Limits to Internet Growth; 12.11.19
by Katie Singer

The Internet is the largest thing that humanity has built.[1] Its energy consumption, greenhouse gas (GHG) emissions, toxic waste and worker hazards are therefore significant. And yet, the Internet's footprint has remained largely invisible and unregulated. Isn't it time to ask: *How does the Internet impact the ecosystem upon which our survival depends? How does it contribute to climate disruption? How/can we reduce the Internet's impacts?*

Most people now consider Internet access necessary for family connections and educational and economic opportunities. Meanwhile, by 2025, with power-hungry servers storing data from billions of smartphones, tablets and Internet-connected devices, some researchers predict that information-communications-technologies (ICT) could consume 20% of the entire world's electricity, hampering climate change targets and straining grids.[2] Other analysts claim that ICT could consume 51% of total global electricity and emit as much as 23% of total GHGs by 2030.[3]

Smartphones' $CO_2$ emissions will grow from 4% of total global emissions in 2010 to 11% by 2020. This translates to a jump from 17 to 125 megatons of $CO_2$ equivalent per year—or a 730% growth.[4] Indeed, one smartphone includes more than 1000 different substances, each with its own supply chain.[5]

*Given the staggering nature of these statistics, how does any user recognize the true cost of Internet access?* Each Google and GPS search; every social media post and video stream; every email, text message and Skype call; every online purchase; every transfer of funds or medical or educational records; every "smart," "energy-saving" Internet-of-Things-connected refrigerator messaging its owner to buy more milk—*every* online activity—requires international networks of cell sites and data storage centers that start with extraction of natural resources and consume huge amounts of water and greenhouse gas-emitting electricity. Manufacturing every smartphone, tablet and access network is powered by fossil fuels and workers subject to hazardous conditions. Manufacturing depends on refineries, GHG-emitting power plants, nuclear plants, chemical plants, steel mills, metal smelters, wood (for smelters) and factories of all kinds. Each energy-guzzling, toxic waste and greenhouse gas-emitting operation depends on all of the others. They interconnect by networks of power lines, natural gas pipe lines, cargo ships, trains, trucks, airplanes, shipping lanes, railways, highways, airports, telecom access networks and data storage centers to form one gigantic super factory.

As Boston College School of Management Professor Emeritus Bill Torbert says, "If you're not aware that you are part of the problem, you can't be part of the solution."

Call me part of the problem: I don't know how to research, write and post papers like this one without Internet access, websites, email and a telephone; and, like many people I know, I'm ready to get informed about the Internet's footprint and do my part to reduce it.

**The Internet's main energy guzzlers**

Internet technologies change faster than anyone can grasp. Here are four primary energy guzzlers:

1. *Access networks:* An access network is infrastructure that allows a computer (including a smartphone, an iWatch or tablet) to transmit and receive data. It connects subscribers to their service provider, which then connects them to the Internet.

An access network can be entirely wired or partly wireless. Because mobile phone systems now use the Internet to transmit voice and data, access networks provide mobile phone *and* Internet service. They can comprise public and private cellular, wireless, copper and fiber optic[6] networks, transmitters, antennas, routers, radio power amplifiers, cooling systems, data processing and power supplies and battery backups.

Mobile access networks are called 3G (third generation of wireless infrastructure), 4G or 5G. Because of power-hungry radio transmitters, whenever a user accesses the Internet through a *wireless* network, energy use soars.[7] 3G uses 15 times more energy than wired access (fios, DSL or cable). 4G consumes 23 times more energy than wired access.[8]

In 2013, the University of Melbourne's Center for Energy Efficient Telecommunications (CEET) calculated that by 2015, the wireless Cloud would consume "up to 43 terawatt hours, compared to 9.2 TWh in 2012, an increase of 460%." CEET further calculated that such energy consumption increased the Internet's carbon footprint from six megatons of $CO_2$ in 2012 to up to 30 megatons in 2015, the equivalent of 4.9 million cars' emissions. "Up to 90% of this consumption is attributable to wireless access network technologies."[9]

This cell tower is part of a wireless access network.

Photo available here: https://commons.wikimedia.org/wiki/File:Large_cell_tower.jpg

2. *Data storage centers:* Packed with computers that store websites, GPS, data collected by "smart" utility meters, medical and educational records, social media posts, Amazon listings, etc...and swamp coolers and air conditioners that keep the computers cool, data centers guzzle electricity and water. Their $CO_2$ emissions grow 13% per year. Data centers are run by businesses, universities, governments and hospitals. Data centers account for two percent of global greenhouse gas emissions.[10]

Google, Facebook, Amazon, Microsoft and Yahoo host some of the world's largest data centers. In 2011, Facebook's electricity consumption was 532 gigawatt (GW) hours; by 2016, it reached 1830 GWh—an average yearly growth of about 20%.[11] The world's largest data center, at Inner Mongolia Data Park in China, is nearly eleven million square feet. In 2014, the U.S. had three million data centers.[12] The largest one is in Nevada, nearly four million square feet. In the midst of a statewide drought, in 2014, the U.S. National Security Administration's data center in the Bluffdale, Utah desert *daily* used no less than 1.7 million gallons of water to keep its computers cool.

