Life Cycle Assessment of a Solid Ink Printer Compared with a Color Laser Printer

White Paper

General Conclusion:
A life cycle assessment (LCA) of a 30 ppm color solid ink printer and a comparable 25 ppm color laser printer under similar operating conditions was conducted by Xerox Corporation and underwent peer review by the Rochester Institute of Technology to confirm that it adhered to generally-accepted LCA methodologies. The study assessed the total life-time energy invested in the manufacture, transportation, and use of the two printers. Global warming impacts were also studied. The assessment concludes that the solid ink printer studied has 12% lower life cycle energy demand and 18% smaller global warming impact than the laser printer.

This document summarizes a life cycle assessment of a solid ink printer and a comparable color laser printer.

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Executive Summary:

This report summarizes the life cycle assessment (LCA) of a 30 ppm color solid ink printer and a comparable 25 ppm color laser printer under similar operating conditions. The study was conducted by Xerox Corporation and underwent peer review by the Rochester Institute of Technology to confirm that it adhered to generally-accepted LCA methodologies. The assessment concludes that the solid ink printer studied had 12% lower life cycle Cumulative Energy Demand and 18% smaller Global Warming Potential than the laser printer.

Introduction:

Laser printers create an image by fusing powdered toners to paper. Color laser printers typically include parts such as photoconductors, transfer rollers, fuser rollers, fuser oilers, four toner cartridges and waste toner bottles. The life expectancy of these components is dependent on either the number of pages printed or the amount of each color used per print. Most consumer and small business laser printers use a cartridge that combines the photoconductor with the supply toner and waste toner bottles and various other parts in a cartridge assembly. When the supply toner is consumed, the cartridge is replaced.

Solid ink printing technology is a relatively new technology, with the first commercial printer introduced in 1991. It creates an image by applying melted ink to paper where it instantly solidifies. Solid ink sticks are melted into the printhead which jets the ink onto the print drum. Paper is passed between a roller and the print drum under pressure and the image is transferred from the print drum to the paper. Solid ink has the critical property of remaining in solid form until heated to a very specific temperature whereupon it turns to liquid, then instantly turns back to solid when printed. Since the ink sticks are solid, there is no need to contain the ink in a cartridge, leaving nothing to dispose of when the ink stick has been consumed. There is only one replacement item in the solid ink printer, the drum maintenance unit. All of the remaining parts, including the printhead are designed to last the lifetime of the printer.

Despite being a relatively new technology, solid ink printing has several attributes that are environmentally equivalent, or in some cases even superior to, laser technology. For example, solid ink technology produces less post-consumer waste (up to 90 percent), and requires fewer replacement parts and supplies, thus reducing the number of items that need to be transported to the customer.

Objective:

In order to quantify the differences between the printing technologies, a study was undertaken to compare the environmental impacts of a solid ink printer to a conventional laser printer using a transparent, internationally recognized LCA method. Prior internal assessments have indicated that paper use and energy consumption are the two largest contributors to the environmental impacts of office printing. Based on this understanding, the primary purpose of this study was to evaluate both the Cumulative Energy Demand (CED) and the Global Warming Potential (GWP) impacts of these technologies. Cumulative Energy Demand is the total life-time energy invested in the manufacture, transportation, and use of a product. Global Warming Potential is a measure of greenhouse gas contribution to global warming of these same activities and is expressed as carbon dioxide equivalents. While the impacts of the paper cycle are important, they were excluded from the analysis as this was assumed to be equivalent for both devices.

Methodology:

A life cycle assessment (LCA) is an evaluation of the environmental impacts of a product or service over all stages of its life. An LCA model typically begins with the extraction of raw materials to create the components of a product, and continues through its manufacture, use, and end-of-life disposition, including transportation steps along the way. Various categories of environmental impacts are typically evaluated, including energy demand, global warming potential, ecological and human toxicity, impacts to air and water quality, and depletion of raw materials.

LCA is a well-recognized technique with international standards defining its use. There are four distinct steps of an LCA:

1. Goal definition and scope
2. Life cycle inventory of the inputs and outputs that flow to and from the environment during every step of the product's life
3. Impact assessment that characterizes the effect of the inputs and outputs on the impact categories.
4. Interpretation of results to determine major contributors to the outcome, as well as sensitivity and uncertainty analysis.

