



**Life Cycle Environmental Impact Study  
on LaserJet Toner Cartridges in the  
Europe, Middle East & Africa (EMEA) Region**

**Production of HP Reused Cartridges  
vs.  
Original HP Cartridges**

**SUMMARY REPORT**

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## EXECUTIVE SUMMARY

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HP has developed a technology to recycle, or “evocycle”, Original HP LaserJet toner cartridges into new cartridges. Designed with sustainability, environment, and performance in mind, HP EvoCycle cartridges use parts from a predecessor cartridge, new parts that contain post-consumer recycled content plastic from previous Original HP cartridges, and new parts. HP has commissioned Four Elements Consulting, LLC, to perform a life cycle analysis that compares the production of HP EvoCycle black and color LaserJet toner cartridges to their predecessor Original HP cartridges. The results show that for all environmental impact categories, HP EvoCycle cartridges have lower environmental impacts than their predecessors.

The analysis evaluated the cradle-to-gate production of cartridges sold to customers in the Europe, Middle East & Africa (EMEA) region, from material sourcing and parts production, through manufacturing and assembly of the cartridges. The study is in conformance with the International Standards Organization (ISO) 14040 and 14044 standards on Life Cycle Assessment (LCA). This summary report presents the results.

## SUMMARY REPORT

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### INTRODUCTION

For almost two decades, HP has been evaluating the life cycle environmental impacts of its LaserJet toner cartridges. HP has developed a technology to recycle, or “evocycle”, LaserJet toner cartridges that have been returned for recycling into new cartridges. HP EvoCycle cartridges are built using parts from the predecessor cartridge, parts made from closed-loop post-consumer recycled content from Original HP cartridges, and new parts. HP has commissioned Four Elements Consulting, LLC, to perform a cradle-to-gate Life Cycle Analysis that compares the production of HP EvoCycle black and color LaserJet toner cartridges to their Original HP black and color LaserJet toner cartridge predecessors. Comparing the two sets of cartridges using Life Cycle Analysis will meet the study goal of quantifying the reductions of the carbon footprint and other environmental impact categories that result from evocycling the cartridges. These cartridges are sold to customers in the Europe, Middle East & Africa (EMEA) region.

The study is in conformance with the ISO 14040 and 14044 standards on Life Cycle Assessment (LCA). LCA is one of the most valuable environmental tools for assessing the environmental footprint of a product or process, as it provides quantitative and scientific analyses of the environmental impacts of products and their associated industrial systems. As a comprehensive analysis of a defined product system, this cradle-to-gate LCA provides valuable information pertaining to the production of the products.

### METHODOLOGY

#### PRODUCTS STUDIED

This study compares the production of HP EvoCycle toner cartridges, the 410XR used in HP Color LaserJet Pro M452 and M477 MFP LaserJet printers, to that of Original HP (OHP) 410X cartridges used in the same printers. Four toner cartridges are assessed for each product system: black (K), cyan (C), magenta (M), and yellow (Y). One set of results is presented for all of the cartridges together in each option (shown in Figure 1). Printers and printing are not included in the analysis. The HP 410X cartridges are summarized in the table below:

**Table 1 Summary of the HP 410X Cartridges**

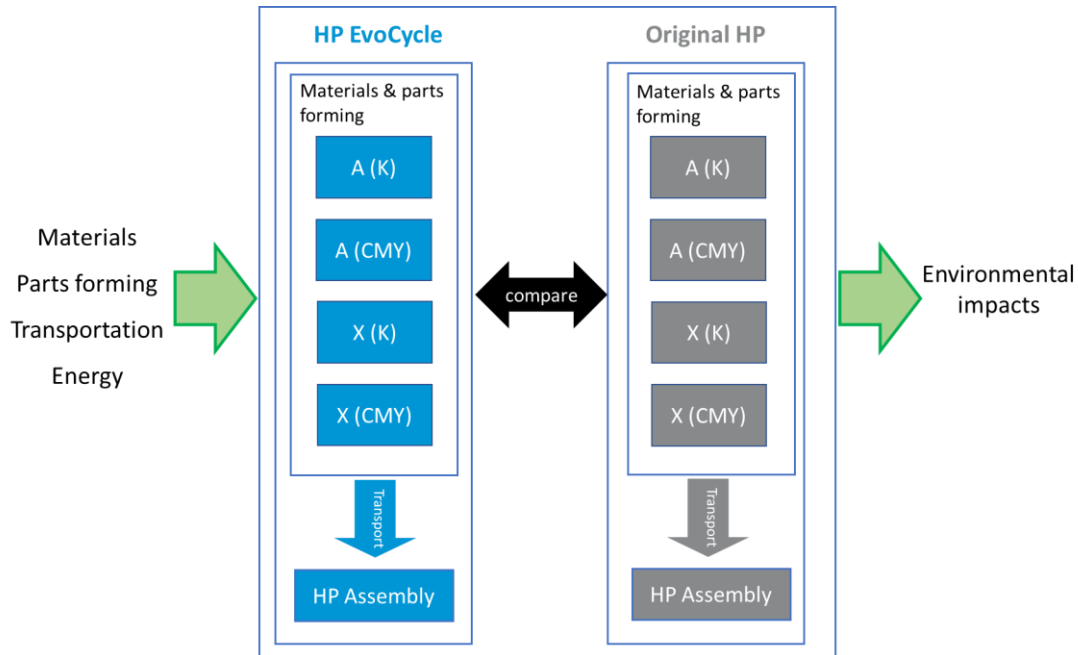
Cartridge SKU	Page Yield <sup>i</sup>	HP Original Printers
CF410X (black)	6,500	HP Color LaserJet Pro M452 HP Color LaserJet Pro M477 MFP
CF411X (cyan)	5,000	
CF412X (yellow)	5,000	
CF413X (magenta)	5,000	

