EuP Preparatory Studies “Imaging Equipment” (Lot 4)

Final Report on Task 6 “Technical Analysis BAT”

Compiled by Fraunhofer IZM

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Content

Introduction

This is the **final report** on Task 6 "Technical Analysis of Best Available Technology (BAT)" for the EuP Preparatory Studies on Imaging Equipment (Lot 4). The findings presented in this report are reflecting the research conducted by the IZM consortium as well as important feedback by industry and other stakeholders. The statements and recommendations presented in the final report however are not to be perceived as the opinion of the European Commission.

We like to acknowledge the fruitful collaboration and trustful working relationship with various industry partners, non-industry stakeholders and the European Commission throughout the study. We like to thank all stakeholders for their contribution and critical reviews of our reports

12th November 2007

6 Technical Analysis BAT

Introduction

Task 6 has the objective to identify, describe, and evaluate best available technologies (BAT) and technologies that are currently in the development (laboratory or prototype level) and are expected to enter the mass market in two or three years (i.e. BNAT). The MEEuP methodology defines BAT as a technology, leading to minimized environmental impacts, which is already available on the market or at least the technical feasibility has already been demonstrated (expected to be introduced at product level within 1-3 years). BNAT refers to technology, which has the potential to lead to further (environmental) performance improvements, but is still subject to research and development and is rather a future option / trend. The reference term is “best technology” and not “best product” indicating an environmental improvement potential through application of new technical principles, components or materials. This intention is reflected by the following subtasks that are prescribed by the MEEuP:

- State-of-the-art in applied research at product level
- State-of-the-art at component level
- State-of-the-art of best existing products outside the EU

The assessment of the BAT and BNAT provides input for the identification of the improvement potential in Task 7. Intellectual property, technical feasibility, and availability on market in a strict sense are not judged here as the objective is to illustrate various technically available (or potentially available) options. However, Task 7 will take these issues into account when suggesting possible improvement options applicable to imaging equipment. A comparison of the MEEuP prescribed subtasks (Task 6) and the proclaimed objective “technical analysis best available technology” show contradictions in the description of Task 6. The subtasks require identification of “best existing products” as well as “best technologies at product and component level”. We come to the conclusion that the prescribed subtasks have to be modified for the purpose of the EuP Preparatory Study Lot 4. By reflecting the results of the market and trend analysis, the technical analysis of existing products and the definition of base cases, we propose the following structure for Task 6 report:

- State-of-the-art in product application
- State-of-the-art on component (technology) and material level

The description of technologies presented here is based on ongoing research. New cutting edge technologies are highly guarded secrets and detailed public information is limited. Thus, the

information presented here should be seen as a general overview of potential improvement options rather than a thorough technical analysis.

Note:

Task 6 is based on a literature search as well as contributions from stakeholders. All the registered Lot 4 stakeholders were invited to provide input to this task, and others were also welcome to contribute. Important BATs have been covered to the best of our knowledge. Most of the technical data for this task has been provided directly by the manufacturers/designers or comes from other published information (mainly from environmental reports/programs of main manufacturers). However, the efficiency or other performance levels claimed by them have not been verified independently.

6.1. State-of-the-art in product application

6.1.1. Power Consumption and Energy Efficiency

The following analysis of energy efficient imaging equipment (best available products) is based on the entries in the Energy Star database[1]. Consequently these data show the best performing products according to the Energy Star test procedures (TEC/OM) only. The limitations of TEC in particular have been discussed in Task 5 already. The TEC values do therefore not reflect real-life conditions however there are an accepted benchmark for energy efficiency. The real-life energy efficiency of imaging equipment is determined by:

- Power consumption per mode (this largely depends on the technology and performance of a individual product, notice also there is the distinction of rated power consumption and average power consumption)
- The preset (optional) default delay times for entering energy saving modes (manual handling of an devices)
- The actual time duration per mode according to the actual use (number of images per print job, time duration between jobs, reactivation time from various energy saving modes)
- Image quality (notice that high coverage and colour/photo prints are more ink/toner and process intensive and demand more time, monochrome draft printing on the other hand is very efficient but might not meet the expected quality and leads to reprints)
- Paper utilization (duplexing) and paper quality (e.g. thickness, surface coating)
- Reliability of print process (e.g. paper jams, misprints)

It seems obvious that we cannot take all of these factors equally into account. But, we like to point your attention to the fact that in case of TEC products a prolonged ready-mode (TEC limits this mode to max. 15 minutes between jobs) is increasing overall power consumption considerably (see Task 7). The actual power requirement per mode is of interest but not transparent according to TEC. It makes a difference if the first ready-mode average power consumption is 150 W, 250 W or 450 W, and the second ready-mode/first sleep-mode is still 100 W, 200 W or 400 W respectively. Furthermore, EP colour printing requires also more energy and this aspect is not adequately reflected by Energy Star TEC test procedure[2].

[1] http://www.eu-energystar.org/en/en_database.htm, latest changes: 22nd August 2007; accessed: 27-08-2007

[2] TEC measurements are based on monochrome images. A colour page test standard however exists and should be considered (ISO/IEC 24712:2006 Colour test pages for measurement of office equipment consumable yield)

6.1.1.1. EP-Copiers/MFD (according to TEC)

Most Copiers and MFDs listed in the Energy Star database are featuring electro photography technology. Only very few MFDs are based on solid ink technology. Power consumption values are therefore measured according to TEC methodology (kWh/week). Figure 1 (Copier) and Figure 2 (MFD) show TEC values according to Energy Star database with distinction of monochrome and colour products as well as thresholds.

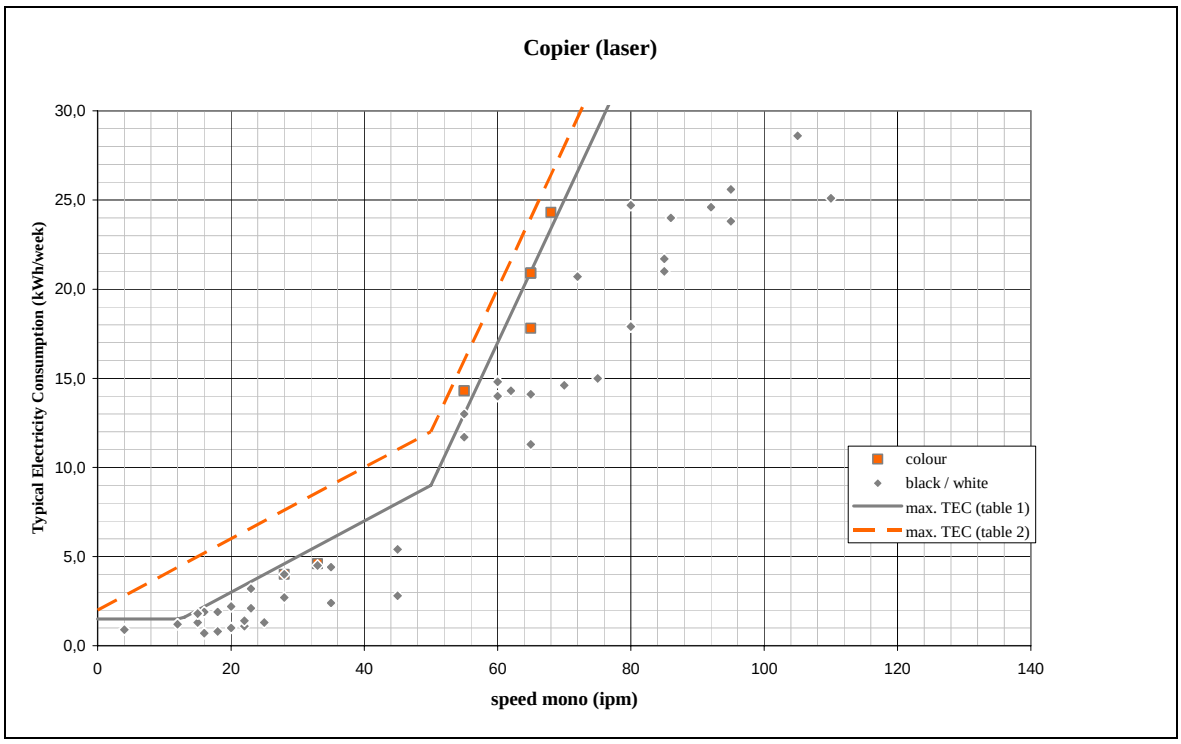

Figure 1: TEC of Energy Star listed copiers

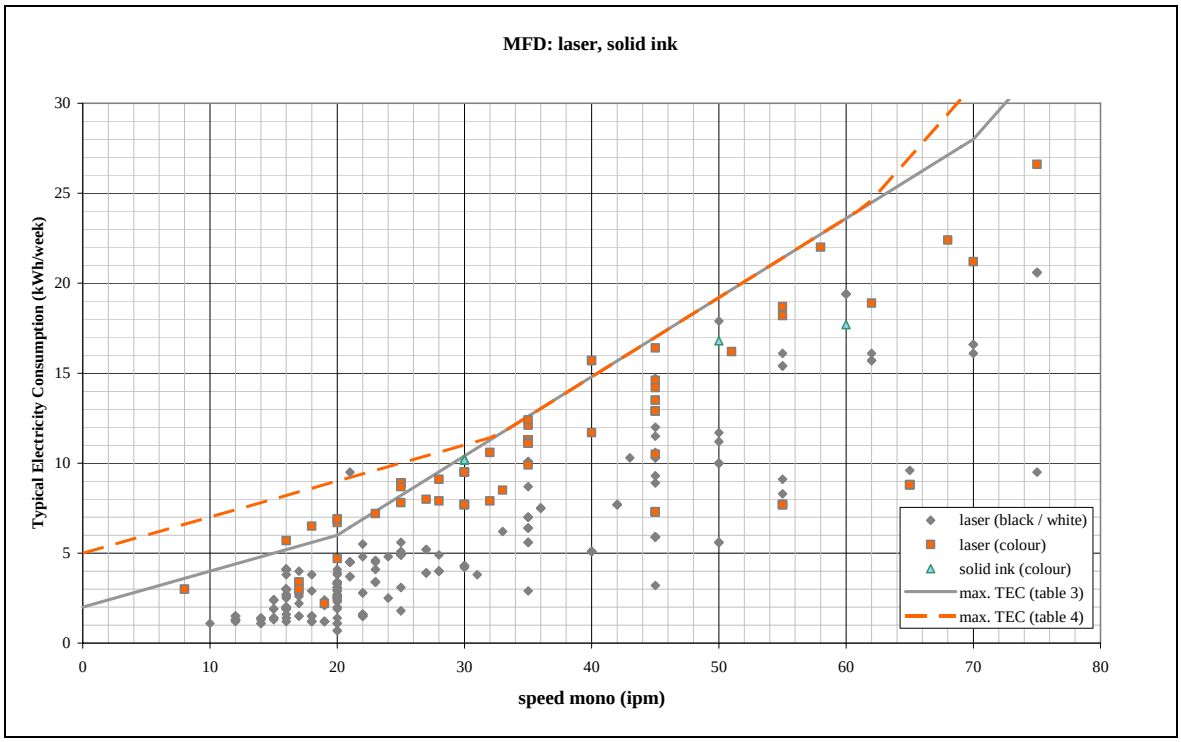

Figure 2: TEC of Energy Star listed MFDs

For comparison our base cases:

- EP-Copier/MFD monochrome (V1) Base Case: 4.8 kWh/week (26 ipm)
- EP-Copier/MFD colour (V2) Base Case: 7.1 kWh/week (26 ipm)

Monochrome EP-Copier/MFD:

There are many monochrome EP-Copier/MFDs, which TEC power consumption values are well below the Energy Star (Tier 1) eligibility criterion. Several Copiers/MFD perform even 70% better. In order to give an example, the 20 ipm Canon MF3240 weekly power consumption is 1.1 kWh/w (Energy Star: 6.0 kWh/w) and the 45 ipm Canon iR3045N is 3.2 kWh/w (Energy Star: 17.0 kWh/w). Table 1, Table 2, and Table 3 provide a selection of best performing MFDs from the European Energy Star database [3]. Above 50 ipm and up to 85 ipm the TEC formula for monochrome machines seems not to reflect the technological dependencies appropriately: The higher the speed the better do the machines perform relatively compared to the threshold value. Take the example of the 75 ipm Ricoh Aficio MP7500 which TEC value is 7.9 kWh/w or the 90 ipm Ricoh Aficio MP9000 with 20.9 kWh/w.

[3] Please note that some manufacturers such as Ricoh are still in progress of registering. The values for Ricoh have been taken from the US Energy Star Programme.

Colour EP-Copier/MFD:

Regarding the colour copiers/MFD the average power consumption values are naturally higher due to the multiple (colour) printing process. As a rule of thumb, the values are four times (four colour) higher than the monochrome machines, but of course it depends on the used technology. There are some machines that perform 50% and better than the Energy Star requirement. To give one example, the 35 ipm Konica Minolta bizhubC353 weekly power consumption is 5.7 kWh/w (Energy Star: 12.5 kWh/w) and the 55 ipm Konica Minolta bizhubC550 is 7.7 kWh/w (Energy Star: 21.5 kWh/w). Over 55 ipm power consumption of colour machines increase to a level of 15 to 20 kWh/w (e.g. the 60 ipm Ricoh Aficio C3260 with 15.6 kWh/w) , although the 65 ipm Konica Minolta C650 shows remarkable 8.8 kWh/w.

