) given that the scope of the current VA is limited to home and office-based products and does not cover professional imaging equipment.

The ENERGY STAR v3.0 specification for imaging equipment includes detailed energy efficiency requirements for many types of domestic and office-based imaging equipment. The ENERGY STAR v3.0 product criteria for imaging equipment can be found in the ENERGY STAR's website[52].

US EPEAT

EPEAT is a green procurement scheme aimed at promoting the development and dissemination of multi-criteria specifications for a range of ICT products[53]. The programme is managed by the Green Electronics Council and supported by the US EPA and US DoE. The programme is based in the US but is active internationally with manufacturers able to register products separately in 42 countries around the world.

The EPEAT scheme adopts all scope, definitions, categorization and requirements from the IEEE 1680.2 standard. The IEEE 1680.2 standard, and therefore the EPEAT scheme, currently include a specification for imaging equipment which adopts the ENERGY STAR v2.0 scope and categorisation process. The reference to ENERGY STAR is dynamic, meaning that the future update on the US ENERGY STAR v3.0 specification will be automatically referenced by the IEEE 1680.2 standard.

The EPEAT scope is slightly wider than ENERGY STAR in that consumables (cartridges as well as toner material) and packaging are also within scope.

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[52] https://www.energystar.gov/products/office_equipment/imaging_equipment/key_product_criteria
[53] http://www.epeat.net/about-epeat/

The EPEAT criteria are taken from standards that are developed either through IEEE or more recently NSF International (an independent, accredited organization that develops standards in the USA)[54]. The EPEAT specification for imaging equipment covers a broad range of environmental performance criteria for the design of imaging equipment products and associated processes. The scheme is intended to provide a tool for government, institutional, corporate, and consumer purchasers to identify products that demonstrate environmental leadership.

The EPEAT initiative contains a large number of criteria that address various environmental impact categories associated with imaging equipment, consumables and surrounding processes such as recycling. The impact areas addressed by the EPEAT specification include:

- Reduction/elimination of environmentally sensitive material
- Materials selection
- Design for end-of-life
- Product longevity/life-cycle extension
- Energy conservation
- End-of-life management
- Corporate performance
- Packaging
- Consumables
- Indoor air quality

US Regulation on External Power Supplies

In April 2014, the US Department of Energy (DoE) published an updated regulation dealing with the energy efficiency of external power supplies (EPS)[55]. The regulation refers to the EPS definition[56] below which dictates the EPS in scope which are referred to as 'Class A':

a. The term "external power supply" means an external power supply circuit that is used to convert household electric current into DC current or lower-voltage AC current to operate a consumer product.
b. The term "class A external power supply" means a device that:
    i. is designed to convert line voltage AC input into lower voltage AC or DC output;
    ii. is able to convert to only 1 AC or DC output voltage at a time;

[54] http://www.nsf.org/about-nsf/
[55] https://www.regulations.gov/document?D=EERE-2008-BT-STD-0005-0219
[56] 42 U.S.C. United States Code, 2010 Edition Title 42 - THE PUBLIC HEALTH AND WELFARE CHAPTER 77 - ENERGY CONSERVATION SUBCHAPTER III - IMPROVING ENERGY EFFICIENCY Part A - Energy Conservation Program for Consumer Products Other Than Automobiles Sec. 6291 -Definitions https://www.gpo.gov/fdsys/pkg/USCODE-2010-title42/html/USCODE-2010-title42-chap77-subchapIII-partA-sec6291.htm

iii. is sold with, or intended to be used with, a separate end-use product that constitutes the primary load;
iv. is contained in a separate physical enclosure from the end-use product;
v. is connected to the end-use product via a removable or hard-wired male/female electrical connection, cable, cord, or other wiring; and
vi. has nameplate output power that is less than or equal to 250 watts.

c. The term "class A external power supply" does not include any device that:
   i. requires Federal Food and Drug Administration listing and approval as a medical device in accordance with section 360c of title 21; or
   ii. powers the charger of a detachable battery pack or charges the battery of a product that is fully or primarily motor operated

The definition illustrates that EPS shipped with imaging equipment would likely be in scope of the US regulation. It should be noted that most non-domestic and also many domestic imaging equipment products are shipped with internal power supply (IPS) units rather than EPS. However, the trend towards more mobile products may influence the market technological trend and may influence also imaging equipment products, especially those on the cheaper range.

China - MEPS

In 2012 China launched their "Hundred Energy Efficiency Standards program", with the aim of developing 100 energy-saving standards (including MEPS) by the end of 2012. A further 100 standards were developed in 2014 and 2015. MEPS were first developed for imaging equipment in 2008, updated standard for minimum allowable values of energy efficiency and energy efficiency grades for copy machines, printers and fax machines was published in 2014[57]. This means that imaging equipment are also mandatorily graded according to the 3 grades of the China Energy Label. See unfilled labels below, where the typical energy consumption (TEC) should be shown in kWh on the label to the left, and consumption during operational modes (OM) such as active and standby mode in W should be shown on the label to the right.

[57] http://www.std.gov.cn/gb/search/gbDetailed?id=71F772D7ED11D3A7E05397BE0A0AB82A

Figure 3: China Energy Labels for copy machines, printers and fax machines, TEC label (left) and OM label (right).

Korea Ecolabel

The Korean eco-label covers a wide range of product types including several different specifications for imaging equipment and related consumables[58]. The Korea eco-label has specifications in place for:

- Printers (revised Feb 2013) - including laser and inkjet printers as well as multi-functional devices. The scope appears to extend to all types of office and domestic printers with the exemption of products which meet any of the following requirements:
    - printers that use continuous roll-type paper and have a printing speed higher than 60 PPM
    - printers with printing speed higher than 70 PPM
    - large format printers shall be excluded.
- Fax machines - thermal and inkjet based (revised Feb 2013)
- Copying machines (revised Feb 2013)
- Toner cartridges (revised May 2017)

[58] http://el.keiti.re.kr/enservice/enpage.do?mMenu=2&sMenu=1

The Korea Ecolabel does not contain detailed definitions for the imaging equipment in scope. The label does contain definitions for consumables in scope of the consumables specification:

- All-in-one optical drum type toner cartridges: all-in-one type toner cartridges to perform functions in one apparatus during a general printing process except the fixing function.
- Optical drum detachable toner cartridges: toner cartridge that excludes optical drums and related functions and that has, at least, the function of directly supplying a toner to an optical drum in an all-in-one type toner cartridge structure. (Note: A structure with a magnetic roller is common and an optical drum can be installed within a printer body or separate cartridge).
- Container type toner cartridge: toner cartridge with the structure that has only the function of transferring the toner in a simple toner container or a container to the stage prior to supplying the toner to the optical drum.
- Original toner cartridges: toner cartridge that is produced by the printer manufacturer directly or in consignment and applicable for each printer model.
- Regenerated toner cartridges: toner cartridge which is made to be reused by filling a new toner after disassembling the use completed toner cartridge to remove the remaining waste toner, and replacing or repairing the limit part (it includes replacing or repairing components, drums and wiper blades that are damaged or inadequate for re-use).

The Korea ecolabel criteria on imaging equipment include requirements on:

- Energy efficiency
- Duplex printing
- Hazardous substance restrictions
- Chemical Emissions
- Noise Emissions
- Take-back system
- Marking of plastics in casings and their components
- Limitations on different types of plastic in parts
- Plastic materials in packaging
- Disassembly
- Reusability of cartridges
- Safety criteria
- Broadcasting and communication quality
- Information ozone filter
- Information on disposal and recycling

- Information on product warranty

The Korea ecolabel criteria on toner cartridges include requirements on:

- Recycled paper support
- Hazardous substance restrictions
- Reusability
- Packaging requirements
- Take back requirements
- Ease of disassembly
- Ability to reuse
- Toner emissions
- Disposal requirements
- Measurable yield
- Minimum yield requirements
- Print quality
- Toner melting point requirements
- Consumer information reporting

The full details of each set of criteria can be viewed on the Korea Ecolabel website.

Vietnam National Energy Efficiency Program (VNEEP)

In 2005, the Vietnamese Government, through the Ministry of Industry and Trade (MOIT) released the Vietnam National Energy Efficiency Program (VNEEP).[59] In 2015, during the second phase of this programme, mandatory energy efficiency measures were placed on some types of imaging equipment (i.e. standard-format printers and multi-functional products). The mandatory energy efficiency requirements include a 1W off mode limit where no fax functionality is present and a 2W off mode limit for products with fax functionality.[60]

Japan - Top Runner Programme

Japan's Energy Conservation Law includes target efficiency standards and requirements for energy-consuming products called the "Top Runner" program.[61] The targets are set by identifying the most efficient model on the market. Manufacturers are then required to ensure that the products they place on the market meet these target values. Compliance can be achieved on a sales weighted average across all products, of the same type, placed

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[59] http://www.moit.gov.vn/tin-chi-tiet/-/chi-tiet/quy-%C4%91inh-dan-nhan-nang-luong-cho-cac-phuong-tien-thiet-bi-su-dung-nang-luong-100136-16.html
[60] https://vanbanphapluat.co/tcvn-9509-2012-may-in-hieu-suat-nang-luong
[61] http://www.enecho.meti.go.jp/category/saving_and_new/saving/data/toprunner2015e.pdf

on the market. The Top Runner programme includes target values for photocopiers and multi-functional devices which were last developed in 2011.[62]

Other initiatives

Voluntary initiatives dealing with the environmental impacts of imaging equipment have been developed in a large number of other countries including the following countries, however they are not presented here in detail:

- Canada
- China (PRC)
- Chinese Taipei (Taiwan)
- Hong Kong
- India
- Iran
- Japan
- Korea (ROK)
- Russia
- Switzerland
- Thailand
- Turkey
- Vietnam

1.2.3 Summary

Imaging equipment is covered by a large range of initiatives with much commonality in terms of scope and categorisation approaches.

Whilst ENERGY STAR appears to have a strong influence on the scope and categorisation approaches used by other initiatives, the ENERGY STAR scope is often truncated when copied into other initiatives.

Most of the specifications are somewhat aged with most having been developed around 2013. Some of the other initiatives, such as EPEAT and Nordic Swan, include a dynamic link to ENERGY STAR specifications. This means that when an ENERGY STAR specification is updated, the requirements are automatically adopted into that initiative. Conversely, changes in scope within new ENERGY STAR specifications are not always transferred over into other initiatives. For example, the scope of the Nordic Swan initiative remains un-changed due to changes in scope within a new ENERGY STAR specification. The product scope within EPEAT is also dynamically linked to the scope in the latest ENERGY STAR specification. The revised ENERGY STAR specification may promote additional initiatives

[62] https://www.asiaeec-col.eccj.or.jp/top-runner-target-standards/

(e.g. Nordic Swan and Blue Angel) to also update their scope and categorisation approaches on imaging products.

The product definitions used by the different initiatives are often taken directly from ENERGY STAR or are based on the ENERGY STAR definitions with alterations made. In some cases, such as in the Blue Angel and Korea Ecolabel there are more significant differences with the ENERGY STAR definitions.

The number and type of environmental criteria covered under each of the main initiatives can vary considerably. Some of the initiatives, such as ENERGY STAR, concentrate on product energy use, whereas other initiatives, such as the US EPEAT and the Blue Angel, address a broad range of the environmental aspects associated with imaging equipment and consumables. Table 7 provides an overview of environmental areas, those marked with blue are aspects of the criteria covered by the different initiatives (unmarked areas represent no criteria coverage), and those marked with red are aspects covered by EU VA on imaging equipment.

Table 7: Overview of environmental areas addressed by the EU VA and most relevant other obligatory and voluntary schemes. Blue indicates aspects of the criteria covered by the different initiatives; red aspects covered by EU VA on imaging equipment; and unmarked no criteria coverage.

Environmental Areas		EU Voluntary Agreement coverage	Coverage by other schemes							
			ENERGY STAR v2.0	ENERGY STAR v3.0	Blue Angel	Nordic Swan	EPEAT/IEEE 1680.1	Korea Eco-label	Ecodesign Standby	Ecodesign EPS
Energy/ Power in Use	Energy in Use (multiple power states)									
	Power Demand in low power modes									
	Power Management									
	Maximum wake times									
	Internal Power Supply Efficiency									
	External Power Supply Efficiency									
	Life-cycle assessment (LCA)									
Paper Use	Automatic duplex									
	N-up printing									
	Use recycled paper									
Content of hazardous substances	Restrictions									
	Inventory of safer substitutions (i.e. intentionally added chemicals)									
Recycled content	Postconsumer recycled plastic content (declaration)									

Environmental Areas		EU Voluntary Agreement coverage	Coverage by other schemes							
			ENERGY STAR v2.0	ENERGY STAR v3.0	Blue Angel	Nordic Swan	EPEAT/IEEE 1680.1	Korea Eco-label	Ecodesign Standby	Ecodesign EPS
	Postconsumer recycled plastic content (inclusion)									
Bio based plastic material content	Bio based plastic materials content (declaration)									
	Bio based plastic materials content (inclusion)									
Product weight	Weight declaration									
Recyclability	Ease of disassembly									
	Limits plastic type per plastic part									
	Manual separation and marking of plastics									
	Restriction surface coatings									
	Identification hazardous substances/special handling needs									
	Design for reusability									
	Reusable/recyclable minimums									
End-of-life analysis and planning	Product end-of-life characterization report									
Product Lifetime extension	Early failure process/Guarantee									
	Spare parts availability									
	Upgradeability									
Product take-back	End-of-life processing requirements									
Corporate performance	Environmental management system									
	Public disclosure of key environmental aspects									
	Public disclosure of supply chain toxics									
	Working conditions									
Manufacturing Impacts	Chemicals used/ emitted during production									
Packaging	Substance restrictions									
	Recyclable materials									
	Separable materials									
	Compostability/ recyclability									

Environmental Areas		EU Voluntary Agreement coverage	Coverage by other schemes							
			ENERGY STAR v2.0	ENERGY STAR v3.0	Blue Angel	Nordic Swan	EPEAT/IEEE 1680.1	Korea Eco-label	Ecodesign Standby	Ecodesign EPS
	Recycled content									
	Plastics marked									
	Take-back service									
Consumables	Use of non-manufacturer cartridges/containers									
	Cartridge/Container Design for Recycling									
	Cartridge/Container Design for Reuse									
	Cartridge/Container Take-back Offered									
	Toner/Ink Recycling Conducted									
	Reporting take-back statistics									
	Reuse of materials from take-back scheme									
	Consumable imaging yield efficiency									
	Measured cartridge yield									
	Minimum cartridge yield									
	Cartridge durability									
	Cartridge print quality									
	Cartridge remanufacturing/ recycling process requirements									
	Restrictions number plastics									
	Marking plastic parts									
	Substance restrictions									
	Ease of disassembly									
Emissions	Chemical Emissions (reporting)									
	Chemical Emissions (limits)									
	Noise Emissions (reporting)									
	Noise Emissions (limits)									
Safety	Safety requirements									

1.3 Review of relevant standards

1.3.1 European and international standards

European (EN) standards are documents that have been ratified by one of the three European Standards Organizations (ESOs), **CEN** (the European Committee for Standardization), **CENELEC** (the European Committee for Electrotechnical Standardization) or **ETSI** (European Telecommunications Standards Institute). Many of the EN standards result from the adaptation of international standards (**IEC** and **ISO**), to ensure that they are appropriate to European conditions, etc.

CEN, CENELEC and ETSI deal with different fields of activity, but cooperate in a number of areas of common interest. They also share common policies on issues where there is mutual agreement.

The CEN/CENELEC Internal Regulations, Part 2, state that the EN 'carries with it the obligation, to be implemented at national level, by being given the status of a national standard and by withdrawal of any conflicting national standards. Therefore, a European Standard automatically becomes a national standard in each of the 34 CEN-CENELEC member countries.

The international standards mentioned in this report are **ISO** (International Organization for Standardization) standards and **IEC** (International Electrotechnical Commission) standards.

Measurement and performance standards

ISO/IEC 24711:2015 Method for the determination of ink cartridge yield for colour inkjet printers and multi-function devices that contain printer components

The scope of ISO/IEC 24711:2015 is limited to evaluation of ink cartridge page yield for ink-containing cartridges (i.e. integrated ink cartridges and ink cartridges without integrated printheads) for colour inkjet print systems. ISO/IEC 24711:2015 can also be applied to the printer component of any multifunctional device that has a digital input printing path, including multi-function devices that contain inkjet printer components. Both liquid and solid ink products can be tested using ISO/IEC 24711:2015.

ISO/IEC 29102:2015 Information technology -- Office equipment -- Method for the determination of ink cartridge photo yield for colour printing with inkjet printers and multi-function devices that contain inkjet printer components

ISO/IEC 29102:2015 is to provide a method to determine the ink cartridge photo yield of ink-containing cartridges (i.e. integrated ink cartridges and ink cartridges without integrated printheads) for colour photo printing with colour inkjet printers and multifunction

devices that contain inkjet printer components. In the case where a cartridge set can be used in multiple printer models, only one yield test needs to be performed as long as the difference between printer models does not impact yield.

ISO/IEC 29103:2011 Information technology -- Office equipment -- Colour photo test pages for measurement of ink cartridge yield for colour photo printing

ISO/IEC 29103:2011 defines a set of test images in a common file format, JPEG, that are used in the testing of cartridge yield for printing of photographs. The defined documents are used in ISO/IEC 29102 to determine the photo yield of cartridges in an inkjet-based printing system.

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 19752:2017 is limited to the evaluation of toner cartridge page yield for toner containing cartridges (i.e. all-in-one toner cartridges and toner cartridges without a photoconductor) for monochrome electrophotographic print systems. This document could also be applied to the printer component of any multifunctional device that has a digital input-printing path (i.e. 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

The scope of ISO/IEC 19798:2017 is limited to evaluation of toner cartridge page yield for toner-containing cartridges (i.e. all-in-one toner cartridges and toner cartridges without a photoconductor) for colour electrophotographic print systems. This document can also be applied to the printer component of any multifunctional device that has a digital input printing path, including multi-function devices that contain electrophotographic printer components.

ISO/IEC 24712:2007 Colour test pages for measurement of office equipment consumable yield

ISO/IEC 24712:2007 defines colour test pages for the measurement of consumable yield. The test page suite includes four "customer" type documents and one "diagnostic" page that is used to determine end of ink or toner consumable life. These pages can be used for electro-photographic, inkjet printers and multi-function devices that have a digital printing path, i.e. an all-in-one electro-photographic machine that has digital printing capabilities.

ISO/IEC 24790:2017 Information technology -- Office equipment -- Measurement of image quality attributes for hardcopy output -- Monochrome text and graphic images

ISO/IEC 24790:2017 specifies device-independent image quality attributes, measurement methods and analytical procedures to describe the quality of output images from hardcopy devices. This document is applicable to human-readable monochrome documents produced from printers and copiers.

ISO 179-1:2010 Plastics -- Determination of Charpy impact properties -- Part 1: Non-instrumented impact test

ISO 179-1:2010 specifies a method for determining the Charpy impact strength of plastics under defined conditions. A number of different types of specimen and test configurations are defined. Different test parameters are specified according to the type of material, the type of test specimen and the type of notch. The method can be used to investigate the behaviour of specified types of specimen under the impact conditions defined and for estimating the brittleness or toughness of specimens within the limitations inherent in the test conditions.

DIN 33870-1:2013-12 Office machines - Requirements and tests for the preparation of refilled toner modules for electrophotographical printers, copiers and facsimile machines - Part 1: Monochrome

The purpose of this document is to specify minimum requirements for a consistent print quality with the intention of ensuring undisturbed functionality over the total service life of toner modules.

DIN 33870-2:2013-12 Office machines - Requirements and tests for the preparation of refilled toner modules for electrophotographical printer, copiers and facsimile machines- Part 2: 4-Colour-printers

This standard contains requirements for the preparation of refilled toner modules for 4-colour-printers. It also specifies test methods for the determination of toner module yield and quality characteristic features of the printouts. The aim of this standard is to specify minimum requirements for consistent print quality and trouble-free operation over the entire time of use of the toner cartridge.

ISO/IEC 24700:2005 Quality and performance of office equipment that contains reused components

ISO/IEC 24700:2004 specifies product characteristics for use in an original equipment manufacturer's or authorized third party's declaration of conformity to demonstrate that a

marketed product that contains reused components performs equivalent to new, meeting equivalent to new component specifications and performance criteria, and continues to meet all the safety and environmental criteria required by responsibly built products. It is relevant to marketed products whose manufacturing and recovery processes result in the reuse of components.

ISO/IEC 10561:1999 Information technology -- Office equipment -- Printing devices -- Method for measuring throughput -- Class 1 and Class 2 printers

The standard specifies a method for measuring the throughput of class 1 and class 2 printers, as defined in ISO/IEC 11160-1. Three different test patterns are provided for:

- a standard business letter;
- a spreadsheet;
- a graphic pattern.

The standard also defines a method for a performance test and one for an endurance test. These tests are intended to measure only the printer throughput for documents in the same class as the test patterns and not to evaluate any other printer features such as character shaping, print compressions, network/controller performance, colour, etc. The method is relevant to class 1 and class 2 printer types (e.g. dot matrix, daisy wheel, inkjet, thermal transfer printers) and to all configurations (e.g. tractor feed, cut sheet feed, 80-column and over 132-column print width, etc.). It is not the most suitable for comparing performance of other classes of printing devices such as high-speed page-oriented printers or colour printers. This method is intended for use by printer manufacturers and test houses so that a common form of test result presentation shall be obtained. It will also enable a user to make a quick and easy comparison of the printing throughput of different printers.

ISO/IEC 17629:2014 Information technology -- Office equipment -- Method for measuring first print out time for digital printing devices

ISO/IEC 17629:2014 specifies a method for measuring first print out time of digital printing devices. It is applicable to digital printing devices and multifunctional devices. It is intended to be used for black and white (B&W) as well as colour digital printing devices and multifunctional devices of any underlying marking technology. It includes instructions for test charts, test setup procedure, test procedure, and the reporting requirements for the digital printing measurements

DIN 33871-1:2013-12 Information technology - 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

The aim of the standard is to achieve constant print quality with black or coloured ink of the refillable inkjet print heads and inkjet tanks. It specifies the principles for recycling as well as testing of colour rendition quality and yield.

EN 12281:2002 Printing and business paper – Requirements for copy paper for dry toner imaging processes

This European Standard specifies the performance requirements for uncoated cut-size paper for dry toner imaging processes (i.e. copy paper), in 80 g/m2 and in A4 format based on EN 20216.

ISO 7779:2010 Acoustics -- Measurement of airborne noise emitted by information technology and telecommunications equipment

ISO 7779:2010 specifies procedures for measuring and reporting the noise emission of information technology and telecommunications equipment. The basic emission quantity is the A-weighted sound power level which may be used for comparing equipment of the same type but from different manufacturers, or for comparing different equipment**.**

ISO 9296:2017 Acoustics -- Declared noise emission values of information technology and telecommunications equipment

ISO 9296:2017 specifies:

a) for a batch of equipment, the method for determining the following values:

- the declared mean A-weighted sound power level, LWA,m;
- the declared mean A-weighted emission sound pressure level, LpA,m;
- the statistical adder for verification, Kv;
- the statistical upper limit A-weighted sound power level, LWA,c;

b) how acoustical and product information is to be published electronically or in hard-copy format in technical documents or other product literature supplied to users by the manufacturer or declarer;

c) the method for verifying the noise emission values that are declared by the manufacturer or declarer.

ISO/IEC 28360:2015 Information technology -- Office equipment -- Determination of chemical emission rates from electronic equipment

ISO/IEC 28360:2015 specifies methods to determine chemical emission rates of Analyte from ICT & CE equipment during intended operation in an Emission Test Chamber (ETC). The methods comprise preparation, sampling (or monitoring) in a controlled ETC, storage and analysis, calculation and reporting of emission rates. The standard includes specific

methods for equipment using consumables, such as printers, and equipment not using consumables, such as monitors and PCs.

Safety standards

The Low Voltage Directive (LVD) (2014/35/EU) ensures that electrical equipment within certain voltage limits provides a high level of protection for European citizens[63]. A wide range of harmonized standards are available to ensure that products meet the requirements of the LVD.[64] These harmonized standards cover both design of whole products and of individual components. Many of these harmonized standards will apply to complete imaging equipment products as well as to imaging equipment components

EN 62368-1:2014 Audio/video, information and communication technology equipment. Safety requirements

EN 62368-1 has been formally documented as a suitable standard for establishing presumption of conformity of AV & ICT equipment with the EU LVD.

Substances, materials and end-of-life standards

ISO 11469:2016 Plastics - Generic identification and marking of plastics products

Specifies a system of uniform plastic material marking. The standard does not cover every aspect of marking (e.g. the marking process, the minimum size of the item to be marked, the size of the lettering or the appropriate location of the marking), but the marking system described is intended to help identify plastics products for subsequent decisions concerning handling, waste recovery or disposal. The standard refers to ISO 1043-1 for generic identification of the plastics.

EN ISO 1043-2:2011 Plastics - Symbols and abbreviated terms. Fillers and reinforcing materials

Defines abbreviated terms for the basic polymers used in plastics, symbols for components of these terms, and symbols for special characteristics of plastics.

IEC TR 62635:2012 Guidelines for end-of-life information provided by manufacturers and recyclers and for recyclability rate calculation of electrical and electronic equipment

IEC/TR 62635:2012(E) provides a methodology for information exchange involving electronic and electrical equipment manufacturers and recyclers. The standard also provides a methodology enabling calculation of the recyclability and recoverability rates of to facilitate optimized end of life treatment operations.

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[63] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2014.096.01.0357.01.ENG
[64] https://ec.europa.eu/growth/single-market/european-standards/harmonised-standards/low-voltage_en

EN 50419:2006 Marking of electrical and electronic equipment in accordance with Article 11(2) of Directive 2002/96/EC (WEEE)

Product marking requirements needed to ensure compliance with the WEEE Directive and additional information relating to the marking requirements, including positioning, visibility, dimensions, location and referenced documents. The marking requirements are applicable to all manufacturers and producers of electrical and electronic equipment placing products on the EU market.

EN 50625-1:2014 Collection, logistics & treatment requirements for WEEE - Part 1: General treatment requirements

Part of a series of standards requested in Commission Mandate M/518 which aim to support implementation and effectiveness of Directive 2012/19/EU (WEEE). The standard contains requirements applicable to the treatment of all types of WEEE and addresses all operators involved in the treatment (including related handling, sorting, and storage) of WEEE. In particular, the standard addresses the following issue areas:

- Management principles
  - Technical and infrastructural pre-conditions
  - Training
  - Monitoring
  - Shipments
- Technical requirements
  - General
  - Receiving of WEEE at treatment facility
  - Handling of WEEE
  - Storage of WEEE prior to treatment
  - De-pollution (including Annex A normative requirements)
  - De-pollution monitoring (including Annex B normative requirements)
  - Treatment of non-depolluted WEEE and fractions
  - Storage of fractions
  - Recycling and recovery targets (including Annex C & D normative requirements)
  - Recovery and disposal of fractions
- Documentation

The standard applies to the treatment of WEEE until end-of-waste status is fulfilled, or until the WEEE is prepared for re-use, recycled, recovered, or final disposal.

EN 62321 series Determination of certain substances in electrotechnical products
The purpose of the harmonized EN 62321/IEC 62321 series of standards is to provide test methods that will allow determination of the levels of certain substances of concern in electrotechnical products on a consistent global basis.

EN 50581:2012 Technical documentation for the evaluation of electrical and electronic products with respect to restriction of hazardous substances
The EN 50581 standard specifies the technical documentation a producer of EEE has to collect for applicable substance restrictions in order to demonstrate compliance with Directive 2011/65/EU (RoHS). The technical documentation required to meet the standard includes:

- A general product description
- Documentation of materials, parts and/or sub-assemblies
- Information showing the relationship between the technical documents and respective materials, parts and/or sub-assemblies
- A list of harmonized standards and/or technical specifications used to prepare the technical documents.

Other standards and initiatives

EN 61000 (IEC 61000) Electro Magnetic Compatibility (EMC) standards
Deals with different aspects regarding electro-magnetic compatibility and sets the basis for the European EMC legislation. Part 1 states general considerations, part 2 describes and classifies the environment and specifies compatibility levels, part 3 specifies emission and immunity limits, part 4 defines testing and measurement techniques, part 5 defines installation and mitigation guidelines and part 6 defines generic standards.

IEC 62430:2009 Environmentally conscious design (ECD) for electrical and electronic products and systems
Specifies requirements and procedures to specify generic procedures to integrate environmental aspects into design and development processes of electrical and electronic products including combination of products, and the materials and components of which they are composed.

Circular Economy package
Within the past 10 years the awareness of resource depletion has increased, and the ideas of circular economy have been widely accepted as a solution that can improve the resource efficiency. The European Commission published in 2015 a circular economy package that

included an action plan to promote circular economy[65]. The areas of actions that are most relevant in connection with ecodesign is the general measures on product design.

Product design is key to facilitating recycling, repair and refurbishment, but also more durable products. All measures hold the potential to reduce the consumption of virgin materials (including critical raw materials) and reduce the environmental burden of products.

To reach better design of products the Commission will:

- *"Support repairability, durability, and recyclability of products in product requirements under the Ecodesign Directive, taking into account specific requirements of different products. The Ecodesign working plan 2015–2017 will identify product groups that will be examined to propose possible eco-design and/or energy labelling requirements. It will set out how ecodesign can contribute to the objectives of the circular economy. As a first step, the Commission will propose requirements for electronic displays, including requirements related to material efficiency."*
- *"Propose the differentiation of financial contributions paid by producers under the Extended Producer Responsibility scheme on the basis of the end-of-life management costs of their products. This provision under the revised legislative proposal on waste creates economic incentives for the design of products that can be more easily recycled or reused."*
- *"Examine options and actions for a more coherent policy framework for the different strands of work on EU product policy in their contribution to the circular economy."*

The Spanish Royal Decree (No 110/2015)[66] has a set of requirements regarding the amount of collected WEEE that should be prepared for reuse. The requirements are e.g.:

- 2017 - 2 % of large household appliances collected as WEEE and 3 % of IT equipment collected as WEEE is to be prepared for reuse
- 2018 - 3 % of large household appliances collected as WEEE and 4 % of IT equipment collected as WEEE is to be prepared for reuse
- Improve the monitoring, traceability and supervision requirements of waste management activities by the public administration.
- Separate collection, transport and storage conditions to allow appropriate preparation for re-use and to prevent breakages and loss of materials
- Recognise the role of social-economy actors in waste collection and treatment and the possibility of handing over WEEE to these entities.

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[65] https://ec.europa.eu/growth/industry/sustainability/circular-economy_en
[66] http://www.mapama.gob.es/es/calidad-y-evaluacion-ambiental/temas/prevencion-y-gestion_residuos/spanishlegislationonwasteofelectricandelectronicequipmentsweeeroyaldecree1102015of20february_tcm7-382140.pdf

1.3.2 Mandates issued by the EC to the European Standardization Organizations

M/544 – Standardisation mandate to the European standardisation organisations as regards ecodesign requirements for networked standby in support of Regulation (EC) No 1275/2008 and Regulation (EC) No 642/2009

Regarding networked standby there are some useful definitions in Regulation (EC) No 1275/2008[67]:

Network means a communication infrastructure with a topology of links, an architecture, including the physical components, organisational principles, communication procedures and formats (protocols).

Networked equipment means equipment that can connect to a network and has one or more network ports.

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.

As the outcome of the standardisation mandate M/544 for networked standby, the following standards for measurement of networked standby power consumption have been developed:

CENELEC: EN 50643:2018 Electrical and electronic household and office equipment - Measurement of networked standby power consumption of edge equipment: EN 50643 was published in April 2018. The scope is edge equipment defined as networked equipment that can be connected to a network and interact with that network or other equipment and that does not have, as its primary function, the passing of network traffic to provide a network. In relation to Regulation (EU) No 801/2013, these products are all other networked equipment not being HiNA equipment such as imaging equipment. The standard complements EN 303 423 (see hereinafter) i.e. the two standards together cover all products in scope of Regulation (EU) No 801/2013. The standard specifies methods of measurement of electrical power consumption in networked standby and the reporting of the results. It also provides a method to test power management and whether it is possible to deactivate wireless network connection(s). This standard has been written in particular to support Commission Regulation (EU) No 801/2013 for the measurement of energy consumption in networked standby. This standard applies to electrical products with a rated input voltage of 230 V a.c. for single phase products and 400 V a.c. for three phase products.

[67] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02008R1275-20170109&from=EN

ETSI: EN 303 423 V1.2.1: Electrical and electronic household and office equipment; Measurement of networked standby power consumption of Interconnecting equipment: **EN 303 423** was published in August 2018. The scope is interconnecting equipment (ETSI) defined as networked equipment that has, as its primary function, the passing of network traffic to provide a network. In relation to Regulation (EU) No 801/2013, these products are mainly HiNA (High Network Availability) equipment such as router, network switch, wireless network access point, hub, modem, VoIP telephone and video phone. The standard complements EN 50643 i.e. the two standards together cover all products in scope of Regulation (EU) No 801/2013. The standard specifies methods of measurement of electrical power consumption in networked standby and the reporting of the results. It also provides a method to test power management and whether it is possible to deactivate wireless network connection(s). This standard has been written in particular to support Commission Regulation (EU) No 801/2013 for the measurement of energy consumption in networked standby. This standard applies to electrical products with a rated input voltage of 230 V a.c. for single phase products and 400 V a.c. for three phase products. The standard has been delivered to the European Commission for harmonisation.

M/543 – Standardisation mandate to the European standardisation organisations as regards Material Efficiency

In December 2015, the European Commission published a standardisation request to the ESOs covering ecodesign requirements on material efficiency aspects for energy-related products in support of the implementation of Directive 2009/125/EC.[68] It was noted in the mandate, that the absence of adequate metrics is one of the reasons for the relative lack of ecodesign requirements related to material efficiency in previous ecodesign implementing measures. The mandate therefore requests that the ESOs draft new European standards and European standardisation deliverables on material efficiency aspects for energy-related products in support of the ecodesign Directive 2009/125/EC. This standardisation request clarifies that the following material efficiency aspects should be covered:

- Extending product lifetime
- Ability to re-use components or recycle materials from products at end-of-life
- Use of re-used components and/or recycled materials in products

prEN 45558

This European Standard is currently under development. The aim of the standard is to develop a method so information on critical raw materials can be exchanged up and down in the supply chain of energy related products. Though, it does not provide any

[68] http://ec.europa.eu/growth/tools-databases/mandates/index.cfm?fuseaction=search.detail&id=564

specific method to capture this information. How organisations will capture the data is individually which allow more flexibility.

The standard e.g. allows organisations to

- to assess the use of critical raw materials in energy related products
- to support collection and recycling processes, so the critical raw materials can be extracted End-of-Life
- to use information on critical raw materials in life-cycle management

Furthermore, this standard can support policy makers regarding policy around the or import of critical raw materials. It can also prove to be valuable in connection with Ecodesign studies as more information about the materials are available. This can lead to more precise estimations of both the value and impact of critical raw materials in energy related products, but also measures that can improve the recycling of critical raw materials.

prEN 45554

This European Standard is currently under development and deals with the assessment regarding the ability to remanufacture energy related products. The aim is to ensure a general method for assessing the ability to remanufacture energy related products. The aspects considered are among others:

- Assessment of accessibility (Including a formula that can evaluate the accessibility)
- Assessment of the ability to re-/disassemble (Including disassembly sequence, disassembly index, time for disassembly and different formulas)

This standard may allow requirements regarding disassembly in ecodesign as this standard creates a common framework for documenting the disassembly. Without any standard it is difficult for the market surveillance authorities to control such measures.

prEN 45556

This European Standard is currently under development. The aim is to ensure a general method for assessing the proportion of reused components in energy related products. The aspects considered are among others:

- Calculation of reused component index
- Quality assurance (maintain records of previous quality control)
- Marking and Instructions (e.g. ensure traceability of the reused component)

prEN 45557

This European Standard is currently under development. The aim is to ensure a general method for assessing the proportion of recycled material content in energy related products. This standard relates to the physical characteristic of the materials and manufacturing history of all the parts in the product. The standard includes:

- Methods for calculating the recycled material content
- Specific guidelines per material type
- Traceability
- Reporting

Guidelines for accounting and reporting recycled content will contribute to avoid potentially unsubstantiated and misleading claims on recycled content for which it is not clear how they are determined. This standard enables requirements of recycled content in products as these claims can be controlled by market surveillance authorities

prEN 45555

This European Standard is currently under development and deals with methods for assessing the recyclability and recoverability of energy-related products. This standard suggests a horizontal approach for all energy related products. However, the standard also states that a correct assessment can only be done in a product-specific way, taking into account specific parameters of a specific product group. This standard defines a series of parameters which may be considered to calculate product specific recycling and recoverability rates.

The standard provides a general methodology for:

- Assessing the recyclability of energy related products
- Assessing the recoverability of energy related products
- Assessing the ability to access or remove certain components of interest to facilitate better recycling and recovery operations.
- Assessing the recyclability of critical raw materials from energy related

prEN 45553

This European Standard is currently under development and deals with methods for the assessment of the ability to repair, reuse and upgrade energy related products. This standard suggests a horizontal approach for all energy related products. The standard is described as generic and general in nature which means that it is not intended to be applied directly but may be cited in relation with product specific or product group harmonised standards.

The standard provides a general methodology for:

- the ability to repair products,
- the ability to reuse products, or parts thereof,
- the ability to upgrade products, excluding remanufacturing.

Furthermore, this standard provides a common framework for future vertical and product specific standards.

Standard prEN 50614

This European Standard is currently under development (within the standardisation mandate M/518). The purpose of the standard is to facilitate the preparation for re-use of equipment and support the WEEE Directive. The standards include measures on how to check, clean or perform repair recovery operations, so components of discarded products (waste) are prepared so they can be reused without any other pre-processing. The standard also provides relevant description of quality, safety and environmental requirements that a reuse operator should adopt to ensure safe products for the consumer and also to protect the brand of the product (avoid faulty and dangerous remanufactured products) as consumers still may connect a remanufactured product with the brand of the appliances which not necessarily is the case.

Standard BS 8887-211

This British standard focus on design for manufacture, assembly, disassembly
and end-of-life processing (MADE) of computing hardware. So, this standard is not related to household appliances but some of the requirements could be used across all electronic products. The standard describes the different types of products that potentially could re-enter the production. Examples of products that can re-enters the production are:

- Non-working products (out-of-the-box)
- Products that needs repair within the warranty period (returned to the OEM)
- Unsold products (factory overstock, demonstration models, "try before buy – offer"
- Return of used products (e.g. lease or "trade-in-offers" – relevant in connection with circular economy)

Standard VDI 2343

This standard by the Association of German Engineers (VDI) is providing a common framework for the different definitions on reuse which is crucial to reach a common understanding on the different definitions. Definitions are also crucial in connection with interpretation of Regulation and without any clear definitions any requirements towards reuse/remanufacturing/refurbishment will be invalidated. In general, refurbishment is not clearly defined

in most EU regulation (e.g. fully refurbishment is defined in the regulation on medical devices[69]). The standard defines different levels of reuse such as:

- Repair – restores defective product
- Refurbishing – restores used product to a certain quality
- Remanufacturing – restores used product to 'as good as new' through new and reconditioned components and parts;
- Upgrading – improving the functions/properties of the original product

Definitions are very important in connection with the liability of the product. At which level of repair/reuse is the original manufacturer (brand on the appliance) responsible for the product.

Standard ONR 192102

Standard ONR 192102 is an Austrian standard that establishes a label for electronic products designed for easy repair, see Figure 4.

Figure 4: Austrian standard for label for electronic products

The standard/label established both obligatory requirements that should be followed by anyone claiming the label, but also a set of voluntary requirements. If the also follow the voluntary criteria they are awarded with a score. The score is dependent on the number of criteria the product complies with and an overall reparability score is awarded which are either 'good', 'very good' or 'excellent'.

Examples of the requirements and criteria are:

- Information relevant for disassembly (e.g. instructions, break down plan)
- Requirements on information for repair (e.g. instructions and exploded views)
- Easiness of disassemble (e.g. possibility of breaking down the product and accessibility to inner parts (cable lengths, space for mounting, welding, screw orientation and size, scale of design)

[69] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:L:2017:117:FULL&from=EN

Such standards and labels are very important for both manufactures designing products for the circular economy, but also regarding requirements. European standard can be developed in line with ONR 192102, which makes any requirements towards improvement resource efficiency (design for easy disassemble etc.) more robust and makes it possible for the market surveillance authorities to control such requirements. Summary of relevant standards

1.3.3 Possible problems with test standards

Possible problems on accuracy/tolerances

The ENERGY STAR v2.0 test procedure is currently the most widely used test procedure for measuring the energy use of imaging equipment. There are no known issues with accuracy or tolerances when testing the energy use of imaging equipment according to the ENERGY STAR v2.0 test procedure.

Possible problems on reproducibility

There is no known issue with reproducibility when measuring energy use according to the ENERGY STAR test procedure.

Reflection of real-life use in test standards

It is widely recognised that the ENERGY STAR v2.0 TEC use profiles within the test procedure over-estimate the amount of images equipment likely produce on a weekly basis. For this reason, the US EPA amended the ENERGY STAR v3.0 TEC use profiles, reducing the number of images produced so that it better reflects real-life usage.

1.3.4 Summary

Based on the environmental areas covered by the VA and different initiatives listed in Table 7, Table 8 shows the same areas mapped against standards and metrics available to support measurement of these. Table 8 also shows the potential additional areas that could be recommended for a revised VA or future policy measures (shown highlighted in green). These are:

- Imaging equipment products
  - Hazardous substances content: Restrictions and inventory of safety alternatives
  - Product lifetime extension: Guarantee to avoid early failure
  - Noise emissions
- Imaging equipment consumables
  - Use of non-manufacturer cartridges/containers
  - Consumable imaging yield efficiency
  - Measured cartridge yield
  - Minimum cartridge yield

- Cartridge print quality
- Cartridge remanufacturing/ recycling process requirements
- Marking plastic parts
- Substance restrictions
- Ease of disassembly
- Chemical emissions

In spite there are no standards to test most of these metrics, they are covered by other initiatives which means there are measurement and reporting procedures in place for manufacturers to report on these metrics.

Table 8: Overview of environmental areas mapped against available standards and metrics for measuring, testing and verification (not exhaustive).

*Red fields indicate the coverage of VA on imaging equipment, blue fields indicate the standards and metrics available for testing or measuring of the particular environmental area, and green fields indicate potential additional areas that could be recommended for a revised VA or future policy measures. See table next pages.

Environmental Areas/Metrics		EU VA IE Coverage	ES Test Method (2014)	EAR Test Method(2018)	Uniform Test Method [70]	Blue Angel RAL-UZ 205	IEC Std 62301 Ed2.0	EN 50643:2018	EN 12281:2002	EN 62321 series	EN 50419:2006	IEEE 802.3az-2010	ISO/IEC 10561:1999	prEN 45557	prEN 45555	prEN 45554	prEN 50614	EN 50625 series	ISO 9296:2017	ISO/IEC 28360:2015	ISO/IEC 24711:2015	ISO/IEC 29102:2015	ISO/IEC 29103:2011	ISO/IEC 19752:2017	ISO/IEC 19798:2017	ISO/IEC 24790:2017	ISO/TS 14067:2013	ISO 179-1:2010
Energy/ Power in Use	Energy in Use (multiple power states)																											
	Power Demand in low power modes																											
	Power Management																											
	Maximum wake times																											
	External Power Supply Efficiency																											
	Life-cycle assessment (LCA)																											
Paper Use	Automatic duplex																											
	N-up printing																											
	Use recycled paper																											
Content of hazardous	Restrictions																											
	Inventory of safer substitutions (i.e.																											

[70] US Government, Electronic Code of Federal Regulations, Title 10 Energy, PART 430—ENERGY CONSERVATION PROGRAM FOR CONSUMER PRODUCTS, Subpart B —Test Procedures, Appendix Z to Subpart B of Part 430—Uniform Test Method for Measuring the Energy Consumption of External Power Supplies, available from https://www.ecfr.gov/cgi-bin/text-idx?SID=55aed75e638f7b2766ca2faa3e5bf93b&node=10:3.0.1.4.18.2.9.7.38&rgn=div9

sub-stances	intentionally added chemicals)																											
Recy-cled content	Postcon-sumer recy-cled plastic content (declaration)																											
	Postcon-sumer recy-cled plastic content (in-clusion)																											
Bio based plastic mate-rial content	Bio based plastic ma-terials con-tent (decla-ration)																											
	Bio based plastic ma-terials con-tent (inclu-sion)																											
Product weight	Weight dec-laration																											
Recy-clability	Ease of dis-assembly																											
	Limits plas-tic type per plastic part																											
	Manual sep-aration and marking of plastics																											
	Restriction surface coatings																											
	Identifica-tion hazard-ous sub-stances/spe-cial handling needs																											
	Design for reusability																											

	Reusable/re-cyclable minimums																											
End-of-life analy-sis and plan-ning	Product end-of-life char-acterization report																											
Product Life-time exten-sion	Early failure pro-cess/Guar-antee																											
	Spare parts availability																											
	Upgradeabil-ity																											
Product take-back	End-of-life processing require-ments																											
Corpo-rate perfor-mance	Environmen-tal manage-ment sys-tem																											
	Public dis-closure of key environ-mental as-pects																											
	Public dis-closure of supply chain toxics																											
	Working conditions																											
Manu-factur-ing Im-pacts	Chemicals used/ emit-ted during production																											
Pack-aging	Substance restrictions																											
	Recyclable materials																											

	Separable materials																											
	Composta-bility/ recy-clability																											
	Recycled content																											
	Plastics marked																											
	Take-back service																											
Con-suma-bles	Use of non-manufac-turer car-tridges/con-tainers																											
	Car-tridge/Con-tainer De-sign for Re-cycling																											
	Car-tridge/Con-tainer De-sign for Re-use																											
	Car-tridge/Con-tainer Take-back Offered																											
	Toner/Ink Recycling Conducted																											
	Reporting take-back statistics																											
	Reuse of materials from take-back scheme																											
	Consumable imaging																											

	yield efficiency[71]																											
	Measured cartridge yield																											
	Minimum cartridge yield[72]																											
	Cartridge durability																											
	Cartridge print quality																											
	Cartridge remanufacturing/ recycling process requirements																											
	Restrictions number plastics																											
	Marking plastic parts																											
	Substance restrictions																											
	Ease of disassembly																											
Emissions	Chemical Emissions (measuring)																											
	Chemical Emissions (limits)																											
	Noise Emissions (measuring)																											
	Noise Emissions (limits)																											
Safety	Safety requirements																											

[71] Consumable imaging yield efficiency refers to the minimum page yield per gram of the total consumable material supplied.
[72] Minimum cartridge yield refers to the minimum page yield for an equivalent cartridge/container offered by an alternative.

1.4 Conclusions and recommendations

1.4.1 Proposed product scope

The product scope of VA has been evaluated against the existing ENERGY STAR version 2.0 and version 3.0 as well as other schemes, see Figure 5. Most identified schemes have similar product scope as the ENERGY STAR, which therefore is seen as the most central scheme.

It is recommended to continue the alignment of the scope with ENERGY STAR, particularly concerning imaging equipment products, to make sure the most important products are covered by the agreement concerning sales and energy consumption and other resource impact. This would remove fax machines and standalone copiers from scope, reflecting the US EPA thinking that sales of these product types are now too low to warrant inclusion. Furthermore, to reflect the current market trends for typical speeds and other functionality features. Therefore, it is proposed to remove the speed limit on images per minute and to also consider the inclusion of professional imaging equipment category.

Scanners and digital duplicators are not considered to account for a large market in the EU and there is no evidence suggesting that their sales would develop otherwise. It is therefore not recommended to include them as new products in scope for the VA.

Lastly, it is recommended to define the cartridges and containers and include them in the scope as discussed in section 1.1.3. See Figure 6 for the proposed revised scope for VA.

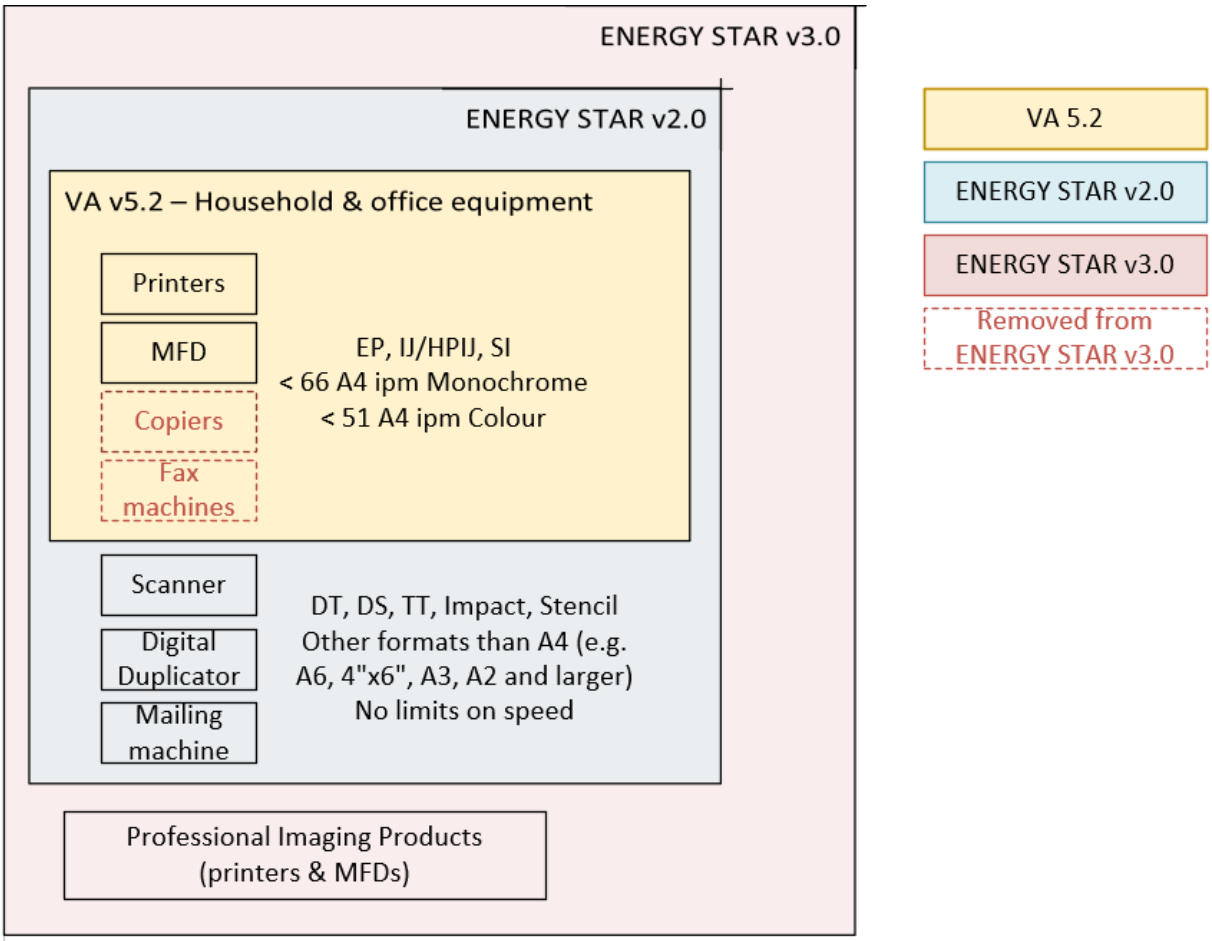

Figure 5: Comparison of VA and ENERGY STAR product scopes

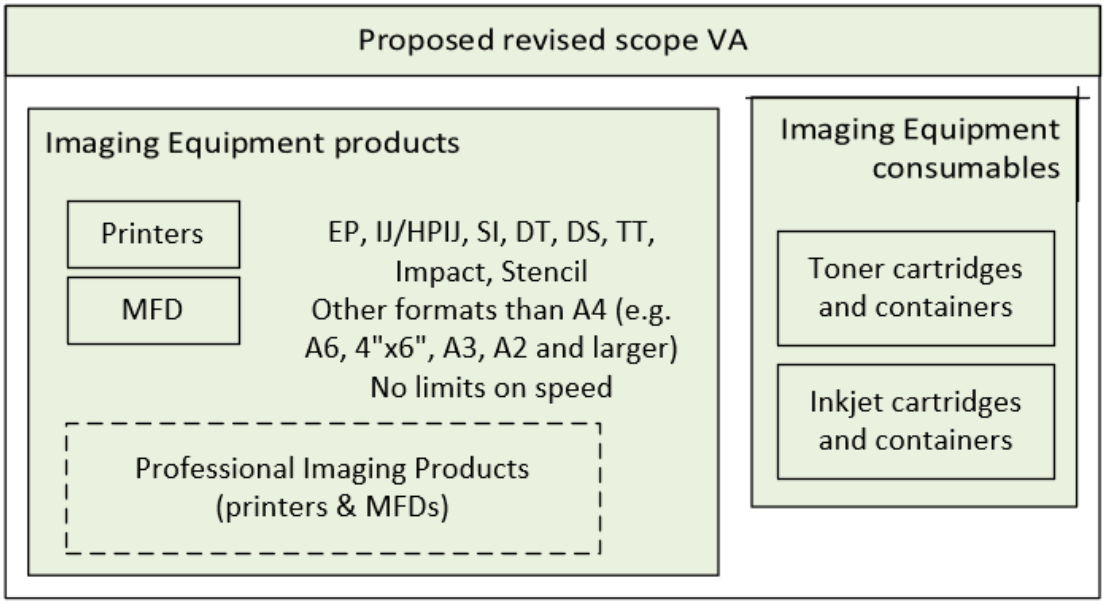

Figure 6: Proposed revised scope for VA

In Table 9 and Table 10, definitions of consumables, cartridges and containers are shown, which are aligned with the current GPP criteria (for products) and with EPEAT, Blue Angel and the Korea Ecolabel (for consumables).

Table 9: Imaging Equipment products definition

Imaging Equipment products
Products that are 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 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.

Table 10: Imaging Equipment consumables definitions

Imaging Equipment consumables
A replaceable product that is essential to the functioning of the imaging equipment product. Consumables are replaced or replenished by either the end user or service provider during the normal usage and life span of the imaging equipment product. Examples of consumables include, but are not limited to: toner, toner containers, toner bottles, toner cartridges, waste toner cartridges, ink cartridges, ink heads, ink sticks, ribbon ink, thermal paper, office paper, imaging units, transfer belts, transfer roller, fusers and drum maintenance units. Items that are not intentionally designed to be normally replaceable are considered to be "spare parts."

The definitions of product types in the proposed scope are shown in Table 11. These are aligned with definitions found in ENERGY STAR v3.0. The definition of professional imaging products is also proposed in the v3.0 specification.

The definition of consumables types proposed in the scope, see Table 12, have been elaborated to be aligned with EPEAT, Blue Angel and the Korea Ecolabel.

Table 11: Imaging Equipment definitions for product types in scope

Imaging equipment product	Definition
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 an 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).

Imaging equipment product	Definition
Multifunctional device (MFD)	A product that performs the core functions of a Printer and Scanner. 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).
Professional imaging products	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 color, color product speed equal to or greater than 50 ipm; e) Print resolution of 600 x 600 dots per inch or greater for each color; f) Weight of the base model greater than 180 kg; and Five of the following additional features for color 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) Third-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.

Table 12: Imaging Equipment definitions for consumables types in scope

Imaging equipment consumable	Definition
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.
Toner 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 toner material.
Inkjet cartridge	An end-user replaceable product, which fits into or onto an imaging equipment product, with printing-related functionality that includes integrated components integral to the imaging equipment's function beyond holding ink.

1.4.2 Legislations

Imaging equipment and consumables are covered by a range of EU legislation and directives, none of these address energy and resource efficiency and it would therefore be valuable that the Voluntary Agreement does. Imaging equipment are also covered by a number of voluntary schemes. In spite of these schemes being largely based on the ENERGY STAR specification for imagine equipment both in terms of scope and categorisation, some of them (e.g. Blue Angel, Nordic Swan Ecolabel, US EPEAT programme) cover many more environmental areas than ENERGY STAR. Some of the additional environmental areas can also be important to address in the EU voluntary agreement.

1.4.3 Environmental metrics and standards

Environmental metrics and relevant standards have been reviewed to assess whether the environmental areas covered by the legislation and voluntary schemes can be quantifiable and measurable with widely adopted standards. A summary table is presented in section 1.3.4 to show the requirements of VA and its corresponding test standards, as well as potential additional requirements for other environmental areas. The following requirements could be considered for the future policy measure or a revised VA as they are already covered by the current VA and/or by widely adopted test standards:

- Imaging Equipment products
  - Hazardous substances content: Restrictions and inventory of safety alternatives
  - Product lifetime extension: Guarantee to avoid early failure
  - Noise emissions

- Imaging Equipment consumables
  - Use of non-manufacturer cartridges/containers (additional requirements)
  - Consumable imaging yield efficiency
  - Measured cartridge yield
  - Minimum cartridge yield
  - Cartridge print quality
  - Cartridge remanufacturing / recycling process requirements
  - Marking plastic parts
  - Substance restrictions
  - Ease of disassembly
  - Chemical Emissions

2. Task 2: Markets

Task 2 follows the MEErP methodology and includes the following:

1. Generic economic data: EU sales and trade data based on production, import and export is assessed based on PRODCOM data analysis, aiming at identifying any similarities with our established stock model and/or filling data gaps.
2. Market and stock data: The establishment of the EU installed base (stock) based on EU annual total sales and growth rates and average product lives.
3. Market trends: The trends have been assessed regarding products and product features
4. Consumer expenditure base data and Life Cycle Costs (LCC): Identifying the base cases for analyses, average EU consumer prices, repair and maintenance costs, disposal tariffs and taxes, electricity prices and regional differentiations.

2.1 Generic Economic data

The PRODCOM statistics are the official source for product data on the EU market. It is based on product definitions that are standardised across the EU thus guaranteeing comparability between Member States. Data are reported by Member States to Eurostat.

The PRODCOM statistics have some limitations given the complexities in the market and so are they not always as detailed as necessary to support decision making within ecodesign preparatory studies.

Within this study, the PRODCOM statistics are used to compare against product data sourced from other data sources and expert assumptions in order to provide a higher degree of confidence in the final product dataset. The product data sourced was used to establish annual sales for product categories in scope, and subsequently for establishing the installed base in the EU (i.e. stock).

PRODCOM EU sales and trade (i.e. the EU consumption) is derived by using the following formula based on data from PRODCOM[73]:

$$EU\ sales\ and\ trading = production + import - export$$

[73] PRODCOM has reported that the results of this method are often unreliable (sometimes producing a negative figure) however no other options are available.

For imaging equipment and consumables, the following PRODCOM categories have been used to search for available data in the database:

Table 13: PRODCOM code and description for imaging equipment in scope of current Voluntary Agreement

Product group	Prodcom code and description
NACE 26.20: Manufacture of computers and peripheral equipment	**26.20.16.40**: Printers, copying machines and facsimile machines, capable of connecting to an automatic data processing machine or to a network (excluding printing machinery used for printing by means of plates, cylinders and other components, and machines performing two or more of the functions of printing, copying or facsimile transmission)
	26.20.18.00: Machines which perform two or more of the functions of printing, copying or facsimile transmission, capable of connecting to an automatic data processing machine or to a network
NACE 28.23: Manufacture of office machinery and equipment (except computers and peripheral equipment)	**28.23.21.00**: Photo-copying apparatus incorporating an optical system or of the contact type and thermo-copying apparatus
	28.23.26.00: Parts and accessories of printers of HS 8443 3
NACE 20.30: Manufacture of paints, varnishes and similar coatings, printing ink and mastics	**20.30.22.73**: Organic composite solvents and thinners used in conjunction with coatings and inks; based on butyl acetate
	20.30.22.79: Organic composite solvents and thinners used in conjunction with coatings and inks (excluding those based on butyl acetate)
	20.30.24.50: Black printing inks
	20.30.24.70: Printing inks (excluding black)

Table 14: Sales data from PRODCOM for products in scope

	2009	2010	2011	2012	2013	2014	2015	2016
26.20.16.40: *Printers, copying machines and facsimile machines, capable of connecting to an automatic data processing machine or to a network (excluding printing machinery used for printing by means of plates, cylinders and other components, and machines performing two or more of the functions of printing, copying or facsimile transmission) [Million items]*								
Production	0.5	0.5	0.7	0.5	0.4	0.3	0.3	0.4
Import	27.0	29.6	27.4	23.5	24.1	23.5	21.5	20.5
Export	17.1	23.4	21.7	18.1	16.3	16.1	15.4	14.9
Sales	**10.4**	**6.6**	**6.4**	**5.9**	**8.2**	**7.7**	**6.5**	**6.1**
26.20.18.00: *Machines which perform two or more of the functions of printing, copying or facsimile transmission, capable of connecting to an automatic data processing machine or to a network [Million items]*								

	2009	2010	2011	2012	2013	2014	2015	2016
Production	0.2	0.1	0.1	0.1	0.0	0.1	0.0	0.0
Import	37.6	40.1	17.4	40.3	40.2	42.9	42.2	40.8
Export	21.3	20.5	10.7	24.9	22.5	23.1	22.4	22.2
Sales	**16.5**	**19.7**	**6.8**	**15.5**	**17.7**	**19.9**	**19.8**	**18.6**
28.23.21.00: *Photo-copying apparatus incorporating an optical system or of the contact type and thermo-copying apparatus [Million items]*								
Production	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Import	0.5	0.3	0.3	0.8	0.1	0.1	0.1	0.0
Export	0.2	0.2	0.3	0.8	0.9	0.9	0.9	0.0
Sales	**0.3**	**0.1**	**0.0**	**0.0**	**-0.8**	**-0.8**	**-0.8**	**0.0**
28.23.26.00: *Parts and accessories of printers of HS 8443 3 [Million items]*								
Production	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Import	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Export	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sales	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
20.30.22.73: *Organic composite solvents and thinners used in conjunction with coatings and inks; based on butyl acetate [Million kilograms]*								
Production	72.7	71.2	56.8	66.0	63.6	64.6	58.4	55.6
Import	14.1	16.1	14.5	13.6	15.5	17.1	19.6	19.1
Export	22.4	32.4	31.8	50.1	62.4	51.4	27.2	26.2
Sales	**64.3**	**54.9**	**39.5**	**29.5**	**16.7**	**30.3**	**50.8**	**48.5**
20.30.22.79: *Organic composite solvents and thinners used in conjunction with coatings and inks (excluding those based on butyl acetate) [Million kilograms]*								
Production	697.0	799.9	771.5	762.2	722.7	698.3	806.7	1,131.5
Import	247.5	285.3	276.9	270.2	285.7	274.5	266.2	275.9
Export	308.9	335.2	323.9	388.3	381.8	412.0	383.3	417.8
Sales	**635.6**	**750.0**	**724.5**	**644.0**	**626.7**	**560.8**	**689.6**	**989.6**
20.30.24.50: *Black printing inks [Million kilograms]*								
Production	168.1	169.5	161.2	171.6	175.0	172.0	155.1	163.0

	2009	2010	2011	2012	2013	2014	2015	2016
Import	11.7	12.4	11.2	11.4	10.1	8.9	9.1	9.8
Export	126.6	120.3	123.4	122.9	130.0	138.6	130.5	134.5
Sales	**53.2**	**61.6**	**48.9**	**60.1**	**55.1**	**42.4**	**33.7**	**38.3**
20.30.24.70: *Printing inks (excluding black) [Million kilograms]*								
Production	885.2	977.4	788.5	870.2	867.6	852.2	850.6	855.8
Import	431.3	468.1	446.9	434.6	442.1	444.1	436.9	434.7
Export	470.9	514.7	475.7	477.3	456.7	470.1	457.3	476.1
Sales	**845.6**	**930.9**	**759.7**	**827.5**	**853.1**	**826.3**	**830.2**	**814.5**

Experience from other studies and also the MEErP guidance document itself shows that the PRODCOM data are not very reliable for the analysis of individual products. This also applies to imaging equipment, e.g. negative sales for PRODCOM code 28.23.21.00 (photo-copying apparatus incorporating an optical system or of the contact type and thermo-copying apparatus), while other PRODCOM codes have very fluctuating values with high increase and decreases. Also, it can be difficult to quantify how the different PRODCOM codes for consumables fits with the products in scope i.e. 20.30.22.79: Organic composite solvents and thinners used in conjunction with coatings and inks (excluding those based on butyl acetate). However, the data from PRODCOM can be used for comparison and indications of trends. The data presented in Table 14 is also presented as graphs for better indication of the trend. The sales are presented in Figure 7 for equipment and Figure 8 for consumables.

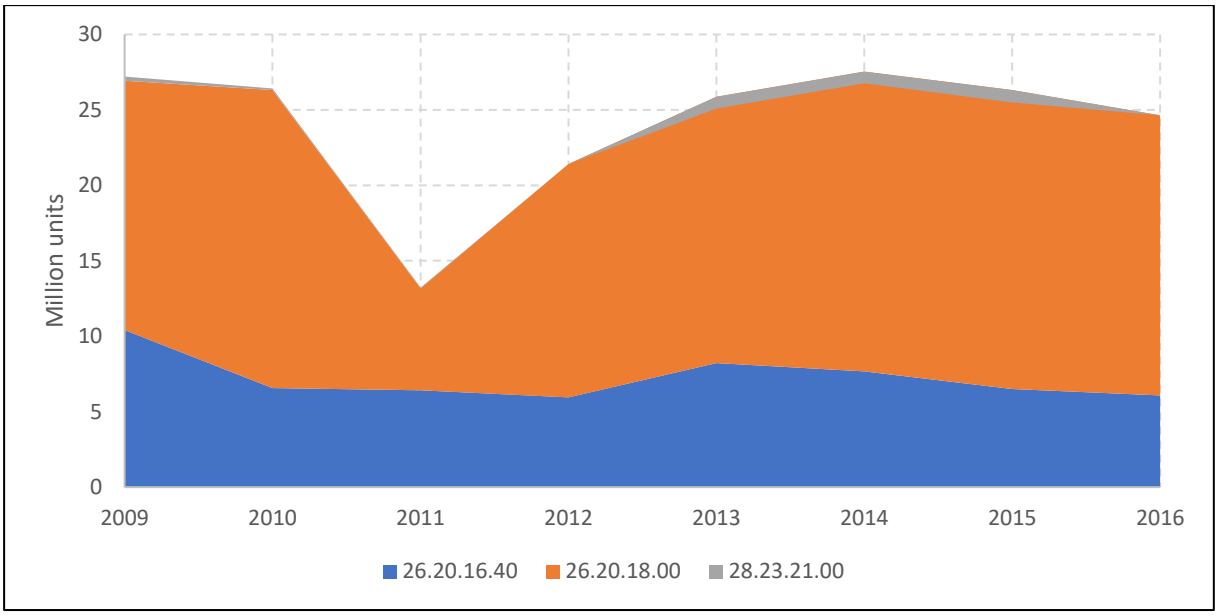

Figure 7: PRODCOM sales data derived for imaging equipment

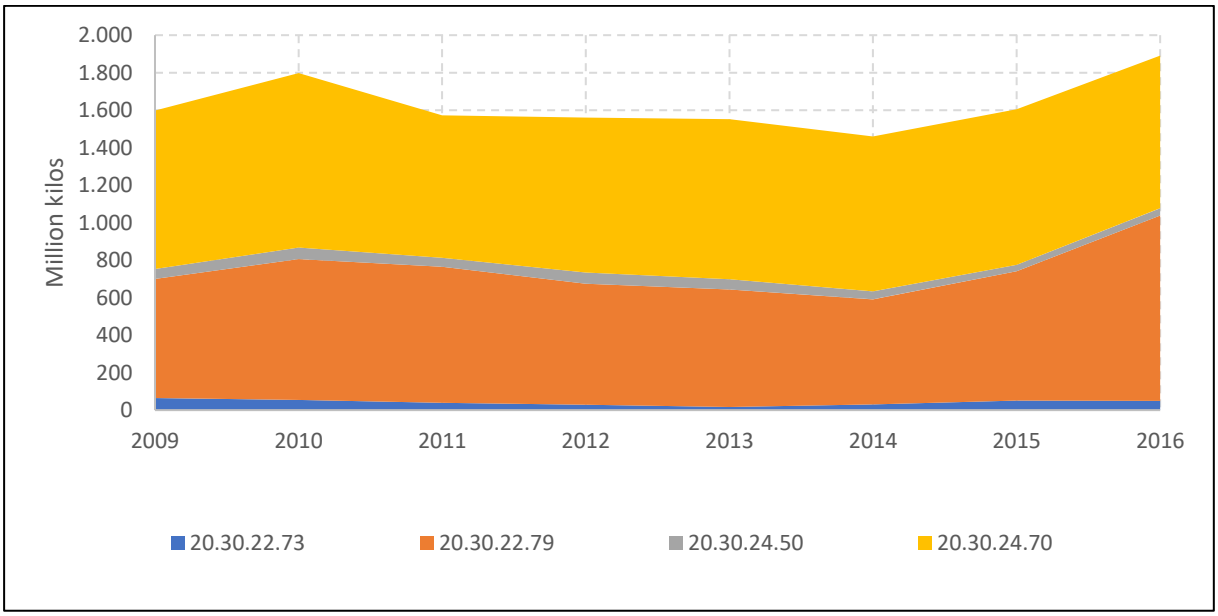

Figure 8: PRODCOM sales data derived for consumables (ink and toner)

Based on Figure 7 and Figure 8, it can be difficult to determine a trend, as the sales are fluctuating, but following trends can be suggested:

- Decrease in the sales of single function equipment (26.20.16.40)
- Decrease in the sales of multi-function equipment since 2014 (26.20.18.00), however the trend is difficult to determine based on high fluctuations.
- In general, decrease of consumables except for organic composite solvents and thinners used in conjunction with coatings and inks (excluding those based on butyl acetate) (PRODCOM code 20.30.22.79)

2.2 Market and stock data

Due to sales data from PRODCOM not being very reliable, other sources are used to determine the market and stock data. In this section the different sources and assumptions made to estimate the market and stock data for each of the product types within the scope (presented in Task 1) are presented. In general, this section presents the needed data to determine the stock of equipment in EU.

2.2.1 Market, lifetime and stock of imaging equipment

Sales of imaging equipment

The sales of imaging equipment are based on a number of different sources to present the historical, current and future sales. Current sales are based on 2015, due to the availability of data is limited to 2015 annual sales from the more reliable source, EU ENERGY STAR market report based on products in the EU ENERGY STAR database, which were registered in USA and EU as available on the EU market. The data and estimation methods used are presented in Table 15.

Table 15: Sources and estimates to the determine the current sales of imaging equipment

	Historical sales	Current sales (2015)	Future sales
Inkjet printers	Impact assessment 2013[74]	EU ENERGY STAR market report	From 2016-2021 estimated based on stakeholder consultation, after 2021 linear regression
Laser printers	Impact assessment 2013[74]	EU ENERGY STAR market report	From 2016-2021 estimated based on stakeholder consultation, after 2021 linear regression
Inkjet MFDs	Impact assessment 2013[74]	EU ENERGY STAR market report	From 2016-2021 estimated based on stakeholder consultation, after 2021 linear regression
Laser MFDs	Zero in 1995[75] and linear regression between 1995 and 2015	EU ENERGY STAR market report	From 2016-2021 estimated based on stakeholder consultation, after 2021 linear regression
Scanner	Online research e.g. InfoTrends[76] and sources[77]	Online research[78]	Linear regression until 2020, afterwards stable sales.
Copier	Impact assessment 2013[74], Ecolabel and GPP Economic and market analysis 2000-2009[79]	Impact assessment 2013[74], Ecolabel and GPP Economic and market analysis 2000-2009[79]	Impact assessment 2013[74], Ecolabel and GPP Economic and market analysis 2000-2009[79]. Assumed zero sales by 2020.
Facsimile (Fax) Machine	Online research, Ecolabel and GPP Economic and market analysis 2000-2009[79].	Linear regression between 2009 and 2020	Assumption: Zero sales in 2020

The impact assessment has been used to determine the historical sales. For other products the historical sales are based on online research and other studies such as the eco label

[74] https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex:52013SC0014
[75] Brother introduced the world's first multi-function machine - https://www.brother.co.uk/about-brother/history

GPP Economic and market analysis 2000-2009. The compiled sales data from 1995 to 2040 are presented in Figure 9.

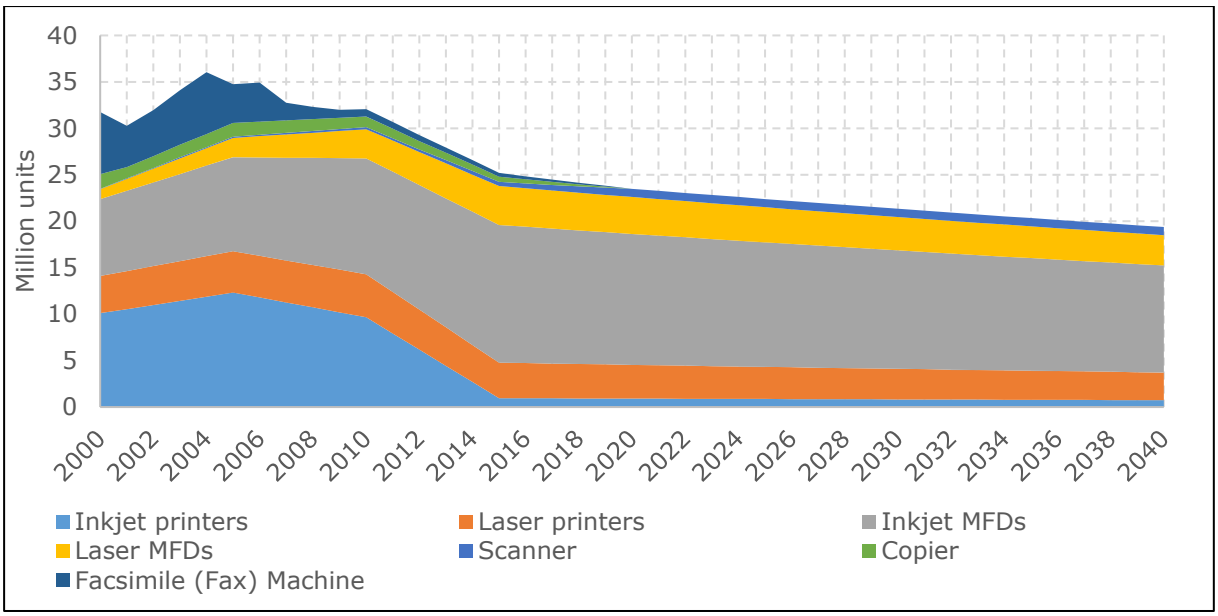

Figure 9: Estimated sales for imaging equipment.

From Figure 9, it is clear that sales of most types of imaging equipment will slowly decrease from 2015 towards 2040. Scanners and copiers are expected to decrease gradually and falls to zero by 2020; this is estimated based on the analysis on the presence of scanners and copiers in the EU ENERGY STAR database. Inkjet printers have had the largest decrease in sales since 2005. In general, the sales of printers have decreased more than the sales of MFDs, and today, based on sales data, MFDs are clearly the preferred type of imaging equipment. The total annual sales amount to ca. 24.8 million units in 2016, this is in agreement with the PRODCOM derived sales for 2016. The sales of imaging equipment are also presented as tables in Table 16.

[76] http://www.infotrends.com/public/Content/INFOSTATS/Articles/2007/07.31.2007.html
[77] http://newbusinesstechnology.co.uk/2011/05/document-scanner-market-analysis/
[78] http://www.syndicatemarketresearch.com/market-analysis/document-imaging-scanner-market-global-industry-perspective-comprehensive.html
[79] http://susproc.jrc.ec.europa.eu/imaging-equipment/stakeholders.html

Table 16: Annual sales of imaging equipment in million units and annual growth rate.

	2015	2020	2025	2030	2035	2040	2015-2040
	Annual sales of imaging equipment in million units						Average annual growth rate %
Inkjet printers	0.96	0.91	0.86	0.82	0.78	0.74	-1.00%
Laser printers	3.82	3.64	3.46	3.29	3.13	2.97	-1.00%
Inkjet MFDs	14.82	14.09	13.40	12.74	12.12	11.53	-1.00%
Laser MFDs	4.18	3.98	3.78	3.60	3.42	3.25	-1.00%
Scanner	0.46	0.88	0.88	0.88	0.88	0.88	2.63%[80]
Copier	0.57	0	0	0	0	0	-
Facsimile (Fax) Machine	0.40	0	0	0	0	0	-
Total sales	25.21	23.50	22.39	21.34	20.33	19.38	**-1.05%**

The assumed decrease in sales can be a consequence of the trend in businesses and offices aiming to become "paper free"[81], where more work is handled digitally e.g. signing of contracts digitally and reports which are handed in online. This also impacted the domestic sector too, where the sales are also falling in the recent years. In many countries, the public sector and semi-public like the energy and water utilities are also going more digital e.g. by using secure e-mail etc. for sending letters and documents to citizens and organisations. However, many people still prefer to print their assignments and reports for different purposes, so a lot of printing is still occurring tough with declining tendency. It can be assumed that the sales of paper follow trend set by the sales of imaging equipment.

In general, very accurate predictions and estimations of the future sales of products are difficult to quantify as many factors might have an impact. However, the sales are assumed to decrease for all types of imaging equipment with varying rates. The highest decrease is expected to be connected with single functionality copiers and fax machines, which are considered to almost disappear from the market in 2020. In reality, single functionality copiers have already almost disappeared from the market in 2018. Very low sales of copiers are modelled to account for the uncertainty. Without any significant sales of single functionality copiers and fax machines, it might not be important to model them separately in

[80] Although no growth from 2020 onwards, this is the estimated total growth averaged over the 25 year period.
[81] A stakeholder suggests that the trend towards a "paper free office" may change due to the risk of e.g. hacking and eye problems.

this study, as no impacts are imposed by these types of equipment when the sales are negligible or zero.

Voluntary Agreement scope coverage

According to inputs from stakeholders[82] most of the imaging equipment put on the market is covered by the Voluntary Agreement. The share of products covered by the Voluntary Agreement is presented in Table 17.

Table 17: Market coverage of imaging equipment in scope by VA signatories only. Data provided by the Secretariat of EuroVAprint.

Calendar Year	Market size represented by VA signatories only (%)
2017	97%
2016	96%
2015	95%
2014	95%
2013	95%*
2012	95%
2011	96%

**Assumptions made by the study team – no data available*

As presented in Table 17 the Voluntary Agreement has covered 95 % or more of the market since 2011. Based on the sales supplied by the signatories and their market coverage of products in scope of VA, the deviation from the estimated total market presented in Table 16 by the study team is relatively small for the recent years of 2014 - 2017. The fluctuation of ca. 0.66 up to 1.75 million units higher or lower than the reported total sales of imaging equipment from signatories, this can be explained by the comparison of the linear regression of the model and the natural year by year fluctuation of real-life sales figures. For the higher estimated annual sales, it could also be partially the number of imaging equipment outside of the scope of VA due to current exemptions and scope boundary.

Lifetime of imaging equipment

In the preparatory study, it was determined that the lifetime of imaging equipment ranged between 4 years for inkjet printers and up to 6 years for laser printers. The lifetime of imaging equipment is a key parameter for assessing the stock, life cycle cost and the resource consumption. The lifetime used in this study is the "economic product life", which

[82] Independent inspector RINA Consulting via VA signatories, stakeholder consultation, July-August 2018

represents the lifetime where the product is in normal use, and it is the lifetime between the design lifetime and the behavioural lifetime. The different definitions of lifetime are presented in Table 18.

Table 18: Different definitions of lifetime

The design lifetime	The behavioural (or social) lifetime	Definition in current study
Is the intended lifespan regarding functioning time, the number of functioning cycles, etc., foreseen by the manufacturer when the product is designed, provided that it is used and maintained by the user as intended by the manufacturer. The design lifetime must not be confused with the guarantee period of products, which is a service offered by the Manufacturer and fulfils other constraints, namely commercial.	Is defined as the number of years until the device is replaced for reasons other than technical failure or economic unattractiveness. This generally regards social and consumption trends, a product including new feature(s) has been released and is preferred, e.g. a more quicker imaging equipment type with enhanced imaging capabilities	The term "lifetime" or "Economic product life" used in the current study must be understood as the period (i.e. the number of years) during which the appliance is used and consumes electricity ("actual time to disposal"). Therefore, it is a value included between the social lifetime and the design lifetime.

According to the preparatory study[83] the lifetime of printers used in private households may only be two to three years. This statement was based on inputs from stakeholders. However, this is not assumed to be the case anymore as more documents are digital and fewer printed.

According to the "Office equipment calculator"[84] made by ENERGY STAR, supported by stakeholder inputs, the lifetime is assumed to be 6 years for laser printers and MFDs. For inkjet printers, inkjet MFDs, ENERGY STAR calculator and preparatory study indicated 4 years, whereas the inputs from stakeholders indicated 5 years lifetime, so from 2017 onwards the lifetime for inkjet products are assumed 5 years. The lifetime of consumables is below one year. It is highly dependent on the cartridge/container yield (i.e. how many pages can be printed) and user use patterns. The lifetime spans used in this study are presented in Table 19.

[83] EuP Preparatory Studies "Imaging Equipment", 2008
[84] https://www.energystar.gov/sites/default/files/asset/document/Office%20Equipment%20Calculator.xlsx

Table 19: Estimated lifetime of imaging equipment.

Product	Lifetime
Inkjet printers	5
Laser printers	6
Inkjet MFDs	5
Laser MFDs	6
Scanner*	6
Copier	6
Facsimile (Fax) Machine	6

* Scanners are not in the scope of the current VA.

Imaging equipment stock

The stock of imaging equipment in Europe are determined based on sales and the expected lifespan. In the current stock model, the statistical standard deviation of the lifetime is assumed to be 1 year for imaging equipment. This is used to calculate the number of imaging equipment in the stock, using a normal distribution for their lifetime of years +/- the standard deviation of years. The sales figures and the lifetime assumptions above are combined to obtain the stock model. The stock of all imaging equipment is shown in Table 20 for every 5th year from 2015 -2040.

Table 20: Stock of imaging equipment from 2015 to 2040 in million units

	2015	2020	2025	2030	2035	2040
Inkjet printers	18.9	4.4	4.9	4.6	4.4	4.2
Laser printers	27.7	24.4	23.1	22.0	20.9	19.9
Inkjet MFDs	62.7	66.9	75.5	71.8	68.2	64.9
Laser MFDs	23.3	26.4	25.3	24.1	22.9	21.8
Scanner	2.1	4.1	5.6	5.7	5.7	5.7
Copier	5.7	2.1	0.1	0.0	0.0	0.0
Facsimile (Fax) Machine	4.2	1.5	0.1	0.0	0.0	0.0
Total stock	**144.6**	**129.7**	**134.6**	**128.2**	**122.2**	**116.5**

When looking at the sales and the stock in compiled graphs it is seen that the sales (and thus the stock) increases over time, resulting in a total stock of almost 180 million products in 2006. After 2006 there is a decrease in the stock originating from the drop in sales. The

average decrease in stock from 2010 to 2040 is approximately 1.3% per year. The sales and stock figures will be used in subsequent tasks to estimate annual energy consumption and the resource consumption.

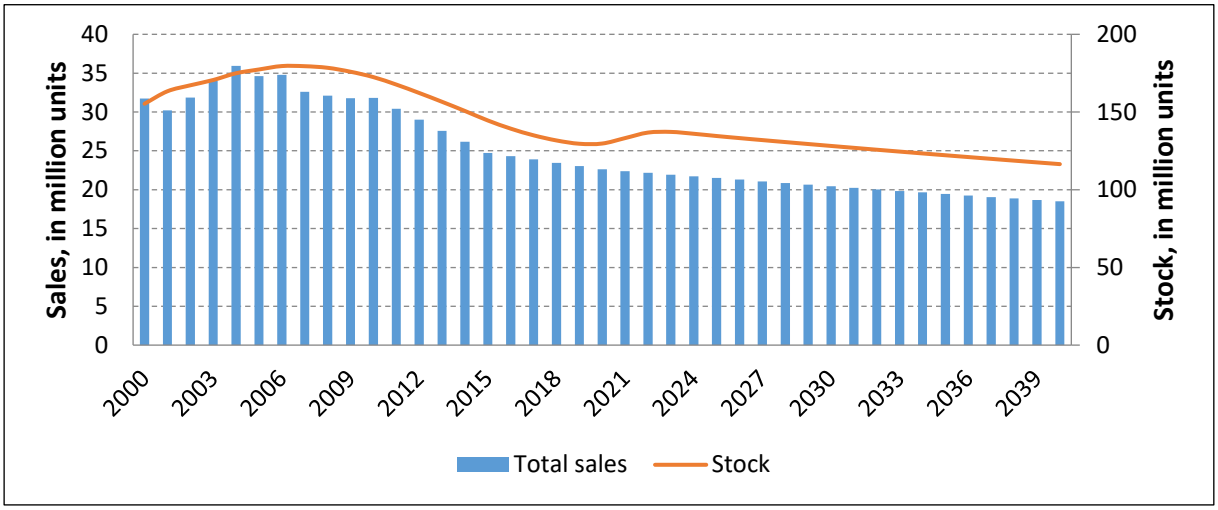

Figure 10: Total annual sales and stock of imaging equipment

The stock of imaging equipment will also be used in the following section on sales of consumables, since the sales of consumables are assumed to be correlated with the stock of imaging equipment.

The decrease in sales of imaging equipment corresponds well with the decrease in sales of paper. The sales of paper have decreased steadily since 2007 (the tendency before 2007 is unknown). The sales of graphic paper[85] are presented in Figure 11.

[85] http://www.euro-graph.org/statistics

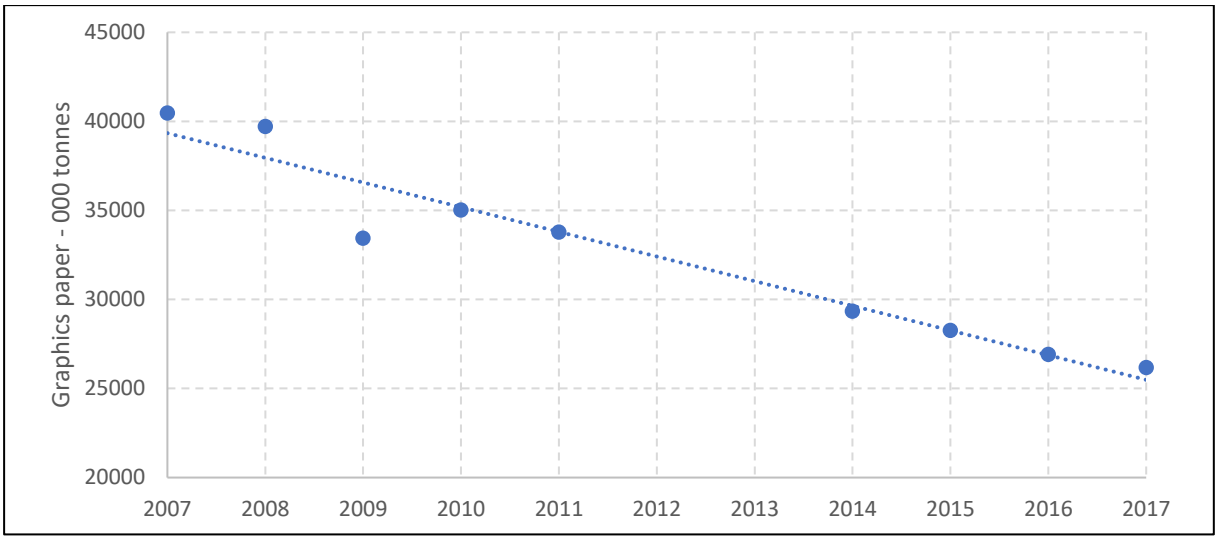

Figure 11: Sales of graphic paper.

The sales of graphic paper have decreased with 4.3 % annually in the period between 2007 and 2017. Within the same timeframe the sales of imaging equipment decreased with 2.8 %.

2.2.2 Market and stock data for consumables (ink and toner)

Sales of consumables

The sales data for consumables are divided into four main categories which are:

- Ink cartridges
- Ink containers
- Toner cartridges
- Toner containers

The definitions of cartridges and containers can be found in Task 1. The main difference is that containers for ink or toner do not contain integrated components or moving parts integral to the imaging equipment's function, whereas cartridges do.

These four categories are expected to cover all types of consumables (inks and toners) for imaging equipment. The sources and assumptions made to calculate the sales are presented below:

- The current annual sales of ink and toner consumables are 2008-2016 data for Western Europe from InfoTrends[86], it is scaled up to the whole EU-28 via a factor derived from GDP.

[86] U.S., Western European and World Wide Market and Trends for Laser and Inkjet Supplies, John Shane, sales data from 2008 - 2016

- The historical data was linearly estimated based on the available data for 2008 - 2016.
- From 2017 and onwards to 2021, it is based on IDC's information[87] that toner and inkjet cartridges sales are falling 2.7% - 4% annually, due to multipack and high yield inkjet cartridges, as well as high yield toner cartridges with the intention to reduce servicing costs in contracts.
- From 2021 onwards, no data is available, sales are assumed to have a steady 1% decrease.
- The data from InfoTrends only consider ink and toner consumables and does not further sub-divide into "cartridges" or "containers", the following assumptions are made:
    - For ink it is assumed that 20 % of the ink is sold as cartridges and the remaining 80 % are sold as containers (unit count), according to inputs from stakeholders[88],[89].
    - For toner it is assumed that 80 % of the toner is sold as cartridges and the remaining 20 % are sold as containers, according to consultant's expert opinion.

A correlation between the current sales of consumables and imaging equipment in stock are determined, this would be inputs for analysis in later tasks, see Table 21.

Table 21: Correlation between consumable sales (inks and toners) and equipment in the stock

	2008	2010	2012	2014	2016	*Average*
Ink cartridges and containers						
Ink consumables sales (million units)	393	392	409	404	404	*401*
Stock of inkjet printers and inkjet MFDs (million units)	100	100	96	87	77	*92*
Ink units/equipment	**3.9**	**3.9**	**4.3**	**4.6**	**5.2**	***4.3***
Toners cartridges and containers						
Toner consumables sales (million units)	144	143	149	147	148	*146*
Stock of laser printers and laser MFDs (million units)	42	46	49	50	51	*48*
Toner units/equipment	**3.4**	**3.1**	**3.1**	**2.9**	**2.9**	***3.1***

[87] IDC, EMEA Consumables Tracker, March 2017. Western Europe Consumables shipments, 2014-2021 by technology.
[88] EFIM (European Federation of ink and ink cartridges manufacturers) inputs, stakeholder consultation July-August 2018
[89] VA signatories do not agree with the data provided

The average sales of ink consumables per each imaging equipment is 4.3 per year, and the average sales of toner consumables per each imaging equipment is 3.1 per year. It is not clear how the data from InfoTrend cover multipacks (e.g. 3 + 1 container package) which consists of the three primary colours and black containers in one pack. However, as the average number of consumables per imaging equipment is quite low 3.1-4.3 consumables per year, it is assumed that the data is based on the sales units reported by companies for the packaged final products, this means multipack with several tanks in one would consider as one consumable. The two packaged products in Figure 12 would be considered as two consumables in the estimated sales, therefore the actual number of cartridges and containers is possibly slightly higher than the estimated figures.

Figure 12: Example of a Canon printer consumables, there are five slots for ink containers, 3 + 1 are sold in one multipack, and a black container sold separately (source: author's own images)

20 % of the inkjet units are assumed to be cartridges and the remaining 80 % are containers. For laser printers and laser MFDs, 80 % are assumed to be cartridges and 20 % containers. The overall consumable sales have been estimated and are presented in Figure 13.

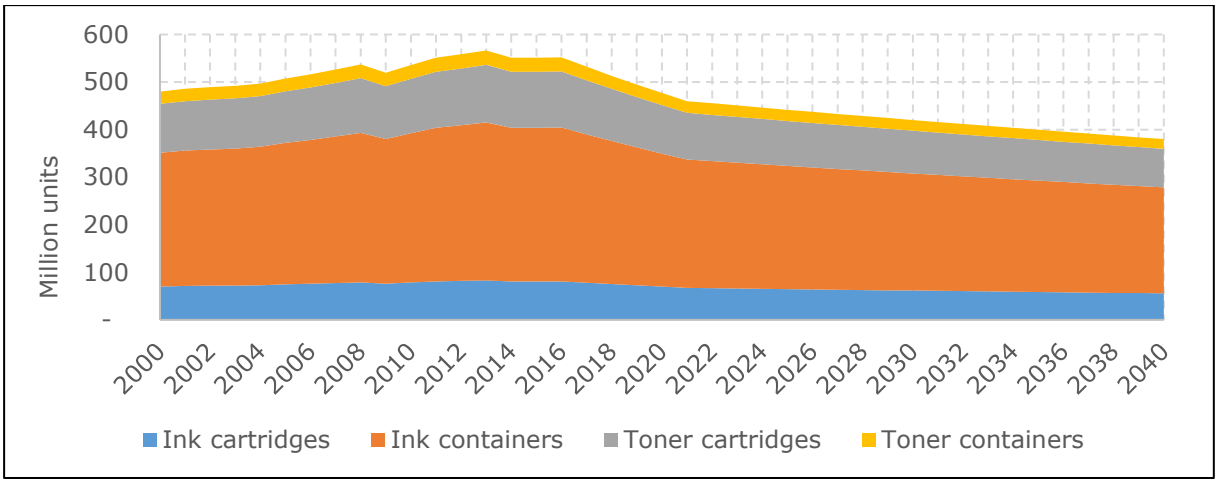

Figure 13: Estimated sales of consumables (ink and toner cartridges and containers)

As a verification of the stock model, in 2018, the current model estimates 376 million inkjet and 137 million toner cartridges, similar figures (370 million inkjet and 135 million toner cartridges) are quoted by the Commission's study on cartridges.[90] The sales of ink cartridges and containers are higher than the sales of toner cartridges and containers throughout the period 1995 to 2040. It is expected that the sales of ink and toner consumables will decrease due to decreasing stock levels of imaging equipment. Whilst other types of imaging equipment also use ink and toner consumables; the sales of these other products are too low to have a significant impact on consumable sales levels. The annual sales are presented in table below.

