Life Cycle Environmental Impact Comparison of Retail Photo Systems

HP Photosmart Minilabs and Microlabs vs. Silver Halide Systems

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September 2010

EXECUTIVE SUMMARY

Retail photofinishing systems provide retail stores with a means to offer photo printing services to their customers. Retail photofinishing systems convert customers' digital images to physical prints. Silver halide (AgX), or wet, technology has been the traditional method for providing retail photo processing services. Due to the nature of the technology, AgX systems consume significant chemicals, water, and energy. Over the past several years, dry photo processing technology alternatives, such as the HP Minilab solutions, have been introduced. HP systems are based on inkjet technology.

HP commissioned Four Elements Consulting, LLC to perform an environmental Life Cycle Assessment (LCA) to quantify the environmental impacts of HP systems compared to AgX systems.

The AgX and HP systems were compared for two distinct markets: North America (NA) and Europe. The systems compared include three HP systems—HP Photosmart ML 1000D Minilab, HP Photosmart ML2000D Minilab and HP Photosmart pm2000e Microlab—and 2 AgX systems for each region: Fuji Frontier 370 and Noritsu QSS-3502 for NA and Fuji Frontier 350 and Noritsu QSS-3212 for Europe.

Results summary

Overall, the HP retail photo systems studied performed better than the AgX systems studied on the set of environmental impacts measured. HP products performed better or on par with AgX processes on 11 of the 12 indicators measured. Key findings included:

- HP performed significantly better on two key measures: carbon footprint and total energy use.
    - HP systems' carbon footprint, or climate change impact, was up to 33% lower.
    - HP systems used up to 26% less total energy over the lifetime of the products.
- HP also performed significantly better or on par with AgX processing on a broad set of measures of water, air and land pollution.
- Overall water use is equivalent. Total water use for both technologies is driven primarily by photo paper manufacturing—a water intensive process.
- During operation, AgX photo printing processes require an external water source and produce water effluent. Printing photos with HP retail photo printers uses no external water and produces no effluent. As a result, the impact on local water supplies is lower for the HP printing process. This is reflected in a difference in process waste water.
- The key driver of lower climate change, pollution measures and total energy is the lower electricity use overall for HP systems compared to AgX systems. The HP systems used about three times less electricity than the AgX systems. See Appendix 3 for the electricity use measurement methodology.

Table 1 Overall Results—HP vs AgX systems

Environmental Impact	**HP compared to NA AgX**	**HP compared to Europe AgX**
Climate change "Carbon Footprint", greenhouse gas emissions	Up to 30% less	Up to 33% less
Ozone depletion Ozone depleting gases	Equivalent for ML1000D and ML2000D Up to14% greater for pm2000e	Up to 26% less
Human toxicity	Up to 31% less	Equivalent
Photochemical oxidant formation Smog forming gases	Equivalent	Up to 16% less
Particulate matter formation Particles in the air due to use of fuels	Up to 32% less	Up to 16% less
Terrestrial acidification Acid rain	Up to 41% less	Equivalent
Freshwater eutrophication Nutrients released with potential species shift in freshwater bodies	Equivalent	Up to 18% less
Terrestrial ecotoxicity Potential for damage to ecosystems on land	Up to 27% less	Up to 12 % less
Freshwater ecotoxicity Potential for damage to ecosystems in freshwater bodies	Up to 63% less	Up to 23% less
Total water use	Equivalent	Equivalent
Fossil fuel depletion	Up to 19% less	Up to 18% less
Total energy Energy from all sources to print photos and produce and transport all upstream materials. Includes 'embedded energy'.	Up to 17% less	Up to 26% less

The differences between NA and Europe in some of the toxicity measures are due to differences between wastewater treatment conventions in the two regions. European effluent management regulations are more stringent, resulting in a lower environmental impact for any waste effluent.

See Appendix 1 for more detail on results.

Methodology

The study was conducted in strict accordance with the International Standards Organization (ISO) guidelines for conducting LCA. The analysis covered the resources necessary in each technology to convert a digital image source to a physical print and evaluated a broad and comprehensive spectrum of environmental indicators.[1] Typical usage trends, materials consumption, processing techniques, and waste management practices specific to each geographic region were assessed, and detailed data collection for the systems in each region was performed. HP supplied the data for the HP systems, and [F/22] Consulting, Inc. and CCDS communication & design GmbH provided data for the AgX systems in NA and Europe, respectively. CCDS provided electricity use measurements for both HP and AgX systems.

This LCA adheres to ISO principles and framework in ISO 14040 as well as the guidelines specified in ISO 14044.[2] LCA is a tool for the systematic evaluation of the environmental impacts of a product through all stages of its life cycle, which include extraction of raw materials, manufacturing, transport and use of products, and end-of-life management—recycling, reuse or disposal. The study has undergone an external peer review process to ensure the credibility and objectivity of the data and results as well as conformance with ISO standards on LCA. See Appendix 8 for peer review letter.

The systems selected for the study were:

		4x6 photos printed/hour[3]
HP systems, NA & Europe	HP Photosmart ML1000D Minilab Printer (ML1000D)	1500
	HP Photosmart ML2000D Minilab Printer (ML2000D)	1500
	HP Photosmart pm2000e Microlab Printer (pm2000e)	720
AgX systems, NA	Fuji Frontier 370 (Fuji 370)	1450
	Noritsu QSS-3502 (Noritsu 3502)	1010
AgX systems, Europe	Fuji Frontier 350 (Fuji 350)	1050
	Noritsu QSS-3212 (Noritsu 3212)	1150

[1] ReCiPe was created by the RIVM, CML, PRé Consultants, Radboud Universiteit Nijmegen, and CE Delft. It was first made available in Fall, 2009. Please see www.pre.nl for more information.
[2] ISO 14040:2006, the International Standard of the International Standardization Organization, Environmental management. Life cycle assessment. Principles and framework. ISO 14044:2006, Environmental management – Life cycle assessment – Requirements and guidelines.
[3] HP speeds from www. hp.com/go/RPS, Fuji speeds from http://home.fujifilm.com Noritsu speeds from http://www.noritsu.co.jp/english

The AgX products selected for comparison are believed to comprise the majority of the installed base in each region, based on primary and secondary research data.[4]

The systems evaluated in this study are comparable. They produce photos of comparable quality in terms of color gamut, longevity and consistency. And, the output speeds for all systems meet the study's daily print assumption. The study took into account differences in output speed and expected service life.