### ADHERENCE TO THE ISO STANDARDS

This LCA adheres to the principles, framework and guidelines in ISO 14040 and 14044.<sup>ii</sup>

## SYSTEM BOUNDARIES

LCA is a tool for the systematic evaluation of the environmental impacts of a product through all or a defined set of stages of its life. Since this system accounts only for the production stage of the cartridges, it is considered a cradle-to-gate analysis. Both sets of cartridges are assembled in the same factory in Japan, using HP assembly and technologies. Figure 1 presents the study's system boundaries.



**Figure 1 System boundaries**

## DATA AND SOFTWARE

HP provided primary data on the cartridges' parts and materials, place of manufacture, packaging specifications, and assembly data. The two cartridge systems' models were built using secondary data which were assessed for their temporal, geographical, and technological coverage. The study utilized data from the latest available version of the ecoinvent database<sup>iii</sup> and LCA data published by industry associations. Utilizing the most current and available data, especially from a widely-known and respected database, enhances the quality of the study and increases its transparency, reliability, and confidence level. The Data Quality section provides more detail on the quality of the data. SimaPro, a commercial LCA software product, was used to model and calculate the LCA.<sup>iv</sup>

## FUNCTIONAL UNIT AND DECLARED UNIT

In an LCA, all flows within the system boundaries must be normalized to a common unit. If the full life cycle of a product is being assessed, the systems are normalized to a unit related to the function of the system, enabling the comparison of products or systems on an equivalent basis. For example, the function of a cartridge is to deliver printed pages, so the functional unit might be a defined number of page outputs. For this study, the cartridges are compared on two bases. The first is on a full-cartridge basis, as a "declared unit," and per-page output, as a "functional unit," in which the full cartridge production system is normalized to the number of pages printed – in this case, the page yields in Table 1, multiplied by a functional unit of 100 pages.

## MODELING AND ASSUMPTIONS

This cradle-to-gate study includes modeling of the production of materials and cartridge parts, production of packaging materials, transport of these to HP facilities, and manufacturing. The sections below summarize the modeling and assumptions.

## PRODUCTION OF MATERIALS, PARTS, AND PACKAGING

Detailed parts and materials lists (PMLs) and packaging data were collected. The Original HP cartridge materials production phase includes the production of over 99.5% by mass of the materials in the 410X cartridges. The energy for forming materials into parts, e.g., injection molding of plastic into cartridge parts, forming of aluminum and steel parts,

coating, etc., were included in the models. The HP EvoCycle is produced when a used Original HP 410X is sent for recycling at HP's Planet Partners facility in Virginia, USA. There, it is disassembled, inspected, and cleaned and sent to the HP cartridge assembly facility in Japan. Using proprietary HP processes, the HP EvoCycle cartridge is assembled with the predecessor Original HP 410X parts, new Original HP 410X parts, and new Original HP toner. A significant portion of its body is made from closed loop recycled polystyrene, originally sourced from Original HP cartridges returned to HP Planet Partners regional recycling centers. Parts needing replacement undergo Planet Partners' patented cartridge recycling processes in Shanghai, China. Both cartridge systems undergo stringent quality testing before being sold to customers in EMEA. Packaging mass and materials are the same for both cartridge systems, and 100% of those materials have been included in the model. Wherever possible, the materials and parts forming datasets for the Asia region were applied, accounting for the location of HP's production facility in Japan.

