The Environmental Case for Digitally Printed Books

A life cycle assessment study

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REDUCING RETURNS

IT IS WELL DOCUMENTED THAT THE BOOK PUBLISHING INDUSTRY PRODUCES A LARGE QUANTITY OF RETURNED BOOKS. ACCORDING TO THE ECONOMIST, ABOUT 30% OF BOOKS IN AMERICA ARE RETURNED TO THE PUBLISHER[1]. THESE BOOKS ARE TYPICALLY RECYCLED, LAND FILLED OR SOLD AS REMAINDERS. THIS LEVEL OF WASTE CAN IN PRINCIPLE BE REDUCED BY BETTER MATCHING THE SUPPLY WITH THE DEMAND. DIGITAL PRINTING TECHNOLOGIES OFFER A MEANS TO ACHIEVE THIS.

The advantages of printing books digitally include the ability to print what is needed, when and where it is needed, and to reduce the costs associated with make ready, with unused books, and with transportation, storage and distribution and are pretty well understood. What is less well understood are the concomitant potential environmental advantages.

As a world leader in digital printing solutions with a commitment to environmental stewardship, Hewlett-Packard Co. (HP) commissioned this study to characterize the potential environmental impacts of alternative approaches to paperback book printing in the US. The study is based on a life cycle assessment (LCA) of various methods scenarios for printing and delivering a paperback book, chosen since it can be printed by all the presses studied and because paperbacks account for a significant portion of the overall environmental footprint of the book industry, representing 59% of books sold in 2009[2].

It was a comparative study of two printing technology categories: offset analog and digital, inkjet using four presses of varying levels of productivity and four distinct distribution scenarios *(see table opposite)*. The study set out to determine the potential environmental profile of each of the systems, to consider possible synergies between them, and to determine the least potential environmentally impactful means of producing and distributing a paperback book given different demand profiles.

The demand profiles chosen were a “best seller” where many books are printed and sold in a relatively short time period (500,000 books over 2 years) and a “classic book” that is a consistent but slow seller (5000 books over 5 years). These demand profiles were met using different fulfillment models, e.g. centralized distribution, in-store printing. Finally, scenarios were used to describe the fulfillment of a particular demand profile with a particular fulfillment model.

PRESSES AND FULFILLMENT MODELS included in the study

Fulfillment Model	Book Production	Presses			
		Timson Offset	Digital T300	Digital T200	Digital R85
Centralized distribution	At one location in the US and delivered to the whole US	●	●		
Regional distribution	At few locations across the U.S. with a minimum of two consisting of the east coast and the west coast			●	
Local distribution	At the county and city level			●	
In-store printing	At a retail store				●

The LCA was conducted by Quantis, a Canadian-based environmental assessment firm. They sourced information from HP, from an independent offset press expert, from leading organizations in the book industry, and a range other sources. In order to comply with ISO standards for comparative LCAs[3], the study was reviewed by an independent review panel. The results of this study are summarized in this report.

System-level analysis of each of the four presses - Timson Offset T48a ZMR, HP T300 Color Inkjet Web Press (Digital T300), HP T200 Color Inkjet Web Press (Digital T200), and HP R85 Inkjet Press (Digital R85) - showed that paper production is the largest source of potential environmental impacts, representing 40 - 80% of the total impacts. This result shows the importance of publishers leading industry efforts to reduce levels of returned books - which have a big influence on the environmental footprint of the industry - and of printers doing what they can to reduce waste paper associated with make ready and trim waste. Other influential parameters include:

- **Print run length**, a bigger issue for offset due to ‘make ready’ waste;
- **Transportation distances**, with regional and local distribution resulting in lower potential impacts;
- **Data management** for the point-of-purchase (POP) digital press.

(1 The Economist (2010). Just Press Print. The Economist. February 27th 2010, 2 p. [online].

