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The Carbon Footprint of Email Spam Report

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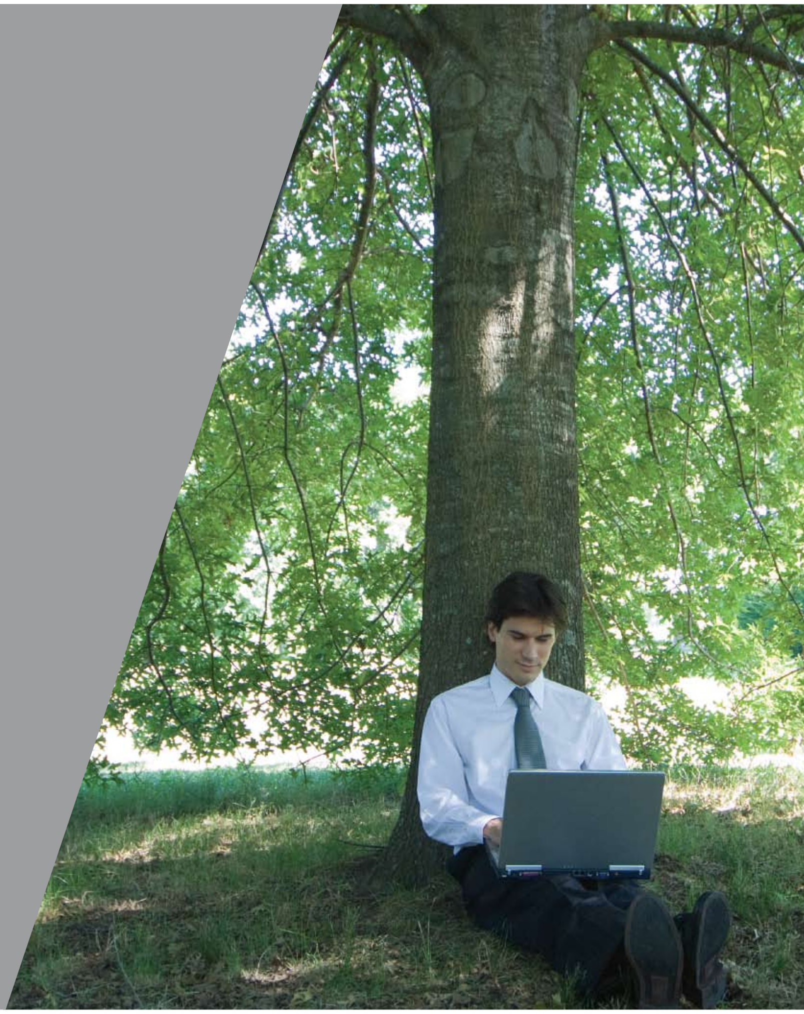
CONTENTS



Key Findings

McAfee commissioned climate-change consultants ICF and spam expert Richi Jennings to calculate the environmental impact of spam. They calculated the energy use associated with each stage in the lifecycle of spam, including the energy used to transmit, process, and filter spam.

- An estimated worldwide total of *62 trillion spam emails* were sent in 2008
- The average spam email causes emissions equivalent to *0.3 grams of carbon dioxide (CO_2) per message*
- Globally, annual spam energy use totals 33 billion kilowatt-hours (kWh), or 33 terawatt hours (TWh). That's equivalent to the electricity used in *2.4 million homes,* with the same GHG emissions as 3.1 million passenger cars using two billion U.S. gallons of gasoline.
- Spam filtering saves 135 TWh of electricity per year. That's equivalent to *13 million cars off the road*
- If every inbox were protected by a state-of-the-art spam filter, organizations and individuals could reduce today's spam energy by 75 percent or 25 TWh per year. That's like taking *2.3 million cars off the road.*
- The average greenhouse gas (GHG) emission associated with a single spam message is 0.3 grams of CO_2. That's like driving three feet (1 meter), but when multiplied by the annual volume of spam, it's like *driving around the Earth 1.6 million times.*
- A year's email at a typical medium-sized business uses 50,000 kWh; more than *one fifth of that annual use can be associated with spam*
- Filtering spam is beneficial, but fighting spam at the source is even better. When McColo, a major source of online spam, was taken offline in late 2008, the energy saved in the ensuing lull, before spammers rebuilt their sending capacity, equated to *taking 2.2 million cars off the road.*
- Much of the energy consumption associated with spam (nearly 80 percent) comes from end users deleting spam and searching for legitimate email (false positives). Spam filtering accounts for *just 16 percent of spam-related energy use.*

Executive Summary

Email spam is a significant problem for both individual users and businesses. Its financial impact and, in the case of some phishing schemes, the personal pain and loss it can cause has been the subject of many research studies. But until McAfee commissioned climate-change consultant ICF International and spam expert Richi Jennings to calculate the environmental impact of spam, spam's contribution to GHG emissions had been largely ignored.

This report looks at the global energy expended to create, store, view, and filter spam. It correlates electricity with its carbon footprint, since fossil fuels are by far the largest source of electricity in the world today.

The ICF analysis makes a compelling argument for stopping spam at its source as well for investing in state-of-the-art spam filtering technology, which not only saves time and money but can pay off in big dividends to the planet by reducing the carbon footprint of email spam.

A day without spam

On November 11, 2008, McColo Inc., a United States-based web hosting provider notorious for its prolific contribution to email spam, was taken offline by its upstream internet service provider (ISP). Overnight, global spam volume dropped by 70 percent. The most obvious benefit of the shutdown for practically anyone with an email address was an immediate reduction in unsolicited junk messages. At the same time, the planet experienced a less obvious environmental benefit. For every spam email not sent, an associated reduction in electricity use, and therefore carbon emissions, took place.

The substantial, though temporary, drop in total spam traffic that accompanied the disconnection was a decided relief for individual email users and organizations worldwide. It also spelled relief for the planet. ICF equated one day of the reduced spam traffic to taking 2.2 million passenger vehicles off the road. While distributing spam does not require shipping physical goods in the way old-fashioned junk mail does, it does require innumerable pieces of computer hardware—for sending spam, moving it across the Internet, processing it, storing it, viewing it, and filtering it out.

As the world struggles with everything from climate change to increased industrialization in developing countries, McAfee believes the time is right for looking at the global impact of an annual 62 trillion spam emails and asking the question, "What is the environmental benefit of blocking email spam?"

The carbon footprint of spam

To determine the carbon footprint of spam, ICF, with the assistance of McAfee, calculated the energy use associated with each stage in spam's life cycle and then applied the appropriate emissions intensity to the total energy associated with spam and spam filtering. The results demonstrate that the average GHG emissions per spam message total 0.3 grams of CO_2-equivalent (CO_2-e). This is far less than the four grams of CO_2 ICF associates with the average legitimate email. However, spam email accounts for just over one-third of the total emissions related to business and personal email globally, because about 80 percent of all email messages are spam messages.

The average business email user is responsible for 131 kg of CO_2 per year in email-related emissions, and 22% of that figure is spam-related.

The average business email user is responsible for 131 kg of CO_2 per year in email-related emissions, and 22 percent of that figure is spam-related. This spam energy is equivalent to the emissions that would result if every business email user burned an extra 3.3 gallons of gasoline annually.

The energy required annually to create, send, receive, store and view spam adds up to more than 33 billion kWh, approximately equivalent to four gigawatts of baseload power generation or the power provided by four large new coal power plants. ICF estimates spam-related emissions for all email users at an annual total of 17 million metric tons of CO_2 or 0.2 percent of the total global CO_2 emissions — a number equivalent to emissions from approximately 1.5 million U.S. homes.

Annual global impact

This study examines spam in 11 countries and, since emissions cannot be isolated to one country, averages its findings to arrive at global impact. According to the study, the level of spam-related emissions generated in any country is usually proportionate to the number of email users in each country and the percentage of a country's email that is spam. Countries with greater Internet connectivity tend to have more email users, and countries where a greater percentage of incoming email is spam have proportionally higher emissions per email user.

Countries with greater numbers of email users generally use more energy for a global average of 22 kWh per user per year. Variations among countries are due in large part to the differences in the percentage of spam emails received in each country. Not surprisingly, countries where spam makes up a higher percentage of all email expend more energy per user than those countries with lower spam rates.

While the spam that arrives in any individual's inbox may create just a small puff of CO_2, the puff multiplied by millions of users worldwide adds up. Taking careful measures to discourage spammers worldwide can lead to meaningful reductions in energy use and GHG emissions and will save the world's email users time and money.