Detailed quantitative and qualitative primary data for the use phase of AgX systems was provided by two firms with specific expertise in the industry: [F/22] Consulting, Inc. in NA and CCDS in Europe. (See Appendix 5 for credentials.) The firms collected data by observing and measuring processes in retail environments and based on their historic experience with the industry. Primary data for HP Minilab processes were based on interviews with HP engineers and suppliers and HP internal data. Some publicly available data were used but data points were checked for sensitivity. All data sources used in the study were evaluated for temporal, geographical, and technological coverage. Data available from LCA software databases were evaluated and the best data available at the time of the study were used. Data from the EcoInvent, U.S. LCI, and SimaPro databases were used. Energy use calculations were based the Cumulative Energy Demand methodology.[5] Electricity use was measured using CCDS methodology.

Sensitivity analyses were done to test the robustness of key assumptions. In all cases, the sensitivity analyses did not change the overall direction of the result.

Typical operating life assumptions are based on information from Photographic Consultants, Ltd for NA and FutureSource and Photographic Consultants, Ltd for Europe.

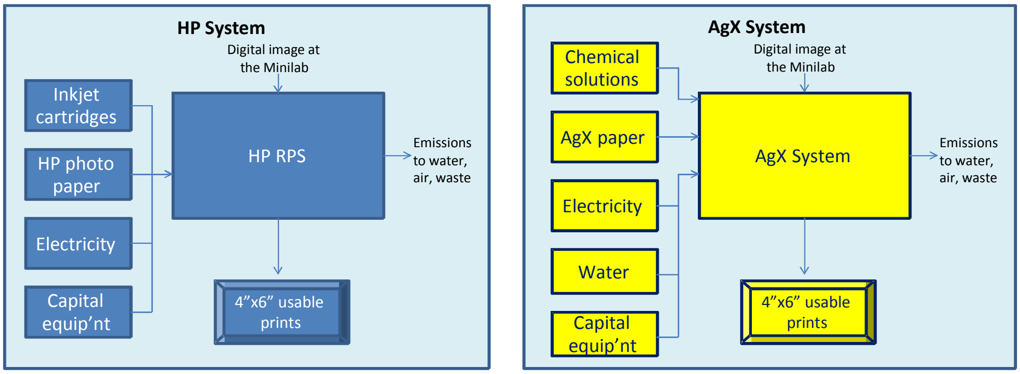
For NA, an average daily print volume of 1250 4x6 prints per day, 450,000 per year, was assumed, based on comparing analyses from two consultants: [F/22] Consulting, Inc. and Photographic Consultants, Ltd. For Europe, 1250 4x6 prints per day, 375,000 per year were assumed, based on comparing input from FutureSource, Photographic Consultants, Ltd. and HP internal data. See Appendix 7 for calculations. Because of typical operating life assumptions, the number of machines included in the capital equipment analysis is two for pm2000e compared to a single machine for ML1000D & ML 2000D.

For further detail on data sources, see Appendix 4.

[4] Market sizing and installed base assumptions for both technologies for NA were based on data from Photofinishing News International Consulting Group, September 2009, along with information from [F/22] Consulting, Inc. Information for the European market is based on a survey of 74 German photo retailers conducted in November 2009 and HP internal data.
[5] CED is based on EcoInvent version 2.0 and has been expanded to include elements from the SimaPro database. See www.pre.nl and www.ecoinvent.org for more information.

The process studied begins with the delivery of a digital image source (i.e., not physical film) to the Minilab printer or photo developer and ends with the photos ready to be picked up by the customer. It is assumed that the upstream and downstream steps are identical for each alternative. The figure below presents the overall system boundaries.

Figure 2 Overall Study System



All consumables in the use phase for both technologies were modeled and included in the analysis. The photofinishing use phase has been determined to drive the overall environmental performance of photo prints,[6] but full life cycle aspects were modeled or evaluated as possibilities for inclusion/exclusion from the system. For all inputs, extraction of raw materials, all resources and materials in the manufacturing process, packaging and average transportation from the manufacturer to retailers and end of life disposition was included. Energy use from all sources for extraction, manufacturing and transportation of inputs and the printing process itself was also included.

The scope and boundaries excluded impacts for human activities, such as employee travel to and from work. Both HP and AgX systems use PCs as input devices and in both cases the options for input equipment set-ups are numerous. As a result, input devices were not considered in the analysis.

The inputs included are:

- Print media/photo paper, including trim waste and other scrap
- Printing consumables, i.e. HP inkjet cartridges and AgX chemicals
- Water consumption, for photo development and for system maintenance
- Photo effluent solution and other water effluents
- Electricity consumption
- Maintenance
- AgX photographic process control strips
- Long-life consumables, parts that are replaced over the life of the machines
- Capital equipment, all system hardware

At least 99.5% of inputs, based on mass, were covered in the analysis. See Appendix 6 for more detail on inputs.

[6] "Life Cycle Assessment of Film and Digital Imaging Product System Scenarios", Georgia Institute of Technology, Eastman Kodak Company, 2006 International Conference on Life Cycle Engineering.

APPENDIX 1—DETAILED RESULTS

The results tables and charts are presented below. Impact categories are treated as distinct and independent from one another. Results within 10% (+/-) can be considered "equivalent".

Table 2 Overall Results: NA (per 1000 4x6 prints)

