A quick guide to your digital carbon footprint

Deconstructing Information and Communication Technology's carbon emissions

Introduction to your digital carbon footprint

Contents

Carbon emissions from digital solutions are generating a lot of interest and debate. Some argue that gaming is comparable in carbon footprint to taking a flight, while others condemn the climate impact of streaming or social media, using flawed or inaccurate figures. This report aims to explore the issue in greater detail and debunk common myths.

Ericsson has spent more than 20 years researching the carbon emissions of digital, while building extensive data sets and publishing findings in peer-reviewed scientific journals and at conferences. Having reviewed multiple statements about the carbon emissions of digital solutions and compared these to our published results, we are sharing some of our findings here. Further explanations, calculations and references behind the statements and figures in this report can be found in a supplementary background report. The main study cited in this report was published in 2018 after scientific review.[1]

This report focuses on the Information and Communication Technology (ICT) sector, which includes IT and telecommunications, as defined in the text box to the right. In this report, we adopt a traditional sector

definition from the Organization for Economic Cooperation and Development (OECD). In reality, however, carbon footprints of sectors overlap, as each uses one another's services.

In this report we explore ICT's carbon footprint. The carbon footprint concept goes beyond just the electricity usage of products. It incorporates greenhouse gas emissions associated with energy and materials used throughout the life cycle of a product. This includes raw material acquisition, production and assembly, transportation, operation and end-of-life treatment. The indirect impacts of ICT usage are not included in the carbon footprint. These effects are often much more significant than the footprint itself. In this report we consider the carbon footprints of all products within the ICT sector. More specifically, the carbon footprint of the ICT sector includes both mobile and fixed access networks, data centers and enterprise networks, as well as all user equipment such as phones, computers, small routers, new Internet of Things (IoT) devices and other tools.

Information and Communication Technology and the climate
The Information and Communication Technology sector is commonly referred to as the "ICT" sector. It impacts the climate in three ways:
1. Direct carbon emissions associated with ICT manufacturing, use and disposal (ICT's carbon footprint)
2. Indirect positive or negative emission effects from using ICT (e.g. travel substitution and transportation optimization)
3. Impacting behaviors and preferences (reshaping how we lead our lives on a societal level)

This report focuses on the first category, which is frequently addressed in public discussions, but not always in an accurate way. However, the other two are often much more significant.

Information and Communication Technology sector
- Comparison to aviation
- ICT carbon footprint
- Decarbonizing ICT
- Outside the ICT sector
- ICT as a driver for a more sustainable world

Personal digital carbon footprint and specific services
- Streaming, downloading and storage
- Gaming
- Reducing your personal carbon footprint

[1] Malmodin and Lundén (2018). The Energy and Carbon Footprint of the Global ICT and E&M Sectors 2010–2015. Sustainability. doi:10.3390/su10093027.

Ericsson has carried out extensive research into ICT's carbon footprint

Key takeaways

- Digital devices are becoming increasingly widespread, but the carbon footprint of the ICT sector remains fairly stable, at around 1.4 percent of overall global emissions.
- The ICT sector's carbon footprint could be reduced by over 80 percent if all electricity consumed came from renewable energy sources.
- The digital footprint of individuals makes up a small percentage of their total carbon footprint and could be reduced further e.g. by switching devices less frequently.

- Calculating carbon footprints is not rocket science but does demand sufficient understanding of the technology itself in order to give accurate results.
- Beyond carbon footprint, digital technologies are powerful tools that can be used either for better or for worse, depending on societal framing. Used well, they provide opportunities to accelerate decarbonization in line with societal goals. However, if framed incorrectly, they can also accelerate carbon intensive activities.

True or false –
why is it so complicated?

Rapidly changing technologies make
estimating carbon emissions difficult.

ICT technology is used by most of the global population to aid home and work life. Increasing access to this kind of technology to reach more people is an integral part of the UN Global Goals for Sustainable Development.[2] Thus it is important to understand the footprint of this expanding technology and how it develops.

As the ICT sector is constantly evolving in terms of usage, equipment and improvements in energy efficiency, it can be challenging to keep its carbon footprint information up to date.

Due to these challenges, the media often has a hard time accurately representing the footprint of ICT and incorrect statements occur every now and then. Our extensive data sets show that numbers in the media (or even research papers) related to electricity consumption and the carbon emissions of data centers, streaming, gaming and other digital activities are often exaggerated. Sometimes, such numbers are more akin to comparing apples to oranges, and unfairly pitch a particular aspect of one service against the full life cycle of another.

So, is it important? Yes; with the world needing to halve overall carbon emissions every decade,[3] correctly understanding the carbon footprint of different activities is crucial.