Table 1: Energy Star Database for MFD (selected products 19 – 28ipm)

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view photos:	MFD EU Energy Star® Qualified Brand+Model	Size format	Colour	Marking technology	Speed mono (ipm)	Speed colour (ipm)	Mac compatibility	Functions standard	Continuous form	Direct photo printing	Standard duplex capable	RAM (MB)	Typical Electricity Consumption (kWh/week)	Sleep mode (W)	Off mode (W)	Recovery time from sleep (s)
All / Selected	▼ /	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
	Canon i-SENSYS MF8180C website	std	Col	laser	19	4		CPSF				48	2.2			
	Canon Laser Base MF3240 website	std	BW	laser	20			CPSF				32	1.1			
	KONICA MINOLTA bizhub C203 website	std	Col	laser	20	20	x	CPSF			x	1024	4.3			30
	Canon i-SENSYS MF6580PL website	std	BW	laser	22		x	CPSF			x	128	1.5			
	Canon iR3025N website	std	BW	laser	25		x	CPS			x	512	1.8			
	Brother MFC-8860DN website	std	BW	laser	28		x	CPSF			x	32	4.0			18

Table 2: Energy Star Database for MFD (selected products 35 – 45 ipm)

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view photos:

All Selected

MFD EU Energy Star® Qualified Brand+Model	Size format	Colour	Marking technology	Speed mono (ipm)	Speed colour (ipm)	Mac compatibility	Functions standard	Continuous form	Direct photo printing	Standard duplex capable	RAM (MB)	Typical Electricity Consumption (kWh/week)	Sleep mode (W)	Off mode (W)	Recovery time from sleep (s)
 Canon iR3035N website	std	BW	laser	35		x	CPS			x	512	2.9			
 KONICA MINOLTA bizhub C352 website	std	Col	laser	35	35	x	CPSF			x	1024	11.3			77
Hewlett-Packard LaserJet M3035 MFP (CB414A)	std	BW	laser	35		x	CPSF			x	256	5.6			
KONICA MINOLTA bizhub C353 website	std	Col	laser	35	35	x	CPSF			x	1024	5.7			30
kyocera KM-C4035E	std	Col	laser	40	35		CPS			x	256	11.7			30
 Canon iR3045N website	std	BW	laser	45		x	CPS			x	512	3.2			
 HP LaserJet M4345xm MFP (CB428A) website	std	BW	laser	45		x	CPSF			x	256	5.9			

Table 3: Energy Star Database for MFD (selected products 50 – 75 ipm)

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view photos:	MFD EU Energy Star® Qualified Brand+Model	Size format	Colour	Marking technology	Speed mono (ipm)	Speed colour (ipm)	Mac compatibility	Functions standard	Continuous form	Direct photo printing	Standard duplex capable	RAM (MB)	Typical Electricity Consumption (kWh/week)	Sleep mode (W)	Off mode (W)	Recovery time from sleep (s)
All / Selected	▼ /	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
	kyocera KM-5050	std	BW	laser	50			CPS			x	512	5.6			15
	KONICA MINOLTA bizhub C550 website	std	Col	laser	55	45	x	CPSF			x	1024	7.7			30
	KONICA MINOLTA C650 website	std	Col	laser	65	50	x	CPSF			x	1024	8.8			30
	Canon iR5075N website	std	BW	laser	75		x	CPS			x	1000	9.5			

This data was last updated on 03-09-2007.

LEGEND

Size format:	std	= standard format: up to A3 (297 x 420 mm)
	large	= large format: A2 (420 x 594 mm) or larger
Colour:	BW	= monochrome (black and white)
	Col	= colour
Speed:	ipm	= images per minute

6.1.1.2. EP-Printer/SFD (according to TEC)

Figure 3 shows the data for all laser and solid ink printers in the Energy Star database. For speed classes above 60 ipm there are only very few monochrome machines, all of them minimum 20% below the threshold.

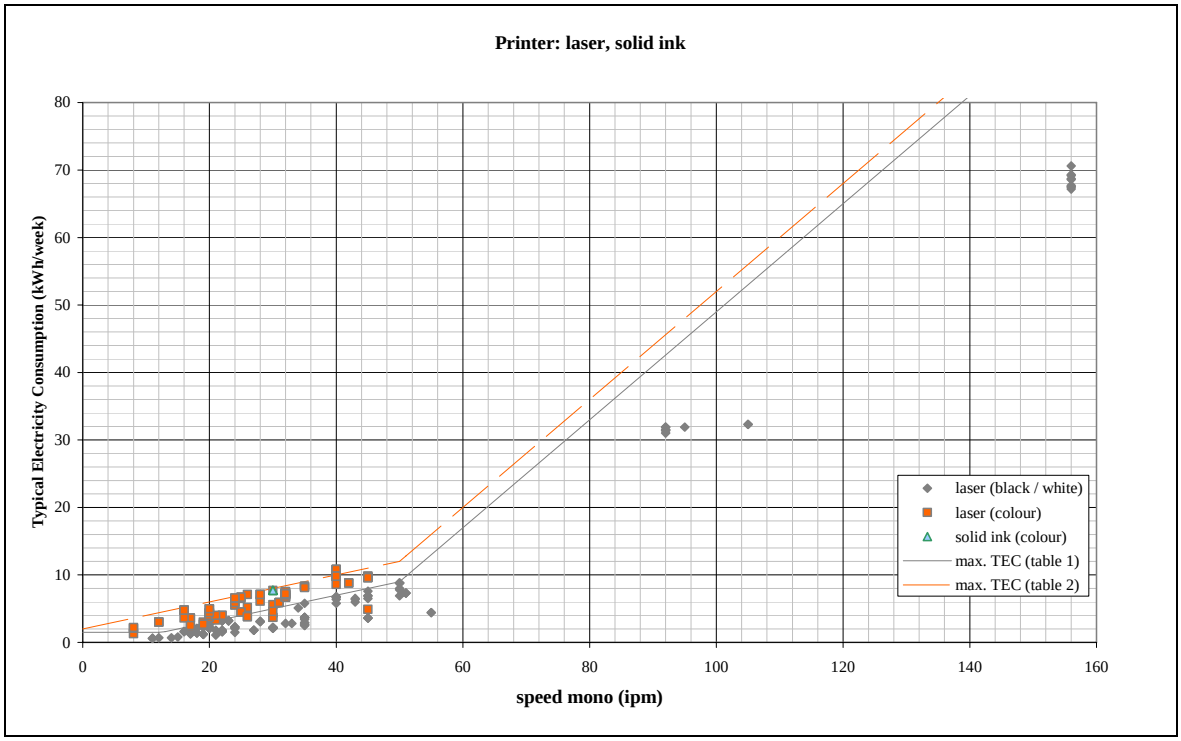

Figure 3: TEC of Energy Star listed printers (laser, solid ink)

Figure 4 shows the market segment up to 60 ipm to allow a differentiated analysis of these products: Due to the technological principles of multiple printing steps, colour printers consume significantly more energy than monochrome printers. As a rule of thumb again we could say four times as much. The Energy Star data show a significant variation even among the Energy Star compliant products. Printers with lowest TEC consumption up to 45 ipm perform approximately 50% better than the threshold. For faster machines, especially colour printers, there are some speed classes where the best performers are not that much better than the threshold.

For comparison:

- EP-Printer/SFD monochrome (V3) Base Case: 5.2 kWh/week (32 ipm)
- EP-Printer/SFD colour (V4) Base Case: 6.9 kWh/week (32 ipm)

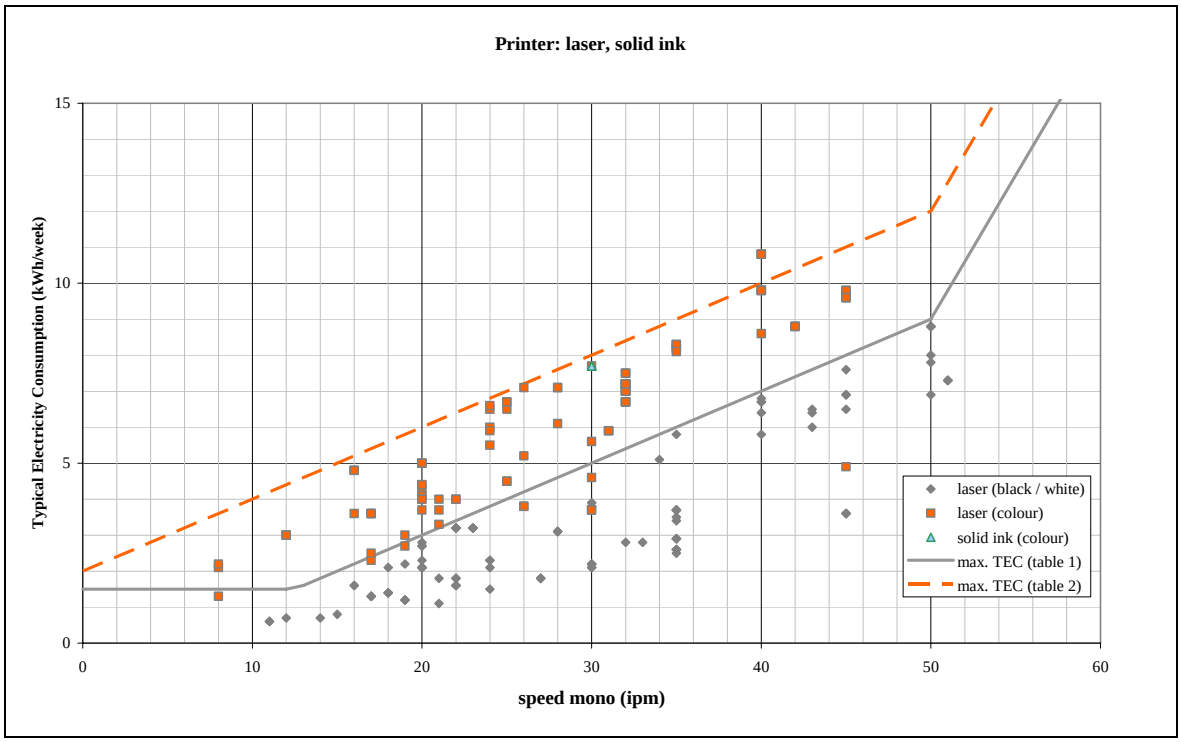

Figure 4: TEC of Energy Star listed printers (laser, solid ink; up to 60 ipm)

Monochrome EP-Printer/SFD:

There are many monochrome EP-Printer/SFDs, which TEC power consumption value are well below the Energy Star (Tier 1) eligibility criterion. Several laser printers perform over 50% better. In order to give an example, the 22 ipm monochrome Kyocera FS1030D weekly power consumption is 1.6 kWh/w (Energy Star: 3.3 kWh/w) and the 45 ipm Kyocera FS4000DN is 3.6 kWh/w (Energy Star: 8.0 kWh/w). The Table 4 and Table 5 provide a selection of best performing EP-Printer/SFDs from the European Energy Star database. There are very few machines listed in the speed segments above 50 ipm[4]. This might indicate that fewer machines can comply with the Energy Star and that they are designed (optimized) for more constant use and less for idle periods.

According to feedback from the Market Transformation Programme "the clustering of SFDs in the lower speeds may be down to higher speed devices tending towards MFDs".

Colour EP-Printer/SFD:

Regarding the colour laser printer the average power consumption values are naturally higher due to the multiple (colour) printing process. As a rule of thumb, the values are four times (four colour) higher than the monochrome machines. There are some machines that perform 50% and better than the Energy Star requirement. To give an example, the 19 ipm HP LaserJet1022 weekly power

[4] There are only 4 solid ink printers listed in the Energy Star database. All of them are from one manufacturer, same platform, and with same power consumption.

consumption is 1.2 kWh/w (Energy Star: 6.0 kWh/w) and the 55 ipm HP LaserJet4350 is 4.4 kWh/w (Energy Star: 11.0 kWh/w).

Table 4: Energy Star Database for EP-Printer/SFD (selected products 19 – 30 ipm)

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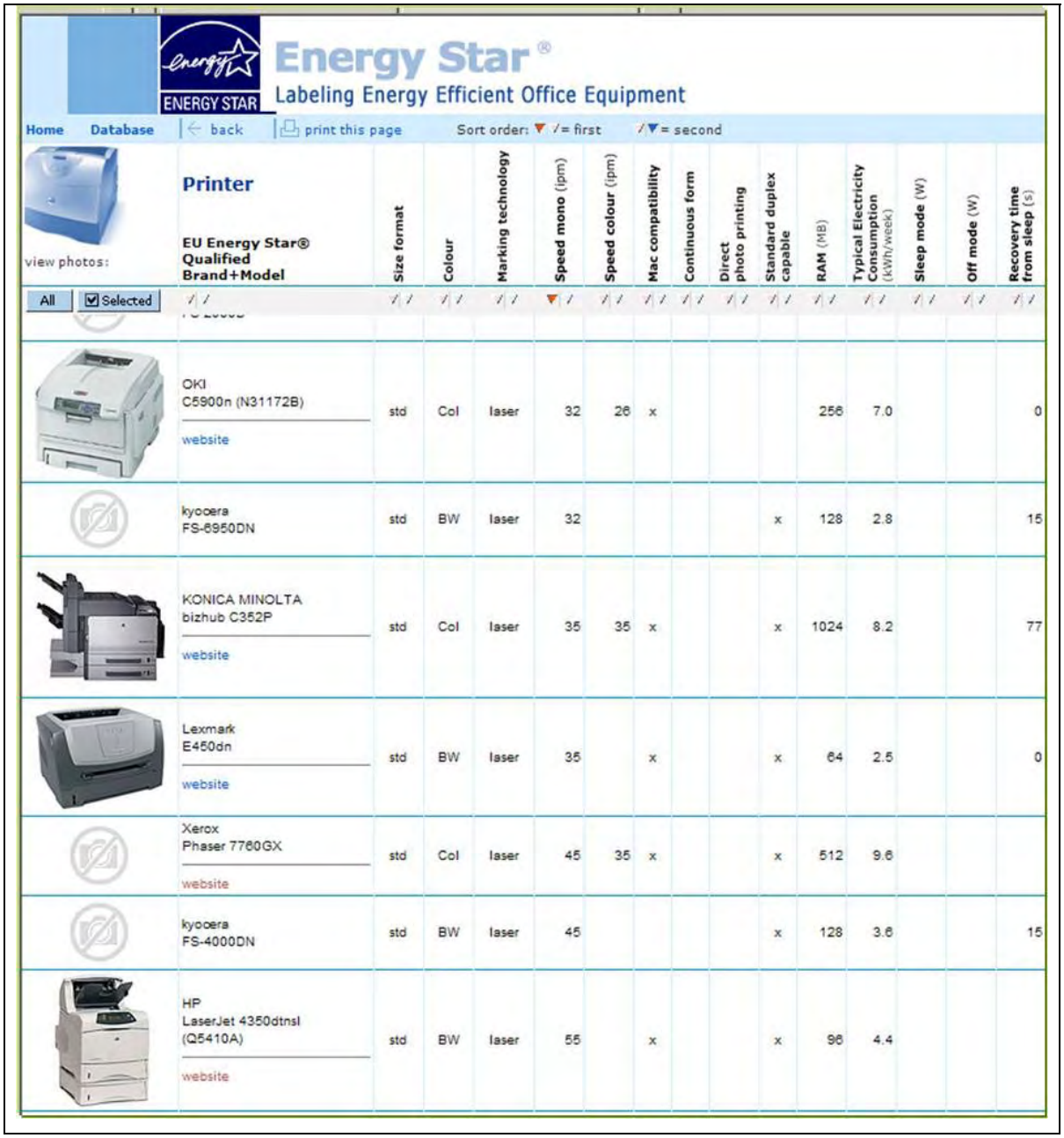
view photos:	Printer EU Energy Star® Qualified Brand+Model	Size format	Colour	Marking technology	Speed mono (ipm)	Speed colour (ipm)	Mac compatibility	Continuous form	Direct photo printing	Standard duplex capable	RAM (MB)	Typical Electricity Consumption (kWh/week)	Sleep mode (W)	Off mode (W)	Recovery time from sleep (s)
All / Selected															
	HP LaserJet 1022 (Q5912A) website	std	BW	laser	19		x				8	1.2			
	Xerox Phaser 6120N website	std	Col	laser	20	5	x				128	4.4			
	Canon i-SENSYS LBP3300 website	std	BW	laser	21		x			x	8	1.1			
	kyocera FS-1030D	std	BW	laser	22					x	32	1.6			15
	HP LaserJet P2015x (CB369A) website	std	BW	laser	27		x			x	32	1.8			
	kyocera FS-2000D	std	BW	laser	30					x	64	2.2			15