### TRANSPORT TO FACILITY

Transportation of parts and materials to the HP facility was included. An average transportation distance of 500 mi (805 km) by heavy-duty truck to the HP facility was assumed.

### PRODUCTION ENERGY

The cartridges are produced in an HP facility in Japan. The per-cartridge electrical assembly energy of 0.778 kWh/cartridge was modeled, using the Japan electricity grid to represent the emissions from the facility.

### RESULTS

Table 2 presents results for the HP EvoCycle and OHP whole-cartridge production systems. The first two columns present the total impact results for each system. The third and fourth columns present how much higher the OHP is relative to the HP EvoCycle and how much lower the HP EvoCycle is relative to the OHP. For all categories except toxicity, the OHP cartridge production system is 52% or greater. The last column shows how much lower HP EvoCycle production is compared to the OHP production, and this ranges from 2.6% to 69%.

As mathematical models of complex systems, all LCAs have inherent limitations that result in some level of uncertainty (see the Limitations section for more details). LCA results are therefore assessed using some margin of error, and a +/- 10% margin of error is used. For the toxicity category, the results fall within this range. However, toxicity impacts used in LCA have much higher uncertainty relative to other LCA impact categories, so the reader should make note of this lower confidence level (See Category Descriptions section).

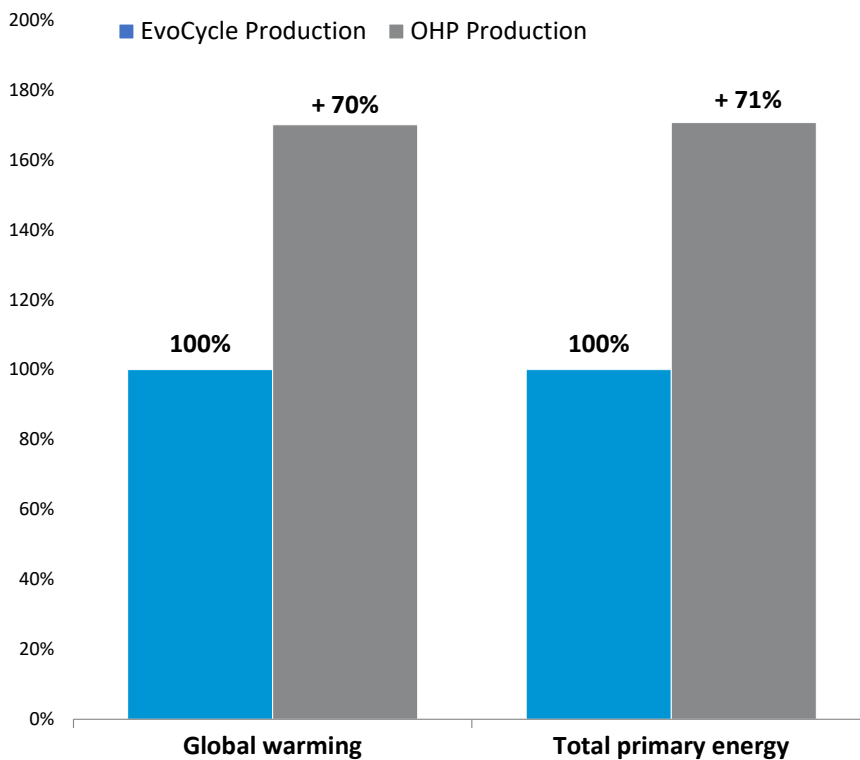
**Table 2 Results – Whole Cartridge Systems**

Impact category	Unit	HP EvoCycle Production	OHP Production	OHP % Higher than EvoCycle	EvoCycle % Lower than OHP
Global warming	kg CO <sub>2</sub> -eq	1.2 E+1	2.0 E+1	+72%	-42%
Ozone depletion	kg CFC11 eq	4.4 E-6	6.7 E-6	+52%	-34%
Ozone formation	kg NOx eq	3.0 E-2	4.8 E-2	+62%	-38%
Terrestrial acidification	kg SO <sub>2</sub> eq	3.7 E-2	7.3 E-2	+98%	-50%
Freshwater eutrophication	kg P eq	5.1 E-3	1.6 E-2	+221%	-69%
Human toxicity	kg 1,4-DCB	7.3 E-2	7.5 E-2	+2.7%	-2.6%
Water consumption	m <sup>3</sup>	4.9 E-1	8.6 E-1	+77%	-44%
Total primary energy	MJ	1.8 E+2	3.1 E+2	+72%	-42%

Table 3 presents the production phase for the HP EvoCycle and OHP cartridge systems in terms of a cartridge-normalized 100-page output. These results are almost identical to the full-cartridge analysis since page yields are the same in both systems, and both cartridge models have comparable output quality, i.e., there is rarely a need to reprint pages due to poor performance. Figure 2 depicts global warming and total energy.