Phases of spam energy use

Spam energy use divides into several phases. First, spammers harvest email addresses, typically by "scraping" websites, a process that uses automated software to download a website's entire content and search it for email addresses.

The spammer then creates the spam campaign by writing the code and creating the copy for the spam messages. Next, a combination of zombie PCs (called botnets when they occur in large numbers) and conventional mail servers send the spam. The spam messages travel over the Internet hardware owned by ISPs and other network providers which acts as a bridge between sender and

Countries with greater numbers of email users generally use more energy for a global average of 22 kWh per user per year.

receiver. After reaching the receiver's network, mail servers process spam and place it into disk storage. Spam filtering devices use energy at several points along the way. Finally, email recipients must view and delete spam that has evaded the filters (false negatives). The recipients also expend energy searching for legitimate mail caught in spam filters (false positives).

Users dealing with spam

The largest single source of spam-related energy consumption and emissions comes from end users viewing and deleting spam (52 percent). Manually sorting, viewing, and deleting spam, as well as searching for legitimate email (false positives), uses almost 18 billion kWh or nearly 80 percent of total spam-related energy use.

It takes an average of three seconds for a user to view and delete a spam message. Although spam filters block approximately 80 percent of spam before it reaches the user, the massive quantities of email spam and the increasing ingenuity of spammers leave a large number of spam messages in end user inboxes. Approximately 104 billion user hours per year go to reading and manually deleting spam (Jennings, 2008).

Energy use for spam filtering

Spam filtering also makes up a significant portion of PC energy use — up to 5,542 million kWh annually or about 16 percent of overall spam energy use. But compared to the energy that users consume searching for false positives and viewing and deleting spam messages, the energy expenditure of spam filtering seems like a small price to pay. Spam filtering helps to reduce the overall number of spam messages, thus decreasing the time spent manually sorting through the messages and the associated energy use and GHG emissions.

A day without spam filtering would have significant environmental consequences. If all spam were allowed to reach inboxes, the time end users would spend clearing spam out of their inboxes would increase dramatically. Not only would this circumstance exact a heavy price in lost employee productivity, it would increase GHG emissions associated with spam by 270 percent, because of the increased computing time required to view and delete these spam messages.

Conclusion

Spam email takes a toll on the finances and productivity of private and business email users all over the world. It also is a significant drain on the global environment. Because this impact is largely due to the amount of time end users spend searching for and deleting spam, investments in next-generation spam filtering technology can pay big dividends — in economic terms and in a positive impact on the carbon footprint of spam.

Introduction

Organizations and consumer end users throughout the world struggle with the scourge of spam email. The costs and risks associated with spam have been well documented (see e.g. Specter, 2007) and have led to attempts by both government and private industry to curtail spam, notably the United States legislature's CAN-SPAM Act of 2003 and proposals that range from large email providers banding together to implement sender authentication systems to pay-to-send models (see e.g. Koomey, et al, 2007).

Until McAfee® commissioned climate change specialist ICF International and spam expert Richi Jennings to study the global environmental impact of spam email, the focus has been on the financial fallout from spam. His study determined that taking measures to discourage spam, which accounts for 80 percent of all emails, not only saves organizations and individual email users time and money but can lead to meaningful reductions in energy use and resulting greenhouse gas (GHG) emissions.

By taking an environmental approach to the cost of spam, McAfee and ICF hope to aid the decision makers who are working to stem the tide of spam email and open a timely conversation on the costs of email spam to the planet.

Results of the Spam Carbon Footprint Study

The carbon footprint of spam

Wrestling with spam email is not new. To date, private industry and government have focused on the financial hardships spam imposes on email uses. Private industry has developed better mechanisms for filtering spam, and governments have attempted legislative action.

ICF parted from standard think tank approaches to spam when it undertook this study, which associates spam with energy use and GHG emissions that result from that use.

Before they could calculate the environmental impact of spam, researchers at ICF International, in collaboration with McAfee and spam expert Richi Jennings, took a hard look at energy-consuming activities that result from spam production. They identified the following emissions sources as key contributors to spam's carbon footprint.

- Harvesting addresses
- Creating spam campaigns
- Sending spam from zombies and mail servers
- Transmitting spam from sender to receiver via the Internet
- Processing of spam by incoming mail servers
- Storing messages
- Viewing and deleting spam
- Filtering spam and searching for false positives

The Life Cycle of Spam

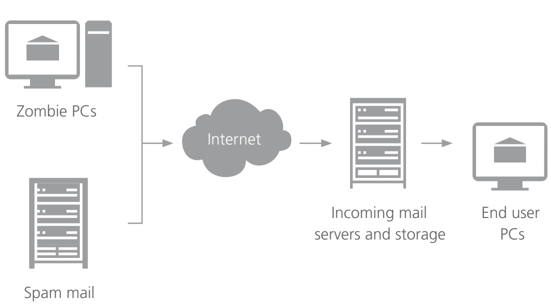


Figure 3-1. Each of the steps in the life cycle of spaam.

To begin the analysis, ICF isolated the energy use associated with each of these steps in the life cycle of spam. ICF then applied the appropriate emissions intensity to find that the total average GHG emissions associated with spam are 0.3 grams of CO_2-equivalent (CO_2-e) per message.

The overwhelming majority of spam's GHG emissions — nearly 80 percent — results from energy used to view and delete spam or search for legitimate email erroneously trapped in spam filters (false positives). At 16 percent, carbon emissions from spam filtering account for the next largest portion of spam's total footprint.

Percentage of GHG Emissions per Spam Message

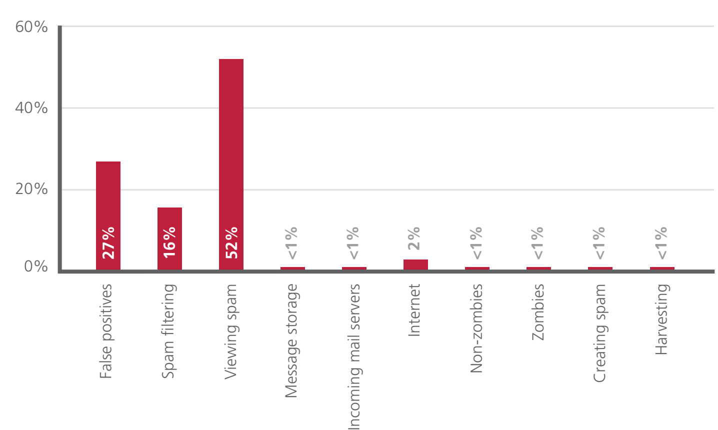


Figure 3-2. This chart describes the percentage of GHG emissions associated with each component of spam energy use.

The energy required annually to create, send, receive, store, and view spam adds up to more than 33 billion kWh, equivalent to almost 4 gigawatts of baseload power generation or four large new coal power plants.

ICF calculated the footprint of spam over the course of a year and estimated spam-related emissions at approximately 17 million metric tons of CO_2-e annually, or 0.2 percent of total global CO_2 emissions. This annual global spam footprint is equivalent to emissions from 2 billion gallons of gasoline, the amount used annually by three million passenger vehicles, or 1.5 million U.S. homes. The energy required annually to create, send, receive, store and view spam adds up to over 33 billion kWh, equivalent to almost four gigawatts of baseload power generation or four large new coal power plants. For equivalency calculations, refer to EPA (2008).

When McColo ISP, a major host of spam groups, was taken offline, McAfee calculated that global spam levels fell by about 70 percent. Other spam researchers reported a similar drop (Hoffman, 2008). If this level of spam reduction continued for one year, it would provide an environmental benefit equal to taking some 2.2 million passenger vehicles off the road for a year.

Compared to other industries, spam is a relatively small contributor to global emissions. Global emissions for all computer servers worldwide totaled an estimated 0.7 percent of total global CO_2 emissions in 2005, while air travel accounted for about 7 percent of global CO_2 emissions (Koomey 2007; Fleming 2007).

Spam filtering makes up a significant portion of PC energy use, but compared to the energy users consume searching for false positives and viewing and deleting spam messages, the energy expenditure of filtering seems like a small price to pay to not only reduce the number of spam messages and the amount of time spent manually sorting through them, but to avoid associated energy use and GHG emissions.