(2 Milliot, J. (2010). Chains, Fiction, Paperback Ruled in 2009. Publishers Weekly. **www.publishersweekly.com/pw/by-topic/industry-news/bookselling/article/44160-chains-fiction-paperback-ruled-in-2009.html**

(3 Gabrielle van Durme, François Charron-Doucet, Édouard Clément, and Tim Strecker, “Environmental Life Cycle Assessment of Paperback Book Printing Alternatives in the USA, March, 2011, **www.hp.com/go/printlifecycleassessments**

ACCORDING TO THE ECONOMIST ABOUT 30% OF THE BOOKS IN AMERICA ARE RETURNED TO THE PUBLISHER (1

The results of the demand profile modeling showed that book returns - unused books - are the primary driver for higher potential impacts from offset printing, due to the well documented return rates in the order of 25% associated with the fulfillment models that rely exclusively on this technology *(see table)*. While there is less return data available for digitally printed books, what does exist indicates a significantly lower return rate for digital, approximately 5%. In other words, digital printing allows the output to better meet the actual market demand, thereby helping to reduce waste and lowering potential environmental impacts.

RETURN RATES FOR BOOK PRINTING – values and sources

Value	Citation	Source
Offset book printing		
35% for best sellers	"In addition, there is a return link for unsold copies as roughly 35% of best sellers are unsold" (US)	(Matthews et al., 2002)
25%	Figure given in "TABLE II Carbon Footprint and Key Figures, 2006" (US)	(Borealis Centre for Environment and Trade Research, 2008) (p.8)
25%	Average value for paperback (hardback = 30%) (US)	(Publisher, 2010)
30% average	"About 30% of books in America are returned to the publisher"	(The Economist, 2010)
up to 30% and more	"In recent years, many publisher have experienced returns of 30% or more" (World)	(Book Industry Study Group, 2010) (p.34)
21%	Pulped portion only, not including resold as used books. Refer to hard cover and paperback books.	Based on data from a major educational book publisher, weighted averages for 2007 - 2009 (contact in 2010)
23.8% 17.8% 23.5%	The 2009 figures are respectively for Adult trade paperback, Juvenile trade paperback and University press paperbacks.	(Greco, 2011)
Digital book printing		
less than 5%		Based on data from a major educational book publisher, weighted averages for 2007 - 2009 (contact in 2010), HP Experts
lower than offset	"As demand for titles and the actual production of books can be more closely matched, fewer books will be returned to publishers"	(Book Industry Study Group, 2010) (p.37)
lower than offset	"USR program produces small amount of inventory to cover a few month's sales, this reducing the risk of obsolescence" (USR = ultra short run)	(Book Industry Study Group, 2010) (p.40)

For the best seller demand profile, analysis showed that combining digital inkjet technology with offset resulted in the need to print 22% fewer books to sell the same amount. In addition, the use of a midsize digital press, Digital T200, to supplement the larger offset press, Timson Offset, allowed for some regional printing with a further modest reduction in potential impacts. Overall, the global warming potential (green house gas emissions) was 17% lower for the scenario where a Digital T200 press was used to supplement a large run on the Timson offset press in comparison to all printing being done on the offset press. Potential impacts related to human health, ecosystem quality and resources were similarly reduced[4 [5.

For the classic book demand profile four scenarios were analyzed. One scenario was one in which all books were printed using the Timson offset press and three in which combinations of different HP inkjet presses, Digital T300, Digital T200 and Digital R85, were used to meet the demand. For all digital scenarios, the potential carbon footprint was from 14 to 19% lower compared to the offset only scenario[6. Again, this was driven primarily by a reduction in returns, though additional reductions were from no make ready and lower consumables usage.

Of the four scenarios, the one that used the small in-store digital press, Digital R85, to supplement runs on larger digital press, Digital T300, had the lowest potential overall impacts. With that said, there is some uncertainty in the data management for the POP system which could influence the magnitude of the improvement. In comparison, offset technology is disadvantaged due to start up and make ready, and also by the relatively low print run length involved with the classic book demand profile.

For both the best seller and the classic demand profiles, the use of HP inkjet digital presses was shown to lower the potential environmental impacts, associated with paperback book printing and selling, including reducing green house gas emissions[7. The Book Industry Environmental Council has set a goal of reducing the U.S. book industry's green house gas emissions by 20% by 2020 and by 80% by 2050 (based on 2006 baseline)[8. This study has demonstrated that the judicious adoption of inkjet digital printing technologies in the industry can help achieve this goal.