Table 22: Annual sales of consumables in million units and growth rate

	2015	2020	2025	2030	2035	2040	2015-2040
	Annual sales ofconsumables in million units						Growth rate %
Ink cartridges	80.76	69.90	64.74	61.57	58.55	55.68	-1.48%
Ink containers	323.03	279.61	258.97	246.28	234.21	222.73	-1.48%
Toner cartridges	117.86	102.02	94.49	89.86	85.45	81.27	-1.48%
Toner containers	29.47	25.50	23.62	22.46	21.36	20.32	-1.48%
Total sales	**551.12**	**477.03**	**441.83**	**420.17**	**399.58**	**380.00**	-1.48%

The stock of ink and toner consumables is not calculated due to consumables are used and discarded a few times within a year. The total sales are an important input parameter to consider in this study since significant environmental impacts occur in the production and distribution phase of consumables, see further in Task 5. In connection to end-of-life, the

[90] Study on the implementation of product design requirements set out in Article 4 of the WEEE Directive. The case of re-usability of printer cartridges. 2018.

number of discarded cartridges is also important, and this can be calculated based on the sales. In addition, the collection rate is highly important for ink and toner consumables since reuse, remanufacture and recycling can reduce the environmental impacts.

Consumables market structure

The market of the consumables in Western Europe as shown in Figure 14 is assumed to be representative for the EU-28. The OEMs account for nearly 68% of ink consumables, and 79% of the toner consumables. In addition, each market intelligence has its own terminology for the market segment, in the "compatible" segment below, remanufactured OEM cartridges and new non-OEMs (such as non-OEM new builds, clones etc.) cartridges are included. Without the exact distribution, it can be expected the OEM cartridges (both new and remanufactured) can account up to ca. 80% of inkjet and ca. 88% for toners. "Refillers" refers to only refilling of ink and toner, no repair or remanufacturing occurring. "Counterfeits" refers to the non-OEMs cartridges labelled as OEMs.

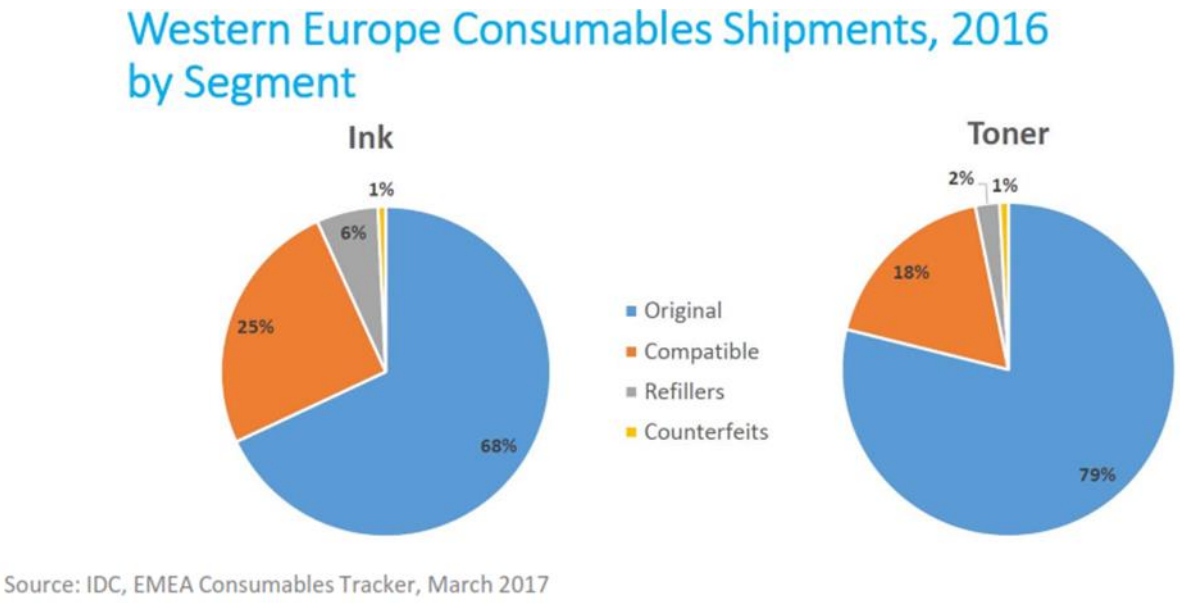

Figure 14: EMEA consumables market segment 2016. (Source: DKWU, referencing IDC as source)

The current VA signatories actually cover a rather large market share of the consumables in the EU market. The signatories cover ca. 73 -78%, depending on the companies included in "others", see Figure 15 below. Combining with OEMs cover 80 – 88% total EU consumables market, this means that VA signatories cover up to 68% of the market. If the VA expands to include more signatories, this coverage would increase. It is therefore worth considering the formal inclusion of consumables in the VA scope as proposed in Task 1.

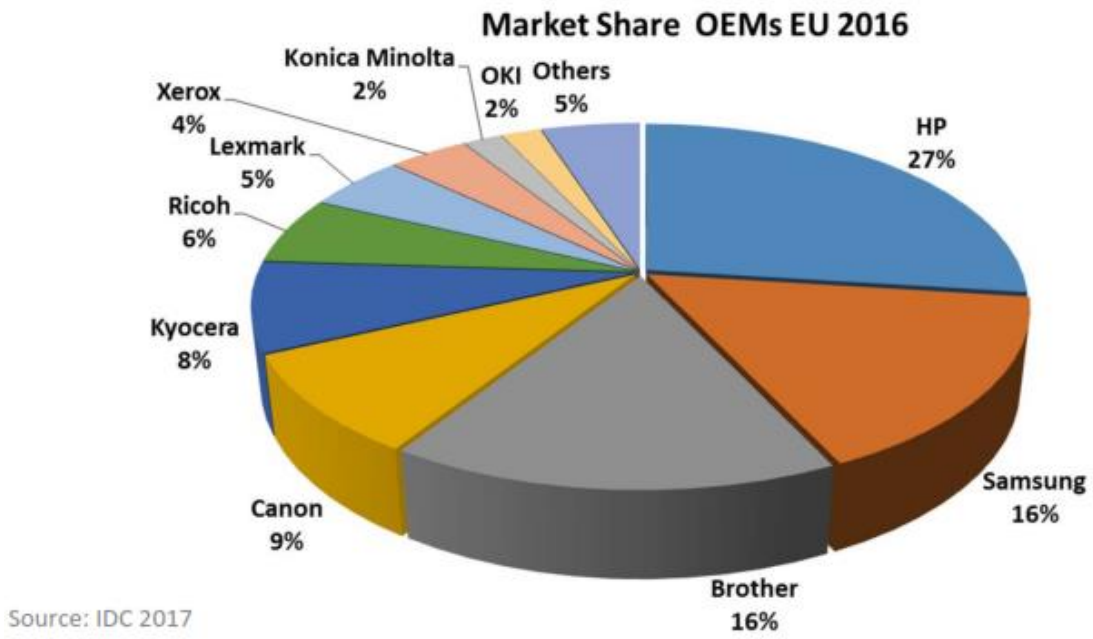

Figure 15: EU Market share of consumables by OEM in 2016. (Source: DKWU, referencing IDC as source)

2.3 Market trends

This section of the report investigates some of the general market trends associated with imaging equipment on the EU market. This includes the trends in sales and trends in functions which all can have an impact on the future market of imaging equipment. This has been taken into account when forecasting the annual sales in previous subsections. This section is divided into the following parts:

- General market trends which gives an estimation of the general market trends (growth/decline per segment)
- Market channels and production structure which describes how imaging equipment is traded
- Product trends which describes how the products in scope are evolving with new features

2.3.1 General market trends

The general market trends are somehow already described in Section 2.2, as it estimates the future sales and thereby the trend. For all product categories the sales are expected to decrease. The average growth/decrease per 5 year from 2000 to 2020 and the average annual growth/decrease from 2000-2040 are presented in Table 23.

Table 23: Average annual growth (green) and decrease (red)

	2000-2005	2005-2010	2010-2015	2015-2020	2020-2040
Inkjet printers	4.1%	-4.8%	-37.0%	-1.0%	-1.0%
Laser printers	2.1%	0.9%	-3.8%	-1.0%	-1.0%
Inkjet MFDs	4.1%	4.3%	3.5%	-1.0%	-1.0%
Laser MFDs	14.9%	8.4%	5.9%	-1.0%	-1.0%
Scanner	26.2%	12.9%	14.8%	13.9%	0.0%
Copier	-1.7%	-5.1%	-12.9%	-100.0%	0.0%
Facsimile (Fax) Machine	-9.0%	-28.1%	-12.9%	-100.0%	0.0%
Ink cartridges	4.5%	1.2%	-4.0%	-3.4%	-1.0%
Ink containers	4.5%	1.2%	-4.0%	-3.4%	-1.0%
Toner cartridges	8.0%	4.4%	2.1%	-0.1%	-1.0%
Toner containers	8.0%	4.4%	2.1%	-0.1%	-1.0%

In the beginning of the century most imaging equipment experienced an increase in sales except for copiers and fax machines. This decline in sales of copiers and fax machines are expected to continue and it is predicted that these types of equipment will disappear from the market by 2020. Scanners are the only type of equipment, which will have stable sales after 2020. The consumables are assumed to follow the general trend with falling sales after 2020. Except for scanners, single function equipment has in general experienced the highest decrease in sales.

2.3.2 Market channels and production structure

Imaging equipment is sold as a product and as a service. In the vast majority of cases imaging equipment sold into domestic premises is sold as a product rather than service. Some repair services may be provided with domestic product purchases, but on-going site-based support is unlikely to be provided. In the commercial sector, there are many organisations, including manufacturers, which offer a broad range of imaging equipment services such as leasing contract and service contracts with a variety of payment schemes. Where imaging equipment services are employed these include management of the imaging equipment from cradle to grave as well as full management of any consumables.

Japanese and US based companies account for the majority of imaging equipment manufacturing, with most of this manufacturing taking place in Asia. Some imaging equipment and consumable manufacturing does still take place within the EU. For example, Canon in

Germany [91], Océ in the Netherlands[92], Xerox in the Netherlands[93] and Brother in Slovakia[94] The consumable remanufacturing business also has well established manufacturing facilities in many EU member states.

2.3.3 Product trends

General trends in technology, design and product performance are investigated in this section. Some market trends have already partly been presented in previous sections where it is clear that MFD equipment have gained popularity over single function printers, but also that the total market size of imaging equipment is decreasing. This decrease is likely attributable to the "paper free office" trend and continued digitisation of services such as e-tickets and digital letters from many public and private organisations. The sales trends which are discussed further in the following section are:

- Single function units to MFDs
- Increase in functions such as "Managed Print Services" (MPS)
- Paperless offices
- Circular economy trends
- Trends for consumables

Single function devices to MFDs

The shift from single function devices to multifunctional devices is present in the sales numbers presented in Section 2.2. This shift was also pointed out in the preparatory study as one of the major trends. A review of historical sales data confirms that the predicted shift to multi-functional devices was correct. It is assumed that this trend will continue towards 2040, with sales of single function devices decreasing dramatically. According to the preparatory study the driving forces behind this trend was:

- Digitalization and miniaturization in electronics which enables smaller devices with more functions without increasing the size of the product.
- The affordability of MFDs compared to single function devices. The price of MFDs had decreased making them more available for consumers.
- Consumer perception of having different functionalities available in a combined device.

These factors are still considered to be the main driving forces for the shift from single function devices to MFDs.

[91] https://www.canon.de/about_us/about_canon/giessen/
[92] https://www.oce.com/about/corporate-information/worldwide/netherlands/
[93] http://www.xerox.com/perl-bin/world_contact.pl
[94] http://brother-slovakia.sk/

Increase in services

Besides functions such as printing, scanning, faxing etc. other functions are also gaining popularity for imaging equipment. Some of these functions are connected with availability and management of devices and internet of things. An example is Managed print services (MPS) which can be defined as:

Managed print services (MPS) are services offered by an external provider to optimize or manage a company's document output. The main components provided are needs assessment, selective or general replacement of hardware, and the service, parts and supplies needed to operate the new and/or existing hardware (including existing third-party equipment if this is required by the customer). The provider also tracks how the printer, fax, copier and MFP fleet is being used, the problems, and the user's satisfaction."

Paperless Offices

The paperless office is not a new idea, as it has been around since the introduction of the personal computers. An early prediction of the paperless office was made in a 1975 Business Week article[95]. The overall idea of the paperless office was based on the premise that digitalisation and general office automation that would make paper redundant for a number of tasks, such as bookkeeping, recordkeeping etc. The article predicted that printing would be almost redundant in 1995. This has since proven not to be correct, but the idea of a paperless office and paperless society is still present and development towards paperless society is taking place but with a much longer lead time. There are many ways in which paper consumption can be reduced, including[96,97]:

- Share files without printing. With cloud solutions such as Microsoft Office 365, Google Docs, Dropbox etc., it is possible to work simultaneously with colleagues on a document or spreadsheet.
- Track the number of pages printed per person and generate monthly reports, so the awareness of printing habits is increased.
- Request paperless statements and bills from service providers (e.g. bank statements, telecommunication bills etc.)
- Overall government decision that all written communication from the public services will take place digitally e.g. through an official e-mail-box (e.g. Denmark)

Many imaging equipment manufacturers published tips on how to use less paper in the office[98]. The trend of paperless office may happen at a slower speed than predicted in 1975

[95] https://www.brother.co.uk/blog/sme/2017/paperless-office-tips-small-business
[96]https://www.cio.com/article/2377681/time-management-productivity/14-tips-for-creating-a-paperless-office.html
[97] https://www.forbes.com/sites/kateharrison/2013/04/19/5-steps-to-a-nearly-paperless-office/#69850f0e7e9a
[98] https://www.brother.co.uk/blog/sme/2017/paperless-office-tips-small-business

but based on the paper consumption presented in Figure 11, it is seen that the paper consumption is dropping. This could also be related to a generation change, younger people more used to work through displays on mobile phones and notebooks instead of paper, are coming into offices and organisations.

Circular economy trends

A circular economy is an alternative to a traditional linear economy (make, use, dispose) in which resources are kept in use for as long as possible, extracting the maximum value from them whilst in use, then recover and regenerate products and materials at the end of each service life. Within recent years the awareness of resource depletion has increased, and the ideas of the circular economy have been widely accepted as a solution that can improve resource efficiency.

Some efforts have already been undertaken to design imaging equipment to account for modularity, maintainability and recyclability as some professional equipment are partly modular with easily replaceable parts/modules. When products are designed in a modular way, the waste generation is reduced as the main equipment expands its lifetime. This is a way to design out waste which a commonly known method to reduce the environmental impacts of products. The design out waste approach are closely connected with the waste hierarchy. The waste hierarchy is presented in Figure 16. The waste hierarchy presents the most environmentally friendly alternative for products, which means that is better to recover materials (incineration for energy generation) than to dispose materials, and it is better to recycle materials than to recover materials and so on.

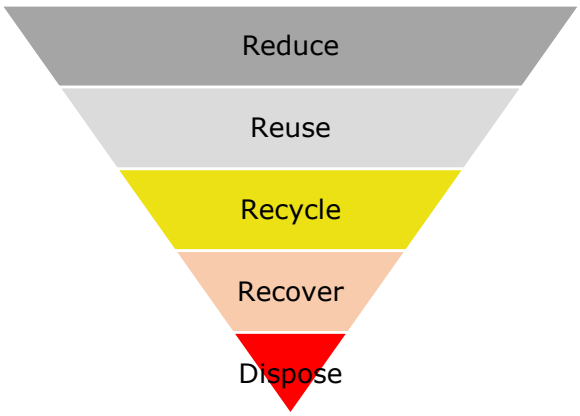

Figure 16: The waste hierarchy

In addition, some efforts have been made on both the design and supply chains of cartridges and containers to increase resource efficiency. The amount of materials used within consumables over the life of an imaging equipment product is not insignificant. Consumables, such as toner and ink cartridges, are less likely to be designed in order to facilitate ease of disassembly and recyclability. It is suggested that potential leakage of ink or toner

could have some negative impact on design features, which facilitate disassembly and recyclability. Design features which eased disassembly and recyclability could be encouraged through wider adoption of remanufacturing of consumables by OEMsSome imaging equipment manufacturers have taken steps to reduce the number of materials used in printer cartridges in order to facilitate more effective material recovery.[99]

The collection rate of OEM cartridges is only 18% to 25% via OEM takeback programmes[100], but the reusable fraction of the collected cartridges is high at 75% to 80%. Other sources indicate that the collection rate for all OEM cartridges is lower, and including B2C products, the total collection of all cartridges sold is expected to be below 25%. Due to the low collection rate, it is unlikely that cartridges are remanufactured or refilled more than once[100]. Other sources also report remanufacturing rates between 20% and 30%[101]. Cartridge remanufacturing is undertaken by a range of organisations ranging from small companies to the major imaging equipment manufacturers themselves. Based on the high fraction of reusable products of the collected products it can be assumed that there is substantial technical potential for increased collection and reuse through improved handling of the fraction of cartridges which enter the WEEE stream, diverting them from recycling and energy recovery.

Another circular design option offered by some manufactures[102] are pay per use or print as a service. The rationale of this idea is that the consumers are not interested in the device itself but the service it delivers, so the manufactures retains ownership of the device. In theory, this could promote imaging equipment that is more durable, maintainable and recyclable as manufacturers and service providers have a vested interest in increasing product longevity. The benefits of the circularity, however, have to be assessed in conjunction with the energy consumption during use because newer products tend to have lower energy consumption.

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[99] https://www.kyoceradocumentsolutions.com.au/environment/Pages/ECOSYSOzoneSafeTechnology.aspx
[100] Study on the implementation of product design requirements set out in Article 4 of the WEEE Directive, The case of re-usability of printer cartridges, http://ec.europa.eu/environment/waste/weee/pdf/KH0418170ENN.pdf
[101] EITRA, Key facts about the cartridge remanufacturing market, available from http://www.etira.org/cartridge-remanufacturing/key-facts/
[102] E.g. https://www.ricoh.co.in/products/printer-as-a-service

Trends for consumables[103]

Some stakeholders[104] report that barriers to consumable remanufacturing are increasing. The stakeholders reported that advanced technical features in consumables, such as embedded software on chips, can have a detrimental effect on the ability to remanufacture consumables at their end of life. Whilst these advanced technical features may not be purposefully hindering remanufacturing, their inclusion in products may result in fewer consumables being remanufactured. This means that less consumables are remanufactured by 3rd party remanufacturers, which may impose increased environmental impacts.

According to an OEM manufacturer[105], remanufacturing toner cartridges has been a successful business, the process of remanufacturing and manufacturing a cartridge from new is identical once the cartridge empties are supplied by either their supplier or collected back from end-users. For cartridges unable to be reused, the materials are recycled into new products. Reuse and recycling of cartridges are gaining the focus of the OEM manufacturers but slowly.

Other OEMs do not undertake significant amounts of consumable remanufacturing. It is unclear whether these other OEMs have plans to increase consumable remanufacturing. Some OEMs have made efforts to reduce environmental impacts of consumables through other approaches such as the inclusion of recycled content in new consumables.

2.4 Consumer expenditure base data

The average consumer prices and lifetime end-user costs are determined by prices in the following categories:

- Purchase price
- Installation costs
- Repair and maintenance costs
- Running costs for operation (i.e. costs for electricity, paper, and toner/ink consumables)
- End of life cost

Each of the above costs are explained in the following sub-sections.

[103] According to a stakeholder, this section does not accurately represent the trends and state of the market
[104] ETIRA, stakeholder consultation, July-August 2018.
[105] LEXMARK, stakeholder consultation, June 2018.

Printers and MFDs come in a wide variety of formats with different purchase and operating costs. Furthermore, prices and costs also vary widely depending on whether the printing is colour or monochrome.

All aspects of the LCC (Life Cycle Cost) analysis, except electricity consumption, were established based on data collected in the study from online retail prices, including costs of consumables, purchasing costs, and maintenance.

2.4.1 Interest and inflation rates

All economic calculations were made with 2016 as the base year, as this is the latest whole year for which data is available. Inflation rates from Eurostat[106] were used to scale costs to 2016-prices. Furthermore, a discount rate of 4% was used in accordance with the MEErP methodology.

2.4.2 Base cases identification

In order to calculate LCC, the base cases have been identified in early stage to avoid time-consuming data collection on speed categories not to be used in the later modelling and analyses. The base cases aim at being representative of the current market. They have been established by the study team with stakeholder input mainly from the industry. The sales presented in section 2.2 have been distributed further into colour capability and product speed in image per minute (ipm). This is done by assuming the composition of the market is more or less the same as the composition of products registered in the US ENERGY STAR database.

As the EU version of the ENERGY STAR database is no longer functional[107] due to expiration of the EU-US agreement, the most comprehensive and updated dataset available for imaging equipment is the US ENERGY STAR database. Unfortunately, in recent years the level of product information provided in the ENERGY STAR database has been significantly reduced. The reduction in data granularity has resulted in a truncated analysis of average technologies for this review project. Table 24 illustrates the numbers and types of imaging equipment that are registered in the US ENERGY STAR database. The total estimated sales for each main product type (e.g. Laser MFD, inkjet printer) in previous sections have been included to help estimate sales at the sub-product type level (e.g. Colour Laser MFD with a speed range of 20 to 40 images per minute (ipm). The total sales values are multiplied by the percentage of each sub-product type in the ENERGY STAR database to arrive at

[106] http://ec.europa.eu/eurostat/statistics-explained/index.php/File:HICP_all-items,_annual_average_inflation_rates,_2006-2016_(%25)_YB17.png
[107] https://ec.europa.eu/energy/en/energy-star

sales at the sub-product type level. Note that there are no inkjet products above 40 ipm registered in the ENERGY STAR database.

The results in Table 24 show that there is considerable variability in the home and office imaging equipment market. This variability makes it difficult to identify typical technologies. It can also be noted that the speed categories outside of the current VA scope accounts for over 12% of the total sales of printers and MFDs, so the speed limits in the VA are outdated as already mentioned in Task 1.

For each technology and colour format, the speed interval with the highest sales are highlighted by bold font in Table 24. The cells shaded in grey illustrate speed categories of products which are not in scope of the current VA.

Table 24: Types of Imaging Equipment Registered in the US ENERGY STAR database (September 2018) and Estimated 2018 Sales Data. Speed intervals with the highest sales are highlighted by bold font. Cells shaded in grey illustrate speed categories of products not in scope of the current VA.

Type	Marking Technology	Colour Format	Monochrome Product Speed (ipm)	Count in Database	% in Database	Sales	
						Per Speed Category Product Type	Per Product Type
MFD	Inkjet (IJ)	Colour	**s ≤ 20**	**186**	**6.7%**	**54,555,905**	87,113,461
			20 < s ≤ 40	111	4.0%	32,557,556	
MFD	Inkjet (IJ)	Mono	20 < s ≤ 40	5	0.2%	1,466,557	2,053,179
Printer	Inkjet (IJ)	Colour	**s ≤ 20**	**102**	**3.7%**	**9,889,318**	13,961,390
			20 < s ≤ 40	42	1.5%	4,072,072	
Printer	Inkjet (IJ)	Mono	s ≤ 20	4	0.1%	387,816	484,770
			20 < s ≤ 40	1	0.0%	96,954	
MFD	Electro-photographic (EP)	Colour	s ≤ 20	69	2.5%	1,011,693	11,685,785
			20 < s ≤ 40	**471**	**17.0%**	**6,905,903**	
			40 < s ≤ 51	150	5.4%	2,199,332	
			51 < s ≤ 60	39	1.4%	571,826	
			60 < s ≤ 80	55	2.0%	806,422	
			s > 80	13	0.5%	190,609	
MFD		Mono	s ≤ 20	71	2.6%	1,041,017	13,108,019

Type	Marking Technology	Colour Format	Monochrome Product Speed (ipm)	Count in Database	% in Database	Sales	
						Per Speed Category Product Type	Per Product Type
	Electro-photographic (EP)		**20 < s ≤ 40**	**472**	**17.0%**	**6,920,565**	
			40 < s ≤ 60	184	6.6%	2,697,847	
			60 < s ≤ 66	32	1.2%	469,191	
			66 < s ≤ 80	42	1.5%	615,813	
			s > 80	93	3.4%	1,363,586	
Printer	Electro-photographic (EP)	Colour	s ≤ 20	29	1.0%	1,139,832	10,219,183
			20 < s ≤ 40	**164**	**5.9%**	**6,445,946**	
			40 < s ≤ 51	32	1.2%	1,257,746	
			51 < s ≤ 60	15	0.5%	589,568	
			s > 60	20	0.7%	786,091	
Printer	Electro-photographic (EP)	Mono	s ≤ 20	20	0.7%	786,091	14,188,943
			20 < s ≤ 40	**154**	**5.6%**	**6,052,901**	
			40 < s ≤ 60	112	4.0%	4,402,110	
			60 < s ≤ 66	12	0.4%	471,655	
			66< s ≤135	50	1.8%	1,965,228	
			s > 135	13	0.5%	510,959	
Copier	All	All	All	10	6.7%	-	8,800,727
Fax	All	All	All	6	4.0%	-	206,267

The base cases are chosen from each category in Table 24, the speed range with the highest sales has been chosen, with the exception for inkjet monochrome printers, whose sales were low in general. The speed ranges have been crosschecked with average speed, they match quite well, except for laser monochrome MFDs and printers. To avoid overestimation of energy and resource consumptions, the speed range 20 < s ⩽ 40 is chosen for these two categories too, as they also match the base case (V3 and V1) from preparatory

study completed in 2008. There is no base case for copiers and fax, as their sales are relatively low and expected to continue to decline.

Professional printer and MFD is also chosen to be a base case, as it is important to assess if they should be in or out of the scope of VA, and to estimate impacts of fully aligning with the newest draft of ENERGY STAR version 3.0 scope.

Based on the sales distribution by speed categories and supported by stakeholder inputs[108], the base cases in current study are chosen, and shown in Table 25. BC 1- 5 are supported by majority of stakeholders, EVAP did not support including BC 6 – 7, however BC 6 still showed relevant amount of sales, and the inclusion of BC 7 in analysis would provide better evidence whether VA should align with US ENERGY STAR and include them in the VA scope. The analyses in the later tasks will focus on these 7 base cases, instead of all speed categories.

Table 25: Base case identified mapped with preparatory study 2008 base cases
"s" denotes the product speed expressed in images per minute (ipm)

#	Base cases for current study	Preparatory study base case[109]
BC1	Monochrome Laser MFD, 20 < s ≤ 40	V1
BC2	Colour Laser MFD, 20 < s ≤ 40	V2
BC3	Monochrome Laser Printer, 20 < s ≤ 40	V3
BC4	Colour Laser printer, 20 < s ≤ 40	V4
BC5	Colour Inkjet MFD, s ≤ 20	V5/V6
BC6	Colour Inkjet Printer, s ≤ 20	-
BC7	Professional printer and MFD	-

2.4.3 Purchase cost

Purchase costs for imaging equipment products can vary depending on the technology, brand and the capability. They range from less than 100 EUR for small[110] inkjet printers, up to many thousands of euros for large MFDs (see Figure 17).

Purchase prices shown in Figure 17 are based on ca. 500 data points via online collection supported by stakeholder inputs[111] and their deviation error bars show the range of varying prices for each product type.

[108] Stakeholder consultation, October – November 2018.
[109] Task 5, EuP Preparatory Studies "Imaging Equipment", 2008
[110] Small means a printing speed of 20 image per minute (ipm).
[111] Stakeholder consultation, inputs received for BC 2 – 3 and BC 5- 6, September – November 2018

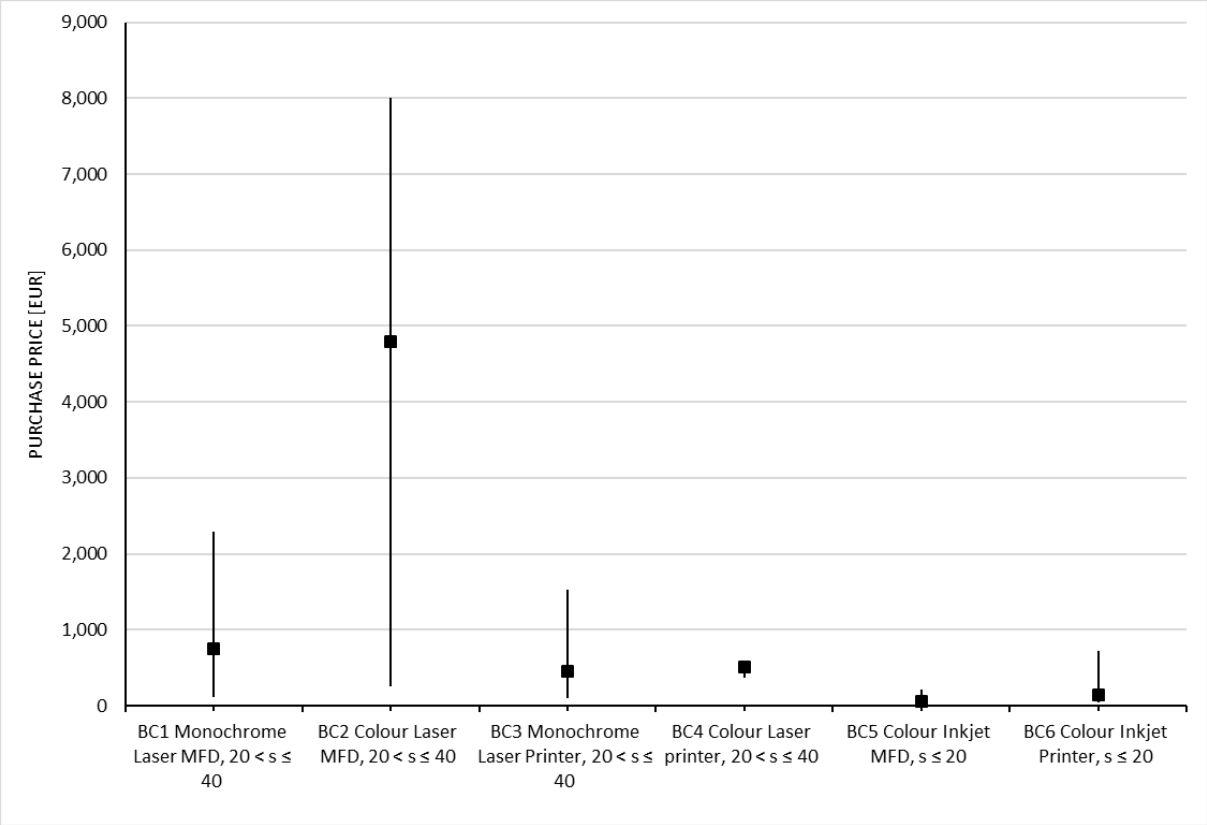

Figure 17: Purchase prices (low, high and assumed for each BC) for imaging equipment products from online collected data[112] excluding professional products

It can be seen in the figure above that colour inkjet printers have a wider variation of prices than inkjet MFDs and therefore the average price is higher, this is mainly because there are only a few of single inkjet printers on the market, these are more specialised and often more expensive.

Average price per unit according to Statista[113] is approx. 114 -115 EUR in 2010 -2015 and it is approx. 122 EUR in 2018 and it is projected to increase to 123 EUR in 2020. The average price in Statista covers all B2C and B2B sales for printers and copiers, and therefore many different sizes and technologies are included in the dataset.

As recommended in Task 1, professional imaging equipment should be included as a new category in VA scope, to align with ENERGY STAR version 3.0 specification. The figure below shows the purchase price and the varying range for professional printer or MFDs, the prices were collected via online research[114].

[112] "s" in each base case indicates the printing speed in image per minute (ipm).
[113] Average price per unit for printers and copiers, https://www.statista.com/outlook/15030500/102/printers-copiers/europe?currency=eur#market-volumePerCapita
[114] Online research, August 2018.

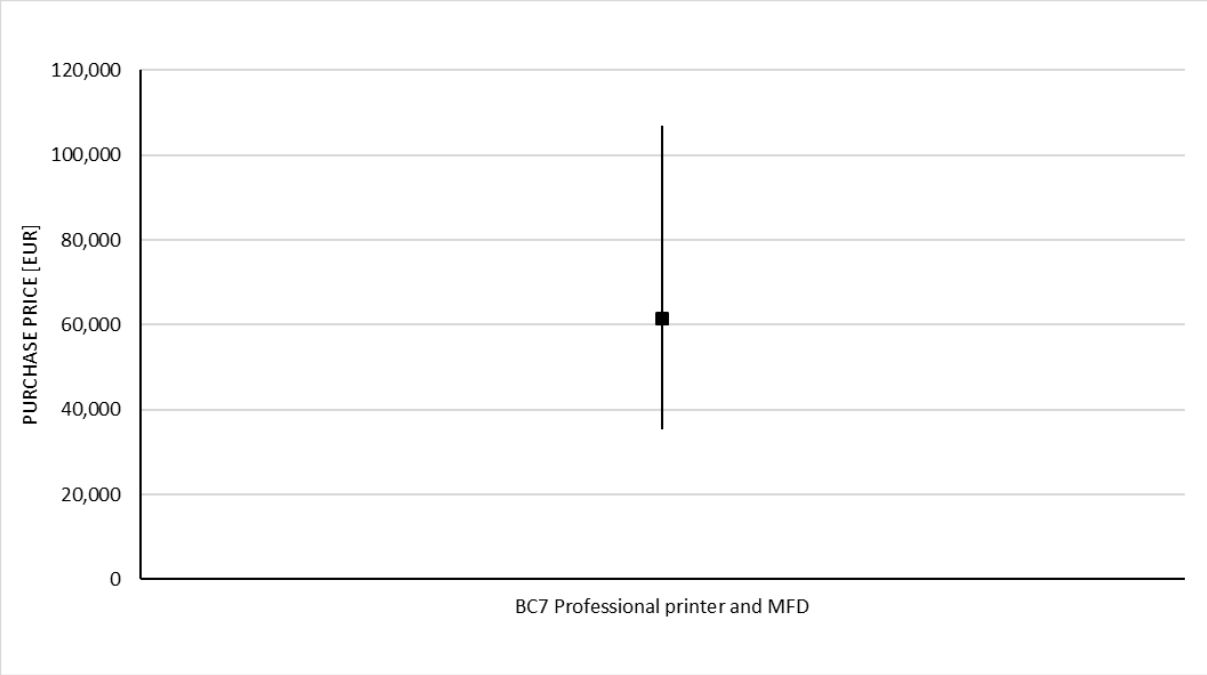

Figure 18: Purchase price range (low, high and assumed) for professional imaging equipment products from online collected data

The average unit price assumed for each imaging equipment type in this study is shown in Table 26. These would be used for the LCC calculation.

Table 26: Average unit purchase prices for imaging equipment used for the LCC calculation

BC#	Product	Average purchase price [€]
BC1	Monochrome Laser MFD, 20 < s ≤ 40	757
BC2	Colour Laser MFD, 20 < s ≤ 40	4800
BC3	Monochrome Laser Printer, 20 < s ≤ 40	456
BC4	Colour Laser printer, 20 < s ≤ 40	513
BC5	Colour Inkjet MFD, s ≤ 20	58
BC6	Colour Inkjet Printer, s ≤ 20	139
BC7	Professional printer and MFD	61395

2.4.4 Installation costs

Installation costs are considered negligible. Consumer printers usually do not require installation from a professional. Even though larger machines require professional installation, the cost level for this is still marginal compared to the cost of the machine, in some

cases, this could cost up to several thousand EUR, but this would be part of the total purchase costs.

2.4.5 Running costs for operation

Imaging equipment running costs typically consist of the costs of electricity and the cost of consumables such as paper, toner and ink cartridges/containers.

Imaging equipment running costs vary considerably depending on a number of variables such as type, functionality, brand and usage. The costs identified below represent averages based on desk research and literature reviews.

Electricity costs

The annual electricity price based on the PRIME Model[115] and provided by the European Commission will be used for the economic calculations in this study. The electricity prices are reported in 2013 EUR/kWh and corrected for inflation to fixed 2016-prices as shown in Table 27. The electricity price is divided into household and services. These premises are assumed to be the most suited for printers and are therefore used. However, it should be noted that the PRIME Model has forecasted lower electricity price development than the MEErP. Previously an escalation rate of 4 % was used according to MEErP methodology but based on the PRIMES number the escalation rate is only approximately 1 %.

Table 27: 2016 electricity rates according to PRIMES

	Price in €/kWh (2016-prices)	
Year	Households	Services
2005	0.159	0.127
2010	0.175	0.151
2015	0.194	0.160
2020	0.207	0.174
2025	0.213	0.179
2030	0.216	0.183

The prices were given every fifth year and linear interpolation is used in between.

[115] https://ec.europa.eu/clima/policies/strategies/analysis/models_en

The preparatory study 2008 has been used for finding the annual electricity consumption of MFDs and printers, the assumptions for usage hours from the study are confirmed still applicable by the 2017 compliance report for the VA[116]. The power consumption may be slightly outdated, as the data was collected in 2008, and with EU VA in place, the average product in the EU could be more efficient. Task 3 presents the current energy consumption for different product types with more recent data, in this section, the aim is to show the overall proportion of the LCC during different phases.

For professional printer and MFD, the EPEAT and ENERGY STAR databases have been assessed to find average annual electricity consumption, and assuming the same lifetime as laser printers and MFDs.

Using the annual electricity consumption presented below and the electricity price for services for 2015, the typical electricity costs for the chosen MFDs and printers are calculated and shown in Table 28.

Table 28: Typical printers and MFDs calculated annual costs from electricity use

Product	Annual electricity consumption, kWh/a	Annual electricity costs, €/a
BC1 Monochrome Laser MFD, 20 < s ≤ 40	250	40
BC2 Colour Laser MFD, 20 < s ≤ 40	370	59
BC3 Monochrome Laser Printer, 20 < s ≤ 40	270	43
BC4 Colour Laser printer, 20 < s ≤ 40	360	58
BC5 Colour Inkjet MFD, s ≤ 20	22	4
BC6 Colour Inkjet Printer, s ≤ 20	18	3
BC7 Professional printer and MFD	664	106

Consumables

Paper

The amount of paper consumed per imaging equipment model is strongly related to product speed. However, it is difficult to match these into the speed ranges in "ipm", therefore the

[116] http://www.eurovaprint.eu/fileadmin/eurovaprint_files/pdfs/2018/REG0405001_EuroVAprint-8th_period_repf.pdf

preparatory study paper usage for inkjet printer and MFDs and the ENERGY STAR usage profile from the ENERGY STAR Imaging Equipment Test Method[117] have been investigated.

According to recent statistics, average daily print volume per user is reduced by 16% annually from 2015 to 2016[118], as well as many paper intensive sectors such as financial and legal sectors, their printed volumes have been decreased by 10% - 18% from 2015 to 2016. Given this trend has been gradually taken place, the printed volume should be significantly reduced compared with data from 2008. Preparatory study 2008 assumed 19.5 kg/year office paper usage, this is equivalent to ca. 17,333 images in a lifetime of 4 years. This is quite high for colour inkjet MFD and colour inkjet printer, which are mainly domestic equipment or operated much less frequent than common office equipment.

For other laser base cases, the images over lifetime is found using the ENERGY STAR number of jobs per day and the equation for calculating number of images per job as part of the test method, then assuming 261 working days per year. It is found to be 742,832 images per lifetime, however this is seen as quite high for most of the laser base cases. The print volumes using ENERGY STAR test method usage profiles has been developed as with the test method in mind. Using these data for assessment of real-life paper use implies uncertainties.

For mono laser printer, the stakeholder inputs indicated a rather small equipment, therefore a lower number of images printed per lifetime is assumed. Based on the stock volume of consumables, and the page yield data obtained via online research and stakeholder inputs, the total printed volume per lifetime deviate from the data from preparatory study 2008 and the images calculated using ENERGY STAR equation. It is therefore decided to align the printed volume with the estimated consumables sales and page yields with credible sources. The assumed total printed pages per lifetime are presented in Table 33.

For professional equipment, the pages per month is found via online search for high, medium and low speed based on recommended and/or maximum monthly volumes, and weighted average was found 78,000 pages per month and 56 million pages over a lifetime of 6 years. This method may over-estimate the print volume because it is part of the technical specification of the equipment capability and not necessarily reflecting typical use of the products.

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[117] https://www.energystar.gov/sites/default/files/FINAL%20Version%203.0%20ENERGY%20STAR%20Imaging%20Equipment%20Program%20Requirements.pdf

[118] From 20.54 pages in 2015 to 17.39 pages in 2016. https://www.printaudit.com/printaudit-blog/by-the-numbers-2015-2016-industry-printing-statistics-are-out-and-the-details-are-surprising

The costs of paper were found to be 0.042 EUR/sheet for A4 paper, and 0.062 EUR/sheet for A3 paper, based on retail prices online of 20 samples from 10 suppliers[119]. Paper prices also vary due to different weights, finishes, and paper type (e.g. recycled or virgin). Normally, paper would be a significant factor in the running costs of an LCC calculation, but paper is however not a key focus in the current review study, so the costs of this consumable is not included in the LCC, in order to concentrate on the other costs of the LCC.

Toner and ink cartridges

Cost of toner or ink consumables vary greatly based on type and capacity. Small laser and inkjet printers tend to have the highest price per EUR/printed sheet, while large laser MFDs tend to have the lowest. Table 29 illustrates the variability in consumable prices according to draft GPP for imaging equipment technical report[120]. OEM produced cartridges tend to be generally more expensive than remanufactured and non-OEM cartridges.

Table 29: Collected price data for toner and inkjet cartridges for MFDs and printers.

Printing technology	Cartridge manufacturer	Color/monochrome	Price range (EUR/cartridge)	Yield range (pages/ lifetime)	Cost per page range (EUR)
Laser	OEM	Black	49-269	1400-50000	0.002-0.054
		Colour	67-326	1000-55000	0.002-0.067
	Remanufactured & non-OEM	Black	26-67	1000-44000	0.002-0.050
		Colour	20-105	1000-38000	0.002-0.021
Inkjet	OEM	Black	6-37	300-2500	0.011-0.058
		Colour	24-26	1020-1500	0.017-0.024
	Remanufactured & non-OEM	Black	9-20	560-1200	0.017-0.032
		Colour	n.a.[121]	n.a.	n.a.

Toner consumable prices in EUR/sheet are highly dependent on consumable yield (i.e. the number of pages that can be printed from a single cartridge/container). Lower yield consumables are approximately 10 times more expensive in terms of price per printed sheet. This cost differential is likely due to the overall consumable costs being largely determined by the manufacturing and distribution of the cartridge itself rather than the toner material. Higher yield consumables are most often used in larger imaging equipment. Lower yield consumables are most often used in smaller imaging equipment.

[119] 4CC, Image, Color Copy, HP, Brother, Lomax, Avery, Rey Text & Graphics, Multicopy, Symbio.
[120] Revision of EU Green Public Procurement (GPP) criteria for Imaging Equipment. Preliminary Report (Draft 1). September 2018. JRC, Viegand Maagøe and Tenvic. Available at: http://susproc.jrc.ec.europa.eu/imaging-equipment/docs/PR_GPP_EUIE_1st_AHWG_September_2018.pdf
[121] n.a. = data not available for cartridges that were compatible to the MFDs/printers where price data were collected

Based on a set a more recent data and stakeholder inputs for BC 2 – 3 and BC 5 - 6, Table 30 below shows the assumed average price of consumable per sheet of paper, which is used to calculate the running costs from consumables usage in the total life cycle costs. However, due to the lack of remanufactured consumables data, the average page yield is assumed the same as OEM cartridges, in addition, the failure rate is assumed at 10% for non-OEMs whereas it is assumed 3% for OEMs to account for the higher failures in non-OEM products, indicated by imaging equipment manufacturers. The term "failure rate" is used to describe any consumable, which does not function on first install into an imaging equipment product, or which ceases to function after a short period of functionality. The assumed failure rates are based on manufacturer data[122]. For professional printer and MFD, the average prices for cartridges are limited, so it is assumed that the prices are the same for OEM and non-OEM cartridges, and the same page yield for non-OEM and OEM laser cartridge yields is applied due to limited data.

It can be noted that some cartridges for colour equipment is cheaper than monochrome equipment, this relates to the page yield. In the data found via desk research online, the average yield is lower for cartridges for colour equipment than mono. As colour equipment has often up to 4 cartridges or containers (for mono, cyan, magenta and yellow), the average yield and prices of each individual consumable is lower, this depends on how the consumables are sold, as mentioned previously. For inkjet products, MFD consumables are cheaper than printers, this can be due to the dataset is skewed towards business products, the inkjet printers left on the market are likely to be more specialised.

[122] http://www.hp.com/canada/en/commercial-printers/designjet/pdf/printhead-reliability.pdf

Table 30: Average price per sheet, average price per cartridge/container and page yield as well as failure rate assumed for OEM and non-OEM consumables (prices take the failure rates into account)

	OEM cartridge and container				Non-OEM cartridge and container			
Product type	Average €/Sheet	Average price	Average Page Yield	Failure rate	Average €/Sheet	Average price	Average Page Yield	Failure rate
BC1 Monochrome Laser MFD, 20 < s ⩽ 40	0.009	€ 140	15729	3%	0.004	€ 59	15729	10%
BC2 Colour Laser MFD, 20 < s ⩽ 40	0.004	€ 90	25499	3%	0.003	€ 67	25499	10%
BC3 Monochrome Laser Printer, 20 < s ⩽ 40	0.041	€ 129	3250	3%	0.018	€ 53	3250	10%
BC4 Colour Laser printer, 20 < s ⩽ 40	0.021	€ 130	6409	3%	0.010	€ 61	6409	10%
BC5 Colour Inkjet MFD, s ⩽ 20	0.064	€ 18	288	3%	0.043	€ 11	288	10%
BC6 Colour Inkjet Printer, s ⩽ 20	0.057	€ 27	480	3%	0.010	€ 4	480	10%
BC7 Professional printer and MFD	0.0014	€ 111	81650	3%	0.0015	€ 111	81650	10%

2.4.6 Running costs for repair and maintenance

Many imaging equipment vendors (e.g. manufacturers and resellers) also offer service agreements on equipment. Imaging equipment service agreements are also available through specialised companies.

The average imaging equipment repair cost has been estimated to be is approximately €52 ($60), with costs varying from €34 to €78 ($40 to $90)[123].

In the USA, one-year on-site service costs approximately €170 ($199)[124] for printers and the same service costs approximately €260 ($299) for copiers. Imaging equipment service costs in the EU in practice can be slightly lower than in the USA, which is due to higher labour costs in the US than the average EU labour costs[125]. A service subscription for large MFD devices can cost around €595 EUR ($700) a year, and around €8 ($9) a year for smaller devices[124]. Some manufacturers note that it is more expensive to repair some types of imaging equipment than it is to manufacture new products[126]. In these cases, manufacturers are more likely to provide a new product (if under warranty) or suggest that users purchase a new product rather than attempt to repair a malfunctioning one. This issue, of buying new rather than repairing, would most frequently relate to inkjet printers and inkjet MFDs given their relatively low purchase prices. Repair prices for these products are therefore assumed to be zero, or it would have to be the same as the original sales price. Repair and maintenance costs include both labour costs and the costs of spare parts. Stakeholders have provided inputs for BC 2 and 3, these have been included.

Table 31: Assumed repair and maintenance costs for typical imaging equipment.

Product type	Repair & Maintenance [EUR/year]
BC1 Monochrome Laser MFD, 20 < s ⩽ 40	170
BC2 Colour Laser MFD, 20 < s ⩽ 40	400
BC3 Monochrome Laser Printer, 20 < s ⩽ 40	50
BC4 Colour Laser printer, 20 < s ⩽ 40	170
BC5 Colour Inkjet MFD, s ⩽ 20	0
BC6 Colour Inkjet Printer, s ⩽ 20	0
BC7 Professional printer and MFD	595

In cases where imaging equipment need to be repaired by a professional, the average EU labour cost in the category "Industry, construction and services (except public administration, defence, compulsory social security)" is used, as shown in Table 32. The labour costs

[123] https://www.thumbtack.com/p/printer-repair-cost , accessed July 2018.
[124] http://www.office.xerox.com/perl-bin/product.pl?product=SERVICE&page=pric , accessed July 2017.
[125] https://tradingeconomics.com/united-states/labour-costs
[126] http://www8.hp.com/uk/en/campaign/out-of-warranty/oow.html

are based on the latest Labour Cost Survey (currently 2012) and an extrapolation based on the quarterly Labour Cost Index (LCI). The data covered in the LCI collection relate to total average hourly labour costs[127].

Table 32: Average total labour costs for repair services in euro per hour

	2000	2004	2008	2012	2013	2014	2015	2016
EU-28 countries, EUR/h	16.7	19.8	21.5	23.9	24.2	24.5	25.0	25.4

As shown in Figure 19, labour costs vary greatly across Europe. The labour cost in each country can affect the end-users' willingness to repair[128].

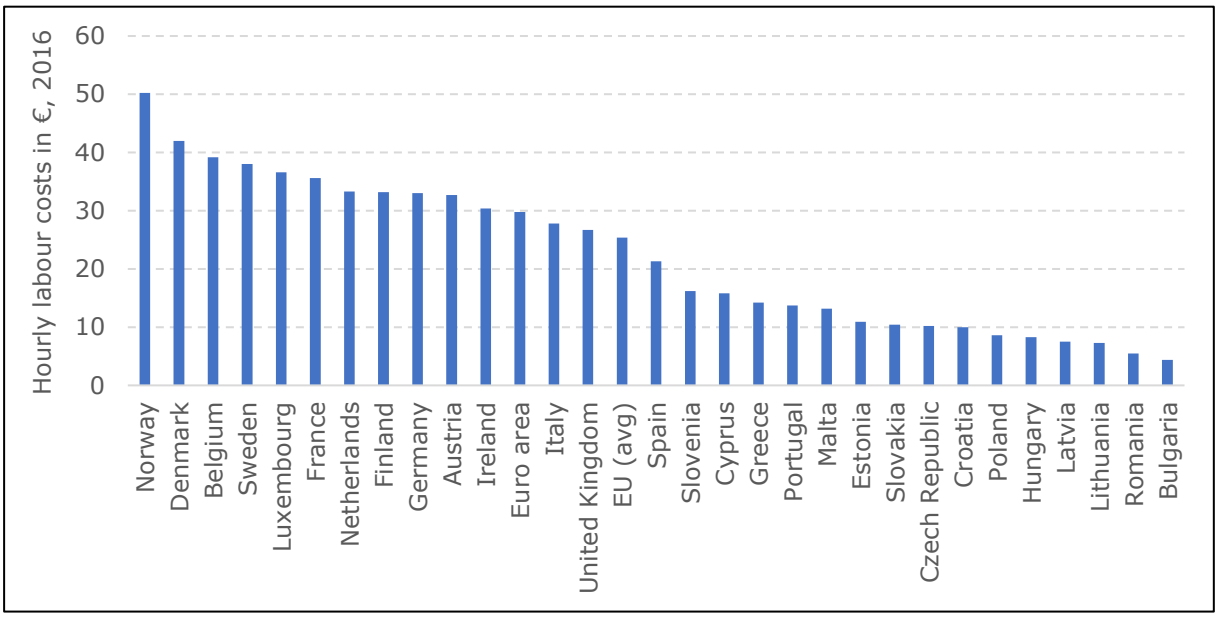

Figure 19: Hourly labour cost in EUR, 2016 for European countries[129]

2.4.7 End of life costs

End of Life (EoL) costs can include the costs for disposal of imaging equipment, costs of purchasing services from recycling companies, or transportation costs to recycling stations or WEEE stations. As most office-based imaging equipment is relatively easy to uninstall, the costs of decommissioning can probably be considered negligible. WEEE recycling costs vary depending on specific EU member state laws and which type of party (i.e. domestic or commercial) initiates the recycling. In the UK, recycling costs begin at around 100 EUR for 70 kilos of waste but can be significantly higher depending on manual labour requirements and transportation capacity[130]. These costs are likely to vary widely across different

[127] http://ec.europa.eu/eurostat/cache/metadata/en/lc_lci_lev_esms.htm#unit_measure1475137997963
[128] Note that the time for repair can vary depending on the operation, and the hourly labour cost is not directly used in later tasks.
[129] https://ec.europa.eu/eurostat/web/labour-market/labour-costs/database
[130] https://www.envirowaste.co.uk/commercial/weee-recycling-and-it-disposal/, accessed July 2017.

EU Member States due to the differences in how WEEE is implemented across the EU. Given that recycling costs are insignificant compared to purchase and running costs, the end-of-life costs have been neglected.

The disposal costs are often paid by the end-user buying the product in the form of the Eco tax under the WEEE Directive, however this can be different for some Member States. For imaging equipment, WEEE fees are usually around 3 to 5 EUR/tonne[131]. This fee is adjusted on a country basis and by product category depending on recycling costs.

Table 33 below shows the EoL costs for imaging equipment, the total numbers of OEM cartridges or non-OEM cartridges used over a lifetime. Imaging equipment is calculated by assuming 5 EUR/tonne and the average weight of each imaging equipment product type. The number of cartridges used over a lifetime is found via the assumed pages prints over the lifetime of the equipment and the page yield previously presented in Table 30. Using the average weight of cartridge and the same WEEE fee of ca. 5 EUR/tonne for cartridges' proper disposal, the total EoL costs for OEM and non-OEM cartridges are estimated. It can be seen in the table below, that due to the number of cartridges used over a lifetime of the imaging equipment, the EoL disposal costs for all cartridges are higher for most cases in comparison with the disposal costs of the imaging equipment itself.

It should be noted that the number of OEM and non-OEM cartridge used in a lifetime is highly dependent on several variables: 1) printed pages over a lifetime, 2) the average page yields per cartridge and 3) the average cartridge unit weight. These contain a number of uncertainties due to previously mentioned disagreement of data on typical printed pages for each speed categories, and the lack of data for average page yields for non-OEM cartridges, therefore the number of cartridges in lifetime per imaging equipment might be over- or underestimated. The aim is to show the distribution of costs from different life cycle phases.

[131] Ca. 4.4 EUR/tonne for business and ca. 5.9 EUR/tonne for households in Denmark, therefore assumed slightly higher than EU average, https://www.dpa-system.dk/da/WEEE/Producenter/%C3%98konomi/Gebyrer

Table 33: EoL costs estimation for imaging equipment products, using OEM or non-OEM cartridges

Product type	Pages/ lifetime	Imaging equipment		OEM / non-OEM cartridge	OEM cartridge		Non-OEM cartridge	
		Average weight, kg	EoL costs, €	Average cartridge weight, kg	Number of OEM cartridges in lifetime	EoL costs, €	Number of non-OEM cartridges in lifetime	EoL costs, €
BC1 Monochrome Laser MFD, 20 < s ≤ 40	350,000	51.94	0.260	0.71	22	0.17	25	0.48
BC2 Colour Laser MFD, 20 < s ≤ 40	576,000	71.50	0.358	0.71	23	0.38	25	0.35
BC3 Monochrome Laser Printer, 20 < s ≤ 40	53,000	12.59	0.063	0.71	16	0.27	18	0.38
BC4 Colour Laser printer, 20 < s ≤ 40	120,000	34.45	0.172	0.71	19	0.41	21	0.48
BC5 Colour Inkjet MFD, s ≤ 20	6,500	7.64	0.038	0.05	23	0.01	25	0.01
BC6 Colour Inkjet Printer, s ≤ 20	10,500	12.59	0.063	0.05	22	0.002	24	0.01
BC7 Professional printer and MFD	56,160,000	323	1.613	0.71	688	2.45	688	2.45

2.4.8 Total Life Cycle Costs

Considering all the information, assumptions and data presented in previous sections of this chapter, the total LCCs were established (see Figure 20 and Figure 21). Please notice that in this section, the electricity consumption data in the LCC is based on the preparatory study from 2008. An updated LCC based on updated electricity consumption data analysed in Task 3 is presented in Task 5.

The cartridges are a major cost during the lifetime of printers and MFDs. The actual printed pages over lifetime presented has a direct influence on the calculated running costs as the number of cartridges needed depends on the printed volume. The LCC presented in this subsection are based on the study team's assumption for printed volumes, this in reality can vary a lot from case to case.

It can be seen that cartridges account for the dominant share of the LCC for both OEM and non-OEM cartridges used. However, slightly more prominent for the OEM cartridges due to average higher costs of cartridges. It is especially important for laser printers and MFDs

with speed more than 20 ipm, because the assumed pages printed over a lifetime is much higher due to the higher speed. For colour laser MFD, the stakeholder input heavily skews the average product purchase price, and maintenance and repair costs, therefore these account for the largest share of the LCC, instead of consumables.

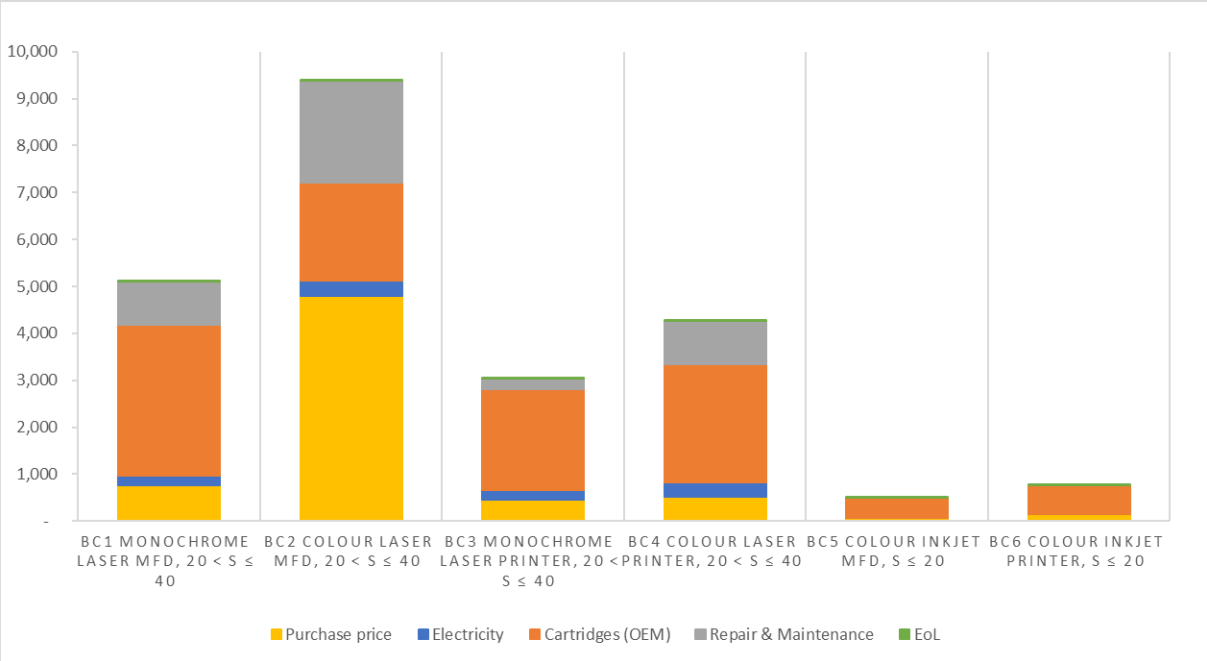

Figure 20: Total Life Cycle Costs for product lifetime with OEM cartridges based on electricity consumption data from the preparatory study.

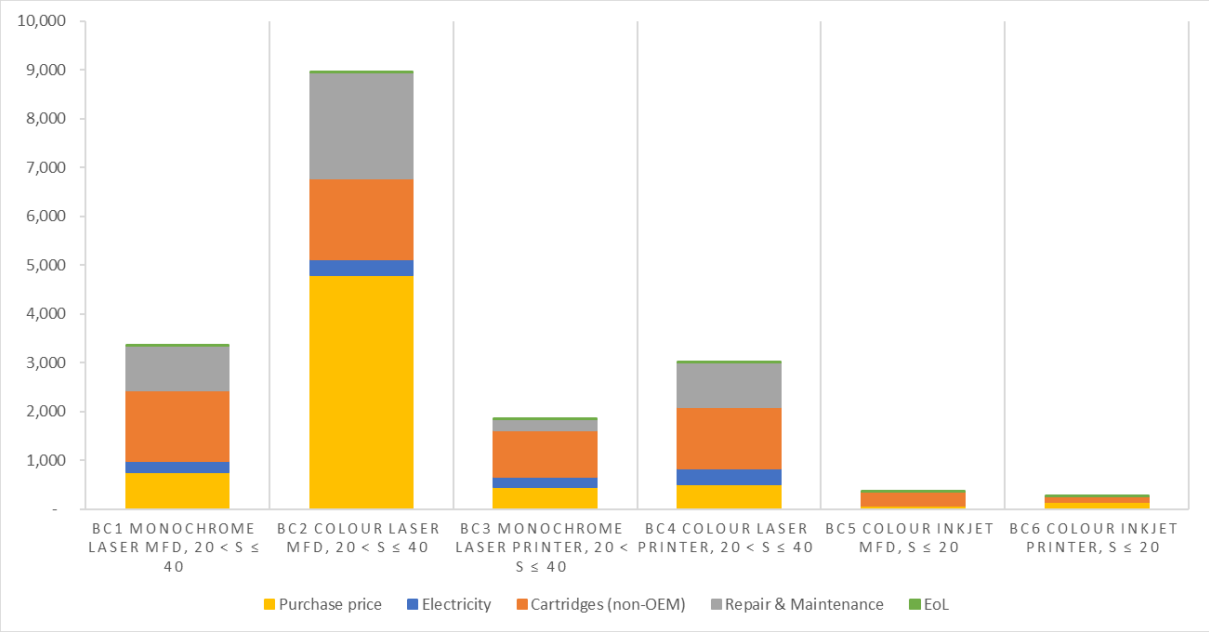

Figure 21: Total Life Cycle Costs for product lifetime with non-OEM cartridges based on electricity consumption data from the preparatory study.

Figure 22 shows the LCC of professional printer and MFD with both OEM and non-OEM cartridges, due to the higher costs per print, the LCC of cartridges is slightly higher for non-OEM. Despite the significantly high purchase price, the cartridges still account for the largest share of the LCC. Again here, the number of pages printed over lifetime and thereby the amount of consumables purchased are based on the study team's assumptions.

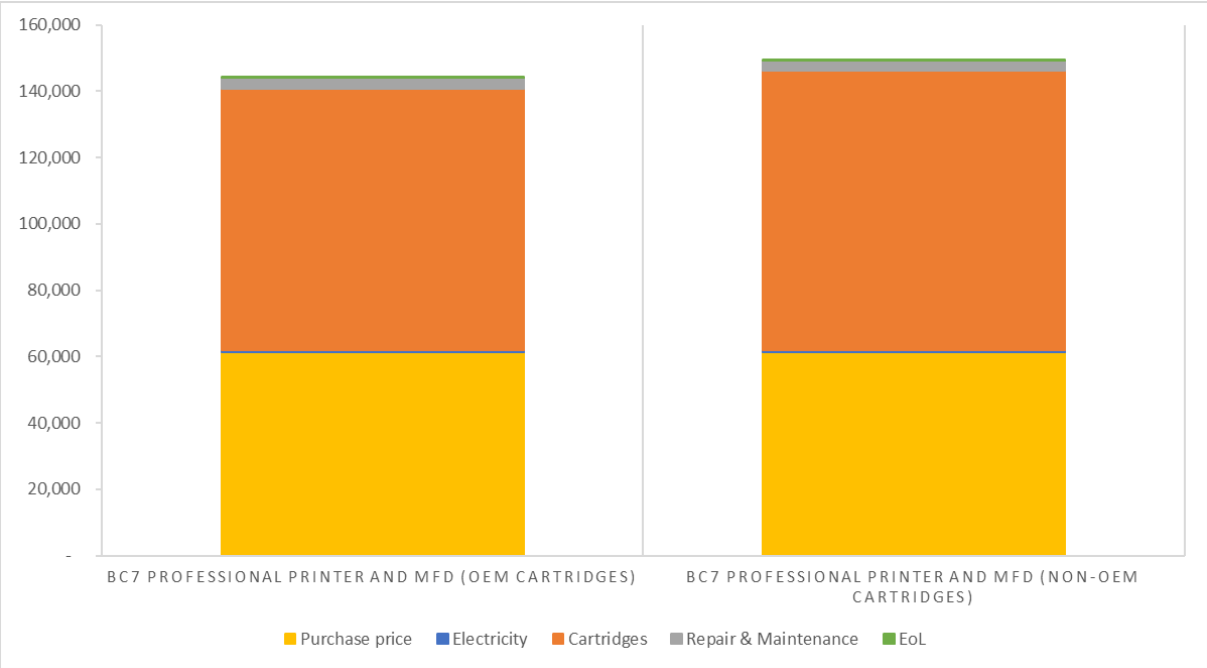

Figure 22: Total Life Cycle Costs for professional imaging equipment with OEM or non-OEM cartridges based on electricity consumption data from the preparatory study.

2.5 Conclusions and recommendations

Based on the market analysis, description of product and market trends, as well as the LCC calculations, the following conclusions can be made.

2.5.1 Market and stock data

Task 2 has reviewed and analysed the PRODCOM production, import and export data in order to derive apparent sales and trade. However, based on experiences, PRODCOM data has not been very reliable, therefore it is not directly used for sales and stock estimation. Annual derived sales in 2016 from PRODCOM shows 24.6 million units of IE equipment, which was used to verify the estimated sales from other sources. The estimated sales derived in this study are presented in Table 34.

Table 34: Annual sales of imaging equipment in million units and growth rate

	2015	2020	2025	2030	2035	2040	2015-2040
	Annual sales of imaging equipment in million units						Growth rate %
Inkjet printers	0.96	0.91	0.86	0.82	0.78	0.74	-1.00%
Laser printers	3.82	3.64	3.46	3.29	3.13	2.97	-1.00%
Inkjet MFDs	14.82	14.09	13.40	12.74	12.12	11.53	-1.00%
Laser MFDs	4.18	3.98	3.78	3.60	3.42	3.25	-1.00%
Scanner	0.46	0.88	0.88	0.88	0.88	0.88	2.63%
Copier	0.57	0	0	0	0	0	-
Facsimile (Fax) Machine	0.40	0	0	0	0	0	-
Total sales	25.21	23.50	22.39	21.34	20.33	19.38	**-1.05%**

Estimated annual sales for all imaging equipment covering inkjet, laser printers and MFDs, copiers, scanner and fax machines are ca. 24.8 million units in 2016, this is more or less in agreement with PRODCOM derived annual sales.

It can be seen in the estimated sales, that copier and fax markets are declining and expected to fall to zero by 2020, therefore they will not be analysed in detailed, this result also supports the proposed scope concluded in Task 1. The market for scanner has also been reviewed, there are sources estimating slight increase in sales up to 2020, however the development beyond which is uncertain, therefore there it is not recommended to include these in the scope of the VA and scanners will not be analysed further in detail. The product scope and recommendations remain as presented in Task 1.

The ink and toner consumables are accounted in kilograms in PRODCOM and in units from other sources and is it therefore not possible to compare these values directly, but it has been used to check the sales indirectly with an assumed weight per unit. In this study the

assumed sales of cartridges and containers are almost 450 million units. The sales of ink and toners is presented in Table 35.

Table 35: Annual sales of consumables in million units and growth rate

	2015	2020	2025	2030	2035	2040	2015-2040
	Annual sales of imaging equipment in million units						Growth rate %
Ink cartridges	80.76	69.90	64.74	61.57	58.55	55.68	-1.48%
Ink containers	323.03	279.61	258.97	246.28	234.21	222.73	-1.48%
Toner cartridges	117.86	102.02	94.49	89.86	85.45	81.27	-1.48%
Toner containers	29.47	25.50	23.62	22.46	21.36	20.32	-1.48%
Total sales	**551.12**	**477.03**	**441.83**	**420.17**	**399.58**	**380.00**	-1.48%

2.5.2 Market trends

The general trend for both equipment and ink and toner consumables is that the market is expected to decrease, and more single function machines are replaced by multifunctional machines which properly in the future will include services such as Managed Print Service. The decline in sales of imaging equipment and ink and toners can be a consequence of the paperless office. However, the paperless office has not yet been fully implemented as many people still prefer to print documents. Another product trend is the implementation of circular economy strategies such as modular printers and equipment as a service (pay per print), however some stakeholders indicates that the recycling of ink and toner consumables are increasing in complexity and thereby reducing the possibility to recycle these consumables. This tendency is not in line with the circular economy, even though some manufacturers are focusing on reuse and recycling.

2.5.3 Consumer expenditure data and LCC

In order to calculate LCC, the base cases have been identified in early stage to avoid time-consuming data collection on speed categories not to be used in the later modelling and analyses. Six base cases have been chosen, mainly based on the highest sales distribution of the speed categories, and in addition, professional printers and MFDs are chosen to be also a base case to assess the impacts of these equipment. See base cases in Table 36 below.

Consumer expenditure, such as purchase costs, installation costs, running costs and end of life costs for imaging equipment have been presented in this task. Based on these data, the LCC for several imaging equipment types have been calculated without including paper

usage. The LCC, summarised in the table below, shows that the running costs of the consumables such as toner and ink containers and cartridges is the largest share of the life cycle costs for most of the base cases chosen. From the consumer expenditure point of view, there could be opportunities to implement policy measures for the cartridges usage and costs.

Table 36: LCC of base cases as the sum of average purchase price, lifetime electricity costs (based on electricity consumption data from the preparatory study), lifetime consumable costs for OEM and non-OEM cartridges and end of life costs discounted back to 1st year.

Product	Average purchase price [€]	Lifetime electricity costs, [€]	Lifetime repair & maintenance [€]	Lifetime consumables		End of Life (equipment and consumables)	
				OEM [€]	Non-OEM [€]	OEM [€]	Non-OEM [€]
BC1 Monochrome Laser MFD, 20 < s ≤ 40	757	217	922	3,210	1,456	0.34	0.35
BC2 Colour Laser MFD, 20 < s ≤ 40	4,800	321	2,169	2,084	1,664	0.44	0.45
BC3 Monochrome Laser Printer, 20 < s ≤ 40	456	195	229	2,163	959	0.12	0.13
BC4 Colour Laser printer, 20 < s ≤ 40	513	312	922	2,507	1,253	0.24	0.25
BC5 Colour Inkjet MFD, s ≤ 20	58	16	-	414	282	0.04	0.05
BC6 Colour Inkjet Printer, s ≤ 20	139	13	-	603	104	0.07	0.07
BC7 Professional printer and MFD	61,395	576	3,226	78,751	84,103	4.06	4.06

3. Users

Printers and MFDs have a diverse range of users. These range from the largest corporate enterprises to individual consumers. Whilst some types of imaging equipment (e.g. large format laser printers) will almost exclusively be used in large organisations or professional print business, some smaller products (e.g. standard format laser printers) may be used by both household and smaller office users.

3.1 Use phase direct energy consumption

According to ENERGY STAR specification v3.0 (effective date 11 October 2019), energy performance of imaging equipment products is compared by two different methods:

- An evaluation of power measured in watts in various operating states. This evaluation method is called Operational Mode (OM). Sleep requirements are applicable for specific imaging equipment products. Off-mode requirements for all OM products.
- An evaluation of typical electricity consumption calculated in kilowatt-hours during normal operation over a week. This evaluation method is called Typical Electricity Consumption (TEC) and it is calculated from energy and time measurements and number of jobs per day (depending on image speed) defined in the TEC test procedure. TEC requirements are applicable for specific imaging equipment products.

The main reason for needing to differentiate between OM and TEC products is that OM products are typically used in households and speciality applications such as large printing equipment. These products spend a significant part of their time in low power modes and have a wide range of usage profiles, which can vary tremendously depending on the type of the user. TEC products are typically used in business applications such as working group devices where power consumption from printing etc. in active mode is also considered important. TEC products would have more harmonised user profiles although they could differ greatly depending on types of users and any corporate policy regarding printing. Therefore, OM products are more fit to an evaluation method that considers only low power modes, while TEC products are better fit to a method that considers active use too.

3.1.1 Applicability of evaluation methods

ENERGY STAR v3.0 classifies in the definition section of the specification imaging equipment products as either “TEC” or “OM” according to the most suitable evaluation method for energy performance. Printers and MFDs are classified as TEC or OM according to their printing media format and marking technology (see Table 37).

Table 37: Applicability of evaluation methods for printers and MFDs (ES V3.0)

Evaluation method	Equipment type	Media format	Marking technology
TEC	Printer	Small[132]	Inkjet: HPIJ
		Standard[133]	Inkjet: HPIJ Laser: EP Others: SI, specialty technologies
	Multifunctional device (MFD)	Standard	Inkjet: HPIJ Laser: EP Others: SI, specialty technologies
	Professional	All	All
OM	Printer	Standard	Inkjet: IJ
		Large[134]	Inkjet: HPIJ
		Large or small	Inkjet: IJ Laser: EP Others: SI, specialty technologies, specialty technologies
	Multifunctional device (MFD)	Standard	Inkjet: IJ, specialty technologies
		Large	Inkjet: HPIJ, IJ Laser: EP Others: SI, specialty technologies

IJ=Inkjet; HPIJ=High Performance Inkjet; EP=Electro-photographic; SI=Solid Ink. Speciality technologies: Some or all of: Direct Thermal, Dye Sublimation, Thermal Transfer and Impact.

Solid ink imaging equipment products are assumed not to be sold in significant volumes in the European market because there are only 6 models of solid ink printer (by one manufacturer) registered in the US ENERGY STAR database (September 2018) and identified as being on sale in the EU. Furthermore, these products have quite similar functionality as laser printers and are targeting the same office users as the laser technology products, so the use patterns are assumed to be similar. Regarding the speciality marking technologies,

[132] Products designed for media sizes smaller than those defined as Standard (e.g., A6, 4"x6", microfilm), including those designed to accommodate continuous-form media less than 210 mm wide.
[133] 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.
[134] 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.

these are sold in very limited numbers and are not assessed specifically. Therefore, the use patterns are only investigated for inkjet (including the HPIJ) and laser technologies.

TEC product requirements and average energy consumption

The TEC evaluation method has been developed by the US EPA for ENERGY STAR as a proxy for a typical use pattern. The measurement and calculation methodologies for TEC products are detailed in ENERGY STAR Product Specification v3.0 and Test Method v3.0 for Imaging Equipment. The specification and test method are periodically reviewed and updated, if necessary, to ensure TEC test results are representative of real-world performance, and this has been the case for version 3.0. The calculation of TEC for TEC products with print capability is shown below:

$$TEC = \left[5 \times \left(E_{JOB_DAILY} + (2 \times E_{FINAL}) + \left[24 - \frac{N_{JOBS}}{16} - (2 \times t_{FINAL})\right] \times \frac{E_{SLEEP}}{t_{SLEEP}}\right) + 48 \times \frac{E_{SLEEP}}{t_{SLEEP}}\right]$$

Where:

E_{JOB_DAILY}=daily job energy (calculation shown below, in kWh)
E_{FINAL}=final energy[135] (kWh)
N_{JOBS}=number of jobs per day
t_{FINAL}=final time to sleep (hours)
E_{SLEEP}=sleep energy (kWh)
t_{SLEEP}=sleep time (hours)

The calculation of TEC for TEC MFDs without print capability is shown below:

$$TEC = \left[5 \times \left(E_{JOB_DAILY} + (2 \times E_{FINAL}) + \left[24 - \frac{N_{JOBS}}{16} - (2 \times t_{FINAL})\right] \times \frac{E_{AUTO}}{t_{AUTO}}\right) + 48 \times \frac{E_{AUTO}}{t_{AUTO}}\right]$$

Where:

E_{AUTO}=auto-off energy (kWh)
t_{AUTO}=auto-off time (hours)

The calculation for daily job energy is shown below:

$$E_{JOB_DAILY} = \frac{1}{4}\left[2 \times E_{JOB1} + \left(N_{JOBS} - 2\right) \times \frac{E_{JOB2} + E_{JOB3} + E_{JOB4}}{3}\right]$$

Where:

E_{JOBi}=energy of the ith job (kWh)

TEC requirements for printers and multifunctional devices being considered by this review study have been aligned to ENERGY STAR v3.0. ENERGY STAR classifies printers and MFDs into speed groups, printing colour and non-professional / professional since energy consumption differs. The product type sub-division according to speed has been revised significantly from v2.0, simplifying this to less categories though adding the professional, assuming this reflects better the current market.

[135] According to ENERGY STAR test method v2.0, it is the energy measured from the time the meter and timer are in zero until the meter shows the product has entered sleep mode, the final sleep mode or auto-off.

The maximum TEC allowed per week for a given printer and MFD is the sum of requirements below plus an adder for A3-capable products an adder for products where Wi-Fi is the interface used during the test, as follows:

$$TEC_{MAX} = TEC_{req} + Adder_{A3} + Adder_{Wi-Fi}$$

Where:

$Adder_{A3}$ =0.05 (kWh/week) for A3-capable products
$Adder_{Wi\text{-}Fi}$ = 0.1 (kWh/week) for products where Wi-Fi is the interface used during the test (only for professional imaging products)

TEC requirements are shown in Table 38 (non-professional) and Table 39 (professional). Version 2 TEC requirements are kept in version 3 for professional products, while the requirements are strengthened for non-professional.

Table 38: TEC requirements for non-professional printers and MFDs for both inkjet and laser technologies (without adders)

Equipment type	Colour	Speed (s) division	TEC_{REQ} to the nearest 0.01 kWh/week for reporting
Printer[136]	Monochrome	s ≤ 20	0.226
		20 < s ≤ 40	0.018 × s – 0.152
		40 < s ≤ 60	0.025 × s – 0.439
		60 < s ≤ 135*	0.049 × s – 1.903
		s > 135*	0.183 × s – 20.127
	Colour	s ≤ 20	0.275
		20 < s ≤ 40	0.032 × s – 0.397
		40 < s ≤ 60*	0.002 × s + 0.833
		s > 60*	0.100 × s – 5.145
Multifunctional device (MFD)	Monochrome	s ≤ 20	0.263
		20 < s ≤ 40	0.018 × s – 0.115
		40 < s ≤ 60	0.016 × s – 0.033
		60 < s ≤ 80*	0.037 × s – 1.314
		s > 80*	0.086 × s – 5.283
	Colour	s ≤ 20	0.254
		20 < s ≤ 40	0.024 × s – 0.250
		40 < s ≤ 60*	0.011 × s + 0.283
		60 < s ≤ 80*	0.055 × s – 2.401
		s > 80*	0.118 × s – 7.504

*The VA contains limits of product speed at 66ipm (mono) and 51ipm (colour), so some of these speed categories do not apply to the VA.

[136] Referred in ENERGY STAR v3.0 as 'Non-MFD'

Table 39: TEC requirements for professional imaging products printers and MFDs for both inkjet and laser technologies (without adder)

Equipment type	Colour	Speed (s) division	TEC_{REQ} to the nearest 0.01 kWh/week for reporting
Printer[137]	Monochrome	s ⩽ 5	0.3
		5 < s ⩽ 20	0.04 × s + 0.1
		20 < s ⩽ 30	0.06 × s – 0.3
		30 < s ⩽ 40	0.11 × s – 1.8
		40 < s ⩽ 65	0.16 × s – 3.8
		65 < s ⩽ 90*	0.2 × s – 6.4
		s > 90*	0.55 × s – 37.9
	Colour	s ⩽ 10	1.3
		10 < s ⩽ 15	0.06 x s + 0.7
		15 < s ⩽ 30	0.15 x s – 0.65
		30 < s ⩽ 75*	0.2 x s – 2.15
		s > 75	0.7 x s – 39.65
Multifunctional device (MFD)	Monochrome	s ⩽ 5	0.4
		5 < s ⩽ 30	0.07 x s + 0.05
		30 < s ⩽ 50	0.11 x s – 1.15
		50 < s ⩽ 80*	0.25 x s – 8.15
		s > 80*	0.6 x s – 36.15
	Colour	s ⩽ 10	1.5
		10 < s ⩽ 15	0.1 x s + 0.5
		10 < s ⩽ 15	0.13 x s + 0.05
		30 < s ⩽ 70*	0.2 x s – 2.05
		70 < s ⩽ 80*	0.7 x s – 37.05
		s > 80*	0.75 x s – 41.05

*The VA contains limits of product speed at 66ipm (mono) and 51ipm (colour), so some of these speed categories do not apply to the VA.

The average energy consumption per week and per year for TEC products are shown in Table 40, which were retrieved from declared data for TEC per week in ENERGY STAR Database (accessed in September 2018). For professional printer and MFD, average TEC

[137] Referred in ENERGY STAR v3.0 as 'Non-MFD'

was based on speed, weight and A3 capability analyses of EPEAT and ENERGY STAR datasets. Assuming 52 weeks in a year, the annual energy consumption is then calculated.

Table 40: Current average TEC per week (from ENERGY STAR database) and annual energy consumption for TEC base cases compared with annual consumption data from preparatory study 2008

Product	Average TEC (kWh/week)	Average annual energy consumption (kWh/year)	Prep. Study annual energy consumption (kWh/year)
BC1 Monochrome Laser MFD, 20 < s ⩽ 40	1.5	79	250
BC2 Colour Laser MFD, 20 < s ⩽ 40	1.8	92	370
BC3 Monochrome Laser Printer, 20 < s ⩽ 40	1.4	71	270
BC4 Colour Laser printer, 20 < s ⩽ 40	2.1	110	360
BC7 Professional printer and MFD	12.8[138]	664	n.a.

All non-professional TEC printers and MFDs, both colour and monochrome, must have automatic duplexing capability integral to the base product and enabled by default for speeds > 19 ipm (colour) and > 24 ipm (monochrome). All professional imaging products must have automatic duplexing capability present at the time of purchase. These requirements do not save energy but paper. Printers whose intended function is to print on special single-sided media are exempt of this requirement.

OM products requirements and average energy consumption

The measurement and calculation methodologies of the OM evaluation method for OM products are detailed in ENERGY STAR Product Specification v3.0 and Test Method v3.0 for Imaging Equipment. The evaluation is done by comparing with requirements of maximum sleep mode power consumption (P_{SLEEP_MAX}, in watts) and off mode power consumption (W).

The calculation of P_{SLEEP_MAX} for OM products is shown below:

$$P_{SLEEP_MAX} = P_{MAX_BASE} + \sum_{l}^{n} Adder_{INTERFACE} + \sum_{l}^{m} Adder_{OTHER}$$

[138]TEC data from the EPEAT and ENERGY STAR databases, accessed 2018.

Where:

P_{MAX_BASE}=Maximum Sleep Mode power allowance for the base marking engine (watts)

$Adder_{INTERFACE}$=Power allowance for the interface functional adders used during the test (watts)

$Adder_{OTHER}$=Power allowance for any non-interface functional adders in use during the test (watts) – see Table 11 of ENERGY STAR v3.0 specification for type of allowances for both interface and non-interface functional adders

n=number of allowances claimed for interface functional adders used during the test (it shall be less than or equal to 2)

m=number of allowances claimed for any non-interface functional adders in use during the test (unlimited)

The maximum Sleep Mode power allowances for the base marking engine (P_{MAX_BASE}) and for standby/off applicable to OM products for ENERGY STAR version 2 and 3 are shown in Table 41. Standby requirements in version 2.0 are substituted with off requirements in version 3.0. The relation between standby and off is further described in the section Power management settings.

Table 41: Sleep mode base power allowance and standby/off mode power requirements for OM products, from ENERGY STAR V2.0 and V3.0

Product type	Format and marking technology	P_{MAX_BASE} (watts), ES V2.0	P_{MAX_BASE} (watts), ES V3.0	Standby (watts), ES V2.0	Off (watts), ES V3.0
Printers	Small, all including inkjet, electro-photo-graphic	4.0	4.0	0.5	0.3
	Standard inkjet	0.6	0.6	0.5	0.3
	Large, all others including electro-photo-graphic	2.5	2.5	0.5	0.3
	Large inkjet	4.9	4.9	0.5	0.3
MFDs	Standard inkjet	0.6	1.1	0.5	0.3
	Large inkjet	4.9	5.4	0.5	0.3
	Large, all others including electro-photo-graphic	8.2	8.7	0.5	0.3

The maximum Off Mode power requirement for all OM products is 0.3 watts. In ENERGY STAR specification v2.0 there were requirements for power consumption on standby, however, v3.0 derogates from these requirements and changes them to Off Mode requirements.

Sleep mode power allowances for functional adders and other general requirements can be found in ENERGY STAR Imaging Equipment version 3.0 specification[139]. These adders are largely the same as version 2.0, but two unnecessary adders are removed in version 3.0, see the adders from version 3.0 in Table 42 below.

[139] Available at: https://www.energystar.gov/sites/default/files/FINAL%20Version%203.0%20ENERGY%20STAR%20Imaging%20Equipment%20Program%20Requirements.pdf

Table 42: Sleep Mode Power Allowances for OM Functional Adders based on ENERGY STAR Imaging Equipment version 3.0 specification

Adder Type	Connection Type	Max. Data Rate, r (Mbit/second)	Details	Functional Adder Allowance (watts)
Interface	Wired	r < 20	Includes: USB 1.x, IEEE 488, IEEE 1284/Parallel/ Centronics, RS232	0.2
		20 ⩽ r < 500	Includes: USB 2.x, IEEE 1394/ FireWire/i.LINK, 100Mb Ethernet	0.4
		r ⩾ 500	Includes: USB 3.x,1G Ethernet	0.5
		Any	Includes: Flash memory-card/smart- card readers, camera interfaces, PictBridge	0.2
	Fax Modem	Any	Applies to MFDs only.	0.2
	Wireless, Radio- frequency (RF)	Any	Includes: Bluetooth, 802.11	2.0
	Wireless, Infrared (IR)	Any	Includes: IrDA.	0.1
Memory	n.a.	n.a.	Applies to the internal capacity available in the Imaging Equipment for storing data. Applies to all volumes of internal memory and should be scaled accordingly for RAM. This adder does not apply to hard disk or flash memory.	0.5/GB
Power Supply	n.a.	n.a.	Applies to both internal and external power supplies of Mailing Machines and Standard Format products using Inkjet and Impact marking technologies with nameplate output power (P_{OUT}) greater than 10 watts.	0.02 x (P_{OUT} – 10.0)
Touch Panel Display	n.a.	n.a.	Applies to both monochrome and color touch panel displays.	0.2

Data on power consumption in active, ready, sleep and standby/off modes were retrieved from signatories' compliance reports data for 2017[140], which were turned into annual average consumption based on the usage patterns presented in section 3.1.2. Usage patterns data were retrieved from signatories' compliance reports, which are based on what reported by 2008 Preparatory study[141], see Table 43 below.

Table 43: Use pattern (hours per mode) based on preparatory study 2008

Type	Active (operating)	Ready	Sleep Mode	Off Mode
Workgroup IJ printer	0.25	1.25	10.5	8
Home IJ printer	0.07	0.5	3.43	16

The average annual energy consumption is calculated by assuming BC 5 colour inkjet MFD follows the Workgroup IJ printer use pattern from Table 43 above, and BC 6 follows Home IJ printer use pattern. Assuming 5 days a week for BC 5, and 7 days a week, and a total of 52 weeks (same as TEC products), the average energy consumption per year for OM base cases is found and shown in Table 44.

Table 44: Average active, ready, sleep, standby/off mode consumption and annual average energy consumption for OM base cases compared with data from preparatory study 2008

Product	Active (W)	Ready (W)	Sleep (W)	Standby/off (W)	Average annual energy consumption (kWh/year)	Prep. study annual energy consumption (kWh/year)
BC5 Colour Inkjet MFD, s ⩽ 20	13.3	5.0	1.1	0.2	5.9	22[142]
BC6 Colour Inkjet Printer, s ⩽ 20	7.8	2.1	0.4	0.1	1.7	18[143]

3.1.2 Parameters influencing energy consumption

Energy use in imaging equipment can vary considerably between different models and it is strongly correlated to the level of functionality provided. Imaging equipment products that utilise thermal technologies, such as laser, tend to use more energy than inkjet-based products. Energy use varies significantly even within distinct product types such as laser printers.

[140] Reported Annex C data from all 11 signatories, received from RINA, September 2018.
[141] Table 4 report, Table 37 and Table 40.
[142] Assuming same as preparatory study base case V6 IJ printer/MFD workgroup
[143] Assuming same as preparatory study base case V5 IJ printer/MFD personal

However, there are certain parameters that have been identified as to all have influence on energy consumption and that are related to consumer preferences in terms of purchase (i.e. imaging speed) and to consumer use (i.e. power management and time use in different power modes). They are described in next sections.

Imaging speed

Figure 23 to Figure 26 illustrate the correlation between TEC energy use and imaging speed amongst TEC monochrome, colour MFDs and printers, based on data from signatories[140]. The charts show that there is a general correlation of higher speed leads to higher energy consumption, but it is not always consistent. Monochrome products have a more consistent trend than colour products. It should be noted that the charts show 0.0 kWh/week for some data points, this simply meant the energy consumption was not reported for that model, these should not be considered.

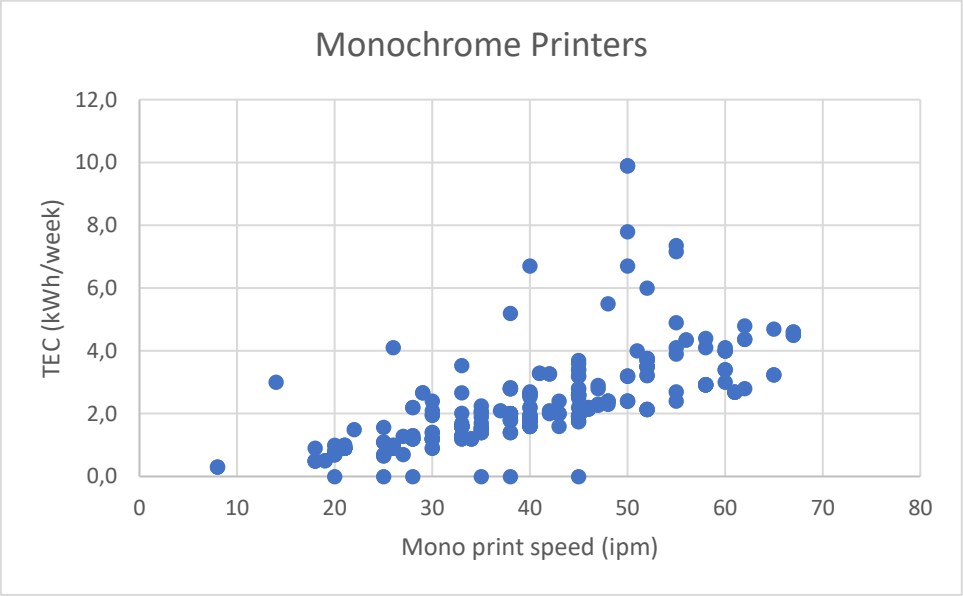

Figure 23: Correlation of TEC and imaging speed for monochrome printers (TEC products)

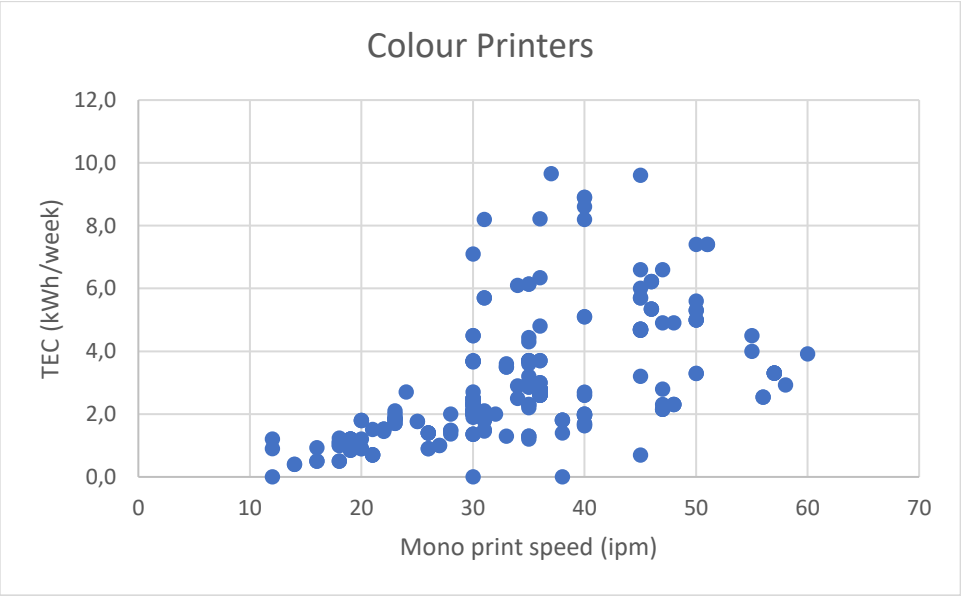

Figure 24: Correlation of TEC and imaging speed for colour printers (TEC products)

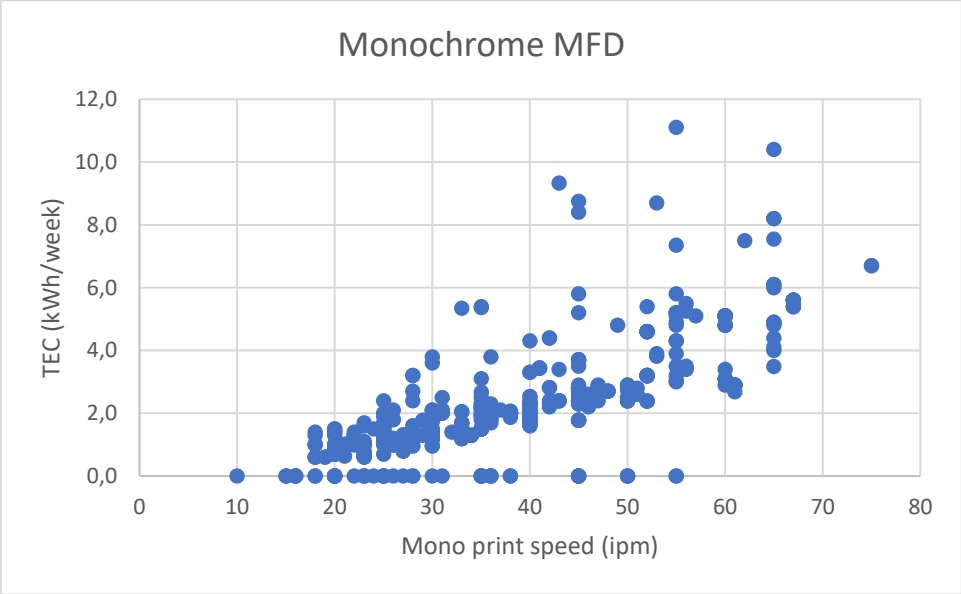

Figure 25: Correlation of TEC and imaging speed for monochrome MFDs (TEC products)

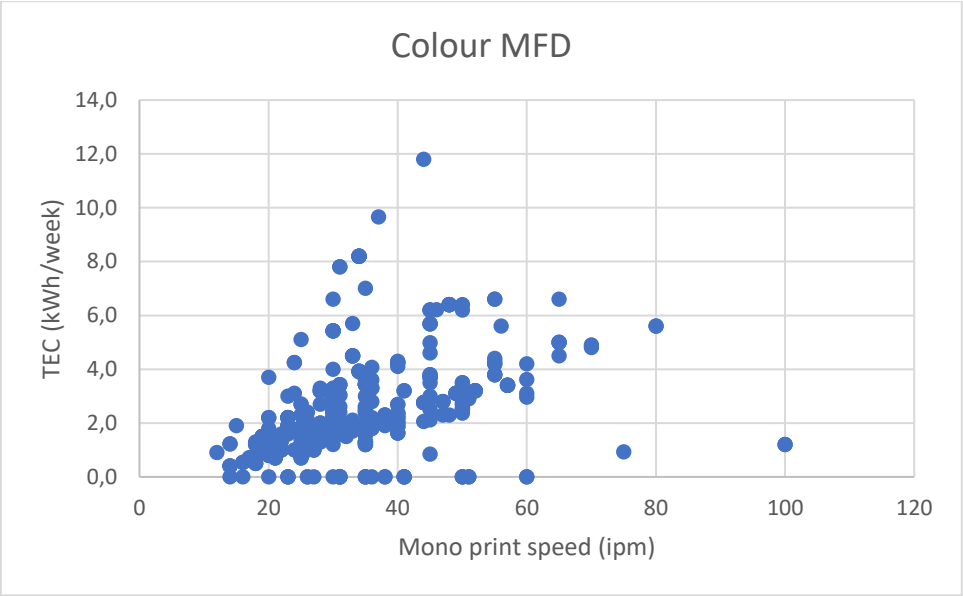

Figure 26: Correlation of TEC and imaging speed for colour MFDs (TEC products)

Power management settings

After the imaging equipment product fulfils the "job", an automatic transition into one or more reduced power mode(s) usually takes place[144]. These power modes are usually fixed by the product design, and are divided into sleep mode, auto-off mode and off mode[145]. Sleep mode is a reduced power state that the product enters automatically after a period of inactivity or in response to user manual action. Sleep mode permits operation of all product features (with a possible delay to transition into Active State). The product can leave the sleep mode after user activation of a physical button, or in response to external electrical stimulus e.g. from the network when print job is sent.