Table 5: Energy Star Database for EP-Printer/SFD (selected products 32 – 55 ipm)



Energy Star®
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Home Database | back | print this page | Sort order: ▼ /= first /▼= second

view photos:	Printer EU Energy Star® Qualified Brand+Model	Size format	Colour	Marking technology	Speed mono (ipm)	Speed colour (ipm)	Mac compatibility	Continuous form	Direct photo printing	Standard duplex capable	RAM (MB)	Typical Electricity Consumption (kWh/week)	Sleep mode (W)	Off mode (W)	Recovery time from sleep (s)
All / Selected															
	OKI C5900n (N31172B) website	std	Col	laser	32	26	x				256	7.0			0
	kyocera FS-6950DN	std	BW	laser	32					x	128	2.8			15
	KONICA MINOLTA bizhub C352P website	std	Col	laser	35	35	x			x	1024	8.2			77
	Lexmark E450dn website	std	BW	laser	35		x			x	64	2.5			0
	Xerox Phaser 7760GX website	std	Col	laser	45	35	x			x	512	9.6			
	kyocera FS-4000DN	std	BW	laser	45					x	128	3.6			15
	HP LaserJet 4350dtnsl (Q5410A) website	std	BW	laser	55		x			x	96	4.4			

6.1.1.3. IJ-Printer/MFD (according to OM)

Figure 5 shows the sleep mode power consumption of those printers falling under the operational mode (OM) approach. For comparison, the eligibility criteria for sleep mode of the marking engine is given, but notice, that functional adders for individual products in fact mean a higher sleep mode threshold.

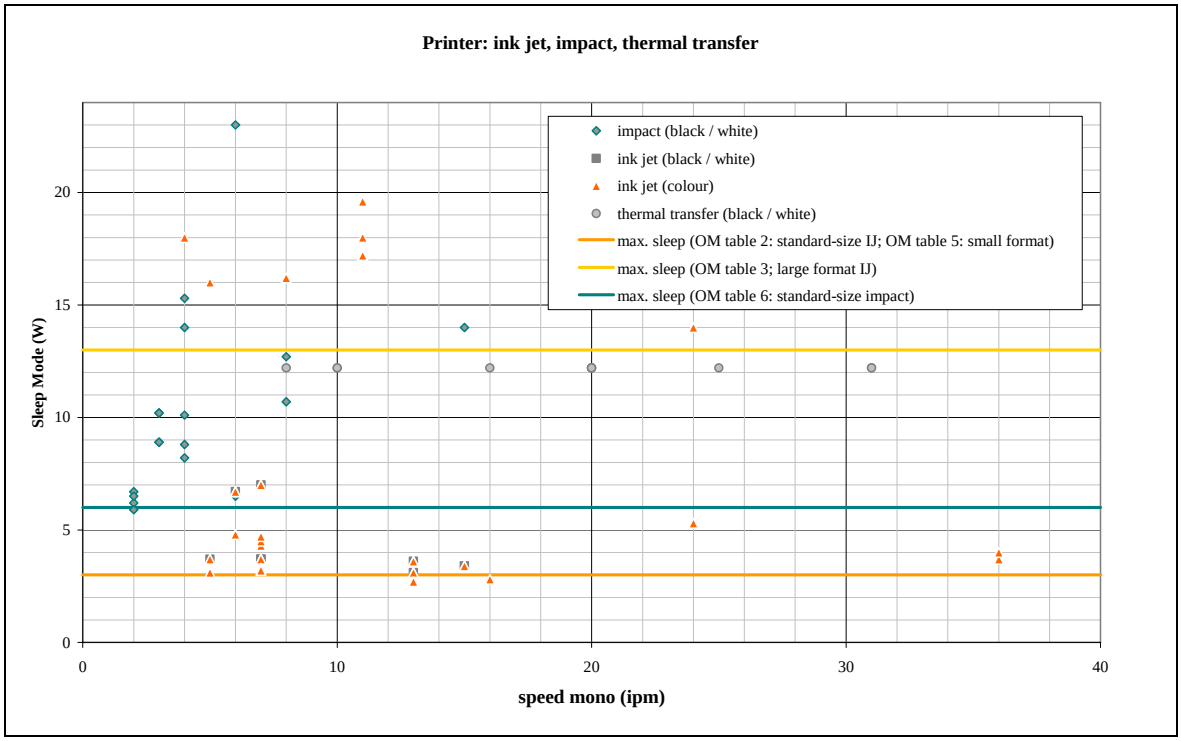

Figure 5: Sleep Mode Power Consumption of Energy Star listed printers (ink jet, impact, thermal transfer)

For comparison:

- IJ-Printer/MFD personal (V5)/ workgroup (V6) sleep: 4.35 W

Large-format colour ink jet printers are in the range between 16 and close to 20 W in sleep mode. Standard-size and small format colour ink jet printers range between 2.5 and 6 W in sleep mode. Regarding the sleep mode there is no difference between colour and black & white ink jet printers. The Energy Star database lists a couple of large format impact printers, which fall under OM Table 8 with a sleep mode threshold for the marking engine of 54 W (not shown in the figure). The Energy Star listed large format impact printers however are well below this threshold (8.8 – 23 W sleep mode).

Table 6: Energy Star Database for IJ-Printer/MFD

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view photos:

Printer EU Energy Star® Qualified Brand+Model	Size format	Colour	Marking technology	Speed mono (ipm)	Speed colour (ipm)	Mac compatibility	Continuous form	Direct photo printing	Standard duplex capable	RAM (MB)	Typical Electricity Consumption (kWh/week)	Sleep mode (W)	Off mode (W)	Recovery time from sleep (s)
All / Selected	▼ /	/ /	/ /	/ /	/ /	/ /	/ /	/ /	/ /	/ /	/ /	/ /	/ /	/ /
HP deskjet 6940 (C8970A)	std	Col	ink jet	36	27	x				32		3.7	0.4	8
HP deskjet 6980 (C8969A-B)	std	Col	ink jet	36	27	x				32		4.0	0.4	6
Lexmark Z1420	std	Col	ink jet	24	18	x				4		5.3	0.9	0

This data was last updated on 03-09-2007.

LEGEND

Size format:	**std**	= standard format: up to A3 (297 x 420 mm)
	large	= large format: A2 (420 x 594 mm) or larger

6.1.1.4. Fax Machines

Not yet investigated

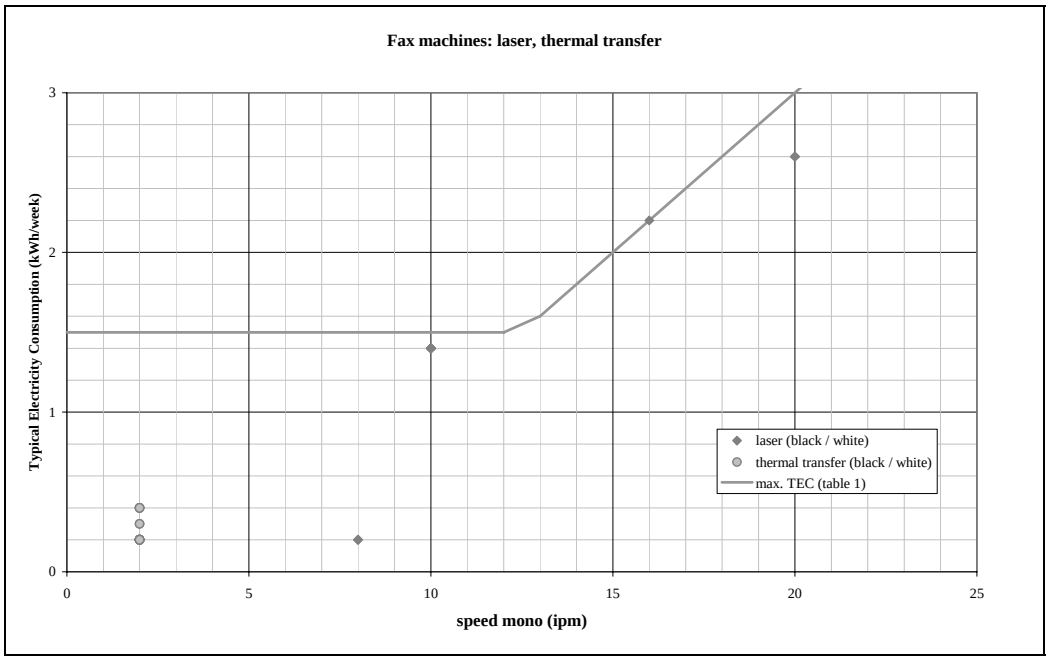


Figure 6: TEC of Energy Star listed Fax Machines

6.1.1.5. Scanners

Not yet investigated

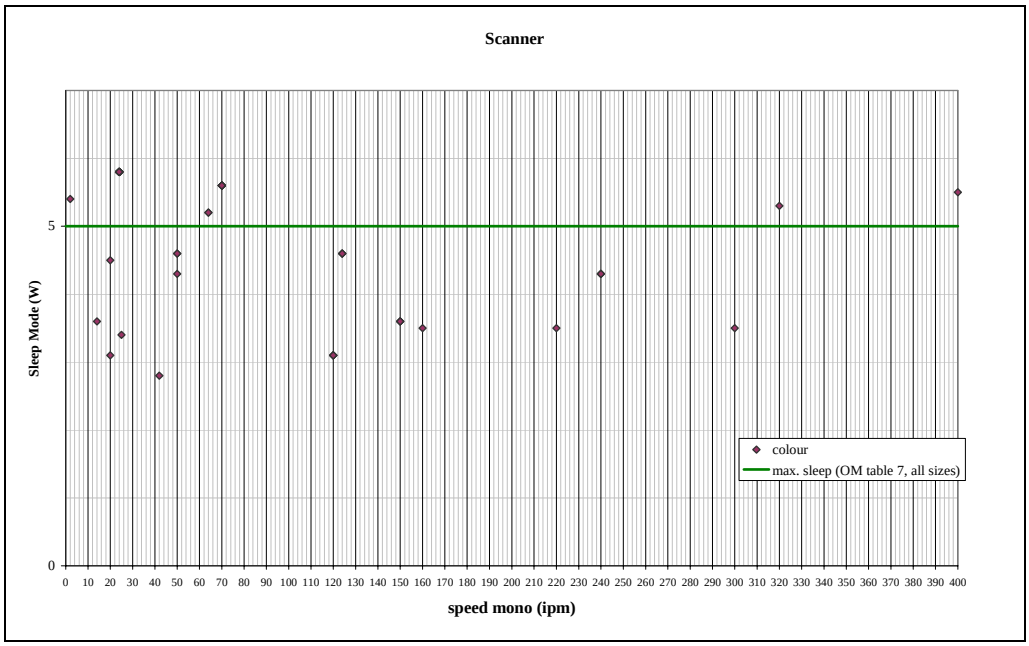


Figure 7: Sleep Mode Power Consumption of Energy Star listed scanners

6.1.1.6. Digital Duplicators

Not yet investigated

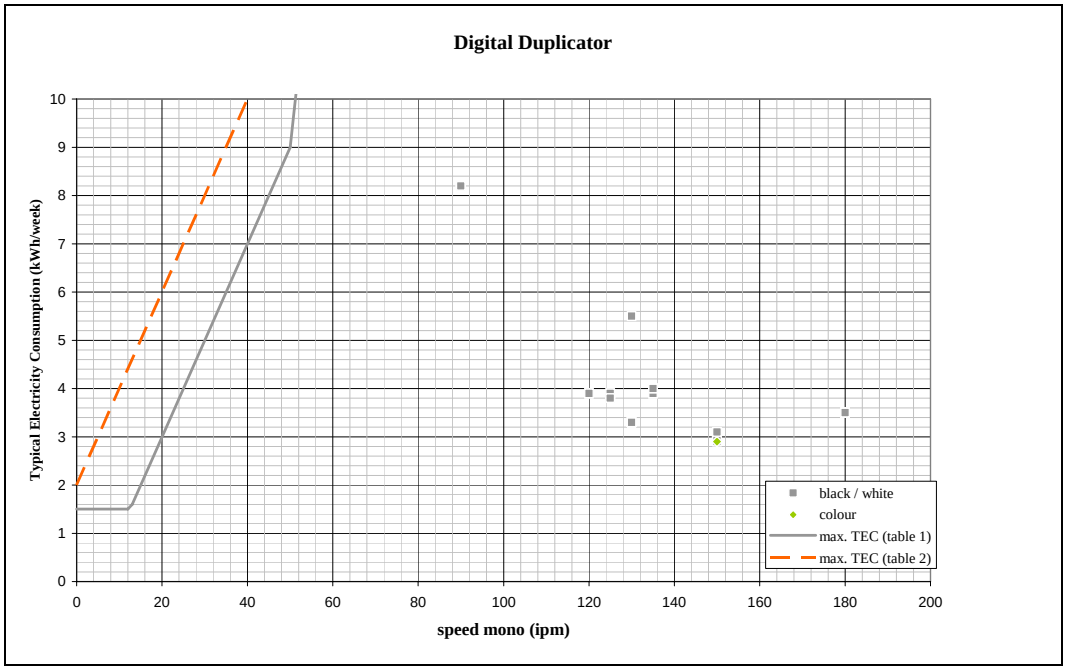


Figure 8: TEC of Energy Star listed Digital Duplicators

6.1.2. Miniaturization and Resource Efficiency

6.1.2.1. Weight and Volume Reduction

Canon: In the field of IJ-Printers a technical trend in the past years was to make the products more compact and lighter. One example is the Canon Pixus MP500, a compact all-in-one IJ-product. In comparison to the MP770 of the previous product generation achieved Canon a reduction in volume of about 36% and a reduction in weight of about 23% (see Figure 9). This example was presented at the EcoProducts 2006 in Tokyo, Japan.