According to a 2016 report from the Lawrence Berkeley National Lab, data centers in the U.S. alone use 70 billion kilowatt hours (kWhs) per year. By 2020, they could consume 73 billion kWh of electricity per year.[13] For perspective, one kWh keeps a smartphone charged for a year.[14] Seventy billion kWhs is about 1.8% of the U.S.'s total electricity consumption. Generating this much electricity requires eight nuclear reactors and generates about 70 million pounds of $CO_2$.[15]

One data center can consume as much electricity as it takes to power 250,000 homes.[16] The average square foot of a data center uses 100 to 200 times more electricity than the average square foot of a modern office building. By 2025, Data centers alone are projected to consume 4.5% of total global electricity use.[17]

Inside view of a data center.

Photo available here: https://secure.fatcow.com/images/data-center-photos/new/SecureWebServer.jpg

Aerial view of the U.S. National Security Administration's Utah Data Center.
Photo credit: Electronic Frontier Foundation.

Photo available here:
https://commons.wikimedia.org/wiki/Utah_Data_Center#media/File:EFF_photograph_of_NSA%27s_Utah_Data_Center.jpg

3. *Embodied energy:* This is the energy used to mine, refine and transport raw materials (i.e. quartz, charcoal, coltan, cobalt, copper, graphite, lithium); manufacture semiconductors, screens and cases; assemble them for usable products; and ship each item to its end-user. The embodied energy in every device, appliance and vehicle is greater than the energy that it will use in its lifespan.[18]

Because of embodied energy (and embodied GHGs and embodied toxic waste), calling any electronic device "zero emissions" or "carbon-neutral" is wrong and misleading.

Note also that "energy efficient" products actually *increase* consumption. William Jevons introduced this paradox in his 1862 book, *The Coal Question*: as products get more efficient and less expensive, manufacturers produce and consumers buy more of them. And so, consumption of raw materials and energy increases; more GHGs and waste are generated. New infrastructure may also operate with increased energy efficiency and speed; but manufacturing and operating it still increases consumption of raw materials and electricity.

*4. Automated processes:* These include advertising bots, automatic updates and backups for apps, video games, websites and operating systems.

**Infrastructure's energy use and $CO_2$ emissions**

Canadian engineers predict that the combined footprint of access networks and data centers will grow from 215 megatons of $CO_2$ equivalent ($MtCO_2$-e) emitted per year in 2007 to 764 $MtCO_2$-e/year by 2020.[19] (Canada's entire footprint in 2016 was 730 $MtCO_2$-e.) These researchers find that data centers account for about two thirds of the Internet's emissions. Meanwhile, in Australia, CEET maintains that access networks are the primary contributor to the Internet's emissions.[20,21]

Largely because of the power demanded by radio transmitters at every cell site, wireless technologies consume at least ten times more electricity than wired technologies when providing comparable access rates and traffic volume.[22]

Wireless Internet access also demands more energy than wired access because mobile users expect connectivity everywhere, 24/7. Further, users who limit their access to a wired desktop use the Internet less frequently than mobile users who can watch videos on trains, in cars, while dining, waiting in a line or walking down a street.

In 2016, electrical engineer Jafaar Elmighani reported that Internet traffic increases 30 to 40 percent each year, and that "If this rate continues and nothing is done, communications technologies (by 2026) could consume about 60 percent of the world's energy resources."[23]

**The true costs of one smartphone**

As mentioned earlier, one smartphone includes more than 1000 different substances.[24] *What happens in each substance's supply chain before the phone is assembled, boxed and transported to its end-user?* Here are a handful of examples:

***Semiconductors***

To process and store data and provide memory and apps, a smartphone's low power microprocessors, optical, GPS, accelerometers and other sensors, transmitters and receivers (for cellular, WiFi and Bluetooth signals) and noise filtering microphones require *semiconductors.* Semiconductors can control the flow of electricity. Transistors, the basic building blocks of a computer, are made from semiconductors.

Semiconductors start by mining pure quartz gravel, harvesting hard, moist wood (i.e. from the Amazon rainforest[25]) and a pure carbon (i.e. petroleum coke from the Tar Sands[26]), then transporting these three substances to a large-scale arc furnace that is kept at about 3000 degrees Fahrenheit.[27] The silica-fuel mixture melts and catalyzes a chemical reaction to isolate the silicon metal and produce metallurgical-grade silicon.[28]

A furnace (also called a smelter or a submerged arc furnace) takes several weeks to heat; a well-managed one may go four to eight years before shutdown is necessary. To smelt quartz into metallurgical grade silicon using carbon as a reductant, the furnace's temperature will need 3000 degrees Fahrenheit.[29]

Smelters are typically powered by coal, nuclear and/or hydro power. Because interrupting the delivery of electricity to a smelter could blow it up, a smelter cannot be powered by "renewable" energy.