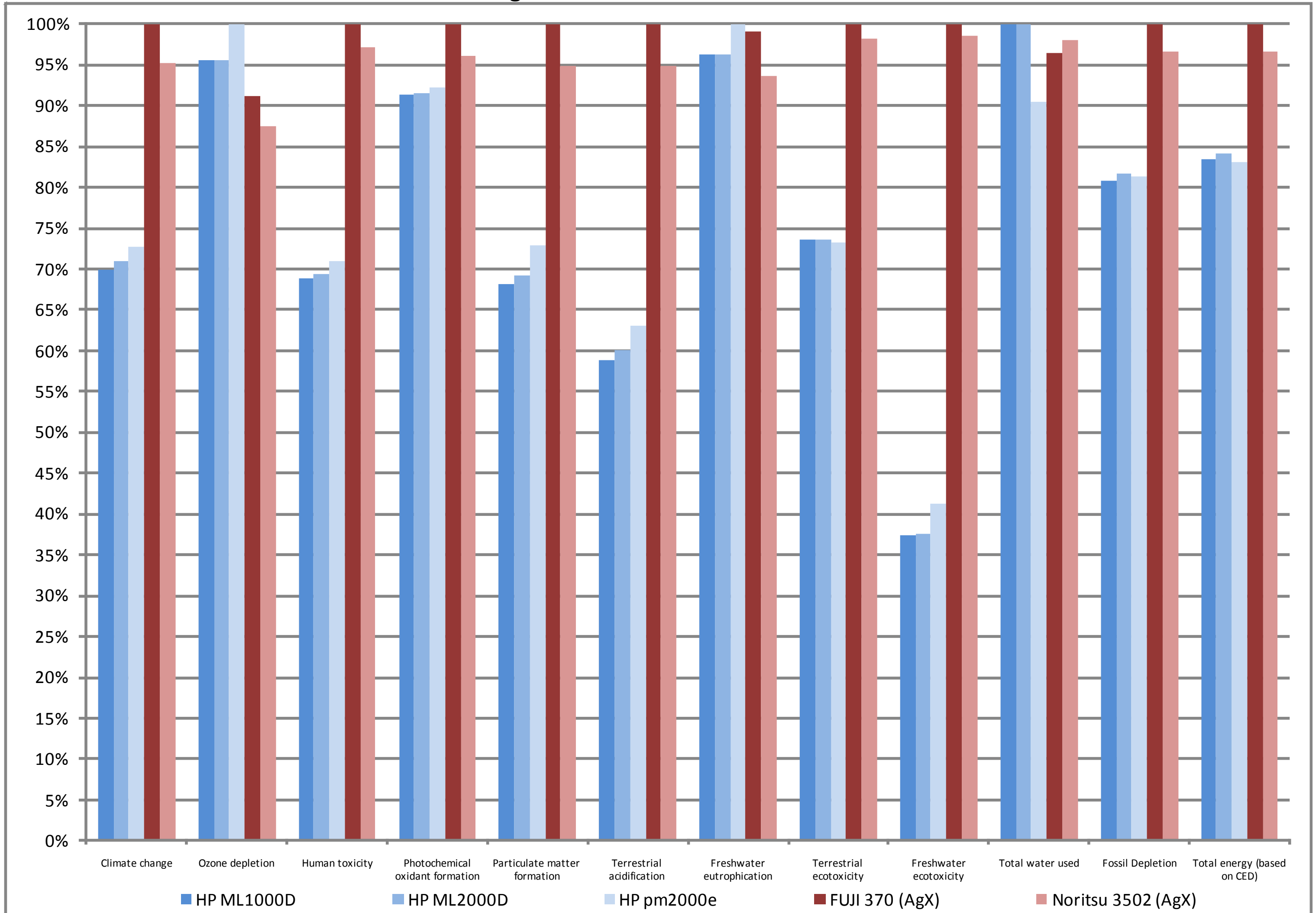
Impact category	Unit	ML1000D	ML2000D	pm2000e	Fuji 370	Noritsu 3502
Climate change	kg CO2 eq - kilograms of carbon dioxide equivalents	17.674	17.960	18.384	25.301	24.108
Ozone depletion	kg CFC-11 eq - kg of trichlorofluoromethane equivalents	9.5 E-07	9.5 E-07	9.9 E-07	9.0 E-07	8.7 E-07
Human toxicity	kg 1,4-DB eq - 1,4 dichlorobenzene	2.5	2.6	2.6	3.7	3.6
Photochemical oxidant formation	kg NMVOC - non-methane volatile organic compounds	0.05	0.05	0.05	0.06	0.05
Particulate matter formation	Kg PM10-eq - particulate matter size </ 10 micrometers	0.03	0.03	0.03	0.04	0.04
Terrestrial acidification	kg SO2 eq - sulfur dioxide	0.08	0.08	0.09	0.14	0.13
Freshwater eutrophication	kg P eq - phosphorus	4.1 E-04	4.1 E-04	4.2 E-04	4.2 E-04	4.0 E-04
Terrestrial ecotoxicity	kg 1,4-DB eq - see above	0.002	0.002	0.002	0.003	0.003
Freshwater ecotoxicity	kg 1,4-DB eq - see above	0.04	0.04	0.04	0.11	0.10
Total water used	Liters	332	332	301	320	326
Fossil Depletion	kg oil equivalents	6.7	6.8	6.7	8.3	8.0
Total energy (based on CED)	MJ - Megajoule	471	475	469	564	545

Table 3 Overall Percentage Results: NA (per 1000 4x6 prints)

Impact category	ML1000D as % of Fuji 370	ML1000D as % of Noritsu 3502	ML2000D as % of Fuji 370	ML2000D as % of Noritsu 3502	pm2000e as % of Fuji 370	pm2000e as % of Noritsu 3502	HP vs. AgX overall
Climate change	70%	73%	71%	74%	73%	76%	Up to 30% less
Ozone depletion	105%	109%	105%	109%	110%	114%	Equivalent for minilab
Human toxicity	69%	71%	69%	71%	71%	73%	Up to 31% less
Photochemical oxidant formation	91%	95%	92%	95%	92%	96%	Equivalent
Particulate matter formation	68%	72%	69%	73%	73%	77%	Up to 32% less
Terrestrial acidification	59%	62%	60%	63%	63%	67%	Up to 41% less
Freshwater eutrophication	97%	103%	97%	103%	101%	107%	Equivalent
Terrestrial ecotoxicity	74%	75%	74%	75%	73%	75%	Up to 27% less
Freshwater ecotoxicity	37%	38%	38%	38%	41%	42%	Up to 63% less
Total water used	104%	102%	104%	102%	94%	92%	Equivalent
Fossil Depletion	81%	84%	82%	85%	81%	84%	Up to 19% less
Total energy (based on CED)	83%	86%	84%	87%	83%	86%	Up to 17% less

HP better than the AgX by more than 10%
HP worse than the AgX by more than 10%
HP and AgX can be considered equivalent

Figure 2 Overall Results: NA



Comparing processes; Method: ReCiPe Midpoint (H) - 4E adds & rem V1.03/ World ReCiPe H / characterisation

Table 4 Overall Results: Europe (per 1000 4x6 prints)

