Carbon Footprint Analysis Comparing a Digital Frame to Printed Photos

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Abstract

Electronic digital photo frames provide a convenient, aesthetically pleasing way for consumers to display several photos in a small space. Though convenient, these displays require continuous electrical input during operation while printed photos rely on reflected ambient light for viewing. To understand the relative environmental impact of both photo display options, a carbon footprint analysis was performed comparing a digital frame over its expected lifespan with 4" x 6" photos printed in album format on a HP printer. We find that operating an average digital frame displaying 200 photos at 44 hours per week for 2 years has a carbon footprint greater than 6 times that of a 200-photo album printed on a HP OfficeJet 6500 All-in-One printer. For the OfficeJet-printed photos the printer bill of materials, photo album materials, and energy consumption all contribute similarly to the carbon footprint. In the case of the digital frame, energy impacts from the usage model are critical for determining the overall impact. In this paper we present our carbon footprint model, the underlying assumptions, and a sensitivity analysis of the results

Introduction

Digital photo frames, table-top or wall-mounted digital displays that allow a customer to show an array of photos on an aesthetically pleasing device, have enjoyed popularity since their introduction. Manufacturers offer an array of displays in various sizes with ever-increasing functionality, including wireless internet connectivity, that make it easy for a consumer to upload, display, and change photos.[1] While convenient, these displays require continuous input power to operate their LCD screens resulting in potentially considerable power consumption over the display life of the photos. Contrast that to traditional, printed photos, displayed using reflected ambient light whose only power requirement for continuous display is the initial power needed to print the photos.

In this study we sought to compare these two popular photo display options to see if there was a significant difference in their carbon footprint, also known as Climate Change Potential. Here we compare 200 photos displayed as a) a continuous, scrolling display on a digital photo frame in a format common in the marketplace and b) 200 photos printed on a typical desktop inkjet printers as a 100-page, simplex photo album. We assess their carbon footprints, perform a sensitivity analysis on the energy input, and look for a cross-over point – the point at which the two options have the same carbon footprint.

Model and Methods

Life Cycle Assessment (LCA) methodology was used to compare the environmental impacts of a printed photo album to that of a digital photo frame. LCA is a comprehensive, quantitative environmental impact analysis protocol that includes all relevant technical processes related to the function provided by a product or system. It also includes a wide range of potential environmental impacts linked to the inputs from the environment, such as raw material extraction, and outputs to the environment, such as emissions to air, water, and soil from these processes. LCA is used for various applications, but it is particularly valuable for identifying opportunities to improve the environmental profile of products, product comparisons, product and technology development, market claims, and environmentally-relevant policy development. The LCA framework has been standardized by the International Standard Organization (ISO 14040, 14044)[2] and consists of four phases: 1) Goal and scope definition, 2) Inventory analysis, 3) Impact assessment, and 4) Interpretation. Although these phases are logically and computationally sequential, they are often iterative, as the results from one phase may dictate revisiting and modifying previous phases.

The goal of this study was to compare the life cycle carbon footprint of a 200 page photo album printed on one digital printer manufactured by HP, the Officejet 6500, to that of a 7-inch (diagonal) digital photo frame. The scope includes deciding what is to be modeled, sometimes called "function", i.e., the function of the product to be modeled, functional unit, choice of impact categories, impact assessment method, system boundaries, principles for allocation, and data quality requirements. The function for this study is defined as viewing 200 photos. The functional unit is defined as a 200-photo album, either viewed as digital images on the photo frame or printed as one, 100-page photo album. The printed album has the following characteristics: 4 process colors at 60% coverage, simplex pages, printed on 149 gsm photo paper. The digital album is viewed for four hours each weekday evening and twelve hours each weekend day, for a total of 44 viewing hours per week, and is in standby or 'off' mode for the remaining time. Both the printed photos and digital photos are judged to provide functionally-equivalent viewing.

System boundaries identify life cycle stages, processes and flows that are included in the LCA. The life cycle stages of digitally displayed photos and photo albums that were included in this LCA are shown in Figure 1. The process flow diagram is representative of the system boundaries for photos displayed on either system. These boundaries cover the entire life cycle, from cradle to grave for the printer, digital frame, paper, and consumables. All consumables that were used to print the album were fully assigned to the functional unit while all other inputs (bill of materials, end-of-life, standby power, etc.) were allocated based on an assumed printer life and overall usage.