ENERGY STAR v2.0 specifications include a standby state, however not as a specific mode but as the lowest power consumption state which cannot be switched off (influenced) by the user and that may persist for an indefinite time when the product is connected to the mains. It can be off mode, but also sleep mode or ready state depending on the product. ENERGY STAR v3.0 does not define standby nor include power requirement to standby. Requirements for the lower power state are substitute by off mode requirements.

ENERGY STAR off mode is comparable to the standby mode in the EU standby regulation 1275/2008, though the definitions differ slightly. ENERGY STAR sleep mode overlaps the standby mode and networked standby in 1275/2008 (with amendments), because it may and may not be able to leave the sleep via an external signal. In 1275/2008, networked

[144] EuP Preparatory Studies "Imaging Equipment" (Lot 4). Final Report on Task 3 "Consumer Behaviour and Local Infrastructure". Öko-Institut and Fraunhofer IZM, 2007.
[145] According to ENERGY STAR v3.0 specifications, applicable for printers and MFDs

standby require ability to resume a function by way of a remotely initiated trigger from a network connection.

When the product enters automatically into sleep mode from ready state, it does it after a period of inactivity called 'Default delay time' or at a specific time of day e.g. close of business, which can be adjusted in the product's settings. Some products are capable of automatically enter multiple levels of sleep modes. The required default delay times to enter sleep mode for MFDs and printers are defined in ENERGY STAR v3.0 specification and is between 5 and 45 minutes depending on product type. This specification defines also maximum delay times the user can adjust either 60 or 120 minutes also depending on product type. The difference between these two requirements can be up to 75 minutes, showing the user can significantly prolong the default delay time and keep power consumption levels higher. An imaging equipment product enters off-mode when it has been manually or automatically switched off, but it is still plugged in and connected to the mains. It is called 'manual-off' if it is result from a manual intervention by a user, and 'auto-off' if resultant from an automatic or predetermined stimulus (e.g. a delay time or clock).

Ready State is not a reduced power mode because in this state an imaging equipment product has reached operating conditions and has not yet entered into any lower-power modes, though the power level is lower than in Active State. In this state a product is not producing output and can enter Active State with minimal delay by responding to any potential inputs including external electrical stimuli[146] and direct physical intervention. However, there is an amount of time the device, once it has entered sleep or off mode, takes to return to ready state. This is called 'recovery time'. ENERGY STAR v3.0 specification sets recovery time requirements depending on print speed and maximum default delay time to sleep values. The length of the recovery time is a design parameter. Shorter recovery time is better, because the user needs to wait less time for the product to produce prints etc.

Frequency and characteristics of use

Active State is the power state in which an imaging equipment product is connected to a power source and is actively producing output, as well as performing any of its other primary functions. Printers convert digital content onto physical media such as paper, and MFDs can also convert physical media into digital format by use of a built-in scanner. The duration of active state is influenced primarily by the job requirement in terms of quantity and quality, together with the speed of the imaging equipment product.

[146] According to ENERGY STAR V3.0 specifications, some examples are network stimulus, fax call or remote control

The preparatory study showed that imaging equipment spent a lot of their time in sleep and off modes during a day, see Figure 27. Average time laser printers spent in different power modes/states is shown in Figure 28.

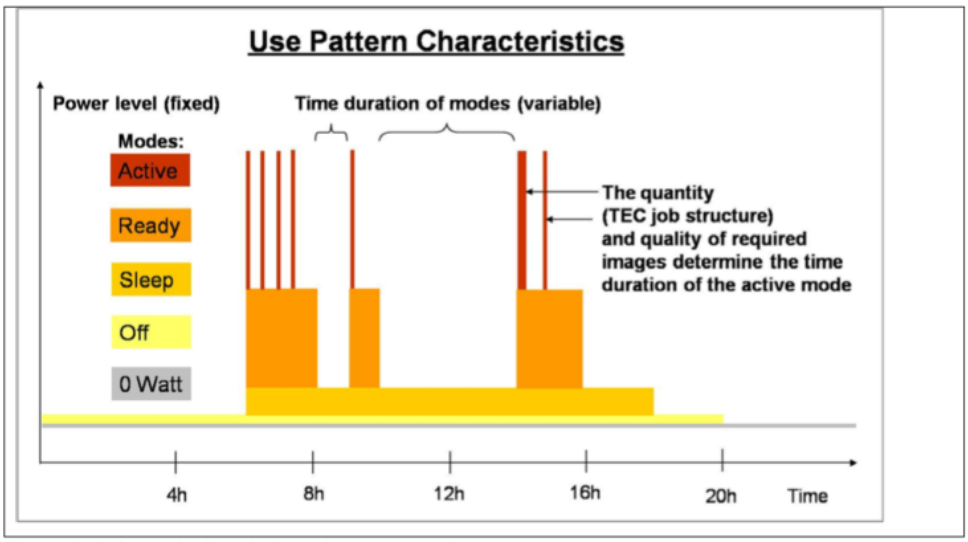

Figure 27: Schematic description of use pattern factors during the course of a day[147]

By the time of the preparatory study, laser printers spent most of their time in soft-off mode and spent very little time in active state (i.e. performing jobs) at households and at offices. The authors quantified these use patterns into four power modes: active state, standby mode, soft-off mode and hard-off mode (as defined in Lot 6 Preparatory study on standby and off-mode losses[148]). Hard-off mode is the mode in which the product is connected to a power source but turned off with a switch, which physically interrupts the electrical connection (referred to as off-mode 0W in Lot 4 preparatory study). In soft-off mode, an electronic switch is used, which allows small amounts of power to be drawn for the soft-off switch and an indication of the off mode (referred to as aff-mode in Lot 4 preparatory study).

[147] Taken from the EuP Preparatory Studies "Imaging Equipment" (Lot 4). Final Report on Task 3 "Consumer Behaviour and Local Infrastructure". Öko-Institut and Fraunhofer IZM, 2007.
[148] Lot 6 EuP Preparatory Study Task 1

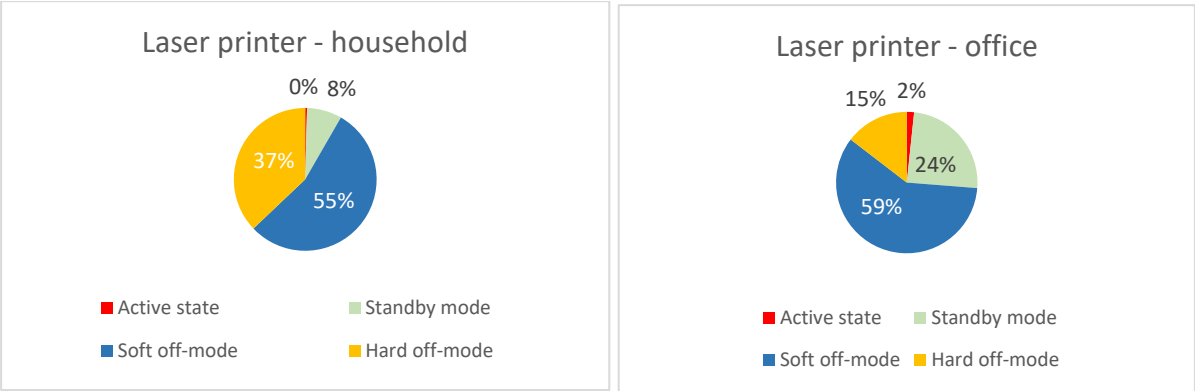

Figure 28: Average time laser printers spent in different power modes/states[147]

For inkjet printers, the preparatory study[149] developed the usage patterns further in order to harmonise with more up-to-date power mode and state definitions. These were divided into active state, ready state, sleep mode, off mode and 0W mode. This was not done for laser products as they are mostly TEC products. TEC product requirements and test method already consider daily usage patterns for the calculation of their energy consumption and for establishing requirement levels of this consumption. For OM products (mostly inkjet technology), the requirements are defined as power consumption levels in different low power modes and thus it is necessary to know their daily usage patterns in these modes to calculate their daily energy consumption.

Inkjet usage patterns defined in the preparatory study are deemed still valid since these are what the Signatories to the VA report in their compliance reports. They are presented in Figure 29.

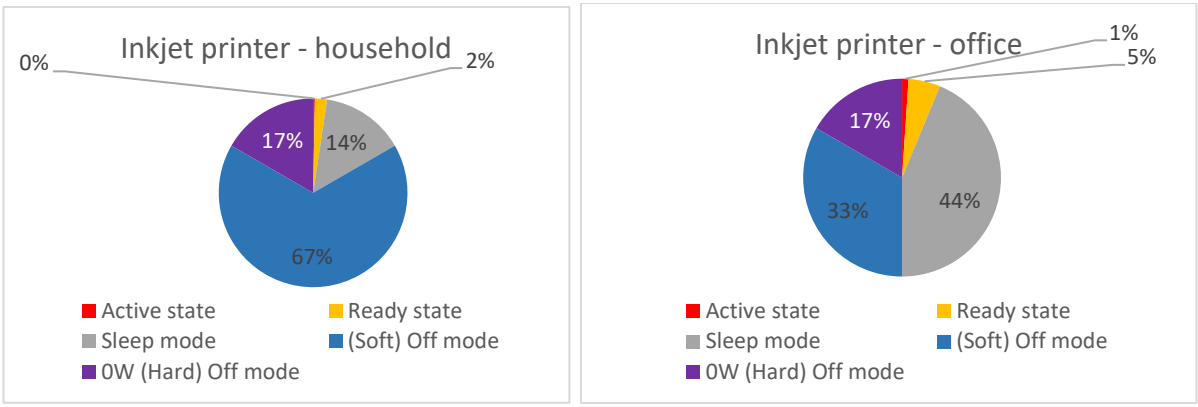

Figure 29: Average time inkjet printers spent in different power modes/states[149]

Overall, it is expected that these use patterns remain overall very similar: printers and MFDs tend to spend a great part of their time in reduced power modes, in particular off,

[149] EuP Preparatory Studies "Imaging Equipment" (Lot 4). Final Report on Task 4 "Technical Analysis". Öko-Institut and Fraunhofer IZM, 2007.

standby and sleep modes. Note that inkjet printers should not necessarily spend extended periods of time in a hard-off state due to considerations of ink drying. However, it is also expected that many users are not aware of this issue and so may unplug inkjet printers when not in use. Hence, 17% of the time imaging equipment is assumed to be in off mode.

The preparatory study established 5 days a week as the standard use per consumer, regardless if they were office or household users. The ENERGY STAR office equipment calculator does consider seven days of the week. It is assumed that household products such as standard inkjet OM products are used 7 days a week, spending most of their time in reduced power modes. Office products such as standard laser and HPIJ TEC products are assumed to be used 5 days a week. Large products (mostly classified as OM products) are used in specialized imaging services companies and it is assumed they will be used 5 a week in average, spending most of their time in reduced power modes.

3.1.3 Best practice in sustainable product use for direct energy consumption

The preparatory study identified short delay times as the sole practice for sustainable use concerning energy consumption. This is now reflected in the TEC calculation for TEC products, where E_{FINAL} and t_{FINAL} are included in the formula.

The preparatory study argued that these delay times are mostly technology related, however, delay times can also be adjusted by the user and may be affected by the recovery time in case it takes long for the product to enter ready state. The balance between delay times (and thus energy consumption) and functionality depends on the applied technology. In the case of laser printers, this depends on the technical design of the fuser technology, which defines recovery time.

3.2 Use phase indirect energy consumption

Imaging equipment products release heat while in operation, which could affect indirectly the heating, cooling and ventilation systems of the building. Additionally, emissions of substances and heat from use can affect the air quality which would require additional ventilation or cooling.

However, this is considered to be negligible compared to the energy consumption in the different power modes and to the embedded energy and environmental impacts from the use of paper and cartridges. Therefore, no need for quantifying and assessing these effects is deemed necessary.

3.3 Use phase resources consumption

As imaging equipment products are becoming more energy efficient, the importance of consumables (mainly toner, ink and paper) is raising. An ongoing study on the revision of

EU GPP criteria for Imaging Equipment[150] concluded that consumables, which are consumed during use phase, are responsible for 20-30% of the life cycle Global Warming Potential and Primary Energy Demand of imaging equipment products, in particular printers and MFDs. Widely used voluntary schemes such as the Blue Angel, EPEAT and the Nordic Swan assess consumables in their certification criteria (as presented in Task 1 report), concurring on their importance. In conclusion, the consumption of toner and ink cartridges has been identified as one of the most important life cycle hotspots of printers and MFDs.

Concerning Life Cycle Costs (LCC), the revision of the EU GPP criteria study shows that paper and cartridge costs are dominant in the lifetime of printers and MFDs at different monthly print volumes, both for laser and inkjet technologies. When removing paper costs from the LCC (since paper is not a key focus in the current review study), cartridges costs are the dominant for all laser and inkjet printers and MFDs, except for professional products where purchase price is also an important life cycle cost.

Normally, paper would be a significant factor in the running costs of an LCC calculation, but paper is however not a key focus in the current review study, so the costs of this consumable is not included in the LCC, in order to concentrate on the other costs of the LCC. Nevertheless, the VA includes requirements that addresses the paper consumption such as the requirement on duplex printing, this can reduce the resource consumption during use phase.

This section presents a short overview of paper and consumables usage patterns and some examples of best practice in sustainable use.

3.3.1 Parameters influencing resource consumption

Use of paper

The total paper usage by different imaging equipment have been reviewed from different sources, such as preparatory study (2008), LCA studies, products' technical specifications[151] and finally compared with the calculated printed volume by using ENERGY STAR specification on number of images per job.

[150] Revision of EU Green Public Procurement (GPP) criteria for Imaging Equipment. Preliminary Report (Draft 1). September 2018. JRC, Viegand Maagøe and Tenvic. Available at: http://susproc.jrc.ec.europa.eu/imaging-equipment/docs/PR_GPP_EUIE_1st_AHWG_September_2018.pdf

[151] https://www.xerox.com/digital-printing/printers/printing-equipment/xerox-nuvera-200-288-mx/enjm.html, https://www.xerox.com/digital-printing/printers/digital-press/xerox-800-1000/enjm.html, https://www.office.xerox.com/digital-printing-equipment/digital-press/enjm.html

According to the preparatory study, the quantity of paper consumption in pages depends on the use pattern and the required image quality in relation to the quality the printer or MFD delivers. Based on EU imaging equipment stock of laser and inkjet printers and their registered output volume in 2005, the preparatory study presented average monthly print volumes of 1351 to 2196 pages for laser printers and 73 pages for inkjet printers.

A more recent literature review of LCA studies in the print industry[152] showed a wide range of monthly print volumes ranging from 2500 pages/month for small capacity printers to 25000 pages/month for large capacity printers. The printing capacity refers to print imaging speed, which is another factor that affects paper consumption (see task 2, section 2.4.5). This monthly print volumes showed some slight alignment with "standard" procedure in ENERGY STAR, which is related to the printers' technical capabilities according to their print imaging speed. Therefore, some of the LCA studies used standard conditions to calculate the average print volumes.

Since the information on printed volume varies between different sources and it should be defined case by case, therefor it is derived as an average using the given variables. The average printed volumes over lifetime for different base cases are found using the ratio of consumables and equipment in Task 2 and the average page yield provided by stakeholders and collected via online research. The printed pages over lifetime for the base cases are then used to calculate the Life Cycle Costs, see Task 2 report, Section 2.4, Table 21. Besides paper consumption itself, it is found that higher printed pages over lifetime means higher number of cartridges needed, this increases the resource consumption during use phase, however this is highly dependent on the page yield of cartridges.

Use of toner and ink cartridges and containers

A 2018 study on re-usability of printer cartridges[153] found that, due to the differences in printing requirements and costs, household users most commonly use inkjet printers/MFDs and thus ink cartridges and containers (see difference of definitions in Task 1), while office/business users most commonly use laser printers/MFDs and toner cartridges and containers.

Cartridges and containers are sold by OEM of printers and MFDs but also by non-OEMs. Non-OEM are sold by remanufacturers and other manufacturers that produce primary cartridges and containers. ETIRA[154] showed that in 2016, for four of the five largest OEM

[152] Life Cycle Assessment in the Print industry. Justin Bousquin, Eni Gambeta, Marcos Esterman, and Sandra Rothenberg. Journal of Industrial Ecology, April 2012.
[153] Study on the implementation of product design requirements set out in Article 4 of the WEEE Directive. The case of re-usability of printer cartridges. Final report, 2018.
[154] Position Paper on the EU Commission Circular Economy policy proposals and the upcoming review of the EU Voluntary Agreement Imaging Equipment. Brussels, July 2016.

brands, original OEM cartridges had 80-90% of their respective inkjet, and 70-82% of their respective toner Western EU markets. This means that more OEM than non-OEM cartridges and containers are used in printers and MFDs in Western Europe. This may be different in Eastern Europe due to the significant difference in purchase price as shown in task 2, section 2.4.

The amount of toner and ink cartridges/containers used per printer and per MFD depends greatly on their yield and failure rate. In task 2, page yields for OEM and non-OEM cartridges and containers on the EU market were collected from desk research and average page yields were established (Task 2, Section 2.4, Table 17). According to expert opinion, failure rates were assumed 3% for OEM cartridges and containers and a higher rate (10%) for non-OEMs. Considering these and the average pages per lifetime of the different printers and MFDs in the selected base cases, the average number of cartridges/containers used per base case have been estimated. It has shown that average page yield per cartridge can influence greatly on the resource consumption during use phase, lower page yield would lead to higher number of cartridges needed over a lifetime, so addressing the page yield of cartridges is a key area for resource efficiency.

3.3.2 Best practice in sustainable product use and design for resource consumption

Concerning paper use, the preparatory study identified two best practices: use of duplex functions in printers and MFDs and use of recycled and low weight paper by the user.

Since ENERGY STAR v2.0 product specification, the requirement of automatic duplex capability has been implemented for colour printers and MFDs over 19 ipm and over 24 ipm for monochrome. ENERGY STAR v3.0 has gone beyond by requiring this capability to be enabled by default. This is not a user-related practice but a technology related capability, however it is user-related practice to keep the default setting. The availability of the printer and MFD to accept recycled paper and low weight paper are also found in many imaging equipment products on the EU market. However, users may be encouraged by organisations to print all documents in recycled paper and/or low weight paper in order to reduce environmental impacts.

Concerning use of toner and ink cartridges and containers, some practices in design that can reduce their life cycle environmental impacts and reduce the use of single-use cartridge and containers are:

- Use of common cartridge and container form factors across multiple imaging equipment models
- Use of fillable containers rather than cartridges
- Increase of toner/ink amounts to increase cartridge yield

- Implement cartridges/containers take-back systems for OEM products – however, the focus should be on increasing the amount of recycled/reused materials rather than sending plastics for incineration

The 2018 study on re-usability of printer cartridges[155] identified market leaders concerning reuse of cartridges and containers based on a semi-quantitative assessment in relation to the following factors:

- Reuse percentage of cartridges
- Closed vs open loop recycling
- Incentives for product returns
- Commendations/awards
- Prominence and detail of re-use scheme marketing
- Life cycle approach

The results of this study's assessment show that Lexmark appears to be the clear market leader in printing cartridge reuse, presenting a comprehensive set of re-use statistics. Brother and to a lesser extent Canon, also appear to be engaged in some re-use activities, with many other OEMs focusing primarily on open loop recycling or energy recovery (i.e. waste to energy production). At least one manufacturer does employ some closed loop recycling within their consumable products. Information provided by Lexmark to this review study show that about 40% of their cartridges placed on the market are collected via their take-back programme, and out of the collected cartridges, 28% of their cartridges are reused, 69% are recycled and 3% are incinerated with energy recovery, with no share sent to landfill.

3.4 End-of-life behaviour

In this section, the importance of end-of-life is discussed and highlighted through reviewing existing literature on identifying hotspots over the lifetime of imaging equipment and its consumables. Aspects concerning the end of life of products are assessed and presented in detail. In particular those that affect the durability, reparability, disassembly and recyclability of imaging equipment.

According to the Ecodesign Working Plan 2016-2019[156], ecodesign related work should investigate especially the following aspects:

- Durability: Minimum lifetime of products with a view to assess possibilities for extending product lifetime

[155] Study on the implementation of product design requirements set out in Article 4 of the WEEE Directive. The case of re-usability of printer cartridges. Final report, 2018.
[156] https://ec.europa.eu/energy/sites/ener/files/documents/com_2016_773.en_.pdf

- Reparability: Availability of spare parts and repair manuals with a view to assess possibilities for design for repair
- Disassembly[157]: Removal of certain components with a view to assess possibilities for increase their reparability and improve maintenance (i.e. by easy removal)
- Recyclability: Identifying materials that hinder recycling with a view to assess possibilities to avoid them in the product design

These aspects are in line with the circular economy package published by the European Commission in 2015, which includes an action plan to promote circular economy[158].

3.4.1 Hot spots for imaging equipment and ink and toner consumables

Traditionally, the use phase (energy consumption) of products has the greatest environmental impact regarding emission of CO_2. So, in the past, the focus has been concentrated on reducing the energy consumption of energy related products. However, due to the high consumption of consumables (paper, ink and toners) by imaging equipment, the environmental hotspots may differ from other energy related products typically covered by ecodesign.

There are a number of life cycle assessment on imaging equipment which point at consumables as a major environmental hot spot. Consumables are used during the use phase of imaging equipment, but they reach end-of-life repeatedly (up to over 100 cartridges can be used by a non-domestic equipment, as seen in Task 2 life cycle cost assessment), and there is a great potential in addressing their end-of-life routes.

To pinpoint potential for improving the environmental performance, the key findings from the literature review conducted in connection with the Revision of EU Green Public Procurement (GPP) criteria for Imaging Equipment[159] is presented below.

For **imaging equipment**, the environmental hotspots are based on the energy consumption (total energy) and the emission of CO_2. There are different impact categories and boundary conditions used in different life cycle assessments, this means that it is difficult to compare different assessments and to draw a clear conclusion from them. Also, the differentiation in boundary conditions might affect the outcome of different LCAs. The GPP project stated that:

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[157] To distinguish from "dismantling", although not directly mentioned, but often a focused aspect of circular economy as well. Dismantling usually refers to the removal of components and operation of taking the product apart at end-of-life, this could in some cases be destructive.
[158] https://ec.europa.eu/growth/industry/sustainability/circular-economy_en
[159] http://susproc.jrc.ec.europa.eu/imaging-equipment/docs/PR_GPP_EUIE_1st_AHWG_September_2018.pdf

- For laser printers and MFDs, the impacts from cartridges itself are at least as important as the contribution from the energy consumption during use. The LCA by Koehler et al. (2010) [160] actually found that the cartridge contribution is on par as the contribution from the energy in use. This means that the end-of-life treatment of cartridges are highly important.
- For inkjet printers and MFDs, cartridges are also becoming important in terms of LCA. It is found in the LCA by Katarzyna (2012)[161], the dominant impact of household inkjet printers come from the manufacturing (excluding the largest impact coming from paper consumption), , the third main impact is the energy consumption in the use phase and the fourth being the liquid ink usage. With increasing energy efficiency, the inkjet consumables become even more important.

This means that the energy consumption during use still is very important for imaging equipment, but consumables are at least as important as energy consumption, and should be quantified in environmental impact assessment during Task 5.

Ink and toner consumables are already pinpointed as hotspots in the assessment of imaging equipment. However, some LCAs are focusing on the environmental performance of different types of consumables (including the treatment at end-of-life) and conclude the following:

- The LCA case study by Krystofik et al. (2014)[162] present significant reductions in environmental impacts when comparing cartridge refills and cartridge remanufacturing to single-use inkjet cartridges. It is found that the cartridge refills presented the lowest environmental impact with a saving of 76% in GWP (Global Warming Potential), and remanufactured inkjet cartridge provides a saving of 36% in GWP compared with a new single-use cartridge. Note that the results varied greatly depending on how the consumer transport was modelled. Hence, with certain travel assumption the result was in favour of new cartridges compared to remanufactured cartridges.
- According to the study commissioned by UK Cartridge Remanufacturers Association[163], where the carbon footprints of remanufactured toner cartridges and single-use OEM cartridges have been assessed, 25 to 40% saving in carbon footprints have been found when the single-use cartridge (called 'single cycle cartridge') is

[160] Life Cycle Assessment of a Solid Ink Multifunction Printer Compared with a Color Laser Multifunction Printer. Total Lifetime Energy Investment and Global Warming Impact. Debra Koehler, Wendi Latko, Anne Stocum. April 2010.
[161] Life Cycle Assessment of an Inkjet Printer. Grzesik Katarzyna, Terefeńko Tomasz, 2012.
[162] When consumer behaviour dictates life cycle performance beyond the use phase: case study of inkjet cartridge end-of-life management. Mark Krystofik & Callie W. Babbitt & Gabrielle Gaustad. International Journal of Life Cycle Assessment, 2014.
[163] Carbon Footprints and Ecodesign of Toner Printer Cartridges. UKCRA 2008.

compared to long life cartridges (which run up to 15 refilling cycles). Furthermore, when performing 5 refill cycles or more, the importance of consumer transport to enable the refilling becomes also a hotspot. However, this could vary widely depending on the fuel allocated per trip per refill of cartridge, as the consumer would most likely use the trip to carry out other activities. Generally, more refills mean less the contribution of manufacturing to the environmental impacts, and a reduction up to about 60% carbon footprint is possible for cartridges that can take 15 refills or more[164].

- The LCA studies done by HP (2014)[165] and Krystofik et al. (2014)[162] show that the amount of paper prints a cartridge can yield is also a key parameter. When the use of paper is included in LCAs (as it is the one of the most dominant factors in an LCA), the cartridge's ability to deliver printouts with high quality determines whether one cartridge is better than other. Due to frequent reprints, cartridges delivering lower quality print outs turned to have slightly higher life cycle environmental impacts due to the need of to use more paper in order to achieve the quality desired.
- HP's study[165] shows lower environmental impacts for OEM cartridges (study was commissioned by HP) or on par with remanufactured cartridges depending on the impact category.

Overall, the environmental impact of ink and toner consumables may be considerably reduced if these are reused/remanufactured a number of times, unless the consumer transport would have a dominant impact depending on means of transport and distance. The prerequisite is that the page yield should be higher than the yield of new cartridges, else their environmental benefits become detrimental because of higher paper consumption. A metric to measure yield and make this comparable is essential to ensure these benefits are achieved.

3.4.2 Durability of equipment

Longer lasting products could have the potential to reduce overall life cycle impacts imposed by equipment. The same may be true for ink and toner consumables and their durability. With a longer lifetime the impacts and consumption of raw materials are reduced

[164] A stakeholder has stated that the study assumes an unsupported number of remanufacturing cycles for a toner cartridge it also specifically states that its findings do not apply outside a narrow group of remanufacturers within the UK

[165] Life Cycle Assessment Original HP LaserJet toner cartridges compared with remanufactured cartridges. HP, April 2014.

since the impacts of mining, production, transportation etc. are spread over a longer period of time and displaces the need for new equipment[166].

The durability of imaging equipment varies depending on the type of equipment, intended use, availability of spare parts and the ease of repair. For example[167]:

- Domestic inkjet printers may not be designed with as much durability as other types of imaging equipment (e.g. a large MFD located in a business premise), since the purchase price is becoming quite low, and the cost of repair and spare parts relative to the purchase price is considered to be too high in most cases.
- Large multi-functional devices are designed to ensure that they are durable enough to perform a significant amount of imaging over an extended period of time (e.g. typical or maximum monthly number of pages printed), and in some cases retain useful value at the end of life to facilitate reuse or remanufacturing. This approach has been applied by a range of manufactures working with durability and an example is Ricoh. In 1994, Ricoh established some guidelines to decrease the environmental impact of their products. This was achieved by designing product and parts with reuse and recycling in mind[168].

However, the lifetime can be influenced by a series of factors besides the initial design and build quality. According to stakeholders[169], the components across the different types of equipment are unlikely to fail, and the non-domestic equipment is often replaced due to a customer desire for a faster machine, more efficient machine of a machine with new functions. In this case, the issue lies in demand side, and only a change in customers' view on replacing well-functioning equipment with new equipment could potentially increase product lifetime.

3.4.3 Reparability, maintainability and availability of spare parts

A way to improve the lifetime of imaging equipment is to design products with more possibilities of repair so it is more affordable for the consumers to repair than replace equipment. However, stakeholders[170] have stated that the business models of many OEMs are to sell their equipment at a lower price and then to sell more consumables which increase

[166] Deloitte (2016) Study on Socioeconomic impacts of increased reparability – Final Report. Prepared for the European Commission, DG ENV
[167] Revision of EU Green Public Procurement (GPP) criteria for Imaging Equipment. Preliminary Report (Draft 1). September 2018. Available at: http://susproc.jrc.ec.europa.eu/imaging-equipment/docs/PR_GPP_EUIE_1st_AHWG_September_2018.pdf
[168] https://www.ellenmacarthurfoundation.org/assets/downloads/publications/Ellen-MacArthur-Foundation-Towards-the-Circular-Economy-vol.1.pdf
[169] EuroVAPrint, Stakeholder consultation, July-August 2018.
[170] Stakeholder consultation with OEMs and remanufacturers, July-August 2018.

the profit. One stakeholder has stated that tn some cases, it is cheaper to purchase a new printer than to buy a full set off new cartridges[171]. A low price means that household equipment may be too expensive to repair compared to new equipment.[172] The low price of new equipment may also have an impact on the second-hand market and makes it unattractive to buy second-hand equipment. To improve the second-hand market of domestic equipment a stakeholder has suggested that a "life metre/print count" system could improve the second-hand market, since consumers are made aware of the usage of the equipment (equivalent to an odometer in a car). Also, the availability of spare parts for household equipment seems very limited[173]. All in all, low priced household equipment is not likely to be repaired and the repair of household equipment are assumed to be negligible in the coming tasks.

To some degree, non-domestic equipment is designed with modularity in mind, as some components can be exchanged quickly by the customers. These parts (e.g. the image drum) are often located easily available from the side of the equipment and could be considered as consumable as these are expected to be exchanged during the lifetime of the equipment. However, some components and parts are difficult to access and would require professional support if they break e.g. printed circuit boards which can be difficult to access, easy access and information for the location of these components would be useful. In Figure 30 an example of the placement of printed circuit boards is presented.

[171] ETIRA, stakeholder consultation, June – August 2018
[172] A stakeholder points out that household printers have very low volume output i.e. household printers simply do not print very much hence need for repair is minimal.
[173] Based on online research, e.g. https://www.idns.co.uk/ (no spare parts, only cartridges available for the domestic models assessed), https://www.psaparts.dk/ (no spare parts, only cartridges available for the domestic models assessed), https://www.unicompparts.com/, No available spare parts for 3 different domestic printers currently available on the market (specific search for spare parts for domestic printers).

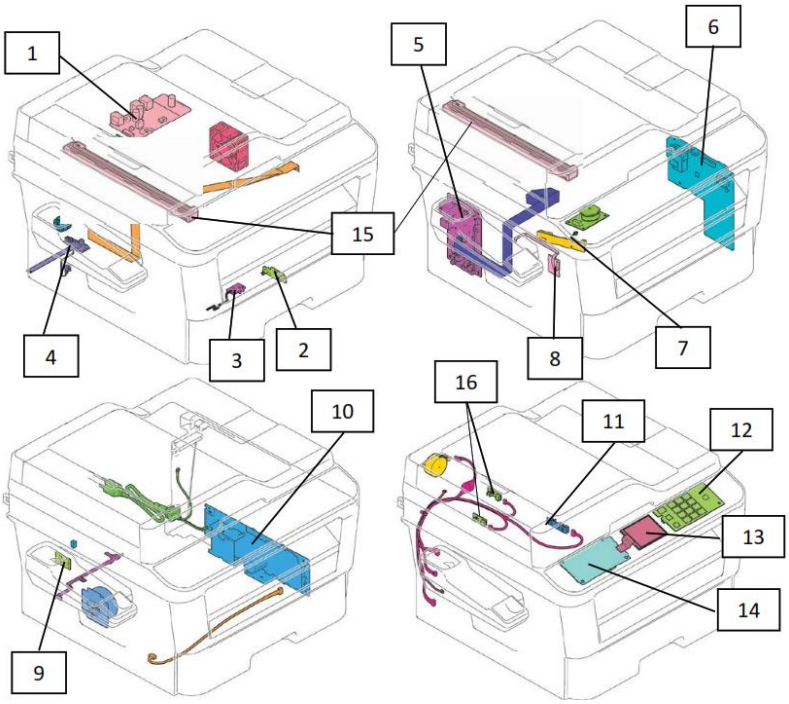

Figure 30: Overview of the location of printed circuit boards in a standard laser MFD[174]

If the repair is done by professionals the cost of repair is constituted of the labour costs and the cost of the spare parts, which means that the affordability of repair is very much dependent on the labour costs. However, in some cases imaging equipment is sold together with a service contract[175], which extends the warranty period and, in some cases, also improve the terms of the warranty. For professional equipment, some spare parts are available on the internet, such as paper trays and other easily exchangeable parts. For non-domestic equipment it is assumed that a great share is sold together with a service contract. This means that non-domestic equipment is repaired more frequent, and more materials are used for spare parts, therefore assumed to be repaired twice as much as household products.

This means that the average amount of spare parts used for imaging equipment is dependent on the sales distribution between domestic equipment and non-domestic equipment. The distribution has been identified by Green Public Procurement study[176], an average is found and used in this study, see Table 45.

[174] Stakeholder inputs, October-December 2018
[175] https://store.hp.com/UKStore/Merch/Product.aspx?id=UG189E&opt=&sel=CPK&jumpid=reg_r1002_uken_b-002_title_r0001
[176] Revision of European Ecolabel and Green Public Procurement (GPP) criteria for Imaging Equipment,2018

Table 45: Sales distribution between domestic and non-domestic equipment

Marking technology	Target group	2010	2011	2012	2013	2014	2015	Used in this study
Inkjet	Domestic	48%	45%	47%	47%	47%	47%	50%
	Non-Domestic	52%	55%	53%	53%	53%	53%	50%
Laser	Domestic	11%	11%	11%	11%	10%	9%	10%
	Non-domestic	89%	89%	89%	89%	90%	91%	90%

It is assumed that 1%[177] of the initial weight of domestic equipment are used for spare parts and that spare parts are purchased more often for non-domestic equipment. Based on this assumption and the distribution on domestic and non-domestic equipment, the amount of materials used for spare parts are 1.5% of the initial weight of non-domestic inkjet equipment and 1.9% of non-domestic laser equipment.

According to stakeholders[178] spare parts are available for minimum 3 years for consumer products (domestic) and 5 years for commercial products (non-domestic). In addition, whenever spare parts are delivered, it is accompanied by user instructions for how to replace them, except for spare parts which need to be replaced by service staff (due to safety reasons).

In relation to availability of spare parts to support durability of products, some environmental initiatives contain requirements that manufacturers must offer extended guarantee or spare parts availability for a defined number of years[179]. Other initiatives, rather than requiring an actual guarantee, require that manufacturers publicly state their processes for dealing with early failure in products. Both approaches aim to encourage manufacturers to build durability into products to save costs stemming from the need to replace products that have failed after a short lifetime.

3.4.4 Remanufacturing and reuse of cartridges

Regarding ink and toner consumables, the reparability is not as important, as these are not usually repaired, but increasing durability and lifetime can still be vital, as they could be remanufactured and reused (also called "refilling" as mentioned above). By remanufacturing, reusing (or refilling) cartridges, it is possible to reduce the consumption of virgin

[177] Standard value in EcoReport tool
[178] EuroVAPrint, stakeholder consultation, July-August 2018.
[179] https://www.ecolabel.dk/-/criteriadoc/3048 and https://produktinfo.blauer-engel.de/uploads/criteriafile/en/DE-UZ%20205-201701-en%20Criteria.pdf

materials, hence minimising environmental impacts. The share of remanufactured and re-used ink and toner consumables are presented in Task 4.

Figure 31 shows the process for recycling and remanufacturing toner and ink cartridges. A successfully tested remanufactured cartridge is subsequently brought to market, a remanufactured cartridge not successfully tested will be disassembled and its materials may be recycled. The inclusion of the figure below does not suggest that all consumables are collected, recycled or remanufactured by manufacturers in the area.

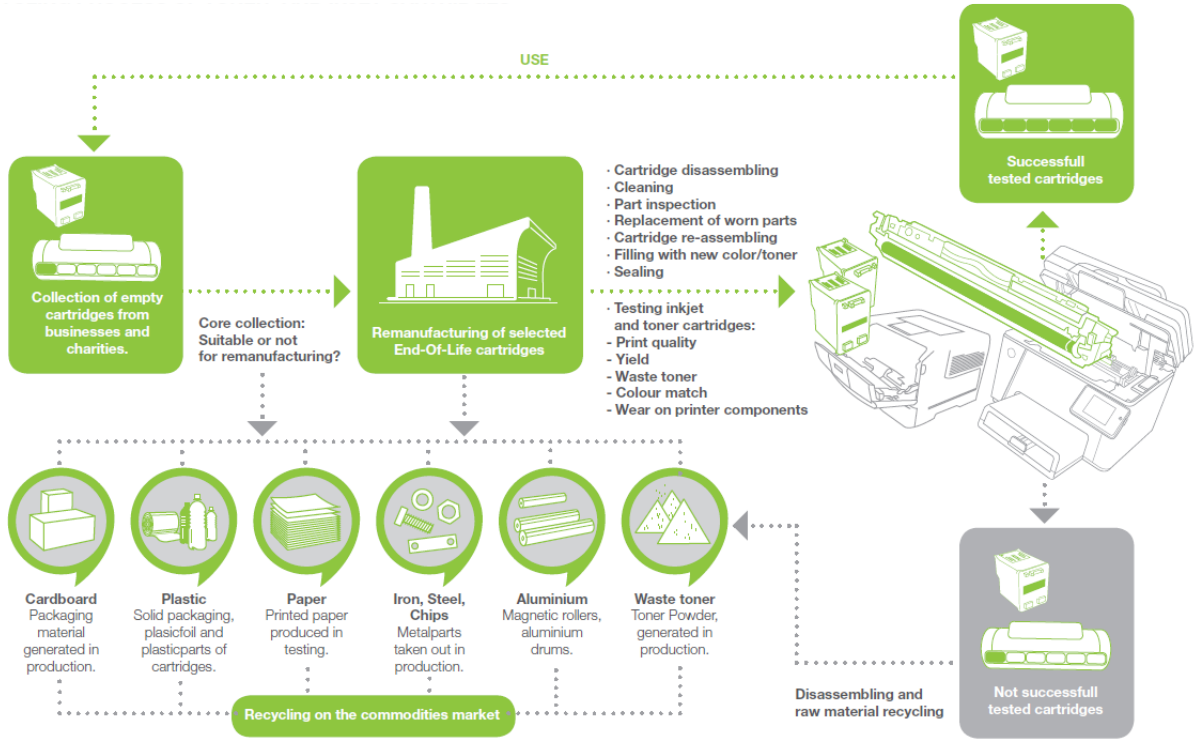

Figure 31: Flow chart for recycling/remanufacturing process of toner and ink cartridges[180]

However, the consultation with remanufacturing industry[181] indicated that currently ink and toner consumables are less likely to be designed to facilitate ease of disassembly and may even actively blocking remanufacturing, due to concerns over leakage and to commercial reasons. According to an EU study on the re-usability of printer cartridges[182], currently remanufactured cartridges account for 20% of toner cartridge market (ca. 27 million units), and 13% of inkjet cartridges market (49 million units). The study also estimated that for the whole cartridge market, the technical potential is 87%-92% for inkjet and

[180] ETIRA, questionnaire response, June 2018.
[181] ETIRA, DKWU, EFIM, stakeholder consultation, June – August 2018
[182] Page 34 – 35, Study on the implementation of product design requirements set out in Article 4 of the WEEE Directive - The case of re-usability of printer cartridges, 2018

toner cartridges respectively, and economic potential is 84%-86% for inkjet and toner cartridges respectively.

The rate of remanufactured ink and toner consumables are challenged by the design changes of ink and toner consumables, but other reports[183] also discuss so-called "killer chips"[184] as a reason for low remanufacture rate[185]. It is important to point out that not all chips included within consumables can be considered "killer chips", as they do not inhibit all usage of a consumable at their end of life.

"Killer chips" hinderer re-use based on technical characteristics of the printer cartridge, which often are introduced at the design phase, whereby design decisions are made without the ambition to facilitate or encourage re-use of the product at end-of-life. Examples of this can be:

- Use of gluing components together (irreversible joining)
- Chips that cannot be reset, which is a problem in connection with e.g. ink levels. This means that the chip often has to be replaced, which not always is an opportunity.

These different types of obstacles could have contributed to the low remanufacturing of OEM cartridges.

However, there are also some innovative actions taken by the industry regarding cartridges. Instead of single use ink and toner consumables some non-OEMs and OEMs[186] sell refillable consumables, which reduces the need for virgin plastic and therefore eliminates the need for cartridges. Instead of purchasing more cartridges the customers can purchase ink in bottles to refill existing cartridges they own, which also reduces the price of ink per print substantially. Some imaging equipment manufacturers have taken steps to reduce the number of materials used in printer cartridges in order to facilitate more effective material recovery[187]. A stakeholder suggests informing customers on the number of prints it can perform, so low capacity consumables are discouraged.

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[183] https://publications.europa.eu/en/publication-detail/-/publication/17b7b664-15f0-11e8-9253-01aa75ed71a1/language-en/format-PDF#
[184] 'Killer chips' are electronic components which provide useful functionalities for the user, e.g. ink detector levels, or page counters, that make re-use difficult if they do not include provision for resetting the chip during reuse.
[185] According to HP this section of the report is not correct in relation to HP printers and cartridges.
[186] https://www.epson.co.uk/for-home/ecotank
[187] https://www.kyoceradocumentsolutions.com.au/environment/Pages/ECOSYSOzoneSafeTechnology.aspx

3.4.5 Collection rates at households/other users for imaging equipment and consumables

When the equipment and consumables are discarded at end-of-life, it is important that it is collected so the materials can be reused or recycled. For imaging equipment and consumables there are different routes for the waste depending on the type of waste and whether the waste is covered by the WEEE directive or not.

Imaging equipment

As electronic products, imaging equipment falls within the scope of the Waste Electrical and Electronic Equipment (WEEE) 2012/19/EU Directive.[188] The WEEE Directive regulates the separate collection, treatment and recycling of end-of-life electrical and electronic equipment, which includes imaging equipment within category 3 "IT and telecommunications equipment".

This means that imaging equipment must be collected at end-of-life and sent to suited facilities for reprocessing. Illegal trade and sales of scrap challenge the collection rate for some product categories. The statistics from Eurostat present products placed on the market and waste collected for IT and telecommunications equipment [189]. No statistics are available specifically for imaging equipment collected so the actual collection rate is difficult to quantify.

From 2019 onwards, the minimum collection rate to be achieved annually shall be 65% of the average weight of Electrical and Electronic Equipment (EEE) placed on the market in the three preceding years in each Member State, or alternatively 85% of Waste Electrical and Electronic Equipment (WEEE) generated on the territory of that Member State[190]. Table 46 shows the collection rate for IT and telecommunications equipment calculated based on the WEEE collected in 2014[191] and the average weight of EEE placed on the market in the three preceding years. 2014 data are presented because the information for many countries are missing or not available for the more recent years 2015–2017.

[188] European Commission, Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE), available from http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32012L0019
[189] http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_waselee&lang=en
[190] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012L0019&from=EN
[191] Only year with information about waste collected for all presented countries.

Table 46: Calculated collection rate of IT and telecommunications equipment in Europe, 2014

Country	Average EEE put on the market 2011-2013	WEEE collected 2014	Collection rate
Austria	27,597	18,057	65%
Belgium	78,315	18,364	23%
Bulgaria	3,280	2,549	78%
Croatia	4,842	2,722	56%
Cyprus	1,281	493	38%
Czech Republic	43,981	8,813	20%
Denmark	22,615	11,625	51%
Estonia	1,726	1,165	67%
Finland	18,876	9,381	50%
France	179,371	67,731	38%
Germany	250,456	144,476	58%
Greece	13,786	5,191	38%
Hungary	11,204	8,995	80%
Iceland	1,213	715	59%
Ireland	17,393	6,412	37%
Italy	94,261	59,582	63%
Latvia	2,087	528	25%
Liechtenstein	56	58	103%
Lithuania	3,296	3,144	95%
Luxembourg	3,193	678	21%
Malta	789	330	42%
Netherlands	51,430	29,699	58%
Norway	24,112	14,448	60%
Poland	55,938	25,884	46%
Portugal	13,242	11,218	85%
Romania	13,511	4,803	36%
Slovakia	4,378	2,691	61%
Slovenia	2,606	2,253	86%
Spain	67,341	20,205	30%
Sweden	38,418	24,006	62%
United Kingdom	276,911	127,093	46%
Total	1,327,506	633,309	48%

The average collection rate for large household equipment at EU level was just below 48 % in 2014[192]. This value should be improved to 65 % in 2019 according to EU targets. Currently, it is unclear where the waste, which does not enter into the WEEE stream, goes.

[192] Based on the available data, the collection rate is slightly better in 2016. In 2016 the collection rate seems to be 50 %.

It is likely that many end-of-life imaging equipment products are stored in owners' premises, disposed of via municipal waste streams or exported as used or end-of-life equipment to non-EU countries.

According to data provided by stakeholders[193], as regard to the alternative collection target of 85% of Waste Electrical and Electronic Equipment (WEEE) generated on the territory of that Member State, the collection rates range between 60-82%, leading by Germany, the UK and Belgium, with 82%, 73% and more than 70% respectively. The average rate is still below target.

EU Member States are also obligated to ensure that EEE producers such as imaging equipment manufacturers and resellers, finance the collection, treatment, recovery and environmentally sound disposal of WEEE, through extended producer responsibility schemes. However, the low collection rate of products cannot be directly addressed in the Ecodesign Regulation but should be addressed by each Member State regarding their obligations with regard to the WEEE Directive.

Ink and toner consumables

For ink and toner consumables the routes of disposal are more difficult to quantify as some consumables consists of electronic components. The European Commission has provided guidance stating that printer cartridges with electronic components, and which are dependent on electric currents or electromagnetic fields to operate, can be considered EEE and therefore can be considered as being within scope of the WEEE Directive (2012/19/EU). This Commission guidance is non-mandatory, and Member States are free to decide whether printer cartridges are to be treated as WEEE. The UK for example has taken the position that printer cartridges are to be treated as WEEE (even when collected separately) and as such they need to be processed in the same manner as any other WEEE[194]. For ink and toner consumables collected as WEEE the collection rate is assumed to follow the trend presented in Table 46 as these consumables are a part the same category.

According to stakeholder inputs[193], recent research from Anthesis[195] shows that collection rate for printer cartridge is 65% in France, 68% in the UK, and 70% in Germany. The later two are the leading countries in terms of general WEEE collection, as mentioned above. For Germany, out of the 70% collected, 46% are reused or recycled, this means ca. 32% of the total cartridges placed on the market that are covered by WEEE are reused ore

[193] EVAP, reply to questionnaire 25-07-2018.
[194] https://b2bcompliance.org.uk/2016/04/printer-cartridges-now-in-scope-from-q1-2016/
[195] Anthesis (2017) All WEEE Flows of Printer Cartridges in France, Germany, and the United Kingdom

recycled. Given that this is one of the best performing countries in the EU, the average is assumed lower.

	France		Germany		United Kingdom	
Placed on Market, 2015	11.7 kt		23.6 kt		16.9 kt	
Collected	65 %	7.5 kt	70 %	16.6 kt	68 %	11.5 kt
By OEMs	35 %	4.0 kt	18 %	4.3 kt	30 %	3.2 kt
By 3rd Party Sector	30 %	3.5 kt	52 %	12.3 kt	38 %	8.3 kt
Reuse/Recycle	53 %	6.3 kt	46 %	10.9 kt	39 %	6.8 kt
Energy Recovery	8 %	0.9 kt	5 %	1.2 kt	5 %	0.8 kt
Landfill	<1 %	<0.1 kt	<1 %	0.2 kt	<1 %	0.1 kt
Export – Rest of World	4 %	0.3 kt	18 %	4.3 kt	23 %	3.9 kt
Unaccounted	35 %	4.1 kt	30 %	7.1 kt	32 %	5.4 kt

Figure 32: Collection rates of printer cartridges in France, Germany and the United Kingdom (Source: EVAP)

Ink and toner consumables that are not covered by the WEEE directive are assumed to be disposed as either household waste or handed in at local waste collection sites.

3.5 Conclusions and recommendations

3.5.1 TEC and OM products

Imaging equipment products are classified as "TEC" and "OM" products, and different energy performance evaluation methods are applicable to each of these product groups respectively. The main reason for differentiating TEC and OM products is that OM products are typically used in households and speciality applications such as large printing equipment. These products spend a significant part of their time in low power modes and have a wide range of usage profiles, which can vary tremendously depending on the type of the user. TEC products are typically used in business applications where power consumption from printing is also considered important. TEC products would have more harmonised user profiles. OM products are more fit to an evaluation method that considers low power modes while TEC products are better fit to a method that considers active use too. The classification of printers and MFDs as TEC and OM products is shown in Table 47.

Table 47: Applicability of evaluation methods for printers and MFDs (ES V3.0)

Evaluation method	Equipment type	Media format	Marking technology
TEC	Printer	Small[196]	Inkjet: HPIJ
		Standard[197]	Inkjet: HPIJ Laser: EP Others: SI, specialty technologies
	Multifunctional device (MFD)	Standard	Inkjet: HPIJ Laser: EP Others: SI, specialty technologies
	Professional	All	All
OM	Printer	Standard	Inkjet: IJ
		Large[198]	Inkjet: HPIJ
		Large or small	Inkjet: IJ Laser: EP Others: SI, specialty technologies, specialty technologies
	Multifunctional device (MFD)	Standard	Inkjet: IJ, specialty technologies
		Large	Inkjet: HPIJ, IJ Laser: EP Others: SI, specialty technologies

IJ=Inkjet; HPIJ=High Performance Inkjet; EP=Electro-photographic; SI=Solid Ink. Speciality technologies: Some or all of: Direct Thermal, Dye Sublimation, Thermal Transfer and Impact.

3.5.2 Use phase energy consumption

Energy use in imaging equipment can vary considerably between different models and it is strongly correlated to the level of functionality provided. Imaging equipment products that utilise thermal technologies, such as laser due to thermal heat loss, tend to use more

[196] Products designed for media sizes smaller than those defined as Standard (e.g., A6, 4"x6", microfilm), including those designed to accommodate continuous-form media less than 210 mm wide.
[197] 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.
[198] 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.

energy than inkjet-based products. However, some parameters related to consumer preferences in terms of purchase i.e. imaging speed and conditions during use phase i.e. power management settings and frequency and characteristics of use have been identified to have influence on energy consumption from a consumer perspective.

In general, it is found that there is a correlation of higher printing speed leading to higher energy consumption, nevertheless the wide range of energy consumptions in the same speed category shows that the energy performance varies greatly. This could be improved by having better power management settings by default, which minimises the time spent in a high-power state.

However, the user has still the possibility to control the power management settings, in particular for time transitioning from active state to reduced power modes (delay time) and subsequently to ready state. Although the latter is more controlled by the fuser technologies, the users will have an influence on the time they prefer to set as delay time. Long delay time can be seen as convenient for users as the waiting time could be shortened, but more energy would be consumed, therefore quick "recovery time" to wake up from low power state to ready state is very important for preventing user-behaviour induced increase in energy consumption.

Information from preparatory study on use patterns in the different power modes is deemed still relevant for OM printers and MFDs. This, together with the assumed 52 weeks per year and power consumption information in the US ENERGY STAR Database (accessed in September 2018) as well as average power consumption in different modes from reported data by VA signatories, annual energy consumption of the base cases has been calculated. These represents the average energy consumption of products currently on the market in 2018 and will be used for the modelling and analyse in later tasks, see Table 48.

Table 48: Annual energy consumption for TEC products

Product	Average annual energy consumption (kWh/year)	Annual energy consumption 2008 (kWh/year)[199]
BC1 Monochrome Laser MFD, 20 < s ⩽ 40	79	250
BC2 Colour Laser MFD, 20 < s ⩽ 40	92	370
BC3 Monochrome Laser Printer, 20 < s ⩽ 40	71	270
BC4 Colour Laser printer, 20 < s ⩽ 40	110	360
BC5 Colour Inkjet MFD, s ⩽ 20	6	22[200]
BC6 Colour Inkjet Printer, s ⩽ 20	2	18[201]
BC7 Professional printer and MFD	664	-

3.5.3 Use phase resource consumption

Two major consumables in the use phase impact greatly on the resource consumption: the use of paper and the use of ink and toner cartridges. The paper usage itself is a resource consumed, but the printed volume assumed for each imaging equipment speed category influence directly on the number of cartridges consumed to produce the prints. Different sources on printed volume have been reviewed and compared with the calculated printed volume by using ENERGY STAR specification on number of images per job. It is clear that there is no agreement between the sources and comparing with the printed volume calculated using the method in ENERGY STAR specification. It is therefore derived based on the ratio of sales consumables and stock of equipment. Even though it is an important factor, the printed volume itself cannot be regulated or addressed by the Voluntary Agreement to minimise resource consumption, as it depends mainly on the user demand and behaviour. In addition, paper as a consumable is not the focus of this study as already mentioned in Task 2. The focus of resource consumption during use phase should be set on cartridges. The consumption of cartridges however can be largely influenced by the page yield per cartridge, given any total printed pages over lifetime, a lower page yield would lead to higher number of cartridges needed.

[199] Preparatory study 2008
[200] Assuming same as preparatory study base case V6 IJ printer/MFD workgroup
[201] Assuming same as preparatory study base case V5 IJ printer/MFD personal

3.5.4 End-of-life behaviour

The durability and lifetime of imaging equipment can be difficult to quantify but in this study the lifetime is assumed to be in the range of 4-7 years depending on the type of equipment. The average lifetime is assumed to be 5 years for inject printers and MFDs, although previously preparatory study and ENERGY STAR calculator indicated 4 years, the newest information provided by stakeholder indicated 5–6 years at present time. The average lifetime all laser printers and MFDs are assumed 6 years, same as ENERGY STAR calculator and preparatory study, although stakeholders provided lifetime varying between 5–7 years. With a standard deviation of 1, most of the products have lifetime between 4 to 7 years in the stock model, developed for the current study. The lifetime of household products may increase if spare parts are available, but currently is seems difficult to find suited spare parts. In addition, many household products are sold at such a low price that it is more attractive for customers to buy new equipment than to get them repaired. Spare parts for non-domestic equipment seem more available and the imaging equipment themselves are to some degree already modular, which ease a potential repair operation. After the useful lifetime of imaging equipment and consumables should be collected and be properly reused and recycled, but the current collection rate is only approximately 50% for EU as a whole, and not yet reached the WEEE targets.

Due to the high consumption of consumables, the environmental hotspots are not only related to the energy consumption in the use phase. For imaging equipment, particularly those with laser technologies, the environmental impacts imposed by consumables are at least as important as the contribution from the energy consumption during use, so the end-of-life treatment of them should be addressed. For imaging equipment with inkjet technologies, the electricity consumption is still highly relevant as the third highest impact source, the fourth being the liquid ink usage. The largest impacts come from the manufacturing phase, right after the paper consumption during use, however paper consumption is not the focus of the current study. This means that the cartridges consumption is a hotspot, more and more so with increasing energy efficiency.

Existing LCAs on imaging equipment and consumables have different scopes, impact categories and conditions, and with different aims, therefore it is difficult to draw unanimous conclusions from them. Based on the LCA on comparing reused (refilled) cartridges with single use cartridge, it can be concluded that the environmental impacts imposed by ink and toner consumables can be significantly reduced if these are reused/remanufactured a number of times (up to 60% of CO2 emission of cartridges reused 15 times). However, the other LCAs show that the quality of the print still needs to be maintained to avoid reprints, which could lead to an increased consumption of paper.

4. Task 4: Technologies

Task 4 follows the MEErP methodology and includes the following:

1. A description of the identified average technology at product level on the current European market including technical specifications and energy consumption levels. This enables the identification of base cases that would be the basis for the analysis and modelling in later tasks.
2. A description of the identified average technology at component level.
3. A description of the Best Available Technology at product level, including technical specifications and energy consumption information.
4. A description of the Best Available Technology at a component level.
5. A short overview of the potential aspects that will define the Best Not yet Available Technology on the European market.

An overview of the implications in terms of use of materials for average technologies and BAT. A description on the use patterns and end of life has been presented already in task 3. Therefore, this task focuses on the technologies and the demand of components and materials.

4.1 Technical product description

The following section provides a general overview of the main technical and environmental aspects of different types of imaging equipment available on the EU market.

There is a large amount of variability in terms of the types of imaging equipment that are placed on the EU market. The products included in the scope of the existing Voluntary Agreement on imaging equipment range from small desktop inkjet-based printers to large commercial laser based multi-functional devices. The products at the extreme ranges of the product scope share few technical similarities apart from being able to place an image on paper. Despite these technical differences all types of imaging equipment, being electronic products, have associated environmental impacts, although the extent and characteristics of these environmental impacts varies across the different types of imaging equipment.

The imaging equipment market can be roughly split into “domestic” and “commercial” with some overlap amongst mid-range products. Both the domestic and commercial markets are constantly changing due to a myriad of factors such as customer demands and continued technological innovation. Imaging equipment used within the commercial sector tends to be larger and faster than those used in the domestic sector.

The majority of the imaging equipment included within the scope of this revision study converts digital content onto physical media such as paper. Some of the imaging equipment types in scope can convert physical media content into digital format (e.g. scanners and MFDs).

A number of different marking technologies are used within imaging equipment to place content onto physical media. The most common marking technologies used in imaging equipment are Electro-Photographic (EP) (Laser) and Inkjet (IJ). Basic illustrations of these imaging processes are provided in Figure 33 and Figure 34.

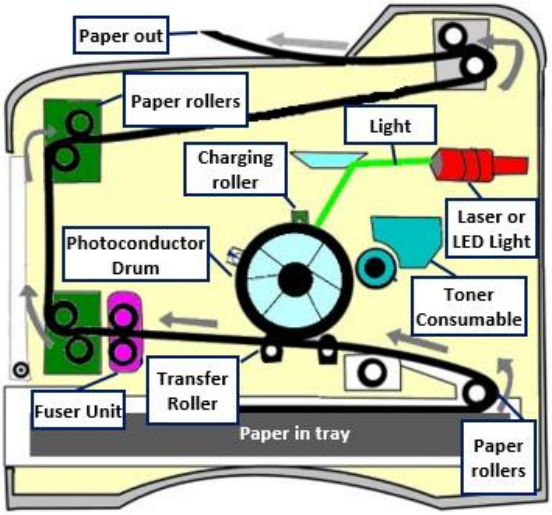

Figure 33: Illustration of typical electro-photographic imaging process[202]

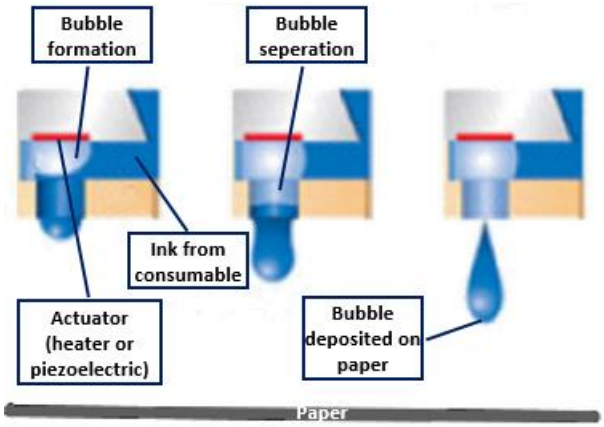

Figure 34: Illustration of typical inkjet imaging process[203]

The EP (Laser) marking technology is an electrostatic digital printing process which uses light and toner particles to imprint images onto output media such as paper. The light may be produced from a laser (e.g. an aluminium gallium arsenide (AlGaAs) semiconductor

[202] Adapted diagram from general online source on laser printing technology
[203] Adapted diagram from general online source on inkjet printing technology

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

Inkjet (IJ) marking technology is characterized by the deposition of colorant in small drops directly to the print media in a matrix manner. There are a number of sub-types including Piezo-Electric (PE) IJ, IJ Sublimation, and Thermal IJ which largely dictate the way in which ink is removed from a reservoir and placed on the output media. IJ based products utilise cartridges or containers which contain ink.

Solid ink (SI) marking technology is also within scope of the current VA on imaging equipment. The SI marking technology uses ink that is solid at room temperature and liquid when heated. The melted ink is applied to output media in a requested pattern via printhead nozzles (in a similar manner to inkjet printers).

4.1.1 Average technology of imaging equipment

The average technology of imaging equipment is described on product type level in the following sections. The average technology was found for each product group by looking at the most frequently occurring performance measures found in the main types of imaging equipment. The performance parameters are all mentioned for each base case in the sections below. The most frequently occurring values for each parameter were then used to identify the average technical product design.

In addition to imaging equipment type (e.g. MDF or Printer) and marking technology (e.g. laser or inkjet), the imaging equipment speed is also used as a key performance attribute. Imaging equipment speed is most frequently defined as the maximum claimed monochrome speed in images per minute when processing a given media. For standard size imaging equipment this is normally defined as the number of pages of A4 paper that can be imaged per minute.

Table 49: Types of Imaging Equipment Registered in the US ENERGY STAR database (September 2018) and Estimated 2018 Sales Data

BC #	Type	Marking Technology	Colour Format	Monochrome Product Speed (ipm)	Count in Database	% in Database	Sales per Speed Category Product Type	Sales per Product Type (all speeds)	
BC1	MFD	Electrophotographic (EP)	Mono	**20 < s ≤ 40**	**472**	**17.0%**	**6,920,565**	13,108,019	
BC2	MFD	Electrophotographic (EP)	Colour	**20 < s ≤ 40**	**471**	**17.0%**	**6,905,903**	11,685,785	
BC3	Printer	Electrophotographic (EP)	Mono	**20 < s ≤ 40**	**154**	**5.6%**	**6,052,901**	14,188,943	
BC4	Printer	Electrophotographic (EP)	Colour	**20 < s ≤ 40**	**164**	**5.9%**	**6,445,946**	10,219,183	
BC5	MFD	Inkjet (IJ)	Colour	**s ≤ 20**	**186**	**6.7%**	**54,555,905**	87,113,461	
BC6	Printer	Inkjet (IJ)	Colour	**s ≤ 20**	**102**	**3.7%**	**9,889,318**	13,961,390	

Table 50 illustrates the average speed of the common types of imaging equipment found in the ENERGY STAR database. The average product speeds, in Table 50, correspond well to the highest selling speed categories of each product type shown in Table 24. Whilst this suggests that average speed may be a viable proxy for "average technology" of each type of imaging equipment it fails to consider the wide variability even within the individual types of imaging equipment. This is seen for the EP technology printers and MFDs, especially monochrome format, the average speed is above the 20 – 40 ipm speed range which has the highest sales, however using 49 ipm and 57 ipm for laser MFD and printer base cases could lead to overestimation of energy and resource consumption etc.

Table 50: Average Imaging Speed of Imaging Equipment Registered in the US ENERGY STAR database

Imaging Equipment Type	Marking Technology	Colour Format	Monochrome Product Speed (ipm)
MFD	Inkjet (IJ)	Colour	16.1
Printer	Inkjet (IJ)	Colour	17.2
Printer	Inkjet (IJ)	Mono	7.0
MFD	Electrophotographic (EP)	Colour	40.9
MFD	Electrophotographic (EP)	Mono	49.4
Printer	Electrophotographic (EP)	Colour	41.8
Printer	Electrophotographic (EP)	Mono	57.3

Energy use in imaging equipment can vary considerably between different models and is strongly correlated to the level of functionality provided. Imaging equipment products that utilise thermal technologies, such as laser, tend to use more energy than inkjet-based products. Variability in energy use not only occurs between completely different types of imaging equipment as it also occurs within sub-types such as laser MFDs. Table 51 shows the average energy use and power demands of imaging equipment (as measured according to the Energy Star v2.0 methodology) for the base cases. Table 74 in Annex A – Additional Tables and Figures shows the results for all speeds categories, and that there is significant variability in energy use across the different types of imaging equipment. The results also show that there is less variability in the power demands within the inkjet-based products and wide variability ion the TEC values for laser-based products.

Table 51: Average Energy Use and Power Demands for Imaging Equipment Registered in the US ENERGY STAR database

BC #	Imaging Equipment Type	Marking Technology	Colour Format	Monochrome Product Speed (ipm)	Average Energy/Power		
					TEC (kWh/week)	Sleep Mode (W)	Standby/ Off Mode (W)
1	MFD	Electrophoto-graphic (EP)	Mono	20 < s ≤ 40	1.5		
2	MFD	Electrophoto-graphic (EP)	Colour	20 < s ≤ 40	1.8		
3	Printer	Electrophoto-graphic (EP)	Mono	20 < s ≤ 40	1.4		
4	Printer	Electrophoto-graphic (EP)	Colour	20 < s ≤ 40	2.1		
5	MFD	Inkjet (IJ)	Colour	s ≤ 20		1.1	0.1
6	Printer	Inkjet (IJ)	Colour	s ≤ 20		1.0	0.2

Figure 35 to Figure 44 provide charts of average TEC values (per ipm speed listed in the ENERGY STAR database) and average sleep and standby/off mode power demand (respectively for TEC and OM products) compared to the ENERGY STAR limits for the most common types of imaging equipment listed in the US ENERGY STAR database.

The figures for laser MFDs and laser printers are limited to only those products as being registered for sale in the EU. Due to limited number of registrations, the figures for inkjet MFDs and printers show all products registered in the US ENERGY STAR database. Given the global nature of imaging equipment, it is not expected that including US registered products would significantly impact the results. The speed categories include maximum imaging speeds of 66 ipm and 51 ipm and represent products that are within scope of the current voluntary agreement[204] on imaging equipment, however for laser MFDs and printers, the speeds categories outside the VA scope are also included.

The ENERGY STAR limits (red lines in figures) are based on the average estimated ENERGY STAR specification limit for each listed product speed (i.e. each listed ipm value). The ENERGY STAR limits (red and black lines in figures) include estimated adders for inkjet products based on the adders listed by the manufacturers in the ENERGY STAR database. Not all adders could be identified accurately as the data was not available in the ENERGY

[204] The VA contains limits of product speed at 66ipm (mono) and 51ipm (colour).

STAR database. For example, the ENERGY STAR v2.0 and ENERGY STAR v3.0 specification includes an adder for power supplies over 10 W rated output, but the database does not list the actual size on the power supply used in the product. Where manufacturers had stated the application of a power supply adder it was necessary to include an assumed power supply size.

The figures show that many products registered in the US ENERGY STAR database have energy efficiency levels well below those required by the ENERGY STAR v2.0 specification limit. The US EPA estimates 99% of printers and MFDs on the US market within the scope of the ENERGY STAR v2.0 specification were compliant with that specification by the end of 2017.[205] This high ENERGY STAR penetration rate suggests that there are unlikely to be large numbers of highly inefficient imaging equipment (i.e. equipment that would not even meet the ENERGY STAR v2.0 specification limits) models on the market. However, the new ENERGY STAR v3.0 specification proves that there is still sufficient variation in products to warrant the development of a new specification.

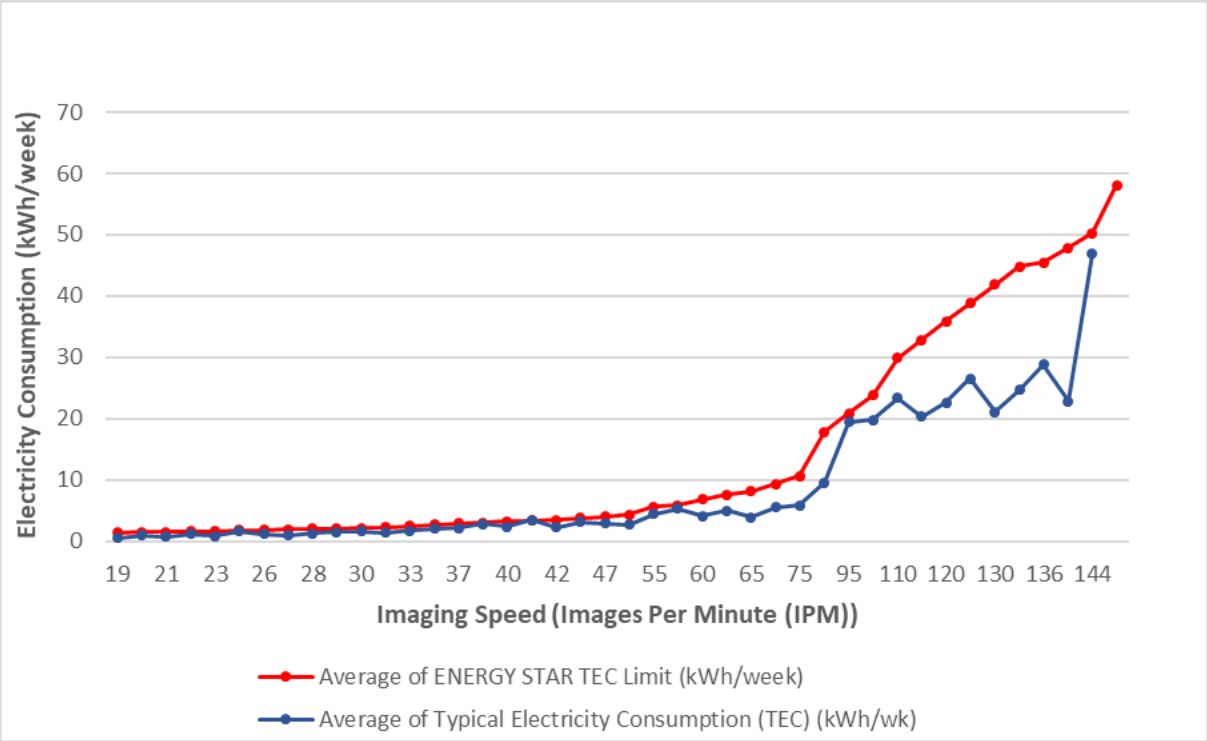

Figure 35: Average TEC values of Mono Laser MFDs

[205] US EPA, ENERGY STAR® Unit Shipment and Market Penetration Report Calendar Year 2017 Summary, available from https://www.energystar.gov/ia/partners/downloads/unit_shipment_data/2017/2017%20Unit%20Shipment%20Data%20Summary%20Report.pdf?915f-26a0

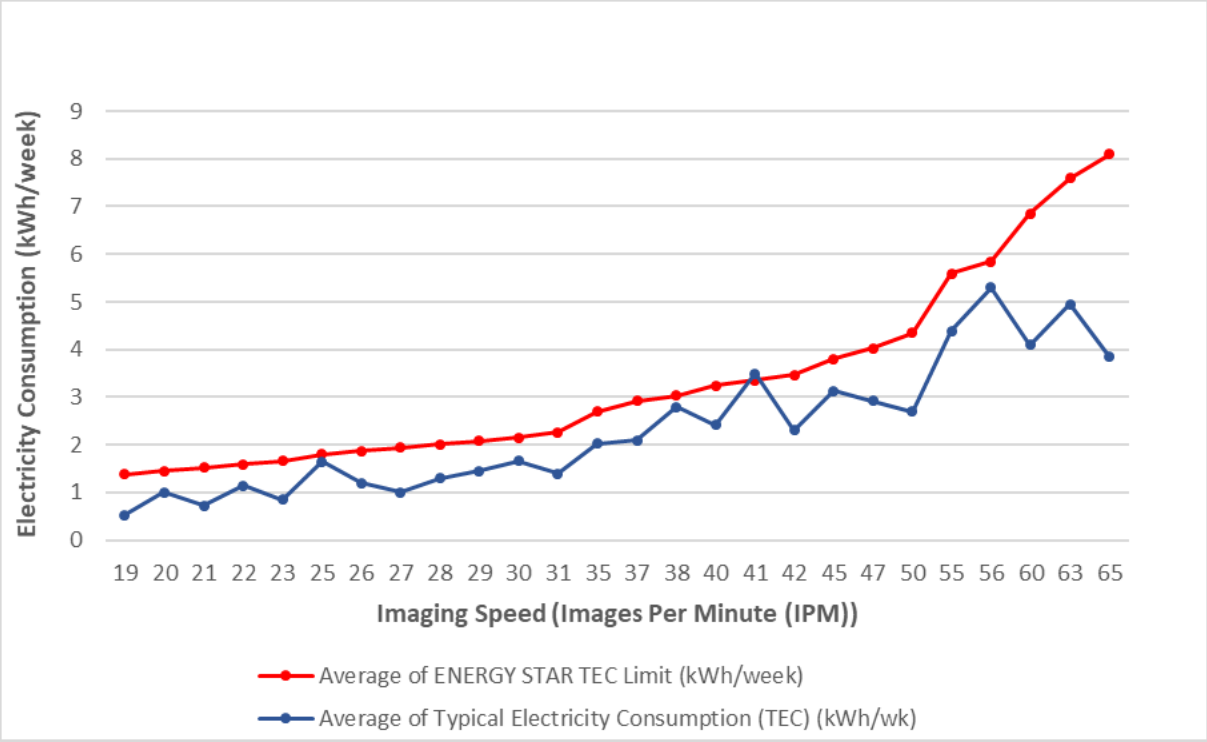

Figure 36: Average TEC of Mono Laser MFDs (under 66ipm)

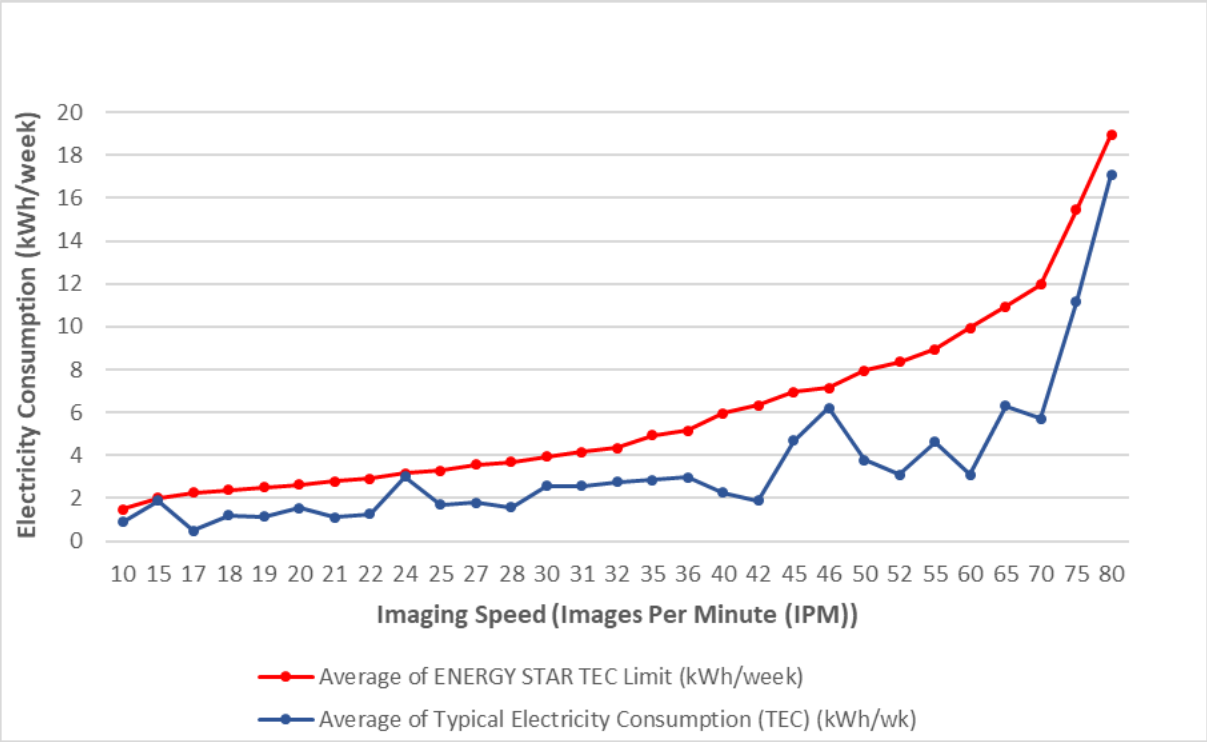

Figure 37: Average TEC of Colour Laser MFDs

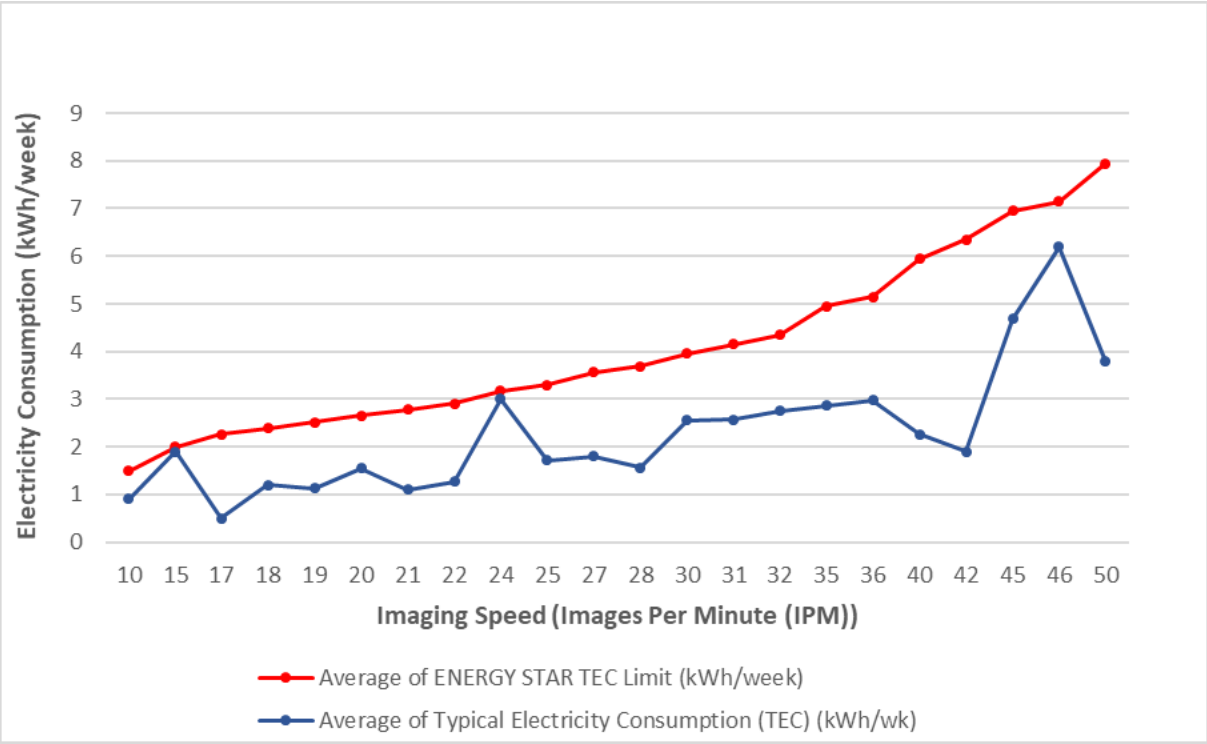

Figure 38: Average TEC of Colour Laser MFDs (under 51ipm)

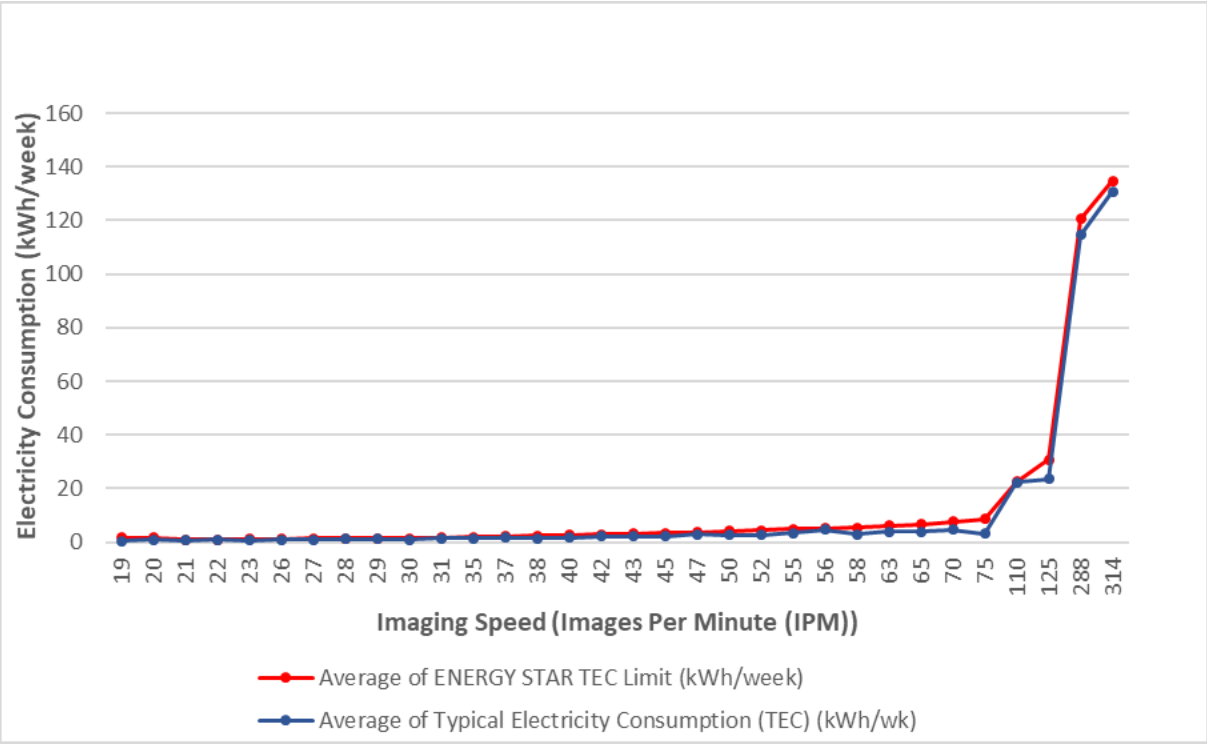

Figure 39: Average TEC of Mono Laser Printers

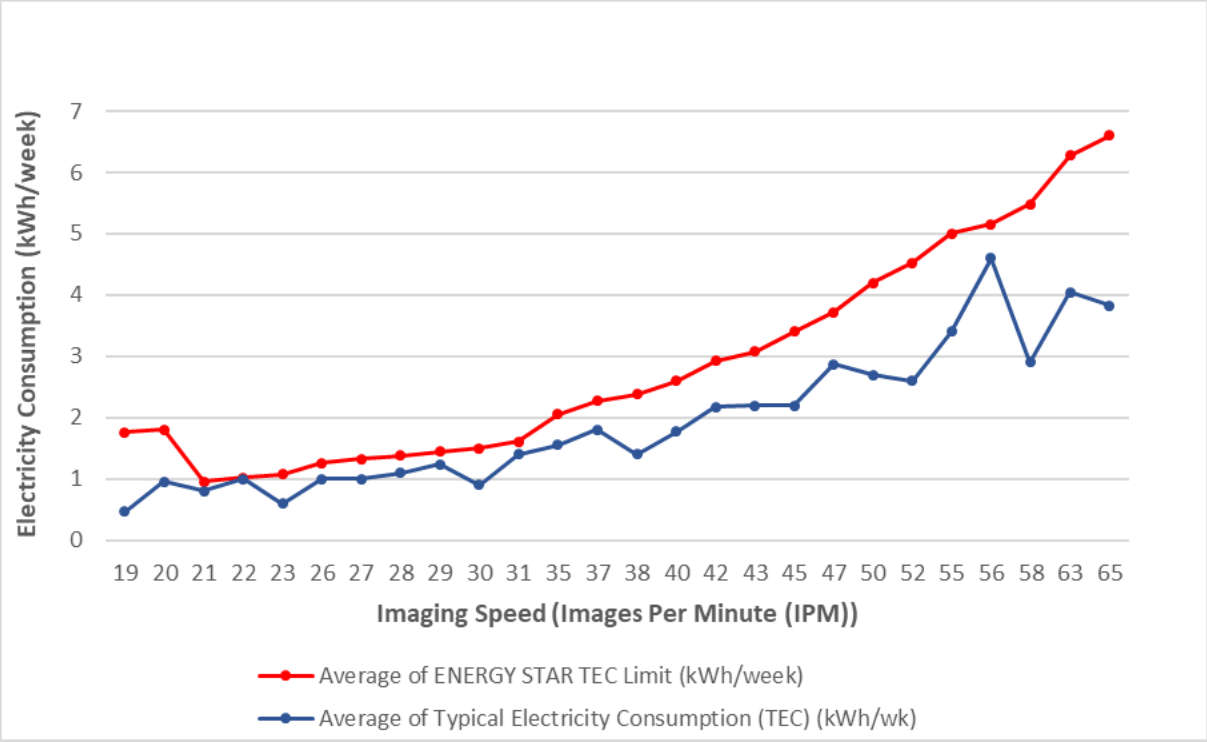

Figure 40: Average TEC of Mono Laser Printers (under 66ipm)

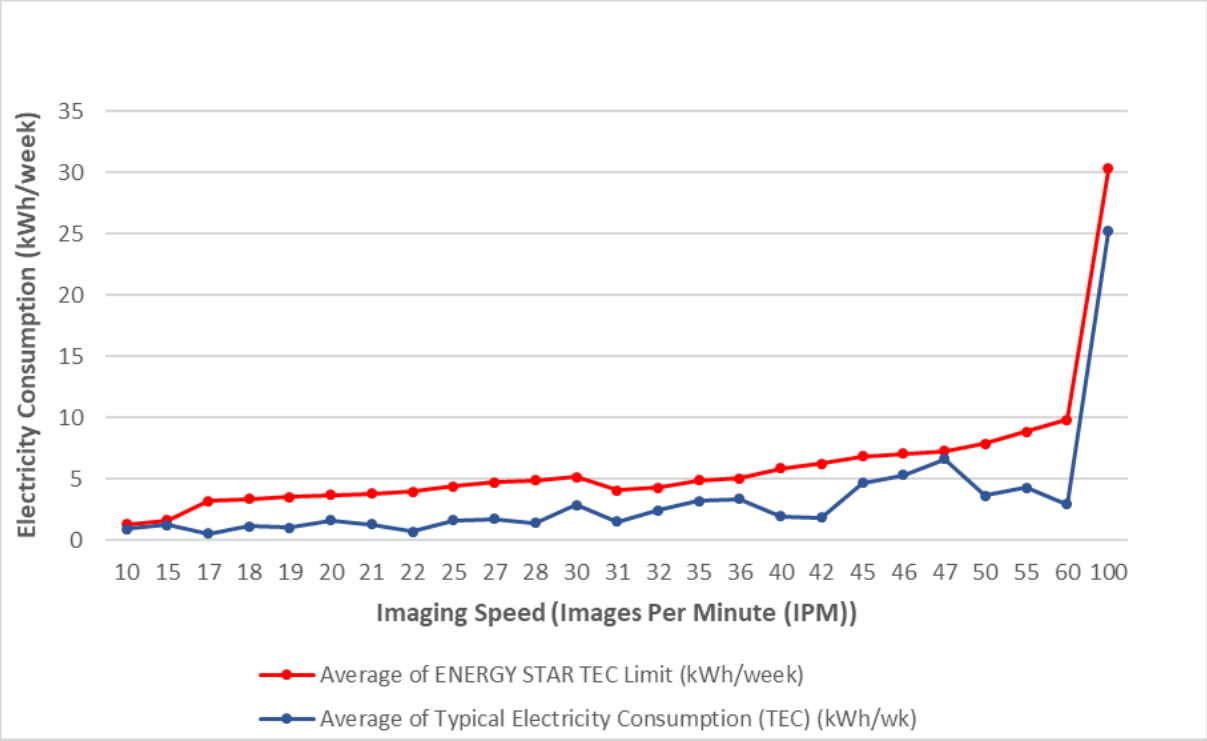

Figure 41: Average TEC of Colour Laser Printers

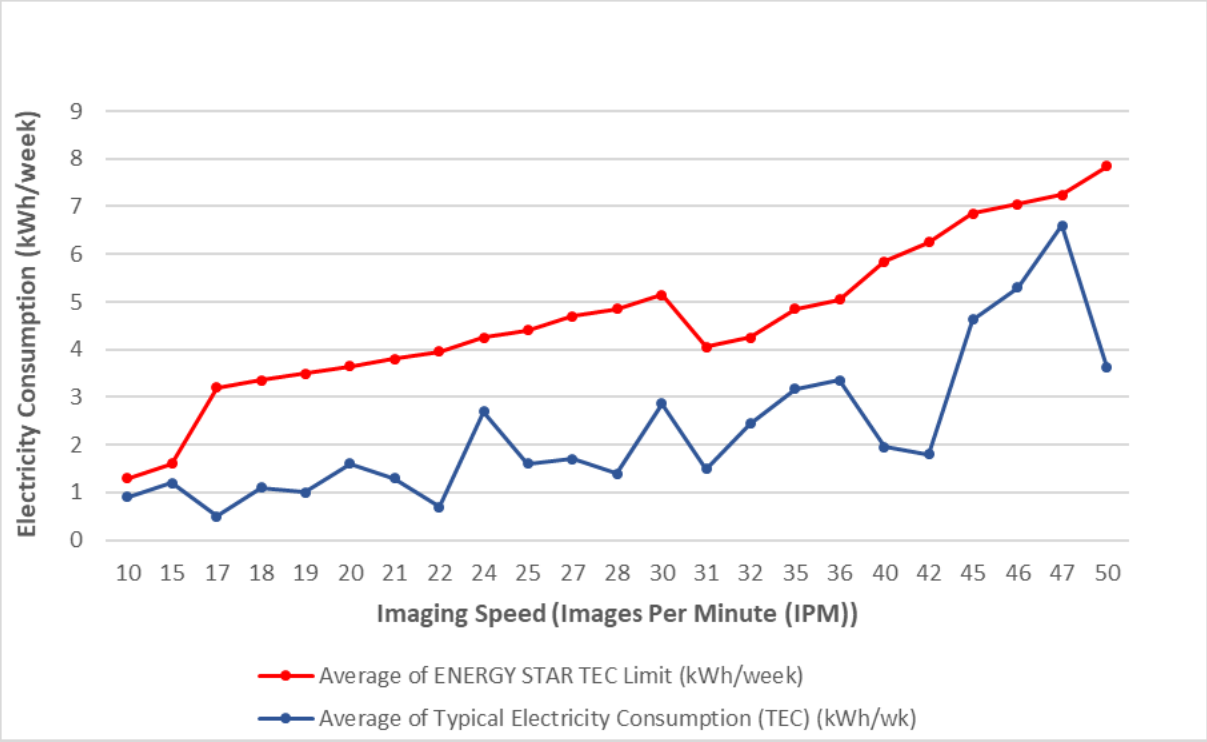

Figure 42: Average TEC of Colour Laser Printers (under 51ipm)

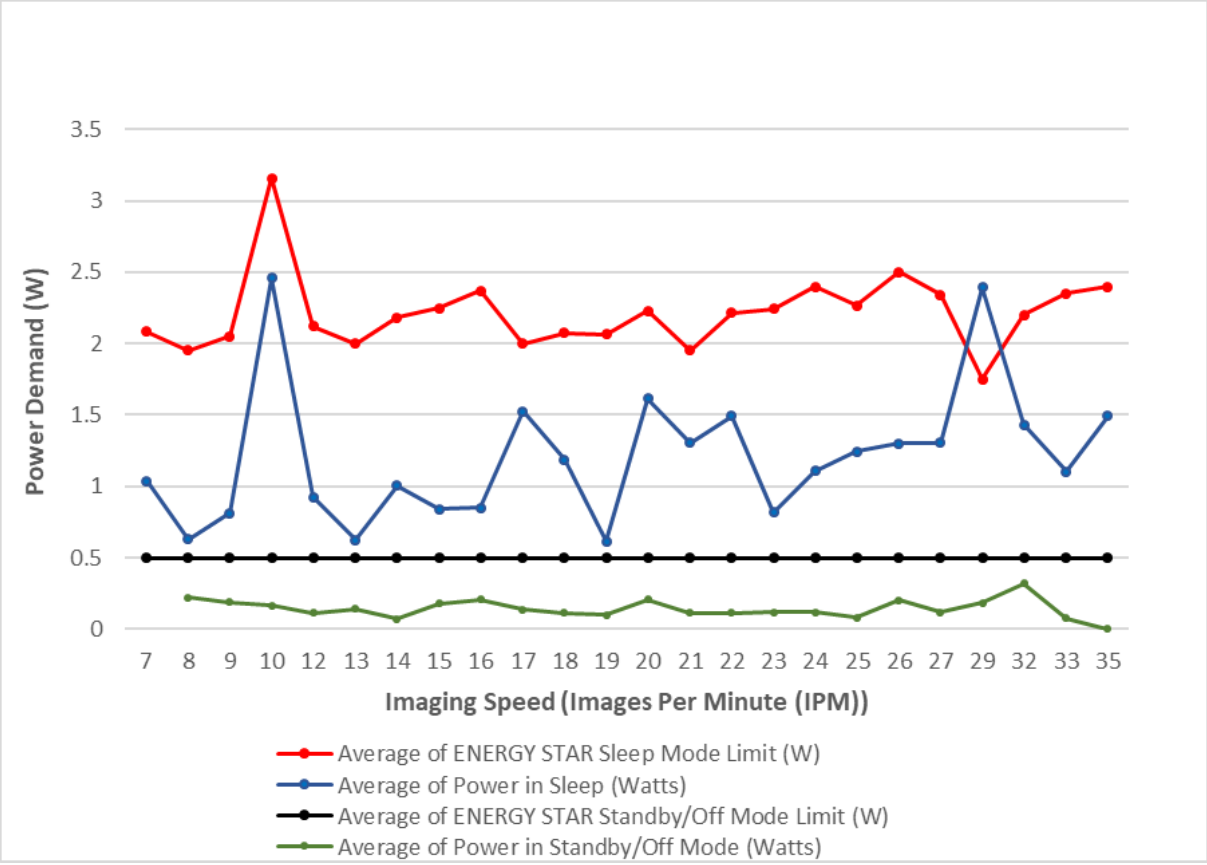

Figure 43: Average Sleep and Standby/Off Mode Power Demand of Inkjet MFDs

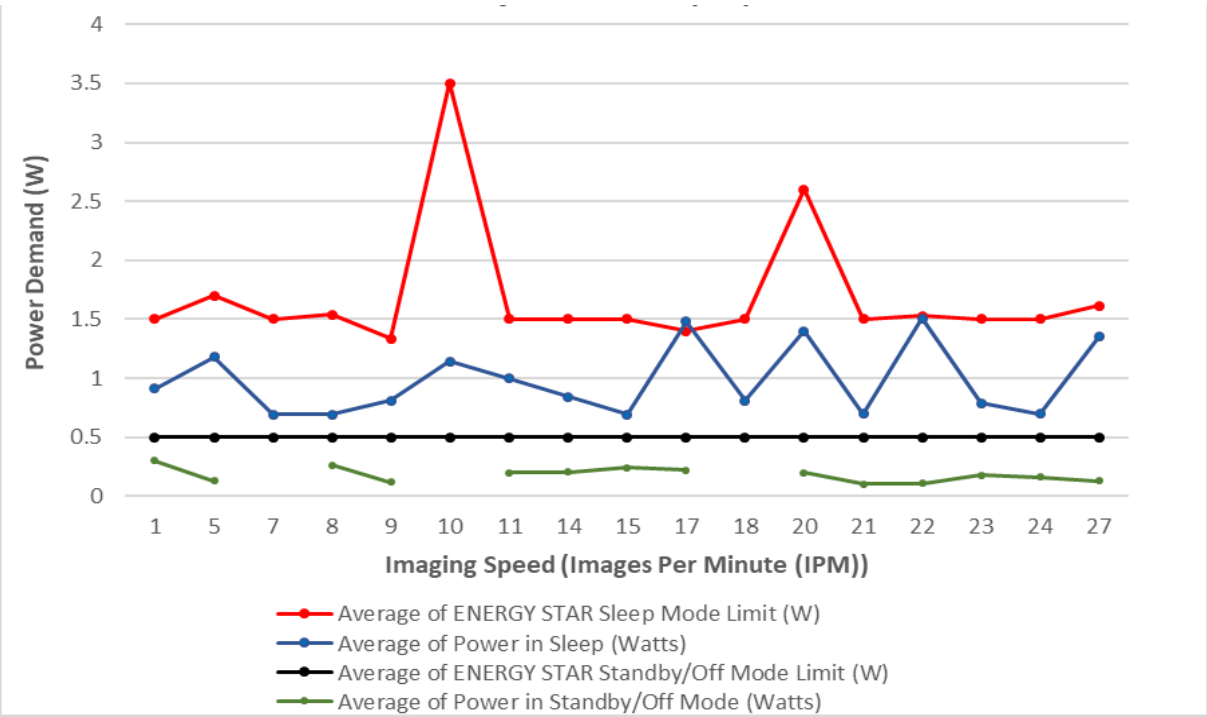

Figure 44: Average Sleep and Standby/Off Mode Power Demand of Inkjet MFDs

4.1.1.1 Professional imaging equipment

Due to manufacturer requests, the US EPA have carved out a "professional imaging equipment" category within the ENERGY STAR v3.0 specification to represent very high-end products. Neither the current ENERGY STAR database nor the EPEAT database provide sufficient information to identify which products fall into the proposed "professional imaging equipment" category. As such, it is difficult to identify the average performance of these product types with a high level of confidence in the results. It is possible to estimate the average energy performance of these products by cross comparing individual product model registrations in the ENERGY STAR and EPEAT databases and using some of the reporting fields in both databases to estimate which products could potentially be classed as "professional imaging equipment". In conducting this analysis, it was possible to identify product performance against 3 of the 4 (speed, product weight and A3 paper capability) mandatory professional imaging functionality requirements (i.e. those in the draft 2 of the US EPA ENERGY STAR v3.0 specification). A total of 63 products in the combined ENERGY STAR v2.0 and EPEAT database (from a total of 3251 EPEAT and 3001 ENERGY STAR registered products) were shown to meet the proposed professional imaging functionality requirements. The TEC and average technical functionalities of the 63 products varied widely. Due to the wide spread of TEC and technical functionality, it was decided that further data would be required to identify the average performance of "professional imaging equipment" with a sufficient level of accuracy.