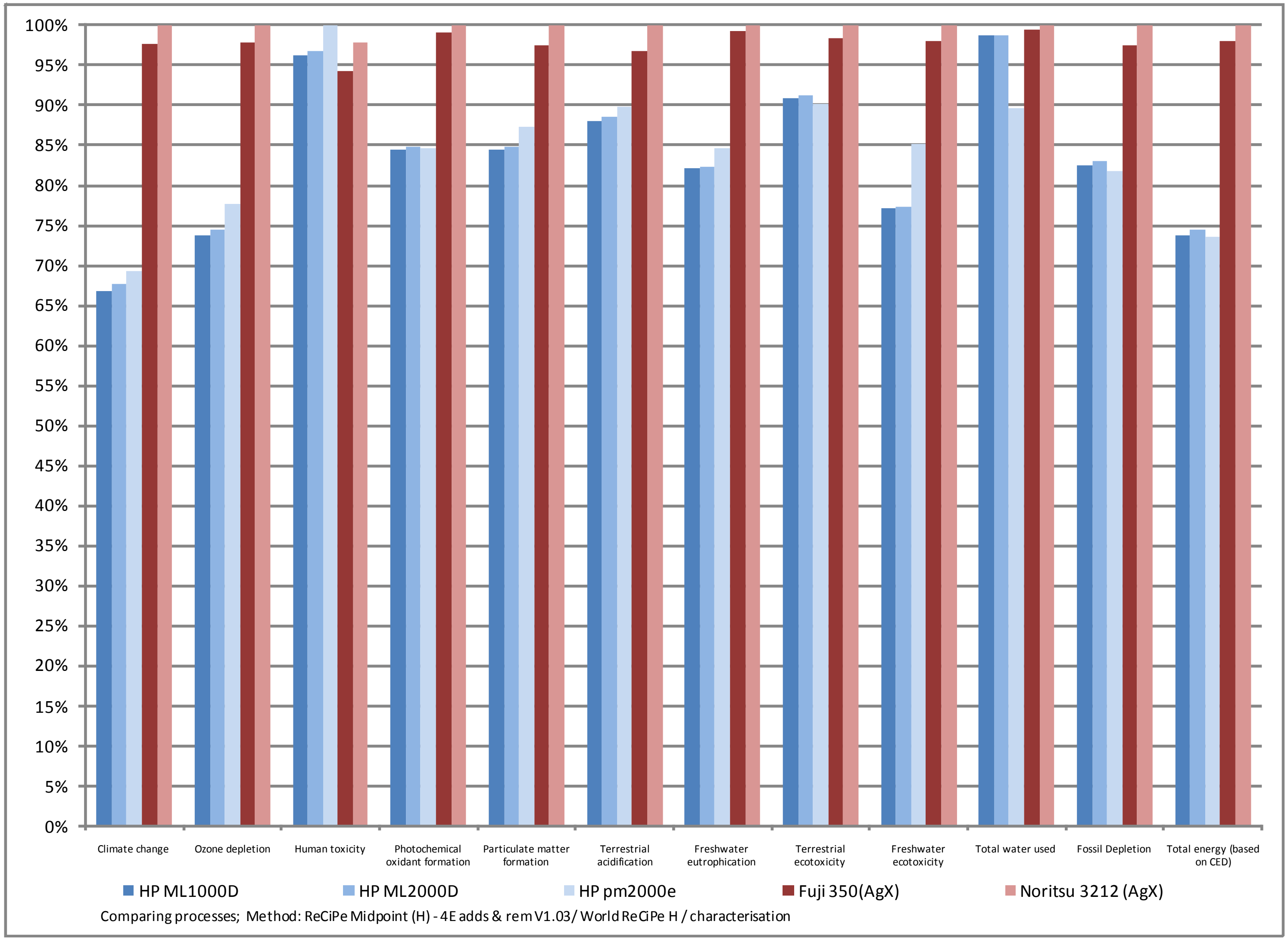
Impact category	Unit	ML1000D	ML2000D	pm2000e	Fuji 350	Noritsu 3212
Climate change	kg CO2 eq - kilograms of carbon dioxide equivalents	15.665	15.870	16.226	22.892	23.432
Ozone depletion	kg CFC-11 eq - kg of trichlorofluoromethane equivalents	1.0 E-06	1.0 E-06	1.1 E-06	1.4 E-06	1.4 E-06
Human toxicity	kg 1,4-DB eq - 1,4 dichlorobenzene	1.8	1.8	1.8	1.7	1.8
Photochemical oxidant formation	kg NMVOC - non-methane volatile organic compounds	0.05	0.05	0.05	0.06	0.06
Particulate matter formation	Kg PM10-eq - particulate matter size </ 10 micrometers	0.02	0.02	0.02	0.03	0.03
Terrestrial acidification	kg SO2 eq - sulfur dioxide	0.06	0.06	0.06	0.07	0.07
Freshwater eutrophication	kg P eq - phosphorus	4.1 E-04	4.1 E-04	4.2 E-04	5.0 E-04	5.0 E-04
Terrestrial ecotoxicity	kg 1,4-DB eq - see above	0.002	0.002	0.002	0.003	0.003
Freshwater ecotoxicity	kg 1,4-DB eq - see above	0.03	0.03	0.04	0.04	0.04
Total water used	Liters	331	331	300	333	335
Fossil Depletion	kg oil equivalents	5.9	6.0	5.9	7.0	7.2
Total energy (based on CED)	MJ - Megajoule	458	462	457	609	621

Table 5 Overall Percentage Results: Europe (per 1000 4x6 prints)

Impact category	ML1000D as % of Fuji 350	ML1000D as % of Noritsu 3212	ML2000D as % of Fuji 350	ML2000D as % of Noritsu 3212	pm2000e as % of Fuji 350	pm2000e as % of Noritsu 3212	HP vs. AgX overall
Climate change	68%	67%	69%	68%	71%	69%	Up to 33% less
Ozone depletion	75%	74%	76%	74%	79%	78%	Up to 26% less
Human toxicity	102%	98%	103%	99%	106%	102%	Equivalent
Photochemical oxidant formation	85%	84%	86%	85%	86%	85%	Up to 16% less
Particulate matter formation	86%	84%	87%	85%	89%	87%	Up to 16% less
Terrestrial acidification	91%	88%	91%	88%	93%	90%	Up to 12% less
Freshwater eutrophication	83%	82%	83%	82%	85%	85%	Up to 18% less
Terrestrial ecotoxicity	92%	91%	93%	91%	92%	90%	Equivalent
Freshwater ecotoxicity	79%	77%	79%	77%	87%	85%	Up to 23% less
Total water used	99%	99%	99%	99%	90%	90%	Equivalent
Fossil Depletion	85%	83%	85%	83%	84%	82%	Up to 18% less
Total energy (based on CED)	75%	74%	76%	74%	75%	74%	Up to 26% less

HP better than the AgX by more than 10%
HP worse than the AgX by more than 10%
HP and AgX can be considered equivalent

Figure 4 Overall Results: Europe



APPENDIX 2—INDICATOR DESCRIPTIONS

The analysis included a comparison of a broad and comprehensive spectrum of environmental indicators including those known to be of interest to consumers.

Climate change measures the greenhouse gas emissions which have been generated by the retail photofinishing systems. The "greenhouse effect" refers to the ability of some atmospheric gases to absorb energy radiating from the earth, trapping the heat and resulting in an overall increase in temperature. Climate Change is also called Global Warming Potential or the "carbon footprint". Climate change is reported in kilograms (kg) of carbon dioxide-equivalents.

Ozone depletion quantifies ozone depleting gases in product systems. These may include chlorofluorocarbons (CFCs or freons), halons, carbon tetrachloride, and trichloroethane. A decline in the ozone layer allows more harmful short wave radiation to reach the Earth's surface, potentially causing damage to human health, plants, and changes to ecosystems. Ozone depletion is reported in kg of trichlorofluoromethane equivalents.

Toxicity categories. Human toxicity provides an indication of the risk to human health, while terrestrial ecotoxicity and freshwater ecotoxicity results provide indication of the risks of damage to ecosystems on land and in fresh water bodies, respectively. All three are reported in terms of 1,4 dichlorobenzene equivalents.