Especially as incorrect information will lead to increased uncertainty and confusion. It can also lead to either inaction or poor decisions, resulting in people chasing only minor carbon reductions while unknowingly leaving the real reduction opportunities untouched.

Comparing different media articles shows that there are common factors behind why incorrect statements materialize. For example, figures can originate from insufficient knowledge about the technology and its electricity usage, or outdated data combined in erroneous ways.

Simple reality checks can easily prove incorrect figures wrong, but these numbers often spread and come to define people's understanding of the footprint of digital solutions.

Key reasons for incorrect statements on carbon emissions:
- Comparing "apples to oranges" (whole life cycle impact vs. electricity use alone)
- Using outdated figures and data due to insufficient technology knowledge
- Incorrect combinations of data

Figure 1: Example of typical media headlines (references to real examples can be found in our accompanying background report)

Common news
headline types

Smartphones consume
as much energy as fridges

Data explosion will result in
major electricity consumption

Social media use has
a major carbon footprint

How badly is your streaming
impacting the environment?

---

[2] United Nations Development Program (UNDP) Global Goals for Sustainable Development
Target 5b: Enhance the use of enabling technology, in particular Information and Communications Technology, to promote the empowerment of women
Target 9c: Significantly increase access to information and communications technology and strive to provide universal and affordable access to the internet in the least developed countries by 2020
[3] IPCC Special Report, "Global warming of 1.5 degrees Celsius": https://www.ipcc.ch/sr15/

Minimum footprint while benefitting many

Comparing the carbon footprint of ICT with the emissions of the aviation sector.

The ICT sector is often described as having a similar footprint as the aviation sector in terms of carbon emissions. Let's dive deeper and see how the two compare, keeping in mind that ICT is used by a very large share of the world's population compared to aviation.

The total life cycle carbon footprint of the ICT sector is approximately 730 million tonnes CO2 equivalent (Mt CO2-eq) or 1.4 percent of total global greenhouse gas emissions.[4] This includes the electricity used by all equipment in the system during their use but also all other parts of the life cycle, like the manufacturing of networks, data centers, phones, computers and other user equipment. Furthermore, the figure includes the construction of ICT-related buildings and, for instance, employee travel and transport.
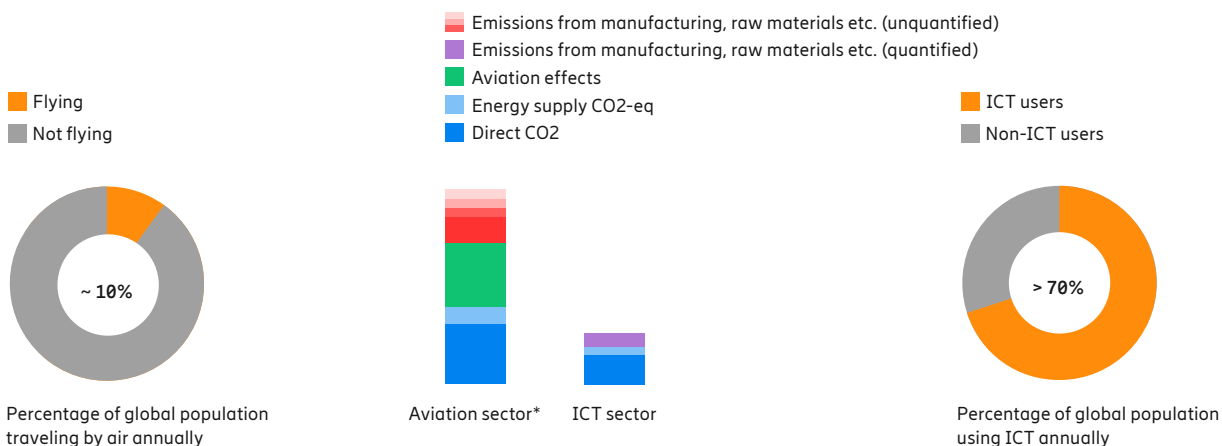
The emissions from burning fuel across the aviation industry were reported to be about 800Mt CO2 in 2015.[5] Air travel, excluding air transport and military flying, forms about 80 percent of the total aviation sector footprint.[5] So, in an unbalanced way, the ICT sector could be compared to the aviation sector (fuel only) — a similarity in terms of numbers but not in terms of scope. A more well-balanced comparison of the two sectors' overall carbon footprints could be carried out if figures for the manufacturing of airplanes, the operation of airports including ground vehicles, end-of-life-treatment and an accurate estimate of any other greenhouse gases (GHG) produced by the sector, including the high-altitude effects, were readily available.

Seventy percent of people globally currently use ICT, while it is estimated that only 10 percent of the global population use aviation services (i.e. airplane travel) each year, with only the wealthiest 1 percent being frequent flyers. This means that even if the footprints of the sectors were of a similar magnitude (a small percentage of global overall carbon emissions at current usage levels, as in the unbalanced comparison), the impact per user would still differ a lot.

