Did *The Shift Project* really overestimate the carbon footprint of online video?

Our analysis of the IEA and CarbonBrief articles

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THE SHIFT PROJECT
THE CARBON TRANSITION THINK TANK

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In a nutshell: An analysis published in March correctly pointed out an error by The Shift Project regarding the climate footprint of online video. This error appeared during an interview. It has no impact on the results published in our reports, which are not contested. Here is our detailed explanation. We call for further scientific discussion.

Background: *The Shift Project* wanted to comment on George Kamiya's CarbonBrief article "Factcheck: What is the carbon footprint of streaming video on Netflix?" published on February 28th 2020 (republished on the IEA, website on March 25th 2020: "The carbon footprint of streaming video: fact-checking the headlines"). G. Kamiya's article testifies to the progress of scientific discussion concerning the environmental impact of digital technology. This is a most welcome development that *The Shift Project* intends to support by discussing in detail G. Kamiya's article.

The current debates on the environmental impact of digital technology have recently acquired a quantitative edge. We, *The Shift Project,* approve of this new stage, as we consider this to be the actual challenge to be met. Along with major historical players in this field, we have been advocating for this type of research since 2018. *The Shift Project* is in contact with George Kamiya, and would like to follow his most recent research developments that could be integrated into our updated results, along the lines presented last January in our interim report.

At this point, we consider G. Kamiya's paper to be the most comprehensive and transparent review of our 2019 results. It does point out to a figure that is undeniably wrong. However, this piece of data is not to be found in any of our reports, the results of which are not disputed: it was provided during an interview by one of our collaborators, who then stated erroneously that *"watching a half-hour show would lead to emissions of 1.6 kilograms of carbon dioxide [which is] equivalent to driving 3.9 miles (6.28 kilometres)"* (AFP, oct. 28th 2019). It was also subsequently presented misleadingly as a statement concerning Netflix in several media outlets, while it was meant as an (albeit wrong) average for all online video. This unfortunate event reveals the importance of considering system-wide dynamics as a whole. The media tend to systematically focus on Netflix in particular, showing how difficult it is to deal with the issue of digital practices. It must be noted that in the media debate, this issue always crystallises around blaming particular uses, thus mostly shunning a systemic reflection on the digital system itself. This is why (among other reasons), when producing figures we, at *The Shift Project,* always refrain from referring to a single player in particular. The source of the figure for "30 minutes of Netflix" in CarbonBrief's article, actually corresponds to a contraction of some data provided by the AFP, regarding an average consumption for a 30 minutes of online video. This figure was later taken up and broadcasted by several media, including France 24, the New York Post, CBC, Yahoo, DW, Gizmodo, Phys.org and BigThink. Another reason why *The Shift Project* figures never refer to a single player in particular is that individual actors rarely disclose enough data to allow for precise conclusions – though they have been increasingly transparent since the topic has come to the forefront in the last 18 months.

No matter how complex a task, it is crucial at this stage to investigate the "digital system" as such and to consider collective strategies to be implemented. G. Kamiya rightly does so in his article, particularly in the last part. Indeed, he addresses the issues that relate to the digital system as a whole, and highlights their central importance: dealing with the rebound effect issue, designing large-scale strategies by bringing all players together, etc. Considering the "digital system" from the point of view of uses means dealing with the uses *as part of* a larger system, which has its own logic, players, infrastructure, regulation, history, and so on. As far as the responsibility of individuals is concerned, as we wrote in 2019: *"The broadcasting platforms (their design, the underlying economic model, audience metrics, etc.) play a central role in the form taken by uses and thus their environmental impact. So, uses are to a great extent the product of a system, and not the sole result of individual consumer behavior."*

Here, we provide here the most recent update on our results, and we will pursue the scientific dialogue with experts on these issues, away from discussions held through the media. As G. Kamiya states in the conclusion of his article for CarbonBrief: "*Instead of relying on misleading media coverage, [achieving the goals of the Paris Agreement] will require rigorous analysis, corporate leadership, sound policy and informed citizens*."

