Developing a Tool for Routine Carbon Footprint Assessment of Printing Systems

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Introduction

With a history of product stewardship and a Design for Environment (DfE) program, Hewlett-Packard's Imaging and Printing Group (IPG) has robust systems for ensuring its printing products meet or exceed regulatory and market access requirements in worldwide markets. However, the world increasingly views product environmental impacts as something that requires continuous improvement rather than point compliance. A continuous improvement focus requires a new measurement that communicates the environmental footprint of printing. Measurements or metrics are necessary to facilitate establishment of new product and portfolio performance goals, enable design, track progress, and support communication to internal and external customers and stakeholders.

Lifecycle carbon footprint is an estimate of the greenhouse gas emissions associated with part or all of a product's lifecycle. It is an acute example of a metric where market interest has progressed ahead of accepted standardized measures. Due to the current and expected increasing interest, HP's product and technology development teams needed a tool to routinely assess carbon footprint with a minimum of prior training.

Developing a functional and sufficiently representative assessment tool required that we balance a number of different objectives, including

- scientific rigor
- broad applicability across a diverse portfolio
- ease of use
- alignment with existing standards of practice

Balancing these objectives required a variety of strategies and trade-offs. Those decisions and their implications are the subject of this paper.

Notes on carbon footprint

A carbon footprint is an estimate of the greenhouse gas emissions associated with part or all of a product's lifecycle. The quality of a product carbon footprint figure can range from a crude estimate to one resulting from an expensive and detailed study for a particular product.

It is important to note that these estimates and studies are just models of the system carbon footprint. Like all models, carbon footprint models are only a convenient approximation of reality. The degree of accuracy with which the model represents a product's actual carbon footprint depends on the scope of the model, and the appropriateness and quality of its data and assumptions. There is no single generally accepted definition of "proper" carbon footprint modeling procedures, although efforts to standardize this definition are underway (i.e. PAS 2050, ISO 14067, GHG Product Protocol).

Carbon footprints are typically expressed as a global warming potential (GWP) which implies that all the relevant greenhouse gas emissions have been accounted for (like methane and nitrous oxide) and that each gas's potency and persistency has been normalized against carbon dioxide for either a 20, 100, or 500 year timeframe. When the phrase "carbon footprint" or the label "CO2e" (carbon dioxide equivalent) appears in this paper, it refers to a GWP over a 100 year timeframe.

Development Methods

The first step in tool development was interviews of a sampling of the envisioned users in marketing, design, and stewardship to understand what they wanted in a metric. Based on this feedback, the team defined the following project goal: Provide product designers (in the broadest possible sense of the word) with a business decision support tool that allows them to understand the carbon footprint implications of their decisions and the opportunities for improvement. In pursuit of the goal stated above, our team broke the printer and cartridge mass into 32 different, but commonly used materials.

The team also developed an energy estimator that allows the user to change several key hardware and firmware parameters and compute a new lifecycle energy estimate. The team then linked all of this together into a "metrics tool". To use the metrics tool, the user must enter basic information about the printer system, including the masses for 32 unique materials, the image yields for the consumables, the expected life and duty cycle, whether or not the printer has a duplexer, the speed of the device, and details about its energy consumption.

When done, the user gets the following metrics in return:

- An estimate for the total system lifecycle CO2e, and a breakdown of such for the printer, consumables, paper, and electricity (energy consumption is also reported as a metric).
- An estimate of system CO2e per image printed and a graph of where this result stands compared to other possible monthly image print levels.

System inputs have several notable omissions—including materials: ink, toner; processing: assembly, end-of life disposal; and logistics past the assembly factory gate. These omissions affect the representativeness of the assessment. However, prior assessments [1] indicated that these lifecycle impact sources had little impact compared with other sources. Thus these simplifications enhanced ease of use, while maintaining the accuracy necessary for internal purposes.