50 years

For the carbon emissions of a person making a transatlantic return flight, a smartphone could be used for over 50 years.

Figure 2: Carbon footprint comparison between the aviation and digital sectors

Legend:
- Emissions from manufacturing, raw materials etc. (unquantified)
- Emissions from manufacturing, raw materials etc. (quantified)
- Aviation effects
- Energy supply CO2-eq
- Direct CO2
- Flying
- Not flying
- ICT users
- Non-ICT users

~ 10%
Percentage of global population traveling by air annually

Aviation sector* ICT sector

> 70%
Percentage of global population using ICT annually

*For the aviation sector, the emissions for fuel production and aviation effects are estimated based on ICCT and IEA figures

[4] ICT carbon footprint for 2015, as reported in Malmodin and Lundén (2018). The Energy and Carbon Footprint of the Global ICT and E&M Sectors 2010–2015. Sustainability. doi:10.3390/su10093027.
[5] ICCT, 2014, IEA/ATAG/ICAO/IATA

More data, same carbon footprint

Exploring the limited impact of ever-increasing
data usage on ICT's carbon footprint.

Rapid digitalization and ongoing increases in data traffic might raise questions about how the carbon footprint of ICT could change in the near future, particularly with the building of larger data centers and the launch of new communications networks. The best starting point for understanding the future is to dig into the past, analyzing historical developments and evaluating real-world measurements of electricity consumption and data traffic.

Looking at the actual development, it is clear that the electricity consumption and carbon footprint of the ICT sector do not follow the same trends as data traffic. Since 2010, total data traffic has increased approximately tenfold, while electricity consumption for the ICT sector has remained constant.

Energy efficiency improvements across the sector, together with replacing larger devices with smartphones, continues to limit ICT's footprint, despite ongoing build-out and the rising number of subscribers. Looking ahead, it is likely that data traffic will increase further, but that ICT's carbon footprint and electricity consumption will not, due to continued developments in efficiency and the phasing out of older technologies. Arguments that the ICT industry will consume most of the world's electricity within a couple of decades are, therefore, unreasonable. Especially given that service provider cost frames would not allow for such expansion of operational expenditures.

1.4%

ICT equipment accounts for about 1.4 percent of total carbon emissions and uses about 3.6 percent of global electricity consumption, while making up around 6 percent of the global economy.

**What is driving
energy consumption?**
In 1965, the advent of Moore's Law brought about the idea that the number of transistors on a microchip should double every two years. It is this concept that today drives consumers to exchange their phones and computers every two or three years to gain access to faster and more powerful devices.

Since 2012/13, development has slowed down. However, as several parameters work alongside each other, a slowing down of Moore's Law does not directly translate into worse energy performance.

For real products, energy performance also depends largely on configuration, cooling, processing algorithms, system setup and many other factors.

Figure 3: Carbon footprint of ICT and data traffic development
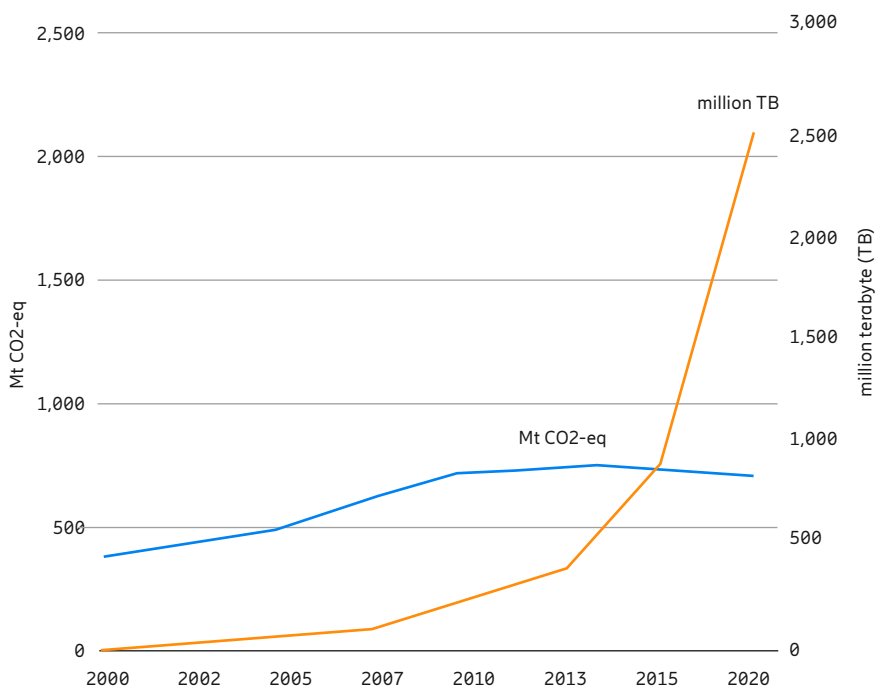
Decarbonizing ICT

Exploring what the sector
can do to reduce its footprint.