Producing metallurgical silicon generates emissions of sulfur dioxide, carbon monoxide hydrogen chloride and nitrogen oxides.[30]

To get electronic-grade silicon (with only one impurity part per billion), metallurgical grade silicon is transported from the smelter to a bell jar furnace for a vapor deposition process that produces polysilicon rods.[31] Such furnaces consume about 105 megawatts, continuously. This amounts to about 48,000 metric tons of coal per year, the amount of power required by 68,000 homes.[32]

Several other energy-intensive, toxic-waste-emitting steps are required (fracturing the polysilicon rods into chunks; etching them with nitric acid and hydrofluoric acid[33] to remove surface contamination; sending these chunks to a crystal grower that generates silicon ingots; labeling these as electronic grade, solar grade or scrap; slicing the silicon ingot into wafers) before key materials and components are chemically embedded in the silicon to create microprocessors usable in a smartphone.[34]

Indeed, a silicon wafer (necessary for electronics and solar photo voltaic panels) is "one of the most highly refined artifacts ever created."[35]

In 1997, citing World Semiconductor Trade Statistics, the Silicon Valley Toxics Coalition reported that producing an eight-inch wafer (each containing thousands to millions of semiconductors) required 4,267 cubic feet of bulk gasses, 27 pounds of chemicals, 29 cubic feet of hazardous gasses and 3,023 gallons of de-ionized water. In 1997, production of an eight-inch wafer generated 3,787 gallons of waste water,[36] negatively impacting the health of waterways and communities near factories.[37]

Since 2013, manufacturers have produced more transistors than farmers grow grains of wheat or rice.[38]

### *Conflict minerals*

Smartphones also require "conflict" minerals, which are extracted under armed conflict and/or human abuse. To power a battery, polish the screen and provide apps, every computer contains multiple conflict minerals. Here are a few examples:

*Coltan* (refined columbite-tantalite) makes a heat-resistant powder that can hold a high electric charge. Refined coltan is crucial to devices that store energy and allow mobility, including mobile phones, cordless phones, tablets, video cameras, wireless printers, shavers, hearing aids and pacemakers. The Democratic Republic of Congo (DRC) holds 64% of the world's coltan. Mining for coltan in DRC (wherein militias control the mining and foreign investors' money) has contributed to mass rapes and more loss of life than any other single situation since World War II.[39] Since 1998, conflicts over DRC minerals have killed more than 5.4 million people.[40]

*Cerium*, used to polish screens, is extracted near Baotou, Inner Mongolia. To get usable cerium, processors crush mineral mixtures and dissolve them in sulfuric and nitric acid on a huge industrial scale, which causes vast poisonous waste.

*Neodymium*, also mined in Bautou, provides lightweight yet powerful magnets for in-ear headphones, cell phone microphones and computer hard-drives. Only a few decades ago, Bautou was farmland. Mining has created "a toxic lake." The writer Tim Maughan called Bautou's "alien, dystopian and horrifying environment" the "byproduct not just of the consumer electronics in (his) pocket, but also green technologies like wind turbines and electric cars that we get so smugly excited about in the West."[41]

*Cobalt*, a byproduct of copper and nickel mining, is essential for lithium-ion battery cells used in smartphones, tablets and electric vehicles. Mined primarily in DRC under Chinese control, human rights abuses abound while Congolese mine for cobalt.[42]

*Copper.* A computer's main circuit board has integrated circuits containing tiny copper leads (each connected to a silicon chip) soldered onto an epoxy glass composite board covered with copper traces. The copper traces serve as conductors for the circuit board's signals. Additional copper wiring connects coils, switches and other components to form the complete circuit board. A U.S. Geological Survey study found that for every kilogram of copper mined, at least 210 kilograms of waste are generated.[43] The electronics industry is the world's second largest consumer of copper (after the construction sector).[44]

For every single ton of metal extracted, 426 tons of waste arise.[45]

The U.S.'s 2010 Dodd-Frank Act requires manufacturers to attempt, with "due diligence," to trace the source of the minerals they use. But the U.S. Chamber of Commerce and the National Association of Manufacturers have challenged Dodd-Frank: they claim that it imposes too many costs and violates corporations' First Amendment freedoms by forcing them to label and condemn their own products.

Exploits will continue until consumers become aware of the conflict minerals in their devices, manufacturers take responsibility for the routine human abuses and environmental destruction caused while mining, and governments make policies that require safer conditions for miners.

### *Worker hazards*

Workers involved in manufacturing smartphones face potentially deadly hazards. Miners of coal, cobalt, coltan and other ores risk long-term health damage and fatal accidents. Amnesty International found that the vast majority of workers mining cobalt (commonly used for batteries) worked without gloves, face masks or other protective gear to prevent lung or skin diseases.[46] Children work in mines and carry heavy loads for as many as twelve hours per day for one or two dollars. According to UNICEF, in 2014, approximately 40,000 children (some as young as four) mined across southern Congo, checking rocks for cobalt.[47] Amnesty International has also found that Apple, Samsung, Sony and other brands fail to check that the cobalt used in their products was not mined by child laborers.[48]

While assembling silicon wafers, workers typically wear head-to-toe protective suits *to protect the semiconductors* from dust.[49] These suits do not prevent workers from inhaling toxic chemicals. At Samsung factories, workers' rights violations have included forced overtime, exhausting working conditions, forced work without pay, abuse of underage workers and lack of worker safety.[50] Workers exposed to n-hexane, a solvent used in assembling smartphones, increase their risk of leukemia and muscular disorders with virtually no protection or compensation.[51]

*Who is responsible for protecting workers from on-the-job hazards? For compensating them when their health is damaged?* Factory owners claim that they can't afford environmental protections. Given the international nature of assembling products, corporations like Apple and Samsung are not legally bound to responsible practices.