(4 Note all impacts should be viewed as "potential" impacts since they are representative for only the print product studied and cannot be extrapolated to other print products.

(5 When printing 500,000 copies of a 240 page mono color paperback book, duplexed with 5% coverage. First 450,000 copies printing using the Timson Offset Press, with supplemental short runs of 1,000 copies using the Digital T200 press. This assumes book return rate of 25% for offset printing, 5% for digital printing.

(6 When printing 5,000 copies of a 240 page mono color paperback book, duplexed, with 5% coverage. There are three digital scenarios. One is where the Digital T300 prints at one centralized location; a second is where the Digital T200 press prints at regional locations; the third is where the T300 prints an initial run at a centralized location and the Digital R85 press prints-on-demand at bookstores. This assumes book return rate of 25% for offset printing, 5% for digital presses, and 0% for print-on-demand in-store presses.

(7 **www.epa.gov/climatechange/downloads/Climate_Basics.pdf**

(8 Book Industry Environmental Council, Press Release April 16, 2009, **www.bookcouncil.org/press_release.html**

THE BOOK INDUSTRY ENVIRONMETAL COUNCIL HAS SET A GOAL OF REDUCING THE U.S. BOOK INDUSTRY'S HOUSE GAS EMISSIONS BY 20% BY 2020 AND BY 80% BY 2050 (BASED ON 2006 BASELINE) [8

LIFE CYCLE ASSESSMENT

LIFE CYCLE ASSESSMENT (LCA) IS A TECHNIQUE FOR EXAMINING THE POTENTIAL ENVIRONMENTAL IMPACTS OF A PRODUCT OR SERVICE THROUGHOUT ITS LIFESPAN – PRODUCTION, DISTRIBUTION, USE AND END OF LIFE. IT IS A WIDE LY ACCEPTED TECHNIQUE THAT HAS BEEN USED BY GOVERNMENTS, NON-GOVERNMENTAL ORGANIZATIONS, AND INDUSTRY TO SUPPORT ENVIRONMENTAL DECISION-MAKING. WHEN CONDUCTED IN ACCORDANCE WITH THE APPLICABLE ISO 14040 STANDARD, LCA HELPS TO IDENTIFY RELEVANT POTENTIAL ENVIRONMENTAL IMPACTS IN COMPLEX SYSTEMS AND, IN THIS WAY, TO COMPARE SIMILAR PRODUCTS OR TO EVALUATE DESIGN, SUPPLY CHAIN OR POLICY ALTERNATIVES.

For this study the process included:

- Defining the scope, function, functional unit and system boundaries
- Determining what data was needed for the model
- Identifying and obtaining sources of data, including that from a test run on actual book publishing equipment and from secondary sources such as respected LCA database, e.g. EcoInvent
- Modeling mid-point and end-point (human health, ecosystem quality, climate change, and resources) impacts
- Conducting a sensitivity analysis and an uncertainty analysis to understand strengths and weaknesses of the model
- Analyzing, writing up the results and reviewing it with an independent review panel of academics and print industry experts

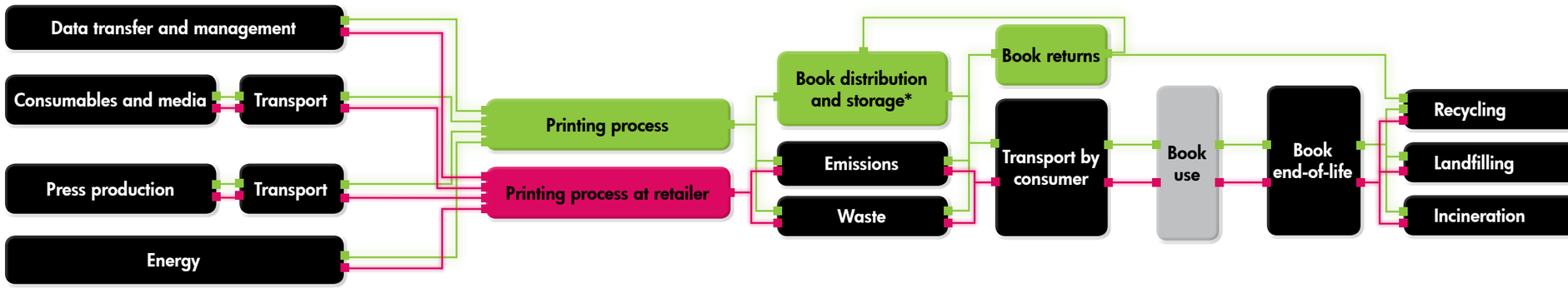
WHAT ENVIRONMENTAL IMPACTS WERE MODELED?