Total E-mail Messages per Minute

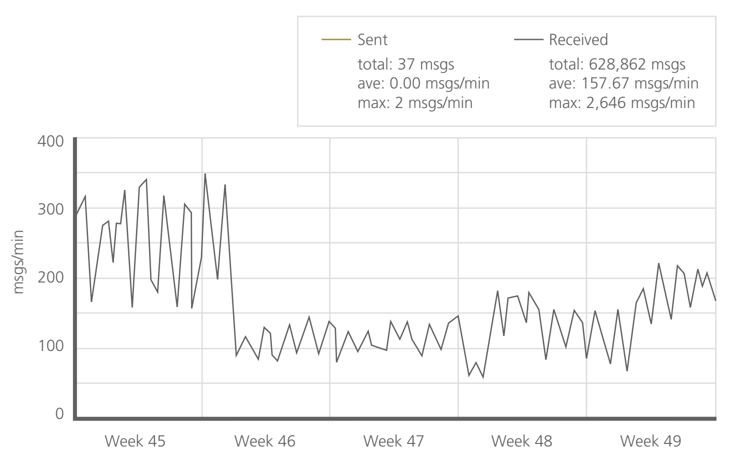


Figure 3-3. Source: McAfee

Total Emissions for Spam by Country (Billion kg CO_2-e / yr)

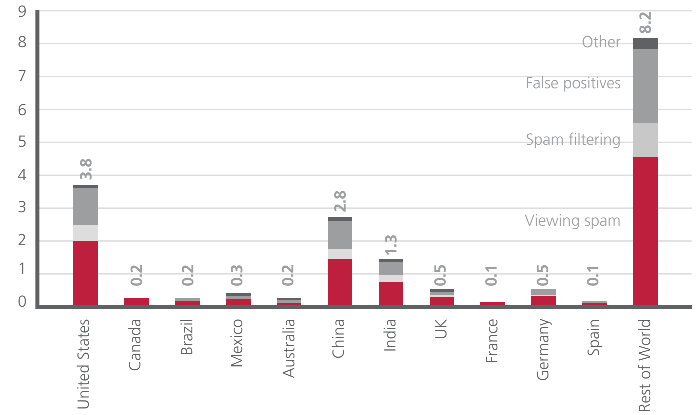


Figure 3-4. Emissions associated with spam for the 11 countries examined in the study

For this report, ICF examines spam across 11 different countries and focuses on global averages, because the researchers found little discernable international difference in the energy use caused by spam or any detailed data on the efficiency of PC and network equipment in each country. ICF attributes regional variations in emissions per spam message to two factors. First, the sending of spam largely mirrors the receiving of spam. Greater national Internet connectivity leads to a greater portion of the population using email and receiving spam. With some exceptions, countries in which a higher percentage of homes have Internet connections see a higher numbers of zombie PCs — those that are unwittingly sending out spam. Because zombie PCs send most spam, their numbers translate into greater volumes of spam. Secondly, emissions per spam message relate to the cleanliness of a country's power. Those nations with cleaner sources of electricity see fewer emissions for every unit of electricity used. As a result, the electricity they use to send, receive and read each piece of spam results in fewer GHG emissions.

Annual global spam footprint is equivalent to three million passenger vehicles on the road annually.

Figure 3-4 shows emissions associated with spam for the 11 countries examined in the study. Countries with greater numbers of email users generally show greater energy usage. Figure 3-5 shows the energy use for spam per user. Globally, ICF estimates spam energy at 22 kWh per user per year. Variations among countries are due in large part to differences in the percentage of spam emails received in each country. Not surprisingly, countries where spam makes up a higher percentage of all email expend more energy per user than those countries with a lower percentage of spam.

Energy Use For Spam Per User

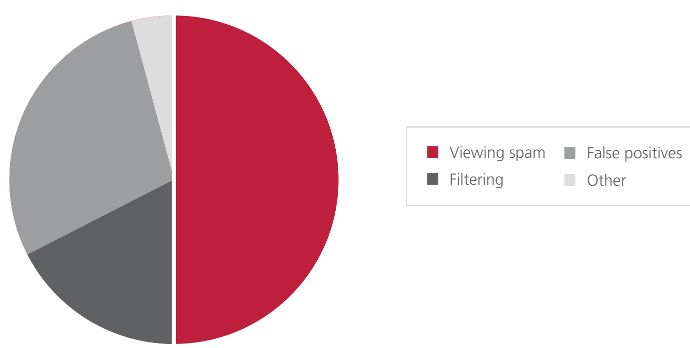


Figure 3-5. The energy use for spam per user.

Energy Use For Spam (million kWh/year)

	HARVESTING	CREATING SPAM	BOTS	NON-BOTS	INTERNET	INCOMING MAIL SERVERS	MESSAGE STORAGE	VIEWING SPAM	SPAM FILTERING	FALSE POSITIVES	TOTAL
GLOBAL TOTAL	63 / 0%	0.2 / 0%	114 / 0%	9 / 0%	747 / 2%	181/1%	148 / 0%	17707 / 52%	5542 / 16%	9222 / 27%	33733 / 100%
U.S.	12 / 0%	0 / 0%	24 / 0%	9 / 0%	151 / 2%	36/1%	30 / 0%	3571 / 52%	1120 / 16%	1860 / 27%	6805 / 100%
CANADA	2 / 0%	0 / 0%	3 / 0%	0.2 / 0%	19 / 2%	5/1%	4 / 0%	457 / 52%	143 / 16%	238 / 27%	872 / 100%
BRAZIL	1 / 0%	0 / 0%	5 / 0%	0.4 / 0%	33 / 2%	8/1%	7 / 0%	784 / 53%	246 / 16%	408 / 27%	1493 / 100%
MEXICO	1 / 0%	0 / 0%	3 / 1%	0.1 / 0%	9 / 2%	2/0%	2 / 0%	224 / 45%	120 / 24%	133 / 27%	495 / 100%
AUSTRALIA	0.5 / 0%	0 / 0%	1 / 1%	0.1 / 0%	4 / 2%	1/0%	1 / 0%	106 / 45%	57 / 24%	63 / 27%	234 / 100%
CHINA	8 / 0%	0 / 0%	23 / 0%	2 / 0%	145 / 2%	35/1%	29 / 0%	3444 / 52%	1080 / 16%	1794 / 27%	6560 / 100%
INDIA	0.5 / 0%	0 / 0%	22 / 0%	2 / 0%	140 / 2%	34/1%	28 / 0%	3317 / 53%	1040 / 16%	1727 / 27%	6310 / 100%
UK	3 / 0%	0 / 0%	4 / 0%	0.3 / 0%	28 / 2%	7/1%	5 / 0%	656 / 52%	206 / 16%	342 / 27%	1251 / 100%
FRANCE	2 / 0%	0 / 0%	3 / 1%	0.1 / 0%	12 / 2%	3/0%	2 / 0%	288 / 45%	155 / 24%	172 / 27%	639 / 100%
GERMANY	3 / 0%	0 / 0%	5 / 1%	0.2 / 0%	17 / 2%	4/0%	3 / 0%	407 / 45%	219 / 24%	242 / 27%	900 / 100%
SPAIN	6 / 2%	0 / 0%	2 / 1%	0.1 / 0%	5 / 2%	1/0%	1 / 0%	122 / 38%	102 / 31%	84 / 26%	323 / 100%
REST OF WORLD	25 / 0%	0.1 / 0%	18 / 0%	2 / 0%	183 / 2%	44/1%	36 / 0%	4331 / 55%	1054 / 13%	2158 / 27%	7851 / 100%

Figure 3-6.

An estimated worldwide total of 62 trillion spam emails were sent in 2008.

Figure 3-6 shows ICF's estimates on the makeup of global energy use for spam by country and by activity. The table outlines the spam energy use of several key countries and characterizes the rest of the world sat the bottom. Further details about each activity and a description of ICF's methodology follows.

A year's email at a typical medium-sized business uses 50,000 kWh; more than one fifth of that annual use can be associated with spam.

Energy Use for Spam by Country

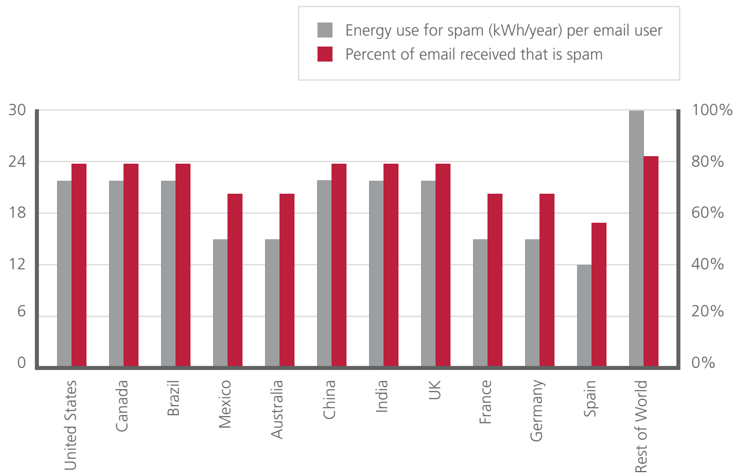


Figure 3-7.