People who work around telecom infrastructure are also subject to hazardous conditions. Electrical and rooftop workers may routinely be exposed to cellular antennas' radiofrequency (RF) radiation emissions without knowing it—or how to protect themselves. Presently, telecom corporations are not required to inform workers that an antenna (which may be disguised or in a chimney) is nearby nor to provide protection. In a 2013 Comment to the FCC, Edwin D. Hill, International President of the International Brotherhood of Electrical Workers (IBEW), suggested that telecom corporations that are licensed to deploy transmitting antennas should be responsible for ensuring that IBEW members "know the unique physical boundaries at every work location so as not to exceed the referenced RF exposure limits."

The underwriter A.M. Best estimated in 2013 that 250,000 U.S. American workers come into close contact with cellular antennas every year. It warns other insurers that at close range, cellular antennas act "essentially as open microwave ovens;" and that exposed workers' health effects "can include eye damage, sterility and cognitive impairments."[52]

## Batteries

### *Lithium-ion batteries*

Nearly all portable electronics use a battery. Lithium batteries power smartphones, tablets, laptops, electric cars and more. A reactive, extremely light alkaline metal, most lithium is extracted by drilling through the crust of a salt flat; then it is left to evaporate from its brine. After several months, it's filtered and evaporated again. This process can take 18 months—and a lot of water. Filtering each ton of lithium consumes about 500,000 gallons of water. Salar de Atacama, a Chilean lithium mine, uses 65% of the area's water. Some of the region's communities already import water; the mine further strains local farming efforts.[53]

Chemicals like hydrochloric acid, used to refine lithium, can leak into waterways, polluting soil and local wells and impacting fish as far as 150 miles downstream.[54]

Lithium-ion batteries also contain graphite, a kind of carbon that can store current. Mining and refining graphite into a powder without sufficient tarps and fans leads to covering crops, waterways, pets, livestock, trees, indoor spaces, peoples' faces and everything else nearby in black soot. Exposure to fine-particle graphite pollution can cause myriad breathing difficulties and has been linked to heart attacks in people with heart disease. In China, graphite production is cheap and often has lax environmental controls. Much of China's refined graphite is sold to Samsung, Chem and Panasonic, the three largest manufacturers of lithium-ion batteries. Demand for lithium-ion batteries and graphite is growing.[55]

Because lithium batteries can short circuit when the extremely thin separator between their positive and negative parts get breached, lithium batteries are not recyclable. Fires and explosions happen, all too frequently.[56] Even when they're removed from devices, lithium-ion batteries can only be stored or dumped.

***Lead-acid batteries***

Lead-acid batteries are commonly used for stationary applications like cell towers' and data centers' backup power.

A battery's useful life typically lasts four to ten years. The lead in a "dead" battery can be recycled indefinitely; and recycling lead saves as much as 65% of the energy required by "virgin" mining and processing. Still, recycling lead can harm the environment and public health. Lead is a notorious neurotoxin. "Even trace amounts of lead—particles so tiny they're barely visible—are enough to cause irreversible health problems in kids who ingest or inhale them."[57] Lead exposure is associated with IQ deficits, attention-related behaviors and poor academic achievement. Pure Earth's 2016 report, "The World's Worst Pollution Problems," identified lead-acid battery recycling as the world's #1 toxic pollution source, endangering almost 1.9 million people.[58] Meanwhile, wireless technologies accelerate demand for lead-acid batteries: in 2012, deploying 4G infrastructure across Europe, the Middle East and Africa was expected to require 8.5 million new batteries containing about 700 million pounds of lead. The U.S. needed another two million batteries.[59]

**Electronic waste**

Electronics generate toxic waste during manufacturing *and* when they are discarded. While *embodied* waste (described earlier) is significantly greater than the waste generated by disposing of the product at the end of its usable life,[60] the waste generated by discarded unusable electronics is more familiar to the public.

Per year, each four-person household in the U.S. discards about 176 pounds of devices with a battery or a plug.[61]

Besides toxic chemicals, one discarded computer can contain lead, mercury, cadmium, brominated flame retardants, n-hexane, polyvinyl chloride and numerous other toxins. These elements, chemicals and heavy metals can penetrate landfills and seep into ground water, creating long-lasting impacts to waterways, soil and air.