	 Volume reduced 36% Weight reduced 23%
Canon MP770 (2004) Weight 12,4kg Volume: 61.000cm³	**Canon MP500 (2006)** Weight 9,6kg Volume: 39.000cm³

Figure 9: Canon product miniaturization

According to Canon the miniaturization was achieved by:

- Miniaturizing and lighting of the scanner unit (e.g. adoption of small LED light source for scanner, miniaturization of electromechanical components)
- Miniaturization of print head unit (e.g. small printer head and carriage)
- Miniaturization/system integration of main board (e.g. reduction of substrate size though use of higher integrated electronic components such as memory chip set and advanced board technology)

6.1.2.2. Refurbishment/Reuse/Recycling of Parts and Products

Ricoh: Since the launch of the recycled multifunctional digital copier, imagio MF6550RC, in December 2001, Ricoh has increased the number of models available. At present, a wide variety of recycled machines with a copying productivity ranging from 35 ipm to 75 ipm have become available. Recycled machines are based on used copiers collected from the market. Compared with

new machines, the environmental impact of a recycled copier over the whole lifecycle from production to disposal is greatly reduced. More than 80% (mass ratio) of the parts used in the imagio Neo 352RC/452RC that were launched in fiscal 2006 are recycled parts, and the imagio Neo 352RC gives a 28% reduction in environmental impact over its whole lifecycle compared with newly produced machines.[5]

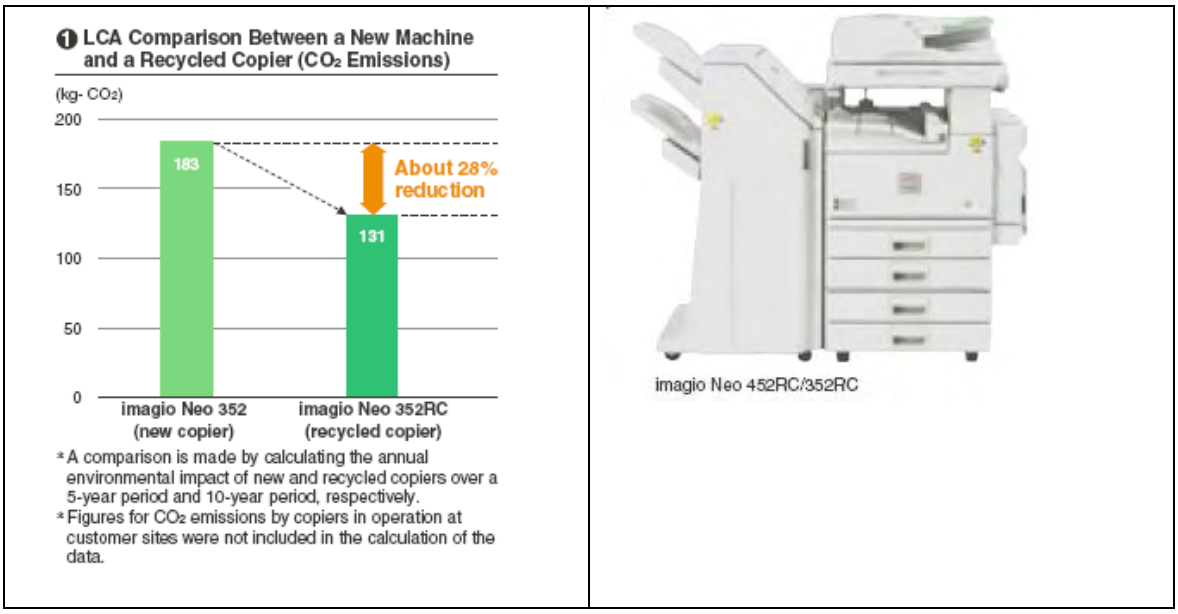


Figure 10: Ricoh LCA comparison of new and recycled Copier/MFD

Fuji Xerox: According to Fuji Xerox Environmental Report 2006, starting from the product planning/design stage, Fuji Xerox assumes that parts will be reused for many generations, and the percentage of parts used for two or three generations is steadily increasing. In FY2005, with the rapid shift of the copy machine market to colour devices over the past several years, the market for monochrome machines in which parts were used for three generations shrank, lowering relatively the ratio of parts used for three generations. To ensure the more effective reuse of parts, Fuji Xerox is promoting designs that enable module-based reuse instead of merely parts-based reuse. These designs modularize parts, such as paper feed units, according to product function, enabling each module to be reused. Within modules, parts with the same service lives are subdivided into single units (groups) to enable replacement and recycling by unit (group) design. This method enables more parts to be reused. Design methods for the reuse of parts are evolving daily from module to unit. These design methods will be applied to more models in the years ahead.[6]

According to Xerox the "Xerox Green World Alliance reuse/recycle program for imaging supplies" makes up a central element of their strategy to achieve Waste-Free Product goals. This partnership

[5] http://www.ricoh.com/environment/report/pdf2007/all.pdf (download 10-09-2007)
[6] http://www.fujixerox.co.jp/eng/sr/2005/environment/product/project.html (download 10-09-2007)

between Xerox and their customers resulted in more than 3.1 million cartridges and toner containers being returned in 2005, with more than 90% by weight remanufactured or recycled. Xerox also processed 1.5 million pounds of post-consumer waste toner for reuse. Off the plastic bottles customers used to return waste toner to Xerox – more than 100,000 – were recycled. The annual reduction in the volume of supplies containers returned to Xerox for recycling primarily reflects a change in technology and product mix. Similarly, waste toners qualified for reuse may account for 25% of the weight of new toner, without compromising toner functionality. The reuse of waste toner saves several million dollars in raw material costs each year. For one of Xerox's most popular product families, a closed-loop recycling process enables scrap plastic parts from damaged cartridges to be re-ground, re-qualified, and moulded into the same parts. These parts, made of 100% recycled plastic, are used in manufacturing new cartridges. Each year Xerox recycles more than 80,000 pounds of post-consumer plastic scrap in this manner[7].

6.1.2.3. Remanufactured Cartridges

Environmental Assessments

Remanufacturing of cartridges is broadly called environmentally benign as the waste savings are quite obvious. Nevertheless, as pointed out in Task 3, based on input provided by EICTA, remanufacturing of cartridges does not per se result in lower environmental impacts: A study by First Environment (contracted by HP) compared the use of an original **toner print cartridge** and remanufactured toner print cartridges[8]. The scenarios compared include:

- New toner cartridge (HP C4096A)
- Remanufactured cartridge (HP facilities): A remanufactured cartridge representing common remanufacturing practices
- "International operation": Cartridges produced by a remanufacturing operation that is considered technically sophisticated and services multiple international markets (e.g. cartridges from Germany are remanufactured in Thailand). The cartridges in this scenario are modelled as having relatively high-end quality and reliability (but still more misprints than new toner cartridges)
- "Drill and Fill" operation: Cartridges of highly variable quality and reliability produced by a remanufacturing operation that uses the least intensive form of processing

The study compares the full life cycle, including production, transports, use (taking into account also the paper losses of misprints caused by the toner cartridge), remanufacturing (certain quota of non-reusable cartridges also in the remanufacturing scenarios), and disposal.

[7] http://www.xerox.com/downloads/usa/en/c/citizenshipreport06.pdf
[8] First Environment, Inc.: LaserJet Cartridge Environmental Comparison: A Life Cycle Study of the HP 96A Print Cartridge vs. Ist Remanufactured Counterpart in the United Kingdom, Summary Report, October 2004

The environmental impact comparisons "do not decidedly favour the HP cartridge or any remanufactured cartridges". As the results in the various impact categories only show minor differences among the scenarios, the authors conclude: "no definitive statement can be made about the environmental preferability of one product type over the other – HP or remanufactured." For example, the higher Global Warming Potential of the new cartridge in the production phase compared to the remanufacturing scenarios are outweighed by the higher use phase impact for two of the three remanufacturing scenarios (due to e.g. the higher number of misprints[9]) and the credit at end-of-life for entering Hewlett-Packard's established return and recycling program (scenario for new cartridge) compared to sent 90% of the cartridges to landfills (remanufacturing scenarios).
The study reveals that "critical drivers of environmental impacts over the life cycle are **print quality, cartridge reliability** and **end-of-life management**." Note: Print quality and cartridge reliability can be considered design aspects, end-of-life management not.

An older LCA study by University of Kalmar also compared a new toner cartridge with a remanufactured one[10]. This study does *not* differentiate potential differences in print quality and cartridge reliability. The compared alternatives are:

- Recycling of HP's toner cartridge C4127X according to HP's present recycling program
- Cartridge is restored at Tepro Rebuild Products AB

Both with the functional unit "30,000 copies, 5% average coverage", meaning a comparison of three original cartridges vs. one toner cartridge reused and remanufactured two times. Not included in the analysis is the end-of-life of the remanufactured cartridge.

These differences in system boundaries and assumptions are also the reason, why Berglind and Eriksson come to other conclusions than First Environment: "The result of each alternative's environmental load […] indicates that the alternative with restoring are better […]. The alternative with restoring are, from an environmental point of view […] barely two times better than the alternative with HP's recycling programme, for the scenario without paper."

The conclusion from these two studies in comparison is: Remanufactured cartridges are only likely to be environmentally favourable ("best available technology"), if they yield the same print quality and cartridge reliability as new ones and if they follow similar end-of-life routes.

[9] Data on print quality of HP and remanufactured cartridges is based on tests performed by Quality Logic, contracted by Hewlett-Packard
[10] Jonas Berglind, Henric Eriksson: Life Cycle Assessment of Toner Cartridge HP C4127X, Environmental impact from a toner cartridge according to different recycling alternatives, University of Kalmar, January 2002

It is assumed, that also the environmental impact of **remanufactured / refilled ink cartridges** is largely a question of print quality and cartridge reliability. A study on this topic is not available, however.

To put the results of Berglind and Eriksson in the right perspective: The benefit of the alternative remanufacturing compared to the original cartridges totals in 11 kg CO_2-equivalent. Adapting this result to the same amount of toner consumption as for the Base Case scenario results in a "remanufacturing benefit" of **130 kg CO_2-eq.**[11], compared to **3,177 kg CO_2-eq** for Base Case V3 and **941 kg CO_2-eq**. (excl. paper) respectively.

Quality and performance of remanufactured cartridges

In 2005 Quality Logic performed another test of non-OEM cartridges (toner and ink) for HP printers, including remanufactured cartridges. This test again confirmed quality problems related to all non-HP products, in most cases even tremendous reliability restrictions.

Recently two independent tests assessed print quality of non-OEM cartridges and came to the contrary result, that quality and reliability of these alternative cartridges are comparable to new OEM products:

- A January 2007 test report by the German Stiftung Warentest confirmed that non-OEM **ink** cartridges are as good as OEM, and that major savings can be made when non-OEM is used, particularly in the case of Epson and Canon. For the HP case Stiftung Warentest did not observe any quality problems with the prints, but for one non-OEM manufacturer much lower filling volumes in the cartridge than stated. The report also states that non-original cartridges do not damage the printer: in long-run tests, none of the 17 tested printers failed to print the 5,000 pages. The quality of the print-outs after this number was equal to the original reference print.
- A Dutch consumer organisation in early 2007 tested non-OEM cartridges, and found that overall, they are a cost-effective alternative to OEM-cartridges. In its May/June 2007 issue of magazine Digitaal gids they conclude that overall, the performance of non-OEM equals that of OEM, but at a lower cost. This applies in particular in the case of refills or non-OEM branded black ink for HP and Canon printers.

[11] As the functional unit is not the same (Berglind & Eriksson: 30,000 prints, Base Case V3: 133,120 prints per year times 6 years lifetime), both data is not directly comparable: The HP cartridge with a content of 450 g toner is meant to last for 10,000 prints, gross consumption per print: 0.045 g, whereas this study calculates with 0.02 g per print. Adapting the Berglind & Eriksson data to 0.02 g toner consumption per page results in a „remanufacturing benefit" of 5 kg CO_2-eq. per 30,000 prints, extrapolated to the Base Case V3 no of prints over 6 years lifetime: **130 kg CO_2-eq.**

Regarding the process of remanufacturing we can note that high-quality remanufactured toner cartridges now undergo a process that renders cartridges equivalent in performance, print quality and page yield to new models and that meet all original equipment manufacturer (OEM) standards and specifications. Moving away from the original "drill and fill" method that created the industry's initial problems, the current remanufacturing process now requires that the cartridges be disassembled and inspected to determine any problem areas. Worn components are replaced with new parts; all sections are completely cleaned, and a fresh supply of toner is added before the cartridge is resealed."[12] But, it seems that the toner cartridges undergoing simple refilling are also sold as remanufactured ones, whose poor performance undermines consumers trust to (non-OEM) remanufactured cartridges.[13]

Based on the above named studies it can be said, that an environmental improvement is mainly a question of print quality and reliability of the remanufactured cartridges. If the remanufactured cartridges are of poorer quality no final statement can be given, whether remanufactured cartridges can be considered "Best Available Technology" or an environmental improvement at all. Cost savings potential from the perspective of the consumer is significant, however.

[12] http://www.green.ca.gov/EPP/OfficeMach/toner.htm#cost, http://web.mit.edu/newsoffice/2003/toner.html; http://www.articlecube.com/Article/Remanufacturing-Toner-Cartridges-Saves-Big-Money-And-Landfills/20522

[13] https://www.stopwaste.org/docs/toner.pdf

6.2. State-of-the art on component and material level

The first focus of this analysis is placed on energy efficiency technologies for EP-products. Within the electro photographic (EP) process the thermal/pressure based fixing of the image requires the highest energy consumption (see Figure 11). Measurements indicate that in active mode about 70% of power consumption is related to the fuser/fixing unit. Consequently, the fixing process provides a good potential for improvement of total energy efficiency. Other sources of considerable power consumption are the paper transport (motors), the scanner unit (florescent lamp), and the overall efficiency of the power supply unit. Nevertheless, the main focus is currently placed on the fuser/fixing technology. In an evaluation of new low power fixing technologies such as fast fuser technologies in combination with low temperature chemical toners it is necessary to take performance aspects (speed) and the issues of safety and reliability into account as well. This means, for instance, that certain technologies can only be applied to certain speed classes; fast fusers usually only for low and medium speed product. High speed machines need reliable thermal operating conditions. Energy efficiency concepts are focusing in that respect on thermal insulation techniques.

Finally, as we will see, most energy saving technologies (hardware) are proprietary technologies and not generally available to all manufacturers. This also leads to the fact that “costs” for these technologies could not be obtained. The considerable competition in the office imaging equipment market is a matter of fact limitation in that respect.