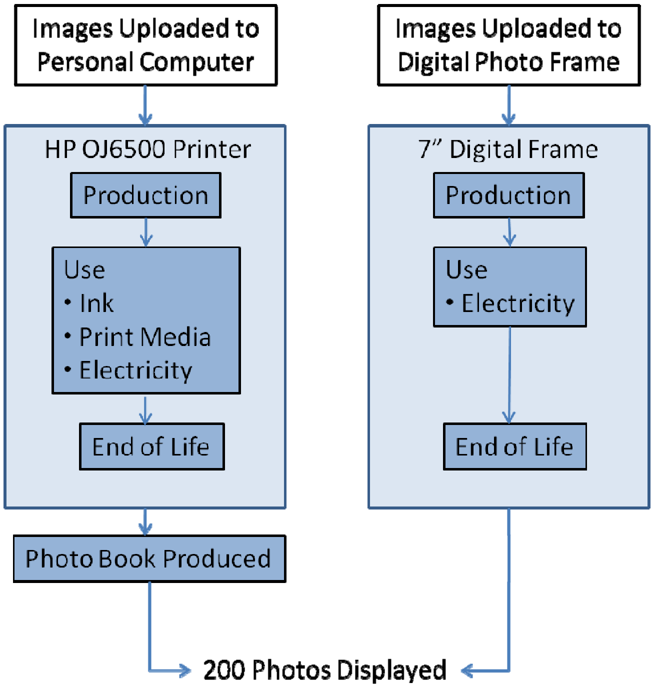

Figure 1. System boundaries defined for this study.

There were two types of data used for this study, primary data and secondary data. Primary data refers to data collected specifically for this LCA and includes printer bill of materials, printer energy consumption during printing, paper consumption, and consumption of other consumables such as print cartridges. HP provided the OJ6500 printer primary data. Secondary data refers to data used in the LCA that was gleaned from other sources, such as raw material extraction, production of materials, and electrical power generation. A European database, EcoInvent 2.2, provided the secondary data for the LCD digital photo frame, all power inputs, and end-of-life modeling.

A life cycle inventory (LCI), a mass and energy balance over the system where only the environmentally relevant flows are considered, was assembled and one life cycle impact assessment (LCIA) method, ReCiPe Midpoint (H) v1.05, was used for calculating the carbon footprint.[3] The ReCiPe method translates the LCI into 10 midpoint impact categories, shown in Table 1. Midpoint categories are meant to give information at the level of distinct potential environmental impacts. For a given impact category (e.g. climate change) the ratio between the potential impact of a unit of any given flow (e.g. emission of 1 kg methane) and that of the reference flow (1 kg CO2 eq. to air) is called a characterization factor. The total impact for a given category is the sum of all the elementary flows contributing to the impact category, as calculated during the inventory phase, multiplied by the corresponding characterization factor. Only climate change impacts were considered for this study but all contributions were calculated for completeness and help ensure no inconsistencies appeared in the calculation.

Impact Category	Units
Climate Change	kg CO_2 eq
Ozone Depletion	kg CFC-11 eq
HumanToxicity	kg 1,4-DB eq
Photochemical Oxidant Formation	kg NMVOC
Particulate Matter Formation	kg PM10 eq
Terrestrial Acidification	kg SO_2 eq
Freshwater Eutrophication	kg P eq
Terrestrial Ecotoxicity	kg 1,4-DB eq
Freshwater Ecotoxicity	kg 1,4-DB eq
Fossil Depletion	kg oil eq

Table 1. Midpoint categories reported by ReCiPe (H).

Once all needed data were obtained, system modeling was carried out using a commercial LCA software package, SimaPro 7.3, developed by Pre, Netherlands. This software allows calculation of life cycle inventories and impact assessment, contribution analysis, parameterization and related sensitivity analysis, and uncertainty analysis.

