Videostreaming: Energy Requirements and CO2 Emissions Background Paper The most important points in a nutshell translated by Stephen Meinke

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2 authors:

Simon Hinterholzer
Borderstep Institute for Innovation and Sustainability

Ralph Hintemann
Borderstep Institute for Innovation and Sustainability

Video Streaming:
Energy Requirements and CO_2 Emissions

Background Paper

The most important points in a nutshell

- → One hour of video streaming in full HD resolution requires 220 to 370 watt hours of electrical energy, depending on the end device used. This produces about 100 to 175 grams of carbon dioxide (CO_2) - about the same as driving one kilometre in a small car.
- → The energy requirement for video streaming depends heavily on the resolution. If streamed in 4K instead of HD, nearly 1,300 watt-hours of electrical energy may be needed per hour, which is roughly equivalent to emitting 610 grams of CO_2.
- → Efficiency improvements may lead to a reduction in the energy requirements for video streaming in the future. However, the trend towards larger screens and higher resolutions might also offset this development.
- → You can significantly reduce the energy requirements and CO_2 emissions by choosing the appropriate resolution and end device. Video streaming doesn't have to require more energy than traditional TVs or DVDs and Blu-ray discs.
- → The climate impact of video streaming can be significantly reduced if we manage to fully utilize the existing efficiency potentials of the streaming service providers and data centers as well as networks and operate the digital infrastructures with electricity generated from renewable sources.

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Wissen das bewegt.

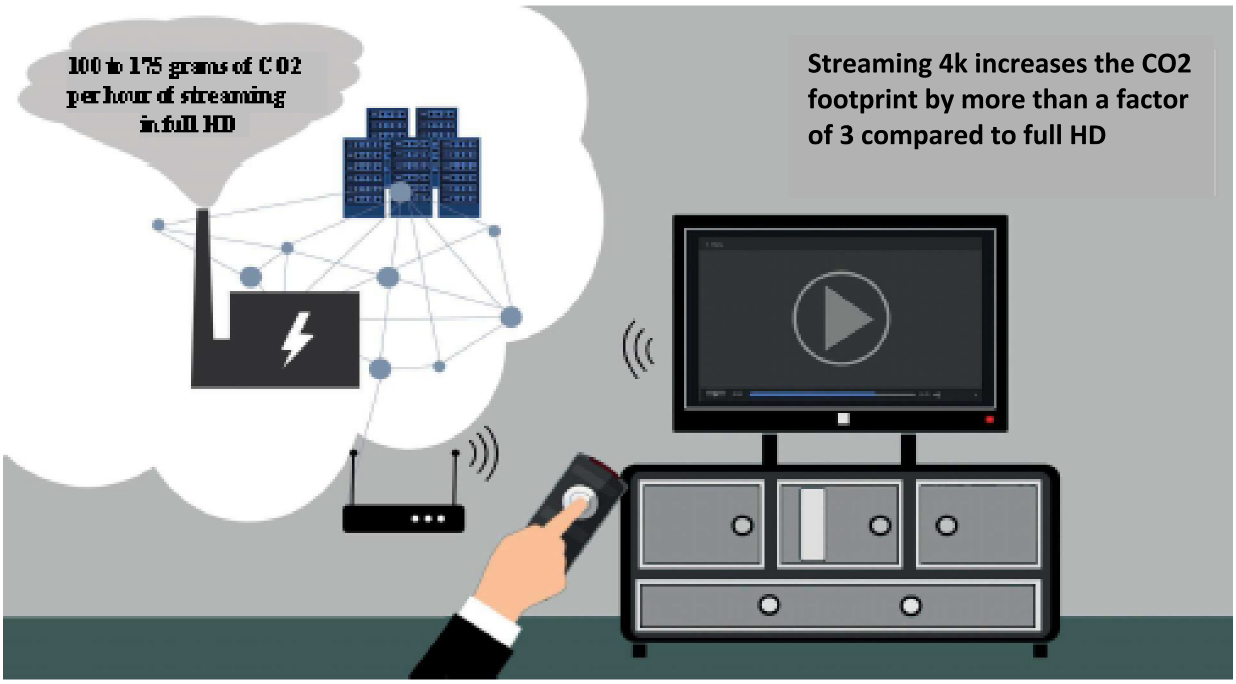
BACKGROUND

Video streaming is booming. More than 24 million people already use paid streaming services in Germany and spend a total of well over one billion hours on these services - per quarter (GfK, 2020). One consequence of the substantial increase in streaming services is the sharp rise in the amount of data transmitted on the Internet. In 2019, around 57 billion gigabytes were transmitted via the fixed network in Germany, which is double the volume compared to 2016 (VATM & Dialog Consult, 2019). Video data currently accounts for about 75 percent of Internet traffic, and video traffic on the Internet is expected to continue to grow rapidly (Cisco, 2018a).