Photochemical oxidant formation quantifies the potential for smog-forming gases that may produce photochemical oxidants. This is reported in kg of non-methane volatile organic compounds (NMVOC).

Particulate matter formation quantifies particles in the air generated by use of fuels for manufacturing and transportation and materials handling. Inhaling these particles may result in health issues such as asthma and other respiratory illnesses. This impact category is reported in kg PM10-eq (particulate matter of size less than or equal to 10 micrometers).

Terrestrial acidification quantifies acidifying gases that may dissolve in water (i.e., acid rain) or fix on solid particles and degrade or affect the health of vegetation, soil, building materials, animals, and humans. Acidification is measured in terms of kg of sulfur dioxide-equivalents.

Eutrophication potential quantifies nutrient-rich compounds released into water bodies, resulting in a shift of species in an ecosystem and a potential reduction of ecosystem diversity. A common result of eutrophication is the rapid increase of algae, which depletes oxygen in the water and causes fish to die. Eutrophication is measured in phosphorous equivalents.

Water depletion measures the use of water from all water bodies and covers cooling water, process water, and water during use phase. Water is reported in liters.

Fossil fuel depletion is the measure of the use – or depletion – of fossil fuels and is measured in oil-equivalents. Fossil fuel depletion tracks use of fossil fuels for energy as well as fossil fuels embedded in products made up of hydrocarbons, such as plastics.

Total energy is reported in Megajoules and includes not only energy to print the photos but also the energy required to produce use phase and upstream materials and transport all materials. Total energy encompasses fuel energy, including fossil- and non-fossil fuels such as nuclear power, hydropower, and biomass, and embodied energy, such as hydrocarbons in plastics.

APPENDIX 3—ELECTRICITY MEASUREMENT METHODOLOGY

From the CCDS Environmental Report (2010)[7]:

The labs that agreed to take part in the study were all professional labs or run by photo specialists.

All silver halide minilabs in Europe run on a 230V (Volts) 3-phase-current power supply and are equipped with either 16A (Amps) or the geometrically bigger 32 A.
No standard measurement devices are available. A specialized device was designed to measure energy consumption in kilo Watt hours.

Figure 3 Voltcraft IS-C 35 80 LE

The HP Photosmart ML 1000D runs on 220V one-phase current. Therefore, a commercially available device, which displayed punctual voltage, amperage and power, as well as the energy consumption, could be used.

[7] From "Environmental Study: A comparison of silver-halide minilabs vs. HP Photosmart ML 1000D", performed for HP by CCDS communication & design GmbH, April 2010.

Figure 4 220 V on-phase measurement device

In order to determine the HP Photosmart's electric energy consumption practically and under conditions that could be compared to the method applied to the competitor's machines, Energy [kWh] was measured over a long period and wattage was calculated. In addition, variation was considered; more than 10 punctual wattage measurements were taken and the average was calculated.

APPENDIX 4— DATA SOURCES DETAIL

The study adheres to the ISO standards on data quality to help ensure consistency, reliability, and clear-cut evaluation of the results. In accordance with ISO 14044, data were selected to ensure:

- Representativeness of the data in the study, including assessment of the temporal, geographical, and technological coverage;
- Consistency – the qualitative assessment of how uniformly the study methodology was applied to the various components;
- Reproducibility – the qualitative assessment of the extent to which information about the methodology and data values allows an independent practitioner to reproduce the results reported;
- Precision – the measure of the variability of the data values for each data category;
- Completeness – the percentage of the process that was measured or estimated;
- Uncertainty of information.

In any LCA, there is an inherent margin of error due to various limitations such as data quality differences and/or lack of availability of potentially relevant data. Wherever possible, this LCA used the best data available at the time of the study, including operation of the Minilabs and database modules on energy, fuels, transportation, and basic materials from data available in the latest versions in the LCA software database.

Table 1 Temporal, Technological, and Geographical coverage

	Temporal Information	Technological coverage	Type of data	Geographical coverage	Source of Data
HP media	Current Bill of Material (BOM)	1 technology: HP's supplier	Primary	Produced in Germany, for the worldwide market	HP
AgX media	Current BOM on base paper, resin, gelatin, patent data on emulsifier	BOM appears representative; some current technological data on processing (base paper)	Primary (HP labs) and secondary, or publicly-available (public patent)	Produced in Japan and EU, for the worldwide market	HP, public patent
HP ink cartridges	Current MSDS	Cartridge BOM, ink BOM, transport, and packaging were included	Primary	Produced in Singapore, for the worldwide market	HP, MSDS on inks

	Temporal Information	Technological coverage	Type of data	Geographical coverage	Source of Data
AgX chemicals	Current MSDS	No data on assembly of the chemicals but BOM, packaging, and transport were included	Secondary	Papers produced in US for the US market and EU for the EU market	[F/22] Consulting, Inc., CCDS, MSDS for chemicals
HP energy use	Energy tested on machines in use	N/A	Primary	Data based on usage patterns assumed for NA and European markets	CCDS,HP
Water use	Data based on current machines in use	N/A	Primary	Data based on usage patterns assumed for NA and European markets	CCDS, [F/22] Consulting, Inc.
Emissions to water and air	Data based on current machines in use	N/A	Primary (theoretical mass balance)	Data based on usage patterns assumed for NA and European markets	CCDS, [F/22] CONSULTING, INC.
Maintenance – HP and AgX	Data based on current machines in use	N/A	Primary	Data based on usage patterns assumed for NA and European markets	HP, CCDS, [F/22] CONSULTING, INC.
Long-life consumables – HP and AgX	Data based on current machines in use	N/A	Secondary, some primary data based on usage experience	Data based on usage patterns assumed for NA and European markets	HP, CCDS, [F/22] CONSULTING, INC.
Capital Equipment	Data based on current machines in use	N/A	Secondary (from manuals)	N/A	HP, CCDS, [F/22] CONSULTING, INC.
Upstream materials data (e.g., chemicals and ink, steel in equipment)	Data mostly from 2000-2010	Average production technologies.	Secondary	European data, or NA data, if no European data were available.	EcoInvent and other databases in the SimaPro software

	Temporal Information	Technological coverage	Type of data	Geographical coverage	Source of Data
Energy and fuel data sets	Data mostly from 2000-2010	The most representative technologies	Secondary	U.S. data for the NA market, European data for the European market.	EcoInvent and other databases in the SimaPro software
Transportation data sets (for distribution)	Data mostly from 2000-2010	Average technologies	Secondary	U.S. data for the NA market, European data for the European market.	EcoInvent and other databases in the SimaPro software

APPENDIX 5— AGX DATA CONTRIBUTORS

US Data Consultant: *[F/22] Consulting, Inc.*

Frank Baillargeon, president of [F/22] Consulting, Inc. is a 32-year photo industry veteran. He incorporated [F/22] Consulting, Inc. in 2001. His industry management and consulting engagements have covered the breadth and depth of the photo-imaging industry including major manufacturers, mass retailers, technology start-ups, and others. Mr. Baillargeon has previously served in numerous roles in the photo industry, including: Director of Imaging Products Services - Kmart, V.P. National Accounts, Fuji Photo Film U.S.A., Director of Marketing - Fujicolor, V.P. Sales and Marketing - Deans Photo Service, District Manager - Eastman Kodak Consumer Markets Division.