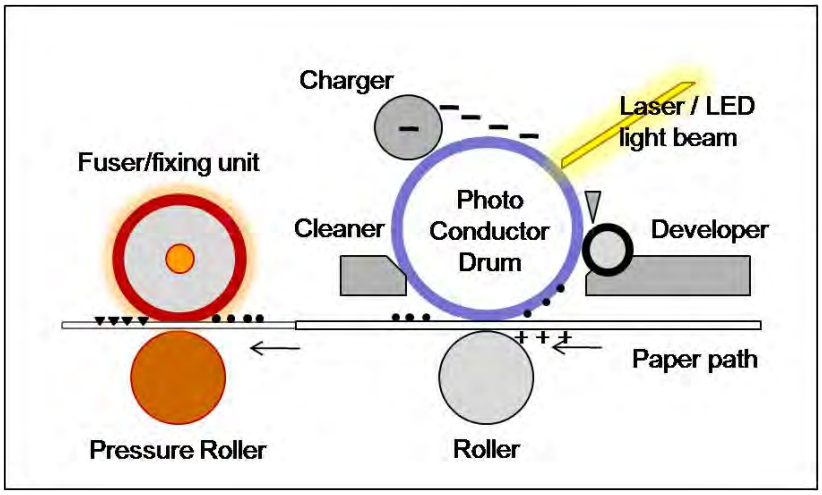
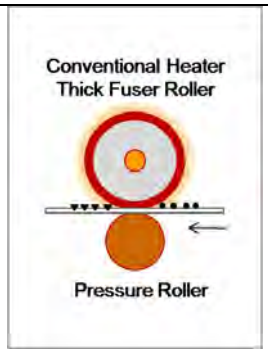
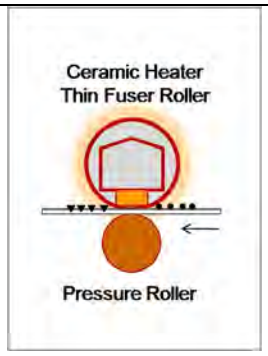


Figure 11: The electro photographic process

6.2.1. Fast Fuser/Fixing Technologies for EP-Products

Most conventional EP-products indirectly heat a fuser roller or fixing belt to about 180 to 200°C using a halogen lamp that requires approximately 900 to 1400 W. Due to the thickness of fuser roller shell the warm-up time is with approximately 180 to 360 seconds quit long and energy intensive. To reduce warm-up time (and save energy) for fast operation advanced fuser/fixing technologies have been developed by individual manufacturers. In principle all fast fuser technologies apply thinned fuser rollers and alternative heating elements such as twin halogen heaters, ceramic heaters or induction heaters. The following Table 7 and Table 8 provide an overview on principle technologies and the manufacturers that developed or apply these technologies[14]. The technical specifications of the individual technologies will be provided further below.

Table 7: Fuser Roller Fixing Technologies for monochrome EP-Products

<table>
<tr><td> 
</td><td colspan="3">Conventional Fuser Roller Fixing Technology (monochrome EP-products)
Thick wall fuser roller with single halogen heater</td></tr>
<tr><td colspan="4">Fast Warm-up Fuser Roller Technologies</td></tr>
<tr><td> 
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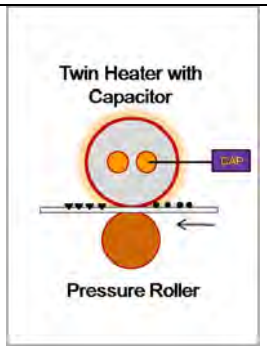
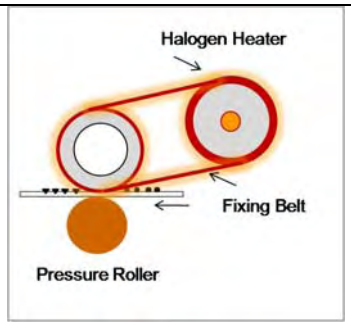
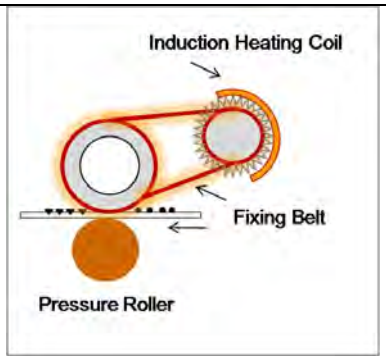
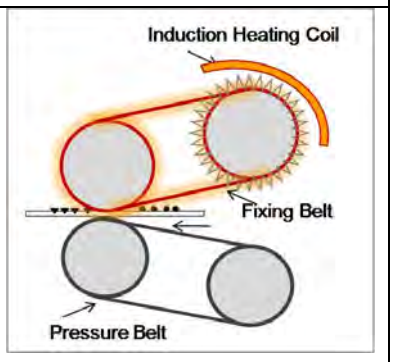
</td><td> 
</td><td> 
</td></tr>
<tr><td>Canon: On-demand system
HP: Instant-on system</td><td>Ricoh: QSU system
(quick start up)</td><td>Ricoh: Hybrid QSU system
(with additional capacitor)</td><td>Canon: Induction Heat (IH)
Konica Minolta: IH system
Toshiba: Twin IH fuser</td></tr>
</table>

[14] The authors could not obtain a complete overview on available technologies and origin. But as these examples show, there are multiple proprietary fast fuser technologies applied in the market.

Table 8: Belt Fixing Technologies for Colour EP-Products

<table>
<tr><td> 
</td><td colspan="2">Conventional Belt Fixing Technology (colour EP-products)
Thick wall fuser roller with single halogen heater transfers heat via fixing belt to heater roller</td></tr>
<tr><td colspan="3">Fast Warm-up Belt Fixing Technologies</td></tr>
<tr><td> 
</td><td> 
</td><td> 
</td></tr>
<tr><td>Fuji Xerox: Free Belt Nip Fixing
Fuji Xerox: Dual heater FBNF</td><td>Ricoh: QSU, IH belt fixing system
Panasonic: IH belt fixing system</td><td>Canon: IH twin-belt fixing system</td></tr>
</table>

The following chapters introduce some examples of advanced fast fuser/fixing technologies.

6.2.1.1. Ceramic Heater Fuser Roller Technology

A time and energy efficient fixing technology promoted by Canon under the name “on-demand” and by HP under “instant-on” uses the same principle of a ceramic heater which localizes the thermal energy to a specific area through a fixing film (flexible plastic sleeve) during printing. The on-demand or instant-on fuser heats up three to four times faster than conventional halogen bulb fusers and allows a transition from a sleep state to printing in less than 15 seconds.

Canon: Canon's proprietary on-demand SURF (Surface Rapid Fixing) technology (utilized since 1990) uses a linear ceramic heater and fixing film of high thermal conductivity and low thermal capacity. The heater activates only when the fixing film rotates, transferring heat via the film to fix the image. This makes possible zero warm-up time, resulting in a 75% reduction in energy consumption compared to conventional roller-fixing systems.

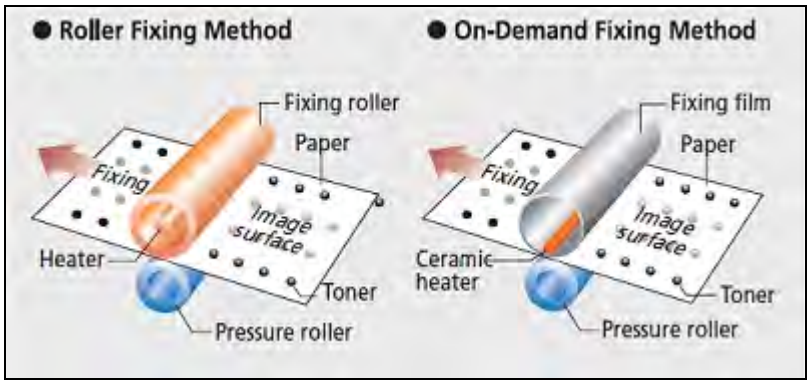


Figure 12: Canon's on-demand fixing method

Canon also developed an "On-Demand" Fusing Method for its colour printers and copiers, changing the material used for the base layer of the fixing film from a heat resistant resin to a thin metal film, and the structure of the fixing unit from two layers to three, adding a layer of rubber between the surface layer and the base layer. The soft rubber layer contributes to improved toner-fixing performance, ensuring uniform application of heat to the toner to produce high-quality, consistent colour images.

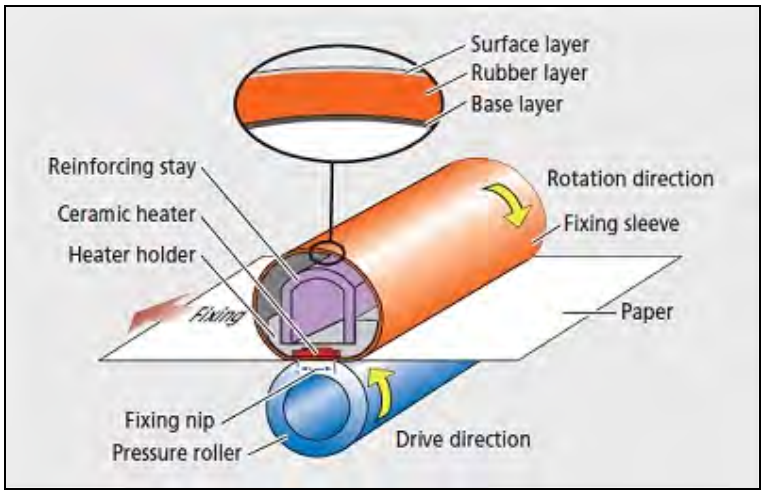


Figure 13: Canon's colour on-demand technology

Hewlett-Packard: In 1993, HP introduced "instant-on fusing" for LaserJet printers. According to the 2006 Global Citizenship Report, HP estimates for monochrome LaserJet products, the total energy consumption saved since 1993 from use of this technology represents 4.1 million tonnes of carbon dioxide (CO_2).[15]

[15] http://www.hp.com/hpinfo/globalcitizenship/gcreport/energy/products/performance.html (download 4-9-07)

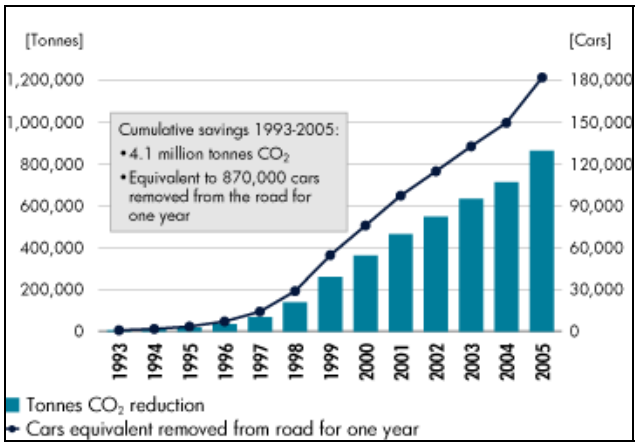


Figure 14: HP mono LaserJet workgroup printer savings from instant-on fusing (1993-2005)

Quick fuser technologies are also promoted for monochrome desktop EP-printer by **Fuji Xerox** (e.g. DP240A DocuPrint, 24 ipm, 10 seconds first page out time) and **Epson** (e.g. EPL-N2550DT, 30 ipm, first page out time of just 8.2 seconds from ready, 12 seconds from 'sleep' mode).

6.2.1.2. Twin Heater Fuser Technologies

Ricoh provides multifunctional digital copiers equipped with QSU (quick start-up) that enables quick recovery from energy-saving standby mode. The QSU technology features an ultra-thin shell-fusing roller in order to shorten the temperature rise time and twin halogen heaters. Because a thin roller is apt to get cold, the temperature is carefully and effectively adjusted by using two separately controlled heaters. In conjunction with the QSU technology Ricoh also features a low-temperature fixing toner. This toner ensures a fixity that is equal to or higher than that of conventional toner even at low temperatures.

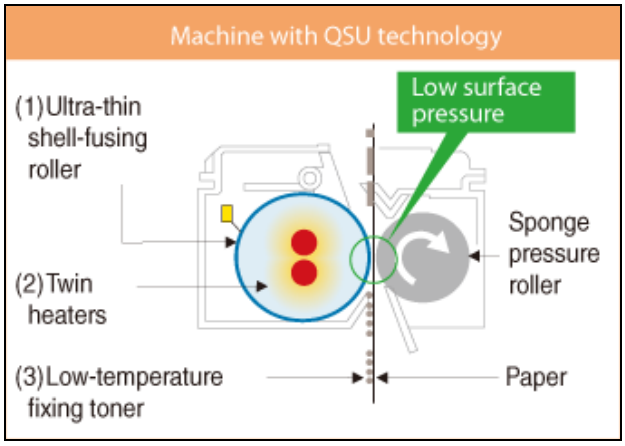


Figure 15: Ricoh's QSU technology incorporated in Aficio (imagio Neo) series

Ricoh: In 2003, Ricoh introduced the HYBRID QSU, an integration of quick start-up (QSU) technology and capacitors (electric storage devices), to the imagio Neo 752 series of high-speed digital multifunctional copiers. This enabled a 30-second recovery time from energy-saving mode. Subsequently, by improving the HYBRID QSU, Ricoh launched the imagio Neo 752ec/602ec, which achieves a 10-second recovery time from energy-saving mode. The capacitors have a quick charge and discharge capability. In the past, capacitors were used to supply heat to the fusing roller. Although the ultra-thin fusing roller, one of the QSU technologies, shortens the temperature rise time, papers tend to absorb heat easily from the fusing roller during high-speed printing, such as at 75 ipm, which resulted in a failure to maintain copy quality and productivity. In the imagio Neo 752ec/602ec, capacitors are used both for printing and to help the restart. Using capacitors in this way, Ricoh succeeded in achieving a 10-second recovery time from energy-saving mode without lowering productivity. [16] However, capacitors are incorporated only in the 100 V machines marketed in Japan.

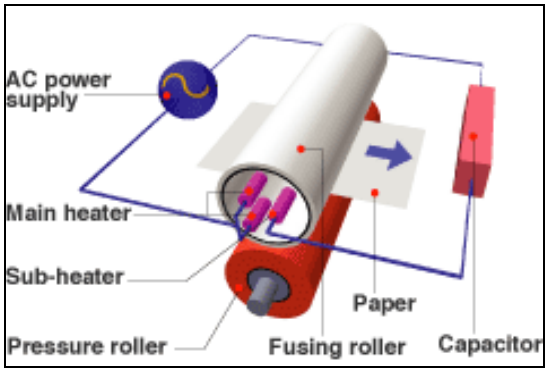


Figure 16: Ricoh's Hybrid power assist QSU technology

6.2.1.3. External Heat Roller Technology

Sharp proprietary external heat roller system provides stable, consistent fusing for high reliability. Designed to shorten warm-up time to less than 120 seconds, this system delivers good energy efficiency[17][18]. The basic idea of this technology is to bring thermal energy more directly to the places where the thermal energy is needed. This approach combines multiple heaters and thin wall rollers with thermal insulation.