We discuss each part of G. Kamiya's article in detail. We intended to make each comment as self-contained as possible (this accounts for the multiple repetitions). Below is a summary:

1/ G. Kamiya quite rightly points out an error on the CO_2e emissions corresponding to watching 30 minutes of video (although the data in question are to be found neither in our 2018 report, nor in our 2019 report: the source is an unchecked oral interview). There was indeed a major error on the bitrate (3 MBps instead of 3 Mbps), which accounts for 90% of the discrepancies exposed in the CarbonBrief article (i.e. discrepancies between G. Kamiya's approach and the misleading figure mentioned by the relevant interview):

- The gap between the emissions calculated by G. Kamiya for a 30-minute video, and the emissions' figure from the interview with *The Shift Project*'s collaborator (including the bitrate error) ranges from a factor of 28 to 57;
- Once the bitrate error is corrected, the difference between these two calculations is down to a factor of 4 to 7.
- The discrepancy is therefore mainly due to one isolated error. This error has no effect on the overall results published in *The Shift Project* reports ("Lean ICT – Towards Digital Sobriety" (2018) and "Climate crisis: the unsustainable use of online video" (2019)). The reason for the absence of effect on the results published by *The Shift Project*, along with the reasons for the remaining discrepancy are discussed in details later in this paper.

2/ Some 10% of the observed discrepancies remain (the difference between the two assessments after correction of the bitrate error, i.e. a gap of 0.143 to 0.172 kgCO_2e), which are mainly accounted for by the different assumptions regarding the power consumption of network infrastructures (kWh/byte of data transferred). These assumptions account for most of the remaining 10% of differences after correction of the bitrate.

- This means that the scientific discussion (i.e. the task of comparing and analysing research results and hypotheses – whereby we engage with the experts, away from discussions held through the media) primarily focuses on network infrastructures' electricity consumption, and on the underlying assumptions. We also plan to update our scenarios' results: this undertaking is part of a new research step on the digital system (see the interim report published on 16th January 2020).

- The scientific discussion could proceed along several avenues. On the one hand, the accounting methods for power consumption should be compared. While our macro approach only allows for reasoning on average values (thus forbidding any calculation on a specific player), it allows us to compute both indirect and fixed consumptions from every component of the network infrastructure. On the other hand, there are major discrepancies between the various evaluations of global power consumption, e.g. the consumption of data centres: the IEA's evaluation is significantly lower than those of *The Shift Project*, Greenpeace East-Asia, GreenIT and Borderstep Institute. If we are to make collective progress, we need to compare and confront both methodologies and results.
- Assumptions other than network infrastructure consumption have interesting, though much less decisive effects.

3/ After correction of the bitrate, our model yields 0.400 kgCO$_2$e per hour. This represents only 10% of the discrepancy noted by G. Kamiya, i.e. 4 to 7 times his own estimates. In order to properly assess these deviations, we must confront them with the uncertainties of his own modelling: his results vary by a factor of 2 between average estimates, and up to a factor of 32 between outlying values. One ought to bear in mind these intrinsic uncertainty ranges in order to correctly interpret the discrepancies observed between the figures produced by various sources (IEA, *The Shift Project*, Greenpeace East-Asia, GreenIT, etc.).