The environmental impact categories covered in this study include: 15 'midpoint categories' such as aquatic toxicity and respiratory inorganics, which were summarized in four 'endpoint categories' (human health, ecosystem quality, climate change, and resources). These represent a broad cross section of environmental impacts within different environmental media (i.e., air emissions, water effluents, waste, etc.) and endpoints (climate change, human health, etc.). Most of the impacts were calculated using well-accepted methodologies in the LCA field, with the remainder, i.e., 'total waste' and 'total energy', coming directly from the inventory results.

WHAT EXACTLY DID THIS LCA COMPARE?

The LCA compared the life cycle environmental impacts of using digital HP Inkjet Presses (Digital T300, Digital T200 or Digital R85) to either supplement or replace printing of paperback books on an analog Offset press (Timson Offset). The function was to print, bind, distribute and sell paperback books to retail store customers in the US and to dispose of them. The paperback book was 5.5"x 8.5", 240 pages, double-sided, with black text at 5% ink coverage. The soft book cover was four color at 60% total ink coverage. Uncoated, wood-free paper was used for all covers. For the book block, coated, wood-free paper was used for the R85 system and uncoated wood-free paper was used for the other three presses. The boundary conditions used for each of the distribution scenarios are illustrated below:

PRINTING SYSTEMS



Boundary of **ALL THE PRINTING SYSTEMS AT THE CENTRALIZED, REGIONAL AND LOCAL** fulfillment model level

Boundary of the **IN-STORE PRINTING SYSTEM** fulfillment model

*Book distribution and storage - this stage varies according to the chosen fulfillment model.

DEMAND PROFILES

THE DEMAND PROFILES EVALUATED INVOLVED SUPPLYING A "BEST SELLER" WHERE MANY BOOKS ARE PRINTED AND SOLD IN A RELATIVELY SHORT TIME PERIOD AND A "CLASSIC BOOK" THAT IS A CONSISTENT BUT SLOW SELLER. FOR THE BEST SELLER, A DIGITAL T200 PRESS WAS USED AS A SUPPLEMENT TO THE TIMSON OFFSET PRESS TO PRINT AND DISTRIBUTE THE 500,000 BOOKS OVER 2 YEARS. FOR THE CLASSIC BOOK, COMBINATIONS OF DIGITAL T300, DIGITAL T200 AND DIGITAL R85 PRESSES WERE USED INSTEAD OF A TIMSON OFFSET TO PRINT AND DISTRIBUTE 5,000 BOOKS OVER 5 YEARS.

In addition to the fulfillment models studied, producing a book on each of the individual systems was characterized to determine their environmental strengths and weaknesses. Due to substitutability requirements, ISO LCA standards for comparative claims do not permit the comparison of these independent system results directly - only within the context of the demand scenarios. With that said, there are some useful insights that can be gleaned from the system-level that analysis as well.