User devices, networks and data centers are the three main parts of the ICT sector. In addition, the ICT sector footprint includes ICT-related emissions of services like gaming, social media and online advertising. Currently, user devices (including phones, tablets and computers) account for the largest chunk of the sector's overall carbon footprint.

Looking at the total carbon footprint, carbon emissions are divided between operation and embodied emissions, including raw material acquisition, production, assembly, transportation and end-of-life treatment. Operation includes electricity consumption for the use of products, and emissions for operation and maintenance activities.

A large part of the sector's carbon footprint can be linked back to electricity consumption, but many key ICT players invest in renewable energy, such as solar and wind power, in a bid to lower their carbon emissions. The emissions during use emerge almost entirely from electricity consumption, but the other life cycle stages consume electricity too, for instance in manufacturing. If the ICT industry and its users only consumed electricity produced by renewable energy sources, more than 80 percent of ICT's carbon footprint could be reduced.

**What is the impact of
artificial intelligence?**
New technologies sometimes cause concerns of potential rising electricity consumption.

Machine learning and artificial intelligence (AI) use deep learning algorithms to compile and process large data volumes in computers. AI can be used either on a small scale, such as for spellchecking, or on a larger scale, such as empowering supercomputers to predict the weather, calculate the likelihood of natural disasters, or quickly interpret medical scan images. Rapid progress in terms of technology development creates both a risk of increased electricity consumption and opportunities in terms of mitigating climate impact.

However, this is still a relatively young technology and it is difficult to lump the electricity consumption of current learning activities together with a future, broader AI education system. Increasing energy efficiency of learning processes overall should be an important task for AI developers moving forward. However, any AI will have substantially lower electricity usage once it has been educated. In the end, the most significant impact will depend on what it is used for.

80%

The ICT sector's carbon footprint could be reduced by over 80 percent if all electricity consumed came from renewable energy sources.

Figure 4: Distribution of ICT's carbon footprint (2015)
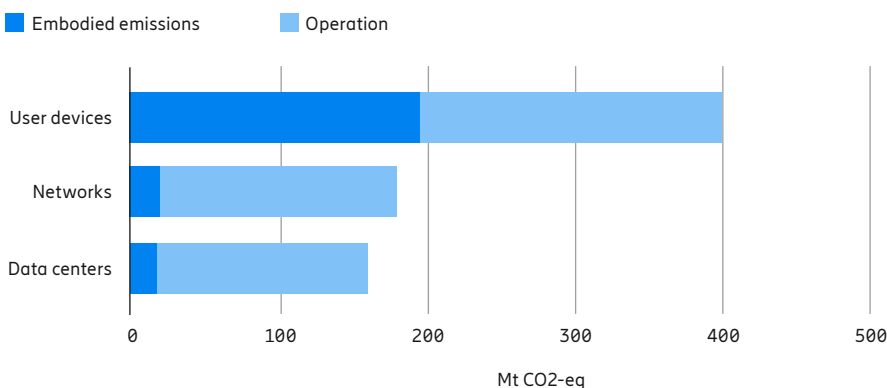
Setting boundaries –
a complex task

## New and overlapping activities blur the traditional boundaries.

Traditionally, ICT's footprint includes devices like computers, phones and tablets, regardless of activity, but excludes entertainment and media devices like TVs and gaming consoles. Today, new complexities arise, such as the increasing number of surveillance cameras, and the advent of smart meters and cryptocurrencies, which do not fit clearly into existing industry sector definitions.

Figure 5 shows the annual electricity consumption of these devices and activities, but it is not at all clear whether these should be directly counted as ICT in the future.

The impact of cryptocurrencies
Cryptocurrencies are sometimes associated with ICT. Although their sector categorization is not clear, cryptocurrency mining consumes a lot of electricity, but only benefits a select few. Total electricity use in this sub-sector is affected by the number of servers and their efficiency and computational load, as well as mining difficulty, location of equipment and overall cost. All these parameters change quickly, which is why estimating total electricity use can prove challenging. For example, Bitcoin mining accounted for 0.2 percent of global electricity usage in mid-2018.[6]