4.1.1.2 Typical design cycle

The imaging equipment market in the EU is dominated by 10 manufacturers. These 10 manufacturers have significant control over the design of most imaging equipment placed on the EU market. Most product design occurs within each of the organisations but with some co-operation amongst the manufacturers on aspects such as consumable design.

In terms of timescales, the release of new models of imaging equipment is, on average, significantly faster now than in the past. Many laser-based products typically have model lifetimes (i.e. the amount of time a model would be sold on the market with no or few changes) of many years. During this time period, changes may be made to key components to increase the level of energy efficiency found in existing models of products. Individual components (e.g. marking engines, motors etc) often have considerably longer lifetimes. Inkjet based models have typically had shorten lifetimes than laser-based models. However, the rapid increase in ENERGY STAR v2.0 penetration rates from 25% in 2013 to 99% by 2017 suggests that either the lifetime of many imaging equipment models is now much reduced or manufacturers are making improvements in the energy efficiency levels of existing models in order to meet new ENERGY STAR requirements.

4.1.2 Average technology of components

Imaging equipment, with the exception of consumables, are placed on the market as complete products. This means that individual components are not normally sold separately unless as spare parts. Given that individual components are not commodity items there is little openly available information about the average performance of these components.

Power Supplies

Imaging equipment power supply units (PSUs) convert AC (alternating current) mains electricity sources into DC (direct current) at specific voltages (e.g. 12 V, 5 V, 3.3 V for IPS) which are then used by different components within the imaging equipment. Two main types of PSUs are used with imaging equipment; External Power Supplies (EPS) and Internal Power Supplies (IPS). EPSs are typically used with lower powered imaging equipment, such as inkjet printers and MFDs, and IPS are typically installed in higher power demanding products such as laser printers and MFDs.

The efficiency of EPS placed on the EU market is addressed in an existing ecodesign regulation[206] and so these products will not be addressed in detail within this report.

[206] COMMISSION REGULATION (EC) No 278/2009 of 6 April 2009 implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for no-load condition electric power consumption and average active efficiency of external power supplies, available from http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32009R0278

The efficiency of IPS within products plays an important part in overall product energy efficiency levels. Given that the ENERGY STAR v2.0 and ENERGY STAR v3.0 TEC test procedures require measurement of energy use across a number of power modes they inherently address some aspects of IPS efficiency. That is, an imaging equipment product with a very low efficiency IPS would find it harder to meet the overall ENERGY STAR TEC limits. However, given that the ENERGY STAR TEC procedures assume high levels of usage, IPS efficiency in lower power modes may not be adequately addressed. This stems from the fact that IPS efficiencies tend to be low when supporting low loads (i.e. low power demands). Where products are sat in low power modes for significant periods of time, the IPS efficiency would become more important. It should be noted that the ENERGY STAR v3.0 test procedure results in imaging equipment spending less time in active and ready states and more time spent in low power modes. As such, the influence of low power demands on the overall TEC value is higher under ENERGY STAR v3.0 than previous ENERGY STAR specifications. However, it is not clear whether this additional time spent in low power modes has a significant weighting on overall TEC performance given that power demand in low power modes is significantly lower than power demands in active and ready states.

For this reason, the efficiency of IPS in many other information technology products, such as personal computers and servers, are covered under various environmental initiatives. The inclusion of IPS efficiency requirements in environmental initiatives results in manufacturers publicly reporting data about the IPS used in their products. This data covers factors such as power rating and efficiencies at different loading levels. Given that there are no IPS efficiency requirements in any of the major environmental initiatives on imaging equipment, IPS data for these products is not widely available.

Charge Producing Components

Imaging equipment based on the electrophotographic (EP) marking technology utilise components that produce charges on the OPC and paper in order to function. In the past these charges were primarily produced via corona wires (a wire with an electrical current running through it). Passing high voltages through corona wires leads to the development and release of ozone. Newer EP based imaging equipment use charged rollers instead of corona wires which limits ozone production.

Light Sources

Light sources are used in two main imaging equipment components. Scanning units within MFDs and standalone scanning products use light sources in their operation (i.e. light is shone on an image and the reflected light is measured and the image is digitally reproduced). Compact fluorescent lamps (CFLs) were the primary light source before being replaced by LEDs. The electrophotographic (EP) marking technology also utilises light in order

to discharge parts of the OPC. Lasers (normally an aluminium gallium arsenide (AlGaAs) semiconductor laser) have traditionally been used to perform this function but have also been replaced by LEDs in some products.

Consumables

Types of consumables

Consumables are used in all imaging equipment that support output of physical media (i.e. printing to paper). There are 5 main types of consumable used in imaging equipment, as detailed in Table 52. Drum, fuser and transfer units have typically much higher page yields than the ink/toner consumables.

Table 52: Types of imaging equipment consumables

Imaging equipment consumables	Description
Container (ink/toner)	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 (other than simple rollers) integral to the imaging product's function.
Cartridge (ink/toner)	An end-user replaceable product, which fits into or onto an imaging equipment product, with printing-related functionality that includes integrated components (e.g. a drum unit) or moving parts integral to the imaging equipment's function beyond holding the ink or toner material.
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.

Inkjet consumables either consist of a separate print-head and ink cartridge (i.e. a separated system), or a combined unit including the ink reservoir and a print-head (i.e. an integrated cartridge). In separated systems the print-head, either permanent or long-life component in the printer, contains most of the electronics required to fire drops with the ink stored in a separate cartridge. Ink cartridges often contain some electronic circuity which support a variety of functions (i.e. anti-counterfeit/fraud, the number of pages/drops printed, enhanced print quality and reliability, etc.) through communication with the imaging equipment to provide the best customer experience. Ink containers with or without electronic circuitry typically used to fill a tank in the printer and are not required to be inserted for printer to print.

Laser toner consumables are typically more complex than inkjet consumables and may consist of a significant number of different components and materials. Most laser toner cartridges also contain electronic chips to support a variety of functionality such as page counting, anti-counterfeit and anti-fraud etc. Laser toner containers may also contain electronic chips.

Imaging equipment containers and cartridges can be further sub-divided into the types shown in Table 53.

Table 53: Types of imaging equipment cartridges and containers. See Task 7 for suggested definitions of them.

Product	Description
OEM manufacturer cartridge	A cartridge manufactured by the OEM imaging equipment manufacturer.
OEM manufacturer container	A toner or ink container manufactured by the OEM imaging equipment manufacturer.
Non-OEM manufacturer cartridge (new-built)	A cartridge not manufactured by the OEM imaging equipment manufacturer but which is unused when first placed on the market. remanufactured and/or refilled.
Non-OEM manufacturer container (new-built)	A toner or ink container not manufactured by the OEM imaging equipment manufacturer but which is unused when first placed on the market.
Non-OEM manufacturer cartridge (remanufactured)	A cartridge not manufactured by the OEM imaging equipment manufacturer which is remanufactured and/or refilled
Non-OEM manufacturer container (remanufactured)	A toner or ink container not manufactured by the OEM imaging equipment manufacturer which is remanufactured and/or refilled.
Remanufactured cartridge	A cartridge that has been used, repaired by replacing wear parts and filled with new toner or ink (incl. solid ink)
Remanufactured container	A container that has been used, repaired by replacing wear parts and filled with new toner or ink (incl. solid ink)
Refilled cartridge	A cartridge that has been used and filled with new toner or ink (incl. solid ink).
Refilled container	A container that has been used and filled with new toner or ink (incl. solid ink).

Additionally, there could be a dedicated category for high yield cartridges and containers: this is a cartridge or container that contains higher volumes of toner or ink to support higher page yields, however these may be manufactured by the OEM imaging equipment manufacturer or an alternative manufacturer.

Table 53 identifies a few types of organisation involved in placing consumables onto the EU market. The terminologies in different studies and used by different stakeholders or industry parties vary, therefore can be confusing. These are:

- OEM manufacturer – this is the same manufacturer that manufactures the imaging equipment product. Consumables from OEM manufacturers are often called "originals".
- Non-OEM manufacturer (new-built) – there are an increasing number of organisations which manufacture compatible new consumables for imaging equipment products. Consumables from these types of manufacturers are marketed under their own brands, these are known as "compatibles".
- Non-OEM manufacturer (remanufactured) – there are a large number of EU based organisations which take used OEM consumables and remanufacture or refill them for further use. There are other non-EU based organisations that also remanufacture consumables and place them on the EU market. The consumables from these manufacturers are often called "remanufactured" or "refilled", the latter in this study is assumed the same as "reused".
- Non-OEM manufacturer (counterfeit) - new cartridges manufactured by a third party (not an OEM), but illegally branded under an OEM brand name, these are also known as "clones".

Identifying average types of consumable is complicated by the wide variety of products on the market. Even within the types listed in Table 52 and Table 53 there is considerably variability in terms of other functionality including:

- Page yield – the number of pages that can be printed from a cartridge or container before a replacement is needed
- Colour type – cartridges/containers can provide mono (i.e. black) or colour (typically cyan, magenta or yellow) outputs or both.
- Consumable complexity – consumables can contain electronic chips which support printing related functionalities such as page counting and security verifications

A central component in ink and toner cartridges is the electronic chip because it controls the use of the cartridges. The first types of chips placed in cartridges were simple devices that could be easily reset at the end of a consumable's life. In the early 2000's electronic chips installed in cartridges started to become more complex. Electronic chips used in cartridges on the market today include extremely complex encryption codes and perform a number of functions. The electronic chips within cartridges are typically mounted on a small circuit board and support communication between the cartridge and imaging equipment (through either direct contact or radio frequency connections). Typically, these electronic chips perform the following functions:

- Include a memory chip(s) to store information

- May include a processor to 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, etc.
- Contains cartridge specific information (allowing connected imaging equipment to verify an authorised cartridge is installed).
- Stores the cartridge yield data
- Stores geographical region data
- Supports authentication to allow communication between the cartridge chip and the imaging equipment.
- Allows the imaging equipment to store data about toner or ink levels and usage

Imaging equipment sends information about the pages printed, page coverage and estimated toner remaining to the electronic chip in the cartridge. The imaging equipment determines the remaining ink or toner levels in the cartridge by estimating previous use. This information can then be retrieved by the imaging equipment through requests sent to the chip. The chip therefore serves the imaging equipment but must be capable of correctly responding to the machine in a pre-defined time frame using the correct encryption. The encryption includes the correct cartridge part number information, correct regional data, whether the cartridge is new or used, the page-count and page coverage data as well as remaining ink or toner levels. The information that the chip returns must match the information expected by the imaging equipment in order to work properly. Any differences in the information will result in the cartridge no longer being able to function.

Imaging equipment uses the information stored on the chip to determine when the cartridge has reached the end of its life. At this point some ink or toner may remain in the consumable. Once the imaging equipment determines the cartridge has reached the end of its life a message is sent to the chip's memory and the cartridge will either no longer function or will provide a warning to a user that no ink or toner is left.

As noted in the Task 3 report, the use of consumables is one of the three life cycle environmental hotspots impacting the imaging equipment product group. Depending on the printing technology, the relative contribution of life cycle environmental impacts from the use of consumables can be as important as energy in use impacts and therefore the joint second most important after the use of paper. When paper use is excluded from the system boundaries, the embodied impacts from the consumables (i.e. from manufacturing) can become at least as important as in-use energy consumption, in terms of Global Warming Potential, Primary Energy Demand, Ozone Depletion, Acidification Potential, Eutrophication Potential, Resource Depletion Potential, amongst others. The relative impacts of paper,

consumables and energy in use are highly dependent on the type and even model of imaging equipment under consideration.

Given the high environmental impacts associated with consumables it is therefore relevant to investigate the average technology inherent in imaging equipment consumables which may impact their environmental performances.

Identifying average consumable re-manufacturability performance is complicated by the wide variety and number of consumables on the EU market. Nevertheless, there are several performance parameters of consumables that are relevant to discuss for material or resource efficiency.

Page yield

The page yield of consumables (i.e. the number of pages that can be printed before a consumable need to be replaced or refilled) is also an important indicator of material efficiency. Page yield is a common metric to benchmark consumables and due to its influence on their overall environmental impacts (i.e. lower yields result in more frequent consumable replacements) is considered important. The page yield of consumables varies significantly across the imaging equipment models on the EU market. Small inkjet consumables may have page yields of less than 300 pages, but consumables used in high volume printing devices may page yields of tens of thousands. In addition, there is often a significant amount of variance in the page yields of consumables designed for use in the same product. That is, manufacturers often offer consumables with either "standard" or "high" yields for the same imaging equipment model. Furthermore, the page yields of consumables offered by different manufacturers for similar performing products can also vary significantly. Table 54 illustrates the variability and average page yield for consumables for the base cases. This is an extract of the complete analysis shown in Table 75 in Annex A – Additional Tables and Figures for some common types of imaging equipment. The values are based on page yield data secured found for a total of 104 products from a single large consumable supplier. Data was not available for some of the highest speed product types as consumables for these product types are not often sold on the open market.

Table 54: Average Page Yields of Consumables[207]

Product Type	Monochrome Product Speed, s, as Calculated in the ENERGY STAR Test Method (ipm)	Consumable (Cartridges/Containers) Page Yield					
		OEM			Remanufactured/ Compatible Consumable		
		Average	Max	Min	Average	Max	Min
BC1 Mono Laser MFD	20 < s ≤ 40	15729	45000	3000	5525	9000	3000
BC2 Colour Laser MFD	20 < s ≤ 40	7646	15000	2900	7460	15000	5000
BC3 Mono Laser printer	20 < s ≤ 40	9727	36000	1200	6978	18000	1200
BC4 Colour Laser Printers	20 < s ≤ 40	6409	30000	1500	5453	12000	1500
BC5 Colour Inkjet MFD	s ≤ 20	384	1130	165	527	1130	165
BC6 Colour Inkjet Printers	s ≤ 20	2371	10000	180	731	1130	500

Consumable imaging yield efficiency

Most modern imaging equipment includes functionality which tracks the amount of imaging undertaken with each newly installed consumable. Once consumables are deemed to have finished their useful lives the imaging equipment notifies the user to replace the consumable. Claims have been made by a French environmental association that some imaging equipment manufacturers face lawsuit in France, because their products stop consumables from working even where there is up to 20% of the ink remaining.[208] However, the excess amount of ink or toner left in consumables at the end of their functional lives has been shown to vary significantly.[209] Material efficiency requirements based on weight and page yield could incentivise manufacturers to ensure more toner and ink is used before consumables reach their end of life.

Despite large variability in page yields, it is possible to identify average performances in terms of consumable imaging yield efficiency, refers to the minimum page yield per gram of the total consumable material supplied. A recent project on the revision of the EU GPP criteria for imaging equipment[210] included detailed analysis of page yields and material efficiencies for a range of consumables on the EU market. Consumable weight data was secured from an EU based remanufacturer[211] and compared to yield data for the same consumables. The analysis was conducted for the following five main types of consumables:

- Toner container
- Toner drum units
- Toner cartridges

[207] Data found via a large consumable supplier, assessed in 2018.
[208] https://www.therecycler.com/posts/printer-manufacturers-face-french-lawsuit/
[209] https://www.pcworld.com/article/152953/printer_ink_costs.html
[210] Revision of the EU Green Public Procurement (GPP) Criteria for Imaging Equipment. Technical report. JRC, Viegand Maagøe and Tenvic. February 2018.
[211] Embatex Iberia S.L, personal communications.

- Ink containers
- Ink cartridges

Each of the five main types of consumables were further subdivided into mono/black and colour. Metrics were developed which ensured that approximately half of the consumables (of each type) met the following proposed EU GPP efficiency requirements:

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

For Toner Cartridges or Containers:

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

For Ink Cartridges or Containers:

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

where, *page yield* is the measured number of images that may be produced by the consumable. Cartridge or Container/Drum mass. *CMass* is calculated as the mass (g) of each cartridge or container plus drum unit, as measured in the condition to be installed (i.e. full of ink or toner and any additional components not present whilst installed in the imaging equipment removed).

The figures below show the results of the EU GPP analysis as well as the proposed criterion limit line. Consumables above the red line would be compliant with the criterion limit, with those below the line not meeting the requirement.

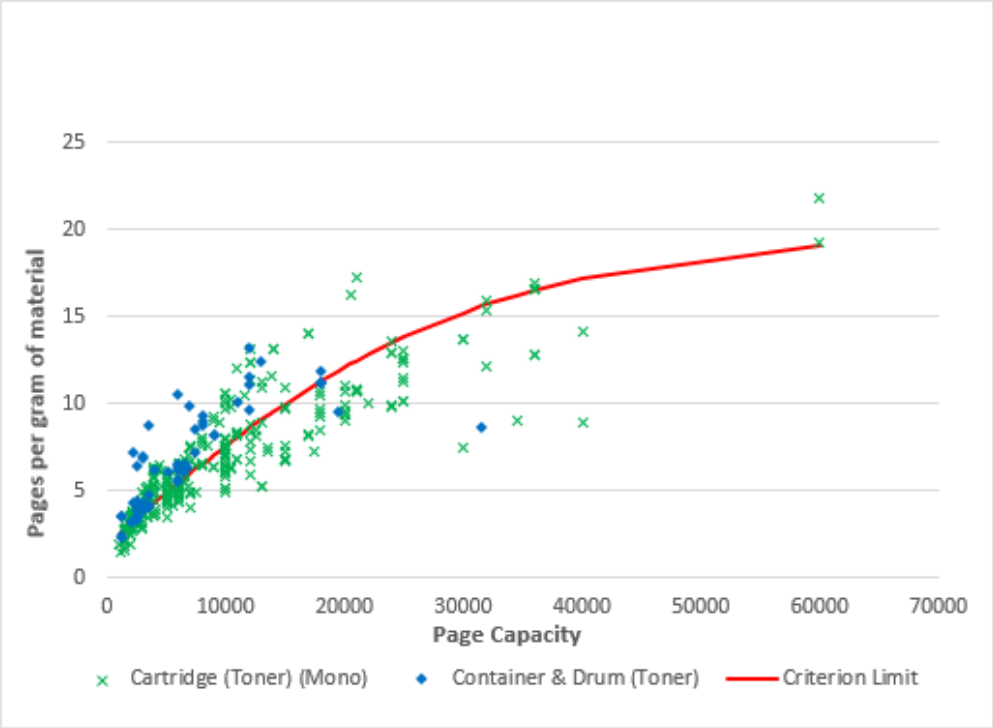

Figure 45: Material efficiency of Mono Toner Cartridges and Containers with associated Drum Units

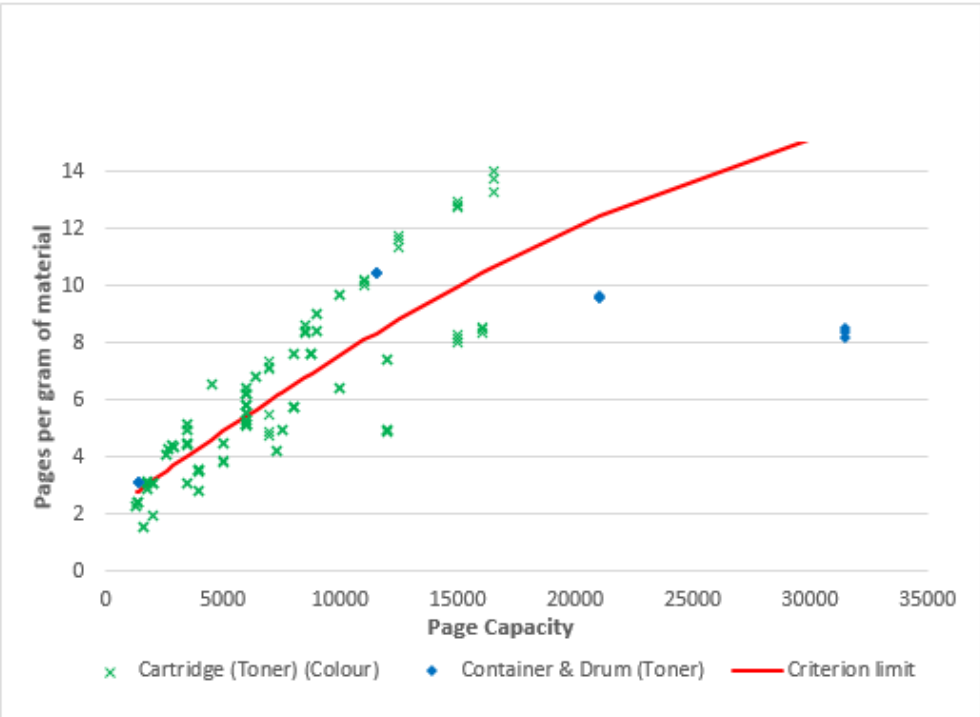

Figure 46: Material efficiency of Colour Toner Cartridges and Containers with associated Drum Units.

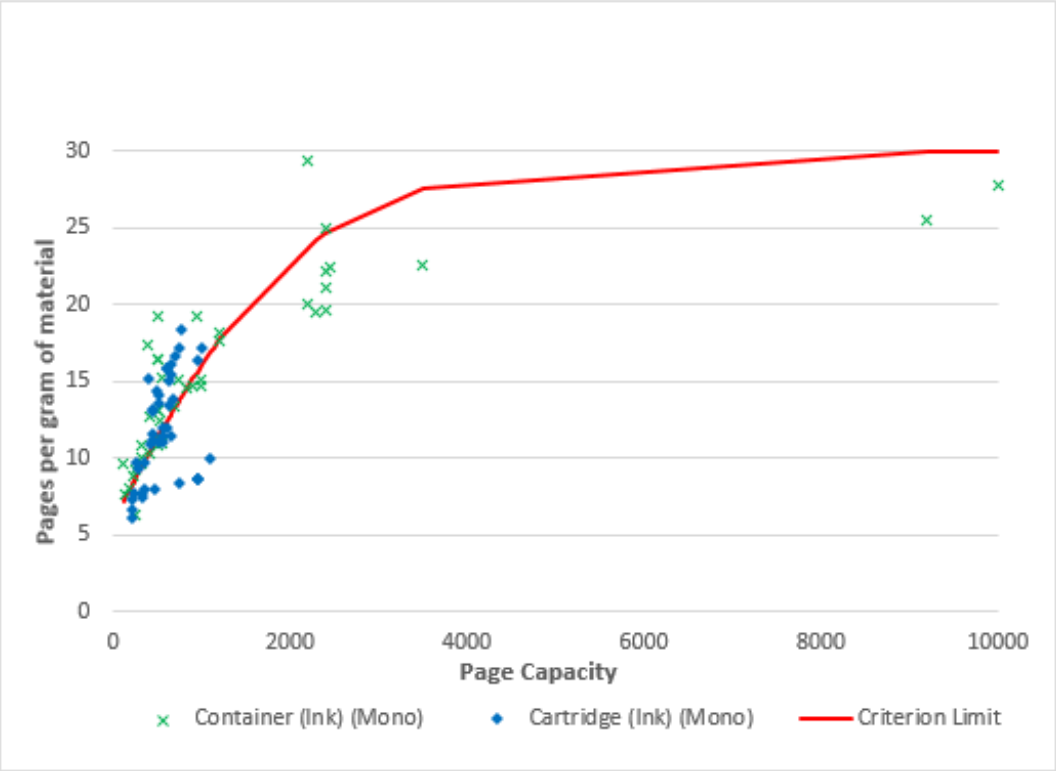

Figure 47: Material efficiency of Colour Ink Cartridges and Containers (all)

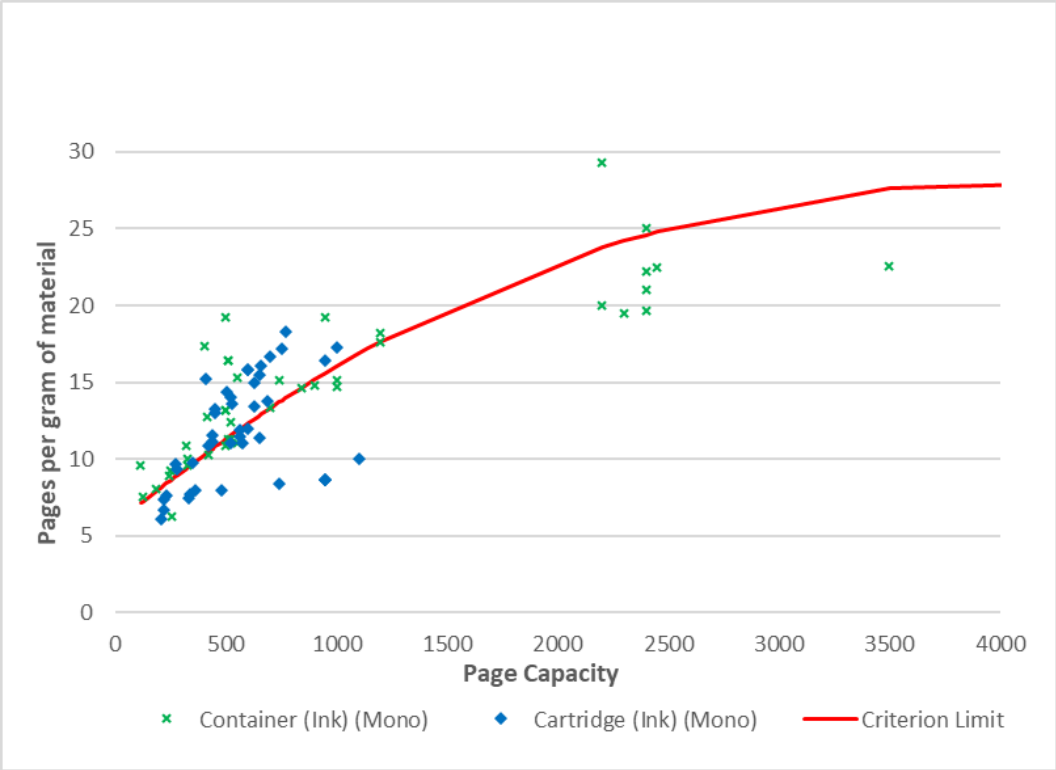

Figure 48: Material efficiency of Black Ink Cartridges and Containers (below 10,000 page yield)

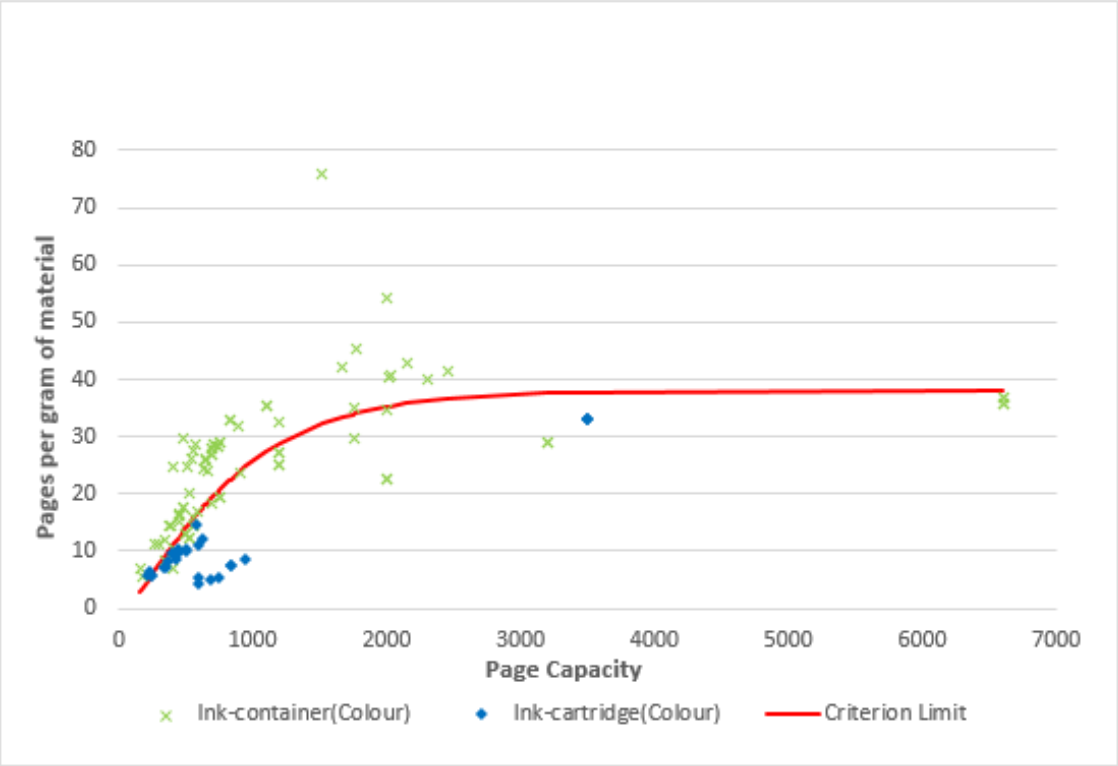

Figure 49: Material efficiency of Colour Ink Cartridges and Containers (below 10,000 page yield)

An overall conclusion is that for containers and cartridges of approximately same page capacity, there are two to four times difference in weight and in some cases even more. This indicates a large resource efficiency potential by setting a maximum weight requirement.

An example of requirement is the proposed EU GPP comprehensive criterion efficiency requirements, where approximately 50% of the toner cartridges and containers in the dataset (571 products) met requirements. Analysis of the inkjet consumables revealed that 54% of the mono and 71% of the colour consumables in the dataset (194 products in total) met the proposed comprehensive criterion efficiency requirements. The consumables in the dataset were assumed to be representative of products on the market. As such, it is assumed that about the 50% of consumables on the market would be compliant with proposed EU GPP comprehensive criterion and could therefore be described as providing average material efficiencies.

Hazardous material

There are often hazardous material concerns associated with consumables stemming from the use of chemicals and additives in toners and inks. Hazardous substances present in cartridges are usually not assessed in Life Cycle Assessments. However, during the operation of the imaging equipment products hazardous substances can be emitted, in the form

of dust, volatile organic chemicals (VOCs), ozone, benzene, particulate matter and semi-volatile organic compounds (SVOCs).

Information about the hazardous material content of cartridges/containers is available in several widely used sources of information and environmental initiatives including:

- Material Safety Data Sheets
- Blue Angel RAL-UZ 205
- Nordic Swan
- Ecma 370

The level of detail provided about hazardous material content of consumables varies across the main initiatives. The material safety data sheets and the Ecma 370 provide the least amount of information about consumable hazardous material content. The Ecma-370 declaration includes criteria relating to:

- cadmium content of photo conductors and inks/toners
- labelling of consumables and provision of Safety Data Sheet (SDS) where consumables are classified as hazardous or where they contain a substance(s) for which there are Community workplace exposure limits

In addition, the Blue Angel RAL-UZ 205 specification requires that no substances which contain mercury, cadmium, lead, nickel or chromium-VI-compounds are to be added to toners and inks. An exemption is included for high molecular weight complex nickel compounds used as colourants. There is also an exemption for production-related heavy metal (e.g. cobalt and nickel oxides and organotin compounds) contamination. Further restrictions are included for azo dyes (dyes or pigments) in toners and inks that can release carcinogenic aromatic amines as listed in Regulation (EC) 1907/2006 (REACH Regulation), Annex XVII, Appendix 8. Biocides which are not covered by an active substance dossier for preservatives for products during storage (product type 6) according to the Biocidal Product Regulation (BPR, Regulation (EU) 528/2012) are also not permitted under the Blue Angel rules. Furthermore, the Blue Angel RAL-UZ 205 specification also prohibits the inclusion of selenium, lead, mercury or cadmium (or any of their compounds) in photoconductor drums.

Consumables remanufacturing and barriers

As shown in Task 3, there are LCAs stating that the ability of a consumable to be remanufactured (i.e. a consumable that has been used, repaired by replacing wear parts and filled with new toner or ink incl. solid ink) can have an important impact on overall environmental impacts. However, there appear to be a range of issues which may limit the ability for

some consumables to be remanufactured. The Commission recently published a study, which investigates the consumable reuse market in detail[212].

The report claims that whilst the consumable market is very competitive, the regulatory environment is not yet well suited to promote the reuse of products or encourage dematerialisation and greater material efficiency. It is also suggested that OEMs have focussed their take-back schemes on recycling material rather than reuse of consumables. The report notes that as the purchasing costs of consumables are significant enough, it has spurred the development of a consumable remanufacturing industry as well as a non-OEM new-built consumable manufacturing industry. The European consumable remanufacturing industry is largely made up of SMEs. Companies manufacturing non-OEM new-built consumables are mostly based in Asia but can also be found in the USA[213].

In investigating the interactions between OEMs and remanufacturers, the report published by the Commission claimed that no evidence of collaboration (such as providing mechanical details or software design of imaging equipment or consumables to the remanufacturers) between OEMs and remanufacturers could be found. The lack of collaboration between OEMs and remanufacturers, suggests that remanufacturers need to reverse-engineer any consumable parts that need to be replaced during the remanufacturing process, this is also confirmed by the stakeholder consultation with remanufacturers[214].

There are a number of major spare parts suppliers that concentrate on providing replacement parts for consumables. Examples of available replacement parts include:

- PCRs
- Wiper blades
- Doctor Blades
- Drums (OPC)
- Mag Rollers / Developer Rollers
- Toner/Ink
- Reset Gears
- Caps/Covers
- Fuses Toner Chips
- Seals
- Replacement electronic chips

[212] European Commission, 2017, Study on the implementation of product design requirements set out in Article 4 of the WEEE Directive The case of re-usability of printer cartridges. Final report
[213] https://www.scc-inc.com/About/Company-History
[214] Stakeholder consultation with ETIRA, EFIM, DKWU, June – August 2018.

There are several different challenges limiting the ability to remanufacture imaging equipment consumables. These can be broken down into technical and non-technical barriers. The technical barriers would limit OEMs' own ability to remanufacture consumables as well if not addressed.

The **technical barriers** include design features such as:

- Sonic welding – which necessitate cutting consumables plastic bodies open to replace worn parts. Some consumables have sonic welds in a zig-zag pattern which makes the cutting process even more difficult.
- Adhesive tapes – some consumables include very adhesive double-sided tapes which also make it difficult to open consumables and replace worn parts
- Glues not screws – some consumables have glued connections rather than screwed connections which again hamper opening of consumables.
- Inclusion on non-reprogrammable electronic chips – most of the electronic chips included in OEM consumables cannot be reset once the imaging equipment has written an end of life message onto the chip. This is often cited as the largest single barrier to consumable remanufacturing by non-OEMs. This means that electronic chips need to be replaced during the remanufacturing process and necessitates replacement of the OEM electronic chip with an after-market electronic chip. Whilst after-market replacement electronic chips are widely available from specialist companies, such as Static Control[215], a significant amount of effort is required to develop these products for each new type of consumable released to market. In order for remanufactured cartridges to work as intended, replacement electronic chips need to be able to provide the same level of functionality as the original OEM electronic chips. This means that replacement chips need to emulate the software communications between the imaging equipment and the chip itself.

The **non-technical barriers** include factors such as:

- Legal restrictions on remanufacturing such as patented remanufacturing processes[216] and patents placed on parts needed to facilitate use after remanufacturing.
- Legal cases where imaging equipment OEMs have taken cartridge remanufacturers to court for copyright and patent infringement [217].
- Imaging equipment firmware updates which stop non-OEM cartridges from being used. Firmware updates sent to imaging equipment after having been placed on

[215] https://www.scc-inc.com/
[216] https://patentimages.storage.googleapis.com/82/e5/84/c022cb4dc55ea9/US20090297208A1.pdf
[217] https://www.therecycler.com/posts/the-canon-legal-train-rolls-on/

the market can result in changes to the encryption process between the imaging equipment and the electronic chip. In some cases, the original OEM chips are able to adapt to these firmware updates and changes to the encryption process, but replacement non-OEM chips cannot adapt. The result is that the replacement chip is no longer able to function correctly which renders the remanufactured cartridge unusable. Some of the examples have been observed from EPSON and HP [218,219,220,221]

- Lack of information sharing by OEMs about how consumables may be remanufactured[222].
- Obligations placed on consumable resellers to only sell original OEM consumables[222].
- Published claims about poor quality issues with remanufactured consumables[223].
- Propagation of inaccurate claims that imaging equipment warranties will be voided by use of non-OEM consumables Published claims that imaging equipment warranties may be impacted by use of non-OEM consumables[224].
- Closed sales systems where OEMs bundle selling of imaging equipment and all consumables to be used through the life of the hardware
- Restricted supply of used consumables due to OEM take-back schemes, however at least one OEM remanufacture the cartridges after take-back schemes[225]

Non-technical barriers related to patents and intellectual property rights are also discussed further in following sections.

<u>The rise of counterfeits from Asia</u>

In the new-built cartridge segment, the rise in sales of the counterfeit OEM consumables known as "clones" from Asia is seen as a high threat. The imports can undercut prime producers through a combination of lower quality units and lower manufacturing standards, particularly in their health and safety aspects. This has a further impact when reuse and

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[218] https://www.therecycler.com/posts/epson-update-blocks-remanufactured-cartridges/
[219] https://www.therecycler.com/posts/epson-faces-class-action-over-firmware/
[220] https://www.therecycler.com/posts/another-hp-firmware-upgrade-impacts-aftermarket/
[221] https://gizmodo.com/one-year-after-bricking-third-party-ink-with-update-hp-1809073739
[222] Stakeholder consultation with remanufacturers and experts, ETIRA, June – August 2018.
[223] https://www.lexmark.com/en_GB/products/ink-toner/genuine-lexmark-cartridges/
https://www.epson.co.uk/consumables/genuine-inks/whybuygenuine
[224] https://www.epson.co.uk/consumables/genuine-inks/whybuygenuine https://infoserve.lexmark.com/ids/ifc/ids_topic.aspx?root=v33076668&topic=v39295550&productCode=Lexmark_XC8155&loc=en_US
https://support.hp.com/us-en/document/c01268315
[225] https://www.lexmark.com/en_us/products/supplies-and-accessories/collection-and-recycling-program.html

remanufacturing is considered, as the cartridges may be unsuitable, contain toxic or restricted hazardous substances and may also fall short in their obligations to be taken back under the WEEE Directive. Toner and ink cartridges with an electronic chip are EEE products and so fall under the scope of WEEE.[226] Producers of EEE in the EU must either register as a producer and if producing over 5 tonnes per year must join a producer compliance scheme (PCS). The PCS takes on the producer's obligations to finance the collection, treatment, recovery and environmentally sound disposal of collected household WEEE. In addition, under WEEE producers must:[227]

- mark products with the crossed out wheeled bin symbol and a date mark
- provide information on reuse and environmentally sound treatment of the products and components (includes materials, dangerous substances and preparations) within one year of putting them on the market
- make sure that distributors are provided with the producer registration number
- keep records for at least 4 years of the amount of EEE put on the market by category
- Producers should aim to improve product design to facilitate recycling and reuse of components and materials.

Enforcement of existing EU legislation including WEEE, RoHS and patent rights on producers of cloned consumables would help to alleviate the negative impacts of these products. For example, enforcing WEEE obligations on producers of cloned cartridges (i.e. consumables with an integrated chip) would ensure that they were not only responsible for providing information on reuse and environmentally sound treatment of the products and components (includes materials, dangerous substances and preparations) within one year but that they would also have to aim to improve product design to facilitate recycling and reuse of components and materials. Enforcement of RoHs restrictions on all cloned consumables would ensure that these product types had a toxicity profile the same as OEM consumables. However, enforcing environmental legislation is complicated by the fact that many cloned consumables, and all counterfeit consumables, infringe intellectual property rights, and so, should not be on the EU market at all.

Consumables and Intellectual Property Rights (IPR)

Within the EU, a patent is defined as a legal title that can be granted for any invention having a technical character provided that it is new, involves an 'inventive step', and is

[226] https://www.gov.uk/government/publications/electrical-and-electronic-equipment-eee-covered-by-the-weee-regulations/electrical-and-electronic-equipment-eee-covered-by-the-weee-regulations

[227] https://www.gov.uk/guidance/electrical-and-electronic-equipment-eee-producer-responsibility

susceptible to industrial application. A patent can cover how things work, what they do, what they are made of and how they are made. Patents gives the owner the right to prevent others from making, using or selling the invention without permission.[228]

The use of patents within the consumables industry is widespread. OEMs ensure that their consumables are covered by patents to ensure that they have the right to stop other organisations from making use of their inventions. Each patent placed on a consumable can contain over a hundred claims, which cover related aspects of the product design.[229] OEM patents, and associated claims, cover a range of consumable related factors including, but not limited to:

- Ink and toner compositions
- Physical and electrical connections between consumables and imaging equipment
- Physical shape of consumable
- Physical shape of refilling container (vessel used to refill existing ink or toner container)
- Physical characteristics of internal components (e.g. wiper blades)
- Methods for authenticating each consumable placed in imaging equipment
- Methods for storing data on consumables
- Methods for determining remaining ink/toner in a consumable
- Methods for refilling ink and toner containers and cartridges

Any organisation wishing to place a remanufactured or compatible/cloned version of an OEM consumable on the EU market needs to ensure that no OEM patents are breached. The wide range of patents and the scope of the patents can therefore cause difficulties for organisations wishing to place a remanufactured or compatible consumable on the market. Organisations need to ensure they are aware of all patents, and associated claims, covering the consumable and secondly ensure that none of these patents are breached during the remanufacturing/manufacturing process. Given the number of patents and their wide scope, ensuring that no patents are breached can be a complex process.

In addition, to identifying patent coverage on any particular consumable, its associated parts and, potentially, the remanufacturing process, there are legal uncertainties associated with identifying when remanufacturing a product or developing a compatible product results in infringement of intellectual property rights, such as patents. The relationship

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[228] https:// ec.europa.eu/growth/industry/intellectual-property/patents_en

[229] http://blakeslee-law.com/pubs/2015-07%20-%20RT%2065%20-%20Not%20so%20patently%20obvious.pdf

between patent infringement and remanufacturing/compatible manufacturing has been the addressed in EU member state court cases. Several examples of court cases involved in discussing the issues surrounding remanufacturing/manufacturer of compatibles were explored in a 2016 paper.[230] A few court cases were discussed in the paper, one of them is about patent infringement by cartridge remanufacturing:

Canon KK v. Badger Office Supplies Ltd [230, 231, 232]

In 2014, Canon launched UK legal proceedings against Badger Office Supplies Limited and two other companies for infringement of their European patent (EP2087407) and stating "*by, inter alia, the importation, manufacture and sale of certain toner cartridges for use in various models of Canon and Hewlett-Packard laser beam printers*". Badger Office Supplies Ltd sold remanufactured toner cartridges, with Canon believing that any remanufacturing of toner cartridges using OEM components infringed their patent. The court case was not finalised and there was an out of court settlement.[232]

The Recycler website published Badgers points of contention with Canon, and publicly asking Canon for clarification on the level of permitted repair to an OEM empty cartridge before patent infringement is reached.[231] In doing so, Badger provided four scenarios, asking which would be considered to be breaching Canon's patent:

1. No replacement of any parts,
2. Replacement of a minor part e.g. magnetic roller or wiper blade,
3. Replacement of toner drum fitted with a new gear/coupling which avoids infringing the patent and
4. Fit OEM gear/coupling from that empty (not another empty) onto a new toner drum and the new combined part then assembled into the empty.

No direct response from Canon could be found but they state on their website that "*Recycling means that toner cartridges are neither refilled nor remanufactured. Toner cartridges that are refilled or remanufactured reuse critical toner cartridge parts that could be damaged or close to the end of their lifespan. They are more likely to malfunction, generate fewer prints, and do not guarantee print quality. By recycling toner cartridges, Canon safeguards toner cartridge quality and protects the environment.*"[233]

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[230] Hartwell et al, 2016, Journal of Remanufacturing (2016) 6:3, "*Management of intellectual property uncertainty in a remanufacturing strategy for automotive energy storage systems" available at https://link.springer.com/content/pdf/10.1186%2Fs13243-016-0025-z.pdf*

[231] https://www.therecycler.com/posts/badger-office-supplies-comments-on-canon-case/

[232] https://www.therecycler.com/posts/badger-office-supplies-settles-with-canon/

[233] https://www.canon.co.uk/for_home/product_finder/multifunctionals/laser/features/environment/cartridge_recycling/recycled.aspx

There appear to be two main IP (Intellectual Property) uncertainties related to remanufacturing. There is a lack of legally recognized definitions for the various activities that are undertaken during remanufacturing. That means that there is legal ambiguity on the exact meaning of activities such as: repair, reconditioning, refurbishment and remanufacturing.[230] This can lead to confusion in the courts about where "remanufacturing" becomes "manufacturing" and therefore breaches IP rights. The second major uncertainty is whether circular activities, such as remanufacturing, regardless of how the "perpetrator" chooses to describe them, are covered by IP rights.[230] The paper discussed the Shültz case and its outcome, which gives an insight to problem with IP rights regarding remanufacturing.

Schütz (UK) limited v Werit (UK) limited[230]

This case is not about imaging equipment or consumables. A manufacturer (Schütz Ltd) of rigid intermediate bulk containers (IBCs) (large plastic containers surrounded by a metal cage) took two companies (Werit Ltd and Delta Ltd) to court for patent infringement. Delta Ltd was reconditioning the plastic containers, after initial use, then placing the reconditioned containers inside an existing metal cage for further resale. Welta Ltd was making new replaceable plastic containers for inclusion in the metal cages. The UK Supreme court ruled that placing new plastic containers in discarded Schütz metal cages, did not constitute the act of 'making' of the IBC covered by the patent. The court noted that:

(a) the bottle
   i. is a freestanding, replaceable component of the patented article,
   ii. has no connection with the claimed inventive concept,
   iii. has a much shorter life expectancy than the other, inventive, component,
   iv. cannot be described as the main component of the article, and
(b) apart from replacing it, Delta does no additional work to the article beyond routine repairs, Delta does not "make" the patented article.

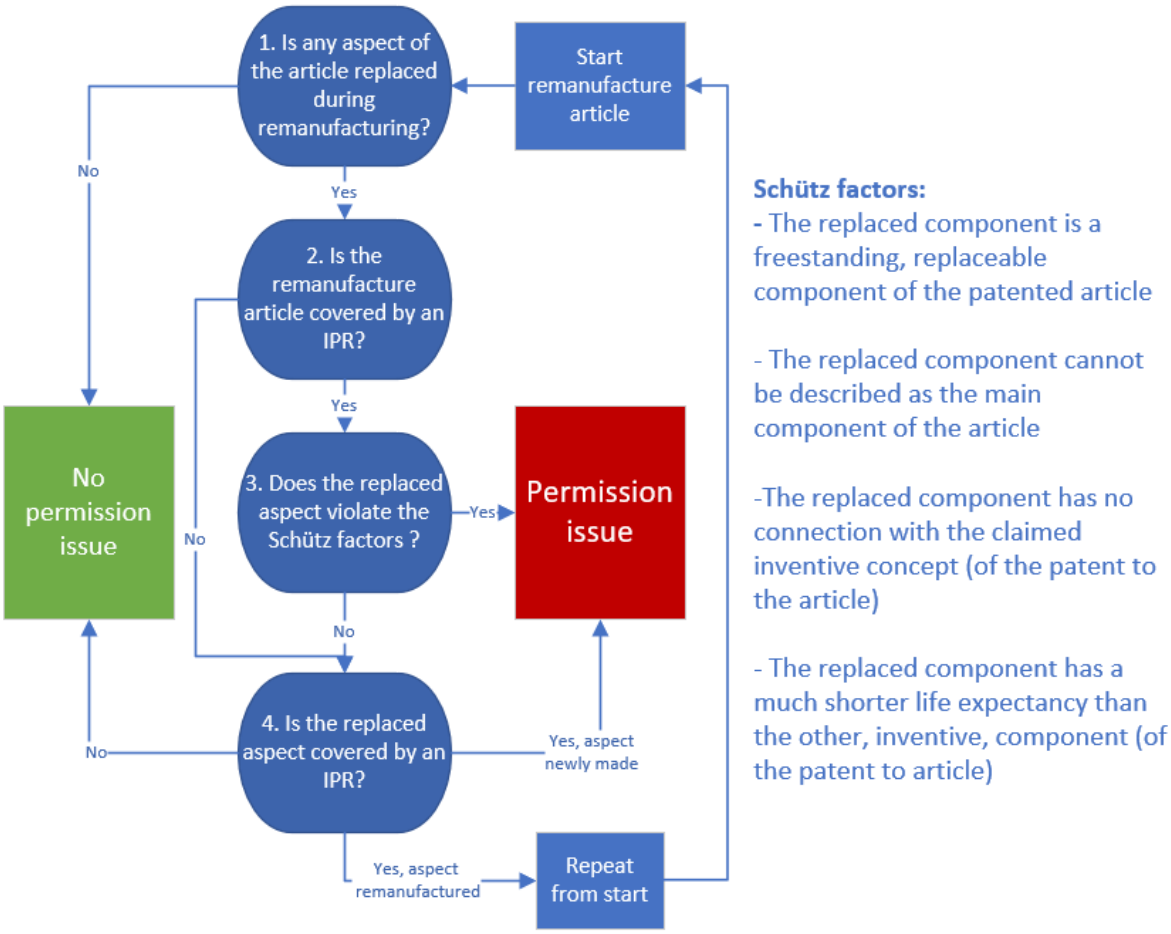

Figure 50 illustrates a proposed framework for managing IP uncertainty in remanufacturing which is based on the court findings within the Shültz case.[230] The figure identifies how, in the case of remanufacturing or manufacturing of clone/compatible toner consumables, IP rights would likely be breached where any replaced components are covered by either an individual patent or covered within the overall product (i.e. consumable) patent.

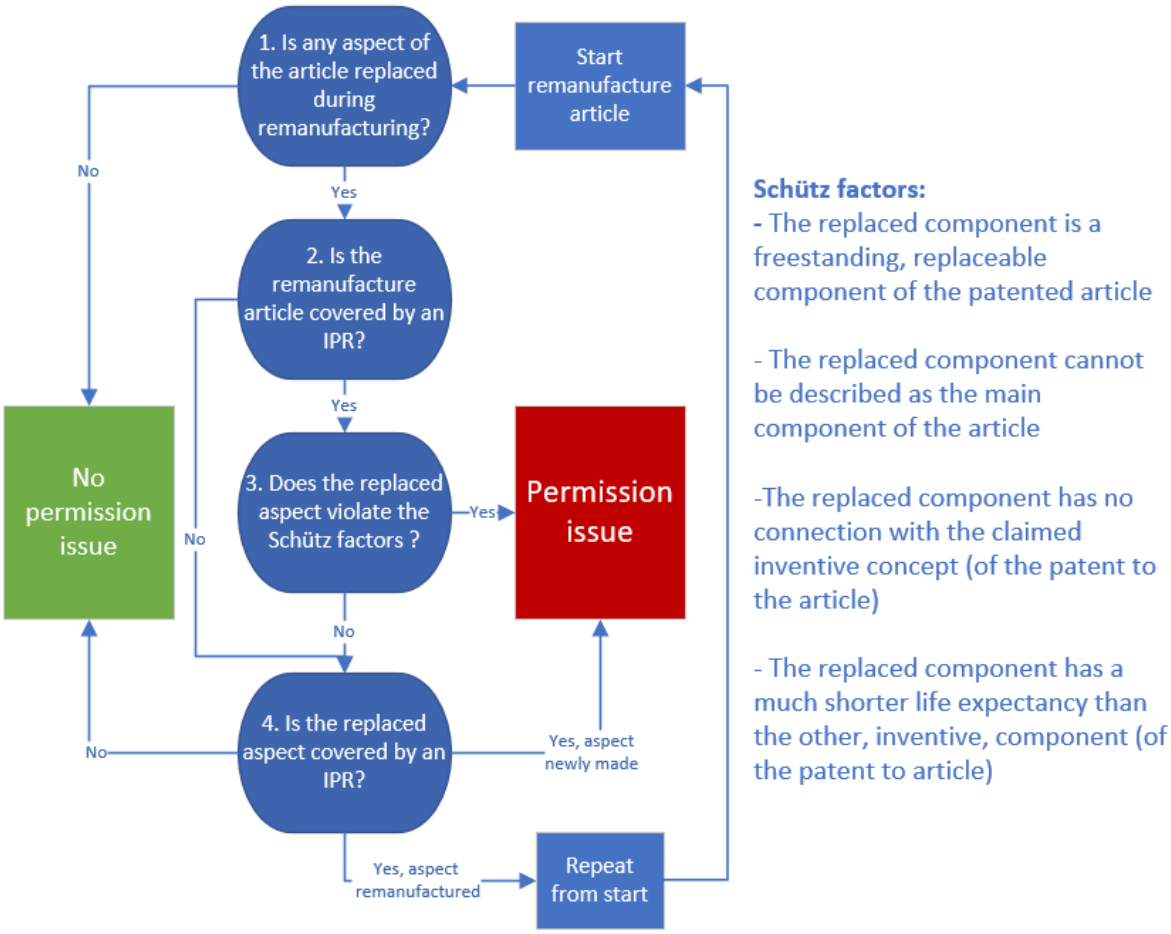

Figure 50: Framework for managing IP uncertainty within remanufacturing (adapted from Hart el al [230])

Upon reviewing the background EU legislation on patents, it is less clear about how toner and ink consumable remanufacturing results in patents being infringed. Article 29 of the Agreement on a Unified Patent Court states the following:

> **Article 29 -Exhaustion of the rights conferred by a European patent[234]**
>
> *The rights conferred by a European patent shall not extend to acts concerning a product covered by that patent after that product has been placed on the market in the European Union by, or with the consent of, the patent proprietor, unless there are legitimate grounds for the patent proprietor to oppose further commercialisation of the product.*

[234] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:42013A0620(01)&from=EN

However, whilst the exhaustion of EU patents does occur after first sale, any remanufacturing is perceived by some EU member state courts to result in the exhaustion of the original patent being cancelled.[235]

The legal situation surrounding the remanufacturing of imaging equipment consumables in the USA appears to be more definitive. In the legal case of Impression Products v. Lexmark International, the US Supreme Court ruled that once a patented item has been sold once, the patent is "exhausted" and can no longer be enforced.[236] The exhaustion of US patents after a product is first sold also extends to instances where the product is first sold outside of the USA.[237] This means that if a toner or ink consumable is sold in the EU any US patent(s) are exhausted on sale.

It can be concluded that IPR has a large impact of consumables remanufacturing industry. It is a great non-technical barrier for remanufacturers in the EU, especially when the patent law is not definitive when the exhaustion of the patent occurs and when or how the patents of consumables are infringed. The US Supreme Court example could provide a good precedent for the EU, however this is one of the non-technical barriers that cannot be easily addressed by the VA under Ecodesign Directive. Nevertheless, given all the hurdles imposed by the IPR, there are still non-OEM and remanufactured consumables on the EU market, so the remanufacturers have been counteracting the impacts of the OEM patents.

4.1.3 Best Available Technology (BAT) at product level

Due to its varied nature, there is no one single best available technology (BAT) found in imaging equipment. Rather there are a series of BATs for each type of imaging equipment and for each associated environmental impact area. This section of the report investigates some of the BATs found in the different types of imaging equipment on the EU market.

Whist ENERGY STAR does not cover all aspects on energy efficiency in imaging equipment, the obvious exception being internal power supply efficiencies, it does cover most of the important area. As such, the ENERGY STAR database is a good source of information for identifying BAT in terms of energy efficiency at the product level. Table 55 shows the single lowest power demands and TEC values found for each type of imaging equipment in the US ENERGY STAR database. It is clear from the table that BAT levels of energy efficiency vary considerably across the different types of products and within the different speed categories.

[235] https://global.canon/en/news/2018/20181116a.html
[236] https://arstechnica.com/tech-policy/2017/05/supreme-court-strikes-down-federal-circuit-again-limits-lexmark-patent-rights/
[237] https://www.osborneclarke.com/insights/us-supreme-court-rules-for-world-wide-patent-exhaustion/

Table 55: Lowest Energy Use and Power Demands for Imaging Equipment Registered in the US ENERGY STAR database

BC#	Imaging Equipment Type	Marking Technol-ogy	Colour For-mat	Monochrome Product Speed (ipm)	BAT Energy/Power		
					TEC (kWh/week)	Sleep Mode (W)	Standby/ Off Mode (W)
BC1	MFD	Electro-photo-graphic (EP)	Mono	20 < s ≤ 40	0.5		
BC2	MFD	Electro-photo-graphic (EP)	Colour	20 < s ≤ 40	0.8		
BC3	Printer	Electro-photo-graphic (EP)	Mono	20 < s ≤ 40	0.6		
BC4	Printer	Electro-photo-graphic (EP)	Colour	20 < s ≤ 40	0.7		
BC5	MFD	Inkjet (IJ)	Colour	s ≤ 20		0.4	0.1
BC6	Printer	Inkjet (IJ)	Colour	s ≤ 20		0.6	0.1

The use of two different energy efficiency approaches in ENERGY STAR (i.e. the TEC and OM approaches) does not always allow for easy comparison of energy efficiency levels across different product types. For example, due to the different measurement methodologies it is not easy to compare laser based MFD (i.e. energy use measured against the TEC test procedure) and inkjet MFD (i.e. power demand measured using the OM approach) levels of energy efficiency. Traditionally laser-based products provided higher levels of functionality, especially in terms on imaging speed, to inkjet products and so direct comparisons between the product types were not required. That is, if users required a high-speed printer they would automatically favour a laser-based product. However, the functionality gap between laser and inkjet-based products continues to close and so direct comparisons between the different types of products are now more valid. Indeed, under ENERGY STAR imaging equipment that offers high performance inkjet technology is measured according to the TEC methodology. Table 56 illustrates how low energy use can be for some of these high-performance inkjet products compared to similar laser-based products.

Table 56: Energy Efficiency of High-Performance Inkjet and Comparative Laser Based Imaging Equipment

Brand Name	Model Name	Type	Marking Technology	Colour Capability	Print Speed (ipm or mppm)	Automatic Duplex Output Capable	Typical Electricity Consumption (TEC) (kWh/wk)
Epson	WF-C20590	MFD	High Performance IJ	Colour	100	Yes	1.2
Brother	HL-S7000DN	Printer	High Performance IJ	Monochrome	100	Yes	1.3
Konica Minolta	Bizhub PRO 1100	MFD	Electrophotographic (EP)	Monochrome	100	Yes	13.5
Xerox	Xerox D95A MFD	MFD	Electrophotographic (EP)	Monochrome	100	Yes	19.8
Konica Minolta	AccurioPress C6100+PF-711 [MFP System]	MFD	Electrophotographic (EP)	Colour	100	Yes	20.0
Konica Minolta	AccurioPress C6100+PF-707m [Printer System]	Printer	Electrophotographic (EP)	Colour	100	Yes	20.0
Xerox	Versant 3100 Press	Printer	Electrophotographic (EP)	Colour	100	Yes	24.5
Xerox	Versant 2100 Press	Printer	Electrophotographic (EP)	Colour	100	Yes	26.1

In terms of environmental design other than related to energy efficiency, a review of the imaging equipment registered with the EPEAT initiative shows some clear best practice examples. Table 57 shows some of the more ambitious environmental design requirements included within EPEAT and the percentage of products in the database that meet those requirements.

Table 57: Availability of Enhanced Environmental Design Features amongst EPEAT Registered Imaging Equipment models

Environmental Design Feature	Compliance %
Reduction of substances on the European Union REACH Candidate List of SVHCs	39%
Production of inventory of intentionally added chemicals residing in the product	39%
Spare parts availability for 5 years or more	49%
Minimum 25% content of postconsumer recycled plastic	4%

4.1.4 Best Available Technology (BAT) at a component level

Information about BAT at the component level in imaging equipment is difficult to identify due to the relative closed box nature of the product group, where it has not been possible to get energy and other environmental data at component level.

4.1.5 Consumables

Design features of cartridges and containers used in imaging are important considerations in identifying BAT levels. The most common design features used to reduce resource use of cartridges and containers include:

- Avoidance of technical features (e.g. non-reprogrammable or non-replaceable chips) which limit the ability to remanufacture cartridges
- Use of common cartridge or container form factors across multiple imaging equipment models
- Use of containers (i.e. simple toner/ink vessels) rather than cartridges (i.e. components which include technical features needed for imaging as well as the toner/ink storage vessel)
- Increase of toner/ink amounts to increase cartridge yield (i.e. number of pages that can be printed)

Consumables which promise high levels of material efficiency can be found on the EU market. Figure 51 illustrates the difference in material content between a Kyocera toner cassette and a conventional toner cartridge. The Kyocera toner cassette is made from five pieces of plastic, rubber and foam, whilst the conventional laser printer cartridge contains 65 components, comprising numerous materials including aluminium and steel. It is important to note that the conventional toner cartridge contains additional components (e.g. drum unit, OPC, waste toner hopper etc) beyond those in the Kyocera toner cassette. In the Kyocera approach these additional components are included in additional consumable

products used within the imaging equipment. Kyocera expressed that these additional components are designed to have a longer useful life than the comparable components in the conventional toner cartridges, and so material impacts are spread out over a longer time frame[238].

Figure 51: Comparison between Kyocera toner cassette and conventional toner cartridge[238]

Other manufacturers also provide simple toner containers for laser imaging equipment rather than complex toner cartridges. Figure 52 shows another example of a simple toner container, from Ricoh, that could promote material savings over conventional toner cartridges.

Figure 52: Simple toner container[238]

The Kyocera and Ricoh toner containers share the fact that they do not include an electronic chip. This means that the toner containers can potentially be reused without needing to reset or replace an electronic chip.

In the inkjet area are some manufacturers offer refillable containers rather than requiring purchasers to continually purchase new container or cartridges.

Epson have developed a product range which includes refillable inkjet containers.[239] These Epson printers are shipped with simple bottles containing ink which are used to refill the

[238] https://www.kyoceradocumentsolutions.eu/index/about/environment/green_technology/ecosys_technology.html
[239] https://epson.com/ecotank-super-tank-printers

ink container installed in the inkjet printer. The manufacturer claims that the ink bottles shipped with the inkjet imaging equipment will provide 2 years' worth of printing (based on 300 pages printed per month).[240]

Canon have also developed a range of inkjet imaging equipment models which include a Continuous Ink Supply System (CISS) utilizing refillable integrated ink tanks.[241] The manufacturer also provides simple bottles filled with ink with the imaging equipment.

These refillable ink tank solutions could help to reduce waste impacts associated with use of conventional inkjet cartridges and containers. However, the material savings associated with these ink tank systems would be significantly smaller than savings from the use of toner container systems.

There are a significant number of consumables on the EU market which meet the hazardous material content restrictions found in the Blue Angel RAL-UZ 205 specification.[242] Consumables which meet these Blue Angel requirements can be considered BAT from a hazardous material point of view.

4.1.6 Best Not Available Technology (BNAT)

The imaging equipment market is relatively mature and there are no known completely new technologies on the immediate horizon that could be described as best not available technology (BNAT). Further improvements in energy efficiency are likely to be achieved through iterative improvements in the energy efficiency of individual components such as power supplies and light sources. Improvements in power management functionality are also likely to result in further energy savings due to reduced impacts on usability of products.

The greatest opportunity for improvements in material efficiency are likely to come from changes to consumables via either enhanced technical design or through changing business practices. This would include a continued move to more simple ink and toner containers rather than complex cartridges. Where a move towards more simplistic ink and toner containers is not possible, efforts should be made to facilitate reprogrammable electronic chips for use in cartridges. Reprogrammable electronic chips would facilitate easier remanufacturing of cartridges at their end of life. Cartridges could also be designed without the use of sonic welds and glues, and instead favour screws and metal clips as in earlier models of

[240] https://epson.com/For-Home/Printers/Inkjet/Epson-Expression-ET-3600-EcoTank-All-in-One-Supertank-Printer/p/C11CF73201
[241] https://www.canon.co.uk/printers/refillable-ink-tank-printers/
[242] https://www.blauer-engel.de/en/products/electric-devices/drucker-und-multifunktionsgeraete

imaging equipment cartridges. This could also facilitate easier remanufacturing of cartridges by any economic operator that secures end of life consumables.

4.2 Production, distribution and end-of-life

This section of the report includes an assessment of some of the production, distribution and end-of-life issues associated with imaging equipment.

4.2.1 Product weight and Bills-of-Materials (BOMs)

The extensive variability of models of imaging equipment on the market means that product weight varies considerably. The box plot in Figure 53 illustrates the wide distribution of imaging equipment weights found in models registered with the EPEAT scheme. The top and bottom bars represent the maximum and minimum weights found in the EPEAT database, with the box illustrating the top and bottom quartiles and the red dot showing the average weight. The maximum weight of printers found in the EPEAT database is 1084 kg and the lightest 1.7 kg with an overall mean of 140 kg. The mean is skewed towards heavily products as the EPEAT scheme is more strongly focussed on non-domestic products.

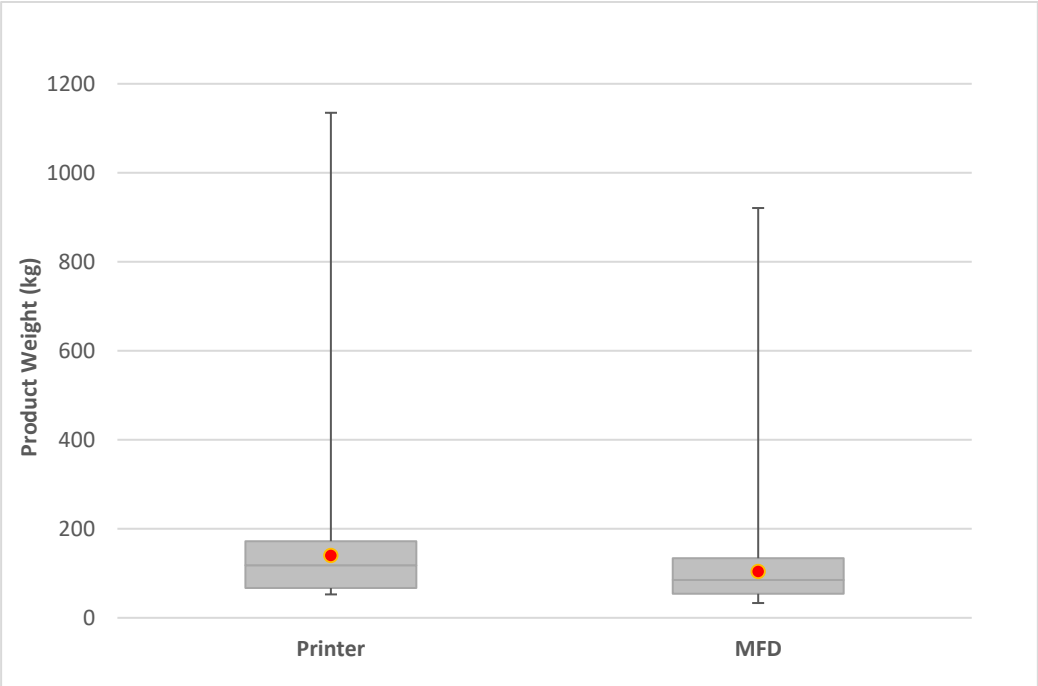

Figure 53: Imaging equipment weight from EPEAT registered imaging equipment weight.

Despite the wide range of imaging equipment weights, similar materials are used in the production of all imaging equipment. To aid more detailed investigations bill of material (BOM) data was requested from external stakeholders. For each base case, data have been received for 2–4 models, therefore for confidentiality reasons the average data are presented in this section, compared with the averaged data provided within the original

Ecodesign Preparatory Study in imaging equipment.[243] It can be observed that some de-materialisation will have occurred over time for some base cases, however due to the differences in models chosen, as it is impossible to choose the exact same models as from preparatory study due to market obsolesce.

4.1.1.3 BC 1: Monochrome Laser MFD, 20 < s ⩽ 40

The original imaging equipment preparatory study included a standard size monochrome laser MFD base case product with an assumed speed of 26 ipm and duplex functionality. The base case was described as including copying, network printing, scanning, and facsimile functionality. Facsimile functionality is less likely to be found in newer MFD on the market due to less use of the technology. The monochrome laser MFD shared all of the same attributes as other comparable laser-based products. The results on the BOM from the preparatory study and the average BOM assumed for the current study can be seen in Table 58. The updated assumptions are based on stakeholder inputs[244].

Table 58: Monochrome Laser MFD, 20 < s ⩽ 40 - Comparison of material input categories by weight

Materials	Current study Average - Monochrome Laser MFD, 20 < s ≤ 40 (g)	Preparatory study Average - Monochrome Laser MFD, 20 < s ≤ 40 (g)
Bulk Plastics	18444	13228
TecPlastics	5645	5406
Ferro	39224	39141
Non-ferro	2871	1834
Coating	0	0
Electronics	4176	2485
Misc.	21878	6048
Total weight	92239	68141

4.1.1.4 BC 2: Colour Laser MFD, 20 < s ⩽ 40

The original imaging equipment preparatory study included a colour laser MFD base case product with an assumed speed of 26 ipm. The BOM data for this product group can be seen in Table 59. The chassis and trays of this product type consist of a metal frame with plastic housing. The original preparatory study noted that the colour MFD was on average

[243] EuP Preparatory Studies "Imaging Equipment" (Lot 4) Final Report on Task 4 "Technical Analysis" Compiled by Fraunhofer IZM and PE Europe
[244] Stakeholder survey, July-December 2018.

30% heavier than equivalent monochrome products due to more complex technology for colour image reproduction. It was further noted that each product had a variety of paper trays and sorters. As laser-based products, the marking technology consisted of in-line multi-colour (cyan, magenta, yellow, black) dry-toner consumables. The laser-based marking technology is supported by a laser beam device, photo conductor drum, toner supply from a cartridge or container, blade and charger roller, clearer blades, transfer rollers, and a high temperature fixing unit consisting of a hot fuser roller and a pressure roller.

The paper transport components included different motors (e.g. stepper motors), belts and rollers of various sizes, sensors and other driving mechanics. The scanner units included cold cathode florescent lamps (CCFL), mirrors, lenses, scan head, glass plate, driving mechanics, and controller boards and digital interfaces. Newer products would more likely use an LED rather than CCFL light source.

The integrated electronic hardware included processor, memory, main boards, and digital interfaces. Each product contained circuit multiple boards. As with most new colour laser MFDs in this speed bracket the original products under investigation included internal, rather than external, power supplies. User interfaces consisted of mechanical (buttons) and optical (colour LCD) panels.

Based on a survey among stakeholders[245] the average weight of colour laser MFDs has decreased considerably. However, the data received from stakeholders varies from approximately 15kg to 130kg. The BOM adopted to the current study is compared to the BOM from the preparatory study in Table 59.

[245] Stakeholder survey, July-December 2018.

Table 59: Colour Laser MFD, 20 < s ⩽ 40 - Comparison of material input categories by weight

Materials	Current study Average - Colour Laser MFD, 20 < s ≤ 40 (g)	Preparatory study Average - Colour Laser MFD, 20 < s ≤ 40 (g)
Bulk Plastics	11493	26262
TecPlastics	10166	17422
Ferro	27653	75416
Non-ferro	2964	7636
Coating	0	0
Electronics	6300	2460
Misc.	9624	14250
Total weight	68200	143446

4.1.1.5 BC 3: Monochrome Laser Printer, 20 < s ⩽ 40

The original imaging equipment preparatory study included a standard size monochrome laser printer base case product with an assumed speed of 26 ipm and duplex capability. As per similar base case products, the chassis and trays consisted of a metal frame with plastic housing. It was noted that the single function laser printer was considerably smaller than the comparable MFD product.

Apart from the size, all other aspects of the marking technology, paper paths, power supply and user interface were the same as other laser-based products studied. It was noted that the mass proportions of the main materials were considerably different across each model. The results on the BOM analysis for the preparatory study and the average BOM assumed for the current study can be seen in Table 60. The updated assumptions are based on stakeholder inputs[246], and it should be noted that the weight is a little lower than presented in the preparatory study, this could be these mono laser printers are becoming highly specialised as the trend is shifting to MFDs.

[246] Stakeholder survey, July-December 2018.

Table 60: Monochrome Laser Printer, 20 < s ⩽ 40 - Comparison of material input categories by weight

Materials	Current study Average - Monochrome Laser Printer, 20 < s ≤ 40 (g)	Preparatory study Average - Monochrome Laser Printer, 20 < s ≤ 40 (g)
Bulk Plastics	4855	4613
TecPlastics	1512	5307
Ferro	4445	7290
Non-ferro	489	807
Coating	449	0
Electronics	1467	823
Misc.	2085	4265
Total weight	15301	23104

4.1.1.6 BC 4: Colour Laser printer, 20 < s ⩽ 40

The original imaging equipment preparatory study included a colour laser printer base case product with an assumed speed of 32 ipm and duplex functionality. It was noted that the component and material composition of the products is basically the same as in the monochrome laser printer base case, with the only exception being support for multiple colour toner cartridges. As with the other products, the chassis and trays consisted of a metal frame with plastic housing. The marking technology was standard monochrome dry-toner electrophotography using the typical components including laser beam device, photo conductor drum, toner cartridge, blade and charger roller, clearer blades, and transfer rollers in a single housing. The other components, with the exception of the scanning unit, were the same as the laser MFD base case example. Based on stakeholder inputs[247] it seems that the average colour laser printer is lighter than in the preparatory study. The BOM assumed for the current study and the BOM from the preparatory study are presented in Table 61.

[247] Stakeholder survey, July-December 2018.

Table 61: Colour Laser printer, 20 < s ⩽ 40- Comparison of material input categories by weight

Materials	Current study Average - Colour Laser printer, 20 < s ≤ 40 (g)	Preparatory study Average - Colour Laser printer, 20 < s ≤ 40 (g)
Bulk Plastics	8439	14998
TecPlastics	3871	2424
Ferro	8045	15901
Non-ferro	772	1619
Coating	0	2
Electronics	3305	1533
Misc.	4316	6625
Total weight	28747	43103

4.1.1.7 BC 5 and BC 6: Colour Inkjet MFD, s ⩽ 20 and Colour Inkjet Printer, s ⩽ 20

The two base cases ("Colour Inkjet MFD, s ⩽ 20" and "Colour Inkjet Printer, s ⩽ 20") have been combined for the BOM analysis due to their similar physical characteristics. The inkjet MFDs would likely contain more material on average due to the extra scanning functionalities included in these product types. The overall difference would likely be minimal though given that these products are primarily small domestic products. The original imaging equipment preparatory study included BOM data, shown in Table 62, for four different Complete Bill of Materials (BOM) were provided by four different brand name manufacturers.

The original preparatory study team noted that the four products, for which BOM data was secured, had some functional differences. It was claimed that these differences related to the print head technology (i.e. mechanical, using piezoelectric system and thermal inkjet technologies), consumable configuration (i.e. single colour cartridge and multi-colour cartridges). The paper transport components, within each product, included motors (e.g. stepper motors) and other mechanics. All four products had integrated flatbed scanner incorporating CCD (Charge Coupled Device) or CIS (Contact Image Sensor) as sensors and with CCFL (Cold Cathode Fluorescent Lamp) and/or LED (Light Emitting Diode) arrays as light sources. Newer products would be unlikely to have CCFL based light sources as they have largely been replaced with LED light sources. Each product also had populated electronic boards (e.g. memory, driver circuitry, digital interfaces). The user interfaces were either

mechanical (buttons) or optical (small colour LCD) components. Each product had an internal power supply. New small inkjet-based products would more likely utilise an external rather than an internal power supply. As with new products, steel and plastics were used for the framing and housing of the products included in the original preparatory study. In the current study the BOMs are divided in printers and MFDs. The inkjet printer is lighter than the MFD, but in general the inkjet imaging equipment is considerable lighter that other types of imaging equipment. The BOM assumed for the current study is based on stakeholder inputs[248]. The current BOM and the BOM from the preparatory study are presented in Table 62.

Table 62: Colour Inkjet MFD, s ⩽ 20 - Comparison of material input categories by weight

Materials	Current study Average - Colour Inkjet MFD, s ≤ 20 (g)	Current study Average - Colour Inkjet Printer, s ≤ 20 (g)	Preparatory study Average - Colour Inkjet MFD/printer, s ≤ 20 (g)
Bulk Plastics	3742	2242	4453
TecPlastics	474	577	489
Ferro	1271	797	1929
Non-ferro	135	259	293
Coating	0	0	0.2
Electronics	566	173	478
Misc.	1081	361	1712
Total weight	7269	4408	9355

4.1.1.8 BC 7: Professional printer and MFD

The original imaging equipment preparatory study did not include a base case for professional imaging equipment. The current BOM is based on stakeholder inputs[249] and supplemented with data obtained via desk research[250], and it reveals the professional equipment is considerable heavier than other types of imaging equipment. The results are shown in Table 63.

[248] Stakeholder survey, July-December 2018.
[249] Stakeholder survey, July-December 2018.
[250] http://www.ecoleaf-jemai.jp/eng/label.html

Table 63: Professional printer and MFD - material input categories by weight

Materials	Current study Average - Professional Imaging Equipment (g)
Bulk Plastics	26205
TecPlastics	10280
Ferro	94116
Non-ferro	9870
Coating	0
Electronics	2855
Misc.	5279
Total weight	148605

4.1.1.9 Consumables bills-of-materials (BOM)

In order to assess the impacts of the consumables, the BOM of the four main types of consumables used by the base cases are collected. Stakeholders have provided inputs for BOM[251] and the inputs have been averaged and shown in Table 64 to Table 67 below.

4.1.1.9.1 Toner cartridge

7 sets of data have been received from 5 different stakeholders on toner cartridges, the total weight of full toner cartridges vary between 600g up to 1700 g. The BOM presented below are the averages of the 7 data sets and therefore a fictive cartridge in order to account the variation in sizes.

[251] Stakeholder consultation via questionnaire, January – February 2019.

Table 64: Toner cartridge - material input categories by weight

Materials	Current study Average – Toner cartridge (g)
Bulk Plastics	339
TecPlastics	86
Ferro	179
Non-ferro	58
Coating	10
Electronics	3
Toner material	166
Misc.	132
Total weight	973

4.1.1.9.2 Toner container

4 sets of data have been received from 4 different stakeholders and supplemented by study team's online research. The total weight of full toner containers varies from 300 g to 1300 g, the average material composition of a toner container is presented below. On average, the material weight of toner containers is lower than cartridges.

Table 65: Toner container - material input categories by weight

Materials	Current study Average – Toner container (g)
Bulk Plastics	264
TecPlastics	150
Ferro	181
Non-ferro	19
Coating	0
Electronics	1
Toner material	130
Misc.	53
Total weight	799

4.1.1.9.3 Ink cartridge

4 sets of data have been collected for ink cartridges, 3 sets of data provided empty cartridge BOM, the total weight of full ink cartridge varies between 140 g to 220 g. Ink cartridges are significantly smaller than toner cartridges and container.

Table 66: Ink cartridge - material input categories by weight

Materials	Current study Average – Ink cartridge (g)
Bulk Plastics	45
TecPlastics	1
Ferro	0.6
Non-ferro	0
Coating	0.1
Electronics	0.2
Ink material	120
Misc.	8
Total weight	174

4.1.1.9.4 Ink container

Data on ink containers were scarce, only one set of data received from a stakeholder, and supplemented by study team's online research. The average of the two data sets have been presented below. It is clear that ink containers do not contain electronics and consist of much less materials but the amount of ink it contains is also rather low.

Table 67: Ink container - material input categories by weight

Materials	Current study Average – Ink container (g)
Bulk Plastics	33
TecPlastics	1
Ferro	1
Non-ferro	0
Coating	0
Electronics	0
Ink material	20
Misc.	9
Total weight	64

4.2.2 End-of-life

The End-of-Life routes for imaging equipment products and consumables are similar to those of other electronic products in the EU (as presented in Task 3). These are:

- Landfilling
- Incineration, with and without energy recovery
- Recycling of materials
- Remanufacturing/Refurbishing
- Reuse/Refilling

Moreover, before their End-of-Life, products are collected and sorted. According to the WEEE Directive[252] and the Waste Framework Directive[253], collection includes preliminary storage and preliminary sorting of waste (the latter being referred as 'primary sorting').

Figure 54 shows that, according to both Directives, recovery operations include incineration with energy recovery[254], recycling of materials and preparing for reuse[255]. Remanufacturing/refurbishing and reuse/refilling are not recovery operations but they depend on preparing for reuse and are part of another product system. Disposal activities are landfilling and incineration without energy recovery[256].

[252] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012L0019&from=EN
[253] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008L0098&from=EN
[254] 60% and 65% minimum efficiency for installations permitted before and after 2009 respectively
[255] 'preparing for re-use' means checking, cleaning or repairing recovery operations, by which products or components of products that have become waste are prepared so that they can be re-used without any other pre-processing;
[256] Or with a lower efficiency than 60% or 65% as described previously

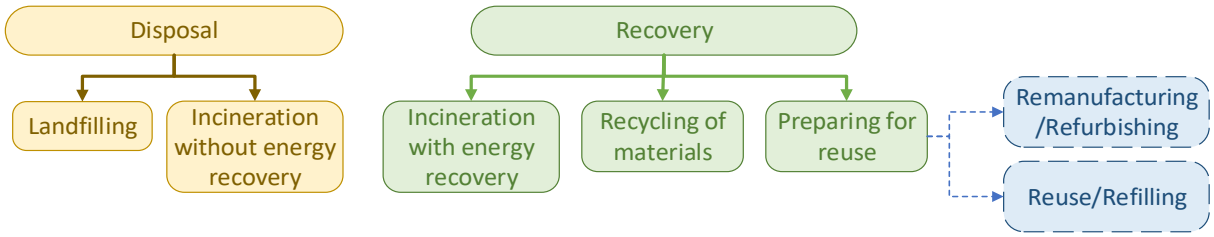

Figure 54. Applicability of Waste Framework Directive definitions to IE products and consumables.

According to Article 4 of the Waste Directive, preparing for reuse is the second most preferred end-of-life route after prevention (see Figure 55). In this hierarchy, recovery comes one before last preferred route, however, it is important to note that in the Directive this route is referred to as 'other recovery' and not as 'recovery'. This may imply why it is second to last since it refers mainly to incineration with energy recovery.

Figure 55. Waste management hierarchy[257]

In the following sections, the recyclability for imaging equipment and ink and toner consumables is assessed and the recycling rates are presented. These recycling rates are used in the EcoReport tool and are important factors for the overall environmental analysis.

4.1.1.10 Recyclability of imaging equipment and ink and toner consumables

After collection from end-users or waste handling stations, imaging equipment and consumables are treated at suited facilities depending on the desired destination. The waste handling is assumed to be very different for equipment and consumable cartridges and different obstacles can occur.

4.1.1.11 Imaging equipment

For imaging equipment, there are several inherent problems that can have a negative impact at the recycling at end of life. Firstly, many of the plastics types used in imaging equipment contain Brominated Flame Retardants (BFRs), which need to be removed from any separately collected WEEE and disposed of or recovered separately. Secondly, waste

[257] http://ec.europa.eu/environment/waste/framework/

plastics containing BFRs may not be suitable for reuse in new products and can be difficult to recycle properly. Other issues include difficulty in ensuring materials can be collected within separate streams in such a manner that they are suitable for reuse or even recycling. Not all types of plastics can be recycled together, and if they are recycled together the resulting plastic quality would be poorer, and not feasible for wide-range of use.

Besides collection targets shown in Task 3, the WEEE Directive also sets recycling and recovery targets for all types of electrical goods, which EU member states are obligated to achieve. Currently, as from 15 August 2018, the WEEE Directive[258] requires that for IT and telecommunications equipment:

- 75% shall be recovered and 55% shall be prepared for re-use and recycled, if it is small IT and telecommunication equipment (i.e. does not have any external dimension more than 50 cm)
- 85% is recovered and 80% shall be prepared for re-use and recycled, it is large equipment (i.e. with any external dimension more than 50 cm)

In addition, the Directive also requires that certain substances, mixtures and components must be removed from any collected WEEE for selective treatment. The following substances, mixtures and components can be relevant for imaging equipment:

- polychlorinated biphenyls containing capacitors
- mercury containing components, such as switches or backlighting lamps
- batteries
- printed circuit boards of electronic devices if the surface of the printed circuit board is greater than 10 square centimetres
- toner cartridges, liquid and paste, as well as colour toner
- plastic containing brominated flame retardants
- gas discharge lamps
- liquid crystal displays (together with their casing where appropriate) of a surface greater than 100 square centimetres and all those back-lighted with gas discharge lamps
- external electric cables
- electrolyte capacitors containing substances of concern (height >25 mm, diameter >25 mm or proportionately similar volume)

However, the actual end-of-life practices for imaging equipment and WEEE, vary both across the EU and within individual member states. Within the WEEE recycling industry,

[258]Annex V of WEEE Directive: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02012L0019-20180704&from=EN

recyclers use a variety of common methods for recycling waste imaging equipment including:

- Fully manual segregation: involves the segregation of imaging equipment from other WEEE streams followed by manual dismantling.
- Fully manual segregation with re-use: process the same as above but with the reuse of certain components
- Semi-automated with commercial shredding: involves the mechanical shredding of WEEE to aid with the recovery of ferrous and non-ferrous metals. Manual picking operations undertaken to recover PCBs and other components.
- Semi-automated with commercial smashing: involves the manual removal of WEEE requiring manual recovery. Remaining WEEE is then spun and smashed into smaller components with magnetic separation and final manual picking lines.

The cost increases with the amount of manual labour, so it is often considered that shredding is the preferred option for separation of materials. However, the valuable material in some professional equipment may make it economically attractive to manual dismantle products with the purpose of reuse of certain components. In some circumstances manufacturers also undertake a significant amount of remanufacturing of used equipment.[259] This is especially true for larger business machines which retain greater value at end of life compared to domestic products.

Some professional products and all household equipment are considered to be shredded as it is a cost-effective segregation process of materials. The shredding process is briefly described in Figure 56.

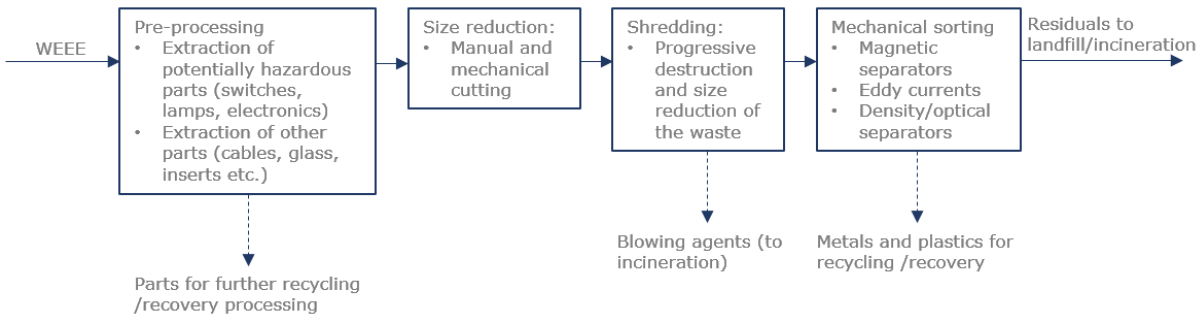

Figure 56: Expected reprocessing of household equipment and some professional equipment at End-of-Life

The pre-processing is the first step in the recycling process of imaging equipment which are shredded. This first step often consists of manual removing of targeted components and/or materials for further treatment. The pre-processing is very important in connection

[259] https://www.xerox.com/corporate-citizenship/2016/sustainability/sustainable-products.html

with an effective recycling process by reducing the risk of contamination, quickly recover selected valuable materials for further reprocessing and allow compliances with current directive on hazardous substances[260] and waste[261] and prevent damage to the facility in the following steps.

Next is a series of shredders, which reduces the imaging equipment in smaller pieces, so the different materials can be sorted. The dust is removed and captured by cyclones. When the equipment is shredded into smaller pieces (approximately 1 cm to 10 cm) different technologies handles the sorting. These technologies are often[262]:

- Magnetic separation removing ferrous metals
- Eddy current separators removing non-ferrous metals such as copper, aluminium, and zinc
- Density separators: Different types of plastic.

Imaging equipment are assumed to follow the same End-of-Life treatment as most WEEE. This means that the majority of the imaging equipment is shredded and only a small part of the imaging equipment is reused. However, most of the metals and half of the electronics are recycled. The default values from EcoReport tool[263] for the End-of-Life treatment for imaging equipment (the share of recovered, recycled, and reused materials) in this study have been modified according to newer information[264] and stakeholder inputs[265]. The values have been averaged and presented in Table 68, these values are used in the current study for modelling.

[260] http://ec.europa.eu/environment/waste/rohs_eee/index_en.htm
[261] http://ec.europa.eu/environment/waste/weee/index_en.htm
[262] http://www.sciencedirect.com/science/article/pii/B9780128033630000031
[263] http://ec.europa.eu/growth/industry/sustainability/ecodesign_da
264 Plastic Europe, Available at: http://www.plasticseurope.org/documents/document/20161014113313-plastics_the_facts_2016_final_version.pdf
[265] Stakeholder consultation via questionnaire, January – February 2019.