HP T300 Color Inkjet Web Press **(Digital T300, PTS)**

HP R85 Inkjet Press **(Digital R85, POD)**

HP T200 Color Inkjet Web Press **(Digital T200, PTS)**

Timson T48a ZMR Offset Press **(Timson Offset, PTS)**

SCENARIOS

The scenarios studied can be described as follows:

BEST SELLER demand profiles - parameters defining the scenarios

	Press	Print run length	Total return rate, R	Partial return rate, Rp	Sold books	Unsold books	Distribution distance
Scenario A	Timson	1*625,000	25.0 %	20.0%	500,000	125,000	2,000 km
Scenario B a	Timson	1*400,000	2.5%	2.0%	392,000	8,000	2,000 km
Scenario B b	Timson	1*50,000	2.5%	2.0%	49,000	1,000	2,000 km
Scenario B c	T200	61*1000	4.1%	3.3%	59,000	2,000	500 km

For the best seller demand profile the publisher plans to sell 500,000 books within 2 years and fulfills the demand by using either of these two scenarios:

- **Scenario A**: All the books are printed at once with the offset press, Timson Offset, at one centralized location.
- **Scenario B**: 400,000 books are printed with the offset press, at one centralized location, a second run of 50,000 with offset, and the extra demand will be fulfilled with short runs, i.e. 1,000 books, after that on the Digital T200.

CLASSIC BOOK demand profile - parameters defining the scenarios

	Press	Print run length	Total return rate, R	Partial return rate, Rp	Sold books	Unsold books	Distribution distance
Scenario C	Timson	1*6,250	25.0%	20.0%	5,000	1,250	2,000 km
Scenario D a	T300	1*2,000	2.5%	2.0%	1,960	40	2,000 km
Scenario D b	T300	7*450	4.4%	3.5%	3,040	110	2,000 km
Scenario E a	T200	3*700	2.4%	1.9%	2,060	40	500 km
Scenario E b	T200	15*200	2.5%	2.0%	2,940	60	500 km
Scenario F a	T300	1*1,000	2.5%	2.0%	980	20	2,000 km
Scenario F b	R85	4,020*1	0.0%	0.0%	4,020	0	0 km

For the classic book demand profile, the publisher plans to sell 5,000 books over 5 years and fulfills the demand by using any of these four scenarios:

- **Scenario C**: All the books are printed at once on an offset press at a centralized location.
- **Scenario D**: An initial run of 2,000 books is printed with the Digital T300 press at a centralized location and then short runs are produced over the remaining 5 years (same press, same location) to maintain the bookstore shelf stock, i.e. print-to-stock.
- **Scenario E**: Three initial runs of 700 copies each are printed on the Digital T200 press at three regional locations and then very short runs are produced over the remaining 5 years to maintain stock (same presses, same locations).
- **Scenario F:** An initial run of 1,000 copies is printed on the Digital T300 press at one centralized location and the rest is printed on demand on the Digital R85 press at retail bookstores.

SUMMARY OF RESULTS

IN ALL SCENARIOS EVALUATED, SUPPLEMENTING OR REPLACING THE OFFSET TECHNOLOGY WITH HP INKJET DIGITAL TECHNOLOGY LOWERED THE POTENTIAL ENVIRONMENTAL FOOTPRINT OF PRODUCING AND SELLING PAPERBACK BOOKS SIGNIFICANTLY. THE CARBON FOOTPRINT ALONE WAS REDUCED BY 14 TO 20%, DEPENDENT ON THE SPECIFIC SCENARIO. POTENTIAL IMPACTS RELATED TO HUMAN HEALTH, ECOSYSTEM QUALITY AND RESOURCES WERE REDUCED BY 14 TO 25%, 18 TO 34%, AND 15 TO 25 % RESPECTIVELY. THE HIGHEST POTENTIAL REDUCTIONS WERE OBSERVED FOR SCENARIO D OF THE CLASSIC BOOK FULFILLMENT MODEL WHERE A DIGITAL T300 PRESS IN COMBINATION WITH A DIGITAL PRINT ON DEMAND, DIGITAL R85 PRESS, WAS USED IN PLACE OF THE TIMSON OFFSET PRESS.