Unlike dead plants, birds and animals, "dead" electronics do not biodegrade. On average, every person in the developed world discards 73 pounds of electronic waste per year.[62] Globally, annually, this amounts to 44.7 million metric tons (49.27 million U.S. tons),[63] more than 5% of municipal solid waste, and 70% of landfills' hazardous waste.[64,65] E-waste typically lands in landfills in Africa and Asia, where children and adults comb for sellable pieces of copper (for example), endangering their health.

In 2000, journalist Russ Arensman described what happened that year to plastics and cathode ray tubes (CRTs) recovered at Hewlett-Packard's recycling plant in Roseville, California.[66] The unusable parts were trucked more than 5000 kilometers (3100 miles) to two smelters in New Brunswick, Canada, where the CRT monitors were crushed and processed for their copper and lead. The CRTs' plastics and other electronics were burned for fuel. In 2000, one of these New Brunswick smelters "emitted 90,000 metric tons of sulfur dioxide, 620 metric tons of particulates, 80 metric tons of lead and 2.2 metric tons of cadmium. Cadmium emissions were traced as far as 25 kilometers (15.5 miles) from the smelter; lead was traced up to 300 kilometers (186 miles) away. The second smelter's atmospheric emissions for the same year included 11,938 metric tons of sulfur dioxide, 86.01 metric tons of particulates, 13.89 metric tons of lead, 2.43 metric tons of zinc, 1.36 metric tons of cadmium and 1.49 metric tons of arsenic." This kind of electronic "recycling," Dr. Josh Lepawsky explains, in his 2018 book, *Reassembling Rubbish: Worlding Electronic Waste*, also "leaves a wake of discards such as emissions from long-distance truck transport."

While researchers find that the cost of "virgin mining" of ore costs less than "urban mining" (wherein robotic processors extract precious metals from [say] discarded TVs), such mining still requires energy and emits GHGs and toxins.[67] Municipalities could actually generate income by "urban mining" at their recycling centers.

**Now come 5G and the Internet of Things (IoT)**

Some researchers predict that by 2030, the Internet will consume 20% of global electricity.[68] Others report that in a worst-case scenario, ICT could consume 51% of global electricity.[69] A 2016 study from the Semiconductor Industry reports that by 2040, computers will require more electricity than the entire world can generate.[70] And yet, we have legislated no limits to Internet growth. With 5G (fifth generation of wireless infrastructure) and the Internet of Things (machine-to-machine communication), a chipped diaper can message your smartphone that your baby's diaper needs changing, a chipped container can put orange juice on your smartphone's shopping list, a feature-length movie can download in ten seconds, and windshields can tell drivers about upcoming traffic jams and preferred routes. By the end of 2020, the number of IoT connected devices could reach 21 billion.[71]

5G will add to—not replace—current wireless infrastructure. 5G's extremely short waves can carry much more data than 4G. However, these waves cannot travel far. Antennas that transmit their signals therefore must be densely deployed. In urban areas, this will mean about one cell site (typically on a public right-of-way [PROW] such as a utility pole) for every three to ten households.[72] In rural areas, each household may need a dedicated cell site.[73]

Internationally, the telecom industry has begun deploying 5G cell sites. Antennas are mounted on utility poles just beyond bedrooms and on school rooftops. *How will such EMR exposure impact the public health?* Peer-reviewed scientific studies suggest that insects, skin, eyes and bacteria will especially be affected by 5G's higher frequency fields.[74] The 5G spectrum spans frequencies between 6 and 80 gigahertz (GHz).

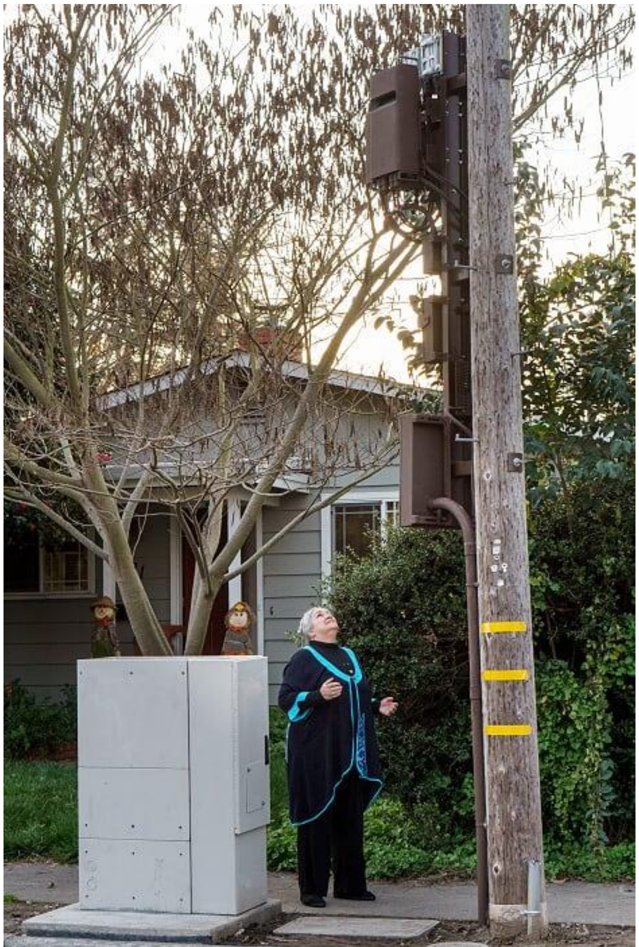
Data volumes at least double every two years.[75] By 2020, our created data will reach 44 trillion gigabytes.[76] Until now, because each human has a limited number of hours to spend online, we could call the Internet's energy use finite. But when unlimited numbers of machines connect to each other (the average U.S. American is expected to own 26 IoT devices), energy use becomes limited only by its availability.