[16] www.ricoh.com/about/technology/showcase/qsu.html (download 05-09-2007)
[17] http://www.sharp-world.com/products/copier/ar-m700_620_500/reliability.html (download 05-09-2007)
[18] www.sharp.co.jp/corporate/rd/24/pdf/89-13.pdf (download 05-09-2007)

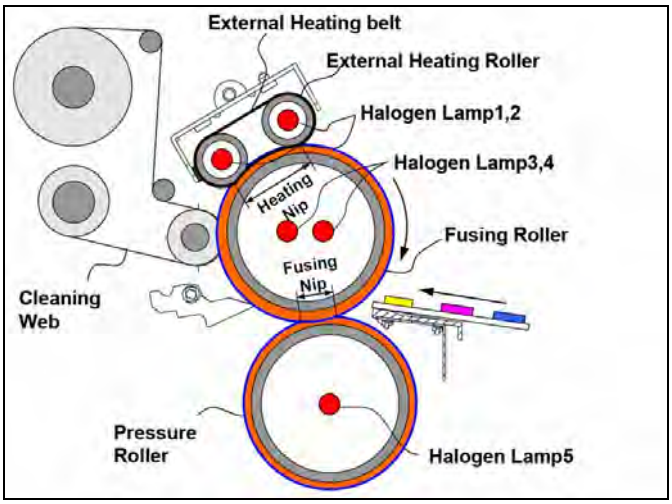


Figure 17: Sharp's external heat roller technology

6.2.1.4. Induction Heating (IH) Fuser Technologies

Induction Heating (IH) is a fuser technology by which high frequency current flows through a coil or multiple coils and creates an electromagnetic field inside the fuser. This magnetic field creates an eddy current, which in connection with the resistance element coating of the surrounding fuser roller generates thermal energy and heats up the metal fuser roller. The surface temperature of the fixing sleeve (spherical component that comes into contact with the paper) is precisely controlled during dual-side printing.

Canon: Canon utilizes since 2002 a proprietary induction heating (IH) fixing system that consists of a thin-walled metal pipe with a thin fluororesin mould-release layer coating. This technology ensures fast heat conduction and cuts energy consumption by 70%. Conventional EP-printers require about 180 to 360 seconds to warm-up. Canon's IH system reduced this to about 35 seconds. Thin-walled fixing rollers made from metal are however subject to rapid thermal changes and mechanical bending fatigue. By thoroughly examining heat and mechanical properties of the material and improving the roller-holding method and the anchor structure, Canon developed a fixing roller capable of producing up to 500,000 prints. To ensure stable temperature control, the company also developed a low-loss, high-frequency inverter power source for broad output control from 20 to 50 kHz.[19]

[19] www.canon.com/technology/canon_tech/explanation/ih.html (download 04-09-2007)

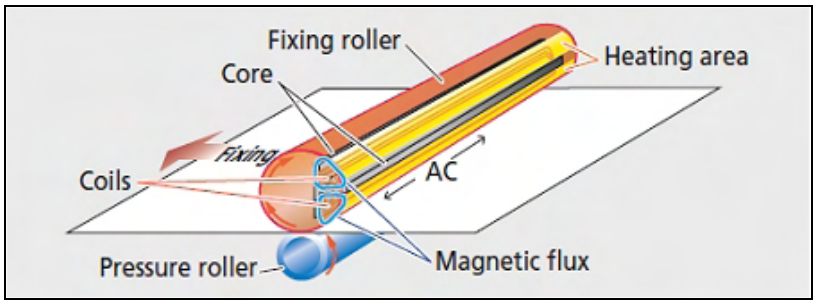
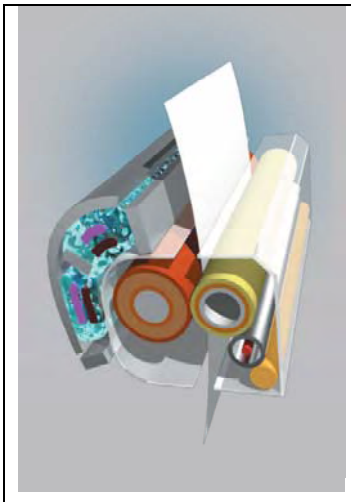
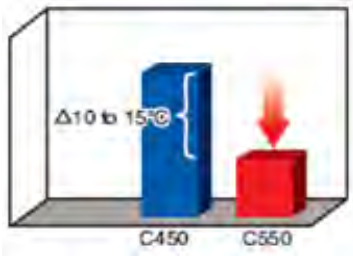


Figure 18: Canon IH Fixing System

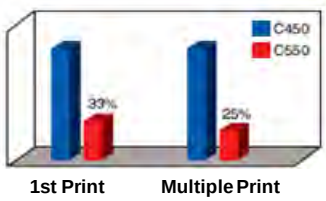
Konica Minolta: First introduced induction heating (IH) fuser technology in the MFP "bizhub600 / 750" in September 2005. This product requires less warm-up time and substantially cuts energy consumption; it features a small-diameter fuser roller with small heat capacity, and a polymerized toner (digital toner) that fuses at lower temperature than conventional toners. The bizhubC550, a digital full-colour MFP that was released in February 2007, employs induction-heating (IH) fuser technology, thereby cutting down the machine's warm-up time. As a result it achieved 40% reduction over its predecessor bizhub C450 (2005). The benefits of this technology are summarized by Konica Minolta:

- Lowering the power capacity during start-up and shortening the warm-up time (less power)
- Even and constant heating
- Compact size helps to downsize the complete device
- CPP reduction, as coil unit corresponds to machine life – no exchange.
- New Blue Angel Mark compliancy (Resumption Time from Sleep mode)
  - Requirement New BAM for 55 ppm in 57.5 sec → bizhubC550: 30 sec.
- New Energy Star Standard compliancy (implemented in April 2007)
  - Requirement 21.4 kWh/week → bishubC550: less than 8.0 kWh/week





Temperature required to achieve same Fusing ability as the C450 could be reduced by 10 - 15°C.



Power consumption could be reduced enormously:
66% reduction for 1st print
75% red. for continuous print

Figure 19: Konica Minolta Inductive Heat Fusing Unit

Panasonic: Panasonic developed a similar technology by 2005. The colour multifunctional product "WORKiO" DP-CL22 / DP-CL18 employs a patented induction heating (IH) technology along with a low thermal capacity heater belt, has eliminated the need for pre-heating (see also Chapter 6.2.1.5).

6.2.1.5. Belt Fixing Technologies

Canon: The iR C4580i and iR C4080i are also energy-efficient and have low warm-up times due to Canon's newly developed Twin Belt Fuser (TBF) toner fusing system, which works in conjunction with the highly efficient Induction Heating (IH) coil to provide fast and energy-efficient fusing. The fixing system utilizes a fixing belt that heats toner from the front side of the paper, and a pressure belt that applies pressure to the paper from the back. Unlike the rollers found in conventional systems, the belts expand the area on which pressure is applied from a line to a plane, enabling significantly improved fixing stability during high-speed output. The most significant feature is the heating of the fixing belt from the outer side (the side that comes into contact with the paper) using an IH heating coil. Also, since the fixing belt is made of a low-thermal-capacity material, the system achieves approximately 20% greater thermal efficiency than conventional systems while consuming less power.[20]

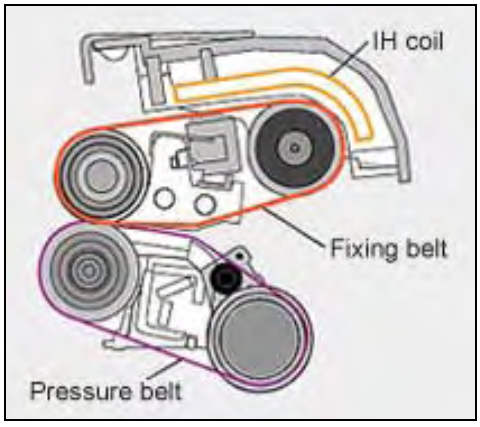


Figure 20: Canon's twin fixing belt system

Panasonic: Panasonic developed a similar technology by 2005. The colour multifunctional product "WORKiO" DP-CL22 / DP-CL18 employs a patented induction heating (IH) technology along with a low thermal capacity heater belt, has eliminated the need for pre-heating. In conventional high-speed heat-up fusers having a low heat capacity, an undesirable excess temperature rise occurs at both ends of a fuser roller when smaller format size paper is being continuously printed. In the newly developed IH fuser, magnetic shield plates using induction-heating principles suppress this excess temperature rise. The DP-CL22 using the newly developed IH-BELT fuser reaches a

[20] www.canon.com/technology/canon_tech/explanation/twin.html (download 04-09-2007)

warmed-up state within 15 seconds and without excess heat-up seen at both roller ends. Thanks to Panasonic's IH Technology, the DP-CL22 / CL18 warms up faster and prints from sleep mode utilizing only 8 W (DP-CL18) or 15 W (DP-CL22) of power.[21]

Ricoh: developed in 2006 a colour QSU technology (quick start up), which adopts the IH fusing system and achieved a reduction in recovery time from energy-saving mode for colour copiers[22].

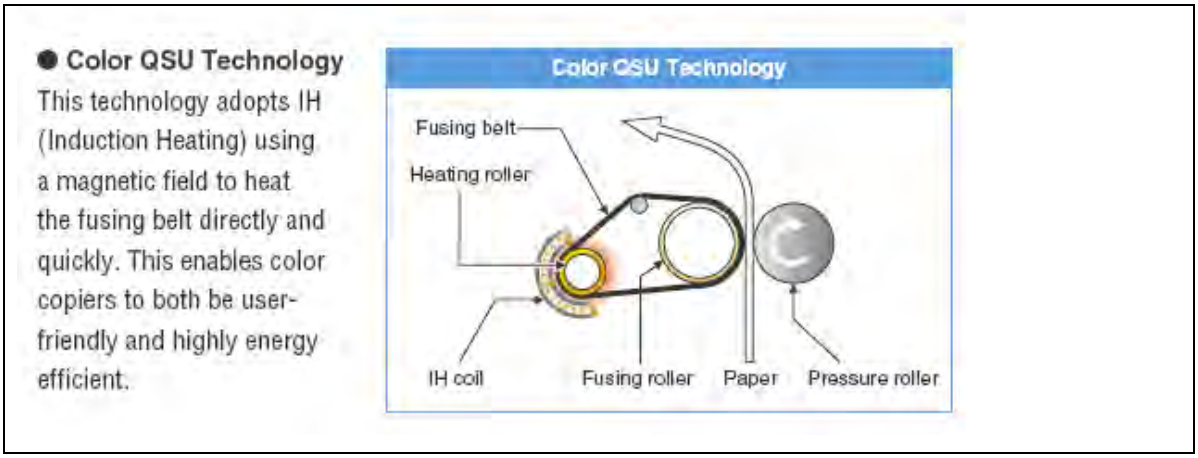


Figure 21: Ricoh colour QSU technology

Ricoh's digital multifunctional colour copier, imagio MP C3500 series, launched in May 2006 uses the new Color QSU technology. This new technology adopts the IH fusing system to warm up the fixation belt, shortening significantly the recovery time from energy-saving mode. Recovery time for imagio MP C3500 series was cut by 75% over the previous series to less than 18 seconds. Gross energy consumption was also cut back by approximately 50%.[23]

Fuji Xerox: The free belt nip fusing (FBNF) technology is applied in many Fuji Xerox products and is continuing to evolve. Different from traditional method of fixing toner on paper by adding pressure from rolls on and under the paper, this scheme increases heat conduction efficiency considerably and shortens fixation time, by changing the lower roll to a belt and widening contact area of the roll. From a technical point of view, a highly efficient heat lamp has been applied to improve heat efficiency. In addition, heat distribution has been evened during warm-up, stand-by, and paper-feed modes by setting the lamp at an optimum location, resulting in lower power consumption. Furthermore, a material with a low friction coefficient was newly developed and used as the sliding material in the fusing belt to stretch the life span of the part and reduce power consumed by the drive motor. This greatly curtails warm-up time from standby point (Sleep Mode),

[21] www.panasonic.com/Business/office/otc_inn_iht.asp (download 04-09-2007)
[22] http://www.ricoh.com/environment/report/pdf2007/all.pdf (download 10-09-2007)
[23] A reference figure to compare the performance of the new imagio MP C3500SP with the previous imagio Neo C355 Model 75 used the revised Energy Star TEC Measuring Procedure from April 2007.

thus realizing energy saving and miniaturization of the fuser unit. In addition to that, by optimizing temperature distribution, further speed-up and energy saving is realized at the same time.

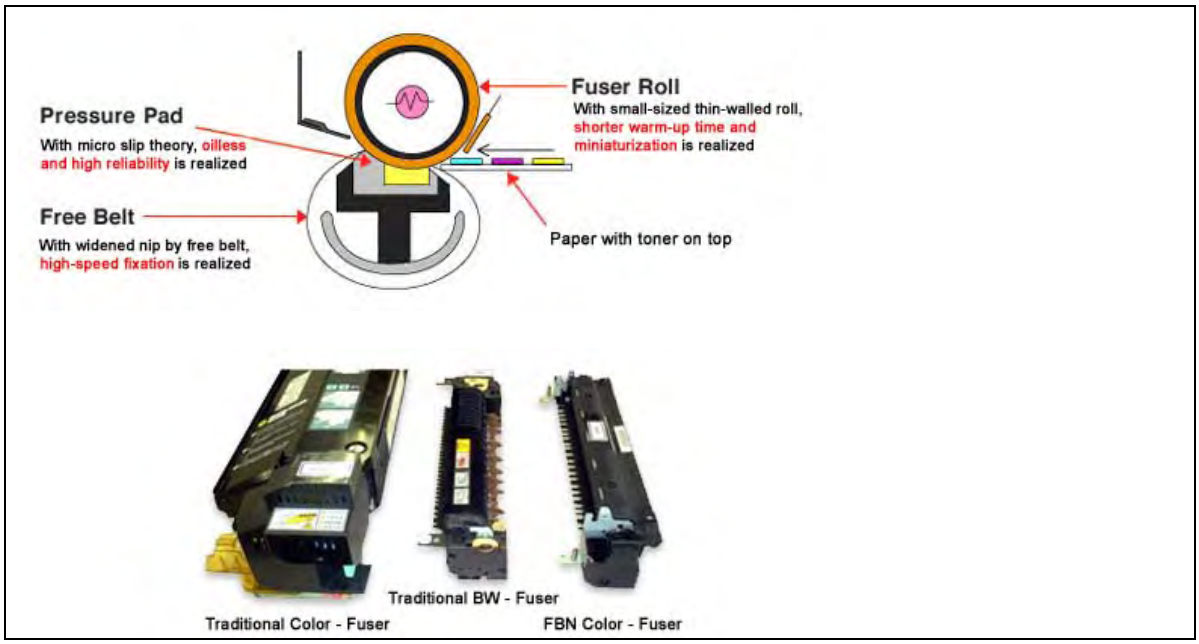


Figure 22: Fuji Xerox free belt nip fusing technology

Fuji Xerox's ApeosPort C7550 I (50ipm, A4 long-edge feed), a multifunctional colour device that applies the high-speed free belt nip fusing technology, requires only one-fourth the warm-up time that is required by DocuCentre C500 (12.5 colour copies per minute – A4 long-edge feed, a device that uses the traditional fusing technology.[24]

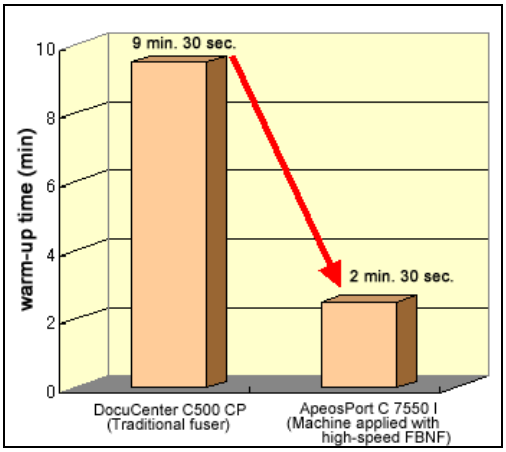


Figure 23: Fuji Xerox free belt nip fuser technology shorter warm-up time

[24] http://www.fujixerox.co.jp/eng/company/technical/fbnf/index.html (download 04-09-2007)

Fuji Xerox's 2006 DocuPrint C3050 colour laser printer (8 ipm colour, 35 ipm monochrome) adopts its own free belt nip fuser technology and employs a new low-power-consumption controller to achieve power consumption of just 3.2 kWh per week[25]. That is a 71% reduction compared to the earlier Fuji Xerox DocuPrint C830, and a warm up time of less than 30 seconds, a reduction of 91%. In addition, power consumption while in sleep mode is reduced by 80%, to less than 4 W.

