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R·I·T Printing Industry Center

June 2011

eReview

Life Cycle Analysis in the Printing Industry

Life Cycle Assessment (LCA) is the leading tool for estimating environmental effects of products and processes. Despite this wide use, LCA analysis remains problematic and limited. Within the printing industry, one of the primary problems is non-standardized assumptions and practices. This makes it difficult, if not impossible, to compare the life cycle impacts of products.

The primary objective of this month's research study, *Life Cycle Analysis in the Printing Industry: A Review* (PICRM-2011-05), by Justin Bousquin, Marcos Esterman, Ph.D., and Sandra Rothenberg, Ph.D., was to compare LCA studies performed within the printing industry in order to identify common practices, limitations, areas for improvement, and opportunities for standardization. This comparison was focused on the data sources and methodologies used in the studies.

Table 1 summarizes the studies. It should be noted that while pulp and paper production are clearly an important contributor to the life cycle impacts of printing, explicit studies of these industries were not included in this review since their impacts are typically accounted for in the studies reviewed in this work.

Table 1. Studies analyzed

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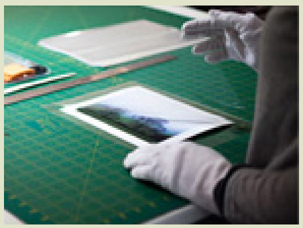
Center Spotlight



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August 17 - 19
Lithographic Relationships & Variables

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Category/#	Short title	Author & Year	Product	Purpose
Printers				
[1]	Product Environmental Metrics for Printers	Ord et al. 2009	Printers	Internal design tool
[2]	Solid Ink LCA	Koehler et al. 2010	Solid ink and ink jet printers	Comparative LCA
[3]	Eco-efficiency Gains From Re-manufacturing	Kerr & Ryan 2001	Photocopier remanufacture	Comparative LCI: Reuse vs. new
[4]	Extended Producer Responsibil-ity for Waste Electronics	Mayers et al. 2005	HP printers	Comparative LCA: End-of-life
[5]	EuP Preparatory Studies "Imag-ing Equipment"	Stobbe 2007	EP & IJ printers, copiers and MFDs	Industry baseline LCA
Cartridges				
[6]	LCA Toner Cartridge C4127X	Berglind & Eriksson 2002	HP cartridge C4127X	Comparative LCA: Remanufacture
[7]	LaserJet Cartridge Life Cycle Refresh Study	Four Elements Consulting 2008	HP LJ 10A and remanufactured cartridges	Comparative LCA: Remanufacture
[8]	Life Cycle Inventory of Toner for Xerographic Processes	Ahmadi et al. 2003	Toner	LCI of toner
Print products				
[9]	Life Cycle Carbon Footprint of the National Geographic	Boguski 2009	Magazine	Carbon footprint
[10]	LCA: Flexographic and Rotogra-vure Printing	Veith & Barr 2008	Packaging materials printing	Comparative LCA
Design methodologies/Tools				
[11]	Methodology for the Evaluation of Product Sustainability at the Design and Development Stage	Silva et al. 2006	Not applicable	Design stage sustainability scoring
[12]	Development of a Green Score-card	Ebner et al. 2009	Printers	Design directional indicator
Consumer "calculators"				
[13]	HP Carbon Footprint Calculator for Printing	Hewlett-Packard 2009	Personal and office printers	Cost and carbon calculator
[14]	Xerox Sustainability Calculator	Xerox 2008	Personal and office printers	Compare baseline and optimized print scenarios

Methodology

Analysis of the studies was based on the life cycle assessment framework specified by ISO 14040 (see Figure 1). The categories shown in the framework served as the basis for conducting the comparisons.

Figure 1. Life cycle assessment framework from ISO 14040
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Orientation to the Graphic Arts

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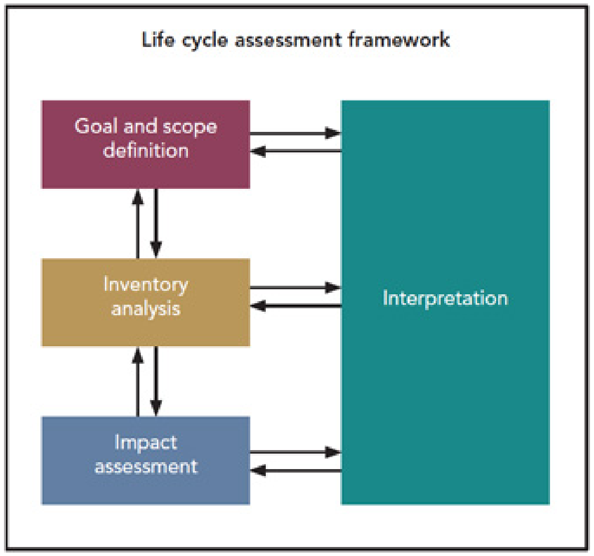

Results

The goal of a particular Life Cycle Assessment (LCA) is essential to identify and assess impacts to be examined, omissions that need to be made, and other basic underlying assumptions. The context within which the study was conducted is also equally important. Organization affiliation and the intended use of the studies were used to identify the context of these studies. Organizational affiliation refers to the sector from which the practitioner who conducted the LCA came from, namely academia, industry external (consultant), or industry internal. The second characteristic refers to the intended audience, which is either "Internal Design," "External Marketing", or to establish a general "Baseline" for comparison of two or more alternative technologies. These results are summarized in Table 2.