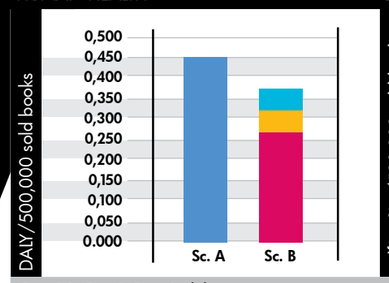
BEST SELLER vs CLASSIC BOOK - potential percent impact decrease

	Scenario	IMPACT CATEGORY: Human Health (DALY)	Ecosystem Quality (pdf-m^2-yr)	Resources (MJ Primary)	Climate Change (kg CO_2 eq)
		Potential Percent Decrease from offset only scenario			
BEST SELLER	Sc.B: Timson vs T200	18%	20%	18%	17%
CLASSIC BOOK	Sc.D: Timson vs T300	14%	18%	15%	14%
	Sc.E: Timson vs T200	19%	21%	19%	17%
	Sc.F: Timson vs T300/R85	25%	34%	25%	19%

LCA IMPACT RESULTS

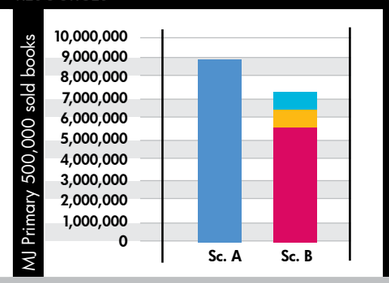
BEST SELLER BOOK Sold For 2 Years

HUMAN HEALTH

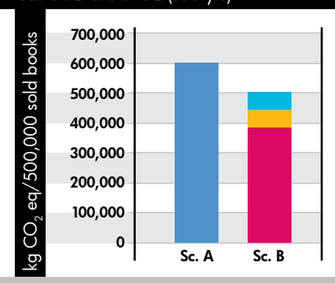


ECOSYSTEM QUALITY

RESOURCES



CLIMATE CHANGE (100 yrs)



- T200-R (61*1,000)
- TIMSON-C (1*50,000)
- TIMSON-C (1*400,000)
- TIMSON-C (1*625,000)

FOOTPRINT

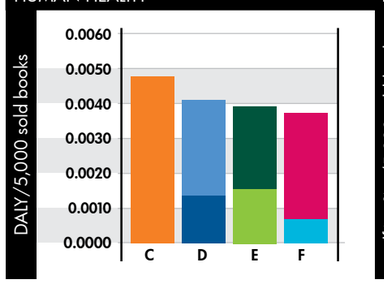
17-20% potentially lower environmental footprint than offset (lower return rate drives this)

BENEFITS

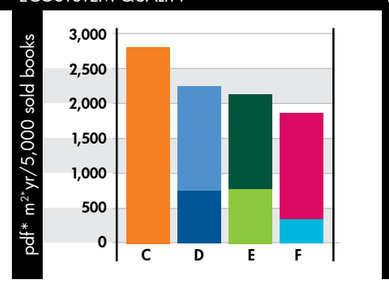
Benefits of digital print-to-stock over offset (per 500,000 books sold) for Climate change:
- 234 barrels of oil saved
- 19 car annual emissions avoided
- 11,302 gallons of gas saved
- 12 home annual electrical emissions avoided

CLASSIC BOOK Sold For 5 Years

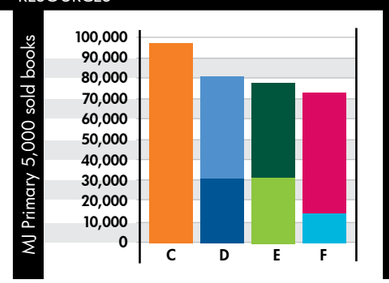
HUMAN HEALTH



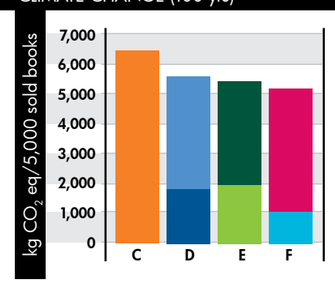
ECOSYSTEM QUALITY



RESOURCES



CLIMATE CHANGE (100 yrs)



- R85-IS (4,020*1)
- T300-C (1*1,000)
- T300-C (7*450)
- T300-C (1*2,000)
- T200-R (15*200)
- T200-R (3*700)
- TIMSON-C (1*6,250)

FOOTPRINT

19-34% potentially lower environmental footprint than offset (lower return rate drives this)