Table 68: Estimated recycling rates for imaging equipment adopted in the current study

	Bulk Plastics TecPlastics	Ferro Non-ferro Coating	Elec-tronics	Misc.
EoL mass fraction to re-use, in %	2	2	2	2
EoL mass fraction to (materials) recycling, in %	64	84	64	64
EoL mass fraction to (heat) recovery, in %	20	0	20	11
EoL mass fraction to non-recov. incineration, in %	9	9	9	5
EoL mass fraction to landfill/missing/fugitive, in %	5	5	5	19
Total	100	100	100	100

The share of imaging equipment to be remanufactured or reused could potentially be improved, as it is very low at 1-2 %. However, it can be very difficult to determine how much it could technically increase, as products not are handled by the manufacturers at End-of-Life. For ferro or non-ferro metals, the recycling rates are high, up to 95%. In Table 69 a possible BAT scenario with increased reuse and less landfilling is presented. These values are based on information available online from manufacturers[266] and information on the content on recyclable materials in office equipment from a waste recycler[267], and supplemented by stakeholder inputs[265]. The BAT reuse and recycling rates for miscellaneous materials is estimated slightly on the high end in order to simplify the model, however it is assumed that with the focus on reuse and recycling, the design of products would become simpler and with fewer components and therefore reduce the amount of miscellaneous materials that cannot be reused or recycled.

[266] https://www.kyoceradocumentsolutions.be/en/index/environment/recycle_and_reuse.html
[267] https://www.envirowaste.co.uk/commercial/weee-recycling-and-it-disposal/weee-guide/weee-recycling-potential-success/

Table 69: Recycling rates for imaging equipment - BAT

	Bulk Plastics TecPlastics	Ferro Non-ferro Coating	Electronics	Misc.
EoL mass fraction to re-use, in %	17	17	17	17
EoL mass fraction to (materials) recycling, in %	83	83	83	53
EoL mass fraction to (heat) recovery, in %	0	0	0	30
EoL mass fraction to non-recov. incineration, in %	0	0	0	0
EoL mass fraction to landfill/missing/fugitive, in %	0	0	0	0
Total	100	100	100	100

4.1.1.12 Ink and toner consumables

Some of the ink and toner consumables are handled as regular WEEE and will follow the same processes as described above for imaging equipment. Mostly the cartridges with electronics chips are considered as WEEE as from August 2018. Containers are still outside the scope of WEEE.

Contrasting to the imaging equipment, however, it is estimated that a larger amount of cartridge recycling and reuse already takes place. The European association ETIRA estimates that between 20 to 30% of all cartridges sold worldwide are remanufactured[268]. Based on stakeholder inputs, the following information has been obtained:

- Concerning collection and primary sorting, approximately 10-15% are collected and processed under OEM material recycling programmes.
- Concerning reuse and recycling for consumables collected:
  - 15-20% of all cartridges in the EU are reused as a cartridge after first use, this includes OEM and non-OEMs[269]
  - In the UK and Germany alone, as best practices in the EU, ca. 30% of all printer cartridges are being recycled or reused (68% - 70% collection rates and 39% - 46% reuse/recycling rates)[270]
  - In Austria and Switzerland, approximately 50 % are being recycled or reused out of those collected, but collection rate is max 65% or lower.

[268] EITRA, Key facts about the cartridge remanufacturing market, available from http://www.etira.org/cartridge-remanufacturing/key-facts/
[269] ETIRA, stakeholder consultation, July-August 2018.
[270] EVAP, reply to questionnaire 25-07-2018.

- In Eastern Europe, the reuse and recycling rate is below 10% of all cartridges placed on the market
- For most OEMs, 0% up to 3% of the cartridges are reused, while 75% of the materials are recycled into new products, see Table 71
- Lexmark estimates that 24% of existing toner cartridges contain post-consumer recycled plastic[271][271]

- The remaining ink and toner consumables not collected, plus all the non-original newbuilt cartridges from outside EU, have no environment-friendly end-of-life solution at all, these follow the fate of normal waste, resulting in that 60-70% of all cartridges ends on landfills or incinerated after a single use[272]
- As a whole industry, 30,000 - 50,000 tonnes of printer cartridges landfilled and incinerated in 2015[273], based on the infotrend estimation

These numbers suggest that there is a potential for further reuse and recycling of ink and toner consumables. The remanufacturing process is undertaken by a range of organisations from small companies to the major imaging equipment manufacturers themselves, such as Lexmark, nevertheless there should be more focus on the remanufacturing market.

Ink and toner consumables in some circumstances follow the same end-of-life routes as imaging equipment, as some countries already consider cartridges as WEEE even before the scope extension in WEEE Directive. This means that they would receive the same treatments and obtain the same recovery rates as presented for imaging equipment in Table 68. However, cartridges are currently also remanufactured by OEMs and the remanufacturing industry. This means that the rate of reuse is higher. The information from stakeholders[265] show rather divergent views on the reuse and recycling rates for different materials, see Table 70 for the best estimates based on all the information provided.

[271] The importance of Remanufacturing in the Circular Economy – A success story. Lexmark. Presentation in June 2018.
[272] As of 2015, approximately 6300 Mt of plastic waste had been generated, around 9% of which had been recycled, 12% was incinerated, and 79% was accumulated in landfills or the natural environment. Production, use, and fate of all plastics ever made. Roland Geyer, Jenna R. Jambeck and Kara Lavender Law. Accessed via http://advances.sciencemag.org/content/3/7/e1700782.full
[273]http://www.lexmark.com/en_gb/about/news-releases/lexmark-applauds-european-commission-plans-and-outlines-measures.html

Table 70: Recycling rates for cartridges adopted in the current study

	Bulk Plastics TecPlastics	Ferro Non-ferro Coating	Electronics	Misc.
EoL mass fraction to re-use, in %	15	15	15	1
EoL mass fraction to (materials) recycling, in %	32	32	32	64
EoL mass fraction to (heat) recovery, in %	35	35	35	1
EoL mass fraction to non-recov. incineration, in %	0	0	0	5
EoL mass fraction to landfill/missing/fugitive, in %	18	18	18	29
TOTAL	100	100	100	100

Based on the presented stakeholder inputs previously in this subsection, it seems that the recovery rate of cartridges can be improved as the combined reuse and recycling rate is ca. 50% in Germany, Austria and Switzerland. In addition, the EPEAT initiative includes requirements on reporting of end-of-life options used within consumable take back programs.[274] Manufacturers registering imaging equipment models with the EPEAT initiative publish total tonnage and percentages of material that are sent to each of the listed end-of-life options. A review of the consumable take-back programme requirements included in the EPEAT initiative provides further insights into current practices amongst some of the larger imaging equipment manufacturers. Table 71 provides an overview of the end-of-life options employed in the consumables take back programmes of some major imaging equipment manufacturers. The results are mostly indicative of activities within US based recycling programmes, verification via some company reports in the EU show similar figures.

[274] https://greenelectronicscouncil.org/epeat-criteria/

Table 71: Use of End-of-Life Options in Consumable Take Back Programmes

Manufacturer		End of life management					
		Reuse of components	Material re-cycling	Waste-to-En-ergy	Material in storage pending pro-cessing	Incineration (non-recov-ery)	Landfill
Canon		2.3%	86.7%	10.3%	0.7%	0.0%	0.0%
Epson		0.0%	0.0%	100.0%	0.0%	0.0%	0.0%
Konica Minolta		0.0%	87.6%	12.4%	0.0%	0.0%	0.0%
Kyocera		0.0%	52.7%	22.8%	24.6%	0.0%	0.0%
HP	Ink	0.0%	73.9%	23.7%	0.5%	1.8%	0.0%
	Toner	2.9%	83.9%	13.2%	0.0%	0.0%	0.0%
Lexmark		27.6%	69.0%	3.4%	0.0%	0.0%	0.0%
Sharp		-	52.0%	17.1%	-	0.0%	0.0%
Toshiba		0.0%	43.4%	11.9%	44.7%	0.0%	-
Ricoh		0.0%	65.0%	0.4%	34.6%	0.0%	0.0%
Xerox		45.0%	20.0%	10.0%	25.0%	0.0%	0.0%

Based on the EPEAT initiative and inputs from stakeholders[265], a possible BAT scenario is estimated and presented in Table 72. These recovery rates can be supported by the findings of the report[212] published by the Commission, which also stated that the reusable fraction of these cartridge is quite high at 75 – 80%. Note that in the BAT scenario, the reuse and recycling rates are increased significantly and that no materials are incinerated or landfilled as some manufactures already have zero landfill and incineration policy[275].

[275] https://kmbs.konicaminolta.us/kmbs/about/environment

Table 72: Recycling rates for cartridges - BAT

	Bulk Plastics TecPlastics	Ferro Non-ferro Coating	Electronics	Misc.
EoL mass fraction to re-use, in %	60	60	60	60
EoL mass fraction to (materials) recycling, in %	40	40	40	40
EoL mass fraction to (heat) recovery, in %	0	0	0	0
EoL mass fraction to non-recov. incineration, in %	0	0	0	0
EoL mass fraction to landfill/missing/fugitive, in %	0	0	0	0
Total	100	100	100	100

Regarding containers there may be a reduced economic incentive to reuse these types of consumables, and they are normally not defined as WEEE according to the definition of electrical and electronic equipment (EEE) and thus nor as WEEE[276]. However, some manufacturer offers a take-back solution for containers as well as for cartridges.

4.3 Conclusions and recommendations

This section summarises the information presented in Task 4 in terms of both average and BAT at product level and at component level. It also discusses if the scope should be refined and sums up the barriers and opportunities for Ecodesign policy measures from a technical perspective.

4.3.1 Average and BAT at product level

Having reviewed the environmental performances of imaging equipment on the EU market, there appear to be significant improvement opportunities available at both the product and consumable level.

Table 73 presents the energy efficiency improvement potential in ENERGY STAR registered TEC based and OM based imaging equipment for each base case. It is calculated using the full dataset with all ENERGY STAR registered products. For each product with its TEC value, a BAT TEC value is found for the same speed (e.g. 30 ipm) and the percentage reduction if reducing the energy consumption from the product's TEC to BAT TEC is calculated. Then all the individual percentage reductions are averaged over the base case, which is the resulting estimated energy efficiency potential for the base case.

[276] 'electrical and electronic equipment' or 'EEE' means equipment which is dependent on electric currents or electromagnetic fields in order to work properly and equipment for the generation, transfer and measurement of such currents and fields and designed for use with a voltage rating not exceeding 1 000 volts for alternating current and 1 500 volts for direct current

The BAT TEC is for actual products on the market using currently available technology and does not assumed any additional efficiency improvements.

For OM products the two base cases are both 20 ipm or below and sleep and standby/off levels for this speed range are independent on the speed and therefore the average can be compared with the BAT for the full speed range.

The results show that for the base case current market technology can reduce electricity consumption for TEC by approximately 14%-26%. Further savings may be achievable by considering other aspects which are not addressed by the ENERGY STAR test procedure, such as internal power supply efficiency.

Table 73: Average and BAT Energy and Power Levels. See body text for description of calculation method. Total number of products in dataset is 659.

BC#	Imaging Equipment Type	Marking Technology	Colour Format	Monochrome Product Speed (ipm)	TEC (kWh/ week) or OM power (W)		
					Average	BAT	Reduction
BC1	MFD	Electro-photographic (EP)	Mono	20 < s ≤ 40	1.5	0.5	25%
BC2	MFD	Electro-photographic (EP)	Colour	20 < s ≤ 40	1.8	0.8	26%
BC3	Printer	Electro-photographic (EP)	Mono	20 < s ≤ 40	1.4	0.6	14%
BC4	Printer	Electro-photographic (EP)	Colour	20 < s ≤ 40	2.1	0.7	30%
BC5	MFD	Inkjet (IJ)	Colour	s ≤ 20	Sleep: 1.1 W	0.4 W	64%
					Standby/off: 0.1	0.1 W	0%
BC6	Printer	Inkjet (IJ)	Colour	s ≤ 20	Sleep: 1.0:	0.6 W	40%
					Standby/off: 0.2	0.1 W	50%

BAT on non-energy in use impact areas can be seen in some of the products registered within the EPEAT initiative. These include:

- Products with up to 54% of their plastics content being postconsumer recycled plastic.
- Products that do not need to utilise cadmium exemptions under the EU RoHS Directive.
- Products that do not contain substances included in the Candidate List of Substances of Very High Concern (SVHC) and REACH Annex XIV (List of Substances Subject to Authorization) above 0.1%.

There are other environmental design features seen in BAT products e.g. those which are registered at EPEAT and Blue Angel. Alone EPEAT contains currently about 5100 copiers, printers and MFDs registered.

4.3.2 Average and BAT at component level

Many consumables designed for use with imaging equipment placed on the EU market are complex devices which utilize significant amount of materials. Simplification of design (i.e. shifting to containers rather than cartridges), remanufacturing and enhanced reuse of materials could all assist in reducing material usage in consumables. Alternative approaches to complex consumables are readily available in the market place and do not seem to impact quality or functionality of the imaging equipment. For example, the Kyocera Ecofys toner consumable system is designed to minimise material use and ensure easier remanufacturing or recycling of consumables at their end of life. Other manufacturers, such as Epson, have developed refillable ink container systems which may result in significantly less plastics being used over the life of an inkjet printer.

4.3.3 Barriers and opportunities for Ecodesign from a technical perspective

Based on the above analysis there appear to be many opportunities to encourage increased environmental savings from imaging equipment and their associated consumables. Further reductions in environmental impacts for imaging equipment products could be achieved through:

- Energy efficiency - The ENERGY STAR v2.0 specifications are mature as witnessed by high penetration rates amongst products on the market. The revised ENERGY STAR v3.0 specification will reflect approximately the most 25% most efficient products on the market. Using the ENERGY STAR v3.0 specification within any future VA or Ecodesign initiatives on imaging equipment could encourage further energy savings. Additional energy savings could be achieved by addressing inefficiencies in

internal power supplies. The internal power supplies of most other information technology have been covered in Ecodesign initiatives and this has resulted in significant energy savings.

- Enhanced wider environmental product design - The current VA includes a truncated set of environmental product design criteria. Analysis of other initiatives, such as EPEAT, shows that there are significant numbers of products on the market, which exhibit better environmental design characteristics than required under the current VA initiative (about 5100 copiers, printers and MFDs are currently registered under EPEAT)

There appear to be significant resource savings available through the reduction of material usage associated with imaging equipment consumables. Further reductions in environmental impacts for imaging equipment consumables could be achieved through development of criteria in the following areas:

- Supporting remanufacturing of consumables by:
    - Requiring, or encouraging, the use of reprogrammable electronic chips in cartridges
    - Requiring that any firmware updates sent to imaging equipment after they are placed on the market do not impact the use of remanufactured consumables. This requirement could be met by allowing users to roll back and report any problematic firmware, however, without rolling back security updates
    - Requirements for, or encouraging the use of, fixings (e.g. screws or clips) that allow access into the consumables for the purposes of replacing worn parts without the need to cut casings.
    - Disclosure of patents on any consumables which may restrict third party remanufacturing
    - Disclosure of any legal actions taken against third party remanufacturers for breaching intellectual property rights that cover any aspect of remanufacturing
    - Production of consumable schematics showing all components and connection types used

- Supporting dematerialisation of consumables by:
    - Inclusion of consumable material efficiency requirements, which take account of consumable mass and page yield
    - Requirements that seek to either minimise, or require disclose of, the number of parts and materials in consumables

- Supporting reductions of hazardous material content in consumables by:
    - Inclusion of restrictions on hazardous material content in toners and inks

- Supporting reduced environmental impacts in OEM consumable end-of-life processing by:
    - Inclusion of criteria which identify the numbers and total weights of consumables collected through take back programmes.
    - Inclusion of criteria which require reporting on the amounts of collected consumable material sent to the following end of life options:
        - Reuse
        - Recycling
        - Waste to energy incineration
        - Incineration
        - Storage
        - Landfill

There may be several technical and non-technical barriers in the way of setting requirements that further environmental savings on imaging equipment and consumables.

The typical internal power supply (IPS) efficiency of imaging equipment is unknown, because the lack of access to data, therefore difficult to develop a requirement on it. One solution could be to source the IPS efficiency data from initiatives on other similar product groups, such as computers, where there has been a strong emphasis on reducing wasted energy in inefficient power supplies. Secondly, the ENERGY STAR TEC requirement indirectly addresses the power supply efficiency, but it is rather limited to the high load levels, therefore the efficiency during low power modes (at low loads) remains unaddressed.

The use of imaging equipment consumables contributes to a very significant share of overall environmental burdens from this product group. It is clear that there are a number of available solutions that can help to mitigate these impacts. However, there are likely to be a number of potential barriers to the inclusion of some environmental criteria on consumables, such as uncertainties of the design features that limits reuse and remanufacturing, issues with patents and intellectual property rights, and the rise of non-reusable counterfeits from Asia that hampers reuse/remanufacturing and impacts the competitiveness of EU businesses in this industry.

It can be difficult to source definitive information about which design features limit further reductions in environmental impacts of consumables. That is, there are often competing

claims that specific design features are both necessary for technical reasons and are purposefully included to limit remanufacturing ability. Many of the technical features which limit the ability to remanufacture are related to the electronic chips included in consumables. These electronic chips are often needed in cartridges to support advanced user functionalities (e.g. toner/ink level reporting) but also to ensure that printers are not damaged from running dry cartridges. To overcome these barriers, it will be necessary to ensure that requirements support the continued usage of advanced functionalities but also facilitate remanufacturing.

There are a significant number of patents and other intellectual property rights that cover the broad range of consumables on the market. Many of these intellectual property rights cover aspects of consumable design, software and remanufacturing processes that could significantly hamper the ability of 3rd party organisations to remanufacture consumables. The US Supreme Court ruling can be of inspiration for the patent disputes in the EU regarding consumables too, and it needs to be clearer about when the patent is exhausted and how the remanufactured consumable infringes the IPR. Any requirements regarding remanufacturing consumables in the VA would need to be developed in a way that it does not infringes IPR, however this non-technical barrier for remanufacturing cannot be easily and solely addressed by the VA under Ecodesign, but it also touches how the patent law should be interpreted.

The rapid increase in the numbers of "cloned" and counterfeit consumables being imported into the EU market from Asia may also cause issues. These cloned and counterfeit consumables are often unsuitable for remanufacturing, may contain restricted hazardous substances and manufacturers may not fulfil their obligations under the WEEE and RoHS Directives. Any requirements placed on OEM consumables would not result in reduced environmental impacts from these cloned consumables. The rise in cloned consumables is also impacting OEM, and remanufacturing organisations' revenue streams. This suggests that OEM consumable manufacturers may be more sensitive to extra financial burdens placed on their products whilst at the same time facing competition from cheaper imported products. Enforcement of existing EU legislation including WEEE, RoHS and patent rights on producers of cloned consumables would help to alleviate the negative impacts of these products. Enforcement of RoHs restrictions on all cloned consumables would ensure that these product types had a toxicity profile the same as OEM consumables. However, enforcing environmental legislation is complicated by the fact that many cloned consumables, and all counterfeit consumables, infringe intellectual property rights, and so, should not even be on the EU market.

Annex A – Additional Tables and Figures

Table 74: Average Energy Use and Power Demands for Imaging Equipment Registered in the US ENERGY STAR database

Imaging Equip-ment Type	Marking Technol-ogy	Colour Format	Monochrome Product Speed (ipm)	Average Energy/Power		
				TEC (kWh/week)	Sleep Mode (W)	Standby/ Off Mode (W)
MFD	Inkjet (IJ)	Colour	s ≤ 20		1.1	0.1
			20 < s ≤ 40		1.3	0.1
MFD	Inkjet (IJ)	Mono	20 < s ≤ 40		1.6	0.1
Printer	Inkjet (IJ)	Colour	s ≤ 20		1.0	0.2
			20 < s ≤ 40		1.3	0.1
Printer	Inkjet (IJ)	Mono	s ≤ 20		1.0	
			20 < s ≤ 40		1.4	0.1
MFD	Electrophotographic (EP)	Colour	s ≤ 20	0.9		
			20 < s ≤ 40	1.8		
			40 < s ≤ 51	3.0		
			51 < s ≤ 60	3.8		
			60 < s ≤ 80	7.7		
			s > 80	12.3		
MFD	Electrophotographic (EP)	Mono	s ≤ 20	0.8		
			20 < s ≤ 40	1.5		
			40 < s ≤ 60	2.7		
			60 < s ≤ 66	4.5		
			66 < s ≤ 80	5.9		
			s > 80	16.6		
Printer	Electrophotographic (EP)	Colour	s ≤ 20	1.0		
			20 < s ≤ 40	2.1		
			40 < s ≤ 51	4.3		

Imaging Equipment Type	Marking Technology	Colour Format	Monochrome Product Speed (ipm)	Average Energy/Power		
				TEC (kWh/week)	Sleep Mode (W)	Standby/ Off Mode (W)
			51 < s ≤ 60	3.4		
			s > 60	17.9		
Printer	Electrophotographic (EP)	Mono	s ≤ 20	0.6		
			20 < s ≤ 40	1.4		
			40 < s ≤ 60	2.6		
			60 < s ≤ 66	3.6		
			66 < s ≤ 135	13.6		
			s > 135	57.6		
Copier	All	All	All	1.2		
Fax	All	All	All	0.5		

Table 75: Average Page Yields of Consumables

Product Type	Monochrome Product Speed, s, as Calculated in the ENERGY STAR Test Method (ipm)	Consumable (Cartridges/Containers) Page Yield					
		OEM			Remanufactured/ Compatible Consumable		
		Average	Max	Min	Average	Max	Min
Mono Laser printer	s ≤ 20	1600	1600	1600	1600	1600	1600
	20 < s ≤ 40	9727	36000	1200	6978	18000	1200
	40 < s ≤ 60	17152	40000	2600	14647	25000	3000
	60 < s ≤ 66	24125	41000	10000	0	0	0
	66 < s ≤ 135	25667	41000	11000	0	0	0
	s > 135	0	0	0	0	0	0
Mono Laser MFD	s ≤ 20	3267	7200	1000	3075	7200	1000
	20 < s ≤ 40	15729	45000	3000	5525	9000	3000
	40 < s ≤ 60	15077	45000	2500	12063	25000	3000
	60 < s ≤ 66	18400	25000	6000	18667	25000	6000
	66 < s ≤ 80	36880	70000	6000	15500	25000	6000
	s > 80	0	0	0	0	0	0

Colour Inkjet Printers	s ≤ 20	2371	10000	180	731	1130	500
	20 < s ≤ 40	2069	5000	700	1534	2500	1200
	40 < s ≤ 51	0	0	0	0	0	0
	51 < s ≤ 60	0	0	0	0	0	0
	s > 60	0	0	0	0	0	0
Colour Laser Printers	s ≤ 20	6633	23000	1400	9185	23000	1400
	20 < s ≤ 40	6409	30000	1500	5453	12000	1500
	40 < s ≤ 51	18910	44000	6000	14500	36000	6000
	51 < s ≤ 60	21117	44000	6000	29250	36000	27000
	s > 60	59000	80000	52000	0	0	0
Colour Inkjet MFD	s ≤ 20	384	1130	165	527	1130	165
	20 < s ≤ 40	1300	4000	250	313	550	250
	40 < s ≤ 51	1300	4000	250	313	550	250
	51 < s ≤ 60	0	0	0	0	0	0
	60 < s ≤ 80	0	0	0	0	0	0
	s > 80	0	0	0	0	0	0
Colour Laser MFD	s ≤ 20	5653	23000	1400	7129	23000	1400
	20 < s ≤ 40	7646	15000	2900	7460	15000	5000
	40 < s ≤ 51	25031	44000	10500	27375	36000	25000
	51 < s ≤ 60	29550	44000	11500	27375	36000	25000
	60 < s ≤ 80	28968	80000	8000	0	0	0
	s > 80	59000	80000	52000	0	0	0

Table 76: Lowest Energy Use and Power Demands for Imaging Equipment Registered in the US ENERGY STAR database

Imaging Equipment Type	Marking Technology	Colour Format	Monochrome Product Speed (ipm)	BAT Energy/Power		
				TEC (kWh/ week)	Sleep Mode (W)	Standby/ Off Mode (W)
MFD	Inkjet (IJ)	Colour	s ≤ 20		0.4	0.1
			20 < s ≤ 40		0.5	0.0
MFD	Inkjet (IJ)	Mono	20 < s ≤ 40		1.1	0.1
Printer	Inkjet (IJ)	Colour	s ≤ 20		0.6	0.1
			20 < s ≤ 40		0.7	0.1
Printer	Inkjet (IJ)	Mono	s ≤ 20		0.7	0.1
			20 < s ≤ 40		0.9	0.1
MFD		Colour	s ≤ 20	0.4		

Imaging Equipment Type	Marking Technology	Colour Format	Monochrome Product Speed (ipm)	BAT Energy/Power		
				TEC (kWh/ week)	Sleep Mode (W)	Standby/ Off Mode (W)
	Electro-photo-graphic (EP)		20 < s ≤ 40	0.8		
			40 < s ≤ 51	1.8		
			51 < s ≤ 60	2.5		
			60 < s ≤ 80	3.9		
			s > 80	5.9		
MFD	Electro-photo-graphic (EP)	Mono	s ≤ 20	0.4		
			20 < s ≤ 40	0.5		
			40 < s ≤ 60	1.5		
			60 < s ≤ 66	2.8		
			66 < s ≤ 80	3.2		
			s > 80	5.8		
Printer	Electro-photo-graphic (EP)	Colour	s ≤ 20	0.4		
			20 < s ≤ 40	0.7		
			40 < s ≤ 51	1.7		
			51 < s ≤ 60	2.5		
			s > 60	5.0		
Printer	Electro-photo-graphic (EP)	Mono	s ≤ 20	0.4		
			20 < s ≤ 40	0.6		
			40 < s ≤ 60	1.5		
			60 < s ≤ 66	2.6		
			66 < s ≤ 135	3.0		
			s > 135	17.5		
Copier	All	All	All	1.1		
Fax	All	All	All	0.5		

Table 77: Energy Efficiency of High-Performance Inkjet and Comparative Laser Based Imaging Equipment

Brand Name	Model Name	Type	Marking Technology	Colour Capability	Print Speed (ipm or mppm)	Automatic Duplex Output Capable	Typical Electricity Consumption (TEC) (kWh/wk)
Epson	WF-C20590	MFD	High Performance IJ	Colour	100	Yes	1.2
Brother	HL-S7000DN	Printer	High Performance IJ	Monochrome	100	Yes	1.3
Konica Minolta	bizhub PRO 1100	MFD	Electrophotographic (EP)	Monochrome	100	Yes	13.5
Xerox	Xerox D95A MFD	MFD	Electrophotographic (EP)	Monochrome	100	Yes	19.8
Konica Minolta	AccurioPress C6100+PF-711 [MFP System]	MFD	Electrophotographic (EP)	Colour	100	Yes	20.0
Konica Minolta	AccurioPress C6100+PF-707m [Printer System]	Printer	Electrophotographic (EP)	Colour	100	Yes	20.0
Xerox	Versant 3100 Press	Printer	Electrophotographic (EP)	Colour	100	Yes	24.5
Xerox	Versant 2100 Press	Printer	Electrophotographic (EP)	Colour	100	Yes	26.1

Table 78: Average and BAT TEC Levels. The percentage reduction is here calculated as reduction from average TEC to lowest TEC in the speed range.

Imaging Equipment Type	Marking Technology	Colour Format	Monochrome Product Speed (ipm)	TEC (kWh/week)		
				Average	BAT	% reduction
MFD	Electrophotographic (EP)	Colour	s ≤ 20	0.9	0.4	55%
			20 < s ≤ 40	1.8	0.8	55%
			40 < s ≤ 51	3.0	1.8	39%
			51 < s ≤ 60	3.8	2.5	35%
			60 < s ≤ 80	7.7	3.9	49%
			s > 80	12.3	5.9	52%
MFD	Electrophotographic (EP)	Mono	s ≤ 20	0.8	0.4	51%
			20 < s ≤ 40	1.5	0.5	67%
			40 < s ≤ 60	2.7	1.5	45%
			60 < s ≤ 66	4.5	2.8	38%
			66 < s ≤ 80	5.9	3.2	46%
			s > 80	16.6	5.8	65%
Printer	Electrophotographic (EP)	Colour	s ≤ 20	1.0	0.4	58%
			20 < s ≤ 40	2.1	0.7	67%
			40 < s ≤ 51	4.3	1.7	60%
			51 < s ≤ 60	3.4	2.5	26%
			s > 60	17.9	5.0	72%
Printer	Electrophotographic (EP)	Mono	s ≤ 20	0.6	0.4	37%
			20 < s ≤ 40	1.4	0.6	56%
			40 < s ≤ 60	2.6	1.5	43%
			60 < s ≤ 66	3.6	2.6	27%
			66 < s ≤ 135	13.6	3.0	78%
			s > 135	57.6	17.5	70%
Copier	All	All	All	1.2	1.1	11%
Fax	All	All	All	0.5	0.5	0%

5. Task 5: Evaluation and environment

In this task, the current Voluntary Agreement will be evaluated. It will include assessment of the primary design, resource efficiency and information requirements, and how effective and efficient the Voluntary Agreement has been in delivering energy and resource efficiency. Lastly, possible recommendations for improvements will be presented.

Task 5 will also partly follow the MEErP methodology and includes the following:

- Product specific inputs, where the data and information collected in Task 1 – 4, will define the all the specific inputs for base cases.
- Base case environmental impact assessment, where the EcoReport tool is used separately for imaging equipment consumables from products, in order to better account for the resource consumption, as well as using product specific inputs, to calculate emissions and resources categories for the life cycle.
- EU total environmental impact assessment, where the base case impact assessment per unit will be scaled up to the whole EU, in order to assessment the impacts of the product group as whole to the EU.

5.1 Evaluation of current Voluntary Agreement

In this section, the current Voluntary Agreement is evaluated for the appropriateness of the various requirements and its effectiveness in delivering energy and resource savings.

5.1.1 Overall compliance

The VA includes requirements on a number of environmental impact areas including energy use, design for recyclability, cartridge design and information provision. The requirements are split into three parts:

- Part I: Primary design requirements
- Part II: Other resource efficiency requirements
- Part III: Information requirements for end-users

For part I, the minimum compliance rates are shown in Table 79. For part II and part III, the required compliance rates are 100% after 2012 or 2015, depending on the type of requirement.

Table 79: Overall sales weighted VA compliance targets

Tier	Period	OM[277] products placed on the EU market	TEC[278] products placed on the EU market
Tier I	Jan-Dec 2015	90%	70%
Tier II	Jan-Dec 2016	93%	80%
Tier III	Jan 2017 onwards	99%	90%

Signatories' compliance to the VA requirements is assessed by an Independent Inspector. The independent Inspector is an independent third party, designated by the VA Steering Committee (which includes the European Commission as a member and that have the right to veto the choice of the Inspector), who is tasked with:[279]

- collecting and processing information supplied by Signatories
- determining a Signatory's compliance with the Agreement; and
- carrying out of audits

The Independent Inspector carries out annual compliance assessments for all signatories, with the results published on the EuroVAPrint website.[280] The compliance analysis includes assessment of whether overall sales weighted targets are met and whether individual products comply with each of the VA requirements.

5.1.2 Part I: Primary design requirements

In this subsection, the appropriateness and the effectiveness of primary design requirements set by the VA are assessed.

For energy in use, the VA requires that targeted percentages of manufacturers' products are compliant to many of the requirements in the ENERGY STAR specification for imaging equipment (v2.0)[281]. According to data collected by Independent Inspector[282], the sales weighted ENERGY STAR compliance rates for the last 8 years have been found. As shown in Table 80, there is a clear trend of ENERGY STAR non-compliance rate diminishing over time, with only 0.1% of the total sales covered by the signatories being non-compliant with

[277] OM: Operational Mode: ENERGY STAR Imaging Equipment (IE) specification. The procedure is to be used to quantify the power consumption of imaging products that do not utilize the Typical Electricity Consumption (TEC) method.
[278] TEC: Typical Electricity Consumption method for the Version 2.0 ENERGY STAR Imaging Equipment (IE) specification. The procedure is to be used to obtain and evaluate the TEC of Standard-size IE products such as copiers, digital duplicators, fax machines, multifunction devices (MFDs), and printers that use high-temperature technologies such as Electrophotography (EP) and Solid Ink (SI), and those that provide comparable functionality.
[279] http://www.eurovaprint.eu/fileadmin/eurovaprint_files/pdfs/VA_version_5.2_April.pdf, section 7
[280] http://www.eurovaprint.eu/pages/compliance/
[281] Energy consumption requirements (TEC and OM products), default delay times (OM products), duplex availability (TEC products)
[282] Period 8 Randomised data in Excel- file, RINA, August 2018.

the ENERGY STAR based requirements. It is important to note that non-compliance does not mean that signatories have incorrectly claimed that products are complaint with the ENERGY STAR requirements. Non-compliance in this instance only means that the products have not been declared to meet the ENERGY STAR specification limits.

Table 80: Overall sales weighted compliance with ENERGY STAR v2.0 for 2011-2017

Period	Dates	% compliant		
		TEC	OM	Total
1	1 January 2011 to 30 June 2011	86.2%	95.5%	91.8%
2	1 October 2011 to 31 March 2012	90.6%	96.3%	94.3%
3	1 January 2012 to 31 December 2012	91.9%	99.9%	97.1%
4	1 January 2013 to 31 December 2013	94.1%	99.9%	97.8%
5	1 January 2014 to 31 December 2014	94.6%	99.9%	98.0%
6	1 January 2015 to 31 December 2015	96.5%	99.7%	98.6%
7	1 January 2016 to 31 December 2016	98.1%	99.9%	99.2%
8	1 January 2017 to 31 December 2017	99.8%	99.9%	99.9%

The VA Annex C data reported for 2017 by signatories have been provided by the Independent Inspector with permission from VA secretariat. The study team assessed the data and verified the conclusion of the Independent Inspector on overall compliance rates.

It can be seen that the overall compliance rates for TEC and OM products have increased from 91.8% in 2011 and up to 99.9% in 2017. Task 2 report has presented the market coverage of the VA signatories to be around 95% - 97% in the period of 2011 – 2017. Taking into account of the brands and models outside of the VA market coverage but actively sold in the EU, the actual compliance of the entire EU market of imaging equipment with the VA requirement is 3 – 5 % lower than the reported value for VA covered market.

See Table 81 for the compliance rates for number of models and sales weighted compliance rates for different types of imaging equipment.

Table 81: Model based and sales weighted compliance rates for different types of IE and matched to the base cases

Type	Compliance rate, models %	Sales weighted compliance rate %	Match to current base cases
TEC Mono-chrome non-MFD	89%	96.4%	BC3 Monochrome Laser Printer, 20 < s ≤ 40
TEC Mono-chrome MFD	79%	99.6%	BC1 Monochrome Laser MFD, 20 < s ≤ 40
TEC Colour non-MFD	93%	90.5%	BC4 Colour Laser printer, 20 < s ≤ 40
TEC Colour MFD	85%	99.1%	BC2 Colour Laser MFD, 20 < s ≤ 40
OM Colour MFD	Off mode: 100% Sleep: 100%	Off mode: 100% Sleep: 100%	BC5 Colour Inkjet MFD, s ≤ 20
OM Colour non-MFD	Off mode: 100% Sleep: 93%	Off mode: 100% Sleep: 99.3%	BC6 Colour Inkjet Printer, s ≤ 20

The 2017 reported energy consumption TEC in kWh/week for TEC products under the VA are plotted against the ENERGY STAR version 2.0 requirements in Figure 57 to Figure 60 below. Some data points show 0 kWh/week due to no data was reported. Each data point represents a particular model. The number of products of each model actually sold can vary from one to many thousands.

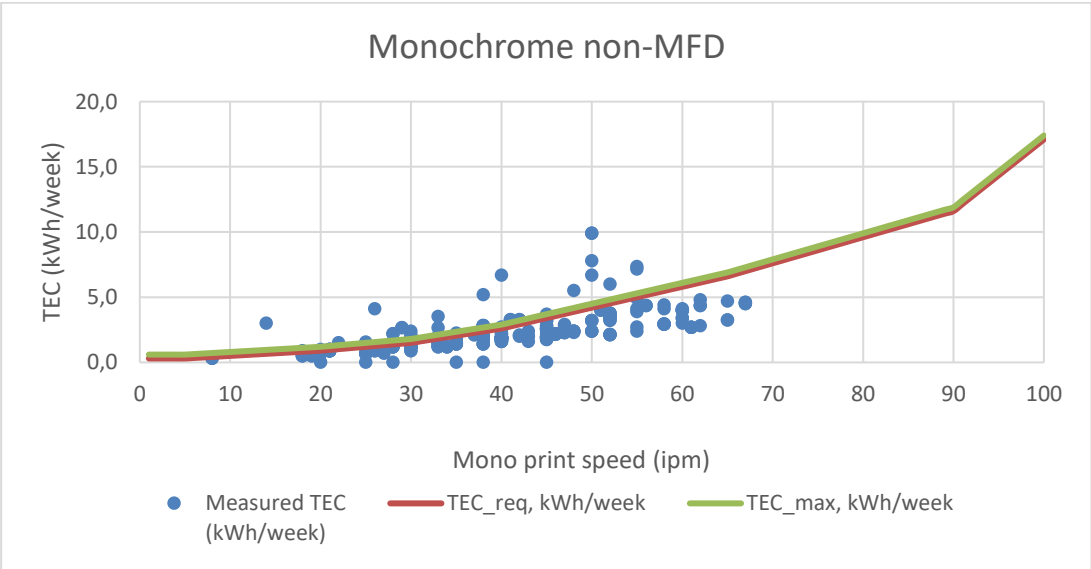

Figure 57: Reported energy consumption TEC (kWh/week) for mono non-MFDs, compared with ENERGY STAR Version 2.0 requirement for TECreq and TECmax (which is TECreq + adder for A3 capability). Each data point represents one model.

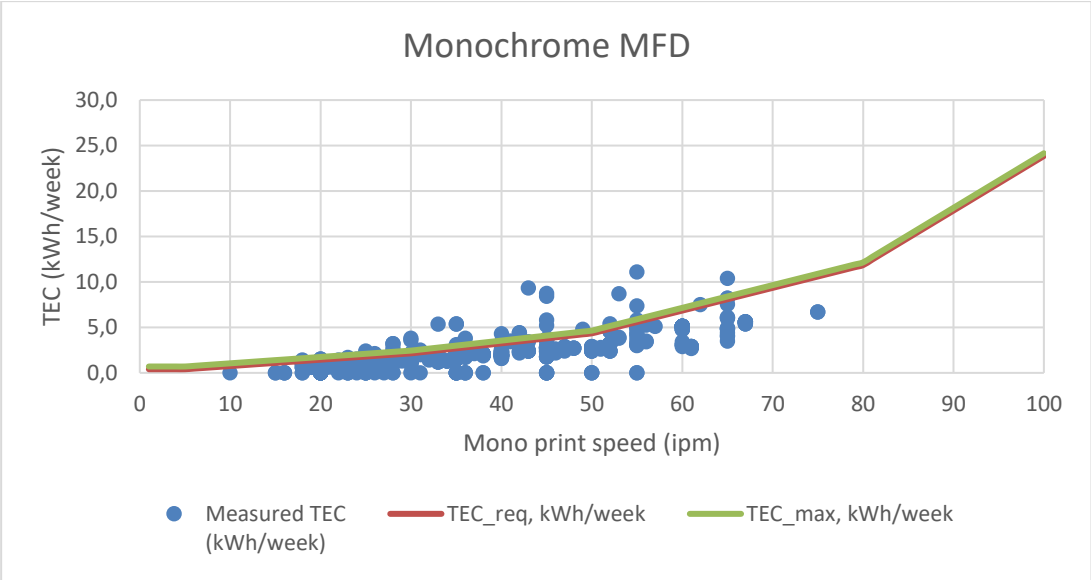

Figure 58: Reported energy consumption TEC (kWh/week) for mono MFDs, compared with ENERGY STAR Version 2.0 requirement for TECreq and TECmax (which is TECreq + adder for A3 capability). Each data point represents one model.

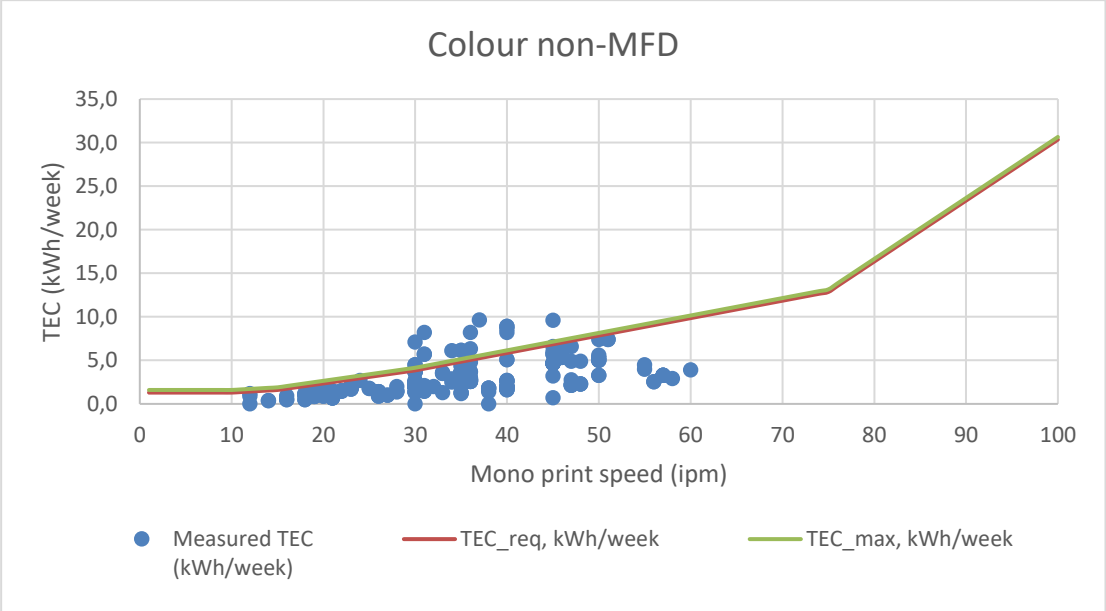

Figure 59: Reported energy consumption TEC (kWh/week) for colour non-MFDs, compared with ENERGY STAR Version 2.0 requirement for TECreq and TECmax (which is TECreq + adder for A3 capability). Each data point represents one model.

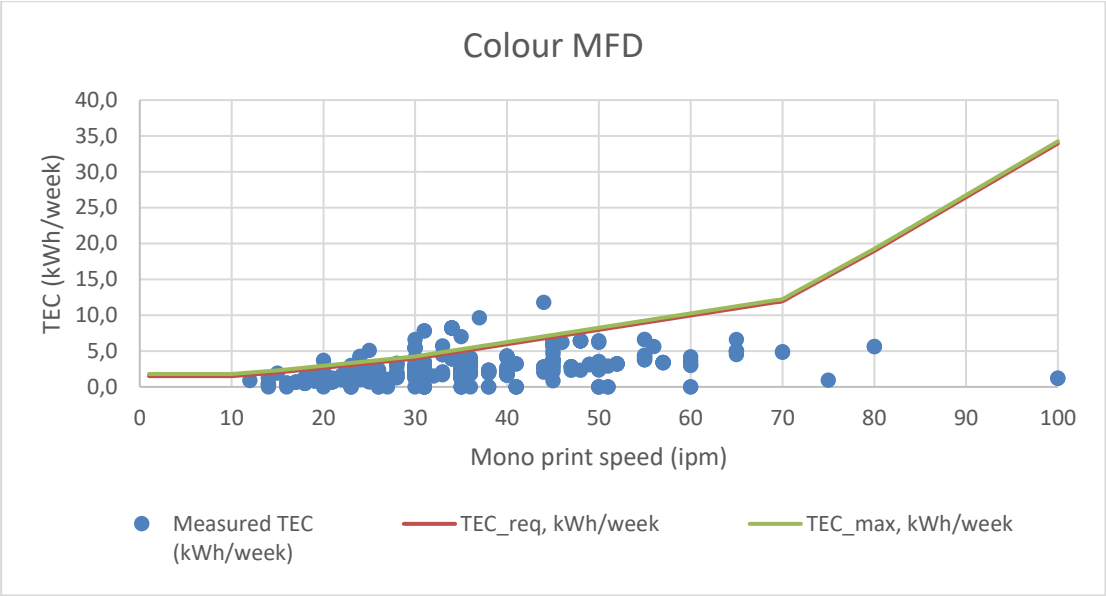

Figure 60: Reported energy consumption TEC (kWh/week) for colour MFDs, compared with ENERGY STAR Version 2.0 requirement for TECreq and TECmax (which is TECreq + adder for A3 capability). Each data point represents one model.

The 2017 reported sleep mode power demand for OM products under the VA are plotted against the ENERGY STAR version 2.0 sleep allowances in Figure 61 and Figure 62 below.

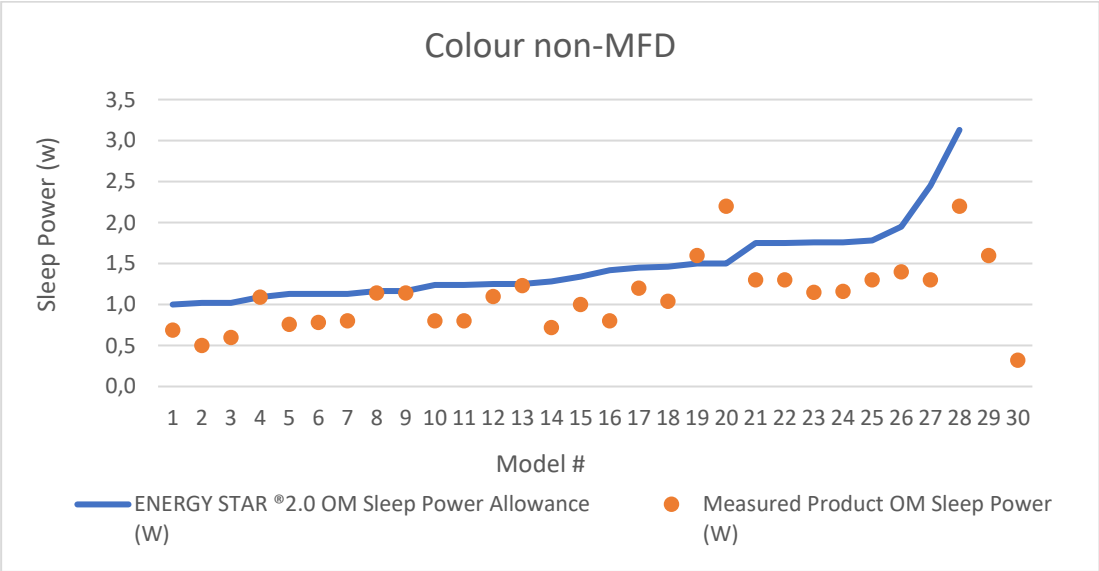

Figure 61: Reported sleep power (W) for colour non-MFDs OM products, compared with ENERGY STAR Version 2.0 requirement for sleep power allowance. Each data point represents one model.

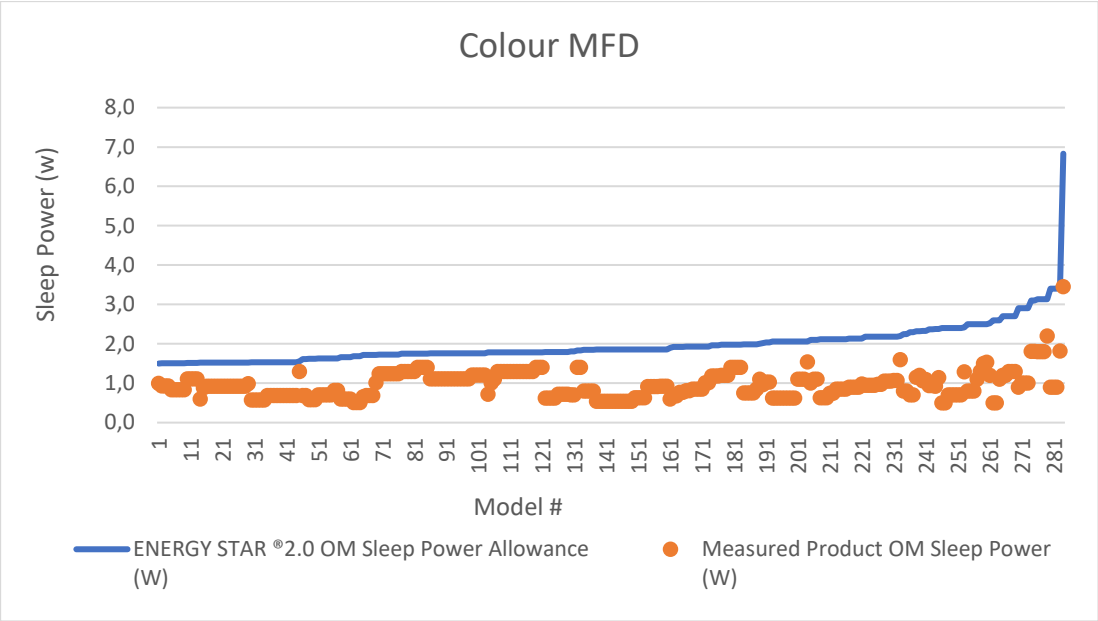

Figure 62: Reported sleep power (W) for colour MFDs OM products, compared with ENERGY STAR Version 2.0 requirement for sleep power allowance. Each data point represents one model.

Based on the results above, the conclusion is that the primary design requirements from ENERGY STAR version 2.0 have been achieved by the majority of the product models. Although there are a number of TEC models that draw more power than the ENERGY STAR limit, they account for a small share of overall sales, therefore allowing for a very high overall sales-weighted compliance rate. The sleep mode power demand of virtually all OM products is well below the ENERGY STAR requirement, especially for colour MFDs, indicating potential for reducing the sleep mode power allowances for OM products.

The VA primary design requirements also include other aspects beyond energy and power, such as auto duplex capability and default auto duplex enabled for TEC products, and default delay time for OM products, see table below for the level of commitment.

Table 82: Level of commitment to primary design requirements in VA

TEC/OM	Provides auto duplex capability	Default Auto duplex enabled	Compliance with default delay time requirement
TEC products	86%	65%	
OM products			100%

Estimated savings in electricity consumption

Earlier Impact Assessments (2013)[283] estimated that the VA will provide direct electricity savings of 7.9 TWh per year in the EU in 2020 and 9 TWh per year in 2030 (excluding the additional savings that will be made through increased resource efficiency). Indirect energy consumption expressed in electricity equivalent assessed in the impact assessment (2013) mainly came from the paper usage. See details in Table 83.

Table 83: Business-as-usual (BAU without VA) and Voluntary Agreement direct and indirect energy consumption for the stock of Imaging Equipment estimated by Impact Assessment (2013)

	1995	2000	2005	2010	2015	2020	2025	2030
BAU (preparatory study)								
Direct (TWh)	27.01	22.33	11.97	8.67	8.69	9.13	9.74	10.40
Indirect (TWh)	23.42	27.74	33.14	38.77	40.89	42.75	44.43	46.99
Total (TWh)	50.43	50.07	45.11	47.44	49.58	51.88	54.18	57.39
Voluntary								
Direct (TWh)	27.01	22.33	9.04	3.54	1.56	1.22	1.27	1.33
Indirect (TWh)	23.42	27.74	33.14	36.67	34.67	35.62	37.03	39.16
Total TWh)	50.43	50.07	42.18	40.21	36.23	36.84	38.29	40.49

Each year, the VA Inspector produces a compliance report, which includes an energy usage report for the products within the scope of the VA placed on the EU market for the particular period. See Table 84 for the estimated energy consumption of TEC and OM imaging equipment for 2011 – 2017. The compliance report by Inspector states that the energy consumption for the TEC products is based on the reported TEC value (kWh/week), and OM products energy consumption is based on the power reported for "printing", "ready", "sleep" and "off" mode and the preparatory study (2008) usage hours and based on actual shipments and actual measured energy values.

[283] Commission Staff Working Document - Impact Assessment Accompanying the document Report from the Commission to the European Parliament and the Council on the Voluntary Ecodesign Scheme for Imaging Equipment - COM(2013) 23 final.

Table 84: VA for imaging equipment – Energy usage report for products placed on the EU market in the particular year 2011-2017[284].

		Energy Star Compliant			Energy Star Non-Compliant			Energy Star Compliant & Non-Compliant		
		Energy Consumption (MWh/a)			Energy Consumption (MWh/a)			Energy Consumption (MWh/a)		
Period	Dates	TEC	OM	TOTAL	TEC	OM	TOTAL	TEC	OM	TOTAL
1	1 January 2011 to 30 June 2011	468,585	64,584	533,168	120,092	3,739	123,831	588,676	68,323	657,000
2	1 October 2011 to 31 March 2012	478,251	74,407	552,657	87,606	3,671	91,277	565,856	78,078	643,934
3	1 January 2012 to 31 December 2012	780,063	103,129	883,192	109,267	473	109,740	889,330	103,602	992,932
4	1 January 2013 to 31 December 2013	813,602	90,058	903,660	81,932	169	82,101	895,534	90,227	985,761
5	1 January 2014 to 31 December 2014	835,916	85,245	921,161	59,478	127	59,606	895,394	85,373	980,767
6	1 January 2015 to 31 December 2015	709,332	75,656	784,988	37,297	638	37,935	746,629	76,294	822,924
7	1 January 2016 to 31 December 2016	592,352	65,123	657,476	20,132	145	20,277	612,484	65,269	677,753
8	1 January 2017 to 31 December 2017	514,378	60,740	575,118	3,621	90	3,711	517,999	60,830	578,829

The energy consumption figures in Table 84 are for the sales in each year and only for the products in scope of the VA and cannot be compared with the figures in Table 83, which are for the stock of all imaging equipment and contains projections.

An updated savings analysis has been undertaken as part of this review study. The updated analysis includes updated sales and stock data sourced from EU ENERGY STAR market report 2017[285] and shipment totals provided by signatories to the Independent Inspector for 2017. Average energy consumption per unit for 2010 are based on figures from Impact Assessment (2013) and average energy consumption per unit for 2017 from ENERGY STAR registration data as well as from energy data reported to the Inspector according to VA Annex C.

The updated savings analysis shows that the direct energy consumption saving from the VA is estimated to be 4 TWh in 2015, 9.5 TWh in 2020 and 10 TWh in 2030, see Figure 63 and Table 85, when allocating all the savings to the effect of the VA (see in next section an assessment of possible separation of savings driven by the VA and by other initiatives). The total direct energy consumption in the BAU 0 scenario (without EU action) is estimated to be higher than suggested in the preparatory study (2008) and Impact Assessment (2013), at 16 TWh in 2015 and 14 TWh in 2030. Under the BAU scenario (with current VA in place and no other changes) total energy consumption is estimated to have been 12 TWh in 2015, decreasing to 6 TWh by 2020 with a further to 4 TWh by 2030.

Manufacturing stakeholders have reported that there is a very good chance that imaging equipment falling under the definitions but not covered by the signatories would also comply with the VA requirements. It is estimated the total EU market including those not under VA have 3–5 % lower compliance rate than VA market coverage only, this is estimated as the BAU scenario "incl. IE outside VA" in Figure 63.

[284] Appendix 4, EuroVAprint Imaging Equipment Voluntary Agreement, Annual Compliance Report of the Independent Inspector - Period 8 (1 January – 31 December 2017), RINA, April 2018.
[285] Q3-Q4 2015: Survey of the Market Penetration of Energy Efficient Office Equipment under the EU ENERGY STAR Programme. 2017

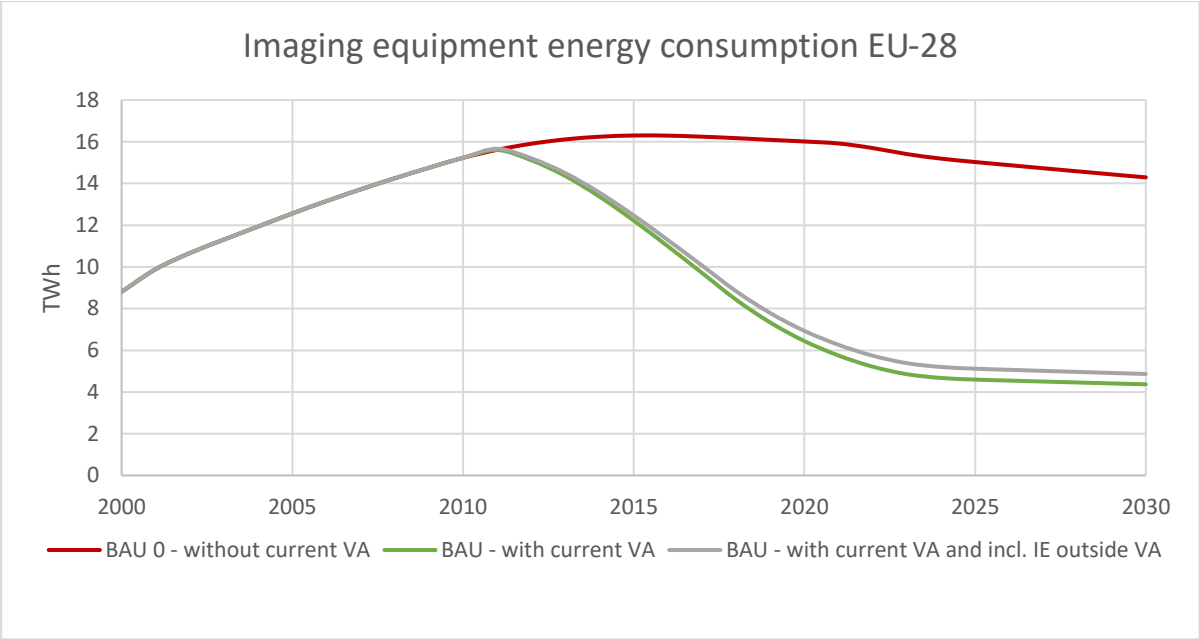

Figure 63: Estimated energy consumption of BAU 0 (no EU action) and BAU (current VA in place) due to various initiatives incl. the VA

Figure 63 shows that there was an increase of energy consumption before the current VA was in place, in contrary to the Impact Assessment (2013). This is because the stock was modelled differently, and the sales data from impact assessment were updated with new data for 2015, this created an incline in stock even though the sales were declining.

Table 85: Imaging equipment energy consumption EU-28 estimated in current study

	2010	2015	2020	2025	2030
BAU 0 (without VA), TWh/year	15	16	16	15	14
BAU (with current VA) TWh/year	15	12	6	5	4

Separating savings driven by the VA and by other initiatives

The commitments within the VA ensuring certain percentages of products meet ENERGY STAR specifications undoubtedly helps to increase the numbers of products on the EU market that meet ENERGY STAR energy efficiency requirements. However, there are other policy drivers, which encourage manufacturers to ensure products meet the ENERGY STAR specifications fully or partly such as the US ENERGY STAR, the EU ENERGY STAR (expired on 20 February 2018), Green Public Procurement, the Blue Angel, the Nordic Swan and initiatives outside the EU (see further in the Task 1 report). All these schemes work towards the same target of increasing the share of purchased imaging equipment products compliant with ENERGY STAR and it is not possible to calculate the contribution from each of the schemes. However, in the following, we provide an estimation of the contribution of the VA by analysing the penetration rates of the ENERGY STAR implementation in the United States.

A basic driver in the US is that US Federal Agencies are required to purchase imaging equipment that meet the ENERGY STAR specifications.[286] As manufacturers strive to achieve ENERGY STAR status for their products the number of ENERGY STAR products available on the market increases rapidly after the development of a new specification.

The US EPA tracks the penetration rate of ENERGY STAR products on the US market through conducting annual assessments.[287] Table 86 includes a summary of the US EPA estimates on ENERGY STAR penetrations against different specifications. The cells coloured green represent the point at which new ENERGY STAR specifications are developed. The US EPA aim to develop new ENERGY STAR specifications which reflect the top 25% most efficient models available on the market when the requirements enter into effect. [288]

The cells coloured blue represent reported data, such as the US EPA published ENERGY STAR penetration rates[287] for the specific years (i.e. the percentages of products on the market that meet the current ENERGY STAR specification). Cells colour orange are interpolated values.

Table 86: US EPA Published ENERGY STAR Penetration Rates for Imaging Equipment and EU ENERGY STAR Penetration Rates driven by the VA – targets and actual reported compliance. See the body text for explanation on colour codes.

	ENERGY STAR v1.0		ENERGY STAR v1.1		ENERGY STAR v2.0		VA targets ES v2.0		VA compliance ES v2.0	
Year	OM	TEC	OM	TEC	OM	TEC	OM	TEC	OM	TEC
2006	25.0%	25.0%								
2007	34.8%	35.8%								
2008	44.7%	46.7%	25.0%							
2009	54.5%	57.5%	62.0%							
2010			99.0%							
2011			100.0%							
2012			91.0%							
2013			90.0%		25.0%					
2014					99.0%					
2015					100.0%		90.0%	70.0%	99.7%	93.8%
2016					100.0%		93.0%	80.0%	99.9%	94.0%
2017					99.0%		99.0%	90.0%	99.9%	97.4%

It is clear from the results that the ENERGY STAR penetration rates in the US have increased rapidly. This suggests that other policy drivers, such as Government procurement requirements, are very strong drivers of ENERGY STAR adoption. The table also provides the EU VA targets and actual reported compliance (blue cells), it is clear that the VA targets

[286] https://www.gsa.gov/governmentwide-initiatives/sustainability/buy-green-products-services-and-vehicles/buy-green-products/energy-efficient-products
[287] https://www.energystar.gov/index.cfm?c=partners.unit_shipment_data
[288] https://www.energystar.gov/ia/partners/prod_development/downloads/guiding_principles_2012.pdf?fefa-854a

have not been very ambitious, given the US ENERGY STAR v2.0 penetration rates is already 100% in 2015, but the targets are set at 90% and 70% for OM and TEC. The actual reported compliance showed 99.7% and 93.8% for OM and TEC, closer to the actual US reported data.

It is important to note that the US EPA reports ENERGY STAR penetration data at the "MFD & Printer" level rather than per sub-categories of MFD and printer. This could result in the penetration rates being skewed where ENERGY STAR penetration rates are high for products sold in high volumes (e.g. MFD inkjets). This concern is somewhat offset by the VA Independent Inspector reported ENERGY STAR penetration rates for OM and TEC products.

The influence of other government policies on ENERGY STAR penetration rates is also an important consideration in the EU. Prior to February 2018 when the US-EU ENERGY STAR agreement ended, all central government bodies in the EU were also required to purchase products that met ENERGY STAR specifications for larger tenders.[289] The energy efficiency directive has the same obligation[290]. Given the significant purchasing power of central government bodies in the EU, it is assumed that this policy should also have a significant impact on ENERGY STAR penetration rates within the EU market, however, no information has been possible to collect about the actual compliance of these requirements in the Member States.

In an attempt to identify the share of ENERGY STAR penetration increases that led by the VA, the study team considered all available penetration data. Table 87 shows an average annual ENERGY STAR penetration rate increase for OM and TEC products. This average is calculated by finding the differences of the figures in green cells and the first blue cells (first reported penetration rate) in Table 86 and divide over the number of years. These average values provide an overall average annual increase, this can be seen as the Business-as-Usual (BAU) baseline for the VA.

[289] https://ec.europa.eu/energy/en/energy-star
[290] https://eur-lex.europa.eu/eli/dir/2012/27/oj

Table 87: Average Annual Increases in ENERGY STAR Penetration Rates

		2006-2014 Annual Increase rate
US ENERGY STAR v1.0	**OM**	7.4%
	TEC	8.1%
US ENERGY STAR v1.1	**OM**	37.0%
	TEC	37.0%
US ENERGY STAR v2.0	**OM**	74.0%
	TEC	74.0%
Average Annual Increase (from v1.0, v1.1 and v2.0)	**OM**	**39.5%**
	TEC	**39.7%**

Table 88 compares the VA target and the VA actual compliance annual increases with the BAU average annual increase driven by the US initiatives.

Table 88: VA target annual increases and VA actual compliance annual increases compared with BAU annual increase driven by the US initiatives

		2015	2016	2017
BAU average annual increase driven by the US initiative	**OM**	**39.5%** (2006-2014)		
	TEC	**39.7%** (2006-2014)		
Overall VA Target Annual Increase	**OM**	**32.5%**	3.0%	6.0%
	TEC	**22.5%**	10.0%	10.0%
Overall VA Compliance Annual Increase	**OM**	**37.3%**	0.2%	0.1%
	TEC	**34.4%**	0.2%	3.4%

The results in Table 87 and Table 88 suggest that the BAU annual increase from the US ENERGY STAR penetration is roughly comparable to the VA targeted increases. Considering the US EPA shipment data and the fact the EU central Government procurement was also tied to ENERGY STAR specification, the study team's conclusion is that the VA has a lesser influence on ENERGY STAR penetration rates in the EU and thereby is not the major driver behind all the energy savings presented in Figure 63. It is however not possible to quantify the amount of savings as result of the VA compared to other initiatives.

Overall, the study team's judgement is that the US ENERGY STAR scheme supported by initiatives by the European Commission, by the Member States and by other schemes outside the EU is a major driver for the development of more energy efficient imaging equipment and for increasing the market penetration rate. Furthermore, the judgement is that the VA is and has been an effective additional policy measure for reducing the amount of non-ENERGY STAR compliant products entering the EU.

Finally, it is assumed that with the cessation of the US-EU ENERGY STAR agreement in February 2018, the VA targets on ENERGY STAR penetration rates may become a more significant driver of energy efficiency in the EU.

Improvement potential

The energy efficiency requirements within the current VA are based on the requirements within the ENERGY STAR v2.0 specification. The ENERGY STAR v2.0 specification was finalised in 2013 and became effective on the market in January 2014. At five years old, the ENERGY STAR v2.0 specification is mature and so unlikely to adequately reflect good levels of energy efficiency in imaging equipment. This is witnessed by the 2017 US EPA ENERGY STAR shipment data, which suggests that 99% of all MFDs and printers sold in the US during 2017 were complaint with the ENERGY STAR v2.0 specification.[291] In 2017, the US EPA launched the development of the ENERGY STAR v3.0 specification, in recognition of the fact that the ENERGY STAR v2.0 penetration rate was too high.[292] The ENERGY STAR v3.0 specification has been published and will take effect on 11 October 2019.

To support the ENERGY STAR v3.0 development process, the US EPA has compiled a product dataset of currently registered ENERGY STAR products. The dataset includes measured energy and power data for each product as well as the ENERGY STAR v3.0 specification limits. Using this data it is possible to estimate the potential energy savings resulting from adoption of the ENERGY STAR v3.0 specifications for each product. Table 89 illustrates the average measured TEC and average ENERGY STAR v3.0 specification limits for products in the ENERGY STAR v3.0 dataset, categorised into each of the TEC Base Cases. The analysis shows that on average the ENERGY STAR v3.0 specification limits result in 21% less energy being used per TEC based product.

Table 89: Estimated ENERGY STAR v3.0 Impacts on average energy use (TEC Base Cases)

Base cases for current study		Average Measured TEC (kWh/wk)	Average V3.0 TEC Requirement (kWh/wk)	Reduction in Energy Use (%)	Average Reduction in Energy Use (%)
BC1	Monochrome Laser MFD, 20 < s ≤ 40	0.56	0.47	16.0%	21.0%
BC2	Colour Laser MFD, 20 < s ≤ 40	0.67	0.48	28.2%	
BC3	Monochrome Laser Printer, 20 < s ≤ 40	0.52	0.44	14.5%	
BC4	Colour Laser printer, 20 < s ≤ 40	0.83	0.62	25.4%	

Table 90 shows the average sleep and standby power demand changes required under the ENERGY STAR v3.0 specification for OM products fitting base case 5 and 6. It is clear from the results that the ENERGY STAR v3.0 specification will result in some additional energy

[291] The US EPA ENERGY STAR Shipment Data only assesses products that are
[292] https://www.energystar.gov/products/spec/imaging_equipment_specification_version_3_0_pd

savings, but these are much smaller than seen for the TEC products. This suggests that the ENERGY STAR v3.0 specification for OM products may be too lenient.

Table 90: Estimated ENERGY STAR v3.0 impacts on average power demand (OM Base Cases)

Base cases for current study		Average sleep mode power (W)		Average standby Mode Power (W)		Reduction in Sleep Mode Power Demand	Reduction in Standby Power Demand
		All Products	ENERGY STAR v3.0 Compliant Products	All Products	ENERGY STAR v3.0 Compliant Products		
BC5	Colour Inkjet MFD, s ≤ 20	1.2	1.1	0.1	0.1	11.0%	0.9%
BC6	Colour Inkjet Printer, s ≤ 20	1.0	0.9	0.2	0.2	11.5%	0.0%

As US federal agencies are required to purchase products that meet ENERGY STAR specifications, manufacturers are often quick to ensure that new products meet revised ENERGY STAR specifications.[293] This is also due to the a nine-month-period between publishing the new specification and the effective date during which the penetration rate increases. Energy used by new products is often significantly lower than the maximum allowed under the revised ENERGY STAR specifications, and so overall energy savings potential is higher than the difference between average current performance and the ENERGY STAR specification line (as calculated in Table 89 and Table 90). This means that the average reduction in energy use for the base cases is assumed to be higher than 21% indicated in Table 89.

5.1.3 Part II: Other resource efficiency requirements

For the resource efficiency requirements, the compliance majority cannot be quantitatively assessed, with the exception of declared percentage of recycled plastic content, see Table 91. The percentages are obtained via the VA Annex C data reported by signatories to the Independent Inspector. It can be seen that the majority of the products have 0–5% of the recycled plastic content in the imaging equipment, as claimed by the manufacturers.

Table 91: Level of commitment regarding percentage of recycled plastic content

TEC/OM	Percentage of recycled plastic content (R)			
	0%	0<R≤5%	5<R≤20%	>20%
TEC products	7%	68%	7%	8%
OM products	20%	77%	0%	0%

A total of about 11,000 products are claimed as exemptions from the resource efficiency and information requirements of the VA, see Table 92. These exemptions mean that even though these number of products placed on the market do not meet the requirement, the compliance rates for Part II and III of the VA can still be 100%, as they are legitimately

[293] https://www.gsa.gov/governmentwide-initiatives/sustainability/buy-green-products-services-and-vehicles/buy-green-products/energy-efficient-products

exempted due to a number of exemption clauses in the VA, such as the small volume of sales (less than 5000 units per year) for section 5.1 and 5.2.

Table 92: Number of products placed on the market claimed exemptions from the VA in 2017

Section	Requirement	Number of exemptions
Section 5.1	II Availability of N-up printing	3625
Section 5.2	II Design for recycling	2080
Section 5.3	II Polymer composition	0
Section 5.4	II Cartridges	0
Section 5.5	II Recycled content	0
Section 6.1	III Resource and energy efficiency	3497
Section 6.2	III Availability of spare parts	0
Section 6.3	III Cartridge disposal and treatment	2080
Section 6.4	III Paper recyclability information	0
Section 6.5	III Paper recyclability improvement	0
Section 6.6	III Environmental characteristics	9862
Part II and III	Exempt in some way	**11290 (0.1% of total sales)**

For the rest of the requirements, according to the compliance report for 2017, all signatories have 100% compliance rates, see figures below. The compliance rates for Part II are 100% for 2012–2017 according to the compliance report each year[294]. However, this shows a contradictory picture to the current situation described by the EU remanufacturers.

[294] http://www.eurovaprint.eu/pages/compliance/

Table 93: TEC products compliance rates for VA Part I, II and III[295]

Signatory Nr.	Part I Compliance Rate	Meets Part I compliance target?	Part II Compliance Rate	Meets Part II compliance target?	Part III Compliance Rate	Meets Part III compliance target?
1	96.00%	Yes	100.00%	Yes	100.00%	Yes
2	99.92%	Yes	100.00%	Yes	100.00%	Yes
3	99.92%	Yes	100.00%	Yes	100.00%	Yes
4	96.90%	Yes	100.00%	Yes	100.00%	Yes
5	97.83%	Yes	100.00%	Yes	100.00%	Yes
6	95.07%	Yes	100.00%	Yes	100.00%	Yes
7	95.70%	Yes	100.00%	Yes	100.00%	Yes
8	99.58%	Yes	100.00%	Yes	100.00%	Yes
9	99.99%	Yes	100.00%	Yes	100.00%	Yes
10	96.53%	Yes	100.00%	Yes	100.00%	Yes
11	99.55%	Yes	100.00%	Yes	100.00%	Yes

Table 94: OM products compliance rates for VA Part I, II and III[295]

Signatory Nr.	Part I Compliance Rate	Meets Part I compliance target?	Part II Compliance Rate	Meets Part II compliance target?	Part III Compliance Rate	Meets Part III compliance target?
5	99.63%	Yes	100.00%	Yes	100.00%	Yes
7	100.00%	Yes	100.00%	Yes	100.00%	Yes
8	100.00%	Yes	100.00%	Yes	100.00%	Yes
11	100.00%	Yes	100.00%	Yes	100.00%	Yes

For Part II requirement section 5.4 on cartridges, remanufacturers[296] claimed that there are repeated cases where VA signatories have actively attempted to prevent the reuse of the cartridges and prevent the use of a non-OEM cartridge in their imaging equipment. For example, there are at least two models from Canon, which involves patents to prevent reuse and remanufacturing by launching lawsuits against non-OEM new-builds and remanufactured cartridges and applying for patent on specific parts such as shaft and memory device[297]. Other infringements mentioned involves firmware updates that occurs during use phase and prevent future use of non-OEM cartridges with the imaging equipment, for example, in 2016 there has been global HP firmware updates resulted in problems for users

[295] EuroVAprint Imaging Equipment Voluntary Agreement, Annual Compliance Report of the Independent Inspector - Period 8 (1 January – 31 December 2017), RINA, April 2018.
[296] Stakeholder consultation with ETIRA, DKWU, EFIM, June – August 2018.
[297] Canon patent lawsuits against newbuilts and remanufactured cartridges -Patent 2 087 407, HP inkjet patent 0940 259/258 on memory device, Canon patent EP 153 6207 on shaft. ETIRA Activity Report 2017 – 2018 accessed via: http://www.etira.org/wp-content/uploads/2017/07/Annual-Report-2017-2018.pdf

of certain printer models not being able to use non-HP cartridges[298]. At least 17 HP models are identified to have warnings to end-users about the dynamic security feature affecting using non-HP cartridges with non-HP security chip[299].

However, as seen in Table 92, there is no exemption claimed for section 5.4 of Part II commitment, in principle, 100% compliant rates with no exemption would mean all products placed on the EU market should be able to use non-OEM cartridges.

Estimated indirect savings

Indirect savings from paper usage is estimated by the impact assessment (2013) to be 4 TWh in 2015, 7 TWh in 2020 and nearly 8 TWh in 2030. No other indirect savings from resource efficiency such as from consumables or equipment were estimated by the impact assessment (2013). As the current study does not focus on the paper usage, it cannot be verified if this saving estimated by the impact assessment has been achieved by the VA.

Improvement potential

The current VA on imaging equipment includes a number of non-energy in use environmental design requirements. Given the high market compliance rates to the additional environmental design requirements in the VA (i.e. the criteria are included in other initiatives which enjoy high market penetration rates) these could be seen to describe average environmental performance of imaging equipment on the market. However, the current VA environmental design requirements are somewhat truncated when viewed in comparison to the requirements in other environmental initiatives which also have high penetration rates. For example, the EPEAT initiative includes significantly more environmental design criteria than the current VA, yet still has over 5000 registered products. Given that ENERGY STAR has similar numbers of registered products and the US EPA estimated a 99% market coverage level, it is assumed that the 5000 products registered with EPEAT also represent a significant share of products on the market. This suggests that average environmental performance for imaging equipment lies somewhere between the requirements laid down in the current VA and those included in more comprehensive initiatives such as EPEAT. It should be noted that EPEAT requires that all products registered with its scheme meet the latest ENERGY STAR energy efficiency specification. In June 2018, there were approximately 5100 imaging equipment models registered with the EPEAT initiative, suggesting

[298] ETIRA Activity Report 2017 – 2018 accessed via: http://www.etira.org/wp-content/uploads/2017/07/Annual-Report-2017-2018.pdf

[299] HP ColorLaserJet Pro M253-M254 series, M153-M154 series, M178-M181 series, M278-M281 series: HP ColorLaserJet Pro M254dn, M254dw, M254nw, M154a, M154nw, M180n, M180nw, M181fw, M280nw, M281fdn, M281fdw, M281cdw. HP LaserJet Pro M15 series, M28-M29 series: HP LaserJet Pro M15a, M15w, M28a, M28w, M29w. https://support.hp.com/lv-en/document/c06121285

that a significant percentage of imaging equipment models on the market have overall environmental performances above that described by the current VA requirements.

The paper used in imaging equipment can contribute to a large share of overall environmental burdens. In general, the faster an imaging equipment product the more paper it can be expected to use over its lifetime (i.e. users buy faster imaging equipment when they expect to use the product more often). As paper usage increases it becomes more important to reduce the associated impacts. For this reason, the VA and other major environmental initiatives include requirements for some products to have automatic duplexing functionality, N-up printing and ability to print on lower weight paper and recycled paper. Automatic duplexing enables the production of images on both sides of an output sheet without the need for users to manually turn and refeed paper into the imaging equipment product. Automatic duplexing is more common on faster laser-based products which are designed to output higher volumes of images.

The current VA on imaging equipment does contain a requirement that cartridges shall not be designed to prevent reuse or recycling. However, the VA does not identify what technical features of consumables could be considered barriers to remanufacturing and so does not provide any clarity on defining average consumable design in terms of remanufacturing.

Furthermore, assessment of the extent of the non-energy in use environmental requirements in the VA compared to requirements in other established initiatives such as Blue Angel, Nordic Swan, and especially EPEAT revealed that the other initiatives contain a much broader range of environmental criteria than the current VA (see Table 6 in Task 1 report). It is also important to note that EPEAT has a wider product scope than the VA as its scope mirrors the ENERGY STAR v2.0 scope. As such EPEAT covers types of imaging equipment (e.g. large format products) that are outside of the VA scope. These factors suggest that the number of environmental criteria included in the VA, and the scope of the VA, should be significantly expanded to ensure that the VA is driving environmental improvements beyond a business as usual scenario.

In addition, some of the VA requirements are worded in such a way that they leave room for interpretation. As example of this issues can be seen with the VA 5.4 criteria, which address remanufactured consumables. The criterion allows signatories to include design features for innovation, development or improvements in design or functionality of the products or consumables cartridges that may inadvertently impact the ability to use remanufactured consumables or for consumables to be remanufactured. This causes a conflict in that one party (e.g. a signatory) may see the innovative design feature as necessary and the impact on remanufactured consumables as unfortunate.

Another stakeholder (e.g. a consumable remanufacturer) may view the innovative design feature simply as a feature designed to impact remanufactured consumables. The Independent Inspector is left to adjudicate on these potential interpretations of the criteria, but where it cannot reach a final decision the VA Steering Committee is charged with making the final interpretation.

Other examples include:

- Non-separable connections (e.g. glued, welded) between different materials shall be avoided unless they are technically or legally required.
- Large-sized casing parts must be designed in a way that the contained plastics can be used for the production of high-quality durable products by applying available recycling techniques.
- The machine shall not be designed to prevent the use of a non-OEM cartridge

Each of the above criteria include some degree of interpretation and thereby ambiguity. For example, there is no definitive list of permissible technical reasons why non-separable connections may be used in products.

5.1.4 Part III: Information requirements for end-users

The VA contains a number of requirements for signatories to publish environmental information to inform end users. As seen already in Table 93 and Table 94, the compliance rates for Part III commitment information requirements are 100%, this applies to the past years since VA is established. For 2017, the majority of the exemptions are applied to Part III information requirements, Section 6.3 Cartridges disposal and treatment and Section 6.6 Information on product environmental characteristics to be provided by Signatories.

Environmental information about products can help to inform users purchasing decisions and decisions about how to best use products to reduce environmental impacts. To support these user processes, some voluntary environmental initiatives publish product data in a centralised location thereby facilitating easy access and availability at any time. The VA does not require that signatories provide the required information at any specific time during the compliance period. As such, signatories could choose to publish the required information on the last day of the year and still maintain their compliance status. The VA information provision requirements also do not cover all of the VA product requirements. That is, signatories are not under any obligation to publish data about how their products perform with respect to a range of the VA environmental requirements. This issue, combined with the lack of centralised publication and potentially delayed publication, means that users have no easy method of identifying which particular imaging equipment models meet the VA requirements.

5.1.5 Verification procedures for VA requirements

The Independent Inspector (hereafter "Inspector") is responsible for verifying the compliances with the VA requirements. The Inspector is a legal entity, a consulting firm, which is an independent third party designated by the Steering Committee. The VA specifies that *The Steering Committee shall engage the services of the Independent Inspector upon terms and conditions that shall require undertakings of confidentiality from the Independent Inspector, and which shall also set out any requirements or applicable mechanisms for a process of appeal, in case this is ever be necessary. The Commission shall have the right to veto the choice of the Independent Inspector*[300]. The costs are borne by the Secretariat of the Voluntary Agreement.

The Inspector is responsible for collecting and processing information supplied by Signatories pursuant to Section 7, Annex B and Annex C; determining a Signatory's compliance with the Agreement; and for the carrying out of audits.

The VA specifies that a maximum of two random audits per year can be financed by the Signatories and that a minimum of two audits should be performed. Till date, the audits have involved verification of documentation, product datasheets, guides and manuals, corporate information etc. No laboratory tests have yet been carried out.

Data reported by signatories to the Independent Inspector

The Inspector receives the VA Annex C data reported by signatories every year for the product model each puts on the market. For each of the model, the number of units shipped (sales) are given, therefore it enables the Inspector to assess sales-weighted compliance rates. The data to be reported for each model are the following:

For all products in scope:

- Product name
- Number of units shipped
- Product description, i.e. mono or colour, MFDs or non-MFDs
- Product introduced on/after 1st January 2012, 1st January 2014, or 1st January 2015
- Mono print speed (ipm)
- Self-declaration on meeting the VA commitments Part I (primary energy)
- Percentage of recycled plastic content (%)
- Self-declaration of meeting the VA commitments Part II (resource efficiency)
- Self-declaration of meeting the VA commitments Part III (information)

[300] From Section 7 of the VA.

- Indicating where non-compliance with Part II and III are excused by low volume exemption

TEC products:

- Measured TEC (kWh/week)
- ENERGY STAR version 2.0 limit for TEC (kWh/week) including adders
- Self-declaration on meeting auto duplex capability requirement or not
- Self-declaration on default auto duplex is enabled or not

For OM products:

- Measured sleep power (W)
- Printing/active mode power (W)
- Ready mode power (W)
- Off (standby) mode power
- ENERGY STAR version 2.0 sleep power allowance (W)
- Self-declaration on meeting the default delay time requirement or not

Verifying compliance with primary energy requirements

The Inspector essentially compiled the data and self-declarations from 11 signatories and calculated the compliance rates for Part I commitment primary energy requirement each year. According to the Inspector[301], no product testing is performed as part of the Independent Inspector's annual compliance reporting because the Independent Inspector does not have a mandate for doing so under the VA). The Inspector stated that ENERGY STAR registration provides an indication of compliance with the energy requirements. Up until expiration of the EU-US agreement on ENERGY STAR ON 20 February 2018, the Inspector had the access to the EU ENERGY STAR database via a website dedicated for the EU, enabling cross checking that values self-declared match with the dataset from ENERGY STAR. The self-regulation guidelines require that *The Independent Inspector should select, at random, an adequate number of products from different signatories for testing, preferably acquiring them from retailers in different Member States (physical or online shops)*[302].

It is important to note that whilst the VA currently relies on ENERGY STAR for energy efficiency performance metrics, it does not require that signatories detail exactly how products meet the ENERGY STAR specification limits. In contrast, when products are registered in the ENERGY STAR database, manufacturers are required to detail exactly how products

[301] Interview with Independent Inspector, RINA, September 2018.
[302] Section 3.6, header *Testing*

meet the ENERGY STAR specifications by providing technical product details used for calculating the compliance threshold level. The lack of detailed reporting in the VA becomes an issue when ENERGY STAR's additional energy allowances (i.e. extra energy allowances for defined product features) are applied in order to meet the ENERGY STAR specification limit because the possible application of allowances should not be reported to the Inspector. The issue concerns TEC products regarding an allowance for A3-capability and Wi-Fi allowance (the latter only in v3.0) and OM products regarding several sleep mode power allowances such as for interface, memory and power supply.

Without insight into which additional allowances have been applied it is not also possible to identify if a product definitely meets the ENERGY STAR specification. The Inspector is required – and specifically limited to – collecting the data as mandated in Annex C of the VA.

Control of compliance data and lack of transparency[303]

The annual compliance reports since 2015 published on the EuroVAprint's website contains a list of all products in scope for signatories indicating for each product's compliance with Part I, Part II and Part III, respectively, however, all manufacturer names and all model names and numbers are anonymised. As per VA Section 8.2 a Market Surveillance Authority may require at the Inspector qualification status of a specific model (yes/no) on a confidential basis. The Inspector is not allowed to disclose lists on the qualification status of signatories' product portfolio.

This means that it is not possible for a Market Surveillance Authority to get an overview of compliance status for marketed products and from this overview, select specific models to check. However, they can require qualification status of one or more specific models on a confidential basis and have thereby a possibility of performing verification of the models' qualification. For some MSAs, the confidential basis may be an issue for them to offer, see also below. Furthermore, the information provided can only be for products placed on the market between four and 16 months ago due to the VA reporting requirements, see Section 5.1.6. It is thereby not possible to require qualification status on a newly placed product on the market.

During the review study of the VA, the study team requested and obtained the randomised and anonymous Annex C data of all 11 signatories from the Independent Inspector, however it required signing a Non-Disclosure Agreement with the study team's legal entity, which prevents the team to share or publish any data obtained, else the Independent Inspector could not receive the permission from the Secretariat of VA to share the data.

[303] A stakeholder states that lack of transparency is evident and that this must be clarified in a possible new VA and that transparency will only be achieved through a legislative proposal and not via the VA.

This level of confidentiality requirement for acquiring data may discourage any Member State to carry out market surveillance on imaging equipment, additionally to the fact that they do not possess the same rights of authority as for Ecodesign regulations[304].

The self-regulation guidelines[305] point 3.5, heading *Access to data* states: *The self-regulation measure should include a requirement that the signatories provide, upon request, market surveillance authorities of the Member States responsible for ecodesign with specific documentation and information, to the extent this is not included in the documentation supplied with the products, to enable them to verify compliance with the requirements of the self-regulation measure, including through testing.* This section does not mention that the data may only be provided on a confidential basis and the Study Team therefore believes that the confidentiality condition may not be in line with the self-regulation guidelines. Furthermore, the Market Surveillance Authorities should have specific documentation and information on the products to enable them to verify compliance and not only information on the qualification status.

Due to the lack of transparency and of full access to the reported data and non-compliant models, verification of the VA primary energy requirements is more difficult for Market Surveillance Authorities (MSAs) compared to an ecodesign regulation.

Shortcomings of verification for resource and information requirements

For resource efficiency requirements and information requirements, the Inspector compiles and assesses relevant data provided by Signatories for annual compliance reporting purposes and conducts random audits in accordance with a VA Steering Committee-approved audit methodology. The audit methodology for the verification of compliance is detailed in the confidential document prepared by the Inspector[306]. The audit method largely echoes the method of inspecting technical documentation for verification of compliance with ecodesign and energy labelling requirements adopted by MSAs[307]. It is therefore considered widely accepted for these unquantifiable requirements. The documentation could include test reports, commercial materials, and internal policy documents etc. Upon receiving dissatisfactory documentation, there are 3 subsequent audit processes for the Inspector to pursue: interviewing in attempt to receive further information, product testing (only for

[304] RINA states that RINA's handling and provision of information as the Independent Inspector is bound by what is written in the VA, specifically: "The Independent Inspector shall be responsible for ensuring that confidentiality of the Signatory's identity and any data or information provided to it under or in relation to this agreement is maintained."
[305] The guidelines were published in November 2016 and the Commission should receive a proposal for revision of the VA measure aligned with the Guidelines as far as possible, at the latest in 2018.
[306] Imaging VA Audit Methodology version 1.0. Methodology for the auditing of Signatories to the "Industry Voluntary Agreement to Improve the Environmental Performance of Imaging Equipment Placed on the European Market Version 5.2". RINA. 2016.
[307] Danish MSA's experiences.

Part I and II) and site visits. Most audits never go beyond interviewing, as it was mentioned that the Inspector has not carried out any testing to date.

For some resource efficiency requirements, the documentation audit method may not be sufficient. For example, regarding the Part II section 5.4 commitment on not preventing the use of non-OEM cartridges, the Inspector searches online to find a non-OEM cartridge for sales for a model of imaging equipment. If there are non-OEM cartridges for sales for this model, it is deemed compliant with this requirement. The study team sees this as an indication of compliance. If more certainty should be achieved, tests of a number of non-OEM cartridges could be performed.

5.1.6 Operation of VA

There appear to be a number of issues with the way in which the VA is managed and operated in relation to verification of compliance, though some of these are regulated by the self-regulation guidelines. These issues are described in the following.

Compliance Reporting periods: Signatories to the VA have two months and two weeks after the end of the 12-month reporting period to provide the Independent Inspector with VA compliance reports according to VA Annex C. The self-regulation guidelines require this period to be maximum 2 months. The Independent Inspector will publish the Annual Compliance Reports by 30 April of each year covering products placed on the market during the previous full calendar year. Prior to this time neither the Independent Inspector nor Market Surveillance Authorities and any other stakeholder is made aware of which products signatories deems to be compliant with the VA. As such, it is not possible for any external stakeholder to question the verification status of any product until 4 months after the reporting period ends.

Allegation of Non-Compliance Process: The VA sets out a process for allegations of non-compliance. However, any external party wishing to raise an allegation of non-compliance must first deposit 4,000 EUR into an escrow account before the Independent Inspector will begin investigations. Whilst this fee is refunded if the allegation is upheld it is lost if either the Independent Inspector or the Steering Committee (Signatories and Commission) do not uphold the allegation and the third party shall also be responsible for additional costs incurred beyond the amount of the escrow. The Secretariat of EuroVAprint informed that

until now (May 2019) no party has entered this process. The study team believes that the fee requirement is not in line with the self-regulation guidelines point 3.5[308].

Steering Committee: Together the signatories and the Commission form the Steering Committee which is the co-ordinating and governing body of the VA. Meetings of the Steering Committee shall be open to observers from EU, EEA and EFTA Member States and permanent members of the Ecodesign Consultation Forum. The Steering Committee has the final say over any interpretation of potential non-compliances. Final decisions are based on voting rights with each signatory afforded a vote and the Commission afforded a vote. Only for the choice of the Independent Inspector, the Commission has the right to veto. Where final decisions are not unanimous, they can be passed by a two thirds majority. This means that the Commission's single vote does not provide much weight in final decisions. This decision-making is according to Self-Regulation Guidelines[309] point 3.5.

Monitoring and reporting: The Independent Inspector is charged with assessing the overall compliance rates for each signatory, with their findings published on the VA website. Whilst it is clear that the Independent Inspector is undertaking vigorous documentation checking, the Independent Inspector has not yet performed any product testing or any physical product inspection within the scope of its random auditing. Furthermore, the documentation checks are performed after the reporting period is over, which means theoretically up to almost 16 months after a certain product has been placed on the EU market before any monitoring and verification checks are being carried out.

5.1.7 Evaluation summary of the current VA

This subsection summarises the evaluation of the current VA in terms of effectiveness, the shortcomings of the current VA, and improvement potential and recommendations for a revised VA in the future.

Effectiveness of the VA

The VA signatories are in compliance with the VA targets for primary design requirements well before the required effective period and the VA can thereby been seen as effective in achieving these targets. The analysis of energy consumption of in scope imaging equipment revealed estimated energy savings to be or expected to be 4 TWh in 2015, 9.5 TWh in 2020 and 10 TWh in 2030 i.e. more than estimated in the Impact Assessment of the VA.

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[308] Extracts of point 3.5: *Complaints. The self-regulation measure should ensure that any party can submit, free of charge, substantiated allegations of possible non-compliance to the Independent Inspector. The Independent Inspector should evaluate these allegations and, where appropriate, follow-up by requesting information from the signatory concerned, by testing and/or by an inspection. The Independent Inspector should at each Steering Committee meeting provide an overview of all allegations submitted since the last meeting and, if it has not investigated any of them, provide its reasons for this.*

[309] COMMISSION RECOMMENDATION (EU) 2016/2125 of 30 November 2016 on guidelines for self-regulation measures concluded by industry under Directive 2009/125/EC of the European Parliament and of the Council

It is however not possible to quantify the amount of savings as result of the VA compared to other initiatives. The judgement is that the VA is and has been an effective additional policy measure for reducing the amount of non-ENERGY STAR compliant products entering the EU, but that US ENERGY STAR scheme supported by initiatives by the European Commission, by the Member States and by other schemes outside the EU is a major driver for the development of more energy efficient imaging equipment. With the cessation of the US-EU ENERGY STAR agreement in February 2018, the VA targets on ENERGY STAR penetration rates may become a more significant driver of energy efficiency in the EU.

According to the compliance report by Independent Inspector, the target compliance rates have been achieved each year since the start of Voluntary Agreement. See Figure 64 below for the first 5 periods up to the end of 2014. From 2015 to the end of 2017, the overall compliance rates are also well above 90%, higher than the target compliance rates.

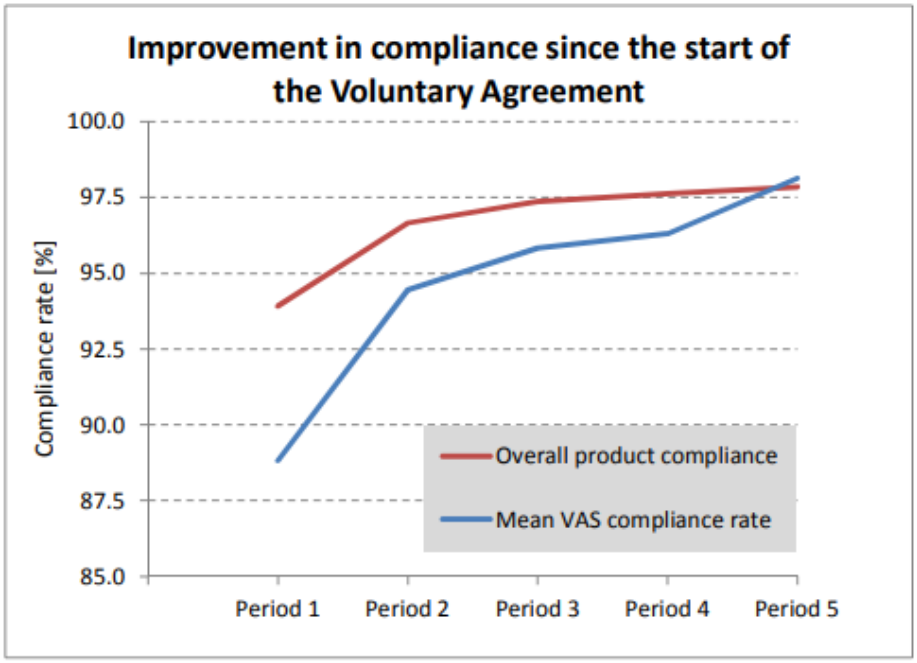

Figure 64: Period 1 (2011) – period 5 (2014) overall compliance rates and mean VA signatories' compliance rate[310]

However, it is inconclusive if the resource efficiency and information requirement have been effective, as contradictory descriptions of compliance have been expressed by signatories and the Independent Inspector on one hand and remanufacturers on another.