Results

Based on the functional unit and function defined in this study, and the available input data, we find a carbon footprint of 6.2 kg CO_2 eq. for the printed photo album and 41 kg CO_2 eq. for the digital photo frame (see Figure 2). In other words, viewing the same images for two years on the digital frame has a substantially higher carbon footprint than printing them in a 100-page simplex album on an OJ6500 printer.

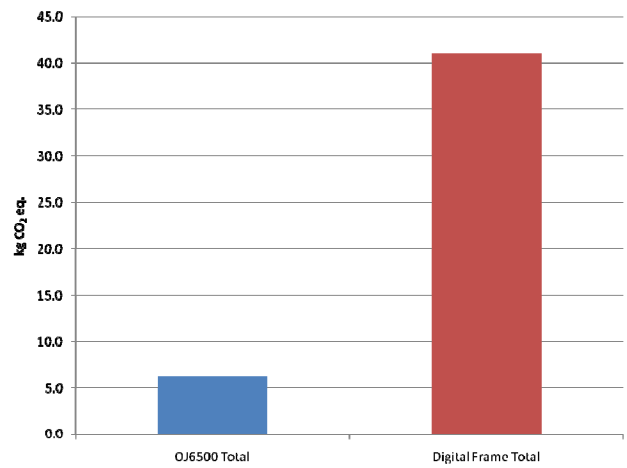

Figure 2. Graphical comparison of the carbon footprints for the digital frame and printed photo album.

The source of this large discrepancy can be seen in the contribution analysis for carbon footprint shown in Figure 3. The three largest contributors to printer climate change are bill of materials, photo paper, and printer energy use whereas for the digital frame they are bill of materials and energy use. The bill of materials is fixed in both cases, as is energy consumption in the case of the printed photos. For the digital frame, however, energy consumption is much greater for viewing the photos (the "function" in our study) and is highly dependent on the total viewing time. We find a total energy consumption of 1.36 kWh for the printed photos vs. 25.5 kWh for the digitally viewed photos. The largest contributor to energy consumption for the printed photos is allocated sleep-mode power for the printer but 'on' power or power consumed during viewing is the greatest contributor for the digital frame. Thus the total energy input for viewing photos on the digital frame exceeds the energy needed to create and view the printed photos by more than an order of magnitude.

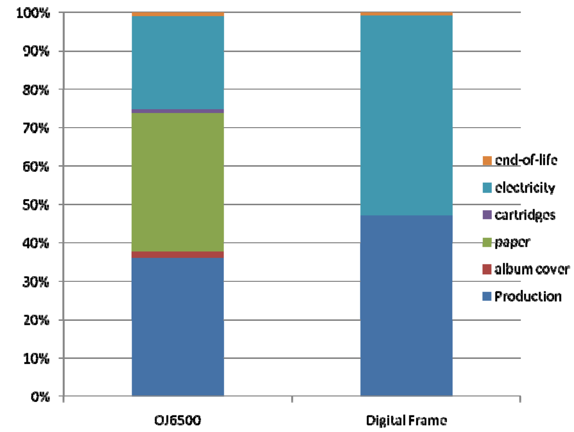

Figure 3. Contribution analysis of the carbon footprint of the two photo display options.

The climate change sensitivity analysis shown in Figure 4 shows how sensitive various parameters are to changing an impact. Since power consumption has the greatest variability in our model, we looked at a case in which the photos were viewed on the frame for one year and compared it to a 'worst case' scenario of a consumer never turning the printer off (leaving it in sleep mode). As would be imagined, the length of time a printer is left on has a significant impact on its carbon footprint but, even if the printer is never turned off, its carbon footprint remains much lower than the digital frame used for half the originally modeled time.