These developments raise the question as to what impact video streaming has on energy requirements and CO_2 emissions. Magazine articles and technical papers sometimes provide very different information on this due to different calculation methods and assumptions (e.g., Chandaria, Hunter & Williams, 2011; Shehabi, Walker & Masanet, 2014; Fuster, 2019; The Shift Project, 2019). This background paper is intended to help assess the current energy requirements and CO_2 emissions resulting from video streaming. Energy requirements and CO_2 emissions are calculated and compared using a transparent calculation method for various video streaming application scenarios.

DR. RALPH HINTEMANN
BORDERSTEP INSTITUT

> STREAMING A SINGLE VIDEO REQUIRES VERY LITTLE ENERGY IN MOST CASES. HOWEVER, THE USE OF THE INTERNET FOR VIDEO STREAMING HAS INCREASED VERY SIGNIFICANTLY IN RECENT YEARS. AS A RESULT, THE TOTAL ENERGY REQUIREMENTS AND GREENHOUSE GAS EMISSIONS RESULTING FROM VIDEO STREAMING HAVE INCREASED SUBSTANTIALLY. WITH EFFICIENT TECHNOLOGIES, SUSTAINABILITY-ORIENTED STREAMING OPTIONS, AND ENVIRONMENTALLY CONSCIOUS CONSUMER BEHAVIOUR, WE CAN PREVENT VIDEO STREAMING FROM BECOMING A CLIMATE KILLER.



KEY FACTS

Streaming videos over the Internet produces CO_2 emissions in a variety of ways. Of particular relevance are the energy requirements caused by the various devices and infrastructures. The following approach describes the energy requirements for:

- end devices (display of the video)
- communication networks (transmission of video data)
- data centers (storage, pre-processing and provision of video data)

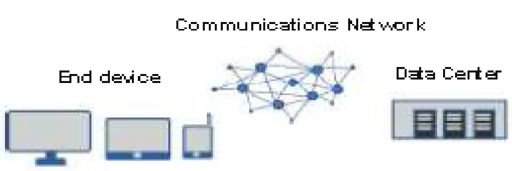


Fig. 1: Relevant devices and infrastructures

As Figure 2 shows, the energy requirement for video streaming clearly depends on the selected resolution. One hour of video streaming on a fixed network in low HD quality (720p) on a 65" TV screen consumes approximately 280 watt-hours (Wh) of energy. This is the equivalent of approx. 130 grams of CO_2 emissions. Of this, more than half of the energy is required by the TV itself. In contrast, one hour of video streaming in 4K on a 65" TV requires almost 1,300 Wh of energy (equivalent to approx. 610 grams of CO_2). Communications networks and data centers account for 88 percent of the energy requirements.

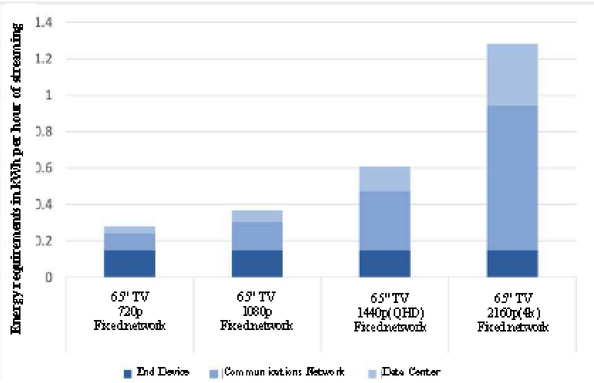


Fig. 2: Energy required for video streaming for various resolutions (base year 2018, not including the manufacturing of devices and equipment). (Source: Borderstep 2020)

Figure 3 illustrates the relationship between the energy requirements for video streaming in HD resolution (1080p) and the end device used. While more than one-third of the energy required for streaming on a large television screen can be attributable to the TV, the energy needed for a smartphone or tablet is only 2 to 6 percent. As the results show, the energy requirement and hence the CO_2 emissions clearly depend on the resolution and the end devices.

