The environmental impact of Amazon's Kindle

Executive Brief

cleantech GROUP LLC

Author

Emma Ritch
Senior Reporter
+1 415-684-1020 ext. 6340
emma.ritch@cleantech.com

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E-readers are currently a niche technology with a little more than 1 million units sold to-date, resulting in little impact thus far—positive or negative—on the environment.

But with sales quickly accelerating to a projected 14.4 million in 2012 alone, it's essential to examine the environmental impact of e-reader devices, both in terms of the emissions they could produce and the emissions they could prevent.

After an analysis of a number of studies on the publishing and e-reader industries, we predict that, on average, the carbon emitted in the lifecycle of a Kindle is fully offset after the first year of use. Any additional years of use result in net carbon savings, equivalent to an average of 168 kg of CO2 per year (the emissions produced in the manufacture and distribution of 22.5 books). There are additional savings in toxic emissions from publishing and water usage that we haven't quantified.

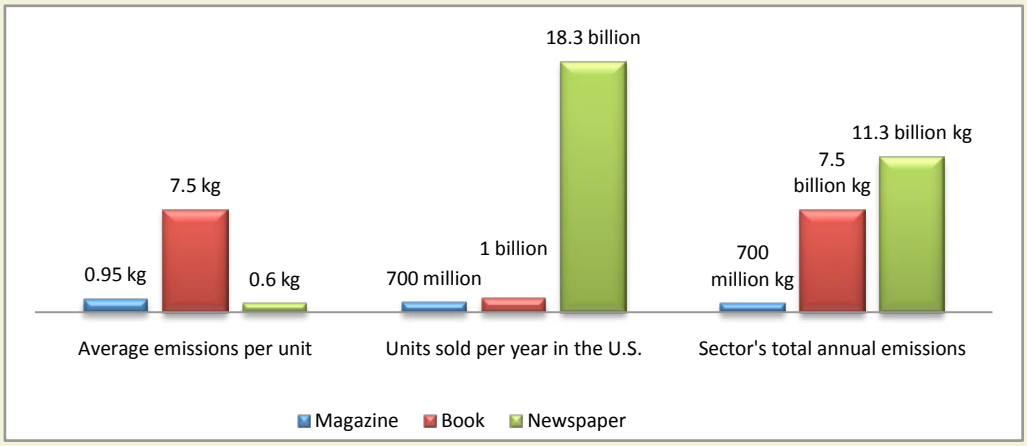
Multiplied by millions of units and increased sales of e-books, e-readers will have a staggering impact on improving the sustainability and environmental impact on one of the world's most polluting industries: the publishing of books, newspapers and magazines.

1. Emissions from paper and pulp

In 2008, the U.S. book and newspaper industries combined resulted in the harvesting of 125 million trees, according to the nonprofit Green Press Initiative (GPI). Paper is responsible for almost 75 percent of the publishing industry's carbon footprint, despite the fact that newspapers already use 35-percent recycled content. Roughly 26 percent of U.S. landfills are composed of paper.

GPI also calculated that books and newspapers produce 153 billion gallons of wastewater annually. As the biggest industrial water user, the publishing industry is responsible for 11 percent of freshwater consumed in industrial nations, according to a 2007 report from the Environmental Paper Network. Ink is estimated to make up 1 percent of the emissions of each printed product because it can release toxins such as toluene, xylene, methanol, and hexane into the water and air.

Books have the highest per-unit carbon footprint in the publishing sector, as well as siginificant sales, making them one of the biggest environmental offenders in publishing. Publishers sold a little more than 3 billion books in 2008 in Asia, Europe and the U.S., according to the Book Industry Study Group. Nielson BookScan estimates U.S. sales around 1 billion.



Environmental impact by sector of U.S. publishing in 2008

Sources: Industrial Design Consultancy, Babcock School of Business, U.S. Environmental Protection Agency, Green Press Initiative, Book Industry Study Group, Newspaper Association of America, Discovery Magazine, Cleantech Group analysis

By our calculations, the average book produces approximately 7.46 kilograms of CO2 over its lifetime. That's based on three independent studies that used life-cycle analysis calculators to assess the impact of raw materials, processing, printing, distribution, and disposal. UK-based product design consulting firm Industrial Design Consultancy (IDC) used its LCA Calculator in 2008 to estimate 8.16 kg of CO2 equivalent results from a children's book. A calculation by the Babcock School of Business using the U.S. Environmental Protection Agency life-cycle assessment tool showed that each kilogram of a textbook results in a little more than 5 kg of CO2.