European Data Consultant: CCDS communication & design GmbH

CCDS communications and design GmbH was founded in 1992. Digital photography has been the core competence of CCDS throughout its history. The team of 18 employees consists of photo engineers (Masters of Media and Imaging Technology), graduate designers, translators and IT-specialists. Today CCDS covers a wide range of services in the field of state of the art photo and media technology.

APPENDIX 6— INPUT DETAIL

Photo Media

Packaging and average transportation from the manufacturer, through distribution centers and to retailers were included. Paper waste and trim were included. The photos produced are assumed to be kept indefinitely, so they do not have an end-of-life phase. Misprints and printing errors were considered but were not included in the calculation because the incidence was not significant enough to affect the analysis result. Frequency of prints not picked up by the customer varies and was included in sensitivity analysis.

HP Media

Primary data was made available by the supplier of HP paper for process energy (specifically, paper manufacturing energy, PVA/fumed silica coating energy, and resin extrusion energy) and water use. The paper model includes secondary data using primarily EcoInvent modules for the paper components including resin coatings.

AgX Media

Silver halide photo paper consists of a resin coated paper base with gelatin-based emulsion layers containing dye-forming couplers, the light-sensitive silver halide crystals, and sensitizers. AgX developing agents reduce the silver halide to silver metal which forms the photographic image. The silver halide in the photo paper modeled for this study is silver chloride (AgCl), the primary halide used for color papers.

According to CCDS, all photo papers have to be processed using a standardized process called RA-4. Manufacturers offer the same process with slight modifications and under different names. The papers differ only slightly. According to CCDS, photo papers from any manufacturer can be used interchangeably. The papers represented in this study are the Fuji Crystal Archive and the Kodak Royal Gold. These papers represent a standard/"average" quality paper and a premium paper respectively. For the NA market, it is assumed that 80% of paper used is standard and the remaining 20% is premium. In Europe, 50%/50% usage is assumed. Sensitivity analyses were performed varying the standard to premium ratio: 100% standard to 100% premium.

Since the formulas for specific papers are proprietary, the data from the Kodak patent was used to obtain the masses for most of the emulsion layers/constituents in the photo paper model.[8] HP laboratories also performed a cross-section analysis of the paper in order to obtain the percentages of each component, including the base layer, and to cross-check some of the data from the patent. The patent and the HP analysis were compared and used to compile the paper analysis.

Printing Consumables (Inks, Chemicals, Water, Other)

Printing consumables include HP systems' inkjet cartridges and AgX photographic developing chemicals which include developer for start-up and replenishment, bleach fix for start-up and replenishment, and super rinse conditioner tablets. Packaging, its end-of-life management, and transport of the printing consumables to the retailer were included.

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[8] Patent No. 5,981,159, Nielsen et al., Eastman Kodak Company (Rochester, NY), November 1999.

HP Printing Consumables
HP ink composition modeling was based on the MSDS. Average coverage and average ink usage were provided by HP. Recycling of the cartridge at end of life through HP's Planet Partners program was included, as well as average transportation from retailers to the recycling site.

Printing photos with HP systems uses no water and produces no water effluent. The HP systems require water for maintenance and other tasks over the life of the systems but this is considered negligible.

AgX Printing Consumables
In AgX systems, the developer and bleach fix concentrated agents are mixed with water and added into the processing tanks based on an exact ml per sq-ft ratio. At the same time, spent chemicals leave the processing tanks as "photo effluent" and are stored in effluent tanks within the machine until silver recovery and/or disposal.
Three commonly used chemical systems were modeled.

- Fuji 370 and Fuji 350: modeled with the Fuji CP-48S chemical processing system
- Noritsu QSS 3502: modeled with the Kodak Ektacolor PC 111 chemical processing system
- Noritsu QSS 3212: modeled with the Kodak Ektacolor Prime LORR chemical processing system

Chemical system composition modeling was based on the MSDS.

The table below summarizes the quantity of deionized water used for chemical dilution and rinse cycles as well as tap water used for preventative maintenance tasks during shut down procedures and for evaporation correction. The deionized water starts as tap water and is purified by an accessory filtration device.

Table 2 Water Consumption for AgX Systems [9]

AgX Systems	Chemical System	Water Liters/Month
Fuji 370	Fuji 48S chemical system:	216 L
Noritsu QSS 3502	Kodak PC 111 chemical system:	236 L
Fuji 350	Fuji 48S chemical system	151 L
Noritsu QSS 3212	Kodak Prime LORR chemical system	207 L

Prior to the start of daily production for all AgX systems, process control strips are used to ensure that the photographic chemical process is within acceptable limits to produce quality photos. Manufacturing, packaging, transportation, storage and recycling of the process control strips were included.

Every processing location uses "start-up" chemicals for a clean start, as needed. According to [F/22] Consulting, Inc. and CCDS, these start-up chemicals are applied an average of two times per year, and this was accounted for in the model.

[9] Fuji and Noritsu data from: "Environmental Study: A comparison of silver-halide minilabs vs. HP Photosmart ML 1000D", performed for HP by CCDS communication & design GmbH, April 2010, Kodak data from the Kodak Ektacolor Prime LORR chemicals manual.

Water Effluents

The AgX photographic developing chemicals and the silver ions released from the paper during processing are collected in a tank and managed. Effluent management differs between regions.

In NA, the photo effluent solution is first desilvered through an approved silver recovery unit (SRU) purchased by the retailer directly from a refiner. The SRU is returned to the refiner for reclamation. This becomes a positive cash flow stream to the retailer. All large retailers in NA utilize SRUs. The NA study reflects silver recovery in the SRU and then disposal of the remaining effluent as prescribed by local waste water regulations. The remaining water effluents are released into municipal sewer systems.

For Europe, the model reflects more stringent water disposal regulations. The Europe model includes average transportation distance of the effluent (containing the chemicals and silver) to an effluent management facility. Data for the treatment of the effluent in Europe came from the EcoInvent data on wastewater treatment for black chrome coating effluent as proxy data.

The recycling of the silver is outside the boundaries of the study. To give the AgX system the benefit of the full recovery of silver, an equivalent quantity of silver mining and beneficiation/milling upstream was subtracted out of the analysis.

Based on measurements by CCDS, 5.4% of the chemicals used are absorbed by the paper or evaporated[10].

Energy Use

Energy use includes the energy consumed by the systems and energy required by the retailer's Heating, Ventilation, and Air Conditioning (HVAC) systems to manage heat load.