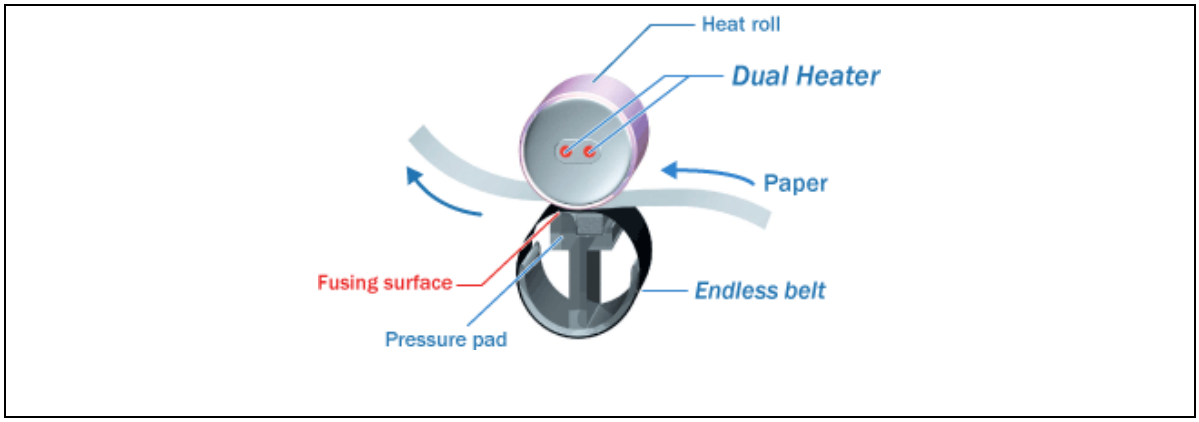


Figure 24: Fuji Xerox FBNF dual heater technology

In addition, the DocuPrint C3050 employs an effective waste heat dissipating structure based on thorough heat flow analysis to arrange the units and place thermal reflecting plates and screens around heat sources in a way that maximizes natural convection currents. This allows the DocuPrint C3050 to be the first A3-capable colour printer that realizes a fan-less airflow structure. This device does not require a fan motor, thus reducing power consumption by approximately 15 W compared to earlier models and virtually eliminating all sound when the printer is in standby mode, making the environment where it is installed more comfortable.[26]

[25] Measured using the Typical Electricity Consumption (TEC). The standard value for a colour printer capable of printing 35 ipm is 9 kWh/week.
[26] http://www.fujixerox.co.jp/eng/headline/2007/0201_ene_save.html (download 04-09-2007)

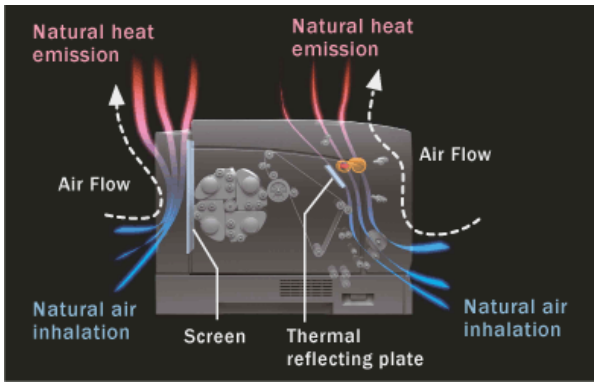


Figure 25: Fuji Xerox fan-less airflow structure

Fuji Xerox also features a Roll-in-Roll fixing system in combination with a twin heater fuser. This system was introduced at the EcoDesign 2003 in Japan (Conference Proceeding p. 809-816).

6.2.1.6. Conclusions

There are many different proprietary fast fuser technologies in the market which by shorting the warm-up time as low as 35 seconds from off-mode and 10 seconds from sleep-mode also reduce power consumption. Energy is saved due to the fact that products with fast fuser technology do not need a prolonged heating in ready-mode. These systems are mostly applied to low and medium speed EP-products up to 50 ipm. Some of the technologies are quite mature such as the ceramic heater / fixing film systems from Canon and HP which are in the market since the 1990th. Multiple Heaters and Induction Heating (IH) systems are more recent technologies that have been introduced in the early years of this decade.

On the up-side of the fast fuser technologies, the required thermal energy is faster distributed to the thinner fuser roller which saves time and energy. On the down-side, a conventional (thick) fuser roller is keeping large amounts of thermal energy over a longer period of time (up to 5 minutes) whereas the fast (thin) fuser rollers keep the thermal energy only a short period of time (<1 minute). Against that background a design for energy efficiency improvements should take a system approach. Furthermore, the thin rollers may by more prone to physical stress factors. This behaviour could cause shorter lifetimes and reliability problems particular in extensive use. According to industry sources the reliability of the system seems to be in the focus of current research. The improvements achieved of the past years in the low and medium speed segments seem to manifest maturity in the fast fixing technologies.

Precise information on totally new fuser/fixing technologies at prototype or research level could not be obtained. But there are indications that industry is working on so called non-contact (non-touch) fuser/fixing systems which are developed in conjunction with new (possibly light-sensitive) toners. The dissolving of printed images and re-writing of printed paper is also an issue of ongoing research.

6.2.2. Low Temperature Toner

6.2.2.1. EPSON AcuBrite™ Toner

EPSON AcuBrite™ is a wax based toner that improves the transfer efficiency of toner to the paper. This is possible because the new toner particles are semi-spherical and have uniform electrostatic properties. A special resin ensures that the distributed wax melts easily during the fusion process. According to Epson is the AcuBrite™ toner production processes more energy-efficient that for conventional pulverized toners.[27]

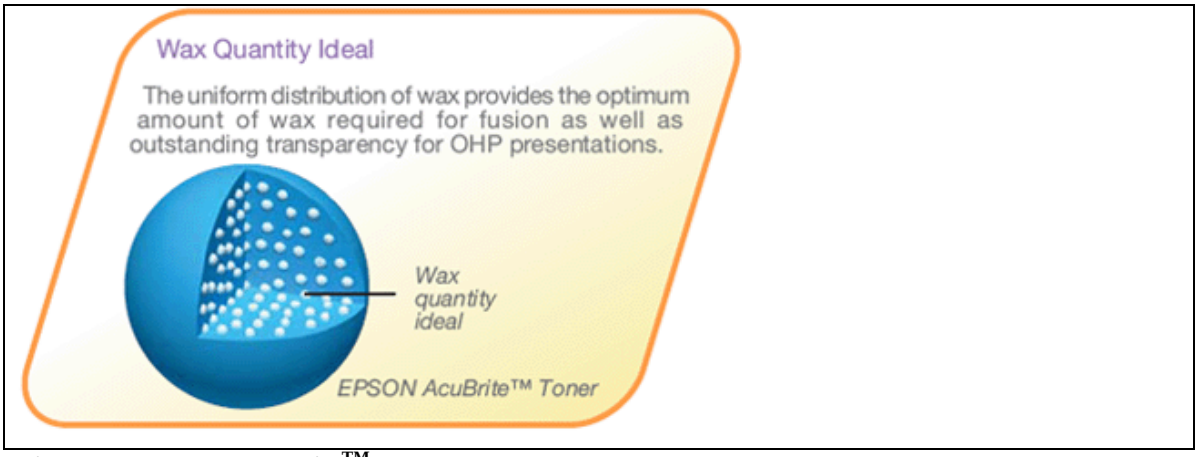


Figure 26: EPSON AcuBrite™ Toner

6.2.2.2. Xerox Emulsion Aggregate Toner

The conventional method of making toners is based on a mechanical process that uses a top-down approach of physically grinding composite polymeric materials to micron-sized particles. The 2002 development of an Emulsion Aggregate technology (EA) utilizes sophisticated chemical design and control based nanotechnology methodology to generate micron-sized particles in a bottoms-up approach from nanoscale components. Key advantages of EA technology are the ability to control the size, shape, and structure of the particles, leading to improved print quality, less toner usage, less toner waste and lower energy usage for manufacturing toner and using it in printing. This new

[27] www.epson.co.id/innovations/technology_acubrite.shtml (download 06-09-2007)

technology enables production of toner using 25-35 percent less energy/lb of toner. Combined with 40-50 percent less toner needed during printing, EA technology offers an estimated 60-70 percent energy saving per printed page. EA technology produces less waste and enables longer life machine parts. EA is a water based and therefore an environmentally friendly process. By eliminating fuser oil, EA technology conserves resources while improving customer satisfaction by eliminating potential service calls for oil streaks. EA toner reduces the amount of energy associated with printing in other ways. The greater latitude in resin design enables image fixing capability at lower temperatures, thus further reducing per-page product energy consumption. EA enables the use of lower melt resins since brittle materials are not required in the fabrication process. This translates into less energy to print since the temperature of the fusing subsystem can be reduced.

Xerox first introduced this new technology in 2002 in its DocuColor 1632/2240 colour copier/printers. As of early 2006, other Xerox products using EA include the Xerox CopyCentre C2128/C2636/C3545 copiers and WorkCentre Pro 2128/2636/3545 multifunction systems.[28]

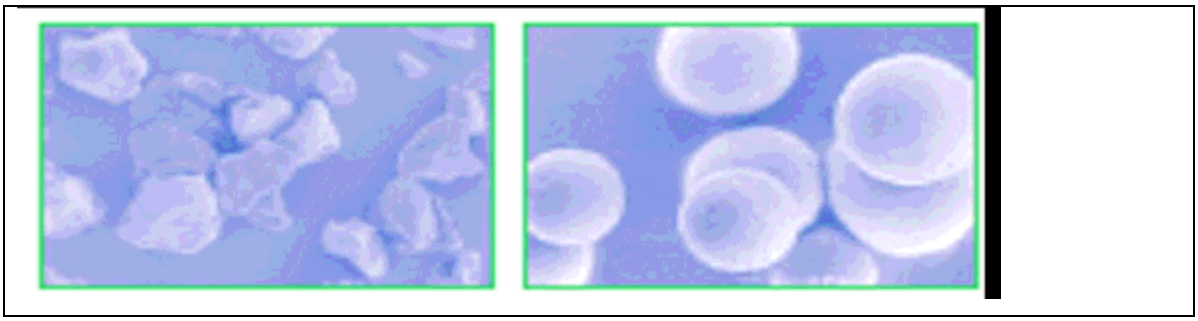


Figure 27: Microscopic views show conventional toner (left) and chemically grown EA toner

For “Super low melt and ultra low melt toners containing crystalline sulfonated polyester” see patent description at FreshPatents.com.[29]

6.2.2.3. Konica Minolta Simitri™ Toner

Simitri™ and Simitri HD polymer toner have a low melting point, which also saves energy and helps to prevent paper jams. Compared to conventional toner, the polymerization toner realizes clearer prints of enhanced contours because its particle is fine and uniform in a form.[30] Compared to the conventional pulverized toners, manufacturing of Simitri HD toner requires less energy, and

[28] www.xerox.com/innovation/Xerox_ea_toner.pdf (download 06-09-2007)
[29] http://www.freshpatents.com/Super-low-melt-and-ultra-low-melt-toners-containing-crystalline-sulfonated-polyester-dt20060720ptan20060160010.php?type=description (download 06-09-2007)
[30] konicaminolta.si/aktualno/marketing/MN02_2005LR_1.pdf (download 06-09-2007)

contributes to environmental preservation, reducing by 40%, the generation of CO_2, NO_x or SO_x that cause greenhouse gases, and acid rain.[31]

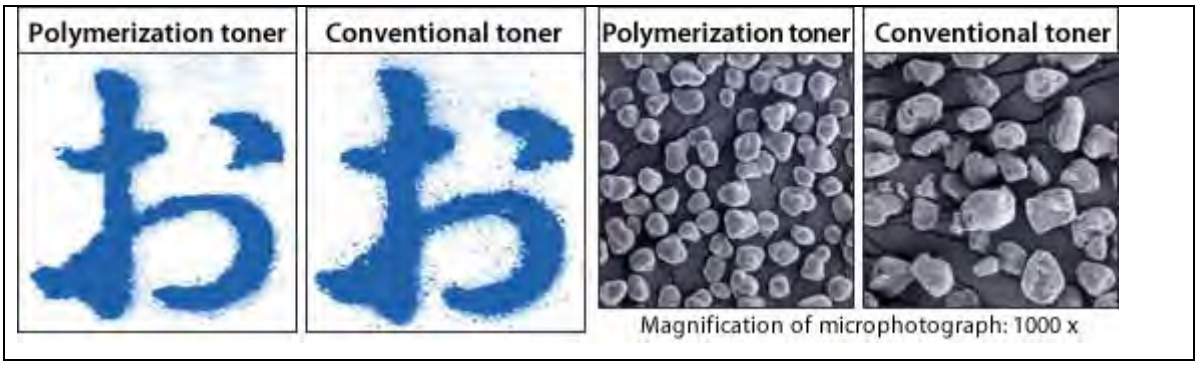


Figure 28: printouts and microscopic views of polymerization toner and conventional toner

6.2.2.4. Canon Quick Fixing Toner

QF (Quick Fixing) toner improves heat-melting performance for fusing and is suitable for on-demand fusing. It fuses quickly at a low temperature. QF toner maximizes the performance of the On-demand fixing systems which achieves high quality output under low pressure and less heat energy with low electrical consumption. It contributes the usability using quick-starting system and also to save power consumption.[32]

6.2.2.5. Ricoh Plant-based Toner

Ricoh was the first manufacturer which applied plant-based plastics containing resin made from corn (more than 50%) for housing material in a copier/MFD. Noticing the fact that more than 80% of the components of the toner supplied to copiers and printers are petroleum-based resins, Ricoh began developing a plant-based toner as well and succeeded in developing a toner containing about 40% of plant-based elements by using a newly-developed polyester resin made from corn and other materials.[33] According to the latest Ricoh Environmental Report 2007, the fixation temperature for this plant-based toner is the same as that for traditional energy-saving fixation type toner. The new toner satisfies similar high standards for heat resistance and picture quality as traditional toner. The remaining issue is cost, and compared with traditional products, the new toner is currently 20 to 30% more expensive. Ricoh aims to establish a mass production system within two years to achieve cost reductions and to put this plant-based toner into practical application. According to

[31] http://www.konicaminolta.eu/printing-solutions/products/technology/simitri-hd-toner/environmentally-friendly.html (download 06-09-2007)
[32] http://www.usa.canon.com/consumables/qf-toner.html (download 06-09-2007)
[33] http://www.ricoh.com/environment/report/pdf2007/all.pdf (download 11-09-2007)

Ricoh's Environmental Report, the world production of toner reaches 185,000 tons annually.[34] If this amount of conventional toner is replaced by plant-based toner, the CO_2 emission could be reduced by approximately 120,000 tons according to Shinya Nakayama and Akihiro Kotsugai from the Ricoh Functional Materials Development Center.