Please note that not all energy use shown actually occurs in the named country because a portion of the energy ICF accounts for is embodied energy used to manufacture users' PCs. It is beyond the scope of this report to disentangle the supply chain for this computing equipment, so all energy use was attributed to the country where users actually receive the spam. If the embodied energy of the servers and other telecommunications equipment used to send, transmit and receive spam could be calculated, the global spam energy figures would increase.

Spam energy use detail

In this section, ICF divides the energy use of spam into several phases and annualizes its findings. First, spammers harvest email addresses, typically by "scraping" websites, a process that uses automated software to download a website's entire content and search it for email addresses.

The spammer then creates the spam campaign by writing the code and creating the copy for the spam messages. Next, a combination of zombie PCs (called botnets when they occur in large numbers) and conventional mail servers send the spam. The spam messages travel over the Internet hardware owned by ISPs and other network providers which acts as a bridge between sender and receiver. After reaching the receiver's network, mail servers process spam and place it into disk storage. Spam filtering devices use energy at several points along the way. Finally, email recipients must view and delete spam that has evaded the filters (false negatives). The recipients also expend energy searching for legitimate mail caught in spam filters (false positives).

As a point of comparison, ICF calculates annual energy use for legitimate email on an annual basis. Researchers divide the energy use into life cycle phases of email and calculate the energy draw and associated GHG emissions in a similar fashion to the calculation methodology they use for spam. These life cycle phases include drafting legitimate email, sending email (including outgoing mail servers and Internet transmission), receiving email (including incoming mail servers and storage), and viewing email.

To calculate each element of the spam carbon footprint, ICF chose the best available information from several sources. Information included statistics on energy use per gigabyte (Gb) of data or operating time for several equipment types, and the volume of email and spam flows. These calculations are described in more detail in the methodology section.

Harvesting addresses

ICF calculated the annual energy requirements to harvest target email addresses for spam mailings and used estimates to determine total harvester traffic per year globally by multiplying the number of page views from harvesters with the average harvested page size, including overhead. ICF researchers multiplied total harvester traffic per year by the energy intensity of website harvesting to determine annual harvesting energy. They based the energy intensity of website harvesting on data from Taylor & Koomey (2008).

Energy use for harvesting addresses varies region by region as a function of estimated proportion by harvester location (Jennings, 2008). As might be expected, the harvesting of addresses makes up a small portion of spam energy use — less than one percent.

Spam Energy Use

	ENERGY USE (MILLION KWH/YEAR)	PERCENTAGE OF ENERGY USE
Harvesting addresses	63	<1%
Creating spam campaigns	0.2	<1%
Zombies sending spam	114	<1%
Non-zombies sending spam	9	<1%
Internet (excluding mail servers) transmitting spam	747	2%
Incoming mail servers processing spam	181	2%
Message storage	148	<1%
Users viewing/deleting spam	17707	52%
Spam filtering	5542	16%
Users searching for false positives	9222	27%
Total emissions from spam	33733	100%

Figure 3-8.

Legitimate Email Energy Use

	ENERGY USE (MILLION KWH/YEAR)	PERCENTAGE OF ENERGY USE
Drafting legitimate email	29512	25%
Outgoing mail server energy use for legitimate email	15077	12.5%
Internet energy use for legitimate email	2489	2%
Legitimate email incoming mail server energy use	15077	12.5%
Legitimate email storage energy use	13693	11%
Energy use to view legitimate email	44267	37%
Total emissions from legitimate email	120115	100%

Figure 3-9.

Creating spam campaigns

To calculate total energy spammers use to create and maintain spam campaigns, researchers approximated the time spammers spend on these activities and multiplied this figure by the average active mode PC power draw. They added to this figure the embodied energy of the PCs that spammers use for this activity. ICF assumed that active spammers own these PCs primarily for the purpose of maintaining their spam campaigns. Average active mode PC came from Roth (2007), while average PC-embodied power came from Williams (2004) and Roth (2008). The energy required to create and maintain spam campaigns is a small proportion of the total energy used for spam — less than one percent.

Zombies sending spam

The term "zombies" refers to compromised computers that have been set up to forward transmissions to other computers on the Internet at the wishes of the spammer, although their owners are typically unaware of this circumstance. ICF researchers calculated the annual energy zombies use to send spam by extrapolating from weekly zombie energy use. They calculated zombie energy use per week by multiplying zombie PC active power draw, which they assumed was the same as average active mode PC power draw, by approximate mean zombie PC weekly spam time, which they assumed was 90 percent of the time zombies are in use.

To reach zombie energy use per year, researchers multiplied annual active computer usage hours (based on Roth, 2007) by the estimated proportion of zombie power used to send spam (50 percent) and the estimated number of zombies co-opted. ICF allocated 50 percent of zombie energy use to the activity of sending spam, because the malware program that actually sends the spam typically operates in the background while the user performs other tasks on the PC. Although this may not lead to a direct 50 percent increase in energy use, it does often slow the user's computer appreciably, leading to sluggish response times. This may, in turn, cause the user to leave the PC on for a greater number of hours and possibly even replace it before the end of its normal life, due to decreased performance.

Because these home PCs are not purchased for the purpose of becoming zombies and sending spam, ICF does not allocate any of a home PC's embodied energy to spam activity.ICF believes it is more appropriate to allocate the embodied energy and emissions to the willful and intended use of the PC. Similar to the two life cycle stages described above, energy used by zombies to send spam is a negligible portion of total spam energy — less than one percent.

The average greenhouse gas (GHG) emission associated with a single spam message is 0.3 grams of CO_2. That's like driving three feet (1 meter), but when multiplied by the annual volume of spam, it's like driving around the Earth 1.6 million times.

The energy required to create and maintain spam campaigns is a small proportion of the total energy used for spam — less than one percent.

Non-zombie mail servers sending spam

"Non-zombies sending spam" refers to computers that are intentionally used to send spam messages to other computers on the Internet. These are the "real" mail servers that behave like (and in some cases are) legitimate marketers. They account for 20 percent of the total spam volume (Jennings, 2008) and include such message types as opt-in lists marketers purchase in good faith from scam artists, unwanted political or charity solicitations, and "blowback" from poorly administered email servers.

ICF calculated the total energy used to send spam from non-zombie mail servers by multiplying total spam sent from non-zombie mail servers by outgoing mail server energy use per sent email. The researchers calculated outgoing mail server energy by assuming one of the servers identified in the Dell Exchange 2007 Advisor (see Mail Servers and Storage) draws approximately 355 watts and sends email at an average rate of 1 Gb per hour. From this they calculated the outgoing mail server energy use at approximately 0.36 kWh per gigabit Gb of email. Total spam volume and the assumption that non-zombie spam accounts for 20 percent of total spam came from Jennings (2008), various anti-spam vendors (including McAfee), various non-profit entities (including Spamhaus), and other email researchers.

Like zombies sending spam, these mail servers ultimately account for a very small portion of the total energy and emissions associated with spam—approximately nine million kWh or less than one percent.

Sending and receiving legitimate email

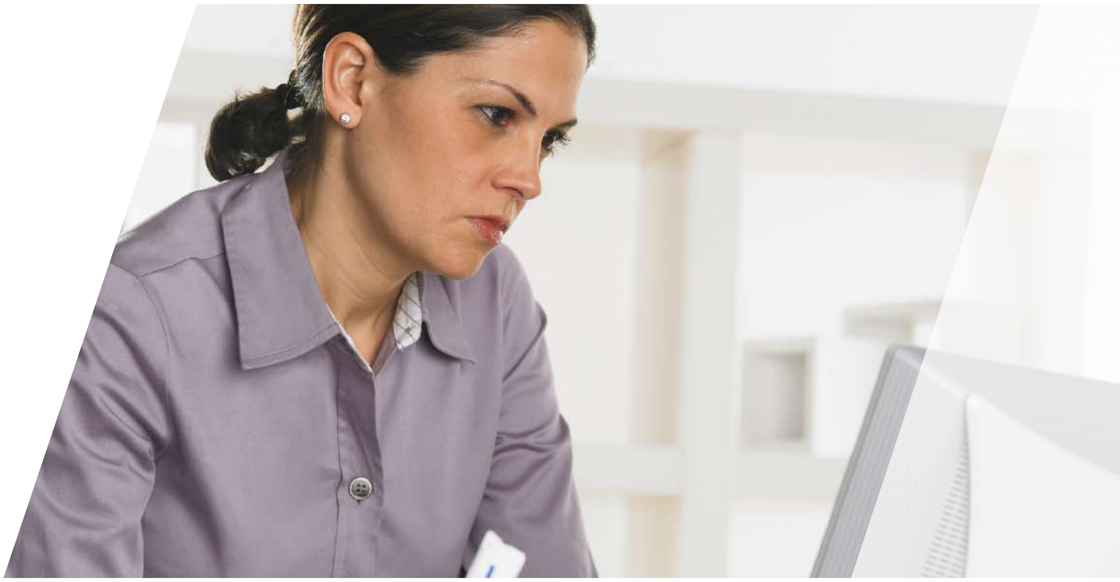
ICF used an analogous methodology to that described in previous sections to calculate the energy used in writing and sending legitimate email. The researchers assumed that users spend two minutes writing the average email and send it to an average of three recipients. They calculated that users spend 173 billion hours per year writing personal and business email globally, which results in active PC energy use of approximately 15.7 billion kWh per year and 13.8 billion kWh per year in embodied PC energy.