BENEFITS

Benefits of digital print-to-stock over offset (per 5,000 books sold) for Climate change:
- 2,8 barrels of oil saved
- 1/4 car annual emissions avoided
- 135 gallons of gas saved
- 1/7 home annual electrical emissions avoided

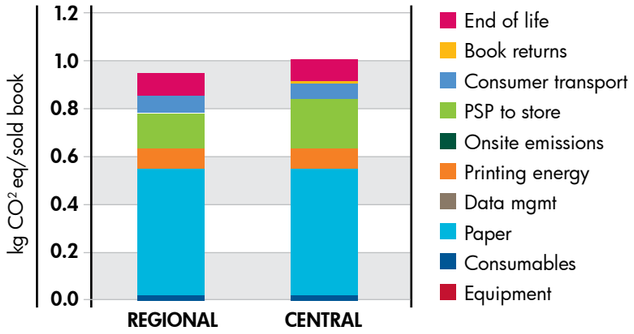
Reading the Legend: **Each color** = 1 module / **Letters:** C = Central, R = Regional, IS = In Store / **Numbers after *** = print run length / **Numbers before *** = number of runs (result gives the amount of printed books)

RETURN RATES

Digital technology reduced return rates from an estimated 25% for offset printing to 5% for print-to-stock runs and to 0% for in-store print-on-demand jobs[9]. This reduction in return rates resulted in the use of less paper, energy and consumables. Paper typically contributes the largest impact for printed books, 40 to 80% , so lowering return rates which saves paper is a critical component to improving the sustainability of the book industry and meeting the carbon reduction goals for the industry.

CLIMATE CHANGE (100 yrs) - T300

Climate change impacts for Digital T300 press system illustrating that paper is the largest potential impact (Note that waste paper from returned books is included in the Paper component and not under book returns.)



OTHER IMPORTANT VARIABLES:

HP digital inkjet technology is favored by lower print run lengths, especially runs of less than 5,000 books where offset is at a disadvantage, and the closeness of distribution to the store.

FOR PRINT-TO-STOCK (PTS):

Three parameters influence the magnitude of the potential environmental impacts generated by the book life cycle:

1. **Return rates** - the lower the return rate, the lower the potential impacts. Digital printers allow lower return rates than offset printers because they facilitate a better matching of production to demand. This in turn leads to lower potential environmental impacts.
2. **Print run length** - for print runs of around 5,000 books and lower, digital technology is less impacting than offset technology.
3. **Distribution** - the closer the production is to the consumer, the lower the impacts. (Warning: For offset, this can be counter balanced by the negative effect of lower print runs, since offset has higher start-up impacts due to plate making, make-ready, etc.)

PRINT-ON-DEMAND (POD) R85 DIGITAL PUBLISHING SOLUTION

Overall, there is no significant environmental advantage or disadvantage from using Digital R85 in a print-on-demand (POD) capacity compared to digital presses that print-to-stock (PTS). Digital R85 POD's advantages in reduced return rates and transport are counterbalanced by higher impacts from the printing process and data management. However, the lower the print run, the better the R85 POD solution is compared to digital PTS presses. For around 100 copies and less, the in-store press will be less potentially impacting than the PTS options. (Warning: There is uncertainty regarding modeling of data management for the R85 press that could influence impacts from in-store POD.)

The in–store Digital R85 POD publishing solution has lowest energy demand per printed book[10], the lowest paper waste compared to other printing options when printed in batch mode[11], and can have zero book return rates. In addition, in-store POD books eliminate publisher warehousing and related distribution impacts, although paper and consumables are required to print the book in the store.

SINCE HP PAID FOR THE STUDY HOW CAN WE BE SURE THE RESULTS ARE CREDIBLE?

This LCA was conducted by experts at the independent LCA consultancy, Quantis, and conforms to the ISO 14040 series standards for research of this type. It was reviewed by an independent, multi-party critical review panel with representatives from the academic world (Rochester Institute of Technology) and from an LCA firm (EarthShift, LLC). Wherever possible, the same tests were run on all presses to obtain primary data. The digital press data on media usage, energy consumption, consumable usage, and accumulated waste were collected in experiments run internally by HP. The offset press data on media usage, energy consumption, consumable usage, and waste were obtained by a printing industry expert, Hal Hinderliter Consulting Services, HHCS, who was retained by Quantis. Where it was not possible to obtain data through direct measurements or known specifications, expert judgment was used. Hal Hinderliter provided such information for the offset press system as well. For secondary data, credible, established sources such as the EcoInvent LCI database where used.