The average textbook weighs 2.18 kg, resulting in 10.2 kg of CO2 equivalent. With a more conservative estimate, GPI estimates each book produces 4.01 kg of CO2 equivalent.

However, there can be significant variables. Picking up a book at a bookstore versus receiving it by mail can double the emissions, according to IDC. The increase is due in part to the fossil fuels burned, but also the high rate of books returned to the publisher after they don't sell. Approximately 36 percent of hardcover and 25 percent of softcover books at bookstores are returned to publishers to recycle, incinerate or send to landfills, where they emit methane gas.

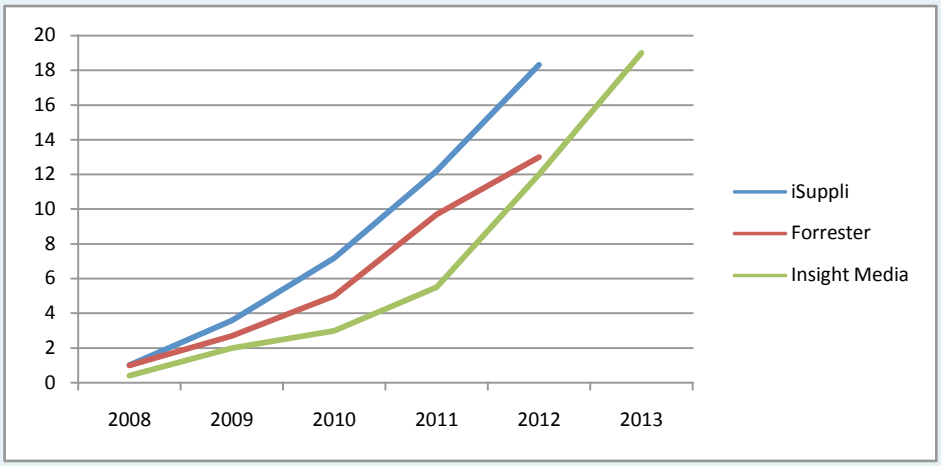
The environmental impact of a newspaper is less than 1/10th that of a book, at about 0.62 kg of greenhouse gases. The EPA life-cycle assessment tool calculates that each kilogram of newspaper produces 2.66 times the emissions. With the Financial Times weighing in at an average of 0.233 kg per issue, and about 18.25 billion newspapers sold each year in the U.S., the sector is responsible for about 11.32 billion kg of GHG annually in that country alone.

The magazine sector generates more modest emissions, thanks in part to annual sales of about 700 million. Discovery Magazine in its May 2008 issue tracked the its monthly product from source to disposal, estimating 0.95 kg of emissions per copy. About 18.3 percent was attributable to disposal because 80 percent of magazines delivered to consumers end up in landfills or incinerators. Interestingly, unsold magazines are recycled 90 percent of time.

2. E-book market share and growth projections

E-readers are just a tiny part of the publishing world, with about 1 million units sold in the U.S. by the end of 2008, and far less elsewhere around the globe. However, adoption rates are accelerating, with NanoMarkets predicting that sales of e-reader backplanes will more than double in 2009. iSuppli predicts sales of 3.6 million e-readers this year across the globe, growing to 18.3 million by 2012.

The rate of adoption isn't expected to match that of MP3 players, a device to which they're often compared, said Sarah Rotman Epps, an analyst with Forrester Research. Fewer people read than listen to music, making the e-reader a niche device for many years to come. Forrester predicts that some brands of e-readers will hit the essential $199 price point in 2010, dropping to $99 in 2012.



Projected global e-reader sales in millions

Sources: iSuppli, Forrester, Insight Media, Cleantech Group analysis

All content is not created equal for e-readers, with most models unable to display the color and graphics desired for newspapers and magazines. Amazon's Kindle is optimized for books but accommodates other forms of print, including magazines, newspapers and blogs. That content is projected to have a slower adoption rate than e-books, resulting in e-books as the driver for e-reader purchases for the next several years.

The growth in sales of e-books compared to physical books is significant. In the first quarter of 2009, e-books made up 1.6 percent of sales in the $24.3 billion-a-year publishing industry. By the end of April, the most recent month for which figures are available, sales of e-books were up 154.8 percent for the year, whereas overall book sales were down 4.1 percent, according to the Association of American Publishers (AAP).