[34] "Worldwide toner production in 2005" researched by Data Supply Inc.

6.2.3. Innovative Inks

Soy ink: Soy ink uses a soy oil base and it has very low levels of VOCs. Petroleum-based inks contain 30-35% VOCs, while soybean oil-based inks typically range from only 0-5% VOCs. In addition, soy ink is recycling-friendly: it is removed more effectively during de-inking, and the resulting waste is not considered hazardous and can be treated more easily, completely and cost-effectively[35].

Development of soy ink began in the late 1970s by the Newspaper Association of America, who sought a different way to make ink because of rising oil prices. Today, soy ink is used in many offset printing presses and newspapers[36].

Gel ink: In August 2006, Launier, subsidiary of Ricoh, launched three printers with exclusive gel ink technology. These GelSprinter™ printers aim to combine the best qualities of inkjet and laser systems to deliver high-quality colour at a very affordable price. Specifically, GelSprinter technology involves pigment-based inks suspended in a viscous gel that bonds with the page like toner and allows the ink to "sit up" on the page. The formulation also minimizes dot spreading, sharpens colour images, prevents bleed-through, and dries immediately on contact with air to eliminate smudging. In addition, GelSprinter technology utilizes a belt-driven feeding mechanism that reduces curling and helps prevent misfeeds. The printers also feature piezo-electric printheads that can print two lines simultaneously and never need to be replaced. With these advances, Lanier GelSprinter printers, according to the manufacturer, “solve all of the maintenance and image quality issues typically associated with inkjet printers”.[37]

[35] (http://www.recycledproducts.com/?cid=25)
[36] Unfortunately not many sources to the use of soy ink could be founded, but soy ink seems not to be used in small printers.
37 http://www.therecycler.com/viewarticle.asp?article=787, http://www.lanier.com/page.php/gelsprinter, http://www.lanier.com/pdf/gx3000-3050n-5050n-final.pdf

6.2.4. New Materials for Housing

6.2.4.1. Canon: Polyester produced by Microorganisms (PHA)

Canon is investigating environment-conscious functional materials according to their current environmental report [38]. One example includes technology that enhances the functionality of polyester produced by microorganisms. Canon has discovered microorganisms capable of producing Polyhydroxyalkanoates or PHA[39], identifying four such microorganism types to date. These microorganisms are capable of efficiently synthesizing PHAs with completely new structures. By employing techniques involving the direct and indirect introduction of functional groups, Canon is exploring ways to apply PHA to piezoelectric materials. The company has also established culturing techniques that enable the efficient incorporation of PHA raw material compounds into microorganisms – a significant step toward establishing volume production technologies toward commercialization.

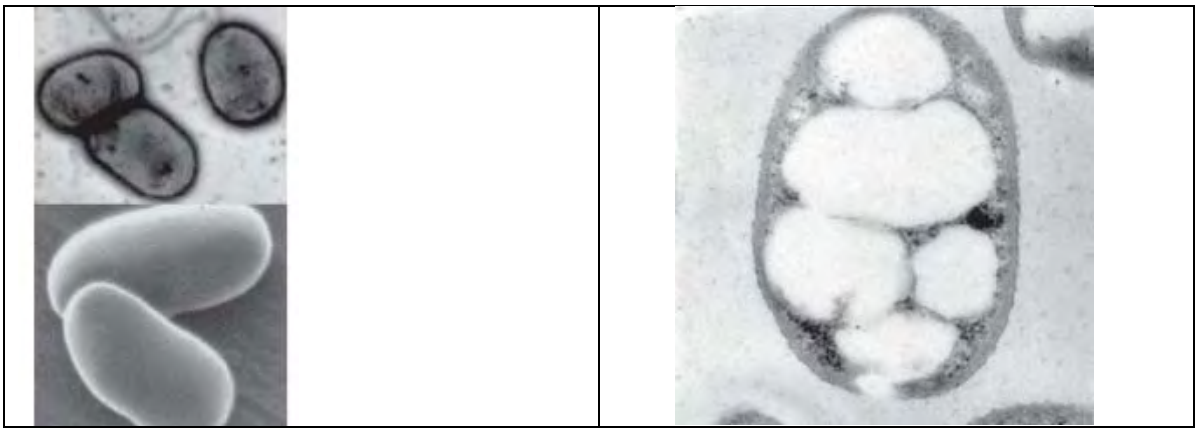


Figure 29: Left: PHA produced microorganism and right: polyester synthesized inside a microorganism

Canon is also examining the application of plastics derived from plants. By replacing conventional petroleum-derived plastics with plant-based plastics, not only for the product bodies but also for the electrical wiring and related units, Canon aims to reduce annual CO_2 emissions by 10,000 tons in 2010. Similar statements were given to the authors of the report by various Japanese companies such as Ricoh and Epson at the EcoProducts 2006 trade show in Tokyo, Japan. However, the environmental and economical feasibility has to be proven.

[38] www.canon.com/environment/technology/p02.html (download 07-09-2007)

[39] Polyhydroxyalkanoates or PHAs are linear polyesters produced in nature by bacterial fermentation of sugar or lipids. More than 100 different monomers can be combined within this family to give materials with extremely different properties (see publications of Y. Doi and A. Steinbüchel on microbial polyester and utilization of bio-polymers).

6.2.4.2. Ricoh: Corn Starch based Bio-Polymers for Housing

Ricoh promotes a strong environmental strategy for their products not only in the field of energy efficiency but also in the development of bulk materials that have less environmental impact. Ricoh launched their first bio-plastic-product (digital multifunctional copiers, imagio Neo 602ec/752ec) into the market in 2006 to spread the idea of renewable and biodegradable housings as quick as possible. Ricoh develops plastics for their products with plant-based (corn starch) percentage of 50%. While plant-based plastic reduces theoretically CO_2 emission, Ricoh is investigating technical properties such as flame retardancy and economical feasibility. The Ricoh Group, in collaboration with Mitsui Chemicals, Inc., has been working to solve these problems since 2002 to find ways to put this material into practical use. According to Ricoh Environmental Report, they have made many improvements to the material and repeated experimental production[40].

Figure 30: Ricoh promotion of plant based plastics in copier/MFDs

Interestingly Ricoh explains the reason for their quick launch of the bio-plastic featuring imagio Neo 602ec/752ec. New materials with a low market penetration rate have the serious disadvantage of entailing a high cost. However, when 10% of the total amount of plastic used in Japan is replaced with plant-based plastic in the near future, it is estimated that more than 700,000 tons of CO_2 will be reduced in a year. With the launch of the more manufacturers will know about plant-based plastic, which may facilitate the cross-industrial development of the material. This will accelerate technological innovation and cost reduction, thus raising the penetration rate of plant-based plastic. Ricoh will further improve such plastic and increase its use in more products.

6.2.4.3. HP: Corn Bio-Polymer Printer

HP developed a prototype desktop printer, where major plastic parts are made of corn starch based bio-polymers (Figure 31).

[40] www.ricoh.com/environment/activity/02/index.html (download 05-09-2007)

Figure 31: HP Corn Bio-Polymer Printer Prototype[41]

HP has also investigated the use of bioplastics made from polylactic acid. In 2001 HP developed a prototype printer that was made with a 100% bioplastic shell: „This award-winning printer illustrated some of the current limitations of bioplastics, including poor heat resistance and brittleness. Addressing these limitations, such as including the use of petroleum-based additives, negates most of the environmental advantages of the plastic.“[42]

Please note that an assessment of the eco-feasibility of bio-plastics is always necessary due to varying supply chain conditions and possible regional difference in plant growing (e.g. use of pesticides).

[41] organicARCHITECT announces 2004 Green Products Award Winners; San Francisco, CA: January 5th, 2005 http://www.organicarchitect.com/research/2004awards/img_winners/cornprinter_hp2.jpg
[42] HP 2006 Global Citizenship Report, p. 26, http://www.hp.com/hpinfo/globalcitizenship/gcreport/pdf/hp2006gcreport_lowres.pdf

6.2.5. Design for Recycling

State of the art in Design for Recycling is demonstrated by the criteria of labels, the most relevant ones for imaging equipment being the Blue Angel.

The label criteria according to Blue Angel / RAL-UZ 122[43] comprise "must" requirements and "should" requirements. "Must" requirements – referring to product design aspects – are those listed in Table 9. Blue Angel labelled products are from Develop, Hewlett-Packard, Konica Minolta, Kyocera Mita, Samsung and Toshiba. Only **laser products** are listed, no inkjet devices.

Table 9: "Must" requirements of the Blue Angel label for Office Equipment with Printing Function

	Requirement	Applies to Module(s)	Explanation
A:	**Structure and Connection Technology**		
A.1	Components made of materials incompatible with each other are connected separably or via separation aids	Case parts, chassis, electric modules, toner modules	Important connections are those between case and chassis as well as those between chassis and electric modules. Their separability is a prerequisite for separate use/recycling of modules and materials as well as for a quick and save separation of pollutant-containing components. Adhesive labels (e.g. company logos and labels) are concerned as well. The term "separation aids" stands, for example, for predetermined breaking points.
A.2	Electric modules are easily traceable and removable	Entire unit, including lamps	Minimum recycling strategy means: removal of the pollutant freight. Electric modules and components according to Annex III, ElektroG (Electrical and Electronic Equipment Act)[44], as, for example, batteries and condensers involving the risk of pollutant-containing ingredients as well as mercury-containing fluorescent lamps must be easily traceable and separable.
A.4	Disassembly can be done with universal tools exclusively	Case, chassis, electric modules	The term „universal tool" stands for general commercial tools.
A.5	Necessary points of application and working space for disassembly tools have been taken into consideration	Case parts, chassis, electric modules	A point of application is the point from where the impact is transferred from tool to connecting element. Sufficient working space is needed for the execution of the tool's separating movement. This requirement particularly refers to snap connections which, unlike during assembly, often require tools to be disconnected.
A.7	Screwed connections between modules can be separated with no more than three tools	Case parts, chassis, electric modules	Standardized and uniform connection elements facilitate disassembly. The less tools must be changed the easier is assembly and disassembly. A tool is characterized by the type of drive (e.g. cross recession) and the drive size (spanner size).
A.9	Disassembly can be done by a single person	Entire unit	An optional number of snap connections of the same joining direction may be assembled at a time but not always be disassembled if the re-entrant angle is ≥ 90°. This requirement shall be considered not fulfilled if more than two connections must be separated at a time.

[43] RAL: Basic Criteria for Award of the Environmental Label, Office Equipment with Printing Function (Printers, Copiers, Multifunction Devices), RAL-ZU 122, Edition June 2006

[44] As Blue Angel is a German labelling scheme reference is to the German implementation of the European WEEE directive

A.11	Case parts are free from electronic modules	Case parts	With regard to a clean and quick pollutant removal and separation of the electronic parts all electric modules must be connected to the chassis. The case may not contain any electronic modules. Here, a control element attached to the case and case parts which simultaneously perform the functions of the chassis are not considered as case parts.
B:	**Selection and Marking of Materials**		
B.1	The variety of materials forming plastic components performing comparable functions are limited to one material	Case parts, chassis mechanical parts (≥ 25g)	The smaller the number of materials the more efficient are separation and recycling processes. This requirement shall not apply to parts that have been reused as can be proved.
B.3	The coating of plastic components has been limited to the minimum necessary	Case parts, toner and ink modules	Large-area layers of lacquer, vapour depositions and printings on plastic components require additional removal processes if recycling by the material is to be done thereafter. Reasons shall be given if metallic coatings are used. Laser-produced labelings shall not be considered as printings. This requirement shall not apply to parts case that have been reused, as can be proved.
B.4	The materials and material compounds used can be recycled by the material	Case parts, chassis, toner modules	This means that recyclate materials identical to the original material (original recycling) can be obtained.
B.7	Components and materials under Annex III to ElektroG (Electrical and Electronic Equipment Act) can be easily exchanged	Entire unit	
B.9	Plastic parts > 25 g according to EN/ISO 11469: considering ISO 1043 are marked	Entire unit	Plastics marking enables all recycling companies to do a type-specific sorting and separation of plastics
C:	**Longevity**		
C.1	At least 50% of the components of the device, except for standard parts, are identical in design to those in other devices of the same manufacturer and the same performance category and generation	Entire unit	
C.2	The use of reprocessed modules or components is possible and permissible	Entire unit	The manufacturer shall be prepared to use modules and components as spare parts or ETN-parts in the product, provided that they have been reprocessed under his guidance – (ETN-equivalent to new)
C.4	Toner or ink modules can be reprocessed	Toner and ink modules, except for containers	Reuse should not be prevented by constructive measures