Scope

The scope of the assessment included the inputs and outputs associated with the manufacturing of the printing device and consumables, the use of the device, and the packaging and transport of the consumable items (such as cartridges) and their reuse and recycling. The model excluded the inputs and outputs associated with the end-of-life collection and disposal of the devices themselves and their non-consumable replacement parts. Service activities during the active life of the product were also excluded. The inputs and outputs associated with these excluded steps were assumed to be roughly equivalent between the solid ink and laser printer.

While the impacts of the paper cycle are very important, they were excluded from the analysis as this was assumed to be equivalent for both devices.

Assumptions

Both printers were assumed to have equal print quality, monthly volumes, and lifespans: 4000 prints per month over a four year life. Based on market distribution data for these types of products, a 60% US/40% European split was assumed, with energy mix and transportation distances determined accordingly. In the model, the solid ink printer is manufactured in Malaysia, while the laser printer is manufactured in Japan.

End-of-life disposition of cartridges was estimated from US Environmental Protection Agency (US EPA) statistics and competitive information, with 10% remanufactured in the aftermarket, 25% recycled, and 65% landfilled. Packaging for both products was assumed to be 60% recycled content and 40% virgin content, based on EPA statistics. For packaging, 70% was modeled as recycled at end of life, with 30% going to landfill.

Data Sources

The analysis was conducted using SimaPro7, a commercially available and widely used software tool. Direct manufacturing data was used when available, with "industry average" data from the tool database being used when direct data were unavailable. Direct data were used for toner and solid ink production and some device and consumable manufacturing. "Industry average" was used for the material inputs to the manufacturing process and the remaining manufacturing activities.

Operating energy consumption was calculated for both machines using the US EPA's Energy Star® Typical Energy Consumption (TEC) test method, which is designed to simulate the energy consumption patterns during a typical office work week. The TEC test procedure job length was modified to achieve the average monthly print volume of 4000 images, but otherwise followed the EPA protocol and utilized actual energy consumption values for both machines.

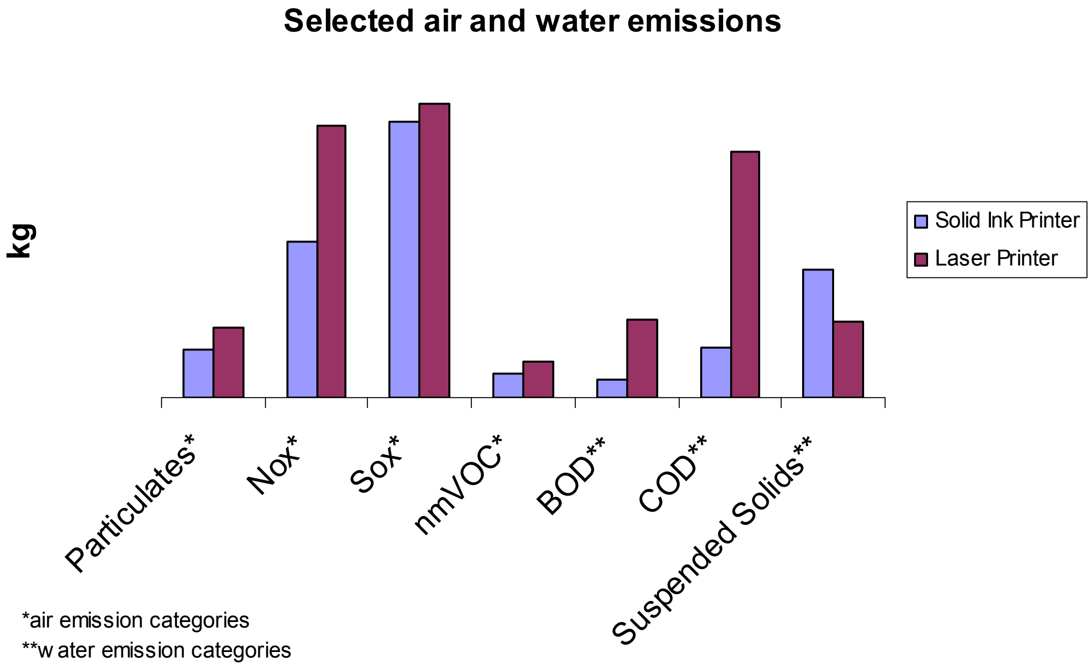
Impacts Studied

Prior internal assessments have indicated that paper use and energy consumption are the two largest contributors to the environmental impacts of office printing. Because equal print volumes (and thus paper use) were defined for the two printers and because the primary purpose of this study was to evaluate the cumulative energy demand (CED) and global warming potential (GWP) impacts of these printers, paper use was excluded from the analysis