The AAP reports $112 million in total e-book sales in 2008, and some projections have the category reaching $400 million in 2012. Amazon doesn't release sales figures for e-reader content, but it's estimated that Amazon sold less than $1 million in e-reader content outside the book sector in 2008. Sales of non-book e-reader content will likely be in the low millions of dollars this year, reaching the low double-digit millions in 2010, according to Forrester.

Forrester estimates that each consumer purchases three e-books a month but that the average will drop when lower e-reader prices entice casual readers. Alternately, average purchases could increase as more books become available in electronic forms. Today, Amazon sells 285,000 e-books on its Web site. Although the number seems significant, there were 275,232 new titles released in 2008 alone, according to Bowkers Industry Statistics.

3. The potential environmental benefits of one Kindle

U.S. consumers are the biggest adopters of e-reader technology to-date, so whichever company dominates the sector will exert great influence on the direction of an industry still in its infancy.

Amazon currently holds a 45 percent market share of e-reader devices in the U.S., with only one real competitor—Sony, which trails with 30 percent, according to iSuppli. Amazon's $299 second-generation Kindle has the capacity to hold 1,500 books, while the new, $489 Kindle DX has the capacity to hold 3,500 books.

A single Amazon Kindle e-reader used to its full storage capacity has the potential to prevent the emission of nearly 11,185 kg of carbon dioxide equivalent, while the Kindle DX could prevent the emission of 26,098 kg. It's doubtful that many users will fill e-readers to the full storage capacity, so by adopting Forrester's rate of three e-books a month, we forecast that the average consumer would purchase 144 e-books in four years, potentially displacing 1,074 kg of CO2.

4. The potential environmental benefit of all e-readers

By taking the projected sales of e-readers by the three research firms, we calculated both the conservative and the potential reduction in emissions due to cumulative sales of e-reader devices.

Our first estimate uses the average of three e-books purchased per consumer each month (or 36 books per year) but doesn't take into account e-newspapers or e-magazines, as sales are expected to be insignificant for the foreseeable future. In that case, the e-readers sold from 2009 to 2012 could prevent the emission of 8.7 billion kg of greenhouse gases in 2012 alone, or 16.8 billion kg in the four years combined. Used to their entire capacity, the cumulative number of e-reader devices sold by the end of 2012 could prevent the emission of more than 1.6 trillion kg of CO2.

However, we know that e-readers don't replace physical books at a 1:1 ratio. Amazon CEO Jeff Bezos said in May that the average Kindle owner bought 1.6 to 1.7 e-books for every physical book purchased on the company's Web site. Therefore, we estimate that the average e-reader device will prevent the sale of 22.5 books each year. Using that data, we calculate that e-readers purchased from 2009 to 2012 will prevent 5.3 billion kg of CO2 in 2012 alone, or 9.9 billion kg during the four-year period.

	2009	2010	2011	2012
E-reader units sold per year (average of below forecasts)	2,763,667	5,060,667	9,136,333	14,438,000
Forrester	2,700,000	5,000,000	9,700,000	13,000,000
iSuppli	3,591,000	7,182,000	12,209,000	18,314,000
Insight Media (est.)	2,000,000	3,000,000	5,500,000	12,000,000
Cumulative e-readers sold	2,763,667	7,824,333	16,960,667	31,398,667
Books purchased per unit each year	36	36	36	36
Ratio of e-books purchased to physical books	1.6:1	1.6:1	1.6:1	1.6:1
Actual physical books offset per year per e-reader	22.5	22.5	22.5	22.5
Average CO2 emitted per physical book in kg	7.46	7.46	7.46	7.46
CO2 prevented by each e-reader device per year	167.85	167.85	167.85	167.85
Kg of CO2 prevented due to e-book sales each year	**463,881,450**	**1,313,314,350**	**2,846,847,900**	**5,270,266,200**

Sources: iSuppli, Forrester, Insight Media, Industrial Design Consultancy, Babcock School of Business, U.S. Environmental Protection Agency, Green Press Initiative, Amazon, Cleantech Group analysis

5. The negative impact of the Kindle on the environment

It's important to note there will be no reduction in emissions attributable to the publishing industry unless publishers print fewer books in anticipation of e-book sales. Industry groups are now adopting technology to help publishers better predict sales so fewer books are returned and destroyed.