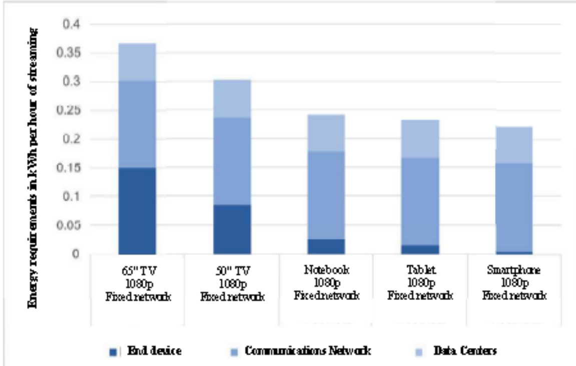


Fig. 3 Energy required for video streaming in full HD (1080p) for various end devices (base year 2018, not including the manufacture of the devices and equipment). (Source: Borderstep 2020)

When streaming video on a smartphone or tablet in SD resolution, the energy required per hour is only 65 Wh or 75 Wh (equivalent to about 30 to 35 grams of CO_2). Video streaming on large TVs and at very high resolutions requires a lot more energy. A video in 8K on a 65" TV needs 1,860 Wh of energy per hour. This translates into about 880 grams of CO_2.

The values shown above apply to video streaming on the fixed network. Considerably more energy is required on the mobile network using current technology. Due to methodological challenges, we have not calculated the energy needed for video streaming on mobile networks (see Methodology).

We can conclude that a large proportion of the energy required for video streaming is used in data centers and communication networks and thus not transparent to the user. The CO_2 emissions resulting from video streaming, for example, range between 100 and 175 grams for an hour in HD resolution on the fixed network and are comparable to driving one kilometre in a small gas-powered car. CO_2 emissions from passenger cars range between 100 and 300 grams, depending on the type of vehicle and the way it is driven.

Therefore, the CO_2 emissions produced by video streaming are relatively low compared to many other leisure activities, especially if they are associated with motorized mobility. The user also has significant control over the energy requirement and CO_2 emissions by choosing the end device and the resolution. For example, streaming in SD on a smartphone, tablet, or notebook requires less energy than watching traditional TV or DVDs on a 50" TV.

TRENDS AND OUTLOOK

The amount of data transmitted for video streaming increases by about 26 percent annually in Germany (Cisco, 2018a). This is due to the increasing use of video streaming services as well as higher resolutions resulting in an increased data volume per video.

The energy requirement in communication networks and data centers increases more slowly than the data volumes. Therefore, we can conclude that the energy requirements per gigabyte (GB) for video streaming are continuously decreasing. Making rough estimates for 2020, we can assume that the energy required in communication networks and data centers per hour of streaming in full HD has decreased by about 25 percent compared to 2018. As the electricity mix in Germany improves, CO_2 emissions are falling even more significantly.

However, the trend toward reduced energy requirements per GB of data volume is offset by the trend toward higher resolutions. According to Cisco, HD and UltraHD resolutions will increase from 54 percent to 70 percent of video traffic between 2018 and 2020. Overall, the trend towards higher resolutions currently appears to offset the efficiency improvements in technology. The average energy requirement for one hour of video streaming is likely to have remained roughly constant.

SIMON HINTERHOLZER
BORDERSTEP INSTITUT

" THE ENERGY REQUIRED IN DATA NETWORKS AND DATA CENTERS DEPENDS ON THE DATA VOLUME AND THUS ON THE RESOLUTION OF THE VIDEO DATA. HOWEVER, THE ENERGY REQUIRED BY THE END DEVICE - THAT PART THAT APPEARS ON THE USER'S ELECTRICITY BILL - IS LARGELY DETERMINED BY THE SIZE OF THE DISPLAY AND THE DISPLAY TECHNOLOGY. WHEN SMALL, ENERGY-EFFICIENT END DEVICES AND SD VIDEO RESOLUTION ARE USED, STREAMING REQUIRES LESS ENERGY THAN TRADITIONAL TVs ON LARGE DEVICES.

Recommended action and conclusions

→ Attention should be paid to energy efficiency when purchasing video streaming devices. This is especially true for TVs. An A++ device usually saves more than 50 percent of electricity compared to a device rated energy efficiency class B.

→ End devices such as tablets or smartphones often need only 1/10 as much electricity as TVs. So if you can or want to do without large screens, the energy need and greenhouse gas emissions can be significantly reduced.