Users receive approximately 15.6 trillion legitimate email messages each year or about 426 petabytes (one petabyte equals one quadrillion bytes, or 1024 terabytes) of data (based on Richi Jennings and other email researchers). This results in energy usage of approximately 15 billion kWh annually.

Internet (excluding mail servers) transmitting spam

ICF calculates Internet energy use for spam email by multiplying total spam email volume by Internet energy intensity. Total spam email volume figures come from Jennings (2008), various anti-spam vendors (including McAfee), various non-profit entities (including Spamhaus), and other email researchers. ICF draws Internet energy intensity figures from Taylor and Koomey (2008), as detailed in a segment on Internet Data Transfer, below. At 747 million kWh per year, data transfer over the Internet (excluding mail servers) is relatively small—about two percent.

ICF uses the same method to calculate the energy used to move legitimate email across the Internet. The total energy used to move an estimated 426 PB of email across the Internet each year is approximately 2.5 billion kWh.



Incoming mail servers processing spam

ICF calculates energy use for incoming mail servers processing spam by multiplying spam volume that reaches mail servers by incoming mail server energy use. Spam volume that reaches mail servers comes from multiplying total spam volume by the industry average proportion of spam that is not blocked at the gateway level. Overall, ICF estimates that 80 percent of spam is filtered before reaching users. Of this total filtering, 80 percent is caught by a software-as-a-service (SaaS) or gateway-level spam filter, according to Jennings (2008), various anti-spam vendors (including McAfee), and other email researchers. ICF draws incoming mail server energy use figures from the Dell Exchange 2007 Advisor and Dell Datacenter Capacity Planner (see figure 3.10). Incoming mail servers processing spam make up a very small portion of total spam energy use for spam — approximately 181 million kWh or 1 percent.

ICF uses the same method to calculate that incoming mail servers use approximately 15 billion kWh annually to process legitimate email.

Message storage

ICF calculates energy use for spam mail storage by multiplying spam volume that reaches storage by mail storage energy use. The researchers consider spam volume that reaches storage as the portion of total spam volume that is not filtered at either the gateway or the mail server levels. Of the 80 percent of spam that is filtered before reaching users, 80 percent is filtered at the gateway; 10 percent, at the mail server; and 10 percent, at the desktop, according to data from Jennings (2008), various anti-spam vendors (including McAfee), and other email researchers. ICF draws message storage energy use figures from the *Dell Exchange 2007 Advisor and Dell Datacenter Capacity Planner* (see figure 3.10). Message storage energy use makes a very minor contribution to the total energy footprint associated with spam — approximately 148 million kWh or less than one percent.

ICFR calculates the energy used to store legitimate email at 14 billion kWh per year. While many systems will allow the eventual deletion of spam email, increasing storage of legitimate email may cause this portion of total energy usage to rise substantially in the future.

Users manually sorting, viewing, and deleting spam

ICF researchers calculate the largest single source of emissions related to spam — the total energy users use to view and then delete spam — by adding PC-direct energy use to delete spam to PC-embodied energy use to delete spam. PC-direct energy use to delete spam is the product of the total time spent manually deleting spam and average active mode PC power draw. Similarly, PC-embodied energy use to delete spam is the product of the total time spent manually deleting spam and average PC-embodied power draw. For more detail, see PC Active Mode Energy Use and PC Manufacture below. Total time to delete spam is calculated by multiplying the number of spam messages viewed by users annually and the estimated time to delete each spam message — three seconds. As noted above, ICF estimates that 80 percent of spam is blocked before reaching the

The total energy used to move the estimated 426 PB of email across the Internet each year is approximately 2.5 billion kWh.

Mail servers and storage

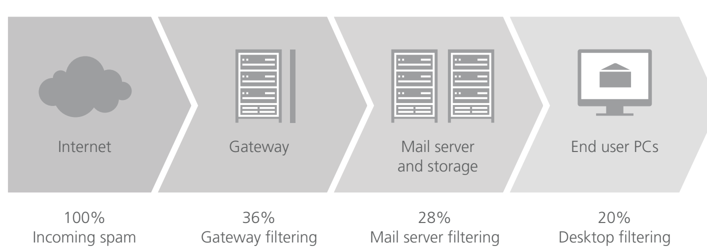


Figure 3-10.

Users viewing and deleting spam is the largest energy drain associated with spam, almost 18 billion kWh or 52 percent of total spam energy.

user, but given the ever more massive quantities of spam being sent and the increasing ingenuity of spammers, this still leaves a large number of spam messages in inboxes. Jennings (2008) believes email users spend 104 billion hours per year reading and manually deleting spam. Users viewing and deleting spam accounts for the largest energy use associated with spam — almost 18 billion kWh or 52 percent of total energy use for spam.

The next largest source of emissions related to spam — total energy use required by end users to filter for false positives (FPs) — was calculated by adding PC-embodied energy use searching for FPs to PC-direct energy use searching for FPs. To arrive at these figures, researchers multiplied total time spent searching for FPs by the respective average PC mode power draws. They calculated the annual number of false positive messages by multiplying the false positive rate by the total email traffic (Jennings, 2008). PC-embodied power draw came from Williams (2004) and Roth (2008). Average active mode PC power draw came from Roth (2007). Twenty-seven percent of the total energy use for spam or nine billion kWh comes from users searching for false positives.

ICF uses the same method to calculate the energy used to read legitimate mail as that for reading spam. This study estimates that users spend an average of one minute reading each email (note that this includes very short emails, such as meeting requests and empty messages with file attachments). Worldwide, ICF calculates that users spend 260 billion hours per year reading legitimate email — approximately eight hours per week for a business user. Researchers calculate the total direct energy used by PCs to view email as 23.6 billion kWh per year and total embodied PC energy for viewing legitimate email as 20.7 billion kWh per year.

Spam filtering

ICF calculated energy use associated with spam filtering based on filtering out spam at the ISP, the gateway, or the mailbox. To calculate total spam filtering, researchers added total consumer filtering energy to total business filtering energy. These totals came from annual filtering energy per mailbox and the number of respective email types. Annual filtering energy and number of mailboxes came from Jennings (2008). Annual energy use to filter spam in businesses was estimated at approximately 8.8 kWh per year for each email account. This was based on an estimated 60 percent of users employing a typical gateway spam appliance (estimated at 1 kW to provide two-way filtering for 1,000 users) and 50 percent of users employing SaaS filtering, which is an estimated 20 percent more efficient than gateway appliances. Overlap exists between these methods, because ICF expects some users to employ both SaaS filtering and a gateway filter. ICF estimates consumer annual energy use to filter spam at approximately 1.1 kWh per year for each email account. This is based on the assumption that all ISPs filter incoming spam, and 20 percent of users employ an additional desktop spam filter that adds 1 percent

Users searching for false positives make up 27% of the total energy use for spam, approximately nine billion kWh.

to their PC's energy use (Jennings, 2008). Spam filtering makes up the third largest proportion of spam energy use — 16 percent.