**Table 3 Results – Cartridges Normalized to a 100 Page Output**

Impact category	Unit	HP EvoCycle Production	OHP Production	OHP % Higher than EvoCycle	EvoCycle % Lower than OHP
Global warming	kg CO <sub>2</sub> -eq	1.0 E-5	1.8 E-5	+70%	-41%
Ozone depletion	kg CFC11 eq	4.0 E-12	6.1 E-12	+51%	-34%
Ozone formation	kg NOx eq	2.7 E-8	4.3 E-8	+61%	-38%
Terrestrial acidification	kg SO <sub>2</sub> eq	3.3 E-8	6.6 E-8	+97%	-49%
Freshwater eutrophication	kg P eq	4.6 E-9	1.5 E-8	+219%	-69%
Human toxicity	kg 1,4-DCB	6.5 E-8	6.7 E-8	+3.0%	-2.9%
Water consumption	m <sup>3</sup>	4.3 E-7	7.7 E-7	+77%	-44%
Total primary energy	MJ	1.6 E-4	2.7 E-4	+71%	-41%



**Figure 2 GWP and Total Energy Normalized to 100-Page Output**

### DATA QUALITY REQUIREMENTS AND EVALUATION

This LCA adheres to the ISO standards on data quality to help ensure consistency, reliability, and clear-cut evaluation of the results.

### Temporal, Geographical, and Technological Representativeness

Temporal representativeness describes the age of data and the minimum length of time (e.g., one year) over which data are collected. The data applied to this study represent current products and practices. The HP 410X color toner cartridges are used in popular current printer models. The parts and materials lists (PMLs) provided by HP are current and representative. Energy and transportation data are mid-2010's, and production data for materials are largely based on data sets ranging from the mid- to late-2010's and beyond. Geographical representativeness describes the geographical area from which data for unit processes are collected to satisfy the goal of the study. Data for energy, materials, processes, and transportation are based on Asia sources and/or Asia-customized data wherever possible.

Technological for the cartridge assembly processes belongs to HP. Technological data for most materials and processes are generally industry average, and in some instances, typical.

### **Consistency**

Consistency is a qualitative understanding of how uniformly the methodology is applied to the various components of the study. Consistency was maintained in the handling of the products as well as the approach to the production phase of previous toner cartridge LCA studies.

### **Reproducibility**

The level of detail and transparency provided in this report allow the results to be reproduced by another LCA practitioner as long as the production datasets are similar.

### **Precision and Completeness**

Precision represents the degree of variability of the data values for each data category. Precision cannot be quantified for this study since only one set of data for each HP cartridge was provided. Completeness is the percentage of flows that have been measured or estimated. The cartridges contain well-measured, accurate data from HP.

## **LIMITATIONS AND UNCERTAINTY**

It should be borne in mind that the LCA, like any other scientific or quantitative study, has limitations. While it provides an indication of the environmental impacts and attributes associated with product systems, LCA is not a perfect tool for assessing actual impacts and attributes. This is true for LCA studies in any sector. As is normal for an LCA, much of the data used for modeling the materials is secondary. Because the quality of secondary data is not as good as primary data, the use of secondary data creates some level of uncertainty since it may cover a broad range of technologies, time periods, and geographical locations. Furthermore, since hundreds of data sets are linked together and it is often unknown how much the secondary data used will deviate from the specific system being studied, quantifying data uncertainty for the complete system becomes very challenging. As a result, it is not possible to provide a reliable quantified assessment of overall data uncertainty for the study, but it is understood that each product compared possesses this similar type of uncertainty. Because of the uncertainty in the study, results within +/- 10% may be considered on par, or characterized as inconclusive as to which option has the lower environmental impact.

## **CONCLUSION**

High quality production data were used to model the cradle-to-gate production of HP EvoCycle cartridges and Original HP cartridges sold to customers in EMEA. In almost all categories assessed, the HP EvoCycle cartridge system has lower environmental impact. HP is finding innovative ways to weave Circular Economy and sustainability into their products and processes. With the innovative evocycling process, where new cartridges are made with reused cartridge parts and closed loop recycled plastic, the overall production phase environmental impacts are greatly reduced.