Figure 5: The operation aspects of ICT electricity consumption in perspective
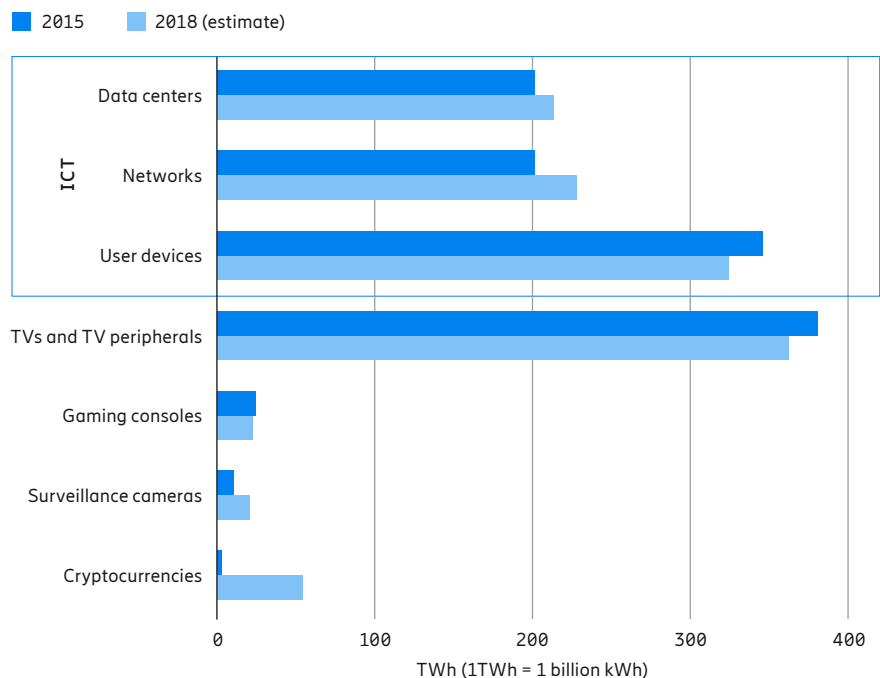
Data centers include enterprise networks (intranet)
Company offices, transport, etc. are included in ICT electricity consumption

[6] Koomey, J. (2019). Estimating Bitcoin electricity use: a beginner's guide, Coin Center Report, May 2019, available at https://coincenter.org/entry/bitcoin-electricity

ICT as a driver for a more sustainable world

ICT has huge potential to be a key driver for a more sustainable world.

Just like all other sectors, ICT needs to reduce its footprint to help decarbonize the world. For this reason Ericsson is working to reduce its own carbon footprint and has a 1.5-degree Science-Based Target (SBT)[7] in place. We are also working with others to halve the emissions of the sector by 2030. However, it is important to understand the ICT sector's footprint in relation to its decarbonization effects, and to make use of its potential to help other sectors decarbonize.

In this context, ICT's footprint is relatively small compared to its potential impacts, as all sectors of the economy become digitalized. This makes ICT a wildcard of the economy — in the right framing the technology could be a major tool to implement low-carbon and circular solutions in all sectors — used wrongly, however, it could also accelerate carbon intensive processes and businesses.

The potential opportunities are profound. ICT can bring remote healthcare to rural areas, improve efficiency of electricity grids and introduce smoother traffic flows.

ICT solutions, including IoT, machine learning and automation, have great potential to reduce carbon emissions globally, in numerous sectors and industries. Existing ICT solutions have an estimated potential to reduce global carbon emissions by up to 15 percent.[8] In terms of global decarbonization, this equals around one-third of the halving of emissions deemed crucial by 2030.

With new technologies like 5G, IoT and AI, additional emission reduction opportunities will materialize.

Whether these opportunities are realized, and whether adverse use is avoided, will be important to how the world manages to limit global warming.

> # 15%
>
> ICT has an identified potential to reduce carbon emissions by up to 15 percent in other sectors.

ICT has great potential to help to build a more sustainable world

[7] https://www.ericsson.com/sustainability, sciencebasedtargets.org
[8] Malmodin and Bergmark, 2015: https://www.atlantis-press.com/proceedings/ict4s-env-15/25836149

The "Despacito" example

"Five billion downloads and streams clocked up by the song, Despacito (released in 2017), consumed as much electricity as Chad, Guinea-Bissau, Somalia, Sierra Leone and the Central African Republic put together in a single year."

This was a statement made in several media articles around spring 2018.

The electricity consumption of the above countries was about 1TWh in 2017 (1TWh = 1 billion kWh). In comparison, let us look at YouTube, which contributes towards Google's overall electricity consumption, being about 7.6TWh in 2017. It cannot be true that one song, even if streamed billions of times, consumes as much as one-seventh of Google's electricity usage.

More accurately, 5 billion downloads of this song to a smartphone requires about 0.005TWh (a factor 200 less) including its share of networks and data centers. Typically, a download of one song requires 0.001kWh.