Table 2. Study context
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About the Center

Dedicated to the study of major business environment influences in the printing industry precipitated by new technologies and societal changes, the Printing Industry Center at RIT addresses the concerns of the printing industry through educational outreach and research initiatives.

Support for the Center comes from:

Sloan Foundation
Rochester Institute of Technology

Adobe
Avery Dennison
Gannett
Hewlett-Packard
NewPage Corporation
NPES
Scripps Howard Foundation
VIGC
Xerox Corporation

Stage	Cartridge Remanufacture		Baseline Academia		Comparative		Design Tools			Calculators		Baseline Industry		
	[6]	[7]	[5]	[4]	[10]	[2]	[11]	[12]	[1]	[13]	[14]	[3]	[9]	[8]
Raw Materials	B	B	C	C	B	B	B	C	B	D	C	C	A	B
Production	B	C	C	E	B	B	E	C	B	C	C	C	A	A
Transportation	B	B	B	E	C	B	E	B	C	D	D	C	B	B
Use	B	B	B	E	A	B	B	B	C	B	C	E	E	B
End-of-life	B	B	B	B	C	B	B	B	C	D	C	B	B	B
Packaging	B	B	C	B	D	B	B	C	E	D	B	D	E	C

Explanation of Grades:

A - Primary data measured on site during the phase. All relevant aspects seem to have been accounted for.

B - Database data or literature-referenced data. May be missing part of a process.

C - Incomplete data or estimates, but still representative of some impacts in this stage.

D - Stage was not included in study scope.

E - NA, was excluded due to lack of applicability to study goals.

The scope of the LCA is defined through choices made as to the definition of the functional unit and the system boundaries. (Comparison of the functional unit and the usage data can be seen in the full monograph.) In terms of system boundaries, most of the studies examined do consider inputs from all stages of the product life cycle. This does not mean, however, that all inputs from each stage are accounted for. In addition, the depth to which the environmental impacts for these inputs are accounted for is also varied. Table 3 shows a "grade" for the data used at each stage of the life cycle by study.

Table 3. Graded life cycle stage data
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Study #	Organization affiliations	Practitioner	Audience
[1]	Hewlett-Packard	Industry Internal	Internal – Design
[2]	Xerox (RIT Review)	Industry Internal	External – Marketing
[3]	Lund University, Melbourne Institute of Technology, Fuji-Xerox	Academia	Internal – Design
[4]	University of Surrey (HP Data)	Academia	Baseline
[5]	Fraunhofer IZM	Academia	Baseline
[6]	Kalmar, Black and Write	Academia	Baseline & Marketing
[7]	Hewlett-Packard, Four Elements Consulting	Industry External	Baseline & Marketing
[8]	Clarkson University (Xerox Data)	Academia	Baseline
[9]	Harmony Environmental, National Geographic, Verso Paper, Quad Graphics	Industry External	Baseline & Marketing
[10]	DuPont, Five Winds International (Review)	Industry Internal	Baseline & Marketing
[11]	University of Kentucky, Lexmark	Academia	Internal – Design
[12]	Xerox	Industry Internal	Internal – Design
[13]	Hewlett-Packard	Industry Internal	External – Marketing
[14]	Xerox, consultants	Industry External	External – Marketing

There were no definite trends concerning life cycle stage omissions. Transportation and packaging were lacking high-quality data or ignored in many of the studies. Raw materials acquisition was missing in the greatest number of studies, likely because the practitioners faced difficulties in obtaining upstream data. Also, it is difficult for practitioners to determine adequate upstream cutoffs, as many times there are unknown processes involved in the production of component materials. Surprisingly, considering the difficulty in accurately estimating it, the end-of-life stage was the most populated. This is partly due to the focus of design tools on reuse and recyclability.

Transportation and packaging are not the only data that are sometimes omitted. As discussed with the functional unit, paper and print speed are two considerations often necessary for consistent comparability of printer LCA data. Yet paper is sometimes removed from comparative assessments under the assumption that the differences between the products will not have an impact on paper (see Table 4).