When compared to what it would replace, the Kindle consistently comes out ahead. An annual newspaper subscription requires 67 times as much water and produces 140 times the CO2 emissions as an electronic version, according to the journal of Environmental Science and Technology. The production of physical books requires 78 times the water needed in the production of e-books, the journal said.

But, as with all electronic devices, there's an environmental cost due to mining, energy use, and disposal of e-waste associated with e-readers. Amazon declined to provide information about its manufacturing process or carbon footprint, but the company says it has established a recycling program by mail for Kindle and its batteries to prevent the improper disposal of e-waste.

Los Angeles-based architecture and construction firm Marmol Radziner Prefab used the IDC lifecycle analysis calculator to estimate that each Kindle produces the same CO2 as 30 physical books ordered online, which would presumably mean that the e-reader would "pay" for itself in an environmental context if it prevents a consumer from driving to the store to buy 15 books. The environmental impact would likely be greater for the Kindle DX, which adds 85 percent to the product's weight but increases battery life by 25 percent, reducing energy use over the life of the product.

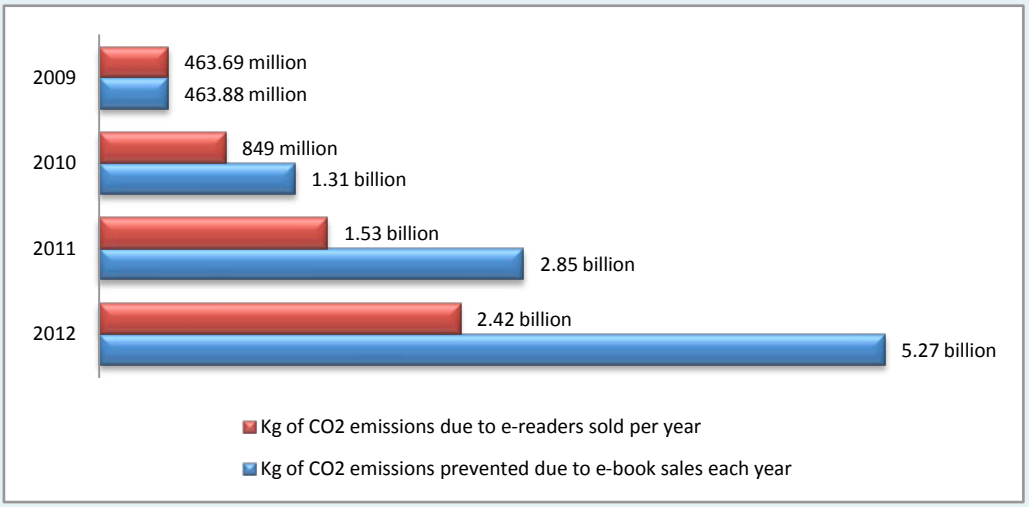
To find the carbon footprint for a single Kindle, we incorporated the estimates of a book's emissions from IDC, Babcock and GPI, in combination with the estimate from Marmol Radziner Prefab of the second-generation Kindle representing the same emissions as 15 books bought in-person or 30 purchased online. That would yield a range of between 60.2 to 306 kg of CO2, or an average of 167.78 kg of CO2 during its lifespan.

That figure is slightly less than our estimate for the CO2 offset by a single e-reader device each year: 167.85 kg, based on the displacement of 22.5 physical books (see table above). That indicates that an e-reader device would have no net environmental impact in its first year of ownership for the typical user, but every year of subsequent use would compound its benefits. The same holds true when looking at the total number of e-reader devices sold across the globe. We estimate that the emissions prevented by e-reader devices in 2012 will be more than double the amount of emissions created in the manufacturing, use, and disposal of the devices.

Estimated emissions per unit

Newspaper	0.62 kg
Magazine	0.95 kg
Book	7.46 kg
iPhone	55 kg
Kindle	168 kg

Sources: Industrial Design Consultancy, Babcock School of Business, U.S. Environmental Protection Agency, Green Press Initiative, Marmol Radziner Prefab, Discovery Magazine, Apple, Cleantech Group analysis



Projected change in CO2 emissions due to e-reader sales across the globe

Sources: iSuppli, Forrester, Insight Media, Industrial Design Consultancy, Marmol Radziner Prefab, Babcock School of Business, U.S. Environmental Protection Agency, Green Press Initiative, Book Industry Study Group, Newspaper Association of America, Discovery Magazine, Cleantech Group analysis

An alternate selection for consumers could come from Apple, rumored to be developing its own e-reader. Apple has already introduced more customers to e-reading devices than Amazon or Sony, recording more than 1 million downloads of the Kindle application for the iPhone 3G, which displays e-content using backlighting. Apple says the 4.8-ounce iPhone produces 55 kg in carbon dioxide emissions over a four-year period, using methodology verified by Germany's Fraunhofer Institute that takes into account the mining of raw materials, manufacturing, packaging, delivery, power use, and recycling. The devices would presumably require more energy than e-readers, many of which incorporate ambient-light displays from E-Ink that draw power from the lithium-ion batteries only when images change.