[310] http://www.eurovaprint.eu/fileadmin/eurovaprint_files/pdfs/REG0220001_EuroVAPrint-5th_period_repd1.1.pdf

Recommendations for improvements

There are a wide range of steps that could improve the effectiveness of a future VA to ensure that it delivers environmental savings beyond a business-as-usual scenario. These steps can be broken down into several key areas:

- **Product scope:** The current VA only covers a truncated version of the ENERGY STAR v2.0 scope. The scope of the VA could be extended to match the ENERGY STAR v3.0 scope, or beyond, to ensure that environmental improvements are stimulated in all types of commonly used imaging equipment.
- **VA information requirements:** The current VA requires that signatories publish some environmental information about their products. However, the VA requirements fail to ensure that users can easily access data on energy consumption and information that addresses each of the VA requirements for each specific model in the VA scope. It is recommended that information requirements will include this information for each model. A central source of information for any in scope models placed on the EU market would provide additional significant benefits for consumers and a range of stakeholders.
- **VA resource efficiency requirements:** The level of ambition in the current VA is weak in comparison to other voluntary environmental initiatives. Large numbers of product registrations to some of the other more ambitious environmental initiatives suggests that the VA may not be delivering savings beyond a business as usual scenario. To combat this issue, the VA should include a wider range of requirements addressing each environmental impact area associated with imaging equipment.
- **Compliance with the self-regulation guidelines**: The VA should be updated to be in line with the guidelines specifically on these points:
    - Signatories should report the compliance data and information for their products within 2 months after the end of the reporting period
    - The deposit and possible fee for allegation of Non-Compliance should be removed
    - Market Surveillance Authorities should have access to specific documentation and information to enable them to verify compliance with the requirements of the self-regulation measure, including through testing and without this being on a confidential basis
    - The Independent Inspector should select, at random, an adequate number of products from different signatories for testing, preferably acquiring them from retailers in different Member States (physical or online shops)
- **Additional coverage targets**: The current VA includes targeted ENERGY STAR compliance rates. This allows the signatories to increase the share of ENERGY STAR qualified models in their product portfolios over time, rather than needing to ensure

that all models meet ENERGY STAR requirements from the outset. This approach could be extended to compliance against other resources efficiency requirements where 100% compliance could not be expected from the start. For example, manufacturers could be required to ensure that a certain percentage of products meet ambition levels of post-consumer recycled content in their products. This would allow the manufacturers some flexibility which ensuring that there were stretch goals on non-energy in use environmental design features.

- **Wording of VA requirements:** Some of the VA requirements are ambiguous, and so open to interpretation. For example, the VA 5.4 criteria, which address remanufactured consumables, includes an exemption for innovation, development or improvements in design or functionality of the products or consumables cartridges that may inadvertently impact remanufactured consumables. This exemption causes some ambiguity in that whilst a particular technical feature may result in the limited the use of non-OEM cartridges, or prevent a cartridge from being reused or recycled, a signatory could suggest that the technical feature was included because of reasons related to "innovation", "development" or "improvements" in the design or functionality of the imaging equipment products or cartridges.
- **Product information for compliance verification:** The VA currently relies on ENERGY STAR for energy efficiency performance metrics. However, the VA does not require that signatories detail exactly how products meet the ENERGY STAR specification limits. In contrast, when products are registered in the ENERGY STAR database, manufacturers are required to detail exactly how products meet the ENERGY STAR specifications. The lack of detailed reporting in the VA becomes an issue when ENERGY STAR's additional energy allowances (i.e. extra energy allowances for defined product features) are applied in order to meet the ENERGY STAR specification limit. Without insight into which additional allowances have been applied it is not also possible to identify if a product does meet the ENERGY STAR specification.
- **More transparency**: A higher level of transparency is generally recommended. In addition to what is mentioned above, it is recommended to publish information on audit methodology; a more detailed compliance report with description of the types of documentation received and actions taken in case of dissatisfactory documentation.

5.2 Product specific inputs for environmental impact assessment

In accordance with the MEErP methodology task 5 identifies the relevant base cases and quantifies the current baselines in terms of economic and environmental impact for each of the base cases. The economic impact is calculated as the life cycle costs of products for

the end-user, while the environmental impact is quantified in terms of energy and resource aspects. The inputs for the calculations consist of the data presented in the previous tasks.

The calculations are performed with the ErP EcoReport tool, which is an Excel sheet developed specifically to aid in the impact analysis of Energy-related Products[311]. All calculations in this task are based on the year 2018, which is the latest year with sufficient available data. The EcoReport tool includes a range of background data for calculating impacts of different materials, distribution, and disposal methods.

The calculations in EcoReport tool are made for each of the following base cases identified for the purpose of this study:

- BC 1 – Mono Laser MFD
- BC 2 – Colour Laser MFD
- BC 3 – Mono Laser printer
- BC 4 – Colour Laser Printer
- BC 5 – Colour Inkjet MFD
- BC 6 – Colour Inkjet Printer
- BC 7 – Professional printer/MFD

In addition, the impacts of ink and toner consumables are also calculated separately in the EcoReport tool.

5.2.1 Inputs for baseline calculations

The inputs needed from the previous tasks to establish a baseline scenario for each base case, is summarised in the following.

Sales, stock and economic base data is all found in task 2 and is summarised in in Table 95.

[311] https://ec.europa.eu/growth/industry/sustainability/ecodesign_en

Table 95: Base case economic and market data for EcoReport, from task 2 to task 4.

Description	Unit	From section
Product Life	years	Task 2, Section 2.2.1
Annual sales	mln. Units/year	Task 2, Section 2.2.1
EU Stock	mln. Units	Task 2, Section 2.2.1
Product price	€ / unit	Task 2, Section 2.4.3
Electricity rate	€ / kWh	Task 2, Section 2.4.5
Repair and maintenance costs	€ / unit	Task 2, Section 2.4.6
Discount rate (interest minus inflation)	%	Task 2, Section 2.4.1
Escalation rate (projected annual growth of running costs)	%	Task 2, Section 2.4.1
Present Worth Factor (PWF)	(years)	Automatically calculated in EcoReport

The present worth factor is automatically calculated by the EcoReport tool using the following formula:

$$PWF = \{1 - 1/(1 + r)^N \}/r$$

Where:

- *N* is the product life
- *r* is the discount rate minus the growth rate of running cost components (e.g. energy and water rates)

The energy consumption inputs are derived from task 3 (section 3.1.1). The derived average energy consumption for each base case 2018 is shown in Table 96.

Table 96: Average annual energy consumption for each base case in 2018 (in BAU scenario).

Description	Annual energy consumption [kWh/year]
BC 1 Mono Laser MFD	78.80
BC 2 Colour Laser MFD	92.00
BC 3 Mono Laser printer	71.10
BC 4 Colour Laser Printer	109.90
BC 5 Colour Inkjet MFD	5.90
BC 6 Colour Inkjet Printer	1.70
BC 7 Professional printer/MFD	664.00

When products are manufactured a considerable amount of energy is used to mine the raw materials, produce them and manufacture the final product. This is referred to as 'embedded energy' in many cases. Some of this energy can be recovered at End of Life (EOL) when products are either reused, recycled, or incinerated for energy production. When products are landfilled, part of this energy is lost, except for that recovered in the form of methane emissions when the landfills are closed. EcoReport tool quantifies this energy, as well as the energy used during the distribution and electricity used by the products and the energy used to collect them and treat them at their End-of-Life (EoL). EcoReport tool calls this 'Total Energy (GER[312])' which we refer to as Primary Energy Demand in the following reports to align with the common terminology used for LCAs. The quantification of Primary Energy Demand has been done by using the EcoReport tools without modification.

The needed inputs to calculate the environmental impacts are presented in Table 97.

Table 97: Inputs to calculate the environmental impacts and where they are presented

Description	Presented in section
The material composition and weight of the materials for the different base cases	Task 4, section 4.2.1
The distribution phase and values used in the EcoReport tool - Volume of package during transportation.	Below in this section
Spare parts weight	Task 3, section 3.4.3
Share and weight of materials send to re-use, recycling, incineration and landfill at End of life	Task 4, section 4.2.2

The manufacturing process is assumed to be negligible or at least small compared to other impacts, which also was the case in the preparatory study. Furthermore, it is not possible to add or adjust values for the manufacturing process itself.

Based on the dimensions of the base cases, and inputs provided by stakeholders, the average package volumes used in the EcoReport Tool are given in the table below.

[312] Gross Energy Requirements

Table 98: Base cases and consumables package volume

Description	Package volume, m^3
BC 1 Mono Laser MFD	0.51
BC 2 Colour Laser MFD	0.44
BC 3 Mono Laser printer	0.08
BC 4 Colour Laser Printer	0.24
BC 5 Colour Inkjet MFD	0.05
BC 6 Colour Inkjet Printer	0.07
BC 7 Professional printer/MFD	3.25
Ink cartridges	0.0005
Ink containers	0.0002
Toner cartridges	0.0067
Toner containers	0.0012

5.2.2 Methodology for base cases environmental impact assessment

The methodology for this review study is important as it deviates slightly from the MEErP from Task 5 onwards, where we utilise the environmental impact assessment at product level from EcoReport Tool results to model scenarios for the whole EU-28 and yearly impacts. In this subsection, a brief introduction to how the Business-as-usual scenario is modelled from the base cases identified.

See Figure 65 for the outline of the calculation method. All the inputs specified above come from previous tasks, exiting literature, desk research as well as stakeholder consultation. These inputs e.g. BOM, energy consumption, reuse and recycling rates for each base case are inserted into EcoReport tool. The same types of inputs for consumables (i.e. ink and toner cartridges and containers) are also inserted, however these impacts from consumables are included in each base case during the use phase. The results from EcoReport Tool shows the total life cycle materials consumption, primary energy demand, GWP and other environmental impacts for each base case. These impacts are then linked with the stock model where annual sales, stock in use and annual discarded products are segregated, to obtain the total EU-28 environmental impacts per category.

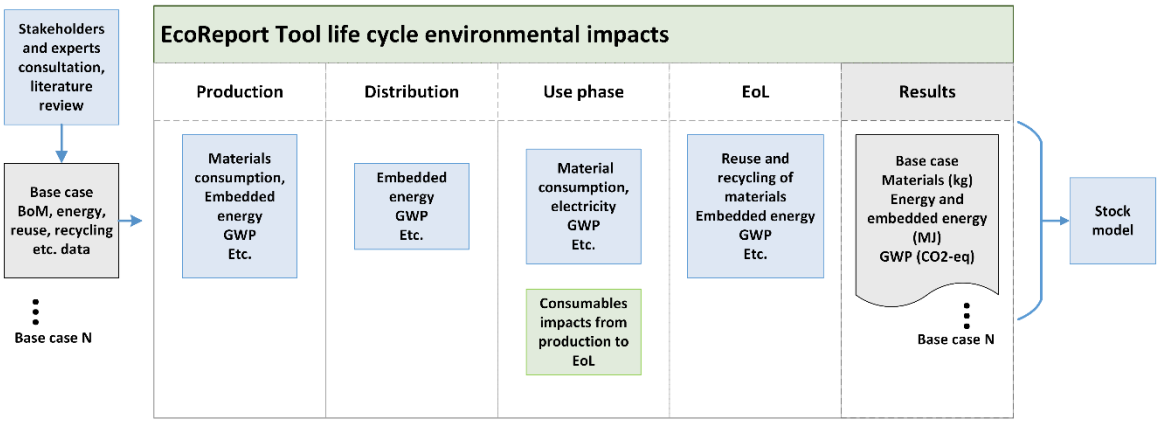

Figure 65: Method for calculating BAU life cycle environmental impacts at product and EU level

5.3 Base case environmental impact assessment

For each base case the following environmental and economic impacts are calculated:

- Life cycle Impacts per product over its lifetime – individual product per base case, showing only primary energy and CO_2-eq. emissions (i.e. Greenhouse Gas emissions) in the next sections
- Impacts of all imaging equipment in EU-28 stock as the baseline scenario (BAU)

The environmental impacts are divided into four different life cycle phases[313]:

- The **production phase**: In this phase the weight of the materials is multiplied with the LCA Unit Indicators[314] so the impacts of using the different materials can be calculated. It includes manufacturing which describes the (OEM) manufacturing of metals and plastics materials.
- The **distribution phase**: This phase covers all distributing activities from OEM components to the final customer.
- The **use phase**: For the use phase, the average product life in years and the annual energy consumption are multiplied with each other to calculate the energy consumption during the whole lifetime.
- The disposal and reuse and recycling in the **end-of-life phase**: These deal with the impacts of end-of-life. In the reuse and recycling phase, the reuse of whole products and recycling of the different materials are credited, and a negative value can appear (due to avoiding the production of new materials).

[313] The lifetime and the life cycle are different parameters. However, the lifetime of imaging equipment products is included in the use phase of the life cycle
[314] see MEErP 2011 Methodology, Part 2

Besides primary energy and greenhouse gas emissions, other impacts are calculated in the EcoReport Tool. The focus of the following assessments is only on these two impact categories.

The EcoReport tool presents the life cycle environmental impacts in fifteen different categories. Total energy (i.e. Primary Energy Demand) and Greenhouse Gas emissions are the most common categories assessed in Ecodesign studies. Other environmental impact categories reported by the EcoReport tool present high uncertainties or inconsistencies in their interpretation, which prevents their more widely application for policy-making. For example, the amount of water consumption for cooling or process water was not yet harmonized by the time of developing the EcoReport tool (2011), so large uncertainties in the results may exist. Environmental impact indicators related to water consumption have been harmonised in ISO standards but are now calculated as water footprint[315]. Also, some other environmental impact categories have been harmonised further such as acidification and eutrophication, where the reference units recommended by the European Commission's Product Environmental Footprint (PEF)[316] are different to those reported in the EcoReport tool.

In order to represent the total amount of energy being used throughout the whole imaging equipment products' life cycle, Primary Energy Demand has been selected as main indicator. This environmental impact category presents usually similar trends as Greenhouse Gas emissions.

All the impacts over the product life cycle are presented in Annex B – Impacts over a lifetime calculated in the EcoReport Tool for the different base cases.

5.3.1 Imaging equipment

The primary energy demand and emission of CO_2-eq in the different life phases of imaging equipment are presented in Table 99 to

Table 100. Note that the life cycle phase with the highest impact is marked with red, and the life cycle phase with the lowest impact is marked with blue.

[315] https://www.iso.org/standard/43263.html
[316] COMMISSION RECOMMENDATION of 9 April 2013 on the use of common methods to measure and communicate the life cycle environmental performance of products and organisations (2013/179/EU). Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32013H0179

Table 99: Primary energy demand in the different life cycle phases of imaging equipment. Red: Highest impact. Blue: Lowest impact.

Product	Production MJ	Distribution MJ	Use MJ	Disposal MJ	Recycling MJ	Total MJ
BC 1 Mono Laser MFD	14,007	722	4,384	124	-4,009	15,229
BC 2 Colour Laser MFD	18,200	644	5,140	164	-5,531	18,617
BC 3 Mono Laser printer	4,511	203	3,242	40	-1,330	6,667
BC 4 Colour Laser Printer	9,467	399	6,024	85	-2,848	13,127
BC 5 Colour Inkjet MFD	1,908	172	283	16	-528	1,851
BC 6 Colour Inkjet Printer	849	195	84	7	-212	923
BC 7 Professional printer/MFD	29,013	4,009	36,110	242	-7,347	62,028

Table 100: Emission of CO_2-eq in the different life cycle phases of imaging equipment Red: Highest impact. Blue: Lowest impact.

Product	Production Kg CO_2-eq	Distribution Kg CO_2-eq	Use Kg CO_2-eq	Disposal Kg CO_2-eq	Recycling Kg CO_2-eq	Total Kg CO_2-eq
BC 1 Mono Laser MFD	775	47	189	1	-225	787
BC 2 Colour Laser MFD	1,027	42	222	1	-315	977
BC 3 Mono Laser printer	247	14	139	0	-74	326
BC 4 Colour Laser Printer	524	27	258	0	-159	650
BC 5 Colour Inkjet MFD	101	12	12	0	-28	97
BC 6 Colour Inkjet Printer	44	14	4	0	-11	51
BC 7 Professional printer/MFD	1,660	255	1,545	1	-429	3,032

The primary energy demand in the use phase of all imaging equipment has decreased over the past years due to the voluntary agreement, ENERGY STAR and the standby regulation. For most energy consuming products, the use phase imposes the greatest primary energy demand in the life cycle. This is only true for professional equipment where 58% of the total energy consumption appears in the use phase (only electricity consumption). For all other base cases the production phase is responsible for at least 68% of the environmental impacts. This is due to a relatively low electricity consumption in the use phase, a short lifetime, and a high content of electronics and other materials with high embedded energy.

The primary energy demand and greenhouse gas emissions are closely connected and there is a high correlation between the parameters. In the use phase there is a direct correlation between energy used and CO_2 emitted. For production, on the other hand, the primary energy demand and emitted CO_2 differs depending on the materials used. For imaging equipment, the use phase is responsible for between 7% and 51% (professional equipment) of the global warming potential (GWP) due to emission of greenhouse gasses.

Besides primary energy demand and the emission of CO_2-eq, other impacts are calculated in the EcoReport Tool. All the impacts over the life cycle are presented in Annex B – Impacts over a lifetime calculated in the EcoReport Tool. Here it can be seen that the production phase has the highest impact in 14 out of the 15 impact categories for base case 1 to base case 6. Compared with other products groups recently reviewed (vacuum cleaners[317], air conditioners[318], tumble driers[319] and local space heaters) it is rather unusual that the impacts imposed by the production phase is dominant in so many impact categories. Base case 7, however due to the still high electricity consumption during use phase, the impacts of use phase is almost as high as the production phase.

Besides the normal impact categories in the EcoReport Tool, the material consumption of the different base cases is calculated. The material consumption can be divided in different ways and could simply be an indication of the amount of materials in the different base cases. However, some of the materials are reused, recycled, incinerated (with or without heat recovery) or end on a landfill at end-of-life. Table 101 presents the share of the different material which are reused, recycled, incinerated or landfilled.

[317] https://www.review-vacuumcleaners.eu/
[318] https://www.eco-airconditioners.eu/
[319] https://www.review-tumbledriers.eu/

Table 101: Material consumption and how the different materials are handled end-of-life
Red: Highest impact. Blue: Lowest impact.

Product	Fraction	Reused (kg)	Recycling (kg)	Incineration (heat recovery) (kg)	Incineration (kg)	Landfill (kg)
BC 1 Mono Laser MFD	Plastics	482	15,417	4,818	2,168	1,204
	Ferro and non ferro	842	26,941	8,419	3,789	2,105
	Electronics	84	2,673	835	376	209
	Miscellaneous	438	14,002	2,297	1,094	4,047
BC 2 Colour Laser MFD	Plastics	433	13,862	4,332	1,949	1,083
	Ferro and non ferro	612	19,595	6,123	2,756	1,531
	Electronics	126	4,032	1,260	567	315
	Miscellaneous	192	6,160	1,011	481	1,780
BC 3 Mono Laser printer	Plastics	127	4,075	1,273	573	318
	Ferro and non ferro	99	3,157	987	444	247
	Electronics	29	939	293	132	73
	Miscellaneous	42	1,334	219	104	386
BC 4 Colour Laser Printer	Plastics	246	7,878	2,462	1,108	615
	Ferro and non ferro	176	5,643	1,763	794	441
	Electronics	66	2,115	661	297	165
	Miscellaneous	86	2,762	453	216	798
BC 5 Colour Inkjet MFD	Plastics	84	2,698	843	379	211
	Ferro and non ferro	28	900	281	126	70
	Electronics	11	363	113	51	28
	Miscellaneous	22	692	114	54	200
BC 6 Colour Inkjet Printer	Plastics	56	1,804	564	254	141
	Ferro and non ferro	21	676	211	95	53
	Electronics	3	111	35	16	9
	Miscellaneous	7	231	38	18	67
BC 7 Professional printer/MFD	Plastics	1,350	43,186	13,496	6,073	3,374
	Ferro and non ferro	5,900	188,807	59,002	26,551	14,751
	Electronics	101	3,245	1,014	456	254
	Miscellaneous	387	12,369	2,029	966	3,575

5.3.2 Ink and toner consumables

The primary energy demand and emissions of CO_2-eq in the different life phases of ink and toner consumables are presented in Table 102 and Table 103. Note that the life cycle phase with the highest impact is marked with red, and the life cycle phase with the lowest impact is marked with blue. The primary energy during use phase comes from the embedded energy in ink and toner used in the cartridges and containers.

Table 102: Primary energy in the different life cycle phases of consumables
Red: Highest impact. Blue: Lowest impact.

Product	Production MJ	Distribution MJ	Use MJ	Disposal MJ	Recycling MJ	Total MJ
Ink cartridges	6.4	0.7	6.0	0.2	-2.3	10.9
Ink containers	4.6	0.3	1.0	0.1	-0.8	5.3
Toner cartridges	81.9	8.8	9.0	1.0	-16.5	84.1
Toner containers	66.0	1.6	7.0	0.7	-13.3	62.0

Table 103: Emission of CO_2-eq in the different life cycle phases for consumables
Red: Highest impact. Blue: Lowest impact.

Product	Production Kg CO_2-eq	Distribution Kg CO_2-eq	Use Kg CO_2-eq	Disposal Kg CO_2-eq	Recycling Kg CO_2-eq	Total Kg CO_2-eq
Ink cartridges	0.3	0.0	0.2	0.0	-0.1	0.5
Ink containers	0.2	0.0	0.0	0.0	0.0	0.2
Toner cartridges	4.1	0.6	0.4	0.0	-0.9	4.2
Toner containers	3.5	0.1	0.3	0.0	-0.8	3.1

For ink and toner consumables the highest primary energy occurs in the production phase. In practice ink and toner have no primary energy demand in the use phase, however due to the modelling setup the embedded energy from the production of ink and toner has been allocated here. Not considering the use phase, the second highest primary energy demand occurs in the distribution phase. However, the impact of transportation is limited. The primary energy and greenhouse gas emissions are closely connected and there is a high correlation between the parameters. The primary energy and emitted CO_2-eq differs only a little depending on the materials used.

Besides primary energy and the emission of CO_2-eq, other impacts are calculated in the EcoReport Tool. All the impacts over the life cycle are presented in Annex B – Impacts over a lifetime calculated in the EcoReport Tool. Here it can be seen that the production phase has the highest impact in 15 out of the 15 impact categories for all ink and toner consumables.

5.3.3 Combined equipment and consumables

The combined impact of imaging and ink and toner consumables is presented in this section and consist of the impact of one equipment and the impact of all the ink and toner consumables used over a lifetime for each base case. The combined primary energy and emission of CO2-eq for imaging equipment and ink and toner consumables are presented in Figure 66 and Figure 67.

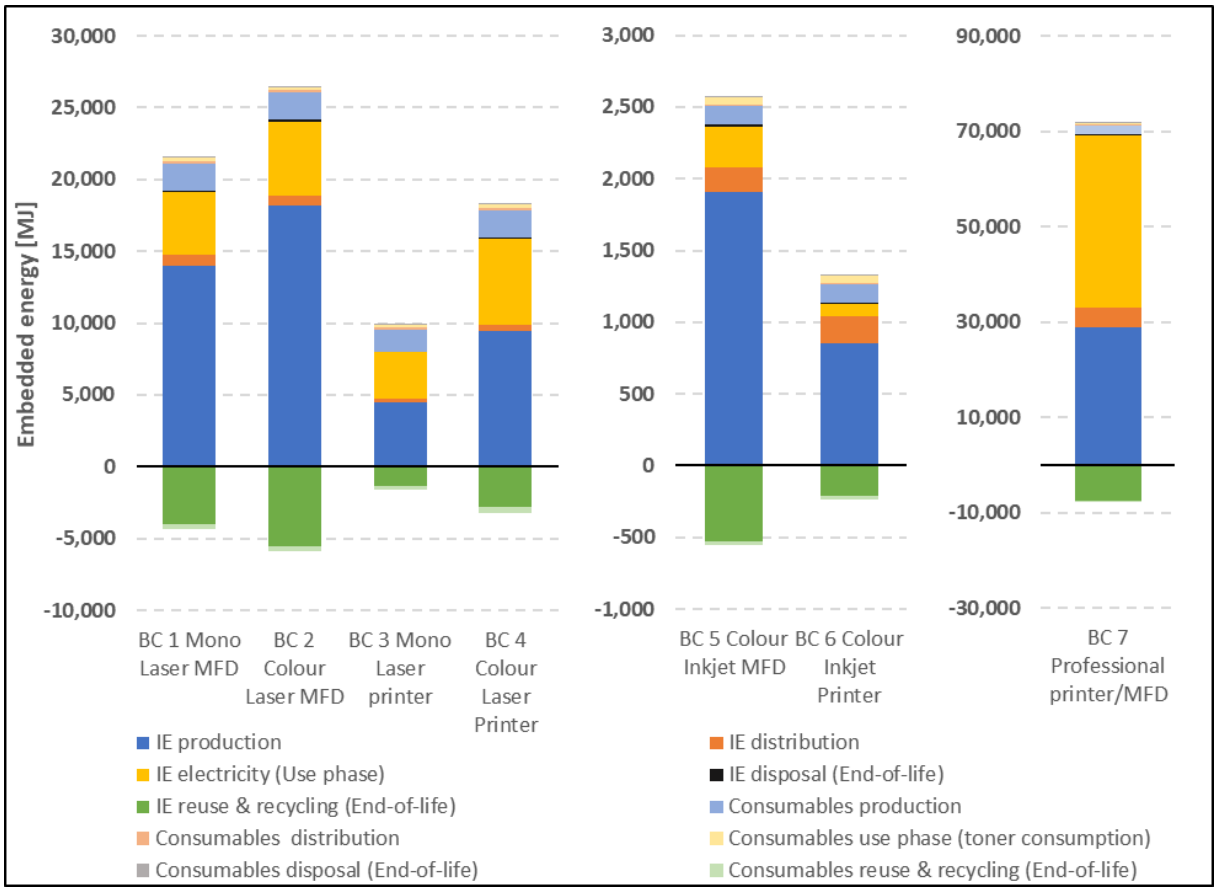

Figure 66: The combined primary energy of imaging equipment and ink and toner consumables for all 7 base cases. Please notice that the scale of the Y-axes is different.

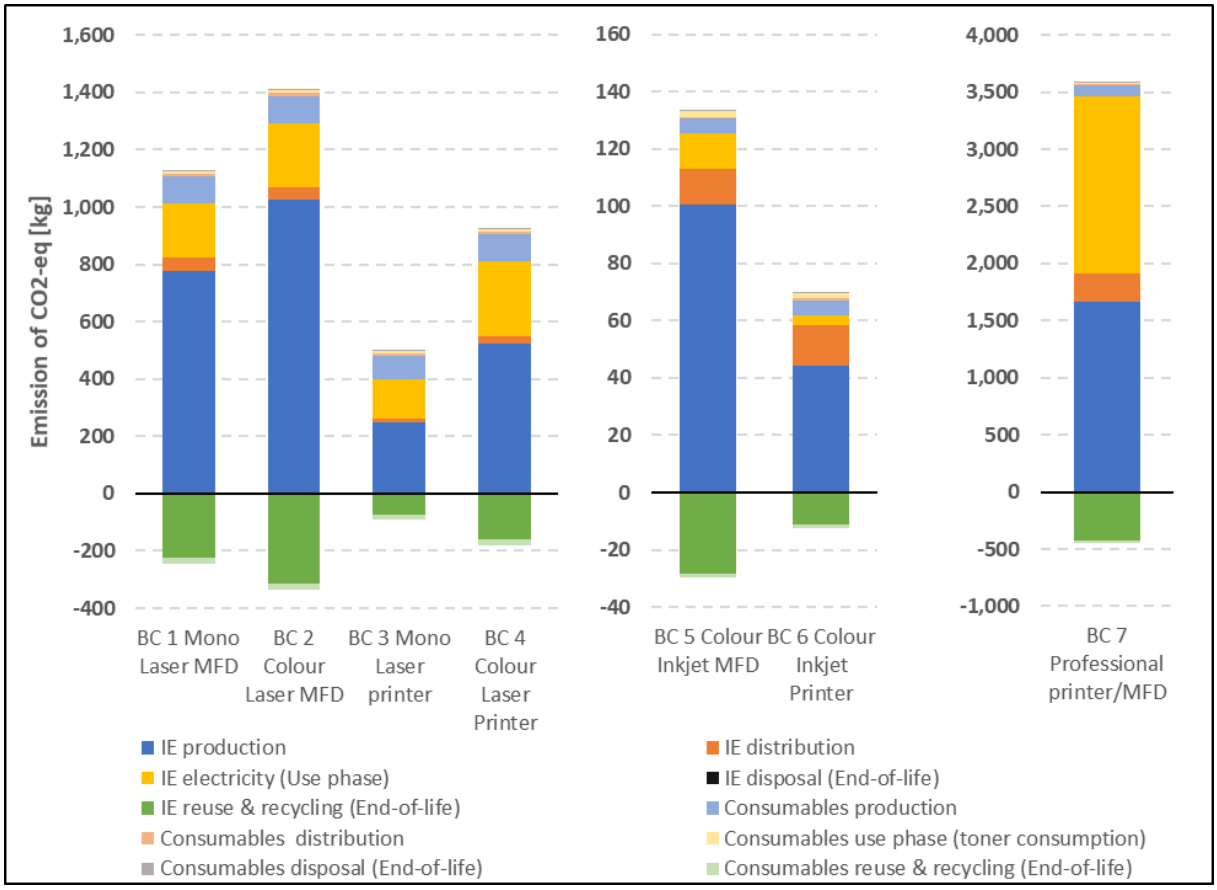

Figure 67: The combined emission of CO_2-eq from imaging equipment and ink and toner consumables for all 7 base cases. Please notice that the scale of the Y-axes is different.

The combined results clearly show that the electricity consumption has less impact than the production phase for BC1 to BC6. For BC7 the impact of production and the electricity consumption in the use phase are approximately on par. The impact of ink and toner consumables is the net impact. This means that for ink and toner consumables the reuse and recycling rates are already credited. Even with the current reuse and recycling rates of ink and toner consumables and equipment, the impacts credited back from reuse and recycling can offset the electricity consumption in the use phase for BC 1, 2, 5 and 6. The impacts of consumables in use phase is actually the third largest impact over th life cycle behind electricity consumption for BC 1 – 6. For BC7 the impact of the electricity consumption in the use phase is considerable higher than the impacts of consumables. Hence, the primary energy for professional equipment is still high.

5.4 EU total environmental impact assessment

The EU totals are the environmental impacts aggregated to EU level. For the EU totals the eEnvironmental impacts of imaging equipment (EU-28 stock) is calculated by multiplying the current stock with the impacts of each of the base cases.

The previous section showed that the production phase has the highest impacts regarding primary energy demand and emissions of CO_2-eq. Other categories are of course also important but assumed to have less overall environmental impact. In addition, the impact of ink and toner consumables is also visible and the third highest over life cycle after electricity consumption in the use phase. In Figure 68 and Figure 69, the primary energy demand and emission of CO_2-eq 2005-2030 for the different base cases and for ink and toner consumables are presented.

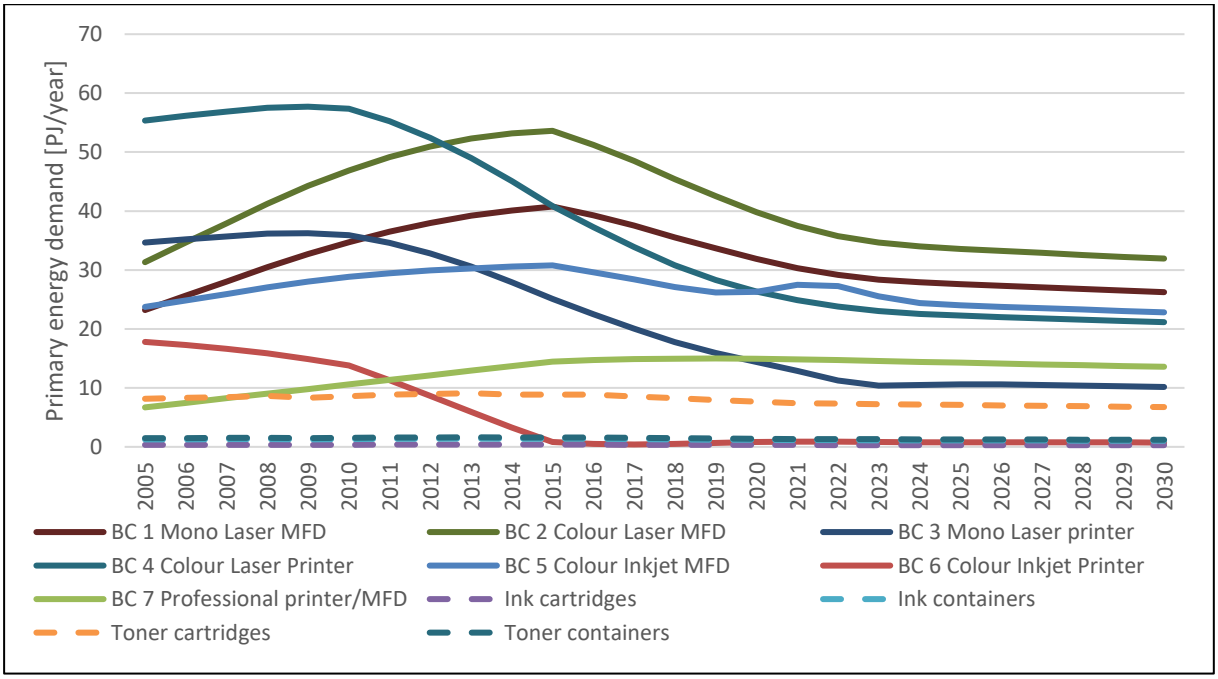

Figure 68: Development in primary energy demand for the different base cases and for ink and toner consumables.

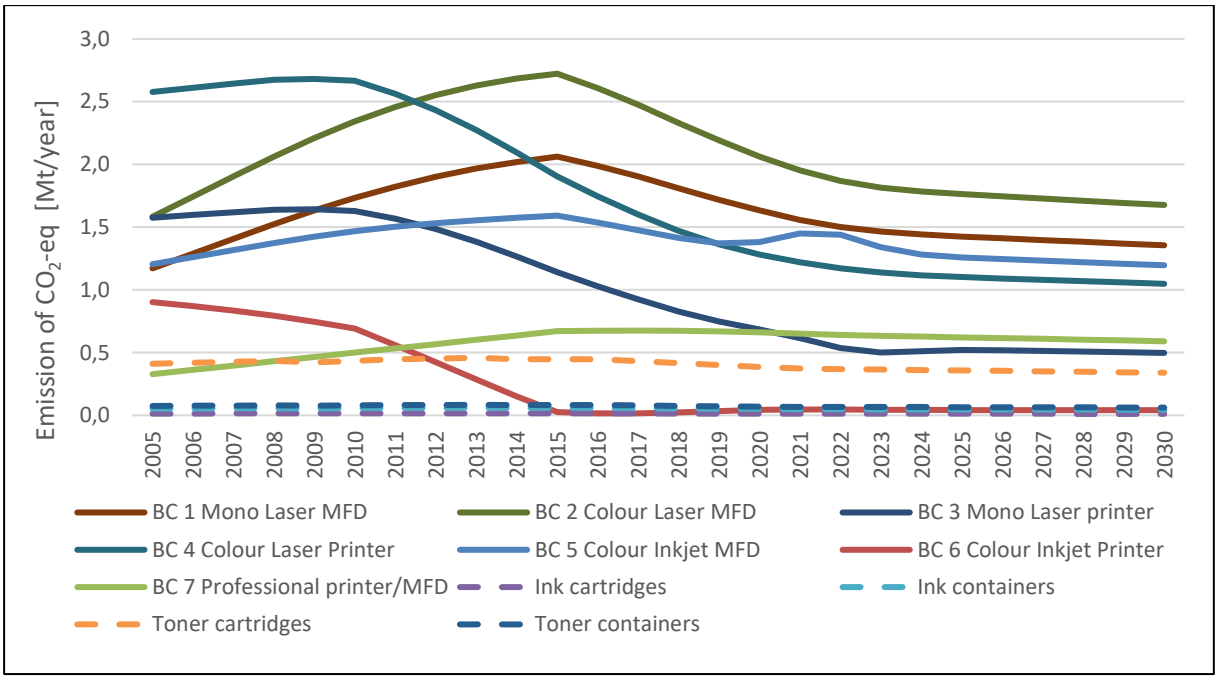

Figure 69: Development in emission of CO_2-eq for the different base cases and for ink and toner consumables.

From the figure it is visible that BC2 and BC1 have the highest primary energy demand and thus the highest emission of CO_2-eq from 2016. This is mostly due the high sales and weight of these base cases. BC7 has the lowest impact regarding primary energy demand and emission of CO_2-eq, which is due to low sales. However, it should still be noted that BC7 has the highest impact per product, as BC7 has a high content of material and a high energy consumption in the use phase. In Figure 70 and Figure 71 the combined impacts (primary energy demand and emission of CO_2-eq) of all base cases and all ink and toner consumables are presented.

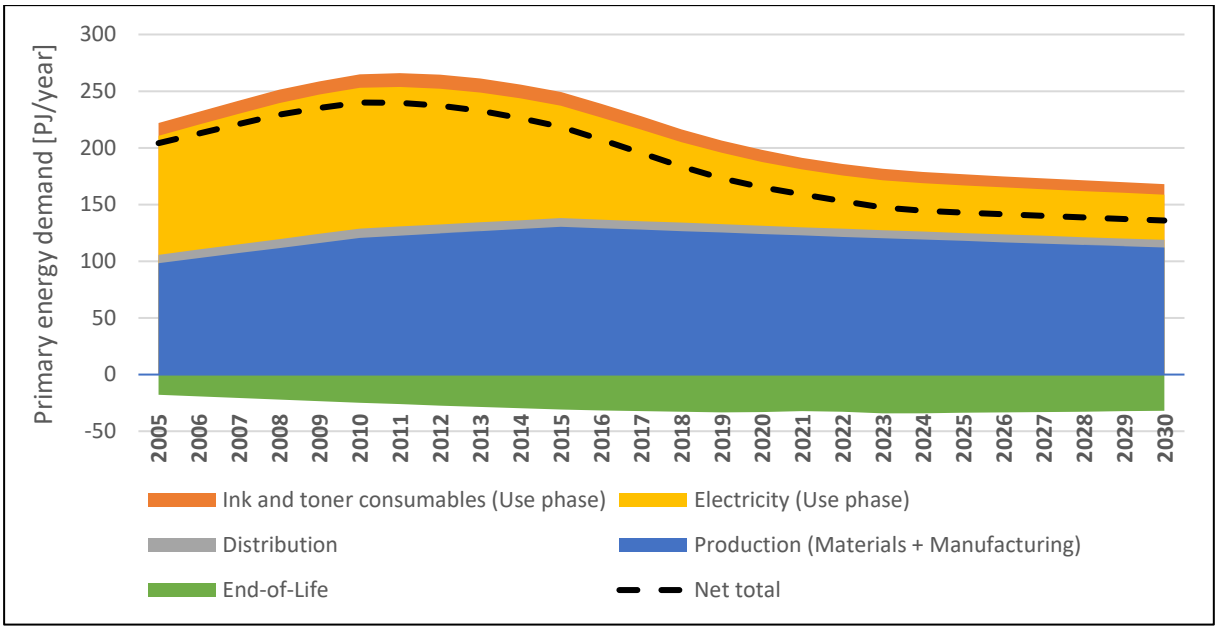

Figure 70: Combined primary energy demand of imaging equipment and ink and toner consumables.

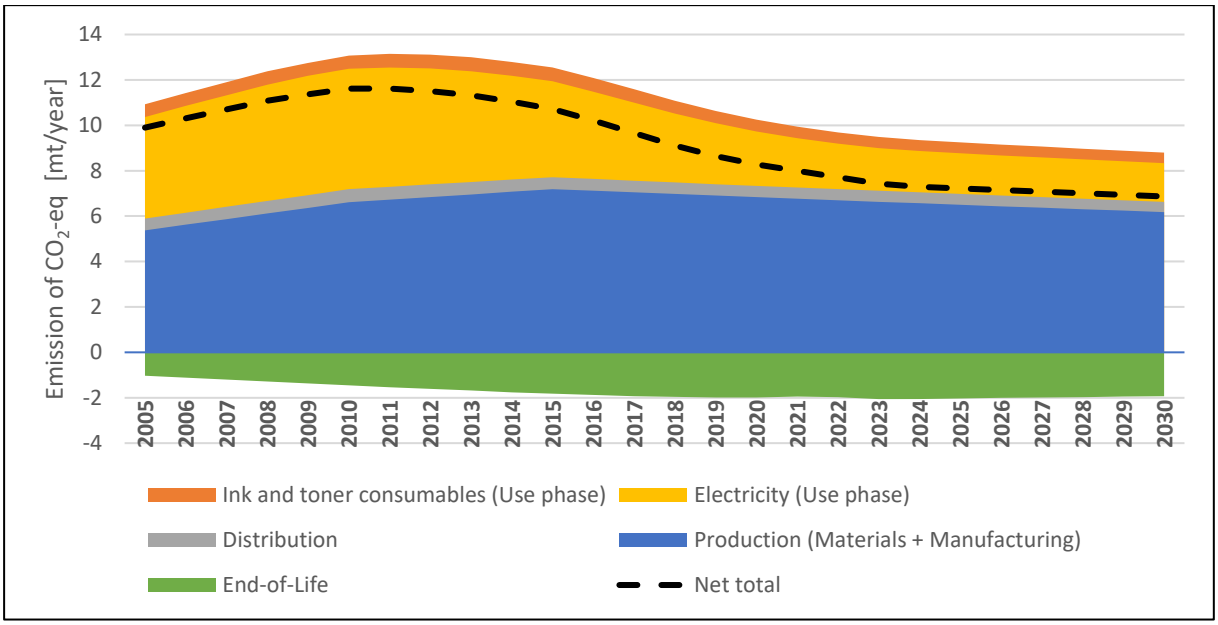

Figure 71: Combined emission of CO2-eq from imaging equipment and ink and toner consumables

Since 2010 the energy consumption and emission of CO_2-eq in the use phase are reduced while the impact in the production phase and impact imposed by ink and toner consumables have remained stable. This means that the greatest potential for further improvements may be connected with materials and ink and toner consumables. However, it should also be investigated if the energy consumption in the use phase can be reduced. In Figure 70 and Figure 71 the dotted line (net total) is the baseline scenario for further assessment in later tasks. The material consumption is also aggregated to EU level in Figure 72.

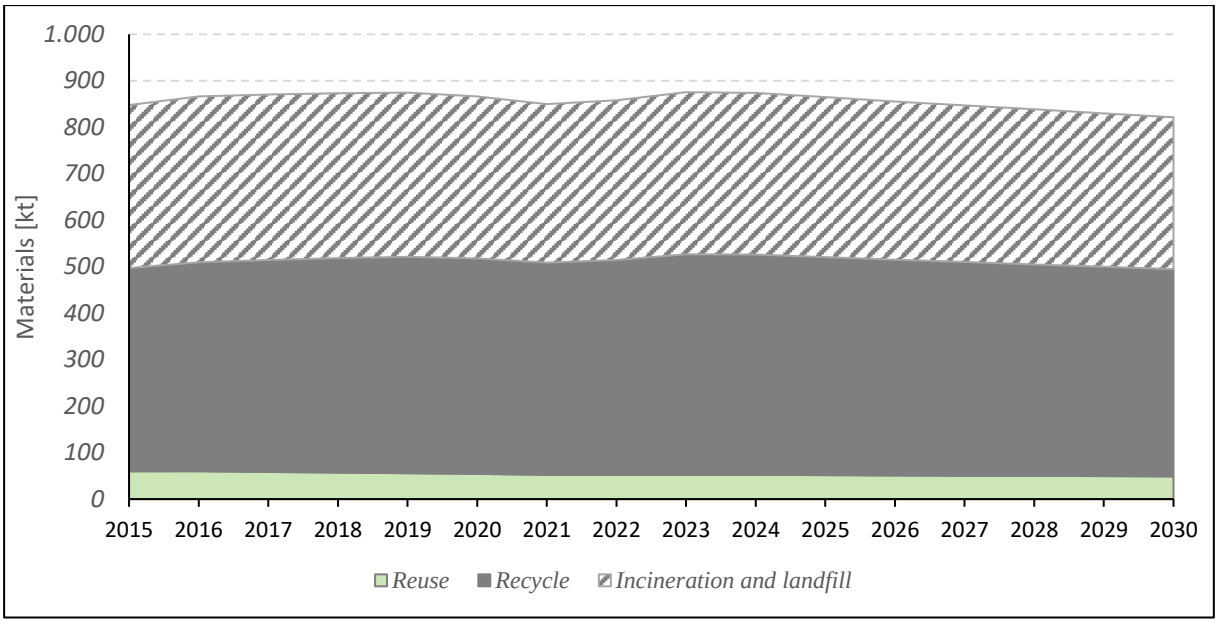

Figure 72: Aggregated material consumption of all base case and ink and toner consumables

5.5 Life cycle cost per product

Based on economic inputs, EcoReport automatically calculates the life cycle costs (LCC) with the following formula:

$$LCC = PP + PWF \times OE + EoL$$

Where:

- LCC is Life Cycle Costs
- PP is the purchase price of the imaging equipment
- OE is the operating expense and are the combined costs of electricity and the repair and maintenance.
- PWF (Present Worth Factor) is a formula described below and is based on the concept of time value of money.
- EoL is End of life costs (disposal costs, recycling charge) or benefit (resale), which are assumed to be negligible based on the analyses in section 2.4.7).

The purchase cost for individual ink and toner consumables are presented in Table 104. The purchase costs for OEM and non-OEM consumables are already presented in Task 2, and the OEM share of consumables also shown in Task 2 that is ca. 80% and 88% for ink and toner consumables, therefore weighting of 80% and 20% are applied to the OEM and non-OEM consumables to find the weighted average price per unit, the averaged prices are used in the LCC and the economic calculations. It is clear from the table that the purchase price of toner consumables is assumed to be considerable higher than the purchase price of ink consumables. The price per consumable is the average price of all cartridges, which

consist of a mixture of all-in-one cartridges with multiple colours and single colour cartridges/containers.

Table 104: Product price for ink and toner consumables in EUR

Product	OEM Product price [EUR/unit]	Non-OEM Product price [EUR/unit]	Weighted average [EUR/unit]
BC 1 Mono Laser MFD	140	59	**124**
BC 2 Colour Laser MFD	90	67	**85**
BC 3 Mono Laser printer	129	53	**114**
BC 4 Colour Laser Printer	130	61	**116**
BC 5 Colour Inkjet MFD	18	11	**17**
BC 6 Colour Inkjet Printer	27	4	**22**
BC 7 Professional printer/MFD	111	111	**111**

The life cycle cost including the purchase price (including installation), repair and maintenance cost, electricity and consumables cost is presented in Table 105.

Table 105: LCC for imaging equipment. Red: Highest impact. Blue: Lowest impact.

Product	Product price [EUR/unit]	Electricity [EUR]	Repair & maintenance [EUR]	Consumables [EUR]	Total [EUR]
BC 1 Mono Laser MFD	757	69	922	2,974	4,723
BC 2 Colour Laser MFD	4,800	81	2,169	2,041	9,091
BC 3 Mono Laser printer	456	53	229	2,274	3,012
BC 4 Colour Laser Printer	513	97	922	2,788	4,320
BC 5 Colour Inkjet MFD	58	4	0	413	475
BC 6 Colour Inkjet Printer	139	1	0	557	697
BC 7 Professional printer/MFD	61,395	585	3,226	2,668	67,874

For imaging equipment, the greatest cost is related to the consumables and the purchase cost or the repair and maintenance cost. This is quite unusual as the electricity cost often are dominant. This is due to low energy consumption in the use phase but relatively high costs of the consumables. The LCCs of imaging equipment are also presented in Figure 73.

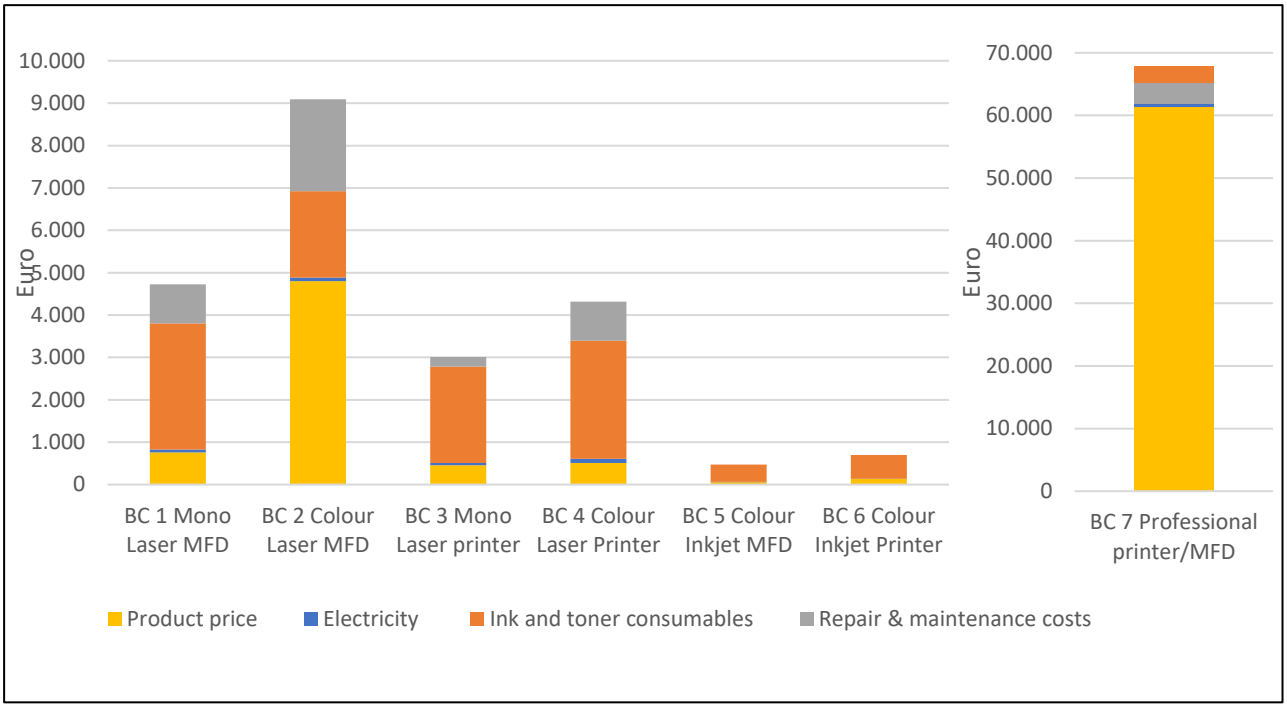

Figure 73: LCC per base cases including costs of consumables in use phase.
Note: The costs of ink and toner consumables for BC 7 are assumed to be higher than shown in the chart. See body text for explanation.

The LCC for imaging equipment and ink and toner consumables reveals that the majority of the costs for five of out seven base cases are connected with the purchase of ink and toner consumables. For all base cases the electricity cost only represents only a smaller share of the cost over a lifetime. The results are - with one exception for BC 7 - similar to the LCC calculation made in Task 2 with the outdated 2008 electricity consumption from the preparatory study. For BC 7 however, the number of consumables assumed in this assessment (same amount consumed for BC1–BC4) is considerably lower than the LCC in Task 2, this is done to balance the data for total EU sales of consumables. In reality, BC 7 is likely to consume many more than BC1–BC4. Due to uncertainty of the print volume and number of consumables used of lifetime, the assumption has been maintained.

5.6 End-user expenditure baseline

The life cycle cost for each of the base cases are also aggregated to EU level. For the EU totals the annual end-user expenditure in EU-28 is calculated based on the life cycle costs per product. The calculated price takes into account the efficiency of the products in stock (electricity/fuel price), annual repair and maintenance and the purchase price (including installation) multiplied with the annual sales. The annual end-user expenditures in EU-28 of all imaging equipment are presented in Figure 74.

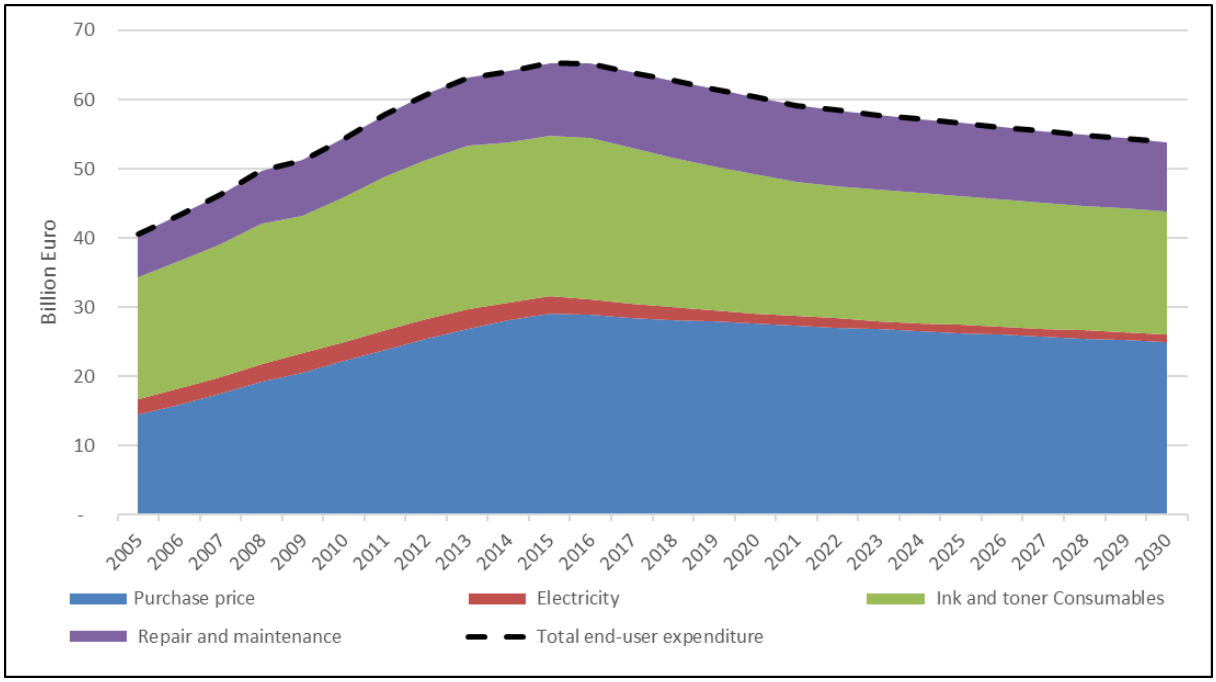

Figure 74: Annual end-user expenditure in EU

The total annual end-user expenditure amounts to above 60 billion EUR in 2018. Figure 74 shows that the annual end-user expenditure is decreasing which is caused by a combination of falling sales and higher efficiency (lower electricity consumption).

5.7 Conclusions and recommendations

The main recommendations and conclusions of the evaluation of the VA and the environmental impact assessment are summarised in this section.

5.7.1 Evaluation of the Voluntary Agreement on imaging equipment

The VA signatories are in compliance with the VA targets for primary design requirements well before the required effective period and the VA can thereby been seen as effective in achieving these targets. The analysis of energy consumption of in scope imaging equipment revealed estimated energy savings to be or expected to be 4 TWh in 2015, 9.5 TWh in 2020 and 10 TWh in 2030 i.e. more than estimated in the Impact Assessment of the VA. It is however not possible to quantify the amount of savings as result of the VA compared to other initiatives. The judgement is that the VA is and has been an effective additional policy measure for reducing the amount of non-ENERGY STAR compliant products entering the EU, but that US ENERGY STAR scheme supported by initiatives by the European Commission, by the Member States and by other schemes outside the EU is a major driver for the development of more energy efficient imaging equipment. With the cessation of the US-EU ENERGY STAR agreement in February 2018, the VA targets on ENERGY STAR penetration rates may become a more significant driver of energy efficiency in the EU.

It is more inconclusive if the resource efficiency and information requirement have been effective, as contradictory descriptions of compliance have been expressed by signatories and the Independent Inspector on one hand and remanufacturers on another.

Key recommendations include:

- Extension of the product scope to match ENERGY STAR v3.0 scope or beyond
- Publication of VA information requirements for each model
- Included a wider range of resource efficiency requirements
- Secure compliance with the self-regulation guidelines
- Additional coverage targets on non-energy in use environmental design features
- Improve wording of VA requirements to avoid ambiguity in interpretation
- Publish product data for compliance verification
- Increase transparency.

5.7.2 Impacts of imaging equipment and consumables

For imaging equipment, the production phase and the use of ink and toner consumables are the most dominant phases of the entire life cycle in terms of primary energy demand and emission of CO_2-eq. However, the distribution of the environmental impacts varies considerably between BC1 to BC6 and BC7. For BC7 the electricity consumption in the use phase is the most dominant in terms of primary energy and emission of CO_2-eq. The imaging equipment product group differs from most other IT product groups by having the production phase and consumption of consumables as the most dominant phases. This is due to relatively low electricity consumption in the use phase, short lifetime, high content of electronics and other materials with high embedded energy and needed use of consumables for the image creations.

It is difficult to quantify the importance of different impact categories, but the focus of this study has mainly been on primary energy demand (i.e. total energy in EcoReport tool) and emissions of CO_2-eq. The combined primary energy demand of imaging equipment is presented in Figure 75. This will provide the baseline (BAU scenario) for Task 7, where other proposed policy scenarios will be assessed against.

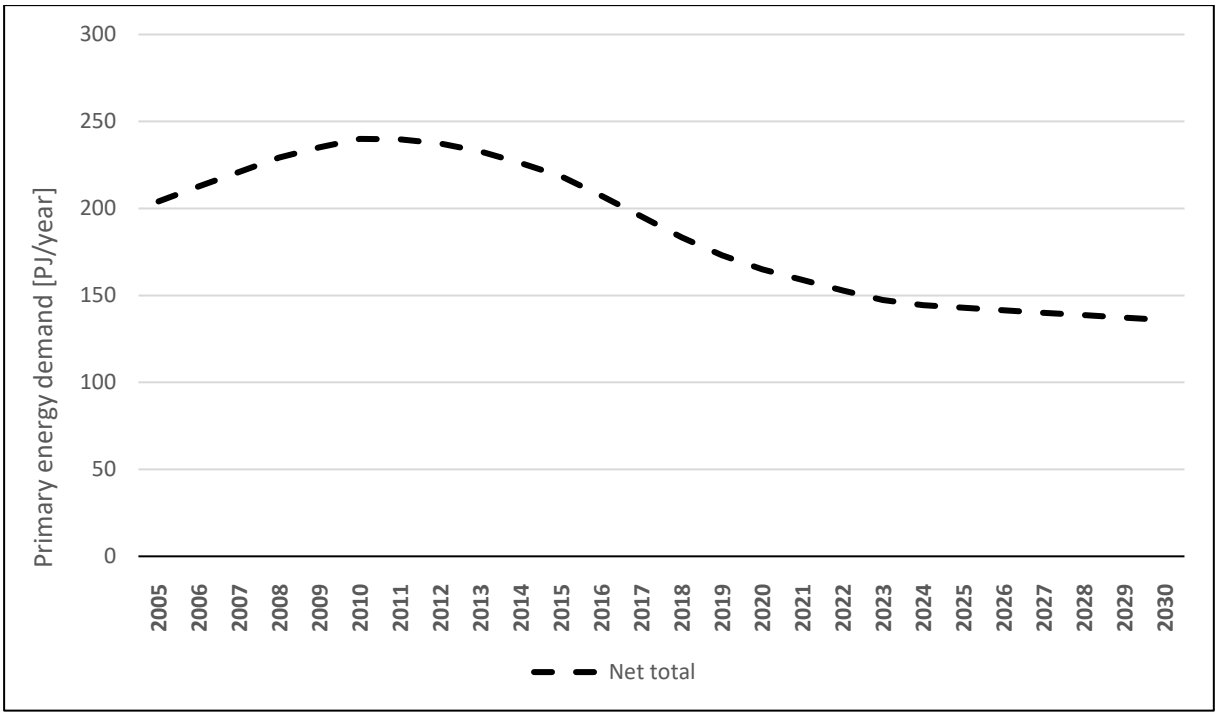

Figure 75: Combined primary energy demand of imaging equipment and ink and toner consumables for EU-28.

The combined primary energy of imaging equipment and consumables will account to above 150 PJ in 2018 resulting in 8 Mt CO2-eq emitted. The primary energy demand is expected to decrease due to falling sales and higher efficiencies.

The decrease in primary energy demand in the use phase has also an impact on the total end-user expenditure which are expected to decrease towards 2030.

The **life cycle costs assessment** also confirmed that the consumables account for the largest share for the majority of the base cases, with exceptions for BC 2 and BC7, out of which BC 2 could be skewed by stakeholder inputs for the very high purchase and repair and maintenance costs, and BC 7 is skewed by the low number of consumables assumed.

Annex B – Impacts over a lifetime calculated in the EcoReport Tool

All the impacts over a lifetime of imaging equipment base cases calculated in the EcoReport Tool in connection with Task 5 are presented in Table 106 to Table 112 for imaging equipment and in Table 113 to Table 116 for ink and toner consumables.

Imaging equipment

Table 106: All impact categories for BC 1 Mono Laser MFD. The life cycle phase with the highest impact for each of the categories is highlighted with red text.

	Production	Distribution	Use	Disposal	Recycling	Total
Other Resources & Waste						
Total Energy (MJ)	14,007	722	4,384	124	-4,009	15,229
of which, electricity (MJ)	8,731	1	4,336	0	-2,650	10,419
Water – process (litre)	2,265	0	23	0	-718	1,570
Water – cooling (litre)	4,874	0	235	0	-1,138	3,971
Waste, non-haz./landfill (g)	27,835	412	2,437	285	-7,102	23,867
Waste, hazardous/ incinerated (g)	705	8	74	0	-211	576
Emissions (Air)						
GWP100 (kg CO_2-eq)	775	47	189	1	-225	787
Acidification (g SO_2-eq.)	5,792	144	859	8	-1,744	5,059
VOC (g)	24	11	95	0	-8	122
Persistent Organic Pollutants (ng i-Teq)	297	2	13	0	-83	230
Heavy Metals (mg Ni eq.)	1,984	21	63	5	-643	1,430
PAHs (mg Ni eq.)	346	25	13	0	-105	280
Particulate Matter (g)	4,125	1,744	58	49	-1,311	4,665
Emissions (Water)						
Heavy Metals (mg Hg/20)	1,012	1	28	1	-315	726
Eutrophication (g PO_4)	33	0	1	1	-9	26

Table 107: All impact categories for BC 2 Colour Laser MFD. The life cycle phase with the highest impact for each of the categories is highlighted with red text.

	Production	Distribution	Use	Disposal	Recycling	Total
Other Resources & Waste						
Total Energy (MJ)	18,200	644	5,140	164	-5,531	18,617
of which, electricity (MJ)	12,367	1	5,086	0	-3,889	13,565
Water – process (litre)	3,051	0	30	0	-990	2,092
Water – cooling (litre)	4,711	0	265	0	-1,236	3,740
Waste, non-haz./landfill (g)	28,134	373	2,811	288	-7,640	23,966
Waste, hazardous/ incinerated (g)	925	7	88	0	-292	728
Emissions (Air)						
GWP100 (kg CO_2-eq)	1,027	42	222	1	-315	977
Acidification (g SO_2-eq.)	7,919	129	1,015	11	-2,472	6,602
VOC (g)	32	9	111	0	-11	143
Persistent Organic Pollutants (ng i-Teq)	250	2	14	0	-71	195
Heavy Metals (mg Ni eq.)	2,880	19	79	8	-941	2,045
PAHs (mg Ni eq.)	428	22	16	0	-134	332
Particulate Matter (g)	5,703	1,521	77	69	-1,848	5,522
Emissions (Water)						
Heavy Metals (mg Hg/20)	1,454	1	36	1	-463	1,029
Eutrophication (g PO_4)	41	0	1	2	-12	32

Table 108: All impact categories for BC 3 Mono Laser printer. The life cycle phase with the highest impact for each of the categories is highlighted with red text.

	Production	Distribution	Use	Disposal	Recycling	Total
Other Resources & Waste						
Total Energy (MJ)	4,511	203	3,242	40	-1,330	6,667
of which, electricity (MJ)	2,937	0	3,227	0	-911	5,253
Water – process (litre)	722	0	7	0	-231	498
Water – cooling (litre)	1,449	0	156	0	-346	1,258
Waste, non-haz./landfill (g)	6,364	153	1,704	63	-1,664	6,620
Waste, hazardous/ incinerated (g)	230	3	53	0	-70	216
Emissions (Air)						
GWP100 (kg CO_2-eq)	247	14	139	0	-74	326
Acidification (g SO_2-eq.)	1,813	43	622	2	-560	1,921
VOC (g)	7	2	72	0	-2	78
Persistent Organic Pollutants (ng i-Teq)	46	1	8	0	-13	41
Heavy Metals (mg Ni eq.)	654	8	39	2	-214	488
PAHs (mg Ni eq.)	107	6	9	0	-33	88
Particulate Matter (g)	1,311	265	26	16	-424	1,193
Emissions (Water)						
Heavy Metals (mg Hg/20)	278	0	17	0	-88	206
Eutrophication (g PO_4)	14	0	1	1	-4	11

Table 109: All impact categories for BC 4 Colour Laser Printer. The life cycle phase with the highest impact for each of the categories is highlighted with red text.

	Production	Distribution	Use	Disposal	Recycling	Total
Other Resources & Waste						
Total Energy (MJ)	9,467	399	6,024	85	-2,848	13,127
of which, electricity (MJ)	6,488	1	5,996	0	-2,034	10,451
Water – process (litre)	1,586	0	16	0	-512	1,089
Water – cooling (litre)	2,532	0	288	0	-620	2,200
Waste, non-haz./landfill (g)	12,776	250	3,169	127	-3,419	12,904
Waste, hazardous/ incinerated (g)	481	5	98	0	-149	436
Emissions (Air)						
GWP100 (kg CO_2-eq)	524	27	258	0	-159	650
Acidification (g SO_2-eq.)	3,878	81	1,158	5	-1,214	3,909
VOC (g)	16	5	133	0	-5	149
Persistent Organic Pollutants (ng i-Teq)	90	1	15	0	-26	80
Heavy Metals (mg Ni eq.)	1,452	13	74	4	-477	1,065
PAHs (mg Ni eq.)	231	13	16	0	-72	189
Particulate Matter (g)	2,901	823	53	35	-943	2,867
Emissions (Water)						
Heavy Metals (mg Hg/20)	612	0	32	0	-197	447
Eutrophication (g PO_4)	20	0	1	1	-6	16

Table 110: All impact categories for BC 5 Colour Inkjet MFD. The life cycle phase with the highest impact for each of the categories is highlighted with red text.

	Production	Distribution	Use	Disposal	Recycling	Total
Other Resources & Waste						
Total Energy (MJ)	1,908	172	283	16	-528	1,851
of which, electricity (MJ)	1,181	0	276	0	-352	1,105
Water – process (litre)	294	0	3	0	-92	204
Water – cooling (litre)	795	0	19	0	-172	642
Waste, non-haz./landfill (g)	2,603	137	157	24	-611	2,310
Waste, hazardous/ incinerated (g)	102	3	5	0	-29	81
Emissions (Air)						
GWP100 (kg CO_2-eq)	101	12	12	0	-28	97
Acidification (g SO_2-eq.)	722	37	57	1	-215	601
VOC (g)	3	1	6	0	-1	9
Persistent Organic Pollutants (ng i-Teq)	15	1	1	0	-4	12
Heavy Metals (mg Ni eq.)	249	7	5	1	-82	180
PAHs (mg Ni eq.)	43	5	1	0	-13	36
Particulate Matter (g)	504	176	6	6	-162	531
Emissions (Water)						
Heavy Metals (mg Hg/20)	101	0	2	0	-32	71
Eutrophication (g PO_4)	5	0	0	0	-1	4

Table 111: All impact categories for BC 6 Colour Inkjet Printer. The life cycle phase with the highest impact for each of the categories is highlighted with red text.

	Production	Distribution	Use	Disposal	Recycling	Total
Other Resources & Waste						
Total Energy (MJ)	849	195	84	7	-212	923
of which, electricity (MJ)	415	0	80	0	-111	384
Water – process (litre)	108	0	1	0	-33	76
Water – cooling (litre)	539	0	8	0	-123	425
Waste, non-haz./landfill (g)	1,384	149	49	11	-286	1,307
Waste, hazardous/ incinerated (g)	50	3	2	0	-14	41
Emissions (Air)						
GWP100 (kg CO_2-eq)	44	14	4	0	-11	51
Acidification (g SO_2-eq.)	296	41	17	0	-82	274
VOC (g)	1	2	2	0	0	4
Persistent Organic Pollutants (ng i-Teq)	8	1	0	0	-2	7
Heavy Metals (mg Ni eq.)	81	8	2	0	-26	64
PAHs (mg Ni eq.)	33	6	1	0	-9	30
Particulate Matter (g)	171	243	2	2	-53	364
Emissions (Water)						
Heavy Metals (mg Hg/20)	64	0	1	0	-20	45
Eutrophication (g PO_4)	3	0	0	0	-1	2

Table 112: All impact categories for BC 7 Professional printer/MFD. The life cycle phase with the highest impact for each of the categories is highlighted with red text.

	Production	Distribution	Use	Disposal	Recycling	Total
Other Resources & Waste						
Total Energy (MJ)	29,013	4,009	36,110	242	-7,347	62,028
of which, electricity (MJ)	12,226	9	35,957	0	-3,273	44,919
Water – process (litre)	3,389	0	34	0	-1,024	2,398
Water – cooling (litre)	13,969	0	1,723	0	-3,138	12,555
Waste, non-haz./landfill (g)	119,957	2,054	19,558	1,229	-29,754	113,044
Waste, hazardous/ incinerated (g)	1,289	41	579	0	-360	1,548
Emissions (Air)						
GWP100 (kg CO_2-eq)	1,660	255	1,545	1	-429	3,032
Acidification (g SO_2-eq.)	12,916	784	6,893	17	-3,539	17,071
VOC (g)	57	68	801	0	-17	909
Persistent Organic Pollutants (ng i-Teq)	1,825	12	102	1	-487	1,452
Heavy Metals (mg Ni eq.)	3,529	104	397	9	-1,060	2,979
PAHs (mg Ni eq.)	1,914	147	103	0	-528	1,635
Particulate Matter (g)	8,564	11,112	228	102	-2,529	17,476
Emissions (Water)						
Heavy Metals (mg Hg/20)	3,192	3	186	3	-927	2,458
Eutrophication (g PO_4)	79	0	8	4	-21	70

Ink and toner consumables

Table 113: All impact categories for Ink cartridges. The life cycle phase with the highest impact for each of the categories is highlighted with red text.

	Production	Distribution	Use	Disposal	Recycling	Total
Other Resources & Waste						
Total Energy (MJ)	5	1	6	0	-4	8
of which, electricity (MJ)	1	0	0	0	0	1
Water – process (litre)	0	0	0	0	0	1
Water – cooling (litre)	7	0	10	0	-4	13
Waste, non-haz./landfill (g)	6	0	19	1	-5	21
Waste, hazardous/ incinerated (g)	0	0	0	0	0	0
Emissions (Air)						
GWP100 (kg CO_2-eq)	0	0	0	0	0	0
Acidification (g SO_2-eq.)	1	0	1	0	0	2
VOC (g)	0	0	0	0	0	0
Persistent Organic Pollutants (ng i-Teq)	0	0	0	0	0	0
Heavy Metals (mg Ni eq.)	0	0	2	0	0	1
PAHs (mg Ni eq.)	4	0	0	0	-1	4
Particulate Matter (g)	0	2	1	0	0	3
Emissions (Water)						
Heavy Metals (mg Hg/20)	0	0	0	0	0	0
Eutrophication (g PO_4)	0	0	0	0	0	0

Table 114: All impact categories for Ink containers. The life cycle phase with the highest impact for each of the categories is highlighted with red text.

	Production	Distribution	Use	Disposal	Recycling	Total
Other Resources & Waste						
Total Energy (MJ)	5	0	1	0	-4	3
of which, electricity (MJ)	1	0	0	0	0	1
Water – process (litre)	0	0	0	0	0	0
Water – cooling (litre)	7	0	2	0	-1	7
Waste, non-haz./landfill (g)	6	0	3	0	-1	8
Waste, hazardous/ incinerated (g)	0	0	0	0	0	0
Emissions (Air)						
GWP100 (kg CO_2-eq)	0	0	0	0	0	0
Acidification (g SO_2-eq.)	1	0	0	0	0	1
VOC (g)	0	0	0	0	0	0
Persistent Organic Pollutants (ng i-Teq)	0	0	0	0	0	0
Heavy Metals (mg Ni eq.)	0	0	0	0	0	0
PAHs (mg Ni eq.)	4	0	0	0	-1	4
Particulate Matter (g)	0	1	0	0	0	1
Emissions (Water)						
Heavy Metals (mg Hg/20)	0	0	0	0	0	0
Eutrophication (g PO_4)	0	0	0	0	0	0

Table 115: All impact categories for Toner cartridges. The life cycle phase with the highest impact for each of the categories is highlighted with red text.

	Production	Distribution	Use	Disposal	Recycling	Total
Other Resources & Waste						
Total Energy (MJ)	66	9	9	1	-12	73
of which, electricity (MJ)	17	0	0	0	-3	14
Water – process (litre)	6	0	1	0	-2	5
Water – cooling (litre)	74	0	14	0	-19	69
Waste, non-haz./landfill (g)	147	5	27	6	-34	151
Waste, hazardous/ incinerated (g)	2	0	0	0	-1	2
Emissions (Air)						
GWP100 (kg CO_2-eq)	3	1	0	0	-1	4
Acidification (g SO_2-eq.)	17	2	2	0	-6	14
VOC (g)	0	0	0	0	0	0
Persistent Organic Pollutants (ng i-Teq)	1	0	1	0	0	1
Heavy Metals (mg Ni eq.)	1	0	2	0	-2	2
PAHs (mg Ni eq.)	35	0	0	0	-6	30
Particulate Matter (g)	5	23	1	0	-2	27
Emissions (Water)						
Heavy Metals (mg Hg/20)	5	0	0	0	-3	3
Eutrophication (g PO_4)	0	0	0	0	0	0

Table 116: All impact categories for Toner containers. The life cycle phase with the highest impact for each of the categories is highlighted with red text.

	Production	Distribution	Use	Disposal	Recycling	Total
Other Resources & Waste						
Total Energy (MJ)	54	2	7	1	-12	52
of which, electricity (MJ)	16	0	0	0	-2	15
Water – process (litre)	5	0	1	0	-2	4
Water – cooling (litre)	70	0	11	0	-21	61
Waste, non-haz./landfill (g)	79	1	21	5	-30	76
Waste, hazardous/ incinerated (g)	3	0	0	0	-1	2
Emissions (Air)						
GWP100 (kg CO_2-eq)	3	0	0	0	-1	3
Acidification (g SO_2-eq.)	15	0	1	0	-5	11
VOC (g)	0	0	0	0	0	0
Persistent Organic Pollutants (ng i-Teq)	0	0	0	0	0	0
Heavy Metals (mg Ni eq.)	1	0	2	0	-1	2
PAHs (mg Ni eq.)	23	0	0	0	-4	19
Particulate Matter (g)	3	4	1	0	-2	7
Emissions (Water)						
Heavy Metals (mg Hg/20)	8	0	0	0	-3	5
Eutrophication (g PO_4)	0	0	0	0	0	0

6. Task 6: Improvement potentials

In this task, the technical design options that present potential environmental improvements are identified and assessed. The task includes:

- The identification of the design options that can deliver potential improvements concerning use of energy and resources, including the quantitative assessment, until the extent possible, of the environmental improvements and additional consumer costs per option
- The identification of the primary energy demand over a life cycle and life cycle cost of the different design options, individually and aggregated in clusters
- Selection of those design options, which present the best balance of primary energy and life cycle costs

6.1 Design options (DOs)

In this section, the design options for the seven base cases are shown and their potential effect on energy consumption, improvement costs and other potential effects are summarised.

These options were identified based on the barriers and opportunities presented in Task 4 report conclusions. They have been defined for imaging equipment products and for consumables, and inspired from ongoing work on the review of the Voluntary Agreement (VA)[320] and the review of Green Public Procurement (GPP) criteria for imaging equipment[321].

Table 117 shows the identified design options and Table 118 the improvement environmental potentials and improvement costs per unit of imaging equipment product or of consumable. A description of their technical implications, ambition level and environmental savings potential as well as improvement costs per unit are presented in the subsections, these assumptions are based on desk research, stakeholders' inputs[322] and data analyses.

[320] Industry Voluntary Agreement to improve the environmental performance of imaging equipment placed on the European market. Draft FY18 v.1. November 2018.
[321] Available at: http://susproc.jrc.ec.europa.eu/imaging-equipment/stakeholders.html
[322] Stakeholder consultation via questionnaire, January - February 2019.

Table 117: Design options for imaging equipment products and consumables

Description of design options	No.	Detailed description	Ambition level
Design for dismantling of imaging equipment products	1.1	Joining, fastening or sealing techniques do not prevent access to relevant components listed in Annex VII of the WEEE Directive[323]	low
	1.2	Joining, fastening or sealing techniques do not prevent access to plastic parts >100 g and spare parts listed in option 3.2, and do not prevent mechanical removal of consumables, when the device is not plugged in. These parts must be able to be removed safely.	high
Warranty for service and repair of imaging equipment products	2	Manufacturers must provide a minimum 3-years warranty, free of additional costs, effective from delivery of the product. This warranty must cover repair and replacement and include a service agreement with options for pick-up and return or on-site repairs. The warranty must not be invalidated as a result of non-OEM cartridges or containers being used in imaging equipment unless it is proven that any malfunction was directly caused by the use of a non-OEM cartridge or container.	medium
Design for disassembly and availability of spare parts for imaging equipment products	3.1	Service information about available spare parts should be available in service manuals, videos or webpages in freely accessible websites or provided with spare parts, except for spare parts intended to be serviced by trained service staff.	low
	3.2	Spare parts[324] must be accessible by using commonly used fasteners for joining components, subassemblies, chassis and enclosure, and must be available for 5 years.	high
Post-consumer recycled plastic in imaging equipment products	4	For all products, total weight of plastic content of the product unit must not contain more than 80% virgin plastic. The remaining 20% content should be made of post-consumer recycled plastic.	high
Firmware in imaging equipment products	5.1	Firmware/software shall be also maintained by signatories over the same period spare parts are made available (period defined in current VA)	low
	5.2	Any firmware updates must not prevent the use of non-OEM and reused/remanufactured consumables	medium
Use of reused and remanufactured consumables	6	Cartridges shall not be designed to prevent its reuse and recycling, and equipment shall not prevent the use of non-OEM cartridges, without exemptions (previously with possibility for exemption in VA requirement 5.4 of Part II)	low
Information on consumables reuse, disposal and treatment	7	Signatories shall provide end-users with information on suitable remanufacturing & reuse, or end-of-life management options for used consumables. This information may be communicated via a freely accessible company website.	low
Consumables page yield	8	Page yield is the measured number of images that are to be produced by the consumable mass. Expected page yield must be declared for all consumables to be supplied in use with IE products and evidence should be provided on how the yield was derived.	low

[323] Batteries, PCB > 10cm2, Toner cartridges, Plastics containing BFRs, Liquid crystal displays >100cm2, External electric cables, Electrolyte capacitors containing substances of concern (height >25mm, diameter >25mm or proportionally similar volume)

[324] Spare parts applicable: Storage devices, Print heads (where not considered a consumable), Laser unit (where not considered a consumable), Fuser units (where not considered a consumable), Drum units (where not considered a consumable), Transfer belts/kits (where not considered a consumable), Maintenance kits (where not considered a consumable), Paper feed components, Density sensors, Power and control circuit boards, Cartridge/container attachment components, External power supplies, Hinges

Description of design options	No.	Detailed description	Ambition level
Consumable imaging yield efficiency	9	Page yield/CMass shall not be lower than: For Toner Consumables: (2 × [10 × tanh(0.1+0.0003 × (CMass-10))-0.5]+1) For Ink Consumables: (2 × [15 × tanh(0.2+0.0004 × (CMass-8))-1]+2) where CMass is calculated as the mass (g) of each cartridge or container plus drum unit, as measured in their to be installed condition (i.e. full of ink or toner and any additional components not present whilst installed in the imaging equipment removed).	high
Indoor air quality of laser products and toner cartridges configurations	10	For all laser equipment models placed on the market after 1 Jan 2020 and tested with a specific toner cartridge according to Blue Angel current test procedure, emissions shall not exceed limit values regarding the release of TVOCs, undefined VOCs, Styrene, Benzene, ozone, dust and ultrafine particles as defined by Blue Angel RAL-UZ-205	low
Hazardous substances in toner cartridges	11	Hazardous substances in toner cartridges shall be declared by Signatories as Safety Data Sheets in the official language of each Member State in freely accessible websites or another readily accessible form for customers	low
Primary energy requirement of imaging equipment products	12	Signatories shall ensure that products in scope of the VA and placed on the EU market by Signatories after 1 January 2017 shall comply with ENERGY STAR ® v3.0 specifications and default duplex settings requirements in accordance with specific market uptake targets[325].	low
Internal power supply efficiency information of imaging equipment products	13	Signatories shall publish the nameplate rated output power and efficiency levels of any power supply included within, or supplied for use with, all imaging equipment within scope of the VA.	high
Compliance information of products and consumables	14	For each product in scope of the VA and placed on the EU market, signatories shall produce environmental documentation detailing compliance with each VA criterion. The documentation, or a URL to the documentation, shall be published on the EuroVAPrint website.	low

Table 118: Improvement potentials and costs per unit for design options

Description of design option	No.	Savings potential per unit[326]							Improvement cost per unit[327] added to price
		BC1	BC2	BC3	BC4	BC5	BC6	BC7	
Design for dismantling of imaging equipment products	1.1	EoL: +2% reuse of materials and +4% recycling				EoL: +2% reuse of materials and +4% recycling		Same as BCs 1-4	Ca. 0.5% of product price: BCs 1-4: 5 EUR BCs 5 & 6: 1 EUR BC7: 5 EUR
	1.2	EoL: +10% reuse of materials and +12% recycling				EoL: +10% reuse of materials and +12% recycling		Same as BCs 1-4	Ca. 1% of product price: BCs 1-4: 10 EUR BCs 5 & 6: 2 EUR BC7: 10 EUR

[325] For Tier I (2021), the compliance rate for both TEC and OM product groups shall be 40%.
[326] When design option concerns IE products, %/unit saving is per product placed on the market. When it concerns consumables, %/unit saving is per cartridge or per container placed on the market.
[327] When design option concerns IE products, the cost is per product placed on the market. When it concerns consumables, the cost is per cartridge or per container placed on the market.

Description of design option	No.	Savings potential per unit[326]							Improvement cost per unit[327] added to price
		BC1	BC2	BC3	BC4	BC5	BC6	BC7	
Warranty for service and repair of imaging equipment products	2	Production: 10% material consumption reduction due to ≤1 year prolongation lifetime EoL: +4% reuse of materials and +6% recycling				Production: 10% material consumption reduction due to ≤1 year prolongation lifetime EoL: +4% reuse of materials and +6% recycling		Same as BCs 1-4	Ca. 4% of product price: BCs 1-4: 40 EUR BCs 5 & 6: 9 EUR BC7: 40 EUR
Design for disassembly and availability of spare parts for imaging equipment products	3.1	Production: 5% material consumption reduction due to ≤ 0.5 year prolongation lifetime							Negligible for all BCs
	3.2	Production: 15% net material consumption reduction[328] due to ≤2 year prolongation lifetime							ca. 1% of product price: BCs 1-4: 10 EUR BCs 5 & 6: 2 EUR BC7: 10 EUR
Post-consumer recycled plastic in imaging equipment products	4	Production: 20% primary plastic consumption reduction							10 EUR for all BCs
Firmware in imaging equipment products	5.1	Production: 5% material consumption reduction because of ≤0.5 year prolongation lifetime due to decreased risk of malfunctioning							0.2 EUR for all BCs
	5.2	EoL: +15% reuse and +2% recycling of cartridges/containers							2 - 3 EUR for all BCs for reprogramming firmware
Use of reused and remanufactured consumables	6	EoL: +15% reuse and +2% recycling of cartridges/containers							Negligible - 0 EUR
Information on consumables reuse, disposal and treatment	7	EoL: +1% reuse and +1% recycling of cartridges/containers							Negligible - 0 EUR
Consumables page yield	8	Production: 5% material consumption reduction due to improved comparison between remanufactured consumables and higher market uptake EoL: +12% reuse of materials and +3% recycled materials[329]							1-2 EUR for all cartridges and containers used in all BCs
Consumable imaging yield efficiency	9	Production: 25% material consumption reduction due to less material used for manufacturing of consumables							10 EUR for all consumables used in all BCs
Indoor air quality of laser products and toner cartridges configurations	10	Negligible impact on energy or resources							No costs added to purchase price. Additional test costs of approximately 800 EUR for manufacturers.
Hazardous substances in toner cartridges	11	Negligible impact on energy or resources							Not possible to quantify

[328] Net = increased materials from more spare parts available – reduction materials consumption due to increased lifetime
[329] Due to higher uptake of remanufactured cartridges because of a harmonised quality metric to compare new and remanufactured cartridges

Description of design option	No.	Savings potential per unit[326]							Improvement cost per unit[327] added to price
		BC1	BC2	BC3	BC4	BC5	BC6	BC7	
Primary energy requirement of imaging equipment products	12	USE: average15-20% energy consumption reduction due to improved energy efficiency							BCs 1-4: 20 EUR BCs 5 & 6: 5 EUR BC7: 30 EUR
Internal power supply efficiency information of imaging equipment products	13	USE: average 3 - 5% additional energy consumption reduction due to improved energy efficiency of power supplies							BCs 1-4: 2 EUR BCs 5 & 6: 2 EUR BC7: 30 EUR
Compliance information of products and consumables	14	Use: 1% additional energy consumption reduction due to better informed purchase decision							ca. 2 EUR for all BCs

6.1.1 Design for dismantling of imaging equipment products (DO 1.1 and 1.2)

The first design option shows a low ambition level option DO 1.1 and a high-level ambition option DO 1.2.

DO 1.1 is based on industry's own proposal and it is considered low ambition level because it is additional to existing but less detailed measure in the WEEE Directive. The WEEE Directive imposes the Member States to "...encourage cooperation between producers and recyclers and measures to promote the design and production of EEE, notably in view of facilitating re-use, dismantling and recovery of WEEE, its components and materials."[330] The Directive further specifies specific substances, mixtures and components listed in Annex VII of WEEE Directive have to be removed from any separately collected WEEE. Therefore, a requirement on design for dismantling of imaging equipment products will complement measures in the WEEE Directive and increase the reuse of materials. E.g a stakeholder has stated that discharge lamps have to be removed in accordance with Annex VII of WEEE Directive, but currently they are difficult to remove. Therefore, implementation of the design option will make it easier to remove these lamps. The assumption is that this option would increase the reuse of materials at end-of-life by 2% and the product materials fraction sent for recycling by 4% for all base cases.

The increase in reuse and recycling rates in all design options are based on the inputs from stakeholders on the possible BAT end-of-life treatments and allocated to each option according to the ambition level.

DO 1.2 takes this technical design to a higher ambition level, since it expands to other parts (plastic parts >100 g and spare parts listed in option 3.2) not listed in the WEEE Directive and it facilitates mechanical removal of consumables, when the device is not plugged in. It is assumed that this option would increase the reuse of materials (incl. whole

[330] The WEEE Directive, Article 4.

products or component reuse) at end-of-life by 10% and the product materials fraction sent for recycling by 12% for all base cases.

In reality, the improvement potentials are likely a bit higher for base cases 1 to 4 and base case 7, since these are B2B products and their appropriate sorting, collection and recovery are better than for B2C products (base cases 5 and 6).

DO 1.1 would not imply large improvement costs (average ca. 0.5% of the product price) as it is assumed that already many products on the market have a certain degree of dismantlability features. DO 1.2 would imply higher costs (doubled as much as DO 1.1) because it requires a larger share of the product having these features.

Stakeholder views: No stakeholder has expressed strong view on this design option. It is assumed that there would be no technical problem. It is however mentioned that the list of components (not spare parts) for DO 1.2 should be refined to reflect more those relevant for imaging equipment.

The recycling industry has two further additions to improve the dismantlability of imaging equipment.

- Specify that discharge lamps should be designed in a way so they can be easily removed, in accordance with any VII requirements of the WEEE Directive
- To ensure that mechanically ink cartridges can be readily removed even when the devise is in OFF mode. Hence, this today can pose a challenge (very time consuming) for recycling facilities today.

Both these comments have been taken into account for the design options.

6.1.2 Warranty for service and repair of imaging equipment products (DO 2)

DO 2 extends the legal guarantee from the EU's 2 years to 3 years for the consumer as a protection against faulty goods, or goods that don't look or work as advertised. It extends to one more year but also to repair and replacement services, which are very important to ensure proper repair and replacement of spare parts. Moreover, it explicitly prevents this warranty period to be invalid due to the use of non-OEM cartridges or containers, as this is a common non-technical barrier that prevents the use of more refilled and remanufactured cartridges, as explained in previous task reports. This design option is not a technical design feature, but as explained in Task 4 report, there are non-technical barriers that prevent more reuse and recycling of products and consumables which are important to tackle, apart from the technical features. This option is considered of medium ambition.

It is assumed that this option would reduce 10% of material consumption due to its contribution to prolong the products' lifetime by up to 1 year.

All lifetime prolongation savings are based on qualitative assessment e.g. a product with average life-time of 6 years , if equally disaggregate its material consumption over a typical lifetime, meaning each year of prolongation in lifetime is equivalent to ca. 17% of materials saved from a new product being purchased, a conservative 10% saving is chosen to account for uncertainties.

It is also assumed that it will increase the reuse of materials at end-of-life by 4% and the product materials fraction sent for recycling by 6% for all base cases.

DO 2 would imply larger improvement costs due to increased repair and transport costs to approved facilities and to the extension of the coverage period. It would also imply larger administration costs. The estimated improvement costs are mainly based on online research of warranty costs. Sources show that 2 years warranty accounts for ca. 12% of the product price and 3 years warranty accounts for 16%, the cost of an extra year warranty is ca. equivalent to 4% product price[331].

Stakeholder views: OEM manufacturers are concerned about providing warranty when non-OEM cartridges are used, as the performance characteristics e.g. emission, lifetime, page yield are determined by the combination of equipment and consumables. Input provided by stakeholders during the revision of the GPP criteria for Imaging Equipment[321] points out at the same concern by OEMs. However, evidence shows that this particular aspect may prevent being to benefit from warranty terms, and it is thus important to ensure that the warranty period includes using such cartridges. This will incentivize the use of refilled and remanufactured cartridges, which would reduce the environmental impacts from the use of cartridges[332].

Stakeholders also suggest that warranty obligation should be set by the legal provisions in each Member State, a suggestion also made during the revision of the GPP criteria. However, there may be some Member States that do not include legal warranties for business customers, particularly important for B2B products.

6.1.3 Design for disassembly and availability of spare parts for imaging equipment products (DO 3.1 and 3.2)

The third design option shows also two ambition levels, DO 3.1 and DO 3.2.

DO 3.1 is based on industry's own proposal and it is considered low ambition level because it is not a technical design feature but an administration procedure to provide information to end-users and service professionals about the availability of spare parts. It is assumed

[331] Service Contract Pricing: Printers 2016. https://www.warrantyweek.com/archive/ww20161103.html accessed March 2019
[332] EuroVAprint states this statement is not necessarily supported by recognized LCA studies.

that this option would prolong the lifetime of imaging equipment products by up to 0.5 years because the end-users would be more informed about repair possibilities by the replacement of spare parts. This would indirectly reduce the material consumption of new products by 5%. Again, 1 year of prolongation in lifetime is equivalent to ca. 17% of materials saved from a new product being purchased, half year prolongation is ca. 8%, but 5% is chosen for accounting for not necessary all users would prolong its lifetime due to more information on spare parts. In addition, a stakeholder has suggested to define spare parts for repair and maintenance parts. This addition does not change the overall assumptions, but it may open for different possibilities for better maintenance of products. Hence maintenance parts could also be available for non-professionals to purchase.

DO 3.2 takes this administration procedure further to a technical design feature, where specific spare parts shall be easily accessible and shall be available for a period of 5 years. This is considered of a high ambition level because of the more extensive list of spare parts to be accessible, and because of the longer period they should be available for repair. Spare parts listed have been defined by finding the most common types of spare parts for imaging equipment products[333]. It is assumed this option would prolong products' lifetime by up to 2 year due to the high degree of accessibility and availability of components. This would indirectly reduce material consumption by 15% per product for all base cases. This is considered a net reduction, taking into account there will be a higher use of materials from spare parts. The lifetime extension counteracts this effect and provides significant savings.

DO 3.1 is assumed not to imply improvement costs as this is purely an administrative feature which requires only edition work to include this information on readily available material. In spite of the high ambition, DO 3.2 is assumed to imply only 1% additional costs per product, because there are already products on the EU market with ease of disassembly features that offer longer spare parts availability periods. These products are usually Blue Angel, EPEAT and Nordic Swan labelled.

Stakeholder views: No strong view on DO 3.1. There are divergent views on DO 3.2. Some stakeholders expressed no issue if the spare parts are already those they supply. Other stakeholders expressed no issue with providing 5 years spare part availability for EP, Solid Ink, and High-Performance Inkjet products, but it is not economically feasible for other inkjet products, which have 3 years availability currently.