PC active mode energy use

ICF estimates the power drawn by average PCs while in active mode to facilitate calculations at several steps in the spam chain. For example, ICF attributes the energy a PC uses while a user views a spam email to that spam email. The researchers estimate the average active mode power draw of a PC at 91W, based on Roth (2007). This value is consistent with data collected by ICF, Ecos Consulting, EPRI Solutions, and NRDC, and presented in Horowitz (2005). This value includes both desktop and notebook PCs, and assumes that 10 percent of notebook PCs are also plugged into external monitors, while 100 percent of desktop PCs use external monitors. ICF assumes, based on Roth (2007), that 70 percent of residential PCs are desktops, while the rest are notebooks. ICF further assumes that the distribution of desktop and notebook PCs is similar in commercial environments.

PC manufacture

Because ICF researchers believe the energy and emissions associated with the manufacture of PCs amounts to a substantial portion of the total energy they use over their lifetime, PC manufacture was included in the calculations. This "embodied" energy from PC manufacture is part of the calculations for energy used in creating spam campaigns, viewing and deleting spam, and searching for false positives. ICF begins with a standard assumption that the energy used to manufacture a PC can be apportioned out over its lifetime of use. The study apportions the energy used in PC manufacture only to the hours a PC is actively in use (Roth (2007). The study assumes an average four-year life for PCs, based on Roth (2008). ICF derives a value for total electricity used in manufacturing a desktop PC from Williams (2004), and assumes that manufacturing a laptop PC involves similar energy use. Williams cites the energy used to manufacture a PC in terms of both electricity and thermal energy. Because the rest of this analysis is in terms of electric energy used, ICF converts the thermal energy in manufacturing into electric energy. To convert the thermal energy values into electric energy equivalents, the researchers first converted the thermal energy to its associated CO_2 emissions output, then converted those emissions into the equivalent amount of electricity (at the world-average electricity emission factor from IEA 2006). This conversion allowed the study to discuss both total energy use in kWh and total emissions in kg CO_2-e in a consistent fashion. Given the ICF estimate of an average of 91 watts for active mode power draw and 80 watts for embodied power draw, embodied energy for the PC makes up 47 percent of the total energy use in the areas where it is counted — creating spam campaigns, viewing/deleting spam, and searching for false positives.

Internet data transfer

While it is impossible to determine exactly which Internet equipment is used to carry spam messages from sender to recipient, ICF can estimate the average energy use to transmit data over the Internet. ICF bases this figure on work done in Taylor and Koomey (2008) and EPA (2007). The analysis found in these papers focuses on the energy intensity of the Internet in the United States. Because of a lack of data in other regions, ICF uses the same values. While ICF does do not believe that all geographic regions have the same energy intensity in their Internet infrastructure, it is not clear whether the world average would be higher or lower than the U.S. Indeed other countries with Internet infrastructures built almost entirely in more recent years may have more efficient equipment in place. Where information does not exist, the study relies on existing estimates.

In this case, ICF uses customized values from Taylor and Koomey (2008) for servers and storage that are particular to mail server environments. ICF's estimate of energy used in data transfer over the Internet excludes servers and storage and includes only hubs, routers, LAN switches, and WAN switches. These types of equipment used a total of 13.4 TWh in 2006 in the United States. ICF also includes the energy used by access technologies (DSL, cable, dialup, fiber, and others) that connect PCs and servers to the network. The researchers went to Taylor and Koomey (2008) for a range of estimates for total data flows over the Internet. This yields a range of energy for email traveling over the Internet of 3.4 to 8.3 kWh/Gb. For this report, ICF assumes the mean value of 5.8 kWh/Gb for all email. We draw from the Taylor and Koomey (2008) estimate of 17.2 kWh/Gb for the energy intensity of web pages scraped in the process of harvesting email addresses.

Mail servers and storage

To estimate the energy used by mail servers, ICF utilized the *Dell Exchange 2007 Advisor and the Dell Datacenter Capacity Planner.* While recognizing the commercial nature of these tools and the possible skew they may introduce, ICF still regards them as a reliable source of reasonable estimates for the hardware requirements of a typical corporate mail environment. ICF also recognizes that consumer email, whether provided as a POP account by a user's ISP or as a web-based mail client (such as Yahoo! Mail, Gmail, or Hotmail) is likely to have a different hardware profile than typical corporate email environments. Extremely large numbers of users for these consumer email providers engender economies of scale not seen in most commercial enterprises, and may allow hardware customization for heightened efficiency. While compliance with government regulations, such as

Sarbanes-Oxley, is causing a substantial rise in the storage requirements associated with commercial email environments, competition among providers of consumer email services has caused the size of personal email accounts to balloon as well. However, due to the highly sensitive nature of information concerning the efficiency of these mail services, little information is in the public domain, and ICF must assume for now that their energy use is similar to that of corporate email servers and storage on a per gigabyte (Gb) basis.

To calculate the typical energy usage from email servers, ICF first used the *Dell Exchange 2007 Advisor* with a configuration of 1,000 mailboxes distributed 300/500/200 among the light/medium/heavy user categories, with 500/500/1000 kilobyte (Kb) mailbox sizes respectively. The researchers then used the output of the *Exchange Advisor* to build a hardware profile in the *Dell Datacenter Capacity Planner (DCCP).* ICF recognizes that the heat values built into the DCCP may overestimate the average energy usage of the hardware because they do not appear to be based on a standardized third-party metric for energy use. Because of a lack of other information, ICF opts to use them in this study. The total server power draw for a 1,000-user environment is estimated at 1,326 watts, including mailbox server, backup server, remote standby mailbox server, and edge server.

The total storage power draw for a 1,000-user environment is estimated at 1,204 watts, including storage, replicated storage, and tape backup. We recognize that not all email implementations will choose to use all of these functions, but we believe this to be representative. Some implementations may also include additional functions, such as additional mirroring that could increase energy use even more. In scaling these energy usage numbers to account for the auxiliary equipment required for temperature and humidity control, as well as power conditioning functions, ICF uses a global average power usage effectiveness (PUE) of 2.0, consistent with Greenberg et al (2006). This yields an annual energy use of 23.2 MWh for servers and 21.1 MWh for storage. ICF recognizes that this PUE may not be representative of conditions worldwide, but believes it to be the best information currently available.

To calculate the total email traffic on this configuration in a year, ICF uses a Microsoft (2008) estimate of an average 50 Kb message size for Outlook email. The ICF researchers believe this is the message size used in the Exchange Advisor tool. Based on these figures and an assumption of 250 days per year of emailing for the typical commercial email user, ICF calculates server energy use at 35.4 kWh/Gb of email and storage energy use at 32.1 kWh/Gb of email, respectively.

Globally, annual spam energy use totals 33 billion kilowatt-hours (kWh), or 33 terawatt hours (TWh). That's equivalent to the electricity used in 2.4 million homes, with the same GHG emissions as 3.1 million passenger cars using two billion U.S. gallons of gasoline.

Uncertainties and Future Research

ICF based the carbon footprint of spam on the best data readily available from various sources. As with any calculation of this nature, this effort involved a number of assumptions and estimations. Recognizing the imperfect nature of this analysis, we offer the following notes on uncertainty.

Much of our input data is based on best estimates. These calculations rely in part on informed estimates of the time spent searching for false positive messages and the time spent viewing and/or deleting actual spam messages. While we recognize that user behavior in working with computers is complex, the researchers believe these to be reasonable estimates that err on the side of being conservative. Similarly, the total volume of spam, the total volume of email, and the average sizes of these messages is based on best estimates but cannot be verified beyond a doubt. The portion of received email that is spam in each country is an estimate that is based on spamtrap data, and while it is probably reasonably accurate, it could likely be improved. Our figures for the number of zombie PCs in each country and the average time during which they are sending spam each year are estimates only and could also be improved. We do not currently account for the fact that some botnets include a substantial number of PCs that do not directly send email but instead act as DNS hosts (Stewart, 2008). We believe these figures are reasonable and represent triangulation among the sources available today.

Mail server data and email user definitions were drawn from the *Dell Exchange 2007 Advisory and Dell Datacenter Capacity Planner,* while message size was drawn from *Microsoft Exchange 2007 Processor and Memory Recommendations.* We recognize that these tools may not be wholly scientifically motivated in design or exact in nature but believe their exchange-related statistics are appropriate for the purposes of approximating the hardware requirements for typical mail servers.

We currently exclude the embodied energy for mail servers, storage, and other network equipment. We recognize that today's spam volumes may indeed cause increased purchasing of this equipment at the margin to handle spam in addition to legitimate email. It is not clear what the magnitude of this marginal effect is on the Internet. There is also a lack of reliable data about the energy embodied in the manufacture of servers and network equipment. We believe this area warrants further investigation.