We all have a carbon footprint, and streaming, downloading and gaming all contribute to this

How does streaming compare to boiling water and running refrigerators?

The electricity consumption of downloads and streaming is significantly lower than commonly believed.
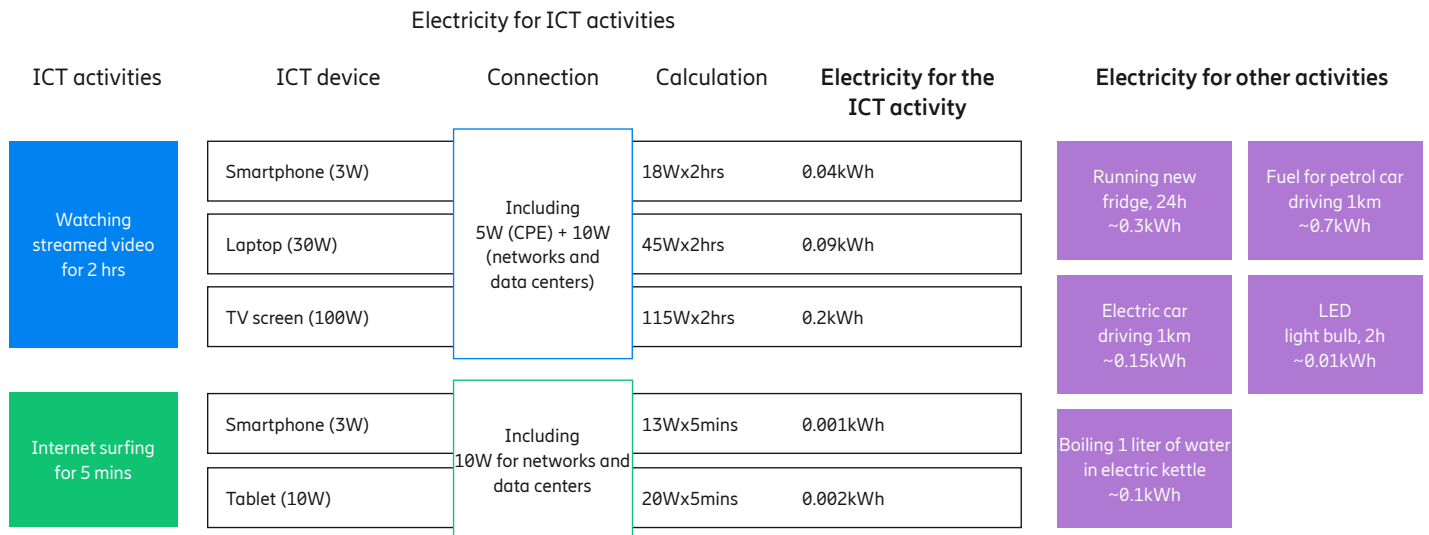
It is sometimes said that streaming videos and downloading music consumes enormous quantities of electricity. The media has compared boiling water for tea, running refrigerators and even the electricity consumption of entire countries to the electricity usage of digital.[9] Let's set the record straight.

The electricity consumption for streaming depends on your device, phone, tablet, computer or screen. The electricity is not directly related to usage, which is one reason why some comparisons end up being incorrect. Instead, the part connected to networks, data centers and customer premises equipment (CPE) is fairly constant. Electricity consumption of networks and data centers should be based on large measures of data from real networks to make estimations more accurate. In a rough comparison, streaming 400 two-hour movies on a laptop connected to an external screen would consume as much electricity as a modern fridge does in a year. If the streaming was on a smartphone, 2,900 films could be streamed using the same amount of electricity.

> The electricity used when driving an electric car for about 0.6km is equal to the electricity used when streaming a 2-hour video to a laptop (network and data centers included).

Figure 6: Streamed video and internet surfing compared to electricity consumption of other activities

Electricity for ICT activities

ICT activities	ICT device	Connection	Calculation	Electricity for the ICT activity
Watching streamed video for 2 hrs	Smartphone (3W)	Including 5W (CPE) + 10W (networks and data centers)	18Wx2hrs	0.04kWh
	Laptop (30W)		45Wx2hrs	0.09kWh
	TV screen (100W)		115Wx2hrs	0.2kWh
Internet surfing for 5 mins	Smartphone (3W)	Including 10W for networks and data centers	13Wx5mins	0.001kWh
	Tablet (10W)		20Wx5mins	0.002kWh

Electricity for other activities

Running new fridge, 24h ~0.3kWh	Fuel for petrol car driving 1km ~0.7kWh
Electric car driving 1km ~0.15kWh	LED light bulb, 2h ~0.01kWh
Boiling 1 liter of water in electric kettle ~0.1kWh	

[9] See examples of media headlines in Ericsson's supplementary background report

Would it be better without streaming?