During the revision of the GPP criteria for Imaging Equipment3 stakeholders found positive the alignment of the proposed availability period with other schemes (e.g. a 5-years period

[333] Online research of imaging equipment spare parts suppliers and identifying the most common parts.

is requested by Blue Angel). However, some stakeholders proposed to align fully with Blue Angel, where no specific list of spare parts is defined. The study team finds that an exhaustive list is crucial to ensure that imaging equipment is not overprovisioned in businesses, or that a consumer purchases a new product too early because of early failures. Other spare parts are not relevant since they do not tend to fail within the product's lifetime and are not as important for the function of the product. Therefore, it is important to focus on the specific parts that will create a disruption of the lifetime.

6.1.4 Post-consumer recycled plastic in imaging equipment products (DO 4)

DO 4 implies that new products have a minimum 20% of total plastic weight in the product as post-consumer recycled plastic (see Table 117). Most material volume in imaging equipment products consists of common plastics (e.g. PS (HI-PS), ABS, PC) and metals (steel, copper, aluminium). In spite of their high embodied impact, steel and aluminium are nowadays highly recyclable but plastics are not. Therefore, it is considered important to address this source of impacts by proposing a criterion to incentivize the use of recycled plastics. In spite other voluntary schemes like Blue Angel, Nordic Swan and EPEAT require similar design features and that the current Voluntary Agreement does too, only EPEAT and Nordic Swan require minimum content. In fact, the compliance of EPEAT requirement in EPEAT registered products in only 4% (see Task 4 report, table 9). The draft GPP criteria for imaging equipment for the ongoing revision defines 25% in the top end of recycled content levels. Because of the presented arguments, this design feature is considered of a high ambition level.

This option would reduce 20% of primary plastic content in products which would be replaced instead by recycled plastic. This would bring environmental savings during the production of the products.

It is assumed that DO 4 imply 10 EUR improvement costs per unit based on stakeholder input[334], duo to that it would require extra quality assurance in order to achieve the same quality of product appearance and additional management costs. The recycled plastics like PP and ABS are readily available on the market and are typically cheaper than new plastics. This would counteract the additional development costs of incorporating recycled materials in the product. Moreover, some products on the EU market are already sold with a share of post-consumer recycled plastic.

Stakeholder views: Divergent views have been received regarding the feasibility. One stakeholder has already demonstrated the technical feasibility of this design option with current product in a successful business model. Some expressed that it is possible at a

[334] Stakeholder consultation via questionnaire, January - February 2019.

cost, others expressed that the absence of a standard on recycled content makes it inappropriate to set a minimum requirement. The latter comment was also pointed out during the revision of the GPP criteria for Imaging Equipment[321], where stakeholders emphasized the lack of a measurement or tracking method to quantify the amount of recycled materials. Tracking of material contents is a complex exercise in particular along the ICT value chain. However, other stakeholders requested to harmonize this requirement with Blue Angel, where a minimum content of 5% of the complete plastic material in imaging equipment should be recycled. Although the threshold is much lower, this would also require the capability of tracking recycled material. It thus seems that some manufacturers have already a tracking system in place and would be able to report on this content.

The recycling industry states that these types of requirements are instrumental to pull the demand for recycled plastic in imaging equipment and must be implemented. However, they suggest that the recycling target should be measured out of the total plastic waste in the product.

6.1.5 Firmware in imaging equipment products (DO 5.1 and DO 5.2)

The fifth design option shows also two ambition levels DO 5.1 and DO 5.2.

DO 5.1 is based on a draft proposal for the VA and it is considered low ambition level because industry already maintains firmware regularly in imaging equipment products through software updates. Whether it is for shorter or longer periods than what industry proposes, it is not known. Because of this, it is assumed that small environmental improvement potentials exist by prolonging the products' lifetime by up to 0.5 years from preventing malfunctioning, for the products which firmware is maintained for shorter periods. This would indirectly reduce the material consumption at the production phase by 5%, same rationale for the amount of reduction as previous options, such that 1 year of prolongation in lifetime is equivalent to ca. 17% of materials saved from a new product being purchased, half year prolongation is ca. 8%, a more conservative figure is chosen to account for uncertainties.

DO 5.2 relates also to firmware maintenance, within the same period of time, but it specifically prevents the updates that block the use of non-OEM consumables[335]. This has been a barrier to use more remanufactured consumables, as explained in previous task reports. This is thus considered of medium ambition, because it does not imply large efforts from industry technically speaking, but it is more a competitive issue. However, it is estimated

[335] According to a stakeholder cartridge blocking by firmware update may be an environmental offence. In the USA there is an increasing number of class actions against this practice.

that this would unblock a higher use of remanufactured/refilled consumables, with increasing reuse by 15% and recycling by 2%, instead of buying brand-new consumables.

DO 5.1 would imply only small improvement costs for extending the maintenance period, for products where it is shorter. DO 5.2 would, in the contrary, imply a slightly larger improvement costs for reprogramming software, but these are not considered to be large since this improvement option is to be implemented at the software rather than at the product levels, this is assumed 2 – 3 EUR per unit of imaging equipment.

Stakeholder views: DO 5.1 is generally accepted. For DO 5.2, there are again different views, some stakeholder expressed no issue, but others stated that firmware updates are used for a number of purposes that may include: To provide optimum product performance in order to protect the quality of customer experience; to protect the device and network from the latest security threats; to protect OEMs' intellectual property; and to reduce counterfeiting of OEM cartridges and warranty fraud.

Firmware updates are technically necessary, especially for security updates and bug fixing, but whether blocking non-OEM cartridges is technically necessary for equipment to work is debatable. As shown in Task 4 and 5 reports, there are currently many cases showing barrier to remanufacturing due to patents, Intellectual Property Rights, allowing firmware updates that block the use of non-OEM consumables is rendering the current VA commitment on resource efficiency requirement for cartridges useless. Moreover, same input was provided by stakeholders during the revision of the GPP criteria for Imaging Equipment[321], however, the proposed GPP criterion requests that firmware is rolled back if it prevents the use of remanufactured cartridges. In the other hand, this design option is more open as it requires to avoid firmware that prevents their use. In this way, there is more space for innovation and different strategies to be implemented by OEMs, and there is no need to disrupt the main functions of the firmware as discussed by some stakeholders.

6.1.6 Use of reused and remanufactured consumables (DO 6)

DO 6 is based on a draft proposal for VA and it implies that imaging equipment products and consumables designs do not prevent consumables' reuse and recycling at any means. An exemption clause in the current Voluntary Agreement prevents this from happening in the cases these designs prevent innovation, development or improvements in design or functionality of the products. Industry's proposal is to remove this clause, and by doing so, the potential for the use of reused and remanufactured consumables is fully unlocked. This option is considered of low ambition, because it does not imply large efforts from industry to change or disrupt technologies already readily available on the market. But it requires that some blocking technologies are reprogrammed or removed, so products and consumables designs do not prevent consumables' reuse and recycling.

This option would imply 15% higher uptake of reused and remanufactured consumables and 2 % higher recycling.

It is assumed that costs would be negligible because, in principle, the designs should have already been made to facilitate the use of reused and recycled OEM and non-OEM cartridges. In reality, some designs exist that prevent these because of the exemption clause. But the costs to reprogram or remove blocking technologies from the market should not be allocated to consumers.

Stakeholder views: No strong view expressed for this design option, it is generally accepted by those not currently using the exemption.

6.1.7 Information on consumables reuse, disposal and treatment (DO 7)

DO 7 is also based on a draft proposal for the VA and it implies that end-users are provided with suitable end-of-life information for consumables. As such, it does not imply any technical change on the design, but it is more an administration procedure to support the provision of the consumables to end-users. However, this information could improve the way consumables are sorted and facilitate their recycling. Proper and available information could help businesses to sort out consumables separately or establish contact with manufacturers if a take-back system exists. And it could help consumers to become aware of any collection centre that can take used consumables for further reuse or recycling. The ambition level of this design option is considered low, since it does not require any technical effort for improving the design of the consumables, but it is more an administration procedure to provide more information to consumers.

This option would increase marginally the number of consumables being reused at their end-of-life (assumed 1% higher reuse and recycling), because the information would not necessarily prevent that they end up being sorted as commercial and household waste. However, chances are larger for them ending up in the electronics, hard plastic or metals recycling bin, if containers are already provided in the relevant Member State.

It is assumed that costs would be negligible because no technical changes are expected on the consumables' design and administration costs to produce this information are considered negligible.

Stakeholder views: This option is generally accepted by stakeholders.

6.1.8 Consumable page yield (DO 8)

DO 8 is not a technical design option, but a technical reporting option to facilitate the comparison of the consumables' functionality. Page yield is the most suitable metric that can be used to compare consumables' function and it can help identify costs per printed

page by knowing in advance the number of pages expected to be printed. By reporting page yield, it is expected that a level playing field is created, which can incentivise longer yields maintaining same printing quality (including refilled and remanufactured cartridges). The latter is of special importance, as printing quality has a strong impact on the use of paper and can also indirectly reduce environmental impacts from new cartridge manufacturing, if this information induces a higher market uptake of consumables with higher yields. The ambition level is considered low because this is already a requirement of the Voluntary Agreement, but this design option involves also the provision of evidence on how the yield was calculated and it includes all consumables including containers, *not only* cartridges.

This option is assumed that it would reduce 5% of materials consumption during production, as an indirect effect from incentivising consumables with longer life by improving their yields. It is assumed that more reused and remanufactured cartridges would be purchased if their declared page yield is similar to a brand-new cartridge but marketed at a lower price and reused/recycled. It is therefore assumed 12 % increase for reuse and 3% increase for recycling.

It is assumed that this reporting option would imply 1-2 EUR compliance costs per model of consumable, because this design option would incentivize signatories to report yields for all consumables, and the non-signatories producing refilled and remanufactured cartridges to join in the Voluntary Agreement. For new members, reporting page yield would imply testing and reporting costs.

Stakeholder views: There is no strong view om this design option, as the VA already address the page yield which follows either ISO standards or other reproducible methods developed by the manufacturers, so there should be no problem providing evidence on how page yield was calculated and apply across all consumables.

6.1.9 Consumable imaging yield efficiency (DO 9)

DO 9 is also a technical reporting option but it has a direct influence on product design, since it provides a metric that can be used to indicate the page yield efficiency in relation to the amount of materials used in consumables. The more materials and sub-components a consumable has, the more difficult becomes to reuse or recycle it, in addition to difficulties from other design features that prevent their reuse (e.g. a programmed chip). Also, the more complex these are, the higher consumables' life cycle environmental impacts. There is significant variation in the amount of material used within consumables that provide the same or similar functionality. Any reduction in weight will reduce the amount of materials used. Reporting this metric, would thus allow for a technical comparison of the yield and material efficiency of consumables that could incentivize the use of highly efficient

consumables. Task 4 report describes how this metric has been developed, based on the ongoing revision of the EU GPP criteria on imaging equipment. Since the estimated cut-off established from this revision is relatively high (50% of the EU market), this design option is considered of high ambition.

It is assumed this option would reduce 25% of materials consumption during production based on stakeholder inputs, since it is expected that more material efficient consumables are placed on the market as an effect of this option.

It is also assumed that this reporting option would imply somewhat high improvement costs (i.e. 10 EUR per model). In spite of this being only a technical reporting option, there is a direct effect on consumables design which would lead to design improvements considered relatively costly, as the design of complex consumables would have to be radically changed.

Stakeholder views: Some stakeholders expressed that the Nordic Swan Ecolabeling criteria should be used instead of the metrics developed for the GPP. The Nordic Ecolabelling sets similar but more simplified requirement on the ratio of consumable weight and page yield, see Table 119. However, during the revision of the GPP criteria for Imaging Equipment[321], stakeholders claimed there should not be differences between ink and toner yield efficiency calculations because criteria and requirements should be technologically agnostic. Because of this and the complexity of calculating this metric, stakeholders were strongly opposed to this criterion. The study team emphasized that ink and toner consumables designs are essentially different and thus need different calculation methods. This is done for other requirements as well. Moreover, the formula only requires collecting cartridge yield and consumable mass and it is thus easy to implement and verify considering page yield is already reported. The proposed Nordic Ecolabelling requirements in Table 119 assess only consumables used in toner imaging equipment. Including ink consumables is of primary importance due to their high sales and stock in the EU.

Table 119: Nordic Ecolabelling Consumable requirement on highest index for weight/1000 pages

Images Per Minute (IPM)	Monochrome application (Kg/1000 pages according to ISO/IEC 19752)	Colour application (Kg/1000 pages according to ISO/IEC19798)
IPM > 19	≤ 0,65	≤ 2
IPM ≤ 19	≤ 1	≤ 3

6.1.10 Indoor air quality of laser products and toner cartridges configurations (DO 10)

DO10 requires that the TVOCs, undefined VOCs, Styrene, Benzene, ozone, dust and ultrafine particle emissions from all laser imaging equipment models placed on the market

after 1 January 2020 do not exceed the limit values included in Blue Angel RAL-UZ-205. The emission rates requirements shall be measured for the whole printing system, i.e. the printer, consumables and paper. Therefore, DO10 applies to laser equipment used with all types of consumables described in previous tasks.

VOC, dust and other emissions from imaging equipment are hazardous to humans when indoor levels become too high. For this reason, most major voluntary environmental initiatives on imaging equipment (in this case Blue Angel, EPEAT, Nordic Swan and the Korean Ecolabel) include limitations on imaging equipment emissions, therefore this option is considered low ambition.

Ensuring that products meeting the VA requirements have reduced substance emissions will help reduce indoor air pollution.

It is assumed that meeting the DO10 requirements would result in some additional testing costs for VA signatories, estimated at 800 EUR per model. The extent of these additional costs is unclear as many signatories already conduct emission testing to achieve compliance with other initiatives such as Blue Angel. In addition, a number of existing VA signatories own laboratories that are accredited to test emissions against the Blue Angel test procedure. These signatories include:

- Kyocera[336]
- Canon[337]
- Xerox[338]
- Lexmark[339]

The impacts of this design option are unfortunately not possible to model with the existing methodology, so it is not included in the assessment in the later sections.

Stakeholder views: Some stakeholders have expressed that the wording of the requirements has to be modified. A stakeholder suggests that information must be presented directly on the packaging. This could be done similar to the EPEAT awards with three categories – Gold, Silver and Bronze.

[336] https://www.kyoceradocumentsolutions.eu/index/about/kyocera_press_area/press_details.L3ByaW50ZXJfbXVsdGlmdW5jdGlvbmFscy9uZXdzLzIwMTQva3lvY2VyYV9kb2N1bWVudF9zb2x1dGlvbnMz.html
[337] https://global.canon/en/csr/product/safety.html
[338] https://www.fujixerox.com/eng/company/icc/test_04.html
[339] https://csr.lexmark.com/emissions.php

6.1.11 Hazardous substances in cartridges (DO 11)

DO 11 is based on a draft of VA proposal and it implies that Signatories declare use of any hazardous substances in toner cartridges in standardised format for end-users. This is different to Blue Angel (RAL-UZ 205 Edition January 2017) and to the ongoing revision of the EU GPP criteria on imaging equipment, where the proposals are to require specific hazardous substances restrictions in all cartridges and in all consumables respectively. Hazardous substances present in cartridges are usually not assessed in Life Cycle Assessments, but they are important because they prevent the recycling of certain materials such as plastics. Moreover, during operation of the imaging equipment products some hazardous substances can be emitted.

Providing information[340] to end-users would help consumers to be aware about their presence in toner cartridges. But in practical terms, it is unlikely end-users know how to interpret Safety Data Sheets without further guidance, and it is questionable whether this highly technical information would change any purchasing decision. It is thus assessed that this reporting option is of low ambition.

It is assumed that the impact of this option on energy and resources consumption is negligible. It is difficult to foreseen so far how much it would cost to implement this reporting option, which would imply testing and administration costs.

Stakeholder views: No issues raised by stakeholders.

6.1.12 Primary energy requirement of imaging equipment products (DO12)

The ENERGY STAR targeted penetration rates are based on historical increases in the percentage of products meeting previous ENERGY STAR specifications for imaging equipment (i.e. v1.0, v1.1 and v2.0).

The savings potential is based on the difference in performance between products in the ENERGY STAR dataset that are compliant and non-compliant with the ENERGY STAR v3.0 specification limits.

The assumed costs are based on the ENERGY STAR guiding principle that ENERGY STAR specifications are set so that if there is a cost differential at time of purchase, that cost is recovered through utility bill savings, within the life of the product, generally between 2 and 5 years. The costs included in DO12 are likely quite high, this is assumed in recognition that in some cases product alteration costs would be higher than the saved energy costs over the life cycle.

[340] A stakeholder has suggested to provide information by a QR code.

In DO 12, there are three ambition levels. The low ambition is based on the natural development of energy efficiency that is driven by ENERGY STAR version 3.0 adopted in the US. The compliance rate of the ENERGY STAR requirement is usually ca. 25% at the time of the assessment of requirement is taken place, i.e. 2018 -2019. In the low ambition option, the compliance target follows the natural development, so the compliance target for VA in terms of primary energy requirement is assumed 30% in 2020 and gradually after 5 years the compliance target should be 100%. Medium ambition for DO 12 assumes the compliance rate for Tier I by 2020 is 40%. These two levels are developed based on stakeholders' comments.

High ambition for DO 12 assumes the compliance rate for Tier I by 2020 is 60% and by Tier II it would be 90%. This is proposed, because Voluntary Agreement guideline states that requirements from VA should apply to 90% of all units, however this includes primary energy, resource efficiency and information requirements. Lower the ambition for primary energy requirement in the first tier, may allow signatories more resources and time to improve resource efficiency requirement compliance.

See Table 120 for the targeted compliances over time assumed for the three levels.

Table 120: Targets for compliance with ENERGY STAR version 3.0 requirements

Ambition level	2020	2021	2022	2023	2024	2025
Low	~30%	40%	60%	90%	95%	100%
Medium	~40%	60%	90%	100%		
High	~60%	90%	100%			

Stakeholder views: The study team proposed the high ambition level for this design option. Some stakeholders expressed that the compliance target in 2019 should be 25%, this could lead to 30% or 40% compliance by 2020, depending on how the market develops, therefore low and medium ambition levels are proposed to assess the impacts.

6.1.13 Internal power supply efficiency information of imaging equipment products (DO 13)

The energy efficiency of internal power supplies can play an important role in the overall energy efficiency of a product. This is widely recognised by the fact that internal power supply units included with many other IT products placed on the EU market are subject to energy efficiency requirements. The ENERGY STAR specifications include a use-based efficiency metric (i.e. TEC) for some types of products and so inherently address internal power supply efficiency. However, it is widely recognised that the ENERGY STAR TEC use profiles do not represent actual usage in all cases. The energy efficiency of PSUs become

more important for products which are not used to the same extent as under the ENERGY STAR TEC use profiles.

In addition, the ENERGY STAR v2.0 specification and the ENERGY STAR v3.0 specification, provide additional sleep mode power demand allowances based on the rated output of PSU's. Information about the rated output of PSUs used with imaging equipment is not always readily available to purchasers.

A test method exists[341] for types of internal power supplies where the dc output can be disconnected from the product allowing measurement to take place and that have detailed input and output ratings.

The reduction in energy consumption and improvement costs are based on experts' estimated values. DO13 is an information only requirement and, as such, the costs to produce the information are spread across sales of all identical products. It is recognised that the cost estimates are probably over estimated. Stakeholders are invited to provide alternative adaptation costs and energy savings.

Stakeholder views: Some stakeholders' view is that it is impossible to measure IPS separate from the equipment. Currently there are no Internal Power supply efficiency levels applicable for IE.

6.1.14 Environmental information of products and consumables (DO 14)

The current VA on imaging equipment states that accurate information on the environmental performance of products will enable customers to make more sustainable purchasing decisions.[342] To support sustainable purchasing, the VA includes requirements for signatories to publish environmental information about products. These information publication requirements need to be met for products to be complaint with the VA.

The current VA includes different stipulations around communication of environmental information. For some requirements information needs to be communicated at the time the product is purchased. This is to ensure that users are made aware of good efficiency practices when they first begin to use a new product. Signatories can communicate this information via:

- Pop-up screens on users' computers during the initial installation of software
- CD
- Printed insertion sheet(s) provided in/on the box of the product
- Publicly available website

[341] Generalized Test Protocol for Calculating the Energy Efficiency of Internal Ac-Dc and Dc-Dc Power Supplies Revision 6.7
[342] http://www.eurovaprint.eu/pages/voluntary-agreement/

The VA includes other general requirements on the provision of environmental information such as the requirement to provide the mandatory information required in the ECMA 370 standard [343] and the requirement to provide users with information regarding recycled paper via their websites or other means.

There are several fundamental issues with the VA environmental information provision requirements, which limit their ability to support sustainable purchasing decisions. Firstly, the VA does not require signatories to publish environmental information covering all VA requirements. This hampers the effectiveness to make purchasers aware of the environmental profile of products. Secondly, the VA does not require that environmental information is provided at a time when users are making purchasing decisions. That is, the VA does not require that signatories publish the environmental information when products are first placed on the market. Thirdly, the VA is vague about how signatories should make environmental information public. That is, there are no requirements that signatories should make all environmental information available on a publicly accessible website.

The VA environmental information provision requirements could be improved in several ways to better support sustainable purchasing decision making. All, widely used, voluntary environmental initiatives on imaging equipment require that information is published in a standard format and provide centralised repositories of data for registered products. These central repositories of data allow users to review the environmental performances of products before making purchasing decisions. Following standard industry practice, the VA should include a requirement for signatories to publish all environmental data in a central repository. This central repository could be provided on the EuroVAPrint website alongside all other VA information. It is recognised that some environmental initiatives have larger budgets to manage product environmental information databases. Due to the extra costs associated with database development and management, it is suggested that the VA central repository should be limited to pdf type documents. To further facilitate sustainable purchasing, the VA should require that all environmental information is published in a standardised format. These two alterations design options would allow prospective purchasers to more easily compare the environmental performance of products at the time they are making their purchasing decisions.

[343] https://www.ecma-international.org/publications/standards/Ecma-370.htm

1% reduction in energy consumption has been assumed for this option, based on based on the findings of a 2015 study[344] on the Impact of Sustainability Information on Consumer Decision Making.

The improvement costs are based on stakeholder inputs. DO14 is an information only requirement and, as such, the costs to produce the information are spread across sales of all identical products. It is recognised that the cost estimates are probably overestimated.

Stakeholder views: No issues raised and the EuroVAprint mentioned that similar requirement is being proposed by the signatories for the revised VA:

The signatories shall publish on the EVAP website information identifying which products meet the requirements of Section 4 from when those products are first placed on the market after the commencement date of this Voluntary Agreement. The information shall be regularly updated.

6.2 Methodology for calculating the environmental impacts and costs of design options

In order to perform the quantitative assessment of the environmental improvements and additional consumer costs of the presented design options, a methodology was followed to calculate their life cycle environmental impacts and costs per imaging equipment product unit, including consumables (see Figure 76). The modelling of the base cases was explained in Task 5 report, which was used as a baseline for comparison with design options, in order to assess life cycle potential environmental and costs savings/burdens and continue further for finding the least life cycle cost.

[344] Dara O'Rourke* and Abraham Ringer, 18 AUG 2015, "The Impact of Sustainability Information on Consumer Decision Making", Journal of Industrial Ecology, DOI: 10.1111/jiec.12310, Yale University. Link: http://onlinelibrary.wiley.com/doi/10.1111/jiec.12310/abstract. "Direct users" (who look actively for the information) were most strongly influenced by sustainability information. The study shows that for the 'direct users', the purchase intention rate increases on average 1.15 %-point for each point increase in product "sustainability" score, reported on a zero-to-ten scale.

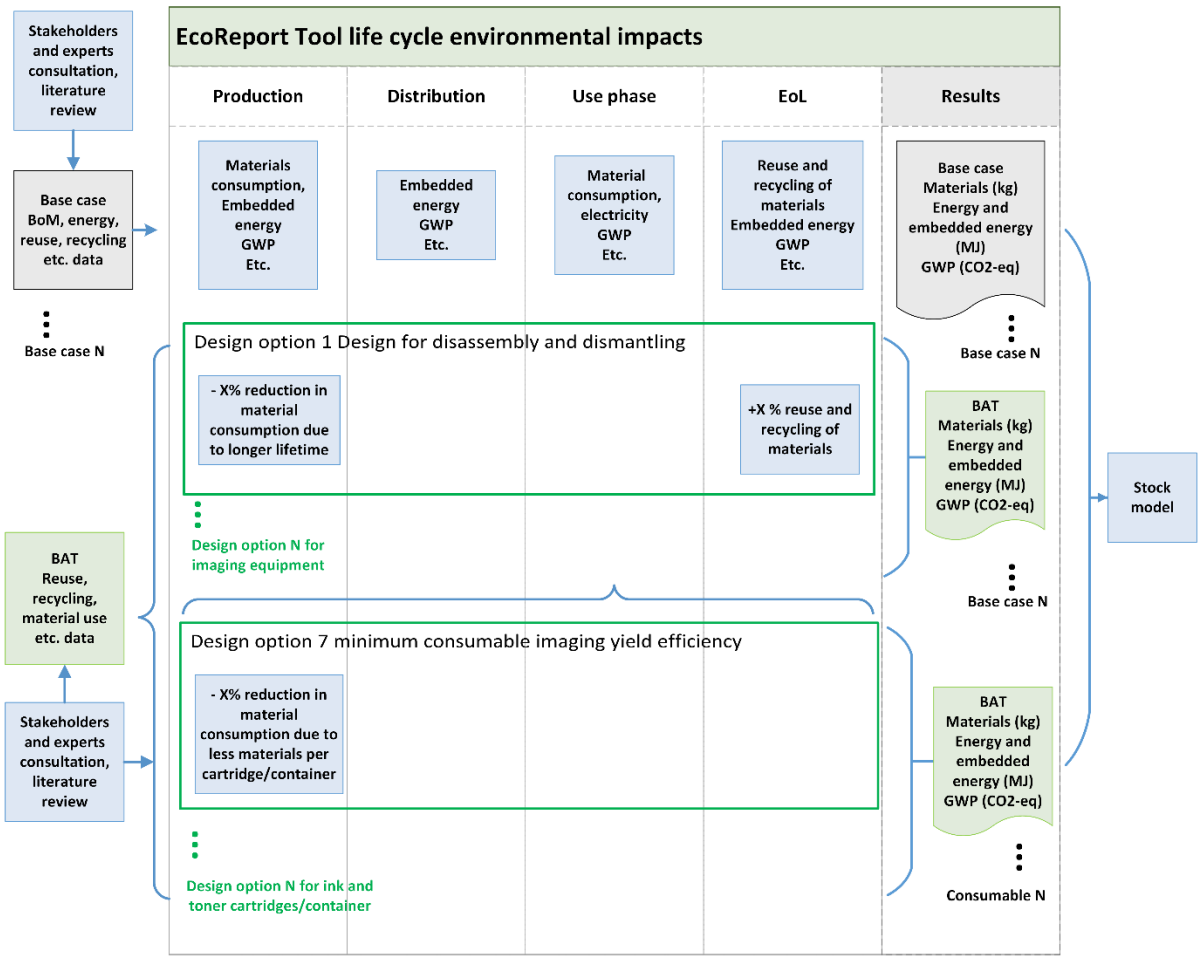

Figure 76: Methodology for calculating the environmental impacts and costs of design options

The design options presented previously describe potential technical and information requirements that could be adopted as policy measures to improve the resource efficiency of the product. According to MEErP methodology, the life cycle environmental improvements and costs are assessed per product unit and produced with the EcoReport tool. Figure 76 shows examples of two design options and how the estimated materials reduction and increased reuse/recycling percentages shown in Table 118 were used as inputs to calculate, the BAT life cycle environmental impacts, using the EcoReport tool. The percentages are estimates resulting from stakeholder and expert inputs as well as separately analysis shown in Section 6.1.

BAT is only one clustering of design options, based on those including the highest ambition levels, but more clusters with different levels of ambition were established and quantitatively assessed, which are shown in section 6.3. Moreover, the life cycle costs of individual and clustered design options were also calculated using the EcoReport tool. All reuse and recycling rates increase from all design options are assumed to sum up to reach the BAT

level, with the rationale that all conditions for reaching current identified BAT will be met by adopting all the design options that improves reuse and recycling.

A key step was to keep the modelling of the design options for imaging equipment and consumables in separate EcoReport Tool files, in order to model the detailed effect of different design options in the life cycle of cartridges and containers, even though consumables ultimately only contribute to use phase impacts of imaging equipment. The results from the EcoReport Tool should represent the improved products, formed by individual option and clusters of options, in terms of resource efficiency for imaging equipment and for consumables.

6.3 Life cycle environmental impacts and costs

As explained in Task 5 report, the focus of this study concerning environmental impacts has been on assessing the primary energy demand and the Greenhouse Gas Emissions.

In the other hand, the Life Cycle Costs (LCC) per product is also a good indicator for cost-effectiveness of the design options.

LCC is the sum of all recurring and one-time costs over the full life span of the product for the consumer. The LCC is being modelled in the EcoReport tool and covers a number of life cycle phases. The phases found relevant to include for imaging equipment are the purchase phase, i.e. the product price, the use phase which entails electricity consumption and repair and maintenance costs. Any costs related to the disposal of the product has not been considered, they were found small enough to be negligible. The main assumptions for equipment and consumables respectively can be found in Task 2 Section 2.2 and 2.4.

The proposed design changes include a cost change per product which is simply added to the purchase price. Proposed reduction in material use is also assumed to affect the purchase price and in order to simplify the model a material reduction of 10% (up to a year of life prolongation) equals a purchase price reduction of 10%. This is a conservative estimation based on that a product with average life-time of 6 years. If material consumption and product price of a new product are equally disaggregated over the lifetime, each year of prolongation in lifetime is equivalent to ca. 17% of materials saved, and the same percentage of product price saved from a new product being purchased.

The results for each design option are presented in the next section for each base case. Figures are presented separately for consumables, to show the particular effect of the design options, which are relevant for cartridges and containers solely. Moreover, results are also shown for clustered design options, which are described in section 6.3.2.

6.3.1 Individual design options LCC and primary energy

Figure 77 shows the primary energy consumption over life cycle (PE) and the LCC of all design options (DO) related to imaging equipment for BC1 (Mono Laser MFD).

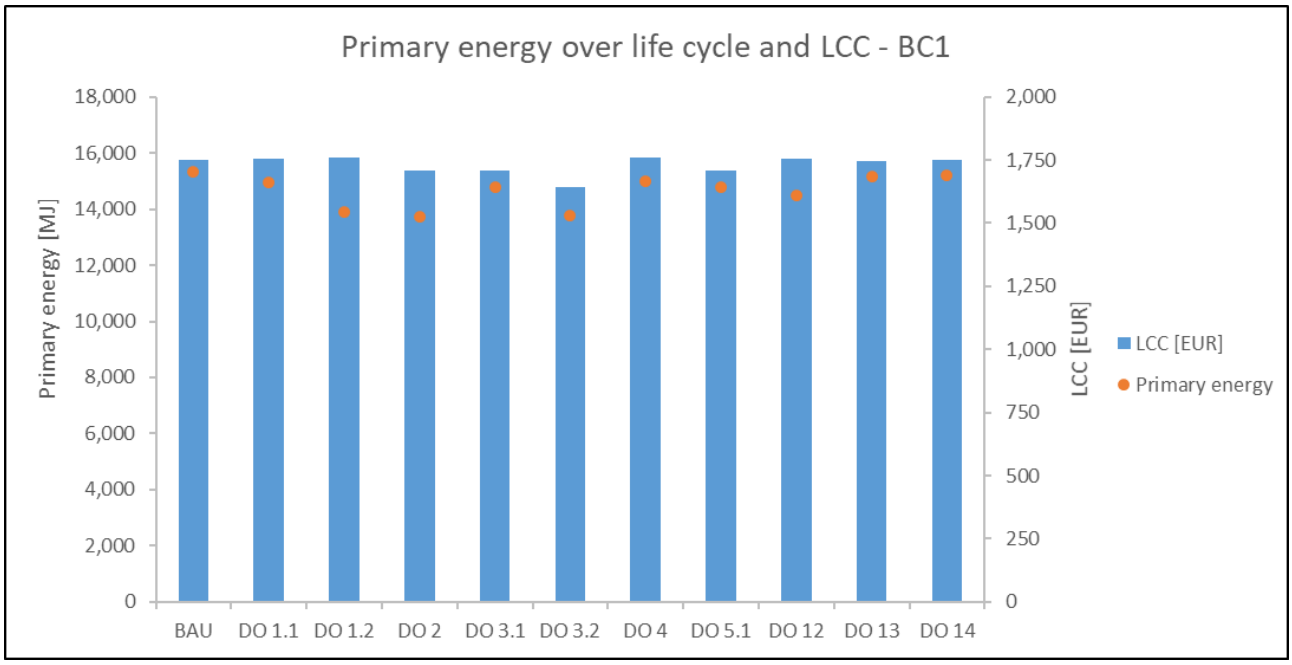

Figure 77: Primary energy over life cycle and LCC – BC1

The results show very small differences amongst different design options, both for LCC and for primary energy over a life cycle.

However, DOs 3.2 and 2 show the lowest primary energy and LCC of all. The determining factors are the high material reductions for the two design options, but also the high level of recycling for DO 2 has an effect on PE. Considering the large energy reduction in DO 12 of 20%, the impact of this design option shows how little impact the use phase has on PE and LCC for BC1, when whole life cycle is considered.

Figure 78 shows the PE and the LCC of all design options related to imaging equipment for BC2 (Colour Laser MFD).

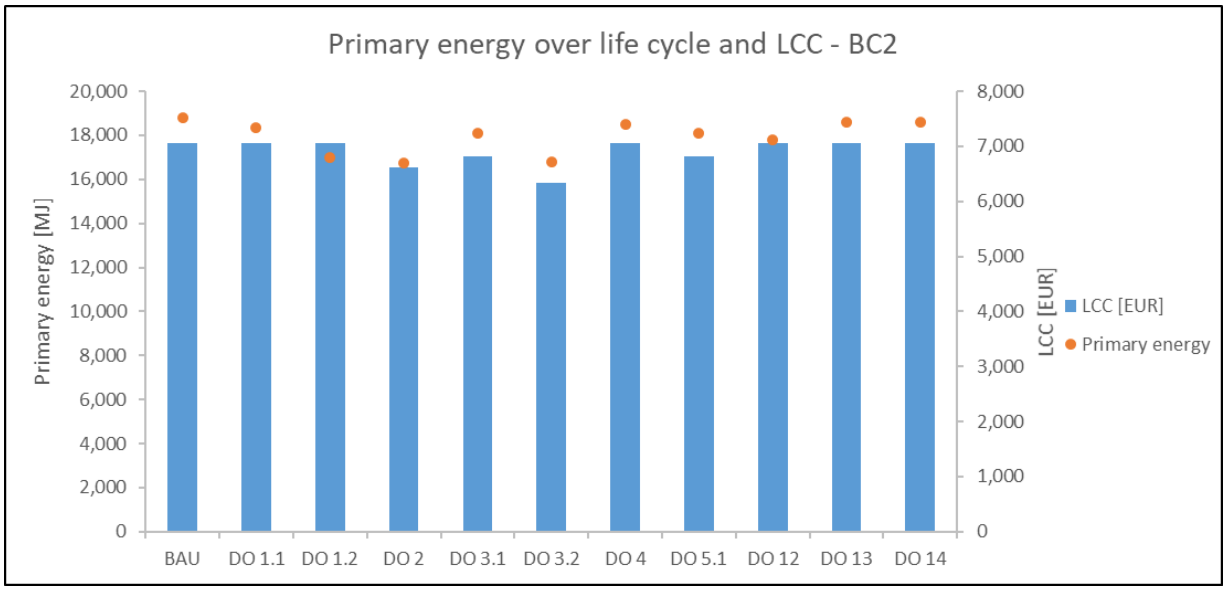

Figure 78: Primary energy over life cycle and LCC – BC2

Similar to BC1, DO 2 and DO 3.2 have the lowest PE and LCC. Furthermore, BC2 presents the highest LCC for all the design options, compared to all base cases except BC7, which is mainly a result of a higher purchase price that was based on stakeholder inputs.

Figure 79 shows the PE and the LCC of all design options related to imaging equipment for BC3 (Mono Laser printer).

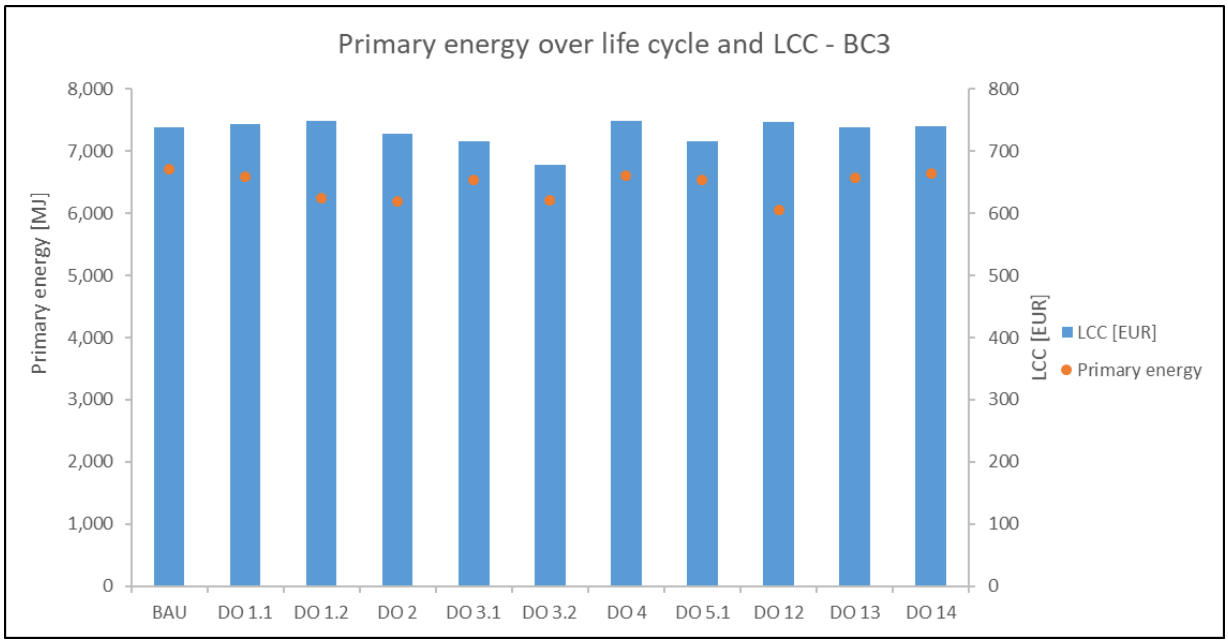

Figure 79: Primary energy over life cycle and LCC - BC3

The results show a small difference between the different design options, similar to BC1. However, the levels for both PE and LCC are considerably lower than for BC1. This is because these products, although being similar, are smaller and cheaper than BC1 products

(see Task 4, section 4.2.1). However, their energy consumption in the use phase is relatedly large in comparison with the size of the equipment, therefore has a higher impact relative to the production phase. Consequently, the DO 12 which entails a 20% energy reduction in the use phase, has the lowest PE over a life cycle.

Figure 80 shows the PE and the LCC of all design options related to imaging equipment for BC4 (Colour Laser printer).

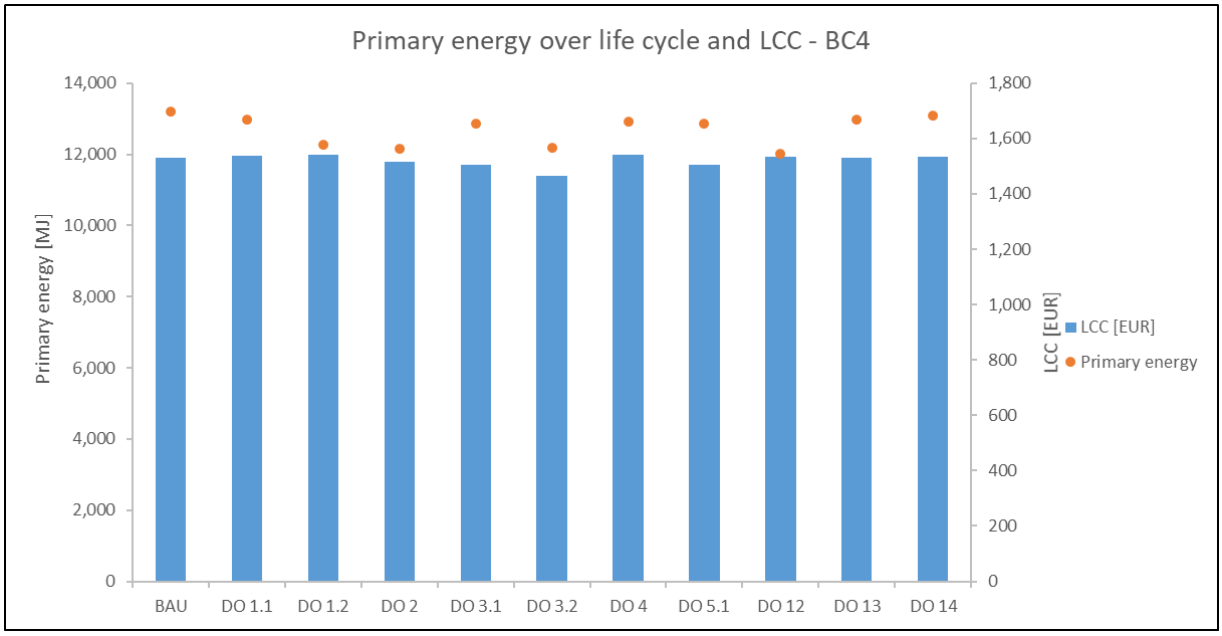

Figure 80: Primary energy over life cycle and LCC - BC4

The PE and LCC are slightly lower than for BC1. This shows no comparison to BC2 which delivers a more complex functionality. Similar to BC3, DO 12 has the lowest PE which indicates a relative high impact from the use phase compared to the production phase.

Figure 81 shows the PE and the LCC of all design options related to imaging equipment for BC5 (Colour Inkjet MFD).

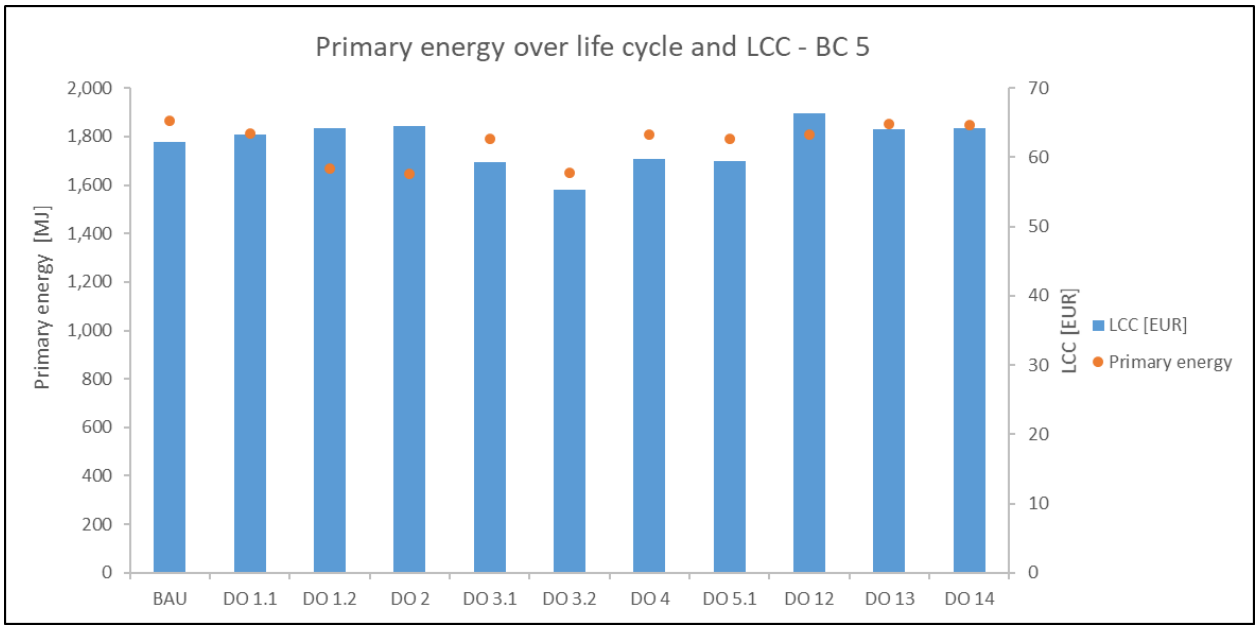

Figure 81: Primary energy over life cycle and LCC - BC5

BC5 presents the lowest levels of LCC of all the base cases primarily driven by a low purchase price. However, as for the previous base cases, LCC levels are similar between design options, but lowest for DO 3.1 and 3.2. PE levels are lowest for DO 2 and 3.2.

Figure 82 shows the PE and the LCC of all design options related to imaging equipment for BC6 (Colour Inkjet printer).

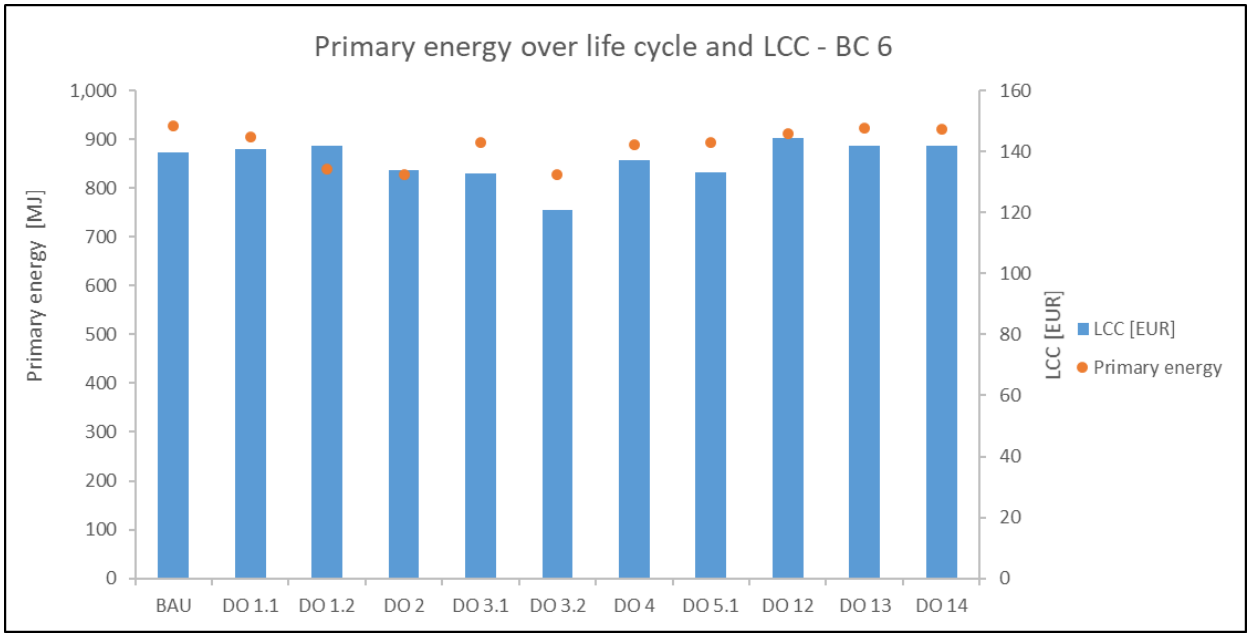

Figure 82: Primary energy over life cycle and LCC – BC6

Generally, these products are more expensive (see Task 5, section 5.5) than inkjet MFDs, because consumers nowadays prefer inkjet MFDs with more functionalities and there are much less inkjet printers left on the market therefore these are more customised. This is why there are significant differences in LCC between BC5 and BC6. On the other hand, the

use of primary energy for BC6 is about half than for BC5. This indicates that inkjet printers are used less due to fewer functions, and the amount of materials needed for the production is also smaller.

LCC is the lowest for DO 3.1 and 3.2. PE levels are lowest for DO 2 and 3.2.

Figure 83 shows the PE and the LCC of all design options related to imaging equipment for BC7 (Professional printer/MFD).

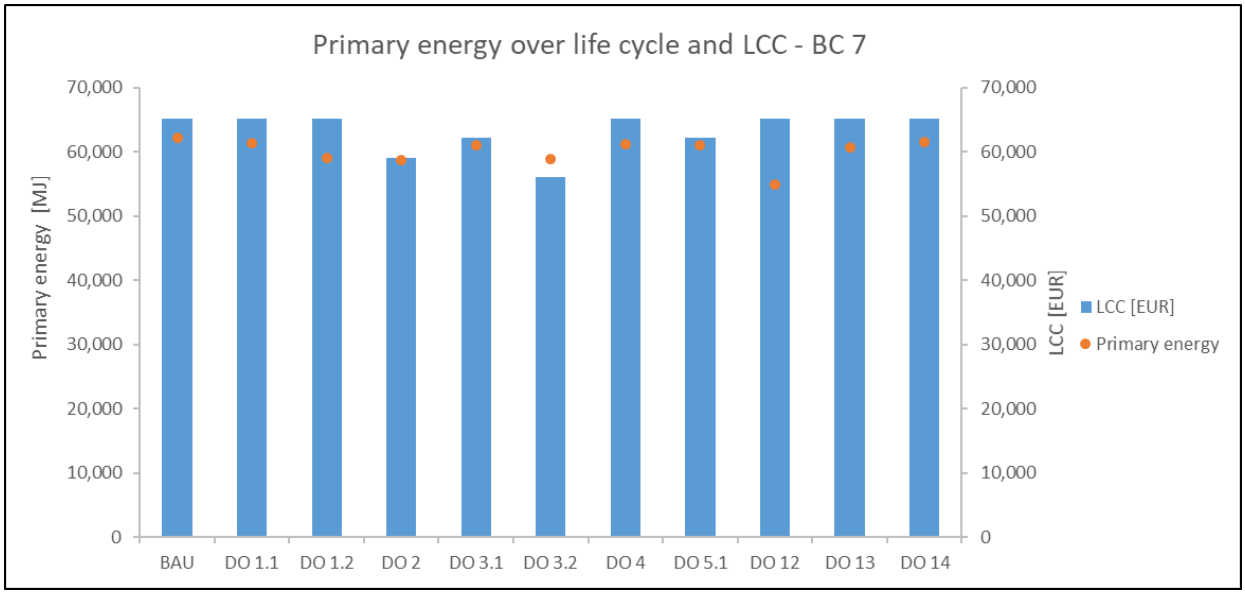

Figure 83: Primary energy over life cycle and LCC – BC7

The scale of LCC is very different compared to previous base cases, since average price and other costs are much higher for professional products. The products are also larger and more frequently used which results in high primary energy demand (see Task 5, Section 5.3). DO 12 stands out with the lowest PE which is similar to BC 3 and BC 4 and indicates a higher impact from the use phase relative to the production phase.

Figure 84 shows the PE and the LCC of all design options related to consumables for inkjet cartridges. Consumables are in reality part of the life cycle of imaging equipment products, but they are shown here separately in order to discuss their LCC and primary energy efficiency.

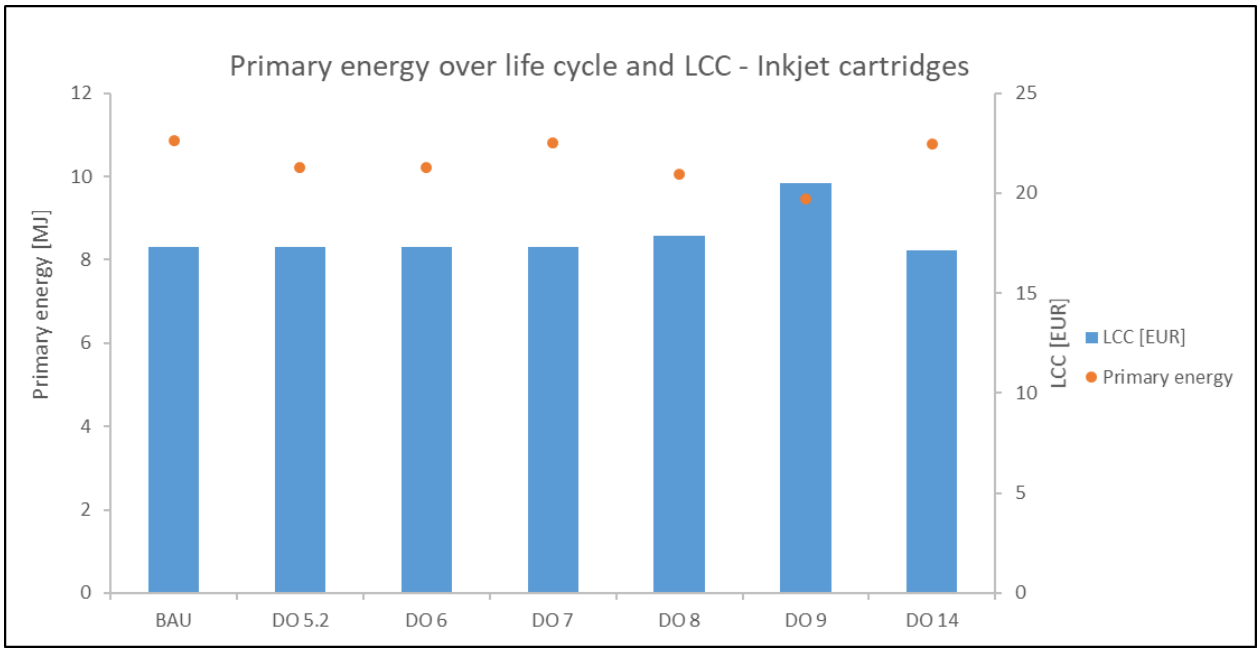

Figure 84: Primary energy over life cycle and LCC – Inkjet cartridges

Differences between consumables design options are also small, although DO 9 (related to consumable imaging yield efficiency) shows clearly a lower PE. This is due to this option leads to a material reduction of 25 %. Increasing the reuse shares for DOs 5.2 and 6 by up to 15% have little impact on PE and no impact on the purchase price because the firmware changes for DO 5.2 only lead to improvement costs in the equipment itself, while DO 6 removes the exemption which can be exploited to hinder reuse and remanufacturing of cartridges, no costs should be added to end-users for removing this exemption, and therefore no changes in LCC for these options compared to BAU. The reduction in material consumption for DO 9 does affect the LCC as for cartridge because the relatedly high improvement costs overshadow the cost savings from prolonged lifetime.

Figure 85 shows the PE and the LCC of all design options related to consumables for inkjet containers.

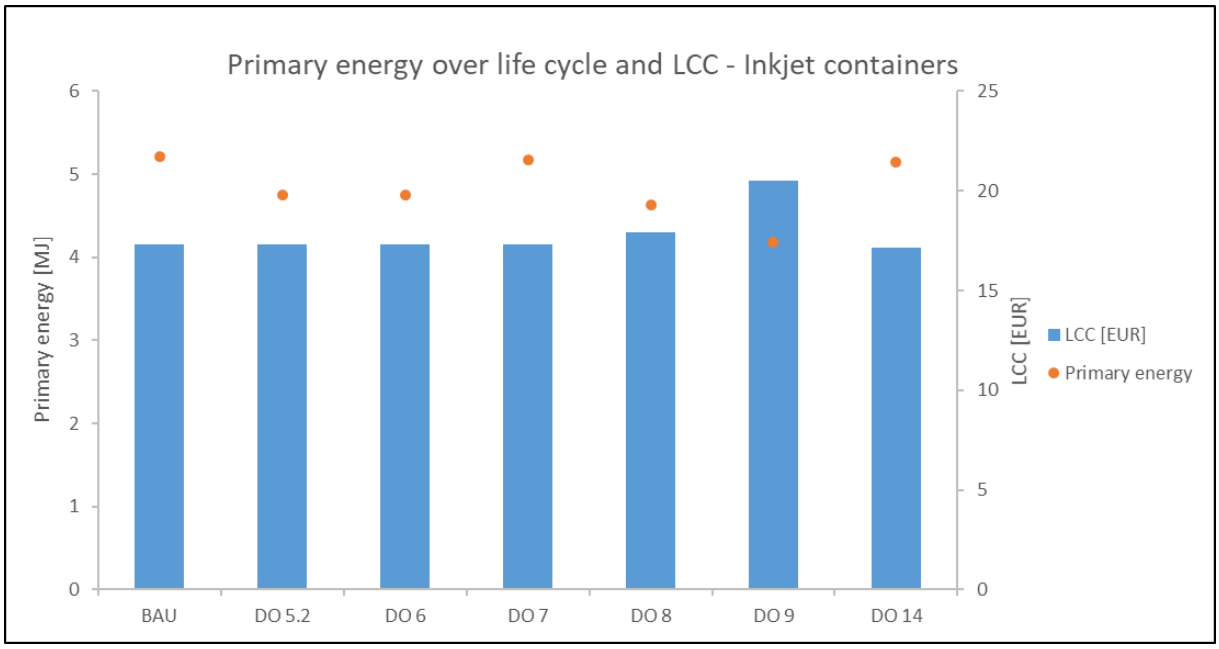

Figure 85: Primary energy over life cycle and LCC – Inkjet containers

The PE is about half compared to inkjet cartridges mainly due to a lower material input but DO 9 still shows a significantly lower PE compared to the other DOs. The LCC is I higher for all options than the BAU levels, due to improvement costs cannot be offset by the cost savings from prolonged lifetime.

Figure 86 shows the PE and the LCC of all design options related to consumables for toner cartridges.

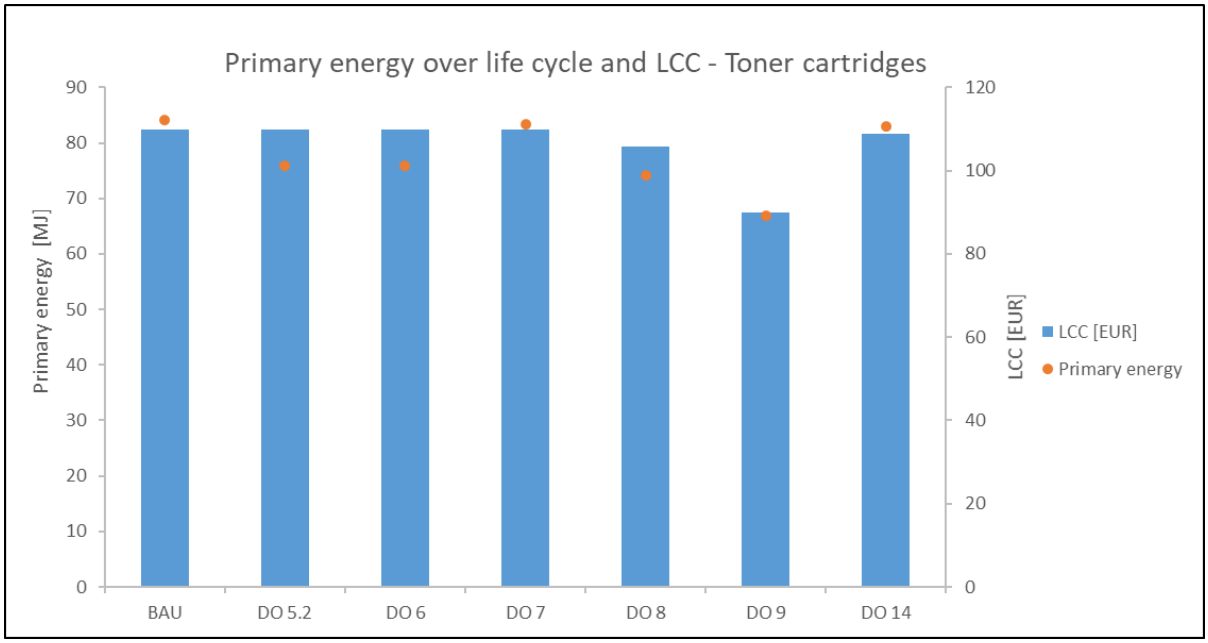

Figure 86: Primary energy over life cycle and LCC – Toner cartridges

The LCC are higher for toner than for inkjet cartridges due to purchase price differences, same as the PE as toner cartridges are larger. Still DO 9 is the best out of the 6 design

options, and in contrast to inkjet consumables the cost savings from prolonged lifetime can be observed in the LCC. This is basically because toner consumables are larger and more expensive products, therefore the improvement costs make up a smaller share of the purchase price for toner consumables, whereas the improvement costs for DO 9 is quite large inkjet consumables. The LCC for DO 6 does not change in comparison with BAU, as the costs of removing an exemption does not assume extra costs for end-users.

Figure 87 shows the PE and the LCC of all design options related to consumables for toner containers.

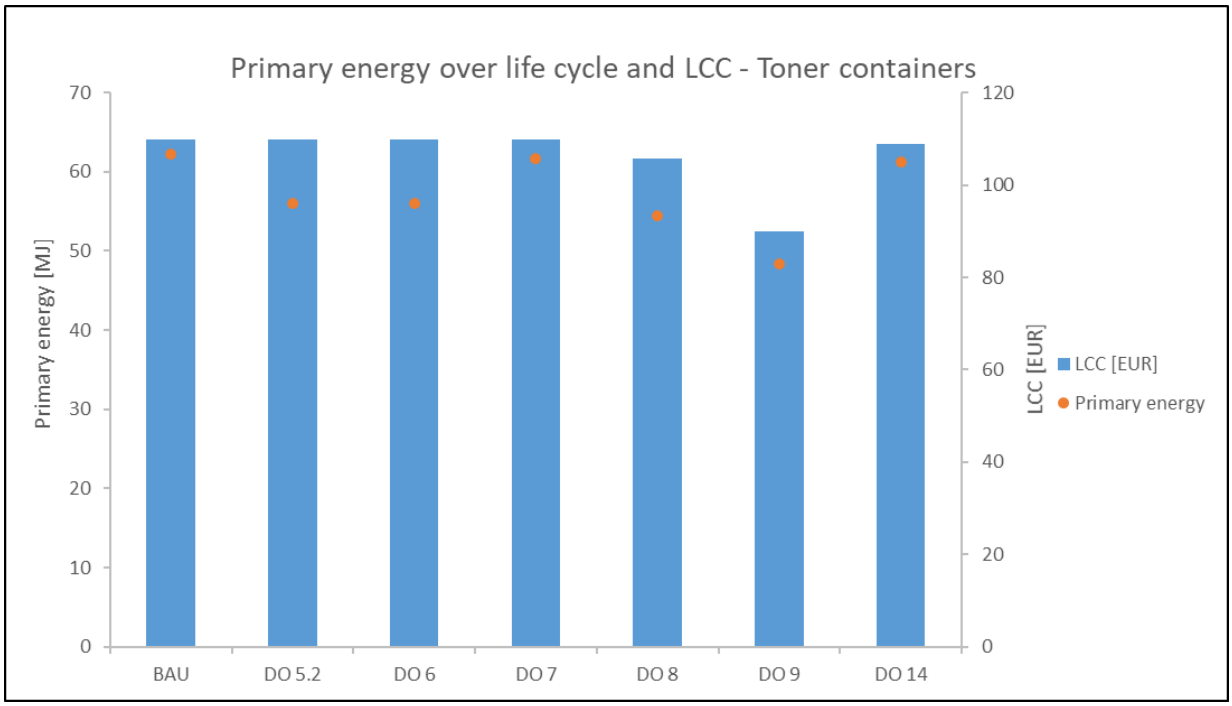

Figure 87: Primary energy over life cycle and LCC – Toner containers

The LCC are the same as for toner cartridges, but the PE levels of toner containers are slightly lower, due to smaller than toner cartridges. The differences between design options concerning the PE are the same as for toner cartridges, where design options 9 stands out with the lowest level for both LCC and PE.

6.3.2 Clustered design options – LCC and primary energy

Design options have been clustered to investigate the potential of implementing several design improvements at the same time. The clustering has been done as it follows in Table 121.

Table 121: Clustered design options

Short name	Description	Design options included
BAU	Business-as-usual.	None
RES_LOW	Design options related to resource efficiency improvements at lowest level of ambition	DO1.1, DO3.1, DO5.1, DO6, DO7
ENER_LOW	Design option related to energy efficiency improvements at low level of ambition	DO 12, DO 14
RES_MED	Design options related to resource efficiency improvements at medium level of ambition	DO1.1, DO2, DO3.1, DO5.1, DO5.2, DO6, DO7
ENER_MED	Design option related to energy efficiency improvements at medium level of ambition	DO12*, DO 14
RES_Con_BAT	Design options related to resource efficiency improvements at high ambition level for consumables	DO5.2, DO6, DO7, DO8, DO9
RES_IE_BAT	Design options related to resource efficiency improvements at high ambition level for IE products	DO1.2, DO2, DO3.2, DO4, DO5.1
RES_BAT	Design options related to resource efficiency improvements at high ambition level both for consumables and equipment	All in previous two
ENER_BAT	Design options related to energy efficiency improvements at high ambition level both for consumables and equipment	DO12**, DO13, DO 14

*Medium ambition for compliance rate, Tier I by 2021, 60% of TEC and OM product shall be compliant with ENERGY STAR version 3.0 requirements.
** High ambition for compliance rate, Tier I by 2021, 90% of TEC and OM product shall be compliant with ENERGY STAR version 3.0 requirements.

A RES scenario can be combined with an ENER scenario by adding the impacts i.e. they are not mutually exclusive.

Figure 88 shows the PE and the LCC of clustered design options for BC1 (Mono Laser MFD). By clustering design options, the LCC are aggregated and become higher for the different clusters.

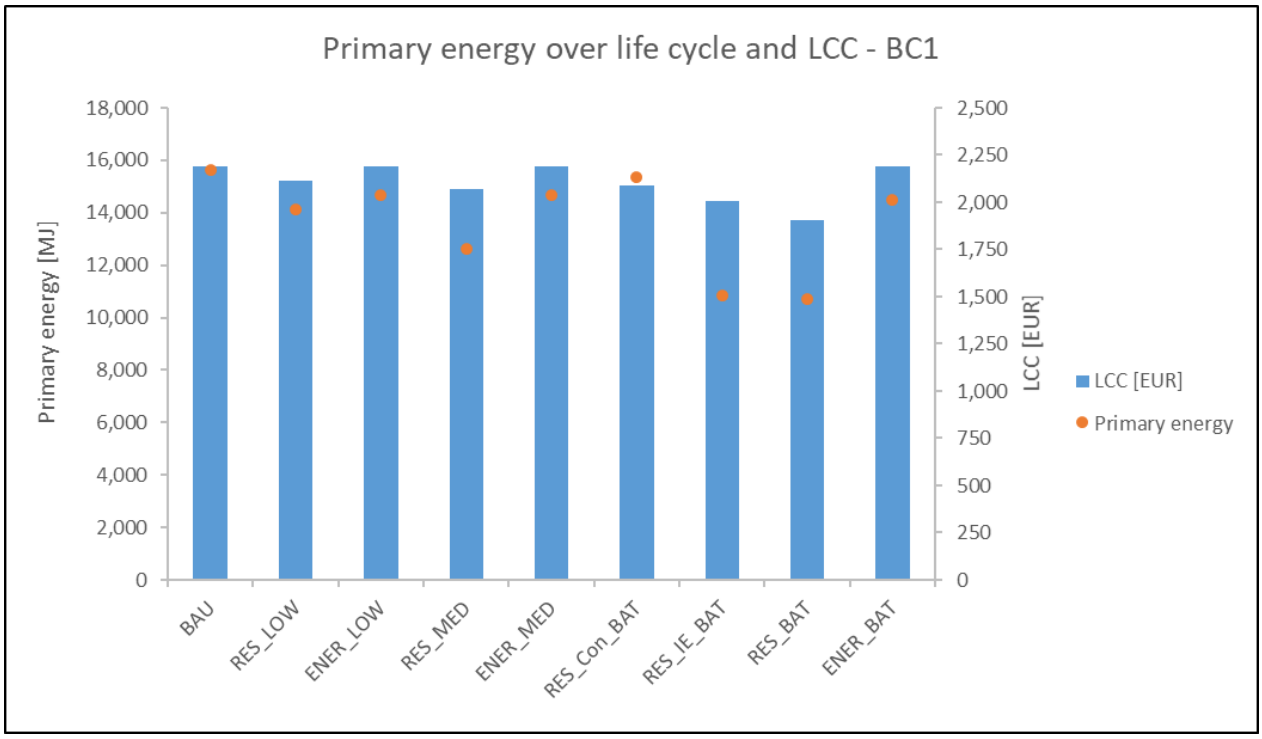

Figure 88: Primary energy over life cycle and LCC for clustered design options – BC1

Figure 88 shows reductions, by implementing clustered design options, of up to 32% of primary energy use compared to BAU for BC1. LCC has for some design options increased slightly (<1%) compared to BAU but most design options see a reduction of up to 13%.

The combination of industry proposals with design options related to resource efficiency improvements (RES_BAT & RES_IE_BAT) show the largest reductions of primary energy used. The same design options show the least LCC.

Figure 89 shows the PE and the LCC of clustered design options for BC2 (Colour Laser MFD). The results from clustered design options show reductions of up to 32% of primary energy use compared to BAU for BC2.

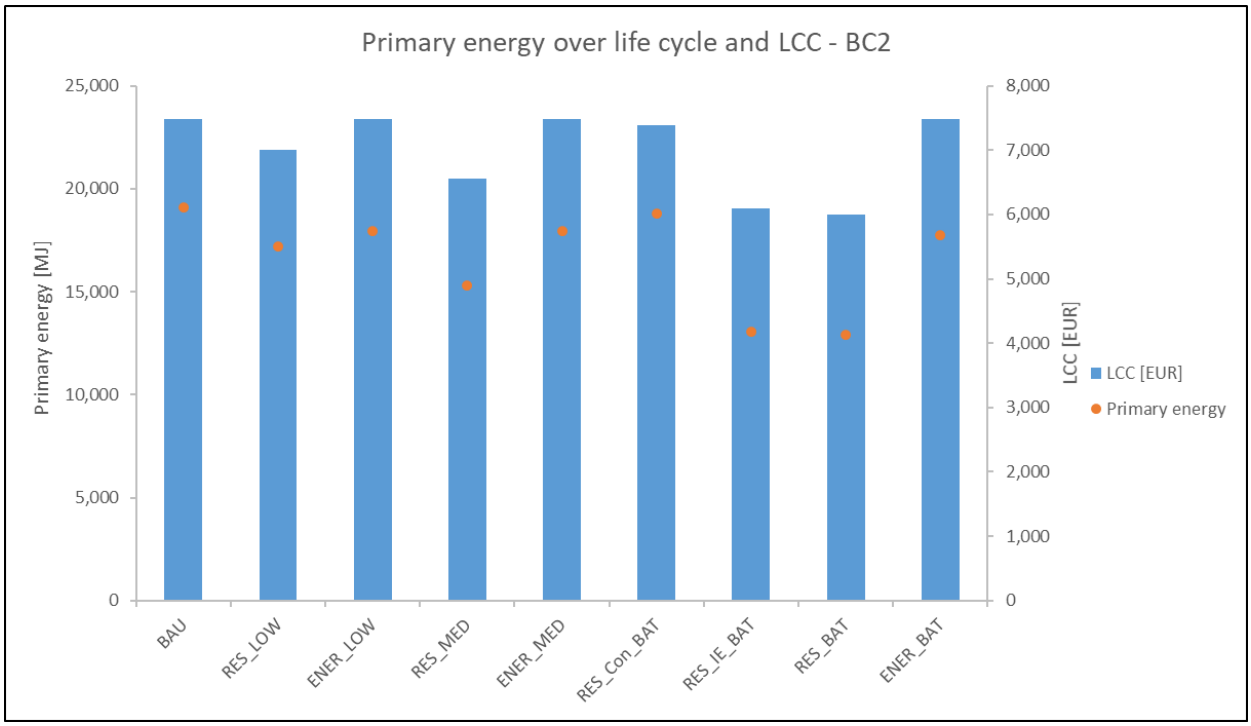

Figure 89: Primary energy over life cycle and LCC for clustered design options – BC2

RES_BAT and RES_IE_BAT show the least LCC and PE.

Figure 90 shows the PE and the LCC of clustered design options for BC3 (Mono Laser Printer).

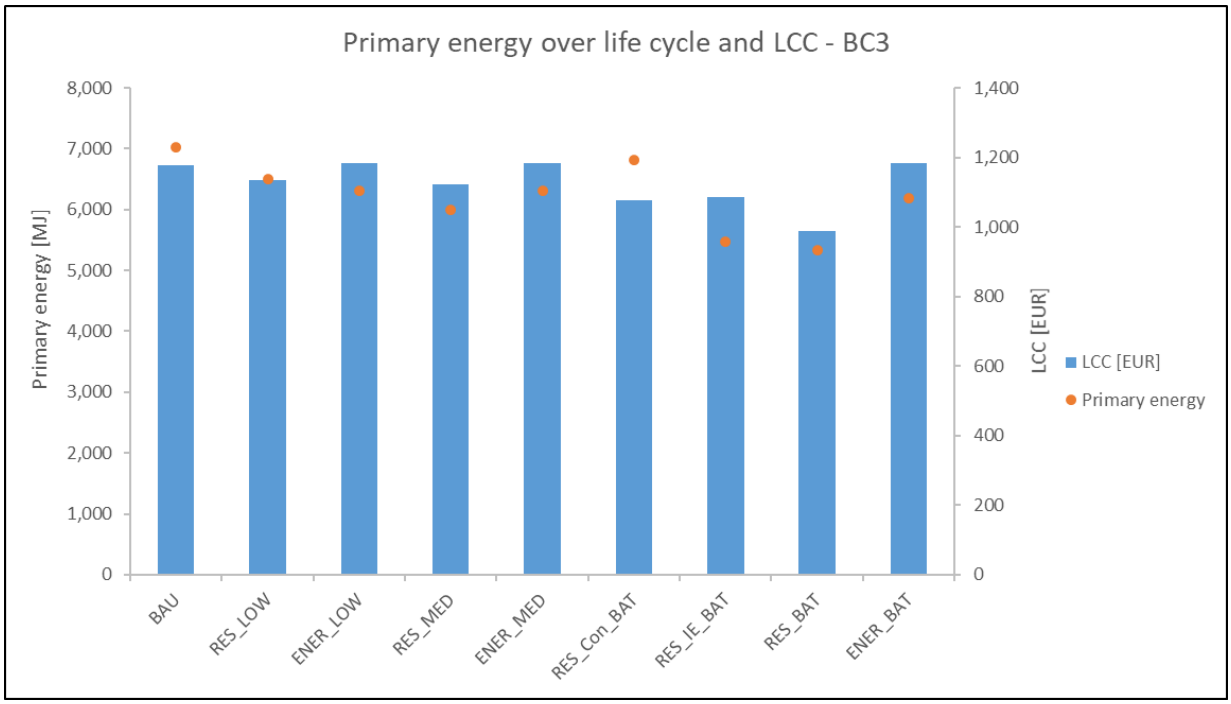

Figure 90: Primary energy over life cycle and LCC for clustered design options – BC3

The results from clustered design options show reductions of up to 24% of primary energy use compared to BAU for BC3, slightly lower than for the previous base cases. On the other hand, LCC shows higher reductions of up to 17%.

RES_BAT shows the least PE and LCC, however RES_Con_BAT, which is related to resource efficiency improvements for consumables, shows a lower LCC than RES_IE_BAT. This is because BC3, products are significantly cheaper than in BC1 and BC2 but the price for consumables is assumed the same and therefore make up a larger share of the total LCC.

Figure 91 shows the PE and the LCC of clustered design options for BC4 (Colour Laser Printer).

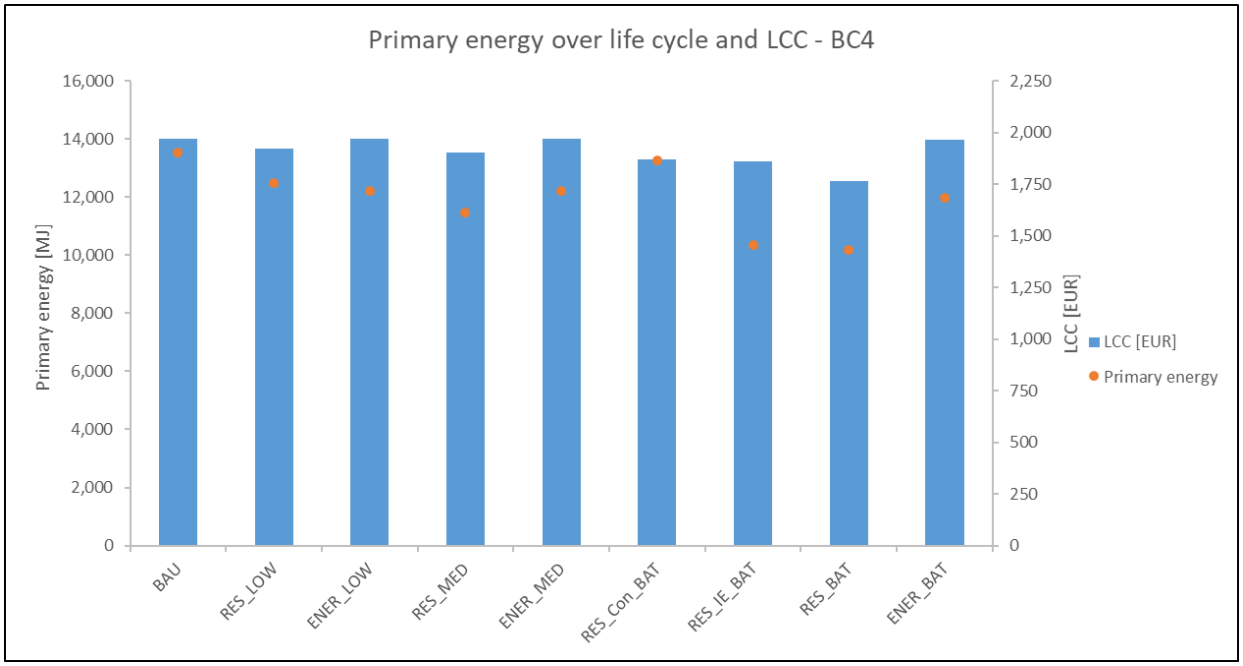

Figure 91: Primary energy over life cycle and LCC for clustered design options – BC4

The results from clustered design options show reductions of up to 25% of primary energy use compared to BAU for BC4. LCC shows reductions of up to 11%.

RES_BAT and RES_IE_BAT show the least LCC and PE.

Figure 92 shows the PE and the LCC of clustered design options for BC5 (Colour Inkjet MFD).

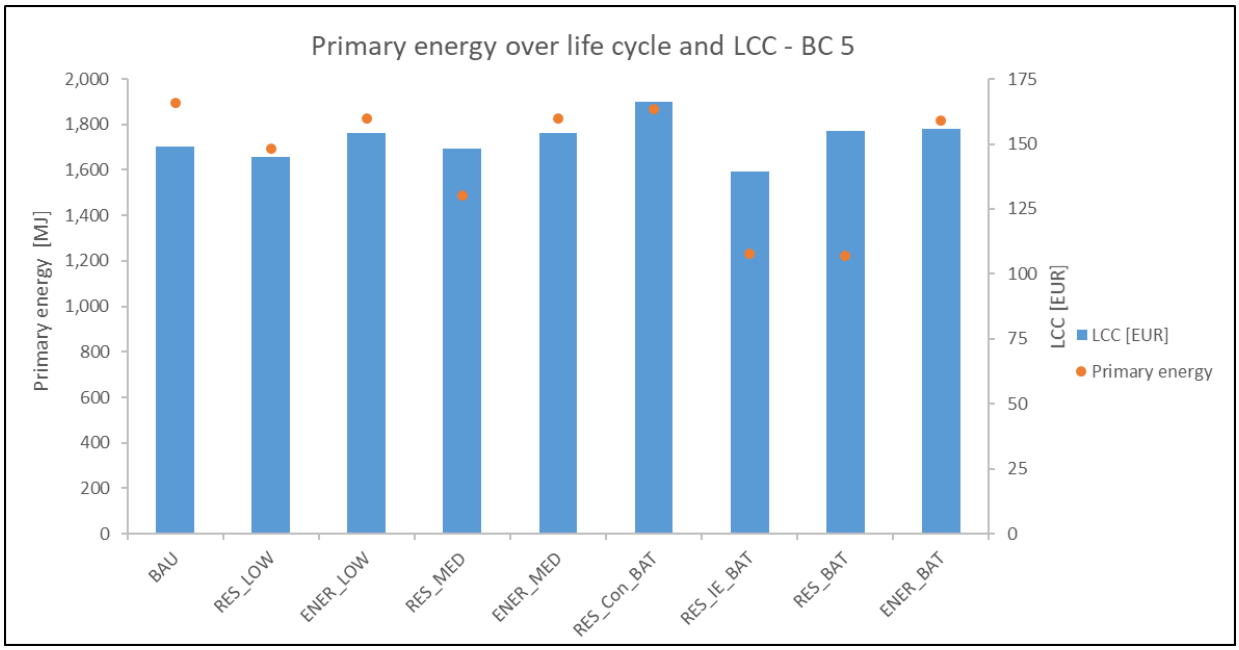

Figure 92: Primary energy over life cycle and LCC for clustered design options – BC5

The results from clustered design options show reductions of up to 36% of primary energy use compared to BAU for BC5. This is the highest reduction of all base cases. In contrast to BC 1-4 the 'ENER' scenarios see a slightly higher increase in LCC of up to 3 %. The electricity consumption of BC 5 products is very small compared to BC 1-4 products which means that energy efficiency improvements count very little in the total life cycle costs. The increased product costs simply outweigh the electricity costs savings.

RES_MED shows the third lowest PE due to a high material reduction (20%) and a high recycling rate (10%). Again RES_BAT and RES_IE_BAT show the least LCC and PE.

Figure 93 shows the PE and the LCC of clustered design options for BC6 (Colour Inkjet printer).

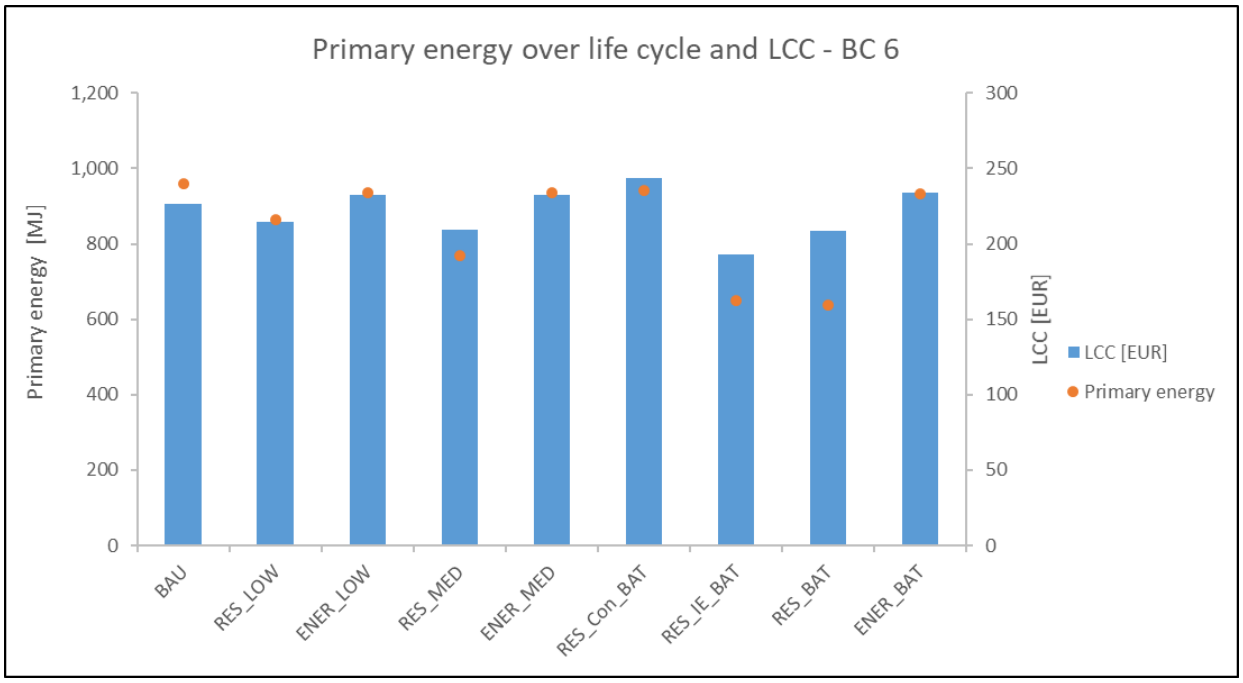

Figure 93: Primary energy over life cycle and LCC for clustered design options – BC6

The results from clustered design options show reductions of up to 33% of primary energy use compared to BAU for BC6. Similar to BC5 there are slightly higher increases in LCC of up to 2% for the 'ENER' scenarios.

RES_BAT and RES_IE_BAT show the least LCC and PE for BC 6.

Figure 94 shows the PE and the LCC of clustered design options for BC7 (Professional printer/MFD).

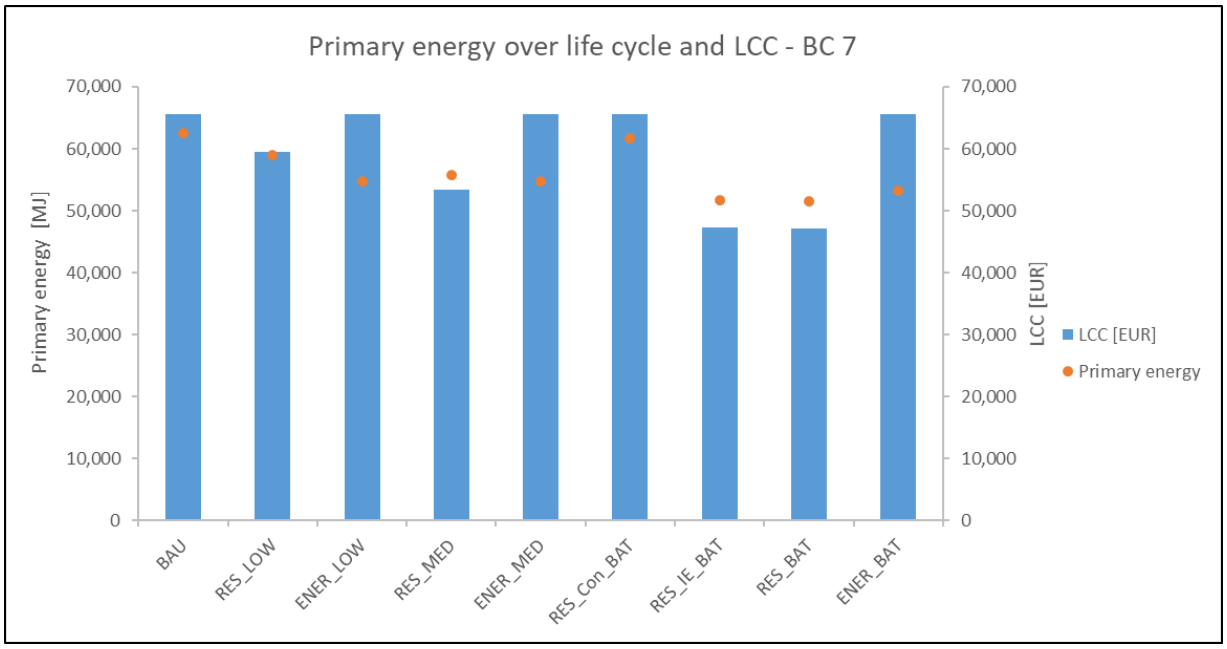

Figure 94: Primary energy over life cycle and LCC for clustered design options – BC7

The results from clustered design options show reductions of up to 17% of primary energy use compared to BAU for BC7. Design options lead to a decrease in LCC of up to 28% which is the highest out of all base cases.

The same pattern as for all base cases is repeated with RES_BAT and RES_IE_BAT having the least LCC and PE.

6.4 Conclusions and recommendations

Table 122 and Table 123 below give an overview of all clustered design options for all seven base cases for primary energy over the life cycle and life cycle cost respectively.

Table 122: Summary of primary energy use for clustered design options per base case
Numbers are colour coded, dark red cells represent the highest primary energy use while dark green represents the lowest.

Primary energy [MJ]	BC 1	BC2	BC3	BC4	BC5	BC6	BC7
BAU	15,640	19,096	7,021	13,526	1,895	959	62,459
RES_LOW	14,131	17,193	6,494	12,479	1,692	865	58,975
ENER_LOW	14,654	17,934	6,316	12,216	1,827	937	54,738
RES_MED	12,620	15,282	5,989	11,465	1,486	769	55,742
ENER_MED	14,654	17,934	6,316	12,216	1,827	937	54,738
RES_Con_BAT	15,362	18,785	6,813	13,260	1,868	940	61,766
RES_IE_BAT	10,853	13,070	5,476	10,336	1,233	650	51,750
RES_BAT	**10,710**	**12,927**	**5,333**	**10,193**	**1,221**	**639**	**51,607**
ENER_BAT	14,484	17,735	6,188	11,978	1,816	934	53,303

Table 123: Summary of LCC for clustered design options per base case
Numbers are colour coded, dark red cells represent the highest LCC while dark green represents the lowest.

Life cycle cost [Eur]	BC 1	BC2	BC3	BC4	BC5	BC6	BC7
BAU	2,188	7,490	1,177	1,971	149	226	65,646
RES_LOW	2,114	7,012	1,134	1,922	145	215	59,502
ENER_LOW	2,191	7,490	1,184	1,968	154	232	65,549
RES_MED	2,071	6,564	1,121	1,903	148	210	53,395
ENER_MED	2,191	7,490	1,184	1,968	154	232	65,549
RES_Con_BAT	2,087	7,389	1,077	1,870	166	244	65,538
RES_IE_BAT	2,006	6,095	1,086	1,862	140	193	47,258
RES_BAT	1,908	5,997	988	1,764	155	208	47,159
ENER_BAT	2,190	7,489	1,184	1,967	156	234	65,555

The clustered design option with the largest reductions compared to BAU for both PE and LCC is the RES_BAT. RES_BAT is therefore the preferred option for all seven base cases and is related to resource efficiency improvements at a high ambition level for both products and consumables. RES_BAT entails a reduction in material use of 30%, improved reuse, recycle and recovery rates of 15%, 18% and 20% respectively (44 %, 8 % and 0 % for consumables) and a minor reduction in electricity consumption (during use phase) of 1%.

The DOs ENER_LOW, ENER_MED & ENER_BAT with high use phase electricity reductions (21% to 25%) only show minor reductions in primary energy use over the life cycle compared to BAU and sees slight increases in LCC for most base cases. These results emphasize the findings from Task 5, which showed a relatively low impact from the use phase compared to the production phase. These design options focus on energy efficiency, they do not improve the rates of reuse, recycling and recovery which affects PE significantly.

Reducing material use for consumables is also showing little impact on primary energy use over the life cycle. Each base case is assumed to use in average between 4-5 consumables per year and between 20 – 25 consumables in total over the equipment life of 5-6 years. The material consumption for consumables is relatively small compared to the material consumption for the imaging equipment, therefore the clustered option RES_Con_BAT results in higher PE and LCC than RES_IE_BAT.

It can be concluded that at an individual equipment level, the resource efficiency improvements with the highest ambition for consumables alone (RES_Con_BAT) is less effective than for the equipment alone (RES_IE_BAT). Implementing resource efficiency options for both equipment and consumables with medium (RES_MED) and low ambitions (RES_LOW) are better than only improving consumables.

Based on the analysis above, RES_BAT is the preferred option on the individual base cases level. It is recommended to model the impacts of the clustered design options in Task 7 to assess the impacts at the EU-28 level.

7. Task 7: Policy scenarios

In this task, the policy analyses are presented with the recommended policy instruments and the measures to be selected. The different policy scenarios with different sets of requirements are analysed against the baseline, a Business-as-Usual (BAU) scenario, the results are presented in terms of life cycle primary energy consumption, GWP, material consumption and electricity consumption during use phase. The impacts on consumer expenditure are also presented for different policy scenarios.

Finally, Task 7 should summarise the analyses results and make recommendations on the policy measures that should be adopted for the product group.

7.1 Policy analysis

This sub-section summarises the findings of Task 1 – 6 and the potential policy measures to be considered.

7.1.1 Stakeholder consultation

The stakeholder consultation process in this study has been carried out in four major steps. Industry stakeholders including OEMs, remanufacturers and industry experts have been active in providing inputs and data. However, the participation from NGOs and Member States (MSs) have been limited.

The first consultation began in June – July 2018, where the study team requested for inputs for base case choices, energy consumption, usage patterns, costs over a typical life cycle, basic information regarding imaging equipment and consumables etc. In addition, the study team also requested views on the VA via more open-ended questions, such as the effectiveness and issues of the current VA. The study team held various telephone conferences with VA signatories, EuroVAprint[345] representatives, remanufacturer representatives and industry experts etc. regarding information on current reuse and recycling situation in this sector; the issues with remanufacturing consumables, and the lack of transparency issues with the VA. During this process, the study team consulted the Independent Inspector[346] for the current VA, upon signing the non-disclosure agreement (NDA), the Independent Inspector, with the permission from the EuroVAprint, submitted reported data for 2017 according to Annex C of the VA.

The second round of stakeholder consultation began in October 2018, where we refined the choices of base cases, and requested more detailed data on each base case, such as the bills-of-materials (BOM), as well as verification of the estimated sales and stock of

[345] EuroVAprint is an association grouping all major manufacturers of imaging equipment that operate in Europe in relation to the VA on imaging equipment. http://www.eurovaprint.eu/home/
[346] RINA Consulting Limited

imaging equipment and consumables. Upon signing a number of non-disclosure agreements with several signatories, the study team received sets of data for each base case and information on the sales of consumables. NDAs prevent the study team from present any data directly, even anonymously, therefore the data for base cases supplied by the signatories have been averaged and then only the averaged values have been presented in the study reports.

The third round of stakeholder consultation began in January 2019, where the study team further requested BOM of consumables, as scarce information was received in the previous round. The study team verified the assumptions needed for the inputs to EcoReport tool and requested inputs or comments on the team's estimation on current reuse and recycling rates as well as a BAT scenario reuse and recycling rates for both imaging equipment and consumables. The study team presented a draft list of design option to improve energy and resource efficiency of imaging equipment and consumables, as well as the estimated savings and associated costs, and requested feedback from stakeholders. The stakeholders' inputs on savings and costs have been taken into the modelling, and the comments on feasibility have been presented in Task 6.

The last round of stakeholder consultation took place at a stakeholder meeting the 25 April 2019 followed by a one-month period for submitting written comments.

7.1.2 Barriers and opportunities for improvements

Task 5 showed that for non-professional IE (BC1-BC6) including consumables (use of ink and toner), the equipment production phase is the most dominant phase of the entire life cycle in terms of primary energy demand and emission of CO2-eq. followed by the electricity consumption and consumables in the use phase. For professional IE (BC7) the most dominant phase is electricity, followed by the production phase and the distribution phase.