Life Cycle Inventory

The Life Cycle Inventory (LCI) provides an inventory of the inputs and outputs of the two systems modeled. For purposes of comparison, a subset of air and water emission outputs were chosen that correspond with those regulated by the US EPA or the U.S. Occupational Health & Safety Administration and that are commonly reported by industry. The results in Figure 1 show that the solid ink printer had lower emissions for 6 of the 7 emissions including particulates, NOx, SOx, VOCs, BOD, and COD and higher emissions for suspended solids.

Figure 1. Selected air and water emissions over the printer life cycles



Results:

Impact Assessment

The IA is used to convert the contribution of the LCI of the two printers modeled to indicators that describe the impact on the environment. Consistent with the objective of the study, two mid-point assessments were chosen - Cumulative Energy Demand and Global Warming Potential

Figure 2: Relative Contribution of a Solid Ink printer to a comparable color laser printer in terms of Global Warming Potential and Cumulative Energy Demand

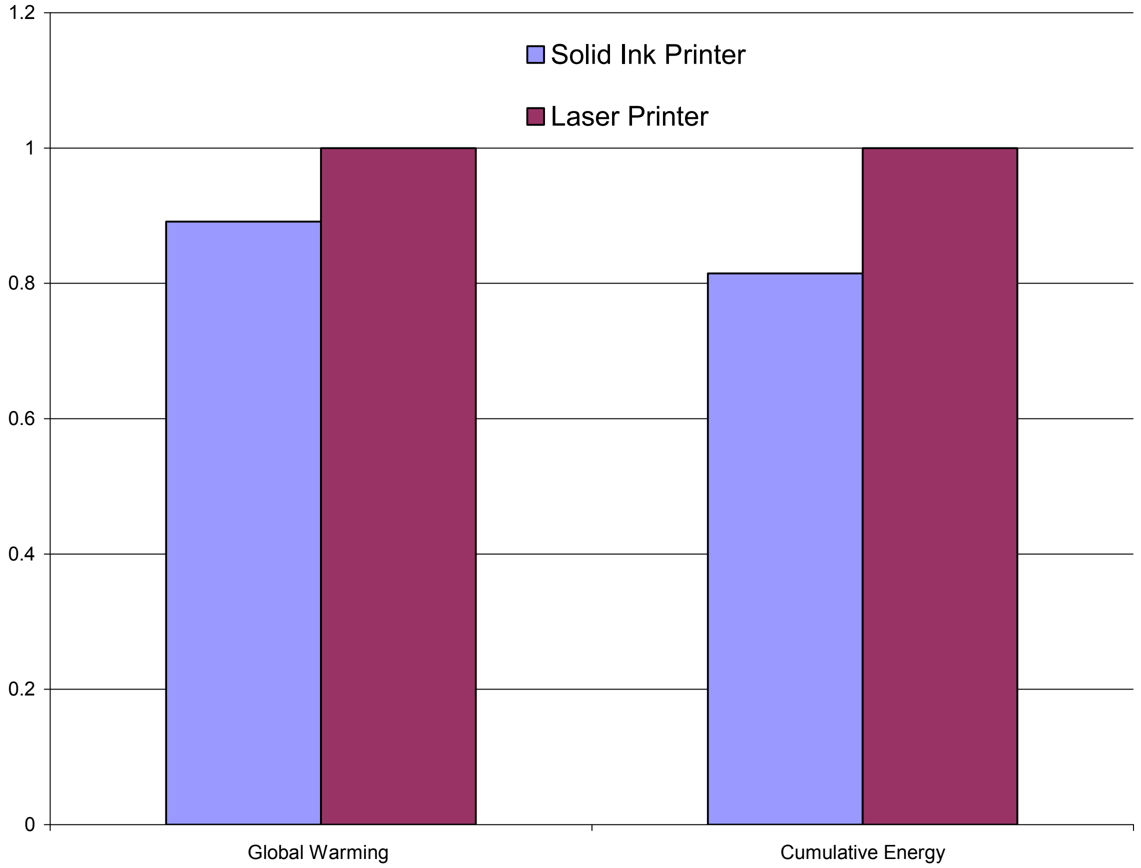
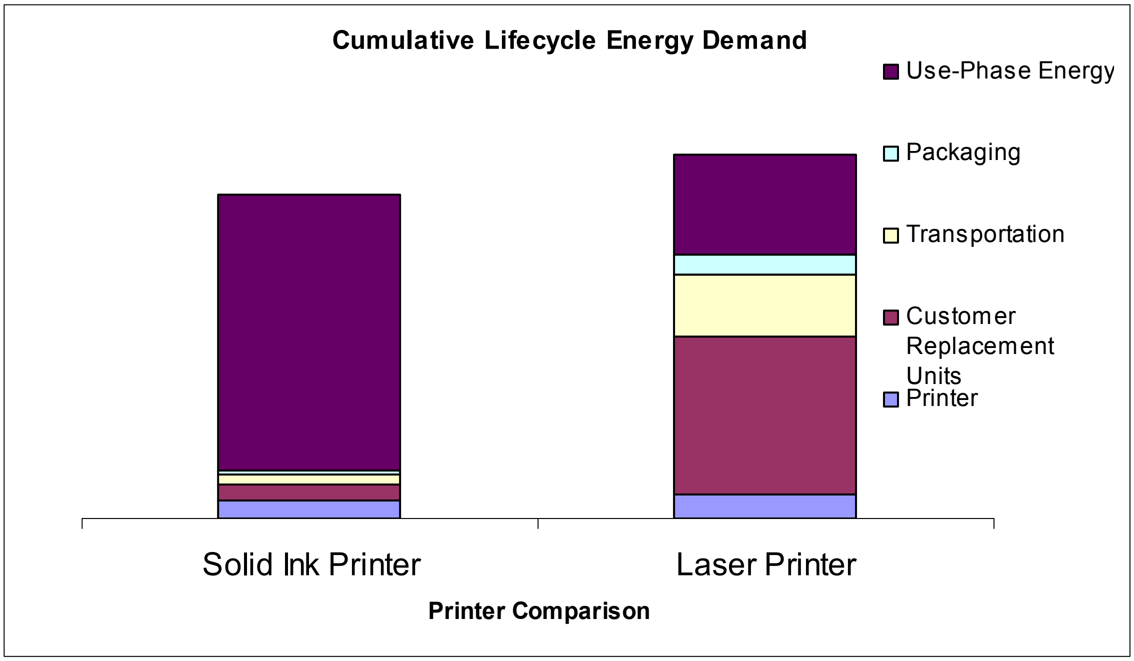