<u>Electricity Consumption</u>

During the course of producing the CCDS Environmental Report (2010), CCDS conducted a survey as well as measurements for the energy consumption of AgX and HP minilabs. Measurements included all operation modes, including sleep, heating (overnight), start-up, active printing, and stand-by. For AgX systems specifically, the measurements included the on and off cycles of the heaters throughout the day, pre-heating time in the morning, replenishing pumps, auto wash cycles, and dryer run time. Appendix 3 details the CCDS testing methodology.

<u>HVAC</u>

HVAC was modeled based on methodology and testing done by CCDS in their 2010 Environmental report. Per CCDS, fans or air conditioning are not required to run AgX minilabs but three of the four polled labs run an air-conditioner or fans. This study assumes that each AgX minilab requires one fan to cool the equipment. The power consumption of the fan was measured by CCDS.

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[10] "Environmental Study: A comparison of silver-halide minilabs vs. HP Photosmart ML 1000D", performed for HP by CCDS communication & design GmbH, April 2010,

Long-Life Consumables

Both the HP and AgX systems have parts that need replacement over the life of the machines, including water filters, chemical solution filters, printheads, backprinter cartridges, web wipes, air filters, etc. These were included in the model.

HP

The ML1000D's long life consumables were collected. All electronic and metal components were included in the analysis. Small plastic parts, with very small masses, were not included as they were not expected to affect the model. Packaging and transportation from Singapore to NA or to Europe were included.

The following long life consumables were included in the analysis.

- Drop Detect Sensor
- Drum Motor Assembly
- Tray Pick Rollers
- Tetris Sensor
- Printheads
- Cutter Bay Assembly
- Pen Wipe

AgX

Long-life consumables for two of the AgX machines (Fuji 370 and Noritsu 3502) were provided by [F/22] Consulting, Inc. All metal components and all components replaced more than once a month were included in the analysis. Small plastic parts, with very small masses, were not included as they were not expected to affect the model.

Fuji 370 Long-Life Consumables:

- Water Filters
- Rubber Tires
- Chemical Circulation Filters
- Fitting Tubes
- Backprint Ribbon

Noritsu 3502 Long-Life Consumables

- Chemical Circulation Filters
- Backprint Ribbon

According to CCDS, the long-life consumables list for the Fuji 350 and the Noritsu 3212 are similar.

Maintenance

Maintenance provided by in-store technicians and specialized service technicians was included in the analysis.

HP Systems

For HP systems some maintenance is done by on-site operators. HP service technicians also set up, install, and repair units at the customer site. Both planned preventative maintenance and unanticipated issues requiring a service technician were included in the model. Assumptions for frequency for both planned and unplanned maintenance was provided by HP engineers. Average travel to the service site was also included.

AgX Systems

According to [F/22] Consulting, Inc. and CCDS, photo technicians are required to perform daily, weekly, monthly, quarterly, semi-annual, and annual maintenance on the photo processing equipment. Minor repairs and daily and monthly maintenance are done by the in-store photo technicians. Major repairs require a highly specialized photo technician. Some retailers have service contracts with a service and repair company to utilize specialized photo technicians. [F/22] Consulting, Inc. and CCDS provided assumptions for service frequency and average travel to the service site.

Capital Equipment

Capital equipment has been accounted for and was based on a physical teardown. Capital equipment was modeled by multiplying the weight of each machine by the breakdown of materials.

Air Emissions

Air emissions coming from production and use of fuels, production of chemicals and ink, etc., were included in the analysis. Localized air emissions due to HP ink or the AgX chemistry are considered to be negligible.

For HP systems, testing was done on potential emissions, and they were found to be below CA prop 65 levels, which are considered to be amongst the most stringent requirements in the U.S. The HP ML1000D and ML2000D systems also meet the program specifications for the Blue Angel program and comply with the formaldehyde limits of the GREENGUARD ecolabel for low-emitting office products.

According to [F/22] Consulting, Inc. and CCDS, localized emissions for AgX systems are also negligible. Photo chemistry manufacturers have developed formaldehyde free stabilizers and chemicals with low benzyl alcohol concentration, minimizing emissions. We found no published data to support that all or any of the 5.4% of chemicals that may have evaporated in the printing process is released to the atmosphere. To be conservative, air emissions from the AgX chemicals due to evaporation/escape into the air were not modeled.

APPENDIX 7— USAGE ASSUMPTION DETAIL

The following table provides the average usage pattern information assumed in the study.

Table 9 Usage Calculation

	NA	Europe
Daily print volume (prints per day)	1250	1250
Avg prints per order	45	30
Orders per day (evenly distributed throughout the day)	28	41
Business hours (# hrs)	12	11
Shop closed (# hrs)	12	13
Days / yr lab in use	360	300
Orders per hr (approx)	2	4
Prints per hour (approx)	104	114
Total prints per year	450,000	375,000

APPENDIX 8— PEER REVIEW LETTER

Hewlett-Packard (HP) commissioned Four Elements LLC (4E) to conduct a Life Cycle Assessment (LCA) evaluating the environmental performance of HP's Retail Photo System (RPS) product in comparison with that of a traditional Silver Halide (AgX) RPS. Since their intent is to share the findings of the study with a diverse audience, in conformance with the ISO 14040 series of standards, HP also requested a comprehensive peer review of the study's goal and scope, assumptions, model and results. This statement is the culmination of that peer review process, and it summarizes the reviewer's overall approach, the initial comments provided to HP and 4E, and the team's conclusions on the overall report.

The Review Team

The peer review was conducted by a team of three independent experts with expertise relevant to the subject of the study. The team members and their relevant background are listed below:

Brian Glazebrook, Senior Manager at Cisco Systems (Lead Reviewer): Mr. Glazebrook has over 15 years experience in the LCA field, as both a practitioner and peer reviewer. He currently works on supply chain sustainability issues within the electronics industry.

Marcos Esterman, Assistant Professor, Industrial & Systems Engineering at Rochester Institute of Technology: Mr. Esterman has a background in mechanical engineering and he has been involved in some previous LCA studies on imaging technology. His research at RIT's Center for Imaging Science focuses on structured product development methods, with an emphasis on sustainability.

David Spitzley, Product Sustainability Manager at Kimberly-Clark: Mr. Spitzley has worked in LCA issues over the past 10 years and is leader in a number of global initiatives to develop global LCA and product design standards. He is currently leading sustainable design initiatives at his company.

The makeup of the team was determined by the Lead Reviewer, independent of HP, to ensure a broad mix of experience with the ISO 14040 series of standards, LCA modeling, the electronics supply chain and imaging technology. None of the team members has specific experience with RPS technology or is currently affiliated with HP or its competitors in the RPS market.