In addition to the production of a cartridge, environmentally based decision-making for cartridges should also consider their reliability and performance during printing, to avoid wasting paper, electricity, and toner during reprinting. Since HP EvoCycle cartridges undergo rigorous HP and third-party quality testing before placement in the market, they maintain the high print performance that Original HP cartridges are known for, making either system a wise overall choice.<sup>v</sup>

## **APPENDIX 1 INDICATOR DESCRIPTIONS**

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The life cycle impact assessment (LCIA) categories evaluated in this study are from the ReCiPe methodology<sup>vi</sup> (except where noted below), and reflect a comprehensive set of environmental issues that cover different environmental media (i.e., air emissions, water effluents, waste, etc.) and endpoints (effects to vegetation, human health, etc.). By presenting results for a comprehensive set of issues, the reader will be able to understand trade-offs in the systems. This reduces the subjectivity of choices made during category selection.

- **Global warming** calculates the greenhouse gas emissions which have been generated by the systems and includes production of materials, production of paper, electricity during use, transportation and distribution, etc. 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. Global Warming is also referred to as “Climate

Change” or the “carbon footprint”. It is calculated using factors from the 2021 Intercontinental Panel on Climate Change (IPCC) report and is reported in kilograms (kg) of carbon dioxide equivalents.<sup>vii</sup>

- **Stratospheric ozone depletion** provides an indication of the decline in the ozone layer, which 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 (CFC-11) equivalents.
- **Ozone formation** quantifies the potential for smog-forming gases that may produce photochemical oxidants or ground-level ozone. This is reported in kg of nitrogen oxides equivalents.
- **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.
- **Freshwater Eutrophication** 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.
- **Human Toxicity:** Human toxicity provides an indication of the risks of health-related issues to humans. This is reported in terms of 1,4 dichlorobenzene equivalents. Human health and other toxicity results have high uncertainties and readers of this report should understand the high limitations with this type of category.
- **Water Consumption**, reported in cubic meters, measures the use of water in the systems and encompasses cooling water, process water, and any water use associated with the systems.
- **Total Energy**, reported in Megajoules and based on the Cumulative Energy Demand methodology,<sup>viii</sup> encompasses fuel energy, including fossil- and non-fossil fuels such as nuclear power, hydropower, and biomass, and embodied energy, such as hydrocarbons embodied in plastics. It includes the energy required for production of cartridge parts and materials and transportation through the supply chain.

## Endnotes

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- <sup>i</sup> Approximate average black yield based on ISO/IEC 19752. Approximate average composite cyan, yellow, magenta yield based on ISO/IEC 19798. Actual yield varies considerably based on content of printed pages and other factors. For details, see <http://www.hp.com/go/learnaboutsupsplies>.
- <sup>ii</sup> 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.
- <sup>iii</sup> Ecoinvent Centre, Ecoinvent data v3.9 (Dübendorf: Swiss Centre for Life Cycle Inventories, 2023), [www.ecoinvent.org](http://www.ecoinvent.org), retrieved from [www.ecoinvent.org](http://www.ecoinvent.org) and within SimaPro.
- <sup>iv</sup> PRé Consultants: SimaPro 9.5 LCA Software. 2023. The Netherlands. More information can be found at [www.pre.nl](http://www.pre.nl).
- <sup>v</sup> 2023 SpencerLab Reliability study, commissioned by HP, comparing Original HP 410X series Toner Cartridges with HP EvoCycle 410XR series Toner Cartridges. See <https://www.spencerlab.com/reports/HP-EvoCycle2023.pdf>.
- <sup>vi</sup> Huijbregts M.A.J., Steinmann Z.J.N., Elshout P.M.F., Stam G., Verones F., Vieira M., Zijp M., Hollander A., van Zelm R. ReCiPe2016: a harmonised life cycle impact assessment method at midpoint and endpoint level. *Int J Life Cycle Assess* (2017) 22: 138: <https://link.springer.com/article/10.1007/s11367-016-1246-y>. Latest adaptations made in 2018. The default version for the midpoint method, “Hierarchist”, was used. See [www.pre.nl](http://www.pre.nl) for more information.
- <sup>vii</sup> IPCC, 2021: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, In press, doi:10.1017/9781009157896. Factors provided in SimaPro.
- <sup>viii</sup> CED is based on ecoinvent version 2.0 and has been expanded to include elements from the SimaPro database. Frischknecht R., Jungbluth N., et.al. (2003). Implementation of Life Cycle Impact Assessment Methods. Final report ecoinvent 2000, Swiss Centre for LCI. Dübendorf, CH, [www.ecoinvent.ch](http://www.ecoinvent.ch). Recent adaptations to the method in 2018. See also [www.pre.nl](http://www.pre.nl) for more information.