Our team chose a "Process" life cycle assessment (LCA) based approach to model the GHG contributions for each print system component. Specifically, each component is modeled with secondary (i.e. "generic") data. The metrics tool converts the electricity consumed by the printer into a carbon footprint via electricity emissions factors in the form of "x kg of CO2e per kWh at the end user". As per the process approach, the metrics tool converts the 32 printer and cartridge material masses, as well as paper, to a carbon footprint using life cycle inventory information from the ecoinvent database [2].

The ecoinvent material processes are converted into CO2e emissions factors using the IPCC 2007 characterization factors for the global warming potential of air emission [3]. The equation below summarizes the process approach. In this equation, GWP stands for the product's lifecycle global warming potential, the ε represents an emission factor, the M is the mass of the material, and the $1-\alpha$ is the fraction of pages saved by duplexing.

$$GWP_{lifecycle} = \sum_{printer} \varepsilon_{material} M_{material} + \sum_{cartridges} \varepsilon_{material} M_{material} + \varepsilon_{elec} E_{elec} + \varepsilon_{paper} M_{paper} \alpha_{duplex}$$

The end result is an emission factor in the form of "x kg of CO2e per kg of material". The electricity emissions factors our metrics tool employs are from 2005 and are published by the World Resource Institute [4]. The handling of paper is critical to the results of our tool given its importance to the end result. At this time, our paper factors do not take into account either the net sequestration or emission of CO2 by the fiber source (forest), or the release of greenhouse gases at the end-of-life (from incineration, aerobic or anaerobic decomposition). Paper is an area of our metrics tool that is under constant improvement.

Discussion

The carbon footprint of a product is not a physical property that can be directly measured. Instead, it is a model that is built from many pieces of primary and estimated data, such as the CO2e emissions for the manufacture of a microprocessor. These pieces of data are then integrated using system level assumptions such as customer behavior. A tension then naturally arises between the level of modeling detail and the accuracy of the result.

To help our metrics package find the right balance between these poles, the team is enlisting four tactics. First, our team has already worked with an external party to review our tool to make sure it achieves its goal, and will continue to do so. Second, our team is staying abreast of all relevant standards that exist or are emerging in this space. Third, our team is engaging a broad community of internal users and experts to help identify problems and improvement opportunities. To this end, the assumptions and calculations are highly transparent to the user. Fourth, the data upon which the metrics are built must be continuously improved and audited. "Improvement" means making data available that is as close to the component being modeled in terms of supplier, location, and point in time as required by the modeling goal.

Initial assessments of the tool indicate it can produce assessments with an acceptable level of training and data collection. Adoption by the design community is accelerating. In addition to providing system-level assessments, the tool, as a result of its electronic format, has proven to be useful for sensitivity analyses and scenario assessments. We expect continued refinements, broader adoption, and increased use in developing product level goals and competitive differentiation.

We see two key areas where industry and academia will need to collaborate to make tools like ours more effective and useful. First, we recommend these stakeholders work together to create and maintain "product category rules" (PCRs) that are an agreed on set of assumptions about scope and usage. These PCRs would allow everyone to benefit from the lessons learned in these areas and would pave the way to externally comparability of the results. Second, these stakeholders will need to design and implement a solution to improve the data used by carbon footprint tools. Ultimately, we see the measurement of product carbon footprints as way to enable sound supply chain energy and carbon management and encourage product innovation.

References

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Author Biography

Jason Ord received his BS (1994) and MS (2006) in mechanical engineering and systems & control from the University of Michigan. He has been the Environmental Life Cycle Assessment program manager in HP's Imaging and Printing Group for the past two years. His job is to identify, prioritize, & communicate environmental improvement opportunities for products. Jason has worked for HP since 1995 as a manufacturing and R&D engineer.

Tim Strecker received his PhD in chemical engineering from Washington State University (1994). He has worked in various aspects of digital printing at Hewlett-Packard since 1996. Most recently his research has focused on life cycle assessments of commercial and industrial printing systems and implementation of environmental metrics for product and technology development.