Disclaimer

The opinions and input provided by the members of the peer review team was provided on their own and do not reflect the opinions of their respective employers. In addition, the reviewers' sole intent was to determine whether the study was consistent with ISO standards and to provide an assessment of the reasonableness of the model and interpretation of results; their participation in this review does not suggest an endorsement of the LCA's goals and conclusions.

The Peer Review Process

The ISO 14040 series of standards provides guidance on how to complete a full LCA and they provided the basis of comparison for the peer review team. Since HP wanted to ensure that the study had the correct approach, the peer review was broken into two parts:

1. A review of the goal and scope for the study.
2. A review of the complete report and findings.

For part one, the team members focused on evaluating whether the goal and scope for the study were clearly defined and consistent with the intended application. In particular, the reviewers asked:

- Does the goal unambiguously state the intended application, including the reasons for carrying out the study and the intended audience?
- Does the scope clearly describe:
    - the function of the studied systems and the functional unit;
    - the system boundaries and how they were defined;
    - how allocation was applied;
    - any assumptions made and limitations to the study;
    - the impact assessment categories to be used;
    - initial data and data quality requirements?
- Are the methodological decisions scientifically and technically valid and do any product alternatives reflect reality, rather than being designed to support the study's argument?

For part two of the review, the team first evaluated whether all significant issues from the first review were addressed satisfactorily. The team then focused on evaluating the data that was collected for the model, the initial findings and the report conclusions. For both reviews, the team provided detailed comments to 4E and HP on all aspects of the report.

Review of the Goal and Scope

The initial goal and scope document provided by 4E was fairly comprehensive and provided a good summary of what the study was looking to address. It answered most of the peer review questions outlined above, though the team still did have some questions and comments. The feedback from the review team on the goal and scope report can be summarized as:

- Requests for clarification of terms and consistency in terminology.
- Suggestions of extraneous information that could be taken out of the report.
- A request for more information on the assumptions behind the selected AgX product alternatives.
- Need for clarification on discrepancies in the source of demand data.
- Questions about the assumptions around the system boundaries related to the technology needed to operate the different systems.

Both 4E and HP responded in writing to the peer review comments and indicated that they made changes to the report where relevant. The only question that the peer review team felt was not completely addressed in their response was related to the decision not to include the peripheral IT equipment associated with RPS products within the system boundaries. (See page 30 for HP comment.)

Review of the Final Report

The draft final report provided by 4E included changes to address most of the comments from the goal and scope review. The report was comprehensive and provided a lot of detail about the system boundaries and the data sources used to develop the model. The comments from the review team on this draft report can be summarized as requests for:

- More information to support the description of data sources and model assumptions.
- Reference sources for data included in data tables.
- Clarification of specific terms and better definitions of those terms in the report.
- A much more comprehensive presentation of model results and better interpretation.
- A better explanation of the assumptions used in the model for capital equipment.
- Sensitivity analysis of some of the key assumptions used in the model.
- Additional explanation of why peripheral IT equipment was not considered to be within the scope of the model.

As with part one of the review, 4E and HP responded in detail to each of the peer review comments on the draft report and indicated where they would make changes to the final report. For a few of the comments, 4E and HP indicated that changes to the report were not warranted, but they provided sufficient justification for their reasoning that the peer review team felt was acceptable.

For the final report, the results and interpretation section was much improved from the draft version, and more effort was put into providing an assessment of the sensitivity of the results to changes in some of the key variables in the model. The conclusions to the report seemed to be reasonable, based on the data presented in the report.

Unresolved Issues

The one question that the peer review team felt was not completely addressed after the first and second review was related to the decision to exclude peripheral IT equipment from the scope of the model. HP made the case that as there was no 'standard' equipment setup for an RPS system and HP does not require a customer purchase any specific equipment with their RPS product, excluding it was acceptable. To the peer review team, while this made logical sense, not enough information was provided to confirm that there were no technological requirements of either system that could require a unique piece of equipment or IT setup.

Without this information on the electronics required by the two systems, it was difficult for the peer review team to determine whether this decision to exclude would have had a material impact on the final results. From the perspective of being compliant with the ISO standards, the case for excluding this part of the system is reasonable, and the comparison between the two RPS technologies can stand on its own. In the future, however, when the question of whether to include/exclude a complex product within the system boundaries comes up, the peer review team suggests that HP provide some quantitative analysis to support its decision. (See page 30 for HP Comment.)

Summary

The peer review team's final assessment of the LCA is that it is consistent with the requirements of the ISO 14040 series of standards. Specifically:

- The study's goal and scope were clearly explained.
- The functional unit is reasonable.
- Assumptions made throughout the report were well documented and acceptable.
- A clear effort was made to collect data that was as representative as possible of the specific technologies.
- The model as defined was very comprehensive and included some elements that normally would have been excluded in other studies.
- The impact categories selected were comprehensive and clearly explained.
- The data interpretation was clearly presented.
- Sensitivity analysis was used correctly to evaluate some of the key assumptions.

Around the issue of comparative assertion, the review team agrees that:

- The model was structured to ensure the comparison between the technologies is fair and equivalent.
- The methodological decisions and assumptions are scientifically and technically valid.

It should be noted that while a peer review can provide valuable input to the authors of an LCA, they are not obliged to accept and implement all of the input the peer reviewers provide. With this in mind, the peer review team appreciates HP's and 4E's willingness to address the issues the team presented up in their comments. While most comments and suggestions were adopted in the final report, in the few areas where there was a difference of opinion, HP and 4E made an effort to provide a detailed response to explain this difference.

HP Comment

The exclusion of the peripheral IT equipment from the study does not impact the comparison, as both the HP and AgX print systems use similar front-end systems. The decision to exclude the peripheral IT equipment is in keeping with the study's goal, which was "to compare the printing component of the HP RPS systems to the processing component of the AgX systems in order to potentially communicate to retailers the environmental performance differences and savings between the AgX and HP RPS products".

APPENDIX 9— LIFE CYCLE ASSESSMENT ANALYST

ANNE LANDFIELD GREIG, Four Elements Consulting, LLC

Anne Landfield Greig, Certified Life Cycle Assessment (LCA) Practitioner, is the principal and owner of Four Elements Consulting, LLC. Four Elements specializes in Life Cycle Management (LCM) and Life Cycle Assessment (LCA) services to help corporations, government and non-governmental organizations find valuable environmental and cost management solutions for their products and operations. Four Elements also carries out product- and corporate-wide greenhouse gas (GHG) assessments and carbon footprints, and assists companies with the preparation of GHG and carbon offset verifications. Anne Greig is an advisor on life cycle issues for CarbonFund's Carbon*free*™ certification program. She is on the American Center for LCA certification committee and a member of the International Council on Mining & Metals LCM Working Group. Anne holds a Bachelor of Science in Geology from Boston College and a Master of Science in Environmental Management from Duke University.