Non-U.S. regional variation is primarily a function of the differences in numbers of consumer and business email mailboxes. We calculate these using a comparative factor based on data about the population and GDP in each country. We believe this is a reasonable proxy for the number of email addresses in each country, but further research in this area may be warranted. The number of Internet users in each country may prove to be a better proxy and would magnify the importance of India and China. Overall, our ability to represent inter-country variation is hampered by the current state of publicly available data. Our estimates of Internet energy use and PC energy use are based on data for the U.S. only and may not accurately represent the world as a whole.

Comparing global emissions for spam with other industries, such as servers and air travel, is best done on a same-year basis, as each of these industries is undergoing substantial growth.

Overall, we believe that the methods presented in this report offer a reasonable approach to calculating the global carbon footprint of spam. We do not believe our results are the last word on this subject but hope that they can serve as a starting point for other researchers to continue and expand the analysis.

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Appendix: Statement of Methodology

To develop the carbon footprint of spam, ICF examined each stage in the process of creating, transmitting, processing, viewing, and filtering spam. The researchers focused on energy used to power spammers' and end users' computer equipment; energy used to manufacture that computer equipment; energy used by servers, routers, switches, and other network equipment to transmit spam across the Internet; energy required by mail servers and storage devices to receive and process spam; and energy used for spam filtering. ICF did not include energy use or emissions from the manufacture of servers and network equipment.

For the purposes of this study, "email" is defined as follows:

Messages sent or attempted to be sent across the Internet using SMTP or ESMTP. This does not include email transmission that is wholly internal to a business (for example, within an exchange network). This does include transmission that is internal to a consumer service provider (for example, Hotmail). This also includes attempted deliveries of spam messages that are blocked before receipt (for example, by firewall, greylisting, or DNS blacklist policy).

The base year for the footprint is 2007. Although not all factors used for calculations are for 2007 due to the availability of information at this time, the use of some data from earlier years is not expected to materially affect the resulting GHG emission estimates.

Spam Statistics

STATISTIC	CALCULATION METHODOLOGY	MAIN ASSUMPTIONS
Internet Users Comparative Factor	"Country X" GDP/Capita (PPP) ÷ U.S. GDP/Capita (PPP) x "Country X" population 2007/2008 ÷ U.S. population 2007/2008	• Population figures are drawn from UN, Census, and CIA data. • GDP/Capita (PPP) figures are drawn from World Bank data. • The Internet Users Comparative Factor expresses how "Country X's" number of Internet users relates to the U.S.'s
Total mailboxes	Number of consumer email mailboxes + Number of business email mailboxes	• Number of consumer email mailboxes (CUs) is drawn from ITU data. • Number of business email mailboxes (BUs) is drawn from Ferris (2005) and Jennings (2008)
Total legitimate messages/year	Total legitimate messages/year received by consumers + Total legitimate messages/year received by businesses	• Total legitimate messages/year received by consumers • = Number of consumer email mailboxes • x Mean legitimate c2c or b2c messages/week • Total legitimate messages/year received by businesses • = Number of business email mailboxes • x Mean legitimate c2b or b2b messages/week • Mean legitimate c2c, b2c, c2b, b2b messages/week are drawn from Jennings (2008).
Total spam messages/year received (by country where received)	Spam received by CUs + Spam received by BUs	• Spam received by CUs = Proportion of email is spam x Total legitimate messages/year received by consumers • ÷ (1 – Proportion of email is spam) • Spam received by BUs = Proportion of email is spam x Total legitimate messages/year received by businesses • ÷ (1 – Proportion of email is spam) • Proportion of email is spam is drawn from data from (Jennings, 2008).
Total spam messages/year sent (by country where sent)	Spam sent to CUs + Spam sent to BUs	• Spam sent to CUs • = Proportion of email is spam • x Total legitimate messages/year sent by consumers • ÷ (1 – Proportion of email is spam) • Spam sent to BUs • = Proportion of email is spam • x Total legitimate messages/year sent by businesses • ÷ (1 – Proportion of email is spam) • Proportion of email is spam is drawn from Jennings (2008).
Mean size of legitimate email message (bytes)	Mean size of legitimate consumer email message + Mean size of legitimate business email message	• Mean size of legitimate business email message refers to email arriving from the Internet and does not include internal messages • Mean sizes of legitimate email messages is drawn from Jennings (2008).
Mean size of spam message (bytes)	Mean size of spam message	• Mean size of spam message is drawn from data from Jennings (2008).
Total email volume (Gb)	Legitimate volume received by CUs + Legitimate volume received by BUs + Spam volume received by CUs + Spam volume received by BUs	• Legitimate volume received by CUs • = Total legitimate messages/year received by consumers • x Mean size of legitimate consumer email message • ÷ 1000 • Legitimate volume received by BUs • = Total legitimate messages/year received by businesses • x Mean size of legitimate business email message • ÷ 1,000 • Spam volume received by CUs • = Spam received by CUs x Mean size of spam message • ÷ 1,000 • Spam volume received by BUs • = Spam received by BUs x Mean size of spam message • ÷ 1,000
Proportion of spam blocked		• Proportion of spam blocked (industry average) and Proportion of spam blocked (McAfee or other state-of-art) drawn from data from Jennings (2008).
Percent of spam blocked at gateway/Saas; mail server; or desktop		• Percentages are drawn from data from Jennings (2008). • Percentages sum to 100 percent

Energy Calculation Methodology by Spam Life Cycle Stage

Creating spam

Harvesting addresses

ENERGY UNIT OF MEASURE	KWH
Data collected	• Number of websites • Proportion of page views from harvesters • Mean site's page views/day • Average harvested page size, including overhead (bytes) • Proportion by harvester location • Energy intensity of website harvesting (kWh/Gb)
Calculation methodology	• Annual harvesting energy = Total harvester traffic per year x Energy intensity of website harvesting
Main assumptions	• Total harvester traffic per year by "X" = Proportion by harvester location x Total harvester traffic per year • Total harvester traffic per year = Number of websites x Proportion of page views from harvester x Mean site's page views/day x Average harvested page size x 365.25 ÷ 1,000,000,000 • Number of websites, Proportion of page views from harvester, Mean site's page views/day, Average harvested page size, and Proportions by harvester location are drawn from Jennings (2008) • 365.25 refers to 365 days adjusted for leap years • Energy intensity of website harvesting drawn from average of low and high web page Internet Energy Intensity, Taylor and Koomey (2008).

Creating spam campaigns

ENERGY UNIT OF MEASURE	KWH
Data collected	• Spammer time spent developing new campaigns (seconds/year) • Spammer time spent tweaking updated campaigns (seconds/year) • Average active mode PC power draw (W) • Average PC-embodied power draw (W)
Calculation methodology	• Total energy use to create and maintain campaigns = PC-direct energy use to create spam + PC-embodied energy use to create spam
Main assumptions	• PC-direct energy use to create spam = Total time spent creating and maintaining campaigns x Average active mode PC power draw ÷ 1,000 • PC-embodied energy use to create spam = Total time spent creating and maintaining campaigns x Average PC-embodied power draw ÷ 1,000 • Average active mode PC power draw calculated by ICF based on data from Roth (2007) and assumptions • Average PC-embodied power draw calculated by ICF based on data from Williams (2004), Roth (2008), International Energy Agency Data Services.2006. "CO_2 Emissions from Fuel Combustion" (2006 Edition), and assumptions • Total time spent creating and maintaining campaigns = Spammer time spent developing new campaigns + Spammer time spent tweaking updated campaigns • Spammer time spent developing new campaigns and tweaking updated campaigns, drawn from Jennings (2008)

Transmitting spam

Total energy use from drafting legitimate email is calculated in a method analogous to that described above, using an ICF assumption of two minutes of writing time per legitimate message.