The biggest opportunity thus relies on tackling the environmental impacts from the production and end of life of imaging equipment and consumables. Increasing products and consumables sent to end of life routes with higher reuse and recycling will decrease the overall life cycle environmental impacts. Designing products and consumables that can facilitate these routes is an important incentive.

The main barriers and opportunities to tackle this are described in the next paragraphs, as well as barriers and opportunities identified to further reduce the environmental impacts from the use phase.

Scope

The current VA covers a truncated version of the ENERGY STAR v2.0 scope. The main truncation is due to limiting the scope to only include IE products with image speeds below

66 A4 images per minute for standard black & white (BW) format products and below 51 A4 images per minute for standard colour format products. Additionally, some product types with lower market shares are also left out, such as scanners and non-standard formats (such as A2 and larger and A6 and smaller products) and less typical marking engines i.e. not being electrophotography, inkjet and solid ink.

Even though the VA scope covers most of the commonly sold imaging equipment, products outside the VA scope still constitutes a non-marginal share of the sales. E.g. - as shown in Task 2 - speed categories outside of the current VA scope accounts for over 12% of the total sales of printers and MFDs. This creates an uneven market level playing field as environmental improvements are not stimulated equally for all types of commonly used imaging equipment in addition to not achieving the environmental improvement potential for this market share.

Therefore, an opportunity exists in extended the scope to match the ENERGY STAR v3.0 scope, in particular concerning the removal of the current VA speed limits and the inclusion of professional products.

Concerning consumables, the scope provided in the VA section on scope (Section 3) is clear, because it states under a sub-section "Product scope": *In this Voluntary Agreement, "products" means imaging equipment meeting the conditions in section 3.3. The terms "imaging equipment" and "product" do not include cartridges or other consumables.* However, in another sub-section cartridges are mentioned as the ones that are produced or recommended by the OEMs for use in imaging equipment in scope for which there are commitments regarding other resource efficiency requirements[347]. The conclusion is that cartridges produced or recommended by the OEMs are in scope for one particular requirement. There is no mention of containers, which account for a significant share of the consumables in particular for ink equipment, as it has been shown in Task 2 report.

An opportunity is to clearly include both cartridges and containers in the scope of the VA. This requires harmonized definitions, which are proposed in Task 1 report and are aligned with the draft GPP criteria for imaging equipment, EPEAT, Blue Angel and the Korea Ecolabel. Furthermore, the VA should be edited to improve the clarity on which products are included in scope.

[347] VA, Section 5.4.1: *Any cartridge produced by or recommended by the OEM for use in the product shall not be designed to prevent its reuse and recycling.* and Section 6.3 *Cartridge disposal and treatment For new product models first placed on the EU market after 1 January 2012, Signatories shall provide end-users with information on suitable end-of-life management options for used cartridges. This information may be communicated via a company website.*

Energy efficiency requirements

Task 4 report showed electricity in use reduction potentials between 14% and 30% for the TEC base cases (BC1-BC4) going from average to BAT products (as per September 2018) and between 0% and 64% for sleep and standby/off for OM base cases (BC5-BC6). A further potential in BAT is assumed due to efficiency developments since September 2018 and due to the introduction of ENERGY STAR v3.0 specification.

An opportunity exists in using ENERGY STAR v3.0 energy efficiency requirements. The Voluntary Agreement supplemented by the US ENERGY STAR and other initiatives in the US, other countries, EU and Member States has been effective in achieving direct energy consumption savings, as it was shown in Task 5 report. Especially in the current situation without an EU ENERGY STAR scheme, the VA can assist in securing that only few ENERGY STAR v3.0 non-complying products will enter the EU market.

A barrier is if the VA will not be updated to be in compliance with the self-regulation guidelines and additionally follow the study team's recommendations on information requirements, transparency etc.

Resource efficiency requirements – Legislation and environmental metrics and standards

The level of ambition concerning resource efficiency requirements in the current VA is weak in comparison to other voluntary environmental initiatives (e.g. Blue Angel, Nordic Swan Ecolabel, US EPEAT programme). Large numbers of product registrations (e.g. more than 5000 in EPEAT) to some of the other more ambitious environmental initiatives suggests that the VA may not be delivering savings beyond a business as usual scenario. To combat this issue, the VA should include a wider range of requirements addressing consumables, so it covers the life cycle environmental hotspots associated with imaging equipment.

A range of potential improvement options and requirements have already been discussed in Tasks 1 and 6 reports. These could incentivize the market for a reduction of the production environmental impacts both by reducing material consumption and shifting to higher reuse and recycling rates at the end of life. Existing metrics and standards are found for most of them, as described in Task 1 report.

Consumable remanufacturing – Technical and non-technical barriers

As discussed in previous tasks, the ability of a consumable to be remanufactured can have an important effect on life cycle environmental impacts. However, there seems to be a lack of regulatory practices to promote the reuse of consumables or encourage dematerialization and greater resource efficiency. This is partly created by the lack of measures to secure an openness between OEMs and remanufacturers (largely SMEs) to remove barriers for reuse.

Many OEMs retain the customers within the brand, once the imaging equipment is purchased, by selling own brand consumables, ensuring both full control of the imaging equipment-consumables system and continuous profit from the same end-users over the lifetime of the product. There is therefore no incentive for the OEMs to encourage competitiveness of non-OEM consumables. From the regulatory perspective, it is positive impact regardless by who, as long as more and more consumables are remanufactured and reused.

However, there are several different barriers limiting the ability to remanufacture imaging equipment consumables. These are mainly technical (e.g. sonic welding, use of adhesive tapes, inclusion of non-reprogrammable chips, use of firmware in equipment that prevents the use of non-OEM cartridges) and non-technical (e.g. use of patented remanufacturing processes that prevent wider remanufacturing, copyright issues when non-OEMS use OEM cartridges for remanufacturing, lack of remanufacturing information, published claims about poor quality printing when using remanufactured consumables).

An opportunity therefore exists for reusing consumables, but large barriers exist.

Wording of VA requirements

Some of the requirements are ambiguous and thus open to interpretation and difficult to verify. These should be revised to avoid loopholes and misinterpretations, see further in Task 5 report.

Other improvements of the VA

Opportunities exist for improving the effectiveness of the VA and securing a higher market pull of customers towards higher efficiency products. The improvements include:

- VA information requirements to secure public information for each specific model in scope
- Compliance with the self-regulation guidelines regarding timing of signatories' reports; removal of the deposit and possible fee for allegation of non-compliance; access to Market Surveillance Authorities to specific documentation and information; and product testing by The Independent Inspector
- Detailed product information for compliance verification
- Increase of transparency of the VA operation.

These suggested improvements options are detailed in Task 5 report.

7.1.3 Policy instruments

There are several product policy instruments available, which could be used to regulate imaging equipment. Given that there is already a Voluntary Agreement available for these

products, the focus of policy instruments is easily identified. The basic types of policy instruments as presented below:

1) No action option – Business as usual (BAU), the current VA is to be retained as it is. The first overall decision to be made is whether there is a need for further EU intervention. This BAU scenario will be used as reference for comparison with other policy scenarios.
2) Ecodesign requirements (under the Ecodesign Directive (2009/125/EC)): This means mandatory minimum requirements would be introduced for a set of parameters; the manufacturers would bear the responsibility for their products to be compliant when placed on the market and the Member States would verify compliance via market surveillance activities. This acts as a "push" instrument for products to achieve better performance because all appliances will have a minimum level of energy efficiency performance regulated by the implementing measure.
3) Energy labelling (under the Energy Labelling Regulation (2017/1369/EU)[348]): This implies mandatory labelling of the product for a set of parameters. Manufacturers are responsible for labelling their products and it is also enforced by Member State market surveillance regarding both the actual labelling and the correct energy class. This acts as a pull instrument because the consumers will choose the products they want to purchase, which can pull the market towards higher energy performance.
4) Self-regulation as an alternative to Ecodesign requirements: The Ecodesign Directive (2009/125/EC) recognizes self-regulation by industry as an alternative to binding legislation. Self-regulation, which can be based on voluntary agreements, is a valid alternative as long as it delivers the policy objectives set out in the legislation faster and in a less costly manner than mandatory requirements. The directive gives specific requirements for self-regulative measures. Since there is already a self-regulative measure i.e. the Voluntary Agreement on imaging equipment regulated by the industry since 2011, this is a highly relevant policy instrument to analyse further.
5) Voluntary labelling implies manufacturers can choose whether to label their products. In the case of ENERGY STAR[349] and Ecolabel[350], the specifications are established through regulations, ensuring that the labelled product belongs to the upper

[348] Regulation (EU) 2017/1369 of the European Parliament and of the Council of 4 July 2017 setting a framework for energy labelling and repealing Directive 2010/30/EU
[349] Regulation (EC) No 106/2008 of the European Parliament and of the Council of 15 January 2008 on a Community energy-efficiency labelling programme for office equipment (recast version)
[350] Regulation (EC) No 66/2010 of the European Parliament and of the Council of 25 November 2009 on the EU Ecolabel

segment of the market in terms of energy consumption and other environmental aspects. Member States are responsible for market surveillance. The ENERGY STAR covers imaging equipment, but since 2018 the EU-US ENERGY STAR agreement expired and it is no longer possible to register under ENERGY STAR in EU. For the EU Ecolabel, EU Regulation 66/2010/EC[351] already covered imaging equipment under electronic equipment category[352], however, the EU Ecolabel on imaging equipment was discontinued by December 2017. It is consider as not an option to reintroduce an EU Ecolabel on imaging equipment.

6) Green Public Procurement (GPP) is directed for mainly Europe's public authorities and through their large purchasing volume, their purchasing power can be used to transform the market. GPP criteria for imaging equipment were published in 2014.[353] The criteria are currently under revision with a target completion date by end of 2019.

Although the energy efficiency of imaging equipment has been improved over the past 8 years, it is difficult to determine if the resource efficiency requirements of the VA have had any tangible impacts. This is also due to the fact that the VA allows incompliance up to a certain percentage, unlike Ecodesign regulations, and the requirements do not have to apply to all products on the market. Furthermore, the information that would prove compliance is not publicly available or can be easily requested by the MS Market Surveillance Authorities (MSA). The evaluation of the VA is therefore less straight-forward than for the ecodesign regulation or energy labelling.

The current VA signatories do not include any consumable manufacturers or remanufacturers and the product scope does not include consumables (whether OEM, non-OEM new built or remanufactured consumables), therefore any potential requirements set for consumables will only cover up to 68% of the EU consumable market (the consumable OEMs that are VA signatories), see Task 2 for more details. This means that the market coverage for consumables will not meet the condition that "self-regulation measure has a market coverage of at least 80%"[354]. In addition, it is unsure how non-OEM and remanufactured consumables will be addressed under the VA. If left unaddressed, the market coverage of these products could increase even more due to the unfair advantages of not being covered by the VA.

[351] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:027:0001:0019:en:PDF
[352] http://ec.europa.eu/environment/ecolabel/eu-ecolabel-products-and-services.html
[353] https://ec.europa.eu/environment/gpp/pdf/criteria/imaging/EN.pdf
[354] COMMISSION RECOMMENDATION (EU) 2016/2125 of 30 November 2016 on guidelines for self-regulation measures concluded by industry under Directive 2009/125/EC of the European Parliament and of the Council

If the structure and the operation of the current VA continues business as usual, the effectiveness of the VA for resource efficiency requirements would continue to be unknown with different sides claiming different situations.

An alternative policy instrument worth considering is an Ecodesign regulation. It would ensure the coverage of the whole EU market, while keeping level playing fields for all, regardless of imaging equipment manufacturers or consumables manufacturers or remanufacturers.

Energy labelling might also be considered, however, main resource efficiency requirements are difficult to distribute over energy classes and thus better suited for an Ecodesign regulation.

An advantage of continuing the VA is that it is already in effect, while an Ecodesign regulation would take a number of years possibly up to four years of development in consultation with stakeholders and the following impact assessment, policy process, voting and adoption, before requirements would take effect. In addition, a VA is more flexible regarding updates, while an Ecodesign regulation would require a technical review and a complete policy process. Furthermore, the industry stakeholders are still highly interested in maintaining the self-regulation.

The following section will therefore recommend policy measures that can improve the existing Voluntary Agreement and achieve the untapped saving potentials.

7.1.4 Recommended policy measures

The design options (DO) presented in Task 6 have been selected for further assessment as specific requirements. Their formulation proposed for the revised VA is explained in next sections, which has been used to develop the policy scenarios presented in section 7.1.5.

VA product scope

No matter which policy measures are chosen, it is recommended that two changes shall be always incorporated:

1) Aligning the VA scope with the ENERGY STAR v3.0 by removing the current VA speed limits. Section 3.3.4 of the current VA shall remove the maximum speeds, see modified section as follows:
   Household and office equipment: This Voluntary Agreement is limited to household and office equipment, meaning:
   - *Standard black & white (BW) format products*
   - *Standard Colour format products*

2) Including consumables in product scope of the VA. Section 3.2 of the current VA should be modified as follows[355]:

In this Voluntary Agreement, "products" means imaging equipment meeting the conditions in section 3.3, and "consumables" means imaging equipment consumables such as containers and cartridges meeting the definitions in Annex A.

Section 3.3.2 of the current VA should be modified so all containers and cartridges are included, as follows:

Consumables: This refers to imaging equipment consumables, such as containers, ink cartridges and toner cartridges meeting the definitions in Annex A.

Annex A of the current regulation should be extended with definitions for consumable, cartridges and containers. The following list of definitions are in most parts harmonized with the most recent version of the GPP Technical Report[356], but the definitions may need to be updated, when the final GPP criteria have been published:

Imaging equipment consumable*: A replaceable product that is essential to the functioning of the imaging equipment product. Consumables are replaced or replenished by either the end user or service provider during the normal usage and life span of the imaging equipment product. Examples of consumables include, but are not limited to: toner, toner containers, toner bottles, toner cartridges, waste toner cartridges, ink cartridges, ink heads, ink sticks, ribbon ink, thermal paper, office paper, imaging units, transfer belts, transfer roller, fusers and drum maintenance units. Items that are not intentionally designed to be normally replaceable are considered to be spare parts.*

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.*

Toner 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 toner material.*

[355] ECOS strongly support the recommendation that consumables (cartridges) be included in scope of the VA.
[356] Revision of EU Green Public Procurement (GPP) criteria for Imaging Equipment. Technical Report 2.0. Draft criteria. June 2019.

***Inkjet cartridge**: An end-user replaceable product, which fits into or onto an imaging equipment product, with printing-related functionality that includes integrated components integral to the imaging equipment's function beyond holding ink.*

Design for dismantling of imaging equipment products

DO 1.1 (low ambition) can be added as a resource efficiency requirement in Part II commitments of the VA as follows:

Joining, fastening or sealing techniques for imaging equipment in scope shall not prevent access to relevant components listed in Annex VII of the WEEE Directive, such as: Batteries, PCB > 10cm^2, Toner cartridges, Plastics containing BFRs, Liquid crystal displays >100cm^2, External electric cables, Electrolyte capacitors containing substances of concern (height >25mm, diameter >25mm or proportionally similar volume).

DO 1.2 (high ambition) can be added as a resource efficiency requirement in Part II commitments of the VA as follows:

Joining, fastening or sealing techniques for imaging equipment in scope shall not prevent access to Polychlorinated biphenyls containing capacitors, mercury containing components such as switches/backlight lamps, plastic parts >100 g and spare parts. They must be able to be removed safely.

Spare parts definition should be added to the Annex, and the list of relevant spare parts could be added to the definition:

Storage devices, print heads (where not considered a consumable), laser unit (where not considered a consumable), fuser units (where not considered a consumable), drum units (where not considered a consumable), transfer belts/kits (where not considered a consumable), maintenance kits (where not considered a consumable), paper feed components, density sensors, power and control circuit boards, cartridge/container attachment components, external power supplies and hinges.

Warranty for service and repair of imaging equipment products

DO 2 (medium ambition) can be added as a resource efficiency requirement in Part II commitments of the VA as follows:

Signatories must provide a minimum 3-years warranty, free of additional costs, effective from delivery of the product. This warranty must cover repair and replacement with options for on-site repairs or pick-up and return. The warranty must not be invalidated as a result of non-OEM cartridges or containers being used in imaging equipment unless it is proven that any malfunction was directly caused by the use of a non-OEM cartridge or container.

Design for disassembly and availability of spare parts for imaging equipment products

DO 3.1 (low ambition) can be added as an information requirement in Part III commitments of the VA as follows:

Service information and installation guidance about available spare parts should be available in manuals, videos or webpages in freely accessible websites or instructions provided with spare parts, except for spare parts intended to be serviced or installed by trained service staff.

DO 3.2 (high ambition) can be added as a resource efficiency requirement in Part II commitments of the VA as follows:

Spare parts must be accessible by using commonly used tools and/or commonly used fasteners that are reusable or at least replaceable fasteners for joining components, subassemblies, chassis and enclosure, and must be available for 5 years after product delivery.

Spare parts definition should be added in the Annex, and the list of relevant spare parts could be added to the definition:

Storage devices, print heads (where not considered a consumable), laser unit (where not considered a consumable), fuser units (where not considered a consumable), drum units (where not considered a consumable), transfer belts/kits (where not considered a consumable), maintenance kits (where not considered a consumable), paper feed components, density sensors, power and control circuit boards, cartridge/container attachment components, external power supplies and hinges.

In addition, the definitions of reusable and removable should be added to Annex A:

Reusable: An original fastening system that can be completely re-used, or any elements of the fastening system that cannot be re-used are supplied with the new part for a repair, re-use or upgrade process.

Removable: An original fastening system that is not reusable, but can be removed without causing damage or leaving residue which precludes reassembly (in case of repair or upgrade) or re-use of the removed part (in case of re-use) for a repair, re-use or upgrade process.

Post-consumer recycled plastic in imaging equipment products

DO 4 (high ambition) can be added as a resource efficiency requirement in Part II commitments of the VA as follows:

For all products, total weight of plastic content of the product unit must not contain more than 80% virgin plastic content. The remaining 20% content should be made of post-consumer recycled plastic.

Firmware in imaging equipment products

DO 5.1 (low ambition) can be added as a resource efficiency requirement in Part II commitments of the VA as follows:

Signatories shall identify if imaging equipment firmware updates can be rolled back to previously installed versions. This functionality may be provided through a network connected computer or within the imaging equipment itself. Instructions detailing how firmware updates can be rolled back must be provided in the technical documentation and on signatories' websites. If the previous version of the firmware is made openly available on the internet, from the time it is first released, and users are provided clear instructions on where this can be located, then the objectives of the criterion are met.

Firmware and software for imaging equipment shall be maintained by Signatories for minimum 3 years after product delivery.

DO 5.2 (medium ambition) can be added as a resource efficiency requirement in Part II commitments of the VA as follows:

The machine or any associated current or future OEM firmware shall not prevent the use of a non-OEM consumable.

Imaging equipment shall include functionality allowing firmware updates to be rolled back to previously installed versions. This functionality may be provided through a network connected computer or within the imaging equipment itself. Instructions detailing how firmware updates can be rolled back must be provided in the technical documentation and on signatories' websites. If the previous version of the firmware is made openly available on the internet, from the time it is first released, and users are provided clear instructions on where this can be located, then the objectives of the criterion are met.

Firmware and software for imaging equipment shall be maintained by Signatories for minimum 3 years after product delivery.

Use of reused and remanufactured consumables

DO 6 (low ambition) is the removal of the exemption clause for paragraph 5.4 on Cartridges of the Part II commitments of the VA, so the following text shall be deleted:

The requirements of paragraph 5.4 shall not be interpreted in such a way that would prevent or limit innovation, development or improvements in design or functionality of the products, cartridges, etc.

Information on consumables reuse, disposal and treatment

DO 7 (low ambition) can be added as information requirement in Part III commitments of the VA as follows:

Signatories shall provide end-users with information on suitable remanufacturing & reuse, or end-of-life management options for used consumables. This information may be communicated via a freely accessible company website.

Signatories shall report the end of life options used for materials collected within consumable take back programmes. Reports should include the percentage of materials sent to each of the following end-of-life management methods as a proportion of total collected weight of cartridges and containers:

- *Reuse of components*
- *Materials recycling*
- *Waste-to-energy*
- *Material in storage, pending processing*
- *Incineration*
- *Landfill*

Signatories shall publish the reports on a publicly available website on an annual basis.

Consumables page yield

DO 8 (low ambition) modifies the existing information requirement 6.6.2 of Part III commitments, so the requirement should include all consumables:

Signatories shall make information on all consumables yield available to customers on the packaging and in all public technical data based on the measurement standards specified, for example, in ISO/IEC 24711:2006 (for ink), ISO/IEC 19752:2004 (for monochrome toner), ISO/IEC 19798:2006 (for colour toner), and through other company methods.

Page yield should be added as parameter to be reported in the Annex C reporting form. The final formulation of the modified requirement, the definitions for consumable, cartridges and containers should be added to Annex A, depending on the final formulation of the modified requirement.

Consumable imaging yield and mass resource efficiency

In this measure, the prerequisite is that the VA will include consumables in the product scope, so the primary design requirement could apply to cartridges and containers.

DO 9 (low ambition) can be added as a primary design requirement in Part I Commitments of the VA as follows:

Signatories shall report the consumable mass resource efficiency for each consumable designed for use within each imaging equipment model placed on the market. The consumable mass resource efficiency should be calculated according to Equation 1.

Equation 1: Consumable mass resource efficiency=(Page Yield)/C_MASS

Where:

- *Page yield is the measured number of images that may be produced by the consumable*
- *Consumable mass (CMass) is the mass (g) of each cartridge or container (plus drum unit, if applicable), as measured in their to be installed condition (i.e. full of ink or toner and any additional components not present whilst installed in the imaging equipment removed).*

DO 9 (medium ambition) can be added as a primary design requirement in Part I Commitments of the VA as follows:

All consumables designed for use within each imaging equipment model placed on the market must meet minimum consumable mass resource efficiency requirements. The consumable mass resource efficiency should be calculated according to Equation 1 and must not be lower than the threshold indicated in below table.

Equation 1: Consumable mass resource efficiency=(Page Yield)/C_MASS

Type	***Minimum consumable mass resource efficiency (page yield/CMass)***
Toner cartridge or container & drum	$(2 \times [10 \times tanh(0.1 + 0.0003 \times (CMass - 10)) - 0.5] + 1)$
Ink cartridge or container	$(2 \times [15 \times tanh(0.2 + 0.0004 \times (CMass - 8)) - 1] + 2)$

Where:

- *Page yield is the measured number of images that may be produced by the consumable*

- *Consumable mass (CMass) is the mass (g) of each cartridge or container (plus drum unit, if applicable), as measured in their to be installed condition (i.e. full of ink or toner and any additional components not present whilst installed in the imaging equipment removed).*

Consumable Hazardous Material Content

As reported in Task 6 on hazardous substances (DO 11) it is assumed that the impact of this option is negligible regarding energy and resources consumption. It is difficult to foreseen so far how much it would cost to implement this option, which would imply testing and administration costs. Hence, this policy measure is not included in the calculations.

However, it is suggested to ban certain substances:

Colourants used in consumable products must not contain any intentionally added substances that meet the classifications in the table below.

Hazard class	***Hazard category***	***CLP-regulation (EC) No. 1272/2008***
Carcinogenicity	Carc. 1A, 1B	H350 May cause cancer
Carcinogenicity	Carc. 1A, 1B	H350i May cause cancer if inhaled
Carcinogenicity	Carc. 2	H351 Suspected of causing cancer
Germ cell mutagenicity	Muta. 1A, 1B	H340 May cause genetic damage
Germ cell mutagenicity	Muta. 2	H341 Suspected of causing genetic defects
Reproductive toxicity	Repr. 1A, 1B	H360 May damage fertility or the unborn child
Reproductive toxicity	Repr. 2	H361 Suspected of damaging fertility or the unborn child
Specific target organ toxicity (Single exposure)	STOT SE 1	H370 Causes damage to organs
Specific target organ toxicity (Single exposure)	STOT SE 2	H371 May cause damage to organs
Specific target organ toxicity (Repeated exposure)	STOT RE 1	H372 Causes damage to organs through prolonged or repeated exposure
Specific target organ toxicity (Repeated exposure)	STOT RE 2	H373 May cause damage to organs through prolonged or repeated exposure

Consumables must also meet the following hazardous material requirements:

- *Not contain any additional REACH Candidate List substances at a concentration of greater than 0.1% (by weight)*
- *Toners and inks must not contain any intentionally added mercury, cadmium, lead, nickel or chromium-VI-compounds. High molecular weight complex nickel compounds used as colourants are exempted.*
- *Toner and inks must not contain azo dyes (dyes or pigments) that can release carcinogenic aromatic amines listed in Regulation (EC) 1907/2006 (REACH Regulation), Annex XVII, Appendix 8.*
- *No biocides must be added to toners or inks unless an active substance dossier as defined under the Biocidal Product Regulation (BPR, Regulation (EU) 528/2012) for preservatives for products during storage (product type 6) has been submitted. Substances must not be used where they have been rejected from inclusion in the list of approved substances for product type 6.*
- *Photoconductor drums must not contain intentionally added selenium, lead, mercury or cadmium (or any of their compounds).*

Primary energy requirement of imaging equipment products

In this measure, the prerequisite is that the VA scope will align with the ENERGY STAR v3.0, especially regarding removing the outdated speed limits and including professional imaging equipment.

DO 12 can replace the primary design requirement 4.1 in Part I commitments of the VA as follows, depending on the level of ambition to be chosen:

Signatories shall ensure that products in scope of the VA and placed on the EU market by Signatories after 1 January 2019 shall comply with ENERGY STAR® v3.0 specifications and default duplex settings requirements in accordance with the following targets:

Tier	Period	OM and TEC products placed on the EU market	OM and TEC products placed on the EU market	OM and TEC products placed on the EU market
		Low ambition	Medium ambition	High ambition
Tier I	Jan-Dec 2020	30%	40%	60%
Tier II	Jan-Dec 2021	40%	70%	90%
Tier III	Jan-Dec 2022	≥60%	≥90%	99%

It should be noted that low ambition level reflects the projected BAU development without any changes to the current VA, due to the driver driven by the US ENERGY STAR, although

the uncertainties exist regarding how the penetration rates for US ENERGY STAR will develop in the EU now the EU and US ENERGY STAR agreement has ended. The Commission guidelines for self-regulation measures specifies that the requirements should be presented with a date of their application and if the self-regulation measure covers a long time-span it should include successive levels of requirements. The requirements should apply to at least 90 % of all units (covered by the self-regulation measure) placed on the market and/or put into service by each signatory.[357]

Figure 95 and Figure 96 show the development in use phase energy and primary energy consumption, respectively, for BAU and for the three ambition levels. Table 124 and Table 125 show the same energy consumption in a table form for 2020, 2025 and 2030.

The same data are shown as energy and primary energy savings in Figure 97 and Figure 98 and Table 126 and Table 127.

[357] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32016H2125&from=EN

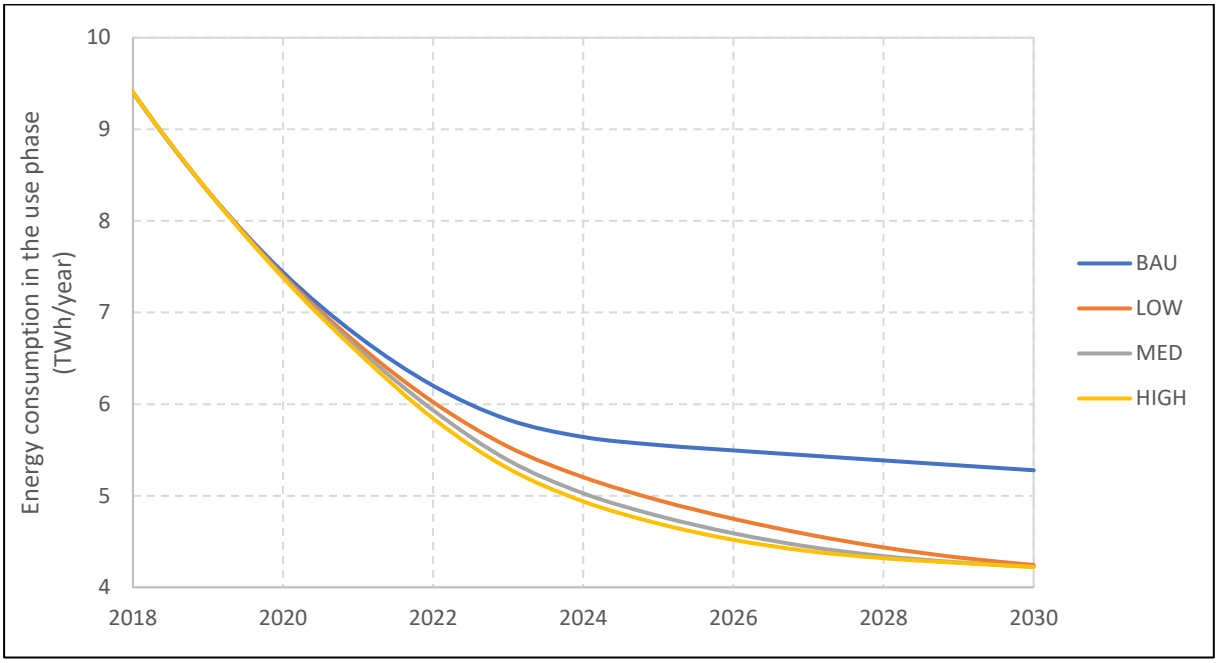

Figure 95: Annual energy consumption in use phase for BAU, low ambition, medium ambition and high ambition for DO 12. Professional imaging equipment is included.

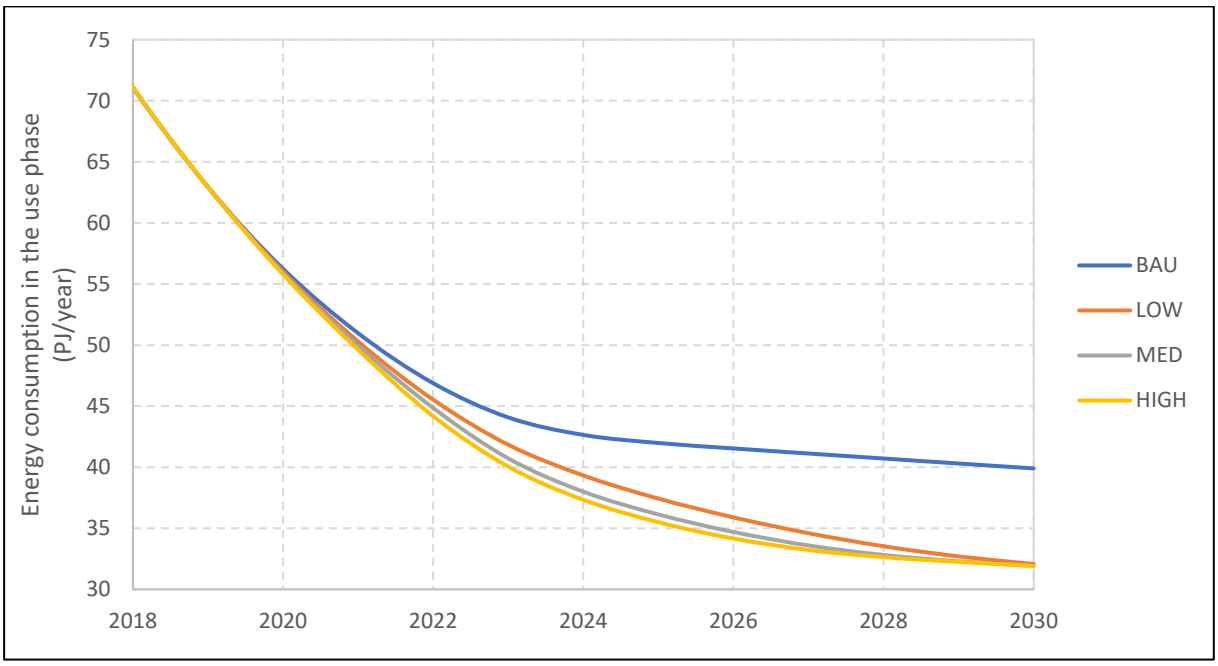

Figure 96: Annual primary energy consumption in use phase for BAU, low ambition, medium ambition and high ambition for DO 12 (primary energy factor: 2.1). Professional imaging equipment is included.

Table 124: Annual energy consumption in use phase for BAU, low ambition, medium ambition and high ambition for DO 12 (same data as used in Figure 95). Professional imaging equipment is included.

TWh/year	2020	2025	2030
BAU	7.4	5.6	5.3
LOW	7.4	5.0	4.2
MED	7.4	4.8	4.2
HIGH	7.4	4.7	4.2

Table 125: Annual primary energy consumption in use phase for BAU, low ambition, medium ambition and high ambition for DO 12 (primary energy factor: 2.1, same data as used in Figure 96). Professional imaging equipment is included.

PJ/year	2020	2025	2030
BAU	56	42	40
LOW	56	37	32
MED	56	36	32
HIGH	56	35	32

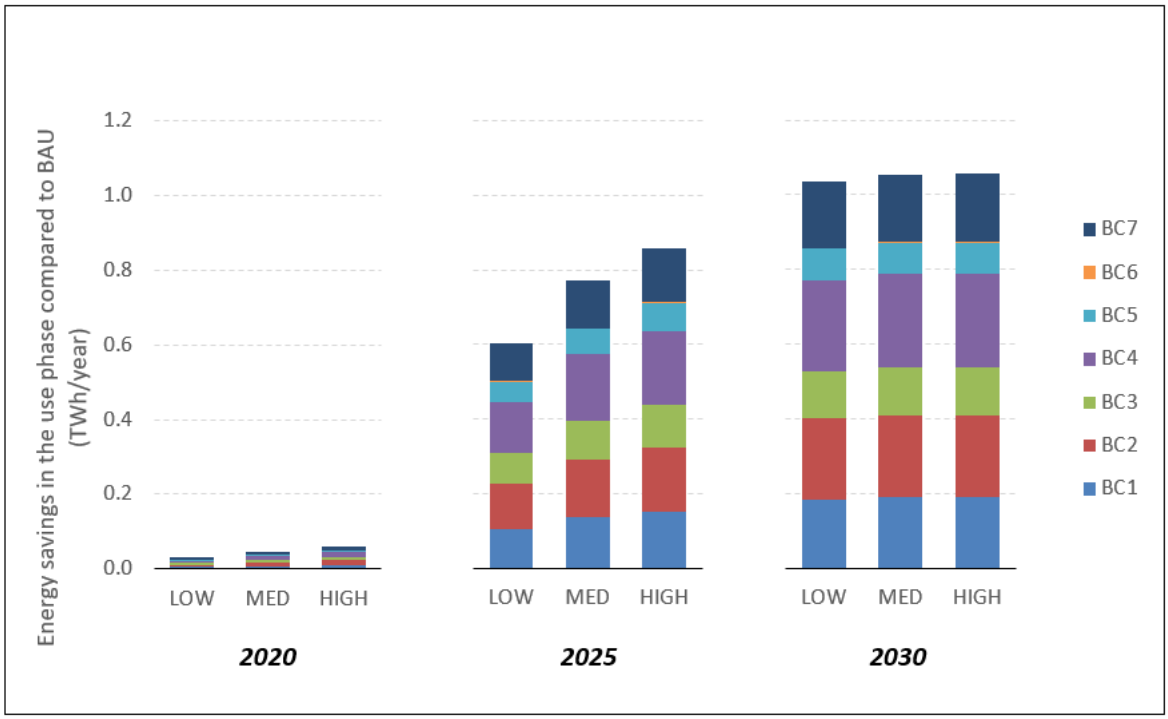

Figure 97: Annual energy savings in use phase for low ambition, medium ambition and high ambition compared to BAU for DO 12.

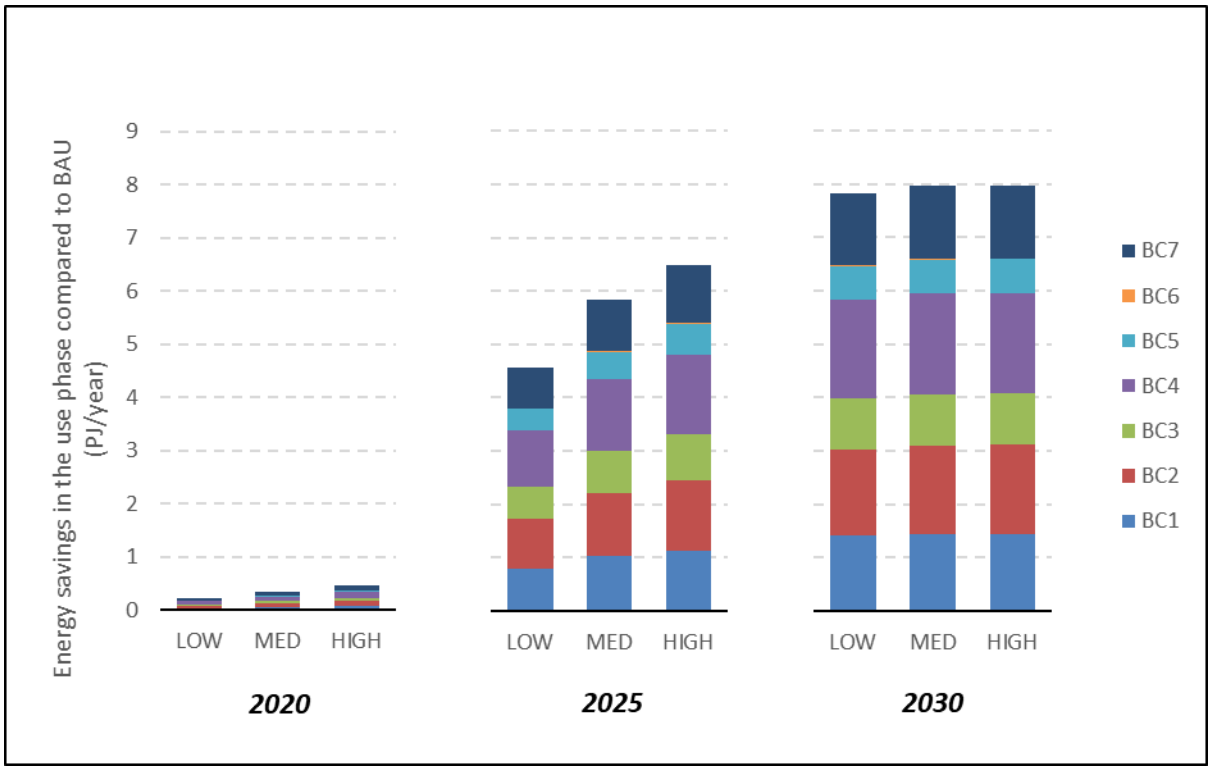

Figure 98: Annual primary energy savings in use phase for low ambition, medium ambition and high ambition compared to BAU for DO 12 (primary energy factor: 2.1).

Table 126: Annual energy savings in use phase for low ambition, medium ambition and high ambition compared to BAU for DO 12 (same data as used in Figure 97).

TWh/year	2020			2025			2030		
	LOW	MED	HIGH	LOW	MED	HIGH	LOW	MED	HIGH
BC1	0.01	0.01	0.01	0.11	0.14	0.15	0.19	0.19	0.19
BC2	0.01	0.01	0.01	0.12	0.16	0.17	0.22	0.22	0.22
BC3	0.00	0.01	0.01	0.08	0.10	0.11	0.13	0.13	0.13
BC4	0.01	0.01	0.01	0.14	0.18	0.20	0.24	0.25	0.25
BC5	0.00	0.00	0.01	0.05	0.07	0.08	0.08	0.08	0.08
BC6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BC7	0.01	0.01	0.01	0.10	0.13	0.14	0.18	0.18	0.18

Table 127: Annual primary energy savings in use phase for low ambition, medium ambition and high ambition compared to BAU for DO 12 (primary energy factor: 2.1, same data as used in Figure 98).

PJ/year	2020			2025			2030		
	LOW	MED	HIGH	LOW	MED	HIGH	LOW	MED	HIGH
BC1	0.04	0.06	0.08	0.79	1.02	1.14	1.40	1.43	1.43
BC2	0.05	0.07	0.09	0.93	1.19	1.32	1.63	1.67	1.67
BC3	0.03	0.05	0.06	0.61	0.78	0.86	0.96	0.96	0.96
BC4	0.05	0.08	0.10	1.04	1.34	1.49	1.84	1.88	1.88
BC5	0.02	0.03	0.04	0.41	0.52	0.57	0.64	0.64	0.64
BC6	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01
BC7	0.04	0.06	0.08	0.76	0.98	1.09	1.34	1.37	1.37

Internal power supply efficiency information of imaging equipment products

DO 13 (high ambition) can be added as information requirement in Part III commitments of the VA as follows:

Signatories shall publish the nameplate rated output power and efficiency levels of any power supply in scope of the test protocol included within, or supplied for use with, all imaging equipment in scope.

Generalized power supply efficiency test protocol[358] can be used for testing and reporting for efficiency as long as the power supplies are in scope of the test protocol. The test protocol applies to power supplies that meet the following criteria:

i. Power supplies that have detailed input and output ratings on their name plate or in available literature from their manufacturer, specifying the maximum loads that can safely be placed on each individual dc output voltage bus and, where necessary, groupings of those voltage busses

ii. Power supplies that have connectors that allow the dc output voltage busses to be connected and disconnected from the powered product non-destructively (In the event if this is not possible a test board may be provided to enable testing)

iii. Power supplies that can be easily detached from the housing of the product they power without causing harm to other circuits and components of the product

Compliance information of products and consumables

DO 14 (low ambition) can be added as information requirement in Part III commitments of the VA as follows:

[358] https://www.plugloadsolutions.com/docs/collatrl/print/Generalized_Internal_Power_Supply_Efficiency_Test_Protocol_R6.7.1.pdf

The Signatories shall publish on the EuroVAPrint website information detailing compliance with each requirement in Section 4, 5 and 6 for products first placed on the market after the commencement date of this Voluntary Agreement. Information can be published as an environmental documentation, or a URL to the documentation. The information shall be regularly updated.

Additional suggestion

The following suggestion is not calculated as a separate policy measure but is a key to a successful recycling of ink and toner consumables. The following should be added to the VA as medium ambition substituting the current 5.4.1:

Any consumable produced by or recommended by the OEM for use in the product contains no design features which prevent its reuse and recycling. Reuse does not necessarily include enhanced user functionalities, such as toner/ink level measurements or page counts.

Furthermore, the current 5.4.2 will be slightly rephrased to: *The machine contains no design features which prevent the use of a non-OEM consumable*.

The previously DO6 includes removal of the following statement currently in the VA: *The requirements of paragraph 5.4 shall not be interpreted in such a way that would prevent or limit innovation, development or improvements in design or functionality of the products, cartridges, etc.* because this could be interpreted ambiguously.

7.1.5 Summary of policy scenarios

For all policy scenarios below, the common changes incorporated are:

1. aligning the VA scope with the ENERGY STAR v3.0 by removing the current VA speed limits
2. including consumables in scope of the VA.

The policy scenarios identified below are based on the clustered design option from Task 6. These are modelled in order to assess the environmental impacts for EU-28, and the savings compared to the BAU scenario. The results are presented in the next section. A RES scenario can be combined with an ENER scenario by adding the impacts i.e. they are not mutually exclusive.

Table 128: Summary of policy scenarios

Short name	Policy scenario description	Design options included
BAU	Business-as-usual	None
RES_LOW	Resource efficiency improvements at lowest level of ambition	DO1.1, DO3.1, DO5.1, DO6, DO7
ENER_LOW	Energy efficiency improvements at low level of ambition	DO 12, DO 14
RES_MED	Resource efficiency improvements at medium level of ambition	DO1.1, DO2, DO3.1, DO5.1, DO5.2, DO6, DO7
ENER_MED	Energy efficiency improvements at medium level of ambition	DO12, DO 14
RES_Con_BAT	Resource efficiency improvements at high ambition level for consumables only	DO5.2, DO6, DO7, DO8, DO9
RES_IE_BAT	Resource efficiency improvements at high ambition level for IE products only	DO1.2, DO2, DO3.2, DO4, DO5.1
RES_BAT	Resource efficiency improvements at high ambition level both for consumables and equipment	All in previous two
ENER_BAT	Energy efficiency improvements at high ambition level both for consumables and equipment	DO12, DO13, DO14

7.2 Scenario analysis

7.2.1 Methodology for scenario modelling on environmental impacts

In this section, the methodology for modelling the policy scenarios is described. The results from EcoReport tool presented in Task 5 and 6 combined with the stock model gives the impacts per policy scenario.

The design options presented in Task 6 describe potential policy requirements to improve the resource efficiency and energy efficiency of imaging equipment products. In Figure 99, as an example, a BAT scenario is used to demonstrate calculation method.

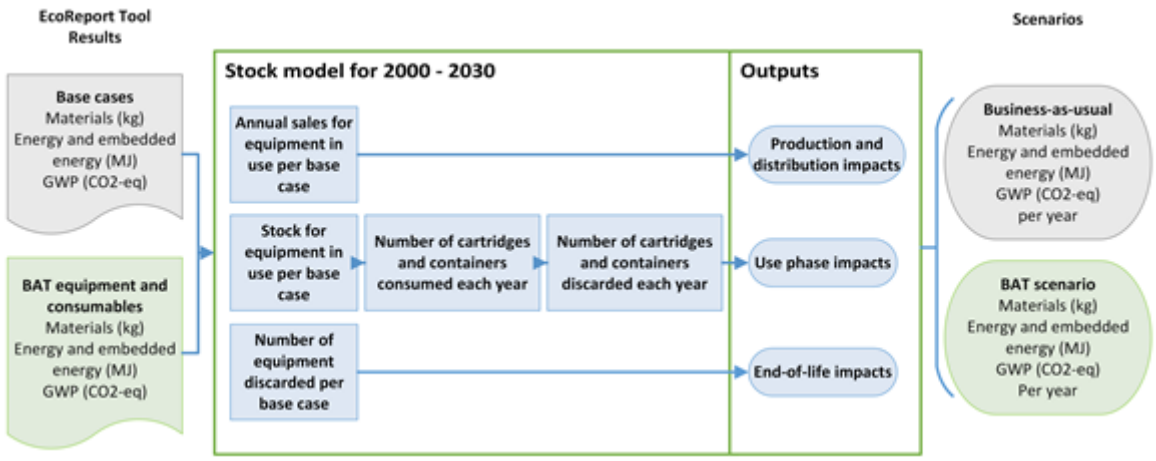

Figure 99: Method for calculating the benefits of different scenarios for improving resource efficiency at EU level

The results from the EcoReport Tool should represent a base case at current condition and an improved product. In the example depicted by Figure 99, the improved product is a BAT product in terms of resource efficiency for imagine equipment which utilizes the BAT for consumables during use phase. For scaling the result per product to the EU-28 level, these results from EcoReport tool are linked with a stock model separately developed in order to model both the energy efficiency and resource efficiency improvements gradually year by year.

The proposed method helps to visualise the environmental impacts against the baseline in a Business-as-usual (BAU) scenario. In the stock model, the new products sold (sales, actual data and forecasts), products in use (and the number of consumables used), and the products being discarded are estimated per year. For the total EU-28 impacts, new sales are used to derive impacts from production and distribution, stock in use (both equipment and consumables) derive the impacts from use phase, and products discarded are used to derive the end-of-life impacts. The output of the model would be the total EU-28 materials consumption per year, energy and embedded energy consumption per year, GWP per year from imaging equipment and consumables. The output can be repeated for as many scenarios as needed, in this example, only BAU and BAT scenarios are given as output.

As described previously, a RES scenario can be combined with an ENER scenario by adding the impacts i.e. they are mutually independent.

7.2.2 Environmental impacts of policy scenarios

In this section, the environmental impacts of each policy scenario have been quantified and described. Detailed analysis of professional equipment (BC 7) has been carried out separately in order to assess the impacts of including them in the VA.

Figure 100 and Table 129 shows the total sum of energy consumption of all base cases for each scenario. The primary energy demand (also known as "total energy" in EcoReport Tool) includes the energy consumption during life cycle of all phases, such as the embedded energy consumption of the consumables and equipment during production, as well as credited embedded energy at end-of-life (EoL) through reuse and recycling. The table includes the annual and cumulative energy savings compared to the BAU scenario for the years 2020, 2025 and 2030.

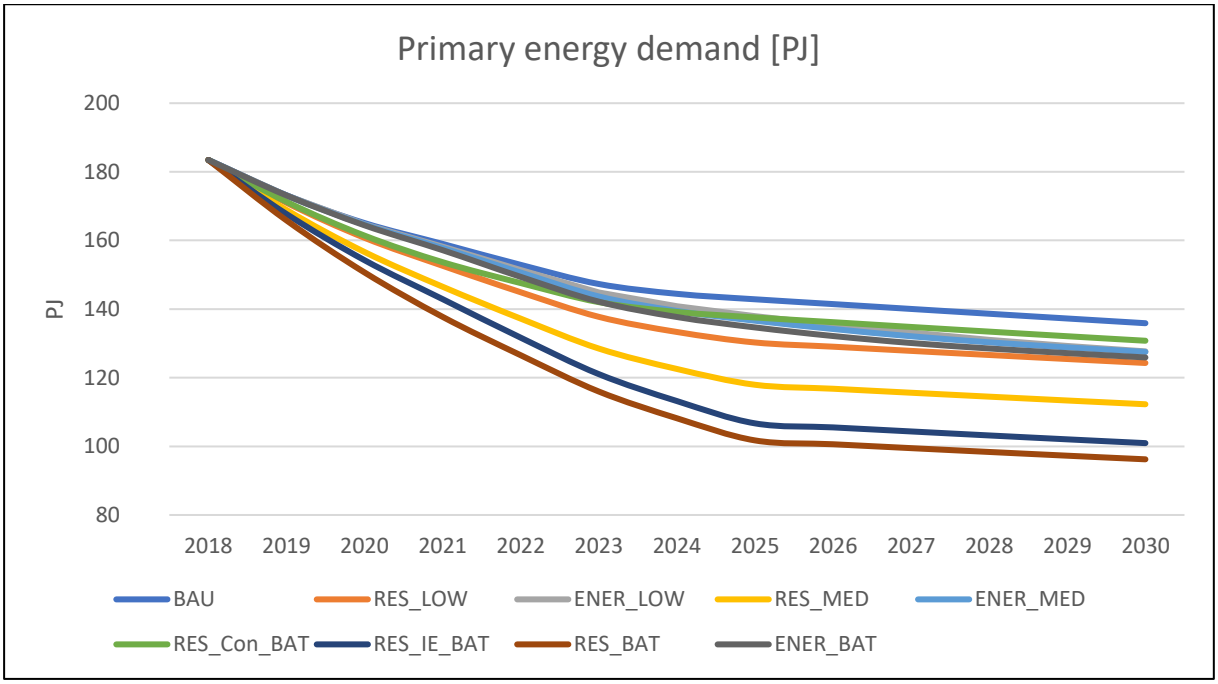

Figure 100: Primary energy demand in PJ for each policy scenario covering EU-28. This includes energy consumption covering all life cycle phases – production, use, and EoL.

RES_BAT is the most favorable scenario and results in a total cumulative saving of 372 PJ in 2030. In general, the scenarios related to resource efficiency improvements ('RES') result in higher energy savings than the scenarios related to only energy efficiency improvements. This underlines the relatively small energy consumption in the use phase compared to the embedded energy consumption from manufacturing and materials. The use phase electricity consumption constitutes only about 15 % of the total primary energy demand.

The RES scenarios also include a high level of material recycling which is credited in the primary energy demand and therefore further increase their reductions. RES_Con_BAT which is related to resource efficiency improvements for consumables only is showing minor reductions. This indicates a relatively low material use from consumables compared to the imaging equipment. The model assumes (rather conservatively) that in average each imaging equipment uses 4-5 consumables per year over a lifetime of 5-6 years in order to balance with the sales data on total consumables sold in the EU. On the other hand, it

could also indicate that the materials used for consumables are less energy intensive compared to the materials used for the products.

Table 129: Primary energy demand in PJ for each policy scenario covering EU-28. Annual savings for each scenario is relative to the BAU scenario and total savings are the cumulative savings.

Policy scenarios	Primary energy demand [PJ]			Annual savings [PJ]			Cumulative savings [PJ]		
	2020	2025	2030	2020	2025	2030	2020	2025	2030
BAU	165	143	136	0	0	0	0	0	0
RES_LOW	161	130	124	-4	-13	-12	-4	-52	-112
ENER_LOW	165	138	128	0	-5	-8	0	-14	-50
RES_MED	157	118	112	-8	-25	-24	-8	-102	-223
ENER_MED	165	137	128	0	-6	-8	0	-19	-59
RES_Con_BAT	161	138	131	-4	-5	-5	-4	-30	-56
RES_IE_BAT	154	107	101	-11	-36	-35	-11	-142	-319
RES_BAT	151	102	96	-14	-41	-40	-14	-171	-372
ENER_BAT	164	135	126	-1	-8	-10	-1	-26	-75

Figure 101 and Table 130 shows the total sum of electricity consumption of all base cases for each scenario only covering the use phase of the imaging equipment.

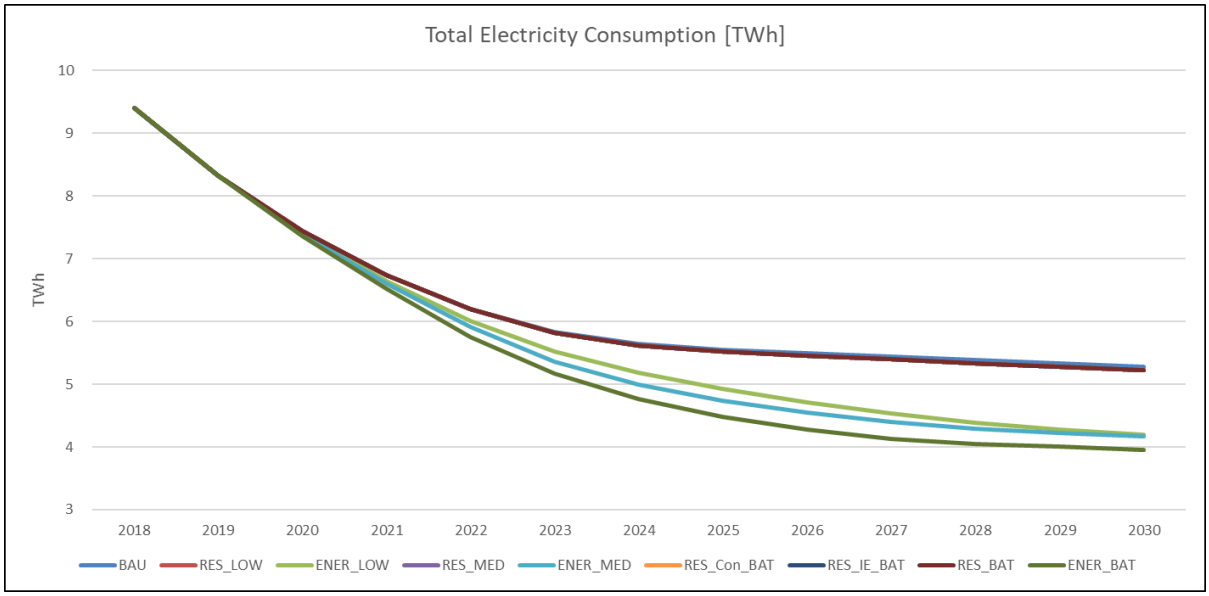

Figure 101: Total electricity consumption in use phase in TWh for each policy scenario covering EU-28. BAU is the upper line followed by the three RES scenarios (overlapping); ENER_LOW and ENER_MED (overlapping), and lowest ENER_BAT.

In contrast to the primary energy demand, the most favorable scenario when looking at electricity consumption is ENER_BAT which is related to energy efficiency improvements in the use phase. This is not surprising since the scenarios related to resource efficiency only include a minor energy efficiency improvement of 1 % that come from the proposed information requirement of compliance documentation. Consequently, the cumulative savings are only 0.3 TWh by 2030 for the RES scenarios compared to 9.9 TWh for the ENER_BAT

scenario by 2030. Even though these are large reductions, it is important to note that the use phase electricity consumption constitutes only about 15 % of the primary energy demand for the BAU scenario. However, this share will rise to about 20 % under the RES_BAT scenario when the embedded energy from production and other life cycle phases are drastically reduced.

It should be noted that the electricity consumption here includes the baseline consumption of professional equipment, therefore it is slightly higher than the total consumption shown in Task 5, which covers only equipment in scope of the VA.

Table 130: Total electricity consumption in TWh for each policy scenario covering EU-28. Annual savings for each scenario is relative to the BAU scenario and total savings are the cumulative savings.

Policy scenarios	Total electricity consumption [TWh]			Annual savings [TWh]			Cumulative savings [TWh]		
	2020	2025	2030	2020	2025	2030	2020	2025	2030
BAU	7.4	5.6	5.3	0	0	0	0	0	0
RES_LOW	7.4	5.5	5.2	0.0	0.0	-0.1	0.0	-0.1	-0.3
ENER_LOW	7.4	4.9	4.2	0.0	-0.6	-1.1	0.0	-1.7	-6.5
RES_MED	7.4	5.5	5.2	0.0	0.0	-0.1	0.0	-0.1	-0.3
ENER_MED	7.4	4.7	4.2	0.0	-0.8	-1.1	0.0	-2.4	-7.7
RES_Con_BAT	7.4	5.5	5.2	0.0	0.0	-0.1	0.0	-0.1	-0.3
RES_IE_BAT	7.4	5.5	5.2	0.0	0.0	-0.1	0.0	-0.1	-0.3
RES_BAT	7.4	5.5	5.2	0.0	0.0	-0.1	0.0	-0.1	-0.3
ENER_BAT	7.4	4.5	4.0	-0.1	-1.1	-1.3	-0.1	-3.4	-9.9

Figure 102 and Table 131 shows the total sum of CO_2-eq. emission of all base cases for each scenario covering all life cycle phases from production to End of Life (EoL).

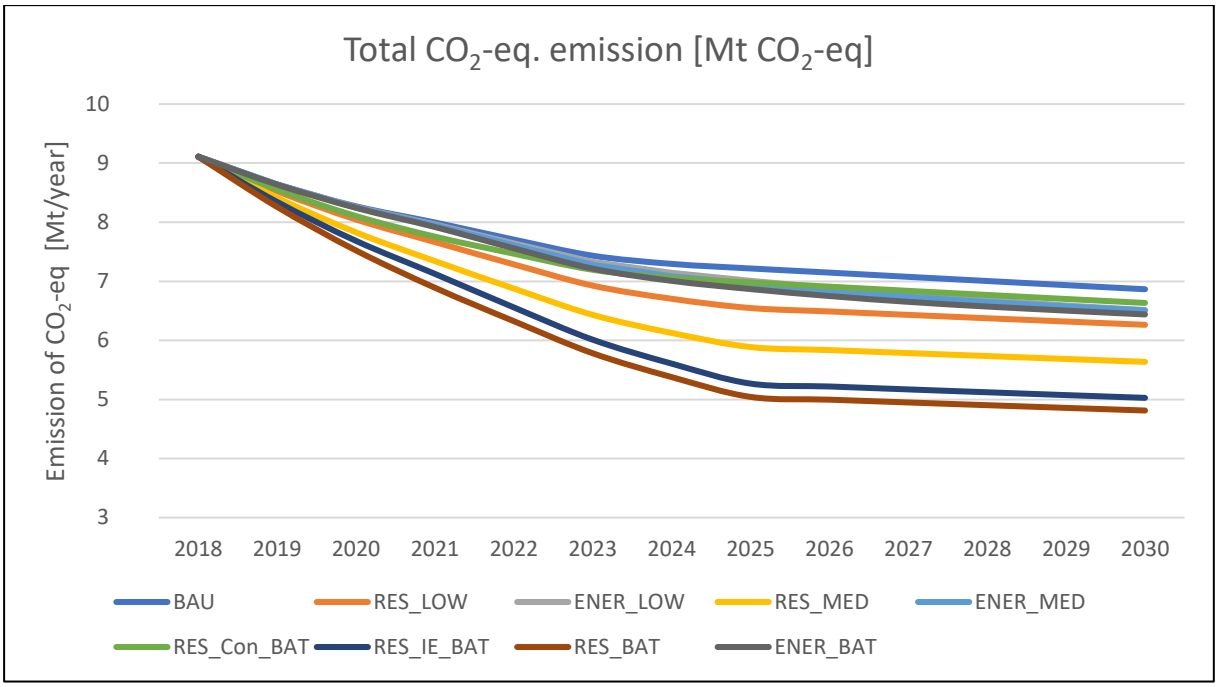

Figure 102: Total CO_2-eq. emission for each policy scenario covering EU-28. This includes emissions covering all life cycle phases – production, use, EoL.

It is clear that CO_2-eq. emissions closely correlates the primary energy demand in Figure 100. Therefore, RES_BAT is also the most favorable scenario for this parameter with a cumulative reduction of 19.5 Mt CO_2-eq. That is a 16.3 Mt CO_2-eq. higher reduction compared to the best ENER scenario.

Table 131: Total CO_2-eq. emission in Mt for each policy scenario covering EU-28. Annual savings for each scenario is relative to the BAU scenario and total savings are the cumulative savings.

Policy scenarios	Total CO_2-eq. emission [Mt CO_2-eq]			Annual savings [Mt CO_2-eq]			Cumulative savings [Mt CO_2-eq]		
	2020	2025	2030	2020	2025	2030	2020	2025	2030
BAU	8.3	7.2	6.9	0.0	0.0	0.0	0	0	0
RES_LOW	8.0	6.5	6.3	-0.2	-0.7	-0.6	-0.2	-2.7	-5.9
ENER_LOW	8.3	7.0	6.5	0.0	-0.2	-0.4	0.0	-0.6	-2.1
RES_MED	7.8	5.9	5.6	-0.4	-1.3	-1.2	-0.4	-5.4	-11.8
ENER_MED	8.3	7.0	6.5	0.0	-0.3	-0.4	0.0	-0.8	-2.5
RES_Con_BAT	8.1	7.0	6.6	-0.2	-0.2	-0.2	-0.2	-1.4	-2.5
RES_IE_BAT	7.7	5.3	5.0	-0.6	-1.9	-1.8	-0.6	-7.7	-17.1
RES_BAT	7.5	5.0	4.8	-0.7	-2.2	-2.1	-0.7	-9.0	-19.5
ENER_BAT	8.2	6.9	6.4	0.0	-0.3	-0.4	0.0	-1.1	-3.2

Figure 103 and Table 132 show the total sum of material consumption of all base cases for each scenario.

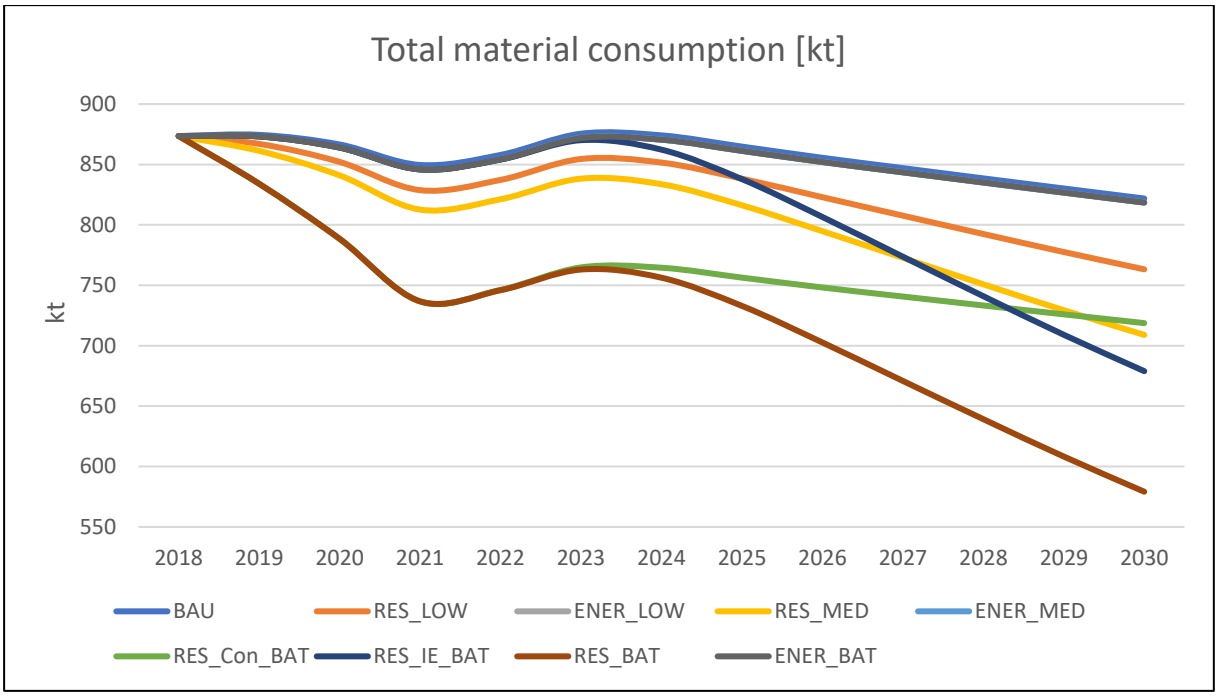

Figure 103: Total material consumption in kt for each policy scenario covering EU-28.

The dip in the curves between 2020 and 2021 is due to the full effect of the proposed policy measures which decrease both energy and material consumption. Partially the decrease in 2020 – 2021, and the increase between 2022 and 2024 are also due to the delayed stock effect of the updated lifetime for inkjet printers and MFDs are now 5 years (assumed for 2017 onwards) instead of 4 years as originally found in the preparatory study in 2008. This meant more inkjet printers and MFDs are still in use or not disposed during 2020 – 2021, and then they are disposed after max. 2 years during 2022 - 2023.

The figure shows that the RES scenarios provides the highest reduction in material consumption, where RES_BAT is the most favorable scenario with a cumulative reduction of 1,658 kt material in 2030. Interestingly, RES_Con_BAT shows the second highest cumulative reduction in 2030 in contrast to its reduction in primary energy demand (Figure 100) where it ranked second lowest. This clearly shows that the materials used for consumables have a significantly lower energy intensity compared to the materials used for the products.

Table 132: Total material consumption in Mt for each policy scenario covering EU-28. Annual savings for each scenario is relative to the BAU scenario and total savings are the cumulative savings.

Policy scenarios	Total material consumption [kt]			Annual savings [kt]			Cumulative savings [kt]		
	2020	2025	2030	2020	2025	2030	2020	2025	2030
BAU	867	865	822	0	0	0	0	0	0
RES_LOW	852	838	763	-14	-27	-59	-14	-126	-355
ENER_LOW	864	861	818	-3	-4	-3	-3	-20	-37
RES_MED	841	816	709	-26	-49	-113	-26	-225	-662
ENER_MED	864	861	818	-3	-4	-3	-3	-20	-37
RES_Con_BAT	788	756	719	-78	-108	-103	-78	-631	-1,157
RES_IE_BAT	864	838	679	-3	-27	-143	-3	-54	-538
RES_BAT	788	733	579	-78	-132	-243	-78	-665	-1,658
ENER_BAT	864	861	819	-3	-4	-3	-3	-20	-37

Environmental impacts of professional equipment (BC 7)

Figure 104 and Table 133 show the four environmental impact parameters, as previously described, for professional equipment (BC 7) for the two policy scenarios RES_BAT and ENER_BAT. The two BAT scenarios are chosen to assess the maximum saving potential that lie within the proposed extension of VA scope to include these products.

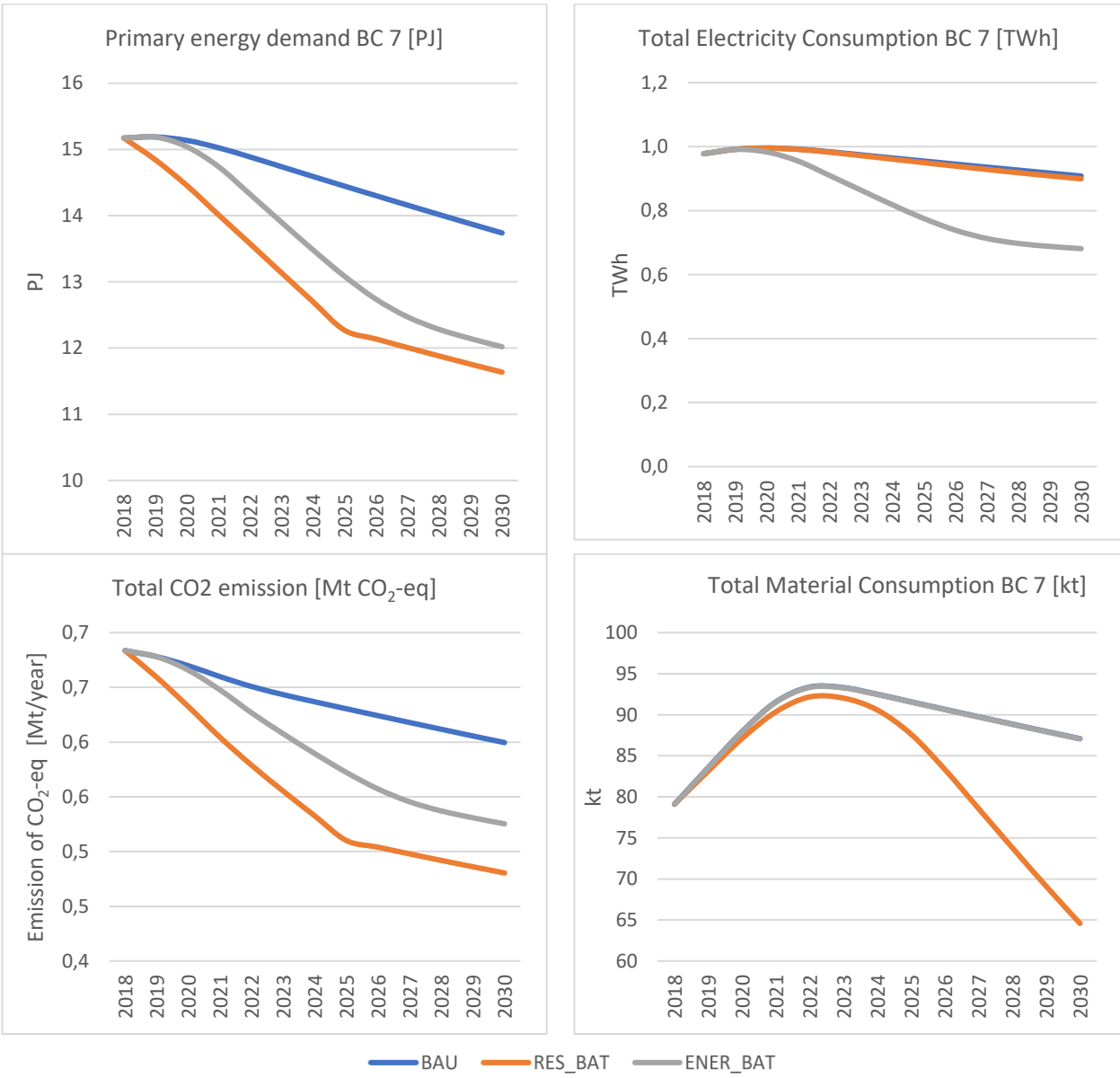

Figure 104: Environmental impact parameters for professional equipment (BC 7) for policy scenario RES_BAT and ENER_BAT

BC 7 constitutes approximately 9 % of the primary energy demand of all imaging equipment (Figure 100), whereas in sales, BC 7 accounts for less than 1 %. If no policies are implemented targeting BC 7 equipment, its share of primary energy demand of all base cases will rise to 12 % under scenario RES_BAT in 2030.

The current share of professional equipment out of the total electricity consumption in the EU-28 are even higher at about 13 %. Again, if no policies are implemented for BC 7 equipment its share will rise to about 17 % under the ENER_BAT scenario in 2030. This fits very well with professional products being larger and more energy intensive in the use phase compared to the other base cases. The electricity consumption in the use phase

compared to its primary energy demand is about 24 % for professional equipment, whereas for other imaging equipment, the electricity consumption accounts for about 15 %. With RES_BAT scenario, the professional equipment would lead to an additional 2.1 PJ/year primary energy savings, but very small savings of 0.01 TWh/year in 2030. With ENER_BAT, it would lead to an additional 1.72 PJ/year primary energy savings, and electricity savings of 0.23 TWh/year in 2030.

Looking at CO_2-eq. emissions and material consumption, BC 7 constitutes about 10 % of the total for all imaging equipment, similar to primary energy demand. The RES_BAT scenario will by 2030, compared to BAU, be 22.5 kt of material and 120 kt CO_2-eq. lower.

Table 133: Environmental impact parameters for professional equipment (BC 7) for policy scenario RES_BAT and ENER_BAT

Primary Energy Demand BC 7 [PJ]			
	2020	2025	2030
BAU	15.14	14.45	13.74
RES_BAT	14.46	12.27	11.64
ENER_BAT	15.04	13.09	12.02

Total Electricity Consumption BC 7 [TWh]			
	2020	2025	2030
BAU	1.00	0.95	0.91
RES_BAT	1.00	0.95	0.90
ENER_BAT	0.98	0.78	0.68

Total CO_2-eq. emission BC 7 [Mt CO_2-eq]			
	2020	2025	2030
BAU	0.67	0.63	0.60
RES_BAT	0.63	0.51	0.48
ENER_BAT	0.67	0.57	0.53

Total Material Consumption BC 7 [kt]			
	2020	2025	2030
BAU	87.9	91.6	87.1
RES_BAT	87.1	87.6	64.6
ENER_BAT	87.9	91.5	87.0

7.3 Impacts on industry and end-users

The proposed policy measures will have impacts on OEMs, non-OEMs manufacturers and remanufacturers, as well as the end-users of imaging equipment.

The resource efficiency requirement proposed for all RES scenarios will affect the design of imaging equipment as well as consumables. Whereas ENER scenarios with only energy efficiency requirements will mostly only affect the design of imaging equipment.

Although the purchase price might increase due to the proposed measures, but the LCC in Task 6 have shown that longer lifetime due to better design for durability and repairability would reduce the average end-user expenditure for purchasing a new imaging equipment in the long-term. Less products being purchased could however lead to lower revenue for the imaging equipment manufacturers. However, with longer lifetime, it means that more repair and maintenance would be needed.

More importantly, the resource efficiency requirements provide consumer protection. It enables the consumers to buy both OEM and non-OEM consumables, trigger competitiveness of the consumables market. It also removes the possibility of being locked in by one

OEM brand, and unnecessarily dispose non-OEM consumables that are no longer compatible due to firmware updates. It stimulates the reuse and remanufacturing market, create regulatory incentive to OEMs to enter this market and create attractive business case. This could also in return produce more jobs for remanufacturing in the EU, for both OEM and non-OEMs.

The total end-user expenditure has been estimated to 60.3 billion Euro annually in EU-28 by 2020 in BAU and decreasing to 53.8 billion Euro by 2030 (see Table 134) due to an assumed decrease in sales. The scenario with lowest end-user expenditure by 2030 is RES_BAT at 44.7 billion Euro annually due to savings from purchase costs and energy and consumable costs. This gives a total cumulative saving of 88.6 billion Euro. The ENER_BAT scenario only sees a marginal end-user expenditure reduction of 0.1 billion Euro and a cumulative saving of 1.3 billion Euro by 2030. The ENER scenarios lead to a reduction in use phase electricity costs, however these are offset by increased product costs.

Table 134: End-user expenditure in billion Euro for each policy scenario covering EU-28 for the years 2020, 2025 and 2030. Annual savings for each scenario is relative to the BAU scenario and total savings are the cumulative savings.

Policy scenarios	Total Expenditure [Bill. EUR]			Annual savings [Bill. EUR]			Cumulative savings [Bill. EUR]		
	2020	2025	2030	2020	2025	2030	2020	2025	2030
BAU	60.3	56.6	53.8	0.0	0.0	0.0	0.0	0.0	0.0
RES_LOW	59.5	53.9	51.2	-0.9	-2.7	-2.6	-0.9	-11.1	-24.3
ENER_LOW	60.3	56.5	53.7	-0.1	-0.1	-0.2	-0.1	-0.4	-1.0
RES_MED	58.8	51.6	49.1	-1.6	-5.0	-4.7	-1.6	-19.9	-44.1
ENER_MED	60.3	56.5	53.7	-0.1	-0.1	-0.2	-0.1	-0.5	-1.3
RES_Con_BAT	58.8	54.4	51.8	-1.59	-2.2	-2.1	-1.6	-12.8	-23.3
RES_IE_BAT	58.0	49.0	46.6	-2.4	-7.6	-7.2	-2.4	-30.1	-66.9
RES_BAT	56.5	47.0	44.7	-3.8	-9.6	-9.1	-3.8	-42.0	-88.6
ENER_BAT	60.3	56.5	53.7	-0.1	-0.1	-0.2	-0.1	-0.5	-1.3

The total number of manufacturers' employees in the EU-28 is estimated based on total end-user expenditure (excluding cost of electricity and repair and maintenance) which corresponds to the companies' total turnover. Based on the turnover the manufacturing sector has been estimated to employ 106,974 by 2020 in BAU and dropping to 95,684 by 2030 due to an assumed decrease in sales (see Table 135). As a result of the decreasing annual turnover (also from few products being replaced as well), most scenarios see a large reduction in number of employees for OEM manufacturers. The ENER scenarios see a slight increase in employment due to higher product costs increasing the companies' turnover.

It is important to note that this analysis however does not account for the extra employees from remanufacturers for consumables, employees for increased repairs and maintenance,

and employees from more reuse and recycling processes at the end-of-life treatment facilities.

Table 135: Total number of manufacturing employees for each policy scenario covering EU-28 for the years 2020, 2025 and 2030. The difference for each scenario is compared to BAU.

Policy scenarios	Total Employees			Difference		
	2020	2025	2030	2020	2025	2030
BAU	106,974	100,615	95,684	0	0	0
RES_LOW	104,963	94,505	89,873	-2,011	-6,111	-5,811
ENER_LOW	106,853	100,794	95,854	-121	179	170
RES_MED	103,445	89,452	85,068	-3,529	-11,163	-10,616
ENER_MED	106,853	100,794	95,854	-121	179	170
RES_Con_BAT	103,398	95,775	91,081	-3,576	-4,840	-4,603
RES_IE_BAT	101,700	83,643	79,544	-5,274	-16,972	-16,141
RES_BAT	98,384	79,086	75,210	-8,589	-21,529	-20,474
ENER_BAT	106,886	100,905	95,960	-88	290	276

7.4 Sensitivity analysis

This section investigates how sensitive the environmental impact parameters presented in the previous sections are to changes in assumed lifetime and in the input variables. In other words, if the lifetime and the improvement potentials described for each design option in Task 6 changes, how will the results and final conclusion be affected. It is important to note that the aim of the analysis is not to test the robustness of the EcoReport model itself and its inherent variables, these will be held constant.

7.4.1 Change in lifetime

A stakeholder has questioned the assumed lifetime of imaging equipment and stated that an assumed lifetime of 4-6 years (depending on the type of equipment) is very optimistic. To support this view, they have linked to a publication from Test-Achats which suggest that some consumers discard the imaging equipment even after 6 months and many discards them after 2-3 years (mostly inkjet printer). Hence, a sensitivity analysis is carried out with half the lifetime of imaging equipment. In the figures below, Figure 7, Figure 8 and Figure 9, the effect of a reduced lifetime is presented regarding primary energy demand, CO2 emission in total material consumption. Note that the electricity consumption it the use phases are not considered to increase, as energy improvements may lead to

reduced electricity consumption in the use phase. However, this factor is considered to be minor and is not included in the figures below.

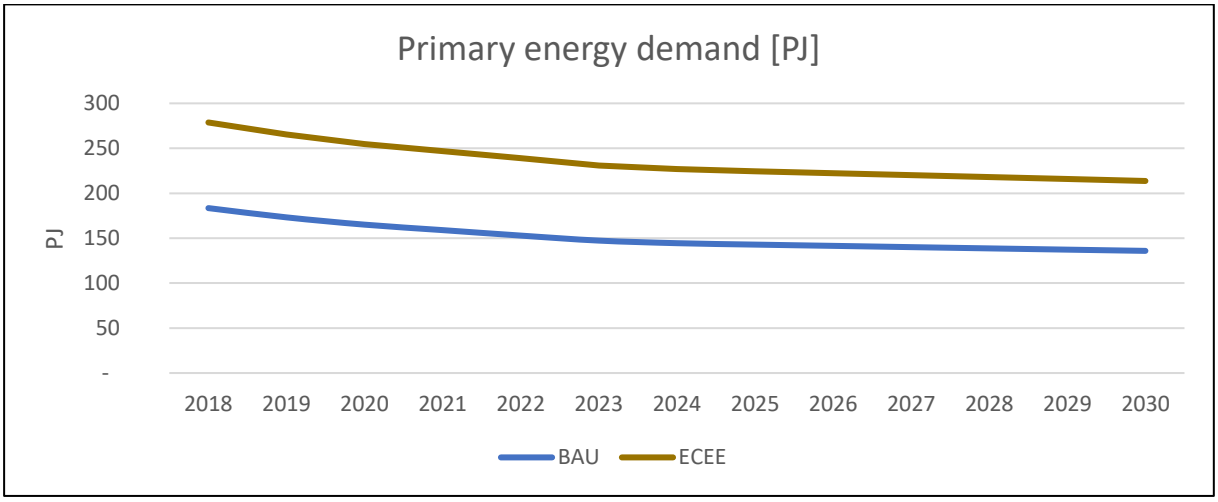

Figure 105: Sensitivity analysis on half the lifetime of imaging equipment - Change in primary energy demand (PJ)

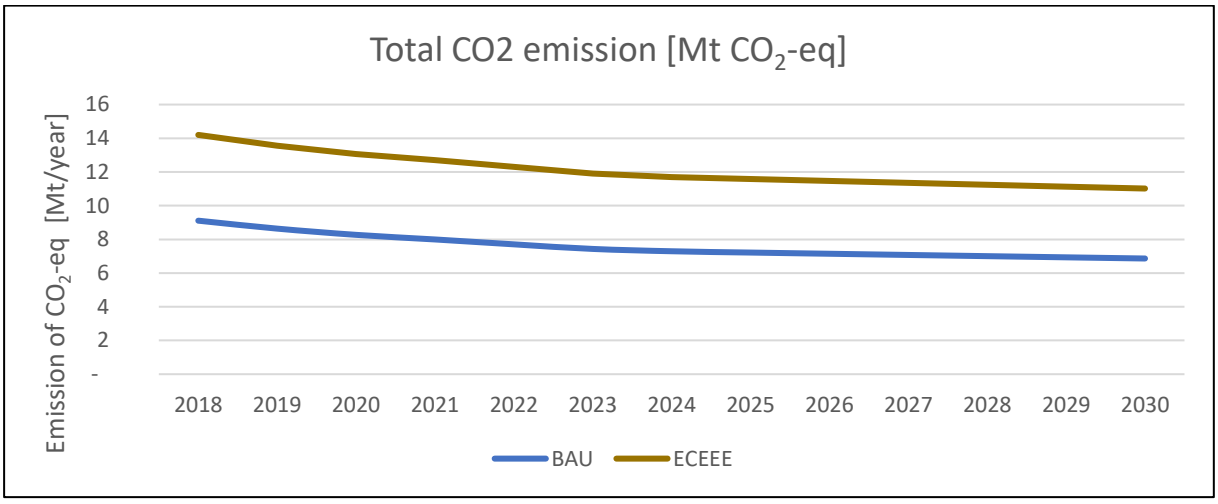

Figure 106: Sensitivity analysis on half the lifetime of imaging equipment - Change in total CO2 emission (Mt CO2-eq)

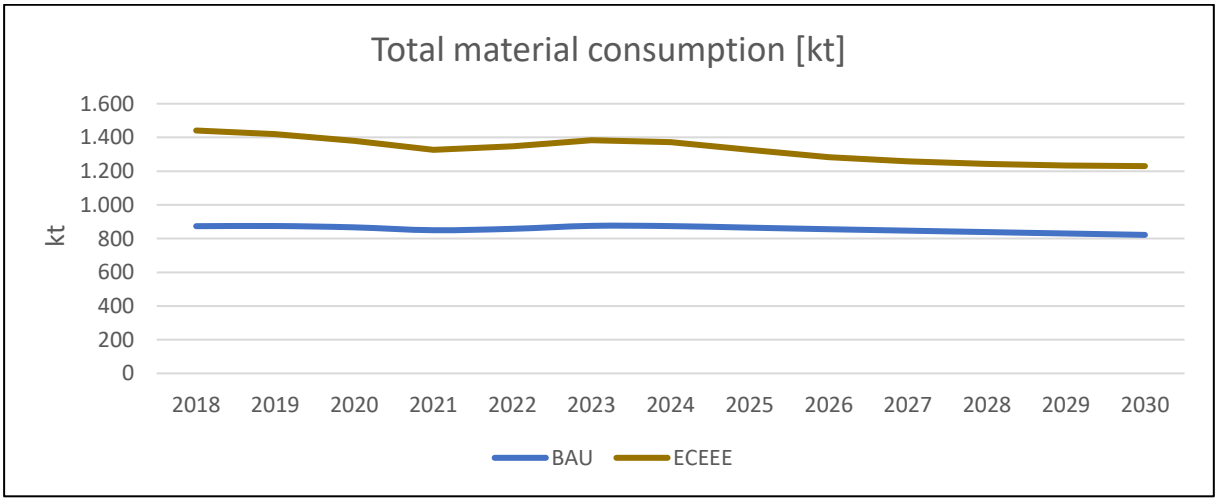

Figure 107: Sensitivity analysis on half the lifetime of imaging equipment - Change in total material consumption (kt)

If the lifetime is reduced by 50%, the primary energy consumption will increase by 45% approximately, the CO2 emission will increase by 55% approximately and the material consumption will increase by approximately 65%. This only supports the results found in Task 5, which highlights the importance of the material phase. With these considerations, more emphasis should be put on resource requirements. However, the overall recommendations do not change, but it should be noted that the potential improvement by the presented resource requirements in connection with lifetime, may hold an even greater potential the reported in Task 6 and 7.

7.4.2 Changes in the input variables for the different policy scenarios

Only the variables believed to have the highest uncertainty have been analysed. These are material reduction, reuse and recycling. As material reduction is assumed based on calculation of materials saved due to prolonged lifetime, this is not supported by an actual case from practice, however stakeholders (OEMs and remanufacturers) inputs have been taken into account. Reuse and recycling rates are based on the BAT rates averaged from all stakeholder inputs, in reality, if the reuse and recycling rates can be improved to the extent assumed is highly uncertain.

The variables with highest certainty are not tested, such as recycled content, energy reduction and cost change. As the recycled contents can be documented in terms of percentage to be achieved, the energy reduction from proposed requirement level is calculated based on current product energy consumption and lastly, the costs changes have been reviewed by or provided by OEMs and remanufacturers.

Table 136 shows the results of the sensitivity analysis with seven different variable tests (1-7). Tests 1 to 3 assess the changes in the assumed material reduction (MR) by lowering it by 50 %, 80 % and 100 % respectively. A lowering of 100 % sets it equal to BAU, meaning no affect at all for life prolongation. Test 4 and 5 lowers the improvements for reuse and recycling (RR) by 50 % and 100 % respectively, again 100% means the scenarios do not improve reuse or recycling at all, equals to BAU level. Test 6 includes a lowering of 50 % for both MR and RR improvements, where Test 7 comprises a lowering of 100 % and 50 % for MR and RR respectively. The values shown in the table represent the total cumulative saving in energy consumption by 2030. Other environmental impact parameters have also been analysed but are either not affected or show a similar pattern and have therefore not been found relevant to include here.

Table 136: Sensitivity analysis on primary energy demand for changes in Material Reduction (MR) and Reuse and Recycling (RR). The percentage (%) indicates the change of the respective parameter compared to model baseline. The values represent the total cumulative saving in 2030 compared to BAU [PJ]. Red represents the two least favourable scenarios and green represents the two most favourable scenarios.

PJ	Model base-line	(1) -50 % MR	(2) -80 % MR	(3) -100 % MR	(4) -50 % RR	(5) -100 % RR	(6) -50 % MR -50 % RR	(7) -100 % MR -50 % RR
BAU	0	0	0	0	0	0	0	0
RES_LOW	-112	-68	-41	-23	-101	-89	-56	-11
ENER_LOW	-50	-50	-50	-49	-49	-48	-48	-48
RES_MED	-223	-136	-84	-49	-201	-178	-112	-24
ENER_MED	-59	-59	-58	-58	-58	-56	-57	-57
RES_Con_BAT	-56	-46	-40	-37	-43	-30	-31	-18
RES_IE_BAT	-319	-196	-123	-73	-302	-285	-176	-49
RES_BAT	-372	-240	-161	-108	-343	-315	-205	-66
ENER_BAT	-75	-75	-75	-75	-74	-73	-74	-73

Overall, the sensitivity analysis shows that the results of the scenario analysis are robust. It requires significant changes to the input variables before the most and least favorable scenarios changes. Even up to 50 % reduction in improvement for the three variables, the most favorable scenarios still amount to significant higher savings by 2030 compared to the rest. Only when MR are set equal to BAU (Test 3), ENER_BAT becomes the second most favorable scenario, but only by a small margin. The "ENER" scenarios only see minor changes, because they primarily relate to energy reduction which is not changed.

Changes in reuse and recycling (Test 4 and 5) only result in minor differences compared to the model baseline and do not create any shifts. For Test 7 with a lowering of 100 % and 50 % for MR and RR respectively the most favorable scenario finally shifts to ENER_BAT, but again only by a small margin. The least favorable scenario also shifts from ENER_LOW to RES_LOW.

This clearly shows that despite uncertainties surrounding the potential improvements in material reduction, reuse and recycling rates, the best scenario is still RES_BAT, but it also shows that to ensure that the most savings are obtained when different uncertainties occur, RES_BAT should be implemented together with ENER_BAT, as if the effect of resource efficiency requirement fail detrimentally, ENER_BAT becomes the best option.

7.5 Conclusions and recommendations

Based on the analyse from Task 1 – 6, it is evident that there are barriers as well as opportunities for improvements in the current VA. There are technical barriers and improvements can be addressed and achieved by the proposed policy measures, and some

non-technical barriers can be tackled by the proposed information requirements. Other non-technical barriers regarding the management of the VA requires an overhaul of the design of the current VA structure and operation.

Although the current study proposed policy measures on the basis of that the self-regulation policy instrument shall continue, it is also worth consider the added value of a minimum requirement policy instrument such as Ecodesign that ensures the full market coverage, closes loopholes and reduce the complexity of the issues with the various market players for consumables.

For the **product scope** of the VA, regardless of the policy scenario chosen, it is recommended that the speed limits are removed from the VA, while imaging equipment consumables shall be added to the product scope.

Based on the **policy scenario analysis** for environmental impacts, the RES_BAT scenario performs best overall looking at the scenarios individually on three out of four parameters, total primary energy, electricity consumption, GWP and material consumption. The cumulative savings from the RES_BAT scenario totals to 372 PJ of energy, 19.5 Mt CO_2-eq. of emissions and 1,658 kt of material by 2030. The ENER_BAT scenario performs best on reduction in electricity consumption and has a cumulative saving of 9.9 TWh by 2030 compared to BAU.

The better performance seen by the RES_BAT scenario, which is related to resource efficiency improvements, is a result of the relatively low energy consumption imaging equipment in general have in their use phase. Resource efficiency improvements relates both to a reduced material input for each individual product but also a higher degree of reusability and recycling plays an important role.

Improving resource efficiency for consumables only has little impact on primary energy demand compared to products, but the effect on material consumption is significant. The RES_Con_BAT scenario, related to resource efficiency improvements for consumables, see a cumulative saving on material consumption of 1,157 kt by 2030 (631 kt by 2025), whereas RES_IE_BAT, related to resource efficiency improvements for products, see a significant lower reduction of 538 kt of material by 2030 (54 kt by 2025). This shows that materials used for consumables are less energy intensive than materials used for products, however there are other environmental impacts connected to a high resource consumption and material use in consumables are therefore important to take into account.

Regarding the specific analysis of **professional equipment** (BC 7) it shows a considerable impact from these products when comparing to their share of sales which amounts to less

than 1 %. Their total annual energy consumption will by 2030 be 14 PJ, 0.9 TWh of electricity consumption, 600 kt of CO_2-eq. emissions and 87 kt of material use by 2030. It constitutes 9 % of the total primary energy of all imaging equipment, and for electricity consumption, they account for as high as 13 % of the total. With RES_BAT scenario, the professional equipment would lead to an additional 2.1 PJ/year primary energy savings, but very small savings of 0.01 TWh/year in 2030. With ENER_BAT, it would lead to an additional 1.72 PJ/year primary energy savings, and electricity savings of 0.23 TWh/year in 2030.

ENERGY STAR specification version 3.0 includes also professional equipment in scope, therefore it is worth considering the inclusion of these products in the VA as well, as it is shown that these products are also very resource and energy intensive.

The preferred policy scenario is RES_BAT, with the largest annual savings in primary energy demand (40 PJ savings), GWP (2.1 $MtCO_{2\text{-eq}}$ savings) and material consumption (243 kt savings) in 2030. However, as the scenarios for ENER and RES are developed with different design options, it is possible and recommended to combine the different ENER and RES scenarios to obtain combined savings. **RES_BAT should be supplemented by an ENER** scenario to secure additional savings and ensure energy efficiency of imaging equipment continues in the policy agenda for this product group. For example, if **ENER_BAT** would be added an additional 10 PJ/year of savings (75 PJ/year savings in total) would be achieved in 2030, equivalent to additional 0.4 $MtCO_{2\text{-eq}}$ savings (3.2 $MtCO_{2\text{-eq}}$ savings in total). Finally, a requirement should be enforced that any consumable produced by or recommended by the OEM for use in the product contains no design features which prevent its reuse and recycling. Reuse does not necessarily include enhanced user functionalities, such as toner/ink level measurements or page counts.

The results of **sensitivity analyses** show that the results of the scenario analysis are robust. It requires significant changes to the input variables before the most and least favorable scenarios changes. Only with Test 7, a lowering of 100 % and 50 % for MR and RR improvements respectively, the most favorable scenario finally shifts to ENER_BAT, but only by a small margin.

This clearly shows that despite uncertainties surrounding the potential improvements in material reduction, reuse and recycling rates, the best scenario is still RES_BAT. It also shows that to ensure that most savings are obtained when the highest uncertainties occur, **RES_BAT should be implemented together with ENER_BAT**, as if the effect of resource efficiency requirement fail detrimentally, ENER_BAT becomes the best option to reduce environmental impacts.