Researchers from the School of Computing and Communications at UK's University of Lancaster say that the IoT could cause unprecedented rises in energy used by Cloud-connected devices. To prevent multiplying use of electronics and electricity (as the IoT and 5G will do), these researchers warn users to limit data growth in order to reduce global carbon emissions.[77]

Cellular antennas and cell towers have been shown to catch fire and collapse.[78] Small cell site antennas and electronic gear would add significant weight to utility poles. Given our world's increased incidence of wind storms, fires and flooding, *will independent, professional engineers (PEs) evaluate whether a utility pole can bear the extra weight of each 5G small cell site before it is installed?*

As wireless access networks shift from 4G (fourth generation infrastructure) to 5G, 4G-compatible televisions (to name one common electronic item) will not work. Consumers will discard billions of 4G TVs and replace them with new ones that require yet more raw materials, water and electricity to manufacture and ship.

*What's the motivation behind the IoT and 5G? Does the public truly demand Internet-connected light bulbs and toasters? Does constant video-access improve society? Could we prioritize investment for nutrient-dense food, drinkable water, healthcare, education and indoor plumbing over IoT devices and infrastructure? To value human health, biodiversity and democracy more than telecom profits, what changes would we make in our Internet use?*



A woman stands in front of the 5G small cell site installed on the utility pole in front of her home in January, 2018, in Santa Rosa, California. Photo credit: Scientists for Wired Technology

Photo available here: http://www.electronicsilentspring.com/wp-content/uploads/2018/08/01-2018-0131-S1667.jpg

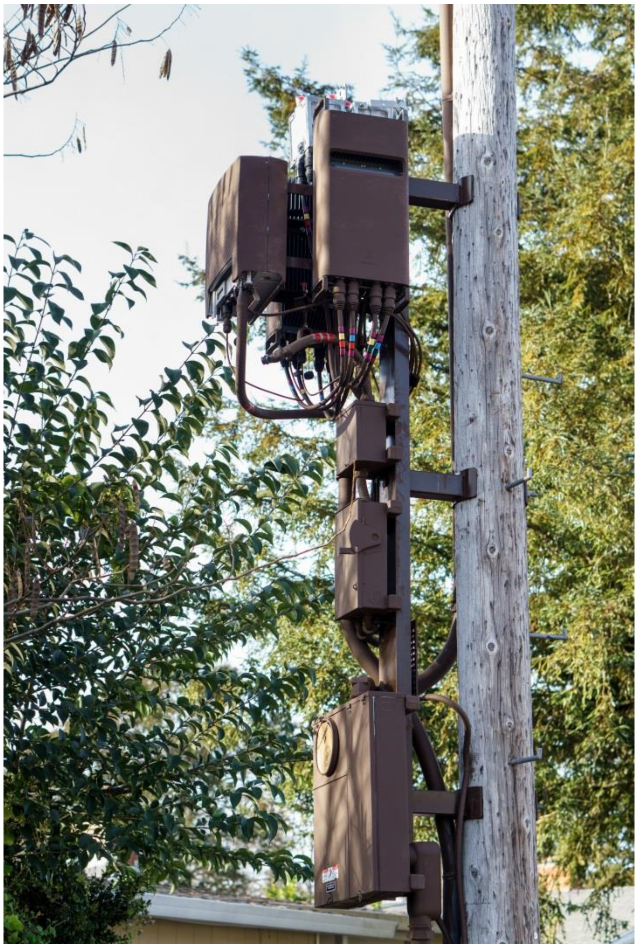


Photo credit: Scientists for Wired Technology

Photo available here: http://www.electronicsilentspring.com/wp-content/uploads/2018/08/03-2018-0131-S1655.jpg

**Other unintended consequences of the Internet**

Artificial Intelligence (AI) now threatens half of all jobs, including in farming, medicine and teaching.[79]

Ineffective cybersecurity threatens every country's power grid, elections and democracy and every citizen's finances and privacy.

Bitcoin and other digital currencies now consume up to 1% of total global electricity. Digiconomist figures that bitcoin operators put 16,000 kilotons of carbon dioxide into the atmosphere per year.[80]

Because of the energy, raw materials and waste embodied in electric vehicles (including their computers, batteries and charging stations), we cannot rightly call them "carbon neutral." We cannot say that they have "zero emissions." Self-driving cars and GPS systems also require infrastructure that holds embodied energy and toxic waste.