Comparing modern trends with outdated traditions.

As streaming is sometimes put forward as a key footprint contributor, one may wonder: should we go back to local storage and traditional video recorders?

The simple answer is no. The correct calculations indicate that streaming a two-hour video on a laptop would require considerably less electricity than an older solution, such as local video storage on DVDs or Blu-ray discs. In early days, consumers might drive to rent a movie, and were required to also rent or buy a specific player to watch it on their television screens. Today many fully connected homes can stream a film to almost any device effortlessly. Large screens have become more energy efficient over the years, but many consumers have purchased larger screens than previously for their homes. This means that electricity consumption when watching a movie remains largely the same. However, if the production and distribution of discs, the specific players etc. are included, there is a significant reduction overall. If the film itself is viewed on a smaller device, such as a laptop or smartphone, there is an even bigger difference in electricity consumption.

Moving to the cloud
Nowadays we often store data in the cloud instead of on private hardware. From a carbon emission point of view, looking at the entire life cycle, it is always better to store data in the cloud than on specific hardware at home. The cloud and all data available on the internet forms part of the data centers included in ICT's overall carbon footprint. Data storage is only a small share of this footprint.

The data centers used for public internet consumed approximately 110TWh in 2015,[10] which was about 0.5 percent of the world's electricity consumption. If these data centers were a country, their electricity consumption would be the same as the Netherlands' usage (the country placed 32nd for electricity consumption).

> If ICT's internet servers were a country, their electricity consumption would be the same as the Netherlands' usage — the country placed 32nd for electricity consumption.

Figure 7: Advancements in movie-viewing technology[11]
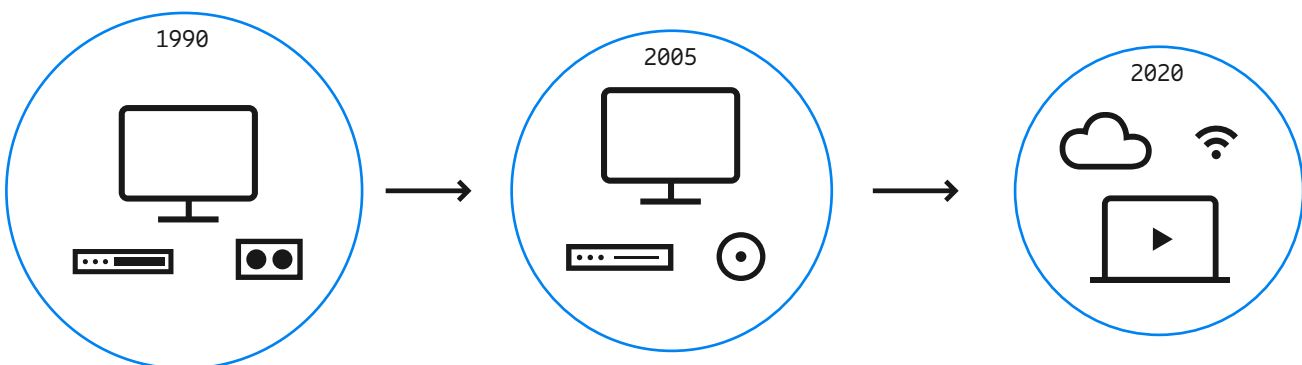
[10] By also including all intranet networks in companies, authorities, etc., we arrive at a consumption figure of about 200TWh
[11] Shrinking circles illustrate lower electricity consumption when watching a movie

Large screens have become more energy-efficient over the years, but viewing video content on smaller screens, such as smartphones, has a lower footprint.

Consuming video content on smaller screens can reduce your ICT carbon footprint

The carbon footprint of gaming

What might heavy gaming mean for the environment?

There is a large difference in electricity consumption and carbon emissions between different ICT users. Generally, the carbon footprint is connected to the time spent and equipment used, and to what extent the networks, servers and data centers are utilized. Powerful gaming computers and large screens are the greatest electricity consumers among user devices.

Let's look at the ICT carbon footprint of Steve, a gamer and major ICT user, Shala, a smartphone user and Sarah, an intermediate ICT user. On average, Steve is connected for 13 hours a day. Of these, 4 hours are spent playing games on a powerful gaming computer with a large screen. Meanwhile, Shala is only connected through her smartphone for 4 hours a day. Sarah uses a smartphone, laptop and tablet for a total of 6 hours per day. Steve's annual ICT carbon emissions are 500kg CO2-eq,

including all life cycle stages and the share of networks and data centers. For Shala, the corresponding figure is 44kg CO2-eq and for Sarah it is 170kg CO2-eq. Compared to the global average carbon footprint of 7,000kg CO2-eq per person, ICT stands

for 7, 0.6 and 2 percent of Steve's, Shala's and Sarah's respective carbon footprints.