WHAT YOU CAN DO AS A PUBLISHER OR BOOK PRINTER?

INVESTIGATE YOUR CURRENT METHODS FOR PRINTING AND DELIVERING PAPERBACKS AND ASK THE FOLLOWING QUESTIONS:

1. **Are there opportunities to reduce returned books rates by using digital printing technology to better match the supply with the demand?**
2. **Are there opportunities to move book printing closer to the customer and thereby reduce distribution impacts?**
3. **To what extent can HP inkjet digital presses help meet your business needs?**

Asking such questions will help your organization, and the book industry as a whole, move toward a more sustainable business model. As this study has illustrated, HP digital inkjet printing technology can help drive reduced carbon footprint and a reduction of other environmental impacts.

Since book return rates are such a large driver of potential environmental impacts, it is worth further discussion. From an economic cost perspective, long runs typically favor analog printing technology while shorter runs favor digital. Offset presses have relatively high fixed costs due to set up and make ready and need to print a minimum number of books per run to be profitable. In addition, their variable costs tend to be lower, so printing additional copies on an analog system often makes sense economically. In comparison digital inkjet presses typically have lower fixed costs and can be more profitable at short run lengths. Their variable costs per print are generally higher, making them more expensive to operate for longer runs. In addition, lead times are longer with offset because of the additional start up requirements, e.g. aluminum plate preparation. For offset, these factors favor ordering and printing more books than may be required for sales to lower the per-book printing costs and decrease the risk of running out of stock. In contrast, digital printing allows more flexibility, enabling smaller runs at a reasonable cost and shorter lead times. Hence, digital publishers can hold less inventory and order several shorter print runs (instead of one large run) so "the demand for titles and the actual production of books can be more closely matched"[12].

In conclusion, while return rates are variable and depend on contexts and publishers' strategies, in general digital printing allows a reduction of return rate in comparison to offset printing. As shown here, it is possible to combine both digital inkjet and offset analog technologies to reduce return rates for a given book and enhance both profitability and environmental performance. Smart application of printing technologies, including a wider adoption of HP inkjet digital presses by the industry, should help meet the goal set by The Book Industry Environmental Council to reduce the U.S. book industry's green house gas emissions by 20% by 2020 and by 80% by 2050 (based on 2006 baseline)[8]. Furthermore, the reduction in book return rates that is enabled by digital printing, can also lead to a corresponding reduction in waste paper, energy and consumables, and hence to a more sustainable model for book publishing.

(8 Book Industry Environmental Council, Press Release April 16, 2009, **www.bookcouncil.org/press_release.html**

(9 Gabrielle van Durme, François Charron-Doucet, Édouard Clément, and Tim Strecker, "Environmental Life Cycle Assessment of Paperback Book Printing Alternatives in the USA, March, 2011, **www.hp.com/go/printlifecycleassessments**

(10 When evaluated individually or in batches of 20 books.

(11 When printing 125 copies of a 2410 paper mono color paperback book, duplexed, with 5% coverage. Assumes copies are printed in 6 runs of 20 books plus one run of 5 books, evenly distributed throughout the day.

(12 Book Industry Study Group, I. (2010). Digital book printing for Dummies. Hoboken, Wiley Publishing, Inc., 64 p.

IN ALL SCENARIOS EVALUATED, SUPPLEMENTING OR REPLACING THE OFFSET TECHNOLOGY WITH HP INKJET DIGITAL TECHNOLOGY LOWERED THE POTENTIAL ENVIRONMENTAL FOOTPRINT OF PRODUCING AND SELLING PAPERBACK BOOKS SIGNIFICANTLY. THE CARBON FOOTPRINT ALONE WAS REDUCED BY 14 TO 20%