The Future of Toner: Life-Cycle Inventory, Impacts and Environmental Technologies

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Abstract

A recent life-cycle assessment (LCA) on remanufacturing of toner cartridges in partnership with a major office supplies retailer determined that the toner is responsible for a significant portion of the full life cycle energy and environmental impact, as well as the energy required to produce a remanufactured cartridge. The details and results of this LCA will be discussed in this paper. Since toner resulted in a key component of the life-cycle, there is considerable opportunity to reduce the environmental impact and energy use of a toner cartridge through the use of more environmentally friendly toners. In anticipation of companies designing copiers and printers that use more environmentally friendly toners, this paper investigates the environmental impacts of these toners. Examples of toners that claim a smaller environmental footprint are emulsion-aggregation toner from Xerox, Simitri HD toner from Konica Minolta, and bio-based toner resin, BioRez® by Advanced Image Resources, Inc. The life-cycle impact of the toners and a qualitative assessment of the environmental tradeoffs associated with petroleum based toners versus bio-based toners are investigated in order to more accurately compare these toners.

The Center for Sustainable Production (CSP) at Rochester Institute of Technology (RIT) was commissioned by a major office supplies retailer to perform life cycle assessments of an original equipment manufacturer (OEM) toner cartridge and a remanufactured toner cartridge counterpart in order to compare the environmental impact of the two cartridges. Life cycle assessment (LCA) is a tool used to quantify the environmental impacts of a product, holistically, throughout the entire life cycle; from material extraction, manufacturing, transportation, use, and end of life. The impacts associated with each cartridge were assessed by compiling an inventory of relevant energy and material inputs and environmental releases, evaluating the potential environmental impacts associated with identified inputs and releases, and interpreting the results (See Figures 1 and 2). CSP modeled and compared the environmental impact and cumulative energy demand of the OEM and remanufacturing cartridge life cycles using a combination of measured and published data, ecoinvent data, and SimaPro 7.2 software. This life cycle assessment was performed in accordance with ISO 14040:2006(E) *Environmental management – life cycle assessment – principles and framework* [1].