If Steve was able to purchase electricity from solely renewable sources his ICT carbon footprint could be reduced to 2 percent of his overall footprint.

Figure 8: Personal ICT carbon footprint of a major, minor and intermediate ICT user
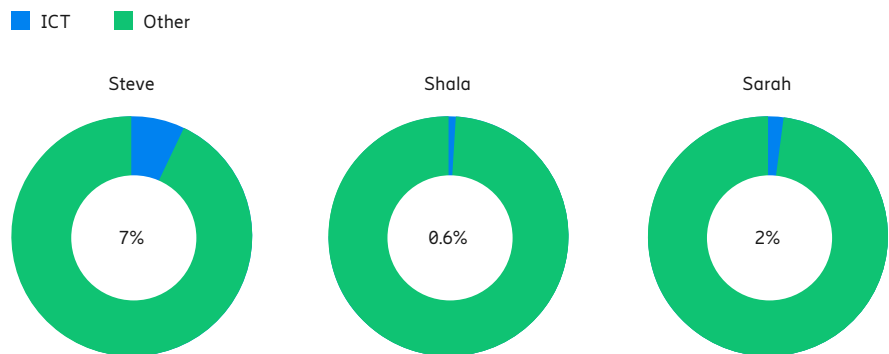
One year's smartphone usage (full life cycle including the share of networks and data centers) is comparable to the level of fuel combusted driving for two hours on the motorway (not including manufacturing of car or infrastructure).

Carbon emissions vary greatly between different ICT users and their device habits

Reduce your ICT carbon footprint

What can we all do to minimize the impact of our online life?

Your digital carbon footprint is greatly influenced by the number of devices you have and how long you use them for, as well as where you live and use them. The carbon emissions stemming from electricity usage are dependent on how the electricity is produced in your country (i.e. hydropower, nuclear, fossils, wind and solar). Hence, the digital carbon footprint of Shala, the smartphone user on the previous page, will depend on where she lives.

Figure 9 shows how Shala's digital carbon footprint differs per region based on how the electricity itself is produced (size of person ~ size of digital carbon footprint).

A skipped trip is a skipped trip — but what do you do instead?
As an ICT user, you might be able to use your smartphone or laptop to save time and money, such as by shopping online, working from home or skipping a business trip in favor of a video conference. However, any reduced carbon emissions might be offset or even outnumbered by what you choose to do with your saved time or money, and how carbon-intense these activities are. This is known as the rebound effect. It is important to be mindful of your footprint and use time and money wisely. Fortunately, it has been shown that ICT solutions helping people who want to live a more sustainable life tend to have little rebound.

We all need to help stabilize the climate and safeguard planetary boundaries. Even though the ICT share of your individual carbon footprint is small, we can all contribute to lowering our collective carbon emissions further.

Figure 9: Digital carbon footprint of Shala, a smartphone user (4h/day) living in different regions with different energy supplies

Global average   India   China   US   EU   Rest of World (ROW)
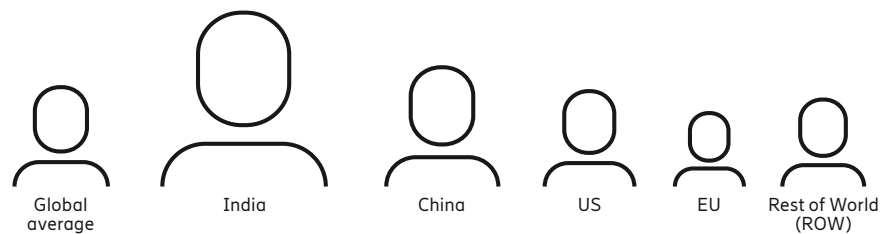
How to reduce your digital carbon footprint
There are many ways of reducing your digital carbon footprint, but the most important thing is to take care of your device so it can be used for many years. You can also:

- Use your smartphone or other ICT devices longer before upgrading
- Make sure you recycle or reuse ICT equipment
- Consume digital services on smaller devices
- Charge the batteries with electricity from renewable sources
- Avoid buying more ICT devices than you have time for (pass unused devices on)
- Show your suppliers that their footprint matters to you
- Buy your digital devices and services from companies that have SBTs
- And, last but not least: use ICT services that help to reduce carbon emissions

Ericsson enables communications service providers to capture the full value of connectivity. The company's portfolio spans Networks, Digital Services, Managed Services, and Emerging Business and is designed to help our customers go digital, increase efficiency and find new revenue streams. Ericsson's investments in innovation have delivered the benefits of telephony and mobile broadband to billions of people around the world. The Ericsson stock is listed on Nasdaq Stockholm and on Nasdaq New York.

www.ericsson.com