Figure 2 shows the relative contribution of Global Warming, or Carbon Emissions and Cumulative Energy demands from each printer. The solid ink printers is 12% lower than the laser printer contribution in terms of CED and is 18% lower in terms of GWP.

As shown in Figure 3, the CED is the sum of five categories: 1) Printer: the material acquisition and manufacturing of the device itself (excluding consumables), 2) CRU: the customer replaceable units including consumables (ink, toner and cartridges), 3) Packaging, 4) Transport of goods and parts and 5) Use-phase operating electricity consumption.

The CED varied by category, with the solid ink printer exhibiting 12% lower CED over the lifecycle

Figure 3. Cumulative Energy Demand Comparison by Category



The Global Warming Potential (GWP) of the solid ink printer is 18% lower than the laser printer. As shown in Figure 4, the GWP is also the sum of five categories and varied in a pattern similar to that of the CED.

Uncertainty analysis supported both of these results.

Figure 4. Global Warming Potential Contributions by Category

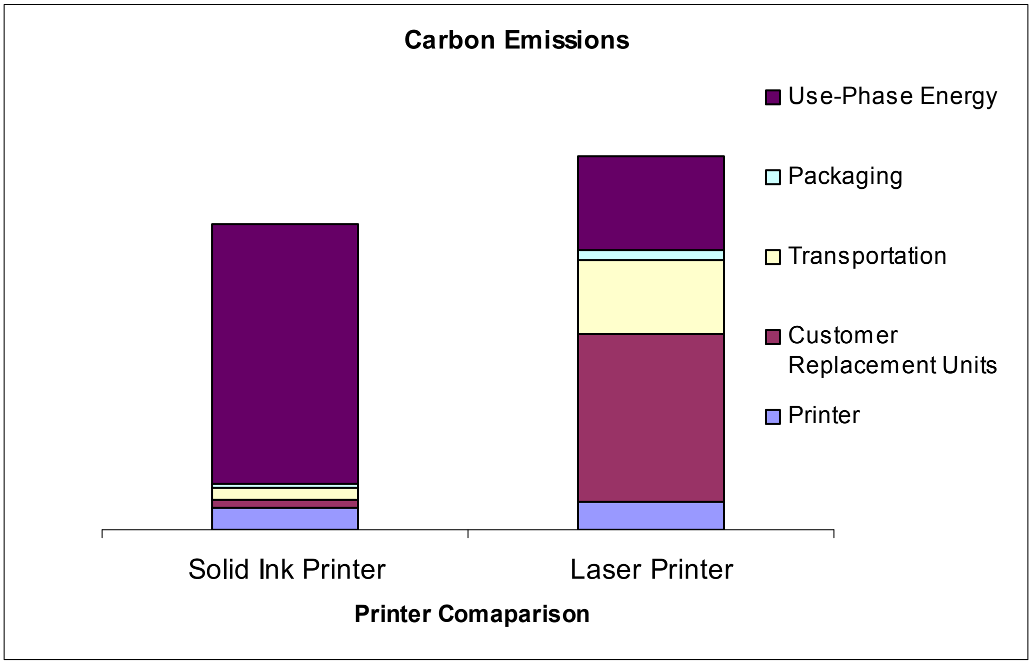
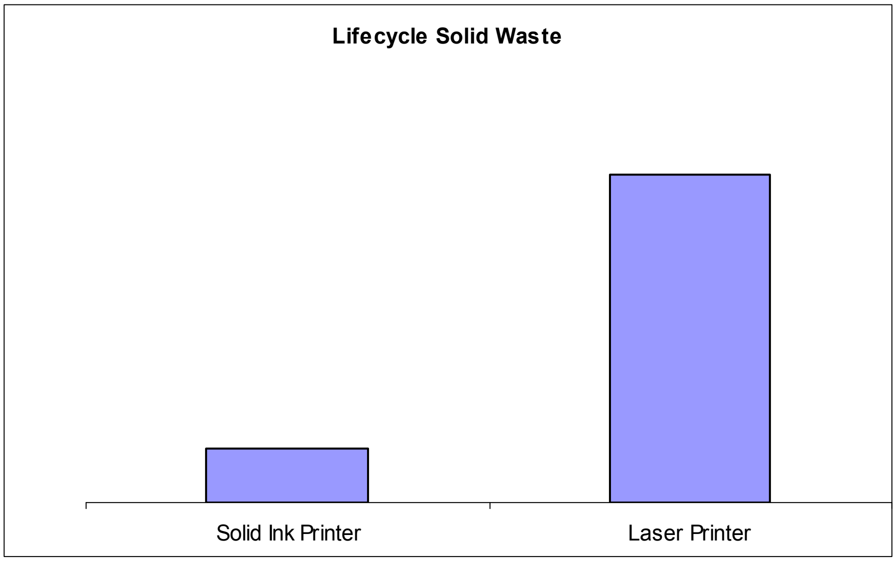


Figure 5 shows the difference between the two printing technologies with respect to post consumer waste. The total post consumer waste numbers were used because it represents the total amount of waste that they customers have to dispose of either through recycle, cartridge return or municipal waste. The solid ink printer creates 90% less waste than the laser printer.

Figure 5. Total Lifecycle Solid Waste



Conclusions:

Over the product lifecycle, the solid ink printer studied exhibited 12% lower Cumulative Energy Demand and 18% smaller Global Warming Potential. This conclusion was supported by an Uncertainty Analysis. It also produced fewer emissions for 6 of the 7 emissions categories, with the only exception being suspended solids. Lastly, the post consumer waste generated by the solid ink printer was 90% less than the comparable color laser printer. All of these results are primarily driven by the number of supplies needed to run the color laser device, while the solid ink printer does not require a cartridge or carrier for the ink, therefore using less energy and materials over the lifecycle, and producing less waste