→ High video resolutions require more energy in data centers and for data transmission. A low video resolution suitable for the purpose and the end device can significantly reduce the energy needed for streaming.

→ Streaming services should utilize the existing technological efficiency potentials and avoid unnecessary data transfer. Transparent and easily accessible customer information should promote energy-efficient and climate-friendly streaming behaviour.

→ Data centers and communication networks as digital infrastructures must be operated as energy-efficiently as possible. They should be supplied with electricity produced by renewable sources.

CALCULATION METHOD

When calculating the energy requirements for streaming, we look at three different groups: user's end device, communication networks, and data centers. The calculations are based on the available data for 2018. We calculate only the energy needed for using the devices and infrastructures. The energy required to manufacture and transport the devices and equipment is not taken into account. While it is relatively easy to measure and calculate the energy requirement for streaming video on an end device, the high complexity of communication networks and data centers poses methodological challenges when we want to establish the energy requirements for streaming. Since many applications use these central infrastructures, we must apportion the total energy requirements to the various applications according to a suitable key.

In this study, we use a top-down approach. We first calculate the total energy requirements for streaming in the data centers and communication networks and compare them to the volume of streaming data (GB). This method allows us to calculate the energy requirement per hour of streaming in different streaming formats.

Figure 4 illustrates the method.

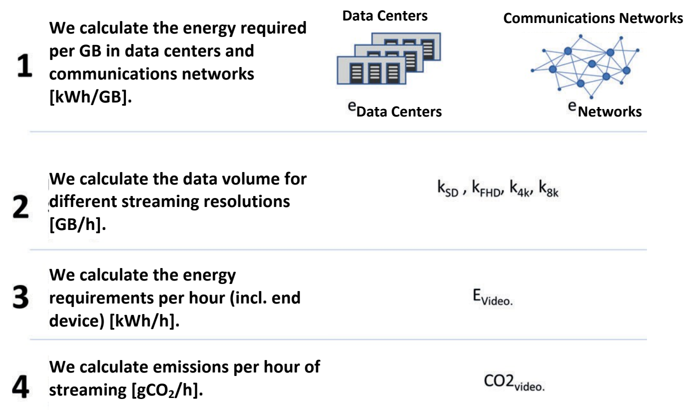


Fig. 4: Top-down approach to calculate the energy requirements for streaming in the data centers and networks.

The following assumptions are made for this calculation:

→ Based on the energy requirements of the global data centers (Hintemann, 2020) and data from Cisco, the share of the data centre's energy requirements for video streaming is estimated (Cisco, 2018b) and compared to the global Internet video data traffic (Cisco, 2019). This shows that data centres required 0.0321 kWh/GB for streaming in 2018.

→ For the communication networks, we compare the annual energy requirements for fixed and mobile network in Germany (Stobbe et al., 2015) to the annual data volume in the networks in Germany (Bundesnetzagentur, 2019). Hence, communication networks require 0.075 kWh/GB on the fixed network and 1.07 kWh/GB on the mobile network. This estimation certainly gives us an upper limit of the energy needed for video streaming as the energy requirements of the telecommunication networks are split among the different applications according to the data volume. The other aspect of mobile networks is that videos are usually streamed via the 4G network, which is energy-efficient in terms of data volume and realized in the future. However, the 1.07 kWh/GB shown above is based on the average of 2G, 3G and 4G networks and therefore not directly representative for video data.

→ The data volumes per hour of streaming vary for different streaming formats and depend primarily on the image resolution and compression of the video data. For this purpose, we use data from a well-known video platform (makeuseof.com, 2020).

→ We calculate the energy requirement of the end device by multiplying the power consumption by one hour:

Desktop PC	60 W
Notebook	25 W
Tablet	15 W

Smartphone	5 W
TV 65"	150 W
TV 50"	85 W

→ National and international CO_2 emission factors for electricity generation in 2018 are used to calculate CO_2 emissions (IEA, 2019; Umweltbundesamt, 2019).

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PUBLISHING INFORMATION

Dr. Ralph Hintemann und Simon Hinterholzer (Authors)

Borderstep Institut für Innovation und Nachhaltigkeit gemeinnützige GmbH

Clayallee 323 | 14169 Berlin | Phone: +49 30 306 45 1000

E-mail: hintemann@borderstep.de | hinterzolzer@borderstep.de

www.borderstep.de