It's important to note that the extent of energy and emissions savings depends on how avid a reader is using the device in place of a printed product. A user that purchasers fewer than 22.5 books per year would take longer to neutralize the emissions resulting from the e-reader, and even longer to help reduce emissions attributed to the publishing industry.

Additionally, the longer one reads on a computer or e-reader, the greater the emissions due to electricity use. The emissions that result from a newspaper subscription are constant at about 28 kg of CO2 per year, according to the KTH Centre for Sustainable Communications in Stockholm. That estimate is in line with the emissions due to 30 minutes of reading a newspaper online (35 kg CO2/year). In this case, the e-reader comes out best with about 13 kg of CO2 per year, but the advantage all but disappears when the user spends just 10 minutes reading online each day. Factoring in the energy use as well as the manufacturing and disposal of the computer, 10 minutes of online reading produces just 14 kg of CO2 a year.

Conclusions

The roughly 168 kg of CO2 produced throughout the Kindle's lifecycle is a clear winner against the potential savings: 1,074 kg of CO2 if replacing three books a month for four years; and up to 26,098 kg of CO2 when used to the fullest capacity of the Kindle DX. Less-frequent readers attracted by decreasing prices still can break even at 22.5 books over the life of the device.

On a macro level, average use (22.5 physical books offset per year) of the projected number of e-readers sold through 2012 could prevent the emission of 5.3 billion kg of CO2 that year alone, or 9.9 billion kg cumulatively—equivalent to 11 percent of the world's emissions in a single day. When used to their fullest capacity (3,500 e-books, or 2,187.5 physical books offset), e-readers sold through 2012 could prevent the emission of 1.6 trillion kg of CO2, or 19 days' worth of global emissions.

The sector must overcome some obstacles if the estimates for sales of devices and content are to be achieved. Amazon's device and content are not compatible with others', prompting many consumers to delay picking a technology because they are unsure which could provide the features and content they want, according to Francis Sideco, an analyst for iSuppli. For that reason, adoption is likely to accelerate more quickly once industry standards are in place, most likely around 2013, he said. We call on the publishing industry to remove this barrier to adoption.

We also encourage schools and universities to run pilot tests of e-reader devices in place of physical textbooks. Books for elementary, high schools and colleges represented a third of books sold globally in 2008, according to the Book Industry Study Group. The average textbook results in the emission of 10.2 kg of CO2, more than double that of a typical softcover book. Princeton University, the University of Virginia, and Arizona State University are among six higher-education facilities participating in such a pilot starting this fall.

We also recommend that an independent research lab perform a thorough analysis of the impact of e-reader devices, but our rough calculations indicate that e-readers undoubtedly will significantly reduce emissions due to the publishing sector.

Finally, we note that any reductions in emissions are fully dependent on the publishing industry reducing production of physical books. In the meantime, the publishing sector is attempting to improve the environmental footprint of physical publishing with cleaner processes and more recycling by 2020. The rate of adoption for e-readers is progressing quickly enough that any improvements would likely be overshadowed by e-readers' growing impact on the carbon footprint of reading.

North America
220 Montgomery Street, Suite 1000
San Francisco, CA 94104
+1 415 684 1020

2250 Genoa Business Park Drive
Brighton, MI 48114
+1 810 224 4310
sales@cleantech.com

China
2513 The Spaces International Center
No 8 Dongdaqiao Road
Chaoyang District, Beijing, China 100020
+86 150 1129 4877
china@cleantech.com

Europe/Israel
175-185 Grays Inn Road, London, UK WC1X 8UE
+44 (0) 20 7812 0575
europe@cleantech.com

India
S-352 Greater Kailash, Part 2, Delhi, India 110048
+91 (11) 4053 6943
india@cleantech.com

Arab Region
P.O. Box 851516, Amman, Jordan 11185
+962 6 5858 734
arabregion@cleantech.com

www.cleantech.com