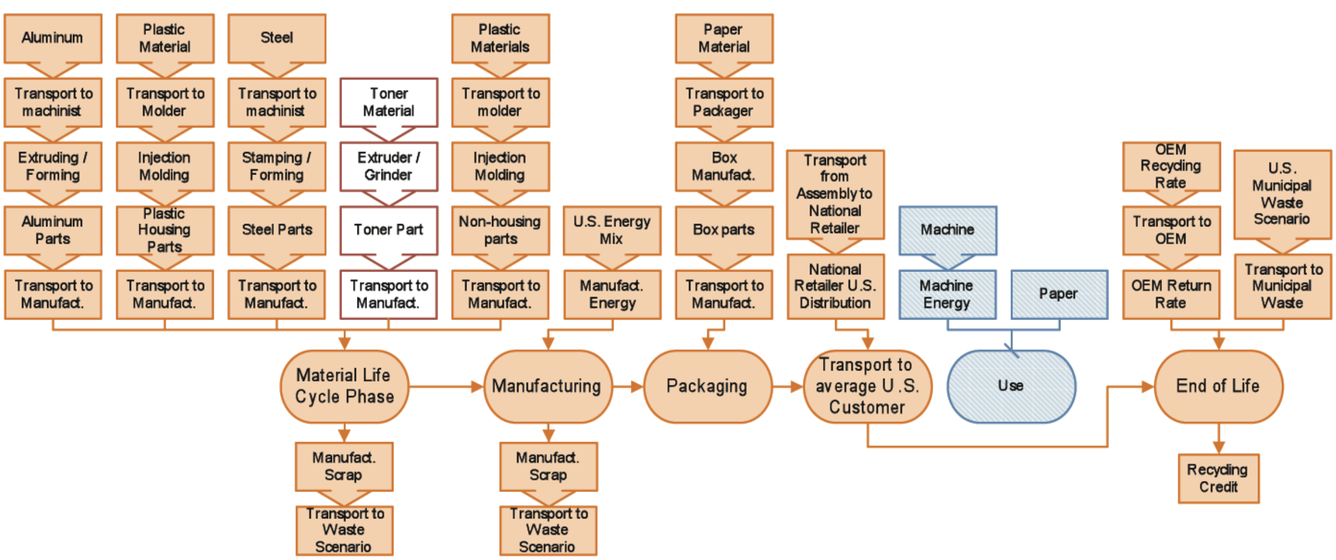

***Figure 1**. OEM Life Cycle System Boundary*

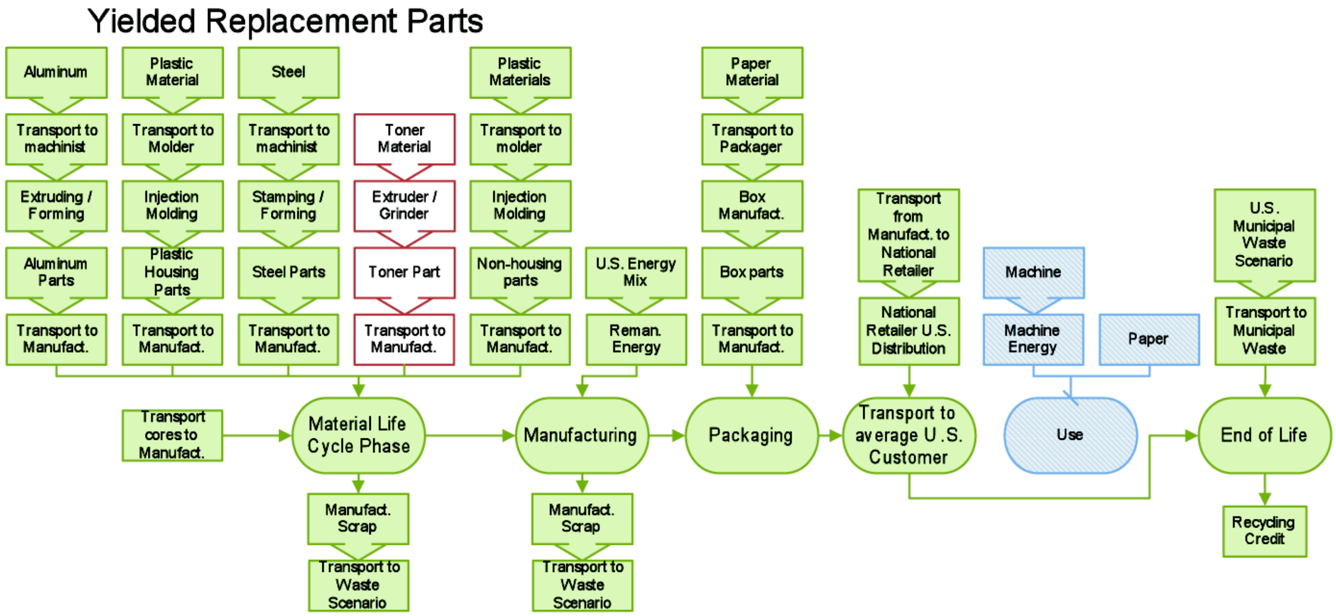

Figure 2. *Remanufactured Cartridge Life Cycle System Boundary*

The system boundary of the LCA was set up to specifically compare the life cycle of toner cartridges, and excludes the printer, energy required to run the cartridge, and the paper required for printing. The printer, energy, and paper were excluded based on five years of data from an independent university lab which showed the image quality and page yield of this specific brand and model of remanufactured cartridge is essentially equivalent to the OEM.

The results from the LCA revealed the "Material" life cycle stage, which includes toner, is the primary contributor to environmental impact of the OEM and remanufactured cartridges. The remanufactured cartridge reuses a significant mass of materials, resulting in a dramatic reduction in the life cycle impact, as seen in Figures 3 and 4. Note that all life cycle stages, including the remanufactured cartridge stages, are normalized as a percentage of the OEM total.

The LCA also revealed that toner is responsible for approximately 30 percent of the OEM full life cycle energy and environmental impact, and greater than 40 percent the full life cycle environmental impact and 50 percent the energy of a remanufactured cartridge. For this evaluation, toner in the OEM and remanufactured cartridges was modeled as equivalent toner

