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Carbon and the Cloud

Hard facts about data storage.



Stanford Magazine

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May 15, 2017 · 6 min read

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SAGE (Sound Advice for a Green Earth) is a project by advanced students in Earth Systems and other programs to answer sustainability questions. [Submit questions.](#)

Q: What is the environmental impact of storing data on a hard drive? Is it better or worse to use cloud storage? — Mark Williams, Cambridge, England

The Essential Answer

A: In the newest versions of most word-processing software, saving a document for the first time presents you with two options: saving to your computer or to a cloud storage service. As your finger hovers over the mouse button and you make your choice, it's important to realize how different the two processes truly are. Saving a document to the cloud takes it out of your hands, so you don't have to worry about losing it and can access it anywhere. Cloud data is stored not in actual clouds but in buildings — massive structures filled with thousands of hard drive-bearing racks using a mind-boggling amount of energy. There are millions of data centers around the world, some taking up nearly 200 acres of land apiece.

How much energy is used in saving to the cloud? That's a complicated question. It takes energy to get the data to the data center — miles of fiber optic cables, studded with other fixtures of internet infrastructure that all require power along the way. At the center, your data is stored multiple times on hard disks, and the constant activity of all those disks creates a lot of heat, which necessitates energy-intensive air conditioners to protect the equipment from overheating.

A Carnegie Mellon University study concluded that the energy cost of data transfer and storage is about 7 kWh per gigabyte. An assessment at a conference of the American Council for an Energy-Efficient Economy reached a lower number: 3.1 kWh per gigabyte. (A gigabyte is enough data to save a few hundred high-resolution photos or an hour of video.)

Compared with your personal hard disk, which requires about 0.000005 kWh per gigabyte to save your data, this is a huge amount of energy. Saving and storing 100 gigabytes of data in the cloud per year would result in a carbon footprint of about 0.2 tons of CO₂, based on the usual U.S. electric mix.

Cloud data storage provides convenience, not to mention the peace of mind of a secure backup. But you can keep these numbers in mind as you decide whether to save data locally or to the cloud. And, if you have a choice of cloud service providers, do some

sustainability research. Some providers power their data centers with 100 percent renewable energy.

The Nitty-Gritty

You may find it useful to save documents in the cloud. It keeps a secure copy of them that will survive any conceivable misfortune to befall your computer. It allows you to access them from any machine, anytime, anywhere in the world. But how do the processes of saving to a hard drive and saving to the cloud differ?

When you choose to save your document to your computer, your hard drive spins up, and its mechanical arm swings across a large magnetic platter to magnetize or demagnetize the tiny cells that represent your information. Your hard drive requires only about 2 watts to write data. A 25 kilobyte text file takes about 0.0002 seconds to write itself to the disk. The total energy expended to do this is about 0.1 microwatt-hours: a rate of about 0.005 watt-hours per gigabyte. For simplicity, we won't consider the power your hard disk uses while it's idle.

But maybe you choose to save your document to a cloud hosting service such as Dropbox, iCloud or OneDrive. This time, your text document is partitioned into a stream of data packets. Its first stop is your Wi-Fi router, and then your cable modem. From there it gets shunted from place to place, taking advantage of network infrastructure like servers, routers, network switches and optical repeaters as it cruises along fiber-optic cables at roughly the speed of light. Soon it enters a huge building. The multi-acre monstrosity contains what seems like endless rows of corn. But there are no vegetables here — the rows consist of huge racks stacked high with hard drives. The building is noisy, with the drone of the ventilation system and the whirring of hard drives. The data center's final routers send your packets to a server rack, where your document is finally saved to a hard drive.

There isn't a lot of agreement on precisely how much energy this journey uses. But data centers themselves are energy hogs — they can never be turned off, and their racks of servers are constantly shuffling and checking data, even creating redundant copies. The

cooling requirements are immense, as all this equipment generates blistering amounts of heat.

The combination of transmitting your data and storing it in a data center probably requires about 3 to 7 kWh per gigabyte. That's about a million times more than the energy you used to save to your hard drive. Instead of 0.1 microwatt-hours, your text document has sucked down 0.1 watt-hours of electrical energy — enough to light an LED bulb for about 30 seconds.

If you save and store 100 gigabytes of data in the cloud during a year, enough space for several thousand photos or a few hours of video, the amount of electricity required to accomplish this would result in the emission of about 0.2 tons of CO₂, based on the U.S. Grid's emission factor. However, it might not be so dire as this — many companies now power their data centers with renewable energy. This often involves simply buying RECs (renewable energy credits). But RECs are another can of worms.

The bottom line is that storing your data on the cloud uses far more energy than storing it on your computer, and thus has an environmental impact commensurate with that difference. And that is on top of the land-use differences — cloud storage requires the construction of expansive data centers, while storing that data on your computer does not. But cloud data storage provides numerous benefits. You can keep your music in the cloud through iTunes Match, edit your documents over the cloud in Google Drive, back up your iPhone to the cloud, keep your documents in Dropbox (and edit them from any computer), keep your calendar in the cloud through Google Calendar, and share pictures via the cloud through Photo Stream. You can even back up the entire contents of your computer, hundreds of gigabytes in all, through cloud backup services like EaseUS or Carbonite. Cloud data storage has become part of the everyday lives of many people.

There are alternatives to cloud backups. Mac computers have a feature called Time Machine, and Windows PCs have a similar capability called File History, allowing you to create a backup of your entire machine to an external hard drive, a data storage device that you can plug into and unplug from your computer as needed to update the backup or recover files. While this won't help if your house is destroyed in a disaster, an external hard drive can safeguard against more common threats, such as viruses or corrupted data.

The cloud offers obvious conveniences. It provides peace of mind and access to your data anywhere and anytime, and, in many cases, it's already baked into the services and technologies we use every day. So, while you probably don't want to swear off cloud storage entirely, the amount of energy that cloud data storage requires is one more thing to keep in mind as your finger hovers over that mouse button while you decide between "Save to My Computer" and "Save to the Cloud." •

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