- The intrinsic sensitivity of G. Kamiya's modelling leads to uncertainties and ranges of values that span factors of 2 to 32: there is a factor of 2 between the *lowest figure in the average range* given by G. Kamiya (0.12 kWh or 56 gCO2e per hour of video) and the *highest figure in the average range* (0.24 kWh or 114 gCO2e per hour); there is also a factor of 32 between the figure for the *lowest consumption extreme scenario* modelled by G. Kamiya (SD video watched on smartphone via Wi-Fi – 0.037 kWh per hour) and his *highest consumption extreme scenario* (4K video watched on smartphone via 4G network – 1.199 kWh per hour).
- **These uncertainties are fully consistent with those typically occurring when modelling the power consumption of digital systems**, with the choice of assumptions and parameters having a very significant impact on the final result.
- After correction, our data still diverge significantly from G. Kamiya's results (by a factor of 4 to 7), but they are very close to the figure from the first scientific paper cited in the CarbonBrief paper (*Shehabi, A., et al. (2014). The energy and greenhouse-gas implications of internet video streaming in the United States*). Three factors account for the discrepancy between G. Kamiya's assessment and the results proposed by Shehabi A. *et al.*, the latter converging with our corrected result:
    - There are significant year-to-year technology-induced energy efficiency gains in data transmission, particularly in network infrastructures and data centres;
    - Some IEA estimates of the global energy consumption of digital systems are lower than those of other studies (including data centre power consumption, as detailed later in this paper);
    - The improving energy efficiency of data transmission processes (i.e. the decreasing energy consumption associated with the transfer of one minute of video) tends to be offset by a competing dynamic of rapid increase in average bitrates and volumes of video content, with the spread of high- and very high-definition (which tends to increase the energy consumption of transferring one minute of video).

4/ In the last part of his article, G. Kamiya expresses concern about the dramatic increase in video usage as well as the soaring energy consumption it involves (he highlights the evolution of Netflix's power consumption, which supposedly increased by 84% between 2018 and 2019). Despite the divergences between our modelling methods, we do agree with his macro results and with the need to closely control the dynamics of our digital system. The bulk of the issue remains indeed the yet unbridled pace of growth of the digital system, which absorbs all the efficiency gains due to technological progress. G.Kamiya concludes: *"What is indisputable is the need to keep a close eye on the explosive growth of […] digital technologies and services to ensure society is receiving maximum benefits, while minimising the negative consequences – including on electricity use and carbon emissions."*

An indeed, by disregarding the constraints of our finite world as we design and choose our digital practices, we run the risk that these constraints will apply randomly: this was the conclusion of our 2019 report "Climate, the unsustainable use of video". Exogenous crises, whether climate- or energy-induced, will challenge the resilience of all our systems, including the digital system – health crises too, as we have been experiencing globally the consequences of the COVID-19 for several months. In the 21st century, it would therefore be a major mistake to disregard the need for an appropriate management of our digital system.

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Commentary on G. Kamiya's article on CarbonBrief by *The Shift Project*.

(https://www.carbonbrief.org/factcheck-what-is-the-carbon-footprint-of-streaming-video-on-netflix)

Each grey box such as this one responds to the paragraph(s) above.

Each of the three colours used for the text corresponds to a category of comments:

- in **blue**, comments relating to the issue of energy **consumption of network infrastructure**;
- in **purple**, comments relating to the issue of **bitrate**;
- in **black**, comments of a more general nature or relating to **other** specific issues.

Factcheck: What is the carbon footprint of streaming video on Netflix?

Guest post on CarbonBrief – Factchecks, by: George Kamiya, digital/energy analyst at the International Energy Agency in Paris.

Published: 25.02.2020 | 1:08pm

The use of streaming video is growing exponentially around the world. These services are associated with energy use and carbon emissions from devices, network infrastructure and data centres.

Yet, contrary to a slew of recent misleading media coverage, the climate impacts of streaming video remain relatively modest, particularly compared to other activities and sectors.

Drawing on analysis at the International Energy Agency (IEA) and other credible sources, we expose the flawed assumptions in one widely reported estimate of the emissions from watching 30 minutes of Netflix. These exaggerate the actual climate impact by 30- to 60-times.

The Shift Project: The figures provided by *The Shift Project* were never intended to assess the emissions of a specific single player, but rather to shed light on the nexus between our digital practices and the infrastructure that supports them, within the digital system. Our approach is macroscopic: it involves *averaged* assumptions that describe the average mechanisms of online video, but are in fact not suitable to rigorously describe a case in particular (e.g. Netflix). While we hadn't expected that our figures could be used this way, we have to face the facts: they have been widely picked up to describe particular uses of video streaming, in the case of the CarbonBrief article, streaming uses on one specific platform: Netflix.