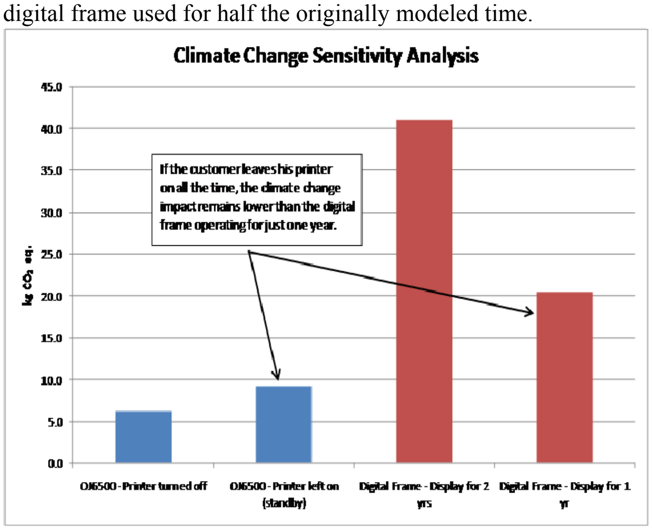

Figure 4. Sensitivity analysis for the two photo display options.

A breakeven analysis is shown in Figure 5. This analysis shows that the printed 200-photo album, as modeled, will always have a lower carbon footprint than a digital photo frame, even at time zero. The reason for this is that the inherent bill of materials for the digital frame alone, regardless of allocation, has a greater carbon footprint than the fully-allocated printed photo album.

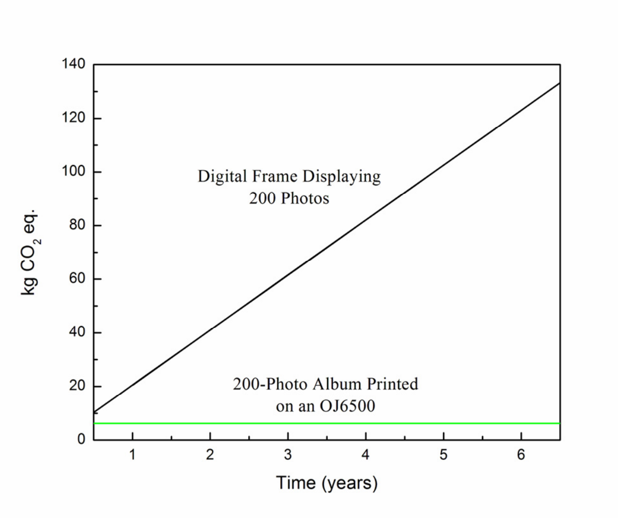

Figure 5. Breakeven analysis for the two photo display options showing that there is no breakeven point. The printed photo album always has a lower carbon footprint.

Conclusions

In this study we find that displaying 200 photos on a digital frame operating at a typical home usage model for two years has a far greater carbon footprint than the equivalent photos printed as an album on a HP OfficeJet 6500 printer. For the printed photos, we estimate a carbon footprint of 6.2 kg CO_2 eq. The impacts are divided comparably among bill of materials for the printer (allocated over the album prints based on an assumed printer life), bill of materials for the album, and energy use, with end-of-life impacts being insignificant. In the digital frame case we find a carbon footprint of 41 kg CO_2 eq. if the frame displays photos for 44 hours per week for two years, with bill of materials and energy use contributing comparably, but at a much higher rate than the printed photo case, to the overall impact. Additionally, the bill of materials for the digital frame is great enough that, as modeled, the printed photo album has a lower carbon footprint than the digital frame even before the frame is uploaded with photos and turned on.

References

[1] Plank, Willa, 'Worth it? A Frame to Display Facebook Photos for Your Mom', The *Wall Street Journal*, WSJ Blogs, July 1, 2011, http://blogs.wsj.com/digits/2011/07/01/worth-it-a-frame-to-display-facebook-photos-for-your-mom/.

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[3] Goedkoop M.J., Heijungs R, Huijbregts M., De Schryver A.;Struijs J.,; Van Zelm R, ReCiPe 2008, A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level; First edition Report I: Characterisation; 6 January 2009, http://www.lcia-recipe.net.

Author Biography

Tom Etheridge is a Senior Scientist in HP's Imaging and Printing Group. His research focuses on understanding the environmental impact of classes of HP products and services, specifically the impact of printing media such as paper and banner materials. Tom has worked in various aspects of printing R&D at HP for 17 years and holds a PhD in Physical Chemistry from the University of Chicago (1993). He is a member of ACS and Sigma Xi.

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Tim Strecker 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. Tim received his PhD in chemical engineering from Washington State University (1994)