Table 4. Study inclusion / exclusion of paper and print speed

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Study #	Paper	Print Speed
[1]	IPCC, excludes fiber source	User input
[6]	Included in sensitivity analysis	Constant
[2]	Assumed to be equivalent	Solid ink: 50 PPM; Laser: 51 PPM
[14]	Excluded	Laser: Input; Ink jet: Excluded
[8]	Outside functional unit	Outside function
[12]	Included, adjusted for duplexing	User input
[10]	All substrates included, 8% & 35% paper	Not included
[4]	Outside scope	Outside function
[3]	Omitted to highlight End-of-Life	100 (1) & 65 (2)
[7]	Essential to conclusion	Outside function
[11]	Omitted by designers and users	Omitted
[9]	Included, from Verso LCA	Outside function
[13]	Energy from paper and pulp production relative to user paper input	Based on brand and model selection

(1) Xerox 5100 Copier specifications

(2) Xerox Document Center 265 Digital Copier specifications

Life Cycle Inventory

Life cycle inventory (LCI) analysis defines and quantifies the flow of materials and energy into, through, and out of a product system (ISO 14040:2006). By this phase of the LCA study, the practitioner has determined what will and will not be included, but there is still an issue of how to allocate the impact data to the inventory data. Much like dilemmas with life cycle costing methods, there are processes that benefit multiple stages of the life cycle and/or multiple products, and these burdens must be properly allocated. For example, if paper is recycled at end-of-life, what share of the original burden of materials acquisition should be allocated to the original LCA and which should be allocated to the next function of that paper? This allocation dilemma is not specific to the printing industry, and practitioners should attempt to follow standards such as ISO wherever possible.

A substantial barrier to the adoption of LCA metrics has been the cost of collecting necessary data (packaging label printer, personal communication, August 10, 2010).
When an LCA is performed, practitioners often note the difficulty of obtaining accurate data. In fact, five studies specifically note that this difficulty impacted their results. It is worth noting the commonly used databases and methodologies, as well as the standards and certifications upon which industry LCAs and decision tools are based. Figure 2 shows the most commonly cited certifications and standards by the number of studies that referenced them.

Figure 2. Referenced data, standards, and certification sources within studies
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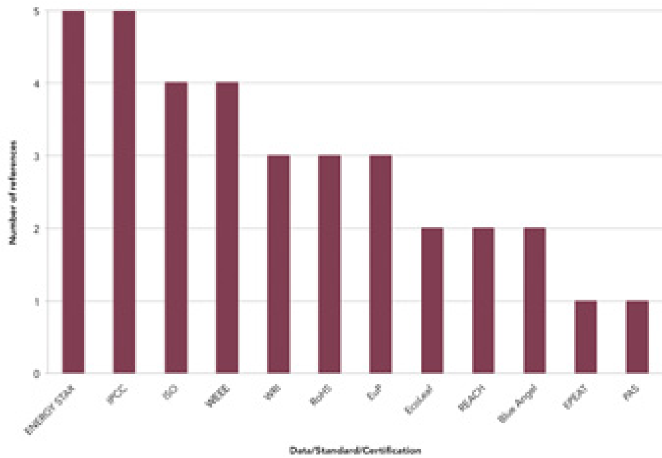

The ENERGY STAR standard and database were used frequently. The standard set forth in Typical Electricity Consumption (TEC) is necessary because of the complexity of energy consumption with varied rates and modes. This standard also is specific to imaging equipment. The ENERGY STAR database helps to identify trends and baselines for studies such as the EuP, and it provides data on competitors' products for inclusion in tools like HP's Carbon Footprint Calculator. Energy is an important component of use-stage environmental impact and this information is therefore very useful.

IPCC is also cited frequently for the standard treatment of Global

Warming Potentials (GWP) over a period of time such as 100 years. All but two of the studies determined impacts for GWP, as this is one of the few impact categories with a clear set of guidelines.

Conclusions

- An approach to standardization needs to include the standardization of measurement methods. This is evident from the prevalent use of GWP 100-years and ENERGY STAR energy consumption standards cited. By following this approach for other categories, more cross-study comparisons will be facilitated.

- Like most LCAs, those performed in the printing industry still lack reliable data for the early life cycle and end-of-life of paper. Some uncertainty issues can be solved by increasing data and data transparency through the inclusion of metadata or reviews.

- Products have diverse functional values beyond simple document production, and these need to be considered in addition to LCA results when making design decisions. Standardization of the functional unit and its included assumptions has a high potential to increase quantitative comparability across studies. At the same time, caution must be taken not to use "paper" to define the imaging device's function, allowing for the inclusion of alternative media in the comparison.

- Assumptions that are not standardized lead to difficulties in comparisons between studies. Some of the most significant assumptions are those on usage behaviors. One approach has been to limit the inclusion of use-phase impacts like paper. This fails to account for any differences that may occur during this phase, however, which may be very significant. Consumer behavior has potential to be the greatest environmental impact reducer (i.e., by reducing misprints or the necessity of printing altogether). The only way to quantify these differences is to gather extensive usage data. A sensitivity analysis should also be included with these behavior data as they are highly variable. Non-LCA decision tools have an advantage in this respect as many of them can simply input qualitative data.

- Consumables should continue to be examined closely. Ink and toner advancements and alternatives have potential to make improvements in less popular impact categories. One such example is the use of soy-based inks. The key to reducing the impact of paper will be wasting less of it and making it more recyclable.

Complexity Rating: 1
Rating reflects complexity level of statistical analysis: 1=none, 2=moderate, 3=difficult.

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