Renewable energy such as solar and wind powered systems cannot meet the demand created by our ever-growing Internet. Energy analyst Kris de Decker points out that "renewable energy sources alone cannot reduce carbon emissions for two reasons. First...solar and wind power plants are not replacing fossil fuels, but accommodating part of a growing demand for energy. Secondly, renewable energy systems are highly dependent on fossil fuels for their manufacture, especially when we count on an infrastructure that aims to match supply to demand at all times."[81]

In 2007, Google committed itself to addressing the world's climate and energy challenges. The company boldly aimed to develop renewable energy that would generate electricity more cheaply than coal-fired plants can. The project's lead engineers believed that by improving renewable energy technologies, "our society could stave off catastrophic climate change." By 2011, Google shut down this initiative. The engineers shocked themselves with the realization that "even if Google and others had led the way toward a wholesale adoption of renewable energy, that switch would not have resulted in significant reductions of carbon dioxide emissions.... Worldwide, there is no level of investment in renewables that could prevent global warming."[82]

Electrification, mobile phones and wireless Internet have nearly saturated our environment with man-made electromagnetic radiation (EMR). Yet, no national or international agency provides exposure safety limits that protect wildlife, pregnant women, infants, children, the infirm or the general public from near-body, whole body, combined or long-term EMR exposure.[83] Section 704 of the U.S. 1996 Telecommunications Act prohibits health and environmental concerns from interfering with the placement of cellular antennas. This law passed more than two decades ago (and many countries adopted it[84]), effectively eliminated the principle of *first, do no harm* with minimal public awareness.

In 2013, the U.S.'s Federal Communications Commission (FCC) revised its specific absorption rate (SAR) standards for mobile devices. SAR measures the amount of radiation that tissue absorbs while exposed to a mobile phone. In August, 2013, the FCC reclassified the pinna (outer parts) of the ear as extremities. Extremities can absorb nearly three times as much radiation as the head and the trunk. *With such "regulations", how does anyone protect themselves, children or the infirm from EMR exposure.*

Screen-time exposure (different from EMR exposure) has been shown to create addiction, attention deficit disorder and other cognitive impairments in adults and children. In 2018, the World Health Organization classified gaming addiction as a mental health disorder.[85] While no agency monitors screen-time exposure, children now commonly learn basic skills on computers and develop hard-to-change habits with an electronic interface.[86]

Federal mandates such as Electronic Visit Verification (EVV),[87] part of the 21st Century Cures Act signed into law by President Obama in 2016, require electronic verification of Medicaid-funded personal care or home health services. Intended to reduce fraud and save money, service providers' location will be tracked by GPS. Their activities—i.e. assisting with meal preparation, bathing, money management—could be filmed. Conversations with clients could be recorded. While many people with disabilities believe that EVV will violate their privacy and limit their independence, states that do not comply with EVV by January, 2020 could lose Medicaid funding.[88,89] How much energy will EVV's tracking devices, data collection and data storage require? I've spoken with a mother whose child requires seizure-sensing equipment that can malfunction around microwave ovens—and, likely, EVV's tracking device. What options will families that want to retain privacy and minimize EMR exposure have? Will EVV really save money?

**Solutions and questions for reducing the Internet's footprint**

Spread the word: transmitting a video takes more energy than transmitting a photo; transmitting a photo takes more energy than a voice message, which takes more than text. Skyping uses more energy than plain talk.

Take note: improved viewing quality likely requires more data and more energy. A blu-ray's data size can range between 25 and 50 GB, five to ten times the size of a high density (HD) video.[90] With 3D movies, a video might be 150 GB. Holographic movies could approach 1000 GB. Don't go there.

Streaming one hour of video per week uses more electricity than two new refrigerators require in a year,[91] yet not every household has a refrigerator. YouTube's largest category is cats. To reduce energy use and GHG emissions (and perhaps help sustain the Internet), *would viewers reduce posting and watching cat videos?*

As we learn more about the true cost of streaming (and posting) videos, *should we ration the number of hours per month that each user can have, regardless their ability to pay? Should cute cat videos (YouTube's most popular category), be "priced" differently than videos that, say, explain how to mulch soil? Would telecom providers collect these payments—or people whose homelands were destroyed by mining computers' raw materials?*[92]

To reduce the Internet's footprint, each sector of society can aim to reduce their Internet use by 3% per month with steps like the following:

***Manufacturers***
Make modular, repairable, wired electronics that re-use functional components.

Make battery replacement for mobile devices easy and safe.

Do not export used lead batteries from the U.S. to other countries with weaker environmental controls. Conduct third party audits of lead battery manufacturing facilities.[93]

Design software so that new or updated versions can be accessed on older hardware—and consumers do not need to buy new computers and printers to use the new software.

Collaborate with multiple companies to require suppliers to disclose all chemicals and use the safest alternatives available.

Buy raw materials and parts only from sources that verify worker protections.

***Service providers***
Maintain copper legacy landlines and wired Internet access. Wire (i.e. install fiber optics) Internet service to each building and household, with no wireless interface in "the last mile."

Do not beam the Internet from space, since black soot emitted by launching (thousands of) rockets could quickly become a potent driver of ozone loss, impact atmospheric heating and speed climate disruption.[94]

Maintain underwriters (not self-insurance programs) to provide liability against fire, safety and health damages.