Zombies sending spam

ENERGY UNIT OF MEASURE	KWH
Data collected	• Zombie PC active power draw (W) • Mean zombie PC weekly spam time (hours/week) • Proportion of zombie power used sending spam • Number of zombies • Proportion of spam sent by zombies
Calculation methodology	• Zombie energy use per year = 52 x Mean zombie PC energy use per week x Proportion of zombie power used sending spam x Number of zombies
Main assumptions	• Mean zombie PC energy use per week = Zombie PC active power draw x Mean zombie PC weekly spam time • Zombie PC active power draw is equal to Average active mode PC power draw calculated by ICF based on data from Roth (2007) and assumptions • Mean zombie PC weekly spam time, Proportion of zombie power used sending spam ICF assumptions • Number of zombies is 0.1% of the number of CUs • Number of spam messages sent by zombies annually = Total spam messages/year received x Proportion of spam sent by zombies • Proportion of spam sent by zombies is ICF assumption

Transmitting spam – continued

Non-zombies sending spam

ENERGY UNIT OF MEASURE	KWH
Data collected	• Outgoing mail server energy use per sent email (kWh/Gb) • Proportion of spam sent from non-bot mail servers
Calculation methodology	• Total Energy Used to send spam from non-bot mail servers = Total spam sent from non-bot mail servers x Outgoing mail server energy use per sent email
Main assumptions	• Total spam sent from non-bot mail servers = Proportion of spam sent from non-bot mail servers x (Spam volume received by CUs + Spam volume received by BUs) • Outgoing mail server energy use per sent email equal to Server energy use per Gb of email (kWh/Gb) as drawn from Microsoft Exchange 2007 Processor and Memory Recommendations • Proportion of spam sent from non-bot mail servers = 1 – Proportion of spam sent by zombies • Number of spam messages sent by non-bots annually = Total spam messages/year received x Proportion of spam sent by non-bot mail servers

Outgoing mail server energy use for legitimate emails is calculated in the same fashion.

Internet (excluding mail servers) transmitting spam.

ENERGY UNIT OF MEASURE	KWH
Data collected	• Internet energy intensity (kWh/Gb) • Total legitimate mail volume (Gb/year) • Total spam email volume (Gb/year)
Calculation methodology	• Internet energy use for spam email = Total spam email volume x Internet energy intensity
Main assumptions	• Internet energy use for legitimate email = Total legitimate mail volume x Internet energy intensity • Internet energy intensity drawn from average of low and high Internet Energy Intensity calculated from data derived from Taylor & Koomey (2008) • Total legitimate mail volume = Legitimate volume received by CUs + Legitimate volume received by BUs • Total spam email volume = Spam volume received by CUs + Spam volume received by BUs

Internet energy use for legitimate email is calculated in the same fashion

Spam processing, storage and viewing

Incoming mail servers processing spam

ENERGY UNIT OF MEASURE	KWH
Data collected	• Incoming mail server energy use (kWh/Gb) • Legitimate email volume that reach mail server (Gb/year)
Calculation methodology	• Spam email incoming mail server energy use = Spam volume that reach mail server x Incoming mail server energy use
Main assumptions	• Spam volume that reach mail server = Spam volume received by CUs + Spam volume received by BUs x (1 – Industry average of proportion of spam blocked) x (1 – percent of spam blocked that is blocked at gateway/Saas) • Incoming mail server energy use equal to Server energy use per Gb of email (kWh/Gb) as drawn from Microsoft Exchange 2007 Processor and Memory Recommendations • Legitimate email incoming mail server energy use = Legitimate email volume that reaches mail server x Incoming mail server energy use • Legitimate email volume that reaches mail server = Legitimate volume received by CUs + Legitimate volume received by BUs

Legitimate email incoming mail server energy use is calculated in the same fashion.

Message Storage

ENERGY UNIT OF MEASURE	KWH
Data collected	• Mail storage energy use (kWh/Gb) • Legitimate email volume that reach storage (Gb/year) • Legitimate email storage energy use (kWh/year) • Spam volume that reach storage (Gb/year)
Calculation methodology	• Spam mail storage energy use = Spam volume that reaches storage x Mail storage energy use
Main assumptions	• Spam volume that reaches storage = Spam volume that reaches mail server x (1 – percent of spam that is blocked at mail server) • Mail storage energy use equal to storage energy use per Gb of email (kWh/Gb), as drawn from *Microsoft Exchange 2007 Processor and Memory Recommendations* on Legitimate email volume that reaches storage • Legitimate email storage energy use = Mail storage energy use x Legitimate email volume that reaches storage • Legitimate email volume that reaches storage = Legitimate volume received by CUs + Legitimate volume received by BUs

Legitimate email storage energy use is calculated in the same fashion.

Spam processing, storage and viewing – continued

Users viewing/deleting spam

Total energy use to view legitimate email is calculated in a method analogous to that of calculating total energy use to view/delete spam, assuming that users spend an average of one minute per message to view legitimate email, or half the time to write legitimate email.

ENERGY UNIT OF MEASURE	KWH
Data collected	• Spam viewed by users (messages/year) • Time to delete spam (seconds/message) • Total time manually deleting spam (hours/year) • Average active mode PC power draw (W)
Calculation methodology	• Total energy use to delete spam = PC-embodied energy use to delete spam + PC-direct energy use to delete spam
Main assumptions	• PC-embodied energy use to delete spam = Total time manually deleting spam x Average PC-embodied power draw ÷ 1,000 • Average PC-embodied power draw is ICF calculation based upon ICF assumptions and drawn from (Williams 2004), International Energy Agency Data Services. 2006. "CO_2 Emissions from Fuel Combustion" (2006 Edition)., and Roth (2008) data • PC-direct energy use to delete spam = Total time manually deleting spam x Average active mode PC power draw ÷ 1,000 • Total time manually deleting spam = Spam viewed by users x Time to delete spam ÷ 360 • Average active mode PC power draw calculated by ICF drawn on data from Roth (2007) and ICF assumptions • Spam viewed by users = Total spam messages/year received x (1 – Industry average of proportion of spam blocked) • Time to delete spam is drawn from Jennings (2008)

Spam Filtering

ENERGY UNIT OF MEASURE	KWH
Data collected	• Annual filtering energy per consumer mailbox (kWh/year) • Annual filtering energy per business mailbox (kWh/year) • False positive rate • Time spent searching for false positives
Calculation methodology	• Total consumer filtering energy = Number of consumer email mailboxes x Annual filtering energy per consumer mailbox • Total business filtering energy = Number of business email mailboxes x Annual filtering energy per business mailbox • Total energy use searching for FPs = PC-direct energy use searching for FPs + PC-embodied energy use searching for FPs
Main assumptions	• Annual filtering energy per consumer mailbox = Consumer total of annual energy used filtering spam ÷ 1,000 as calculated by Jennings (2008). • Annual filtering energy per business mailbox = Business total of annual energy used filtering spam ÷ 1,000 as calculated by Jennings (2008). • PC-direct energy use searching for FPs = Total time searching for false positives x Average active mode PC power draw ÷ 1,000 • PC-embodied energy use searching for FPs = Total time searching for false positives x Average PC-embodied power draw • Total time spent searching for false positives = False positive messages annually x Time spent searching for false positives ÷ 360 • False positive messages annually = False positive rate x Total email traffic • False positive rate and Time spent searching for false positives are (Jennings, 2008).

Spam Greenhouse Gas (GHG) Emissions

ENERGY UNIT OF MEASURE	KWH
Data collected	• Energy use for spam (kWh/year) • Emissions Intensity (kg CO_2-e/kWh)
Calculation methodology	• GHG Emissions = Energy use for spam x Emissions Intensity ÷ 1,000
Main assumptions	• Energy use for spam = Harvesting addresses + Creating spam campaigns + Zombies sending spam + Non-bots sending spam + Internet (excluding mail servers) transmitting spam + Incoming mail servers processing spam + Message storage + Users viewing/deleting spam (three seconds per message) + Spam filtering + Users searching for false positives • Emissions Intensity is drawn from International Energy Agency data sources, emission factors are for 2004

Business User Figures

ENERGY UNIT OF MEASURE	KWH
Data collected	• Annual legitimate email received (messages/year) • Annual legitimate email sent (messages/year) • Annual spam received (messages/year)
Calculation methodology	• Total annual energy use for email = Annual energy use for legitimate email received + Annual energy use for spam received
Main assumptions	• Annual energy use for legitimate email received = Annual legitimate email received x Annual energy use per legitimate email ÷ 1,000 • Annual energy use for spam received = Annual spam received x Average energy use per spam message ÷ 1,000 • Annual energy use per legitimate email = Energy Use for Legitimate Email x 1,000 ÷ Total number of legitimate messages • Average energy use per spam message = Total energy use for spam x 1,000 ÷ Total number of spam messages • Annual legitimate email received = Mean legitimate c2b or b2b messages/week x 52 • Annual legitimate email sent = Annual legitimate email received ÷ Average number of recipients per legitimate email • Annual spam received = Proportion of email is spam x Annual legitimate email received ÷ (1 – Proportion of email is spam) • Average number of recipients per legitimate email is ICF assumption

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For more than 20 years, ICF International has supported public and private clients on issues related to global climate change. Over that time, ICF has amassed significant expertise in developing strategies and analyzing policies to manage emissions of greenhouse gases (GHG) in the public and private sectors. ICF offers a wide-range of energy analysis and climate change-related services.

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