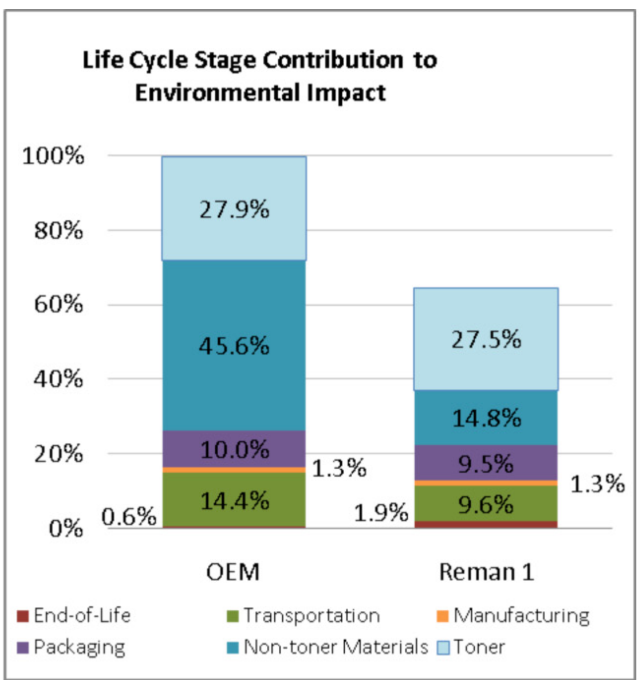

Figure 3. *Life Cycle Stage Contribution to Environmental Impact*

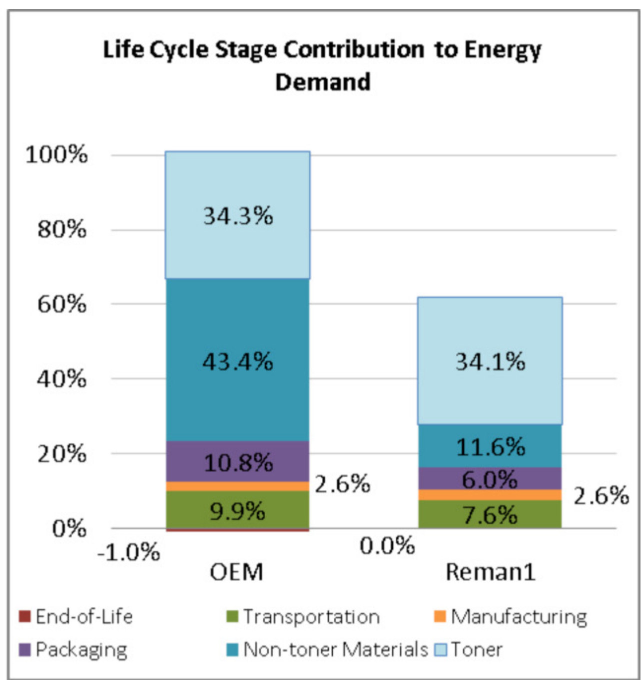

Figure 4. *Life Cycle Stage Contribution to Energy Demand*

material for both cartridges, using representative peer reviewed data from the ecoinvent database. However, the ecoinvent database currently contains the life cycle inventory data set for only one type of toner. This toner is based on a specific manufacturing method where raw materials are compounded, ground, classified and packaged [2]. Since toner is a significant portion of the results, there is considerable opportunity to reduce the environmental impact and energy use of a toner cartridge through the use of more environmentally friendly toners.

There are many other formulations of toner, such as toner produced from soybean extraction [3] and polyester based toners [4]. The raw materials used in formulating toner and their respective manufacturing processes are directly linked to the energy used to fuse the toner to paper and to their fate at the end-of life (landfill, incineration, de-inking and recycling, etc.) and overall life-cycle impact. Therefore, it is important to utilize appropriate toner data so manufacturers can accurately compare the life-cycle of their products to others where different toners are used. By understanding the life-cycle assessment of alternative toners, clients, customers and manufacturers can understand the environmental benefits, degree of benefit expected, and overall impacts of their products.

Due to limited life-cycle data on toners, this paper will incorporate a qualitative assessment of the environmental tradeoffs associated with various toners, such as petroleum based vs. soy-based toners.

References

[1] International Organisation for Standardisation, ISO 14040: Environmental management – Life cycle assessment – Principles and framework, Geneve, (2006).

[2] A. Williamson, et al, “Life-cycle Inventory of Toner Produced for Xerographic Processes,” J. Cleaner Production, 11, 573-582 (2003).

[3] T. Owada, et al., Bio-Toner Containing Bio-Resin, Method for Making the Same and Method for Printing with Bio-Toner Containing Bio-Resin, U.S. Patent 0239969 (September 23, 2010).

[4] G. McAneney-Lannen, et al., Toner Compositions and Processes, U.S. Patent 0099037, (April 22, 2010).

Author Biography

Dr. Williamson holds a B.S. in chemical engineering and M.S. and Ph.D. degrees in civil and environmental engineering, all from Clarkson University. She led numerous teams at Xerox Corporation in defining environmental opportunities within processes/products by optimizing complex system. Currently she serves as Director, New York State Pollution Prevention Institute, a statewide research and technology transfer center funded by the New York State Department of Environmental Conservation, based at Rochester Institute of Technology, Rochester, NY.