***Federal and municipal governments***
Amend legislation to protect local authority over telecom facilities.[95]

Prohibit further buildout of telecom infrastructure (including 5G) until it has been proven safe for public health and weather catastrophes.

Abide by professional engineering statutes that safeguard the public's life, health and property by requiring that independent, licensed professional engineers evaluate and certify the safety of telecom infrastructure before deploying it.

Rather than buying new, establish fix-it clinics in your town (to repair electronics, appliances and clothes); and enact Right to Repair legislation.[96]

As volume purchasers of smartphones and tablets (i.e. for government workers and students) require manufacturers to verify worker protections and create modular electronics with repairable parts.

Remove "smart," digital, wireless, transmitting utility meters and restore/maintain electro-mechanical utility meters.

Ban bitcoin mining.

At recycling centers, let robots "mine" re-usable metals from discarded electronics to generate income.[97]

***Web designers***
While browsers grow less patient with website loading times, webpages grow in size. In 2010, the average page size was 702 kilobytes (kb). In 2016, thanks to flashy images, more videos, customized fonts and advertisements, the average webpage size was 2,232 kbs, a 317% increase from 2010.[98] Viewing a webpage generates about 0.2g of $CO_2$ per second. This increases to about 0.3g per second when the page has complex images, animation or videos. Assuming that webpages are increasing in size by about 16% annually, speedcurve.com predicted that the *average* webpage could be greater than four megabytes by 2019, 25% larger than the average page in 2017.[99] Therefore: minimize videos, pop-ups and slide shows—which consume *lots* of energy and thereby emit *lots* of GHGs.

Compress image files. Disable unnecessary plug-ins. Wait at least four years to upgrade to a new device.

Link or embed videos rather than repost them.

Program videos so that they work only at desktops.

***Parents and schools***
Delay children's use of electronics until they have mastered reading, writing and math on paper.

Create Personal Tech Contracts and ongoing discussion about responsible tech use with your children.[100]

Have each student research one substance in a smartphone and share their research with classmates.[101]

***Individuals***

Petition legislators to repeal legislation that denies local authority over telecom facilities.

Before turning an electronic device on, ask: *Is using this device within my means? Within the means of our global ecosystem?*

Buy repairable, upgradable, modular electronics.

Celebrate mechanics who can repair what's broken.

Wait at least four years to upgrade.

Delete old emails and Facebook posts.

As much as possible, use wired (faster, more secure and more reliable) Internet access. Download videos via wired devices. Borrow from safely wired libraries.

Since videos require more data (and therefore more energy), text, email or call rather than Skype. Better yet, talk in person.

Buy only recyclable ink cartridges.

Reserve mobile devices for exceptional situations. If you must have a mobile phone, keep the WiFi and bluetooth off. Keep "airplane mode" on, and program the phone to remind you to check for messages only every two hours. Move social media from your first page to your second or third page to break the habit of constant checking.

If you have wireless Internet access, turn it off for at least 12 hours while you sleep until you can get wired access.

**Closing questions**

Researchers estimate that four billion people are not yet online. To participate in educational and economic opportunities, they need access, even while this will exponentially increase extraction of natural resources. It will generate more GHGs and e-waste. To safeguard our climate, human health and biodiversity, do we limit the Internet use of the three billion people already online?[102,103] For people who do not yet have access, do we prioritize refrigerators, clean water and indoor plumbing over mobile phones?

Do we require the telecom industry to prove that new technologies are safe for pregnant women, children, wildlife and weather catastrophes *before* they are marketed?

How will federal and municipal governments, manufacturers, banks, businesses and schools inform every user of the Internet's unintended consequences, including climate change, GHG emissions, biodiversity loss, public and worker health hazards and e-waste? Could every institution initiate an educational campaign to inform users about ways to limit Internet use and growth?

As technologies remove human elements from growing and preparing food, raising children, practicing medicine and other basic functions, how will governments, communities and citizens maintain and develop income and meaning?

How can we use the Internet more responsibly? How do we prepare children and ourselves for a world with less computers? Do we regulate Internet use—or wait for nature to impose limits for us?

Who will decide these questions?

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**The Internet's main energy guzzlers**

***Access networks***

6. Fiber optic cables carry signals by pulsing light. Buried or strung on poles like telephone wires, fiber optic cables provide speed, security and reliability for telecommunications. They also require less electrical power than antennas to transmit signals and are more resistant to weather catastrophes than wireless networks. 4G (fourth generation of wireless infrastructure) operates by delivering fiber from the provider's mobile switch office to a cell tower, while the "last hop" from the cell tower to the end-user is wireless. With 5G, the provider delivers fiber optics from its switch office to public right-of-ways (PROWs) such as utility poles and street lights; the last hop from the PROW to the end-user is wireless. 4G and 5G allow mobility. However, because they include wireless components, they decrease reliability (i.e. during power outages); they increase EMR exposure and risk of interception. While fiber was once the gold standard for telecommunications, its pairing with wireless is problematic.


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