Specifically, contrary to the shorthand made in some of the media coverage that followed, our estimate given in the interview* did not refer to the specific case of Netflix, but to a supposed average 30 minutes of video streaming, regardless of the platform or type of streaming use, i.e. to an average of all streaming uses combined. It should therefore be interpreted with all the precautions required when dealing with *average values*.

** The initial interview was conducted by AFP, and broadcasted in particular by France 24: https://www.france24.com/en/20191028-chill-your-netflix-habit-climate-experts-say*

The relatively low climate impact of streaming video today is thanks to rapid improvements in the energy efficiency of data centres, networks and devices. But slowing efficiency gains, rebound effects and new demands from emerging technologies, including artificial intelligence (AI) and blockchain, raise increasing concerns about the overall environmental impacts of the sector over the coming decades.

The Shift Project: The distinction between unit impact and aggregate impact is crucial: while it can be said that streaming one video has a relatively low impact, this does not imply that the aggregate impact of streaming video as a whole is low. Video consumption in the world is indeed massive (today, video accounts for nearly 80% of global data traffic) and has been increasing for several years along very strong dynamics, and its impact is in fact growing (increase in video quality, screen size, extension of video support to new uses and domains such as music, email, print media sites, radio, etc.).

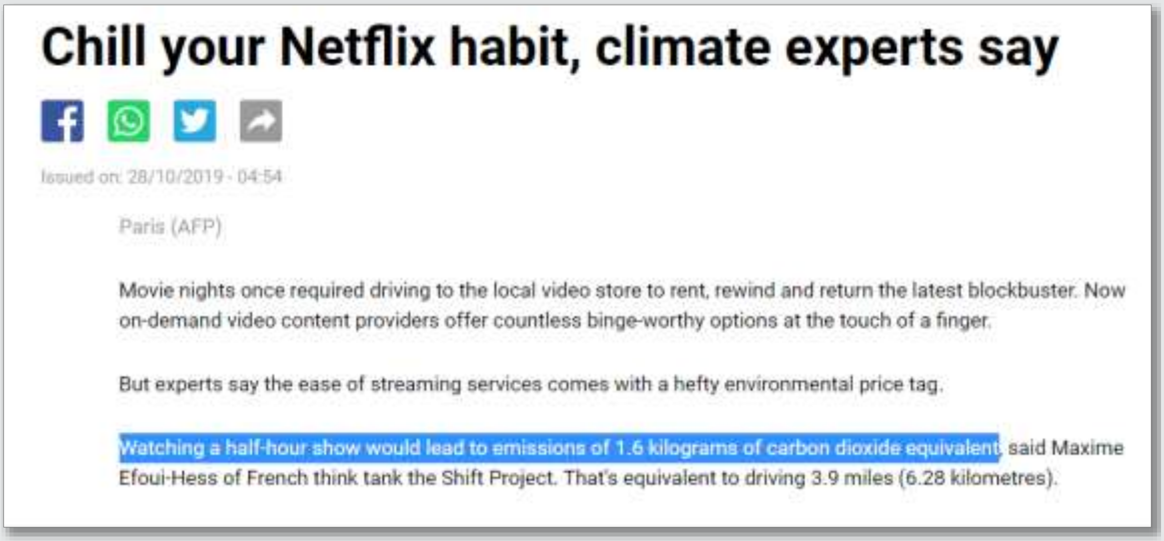
Misleading media

A number of recent media articles, including in the New York Post, CBC, Yahoo, DW, Gizmodo, Phys.org and BigThink, have repeated a claim that "the emissions generated by watching 30 minutes of Netflix [1.6 kg of CO2] is the same as driving almost 4 miles".

The figures come from a July 2019 report by the Shift Project, a French thinktank, on the "unsustainable and growing impact" of online video. The report said streaming was responsible for more than 300m tonnes of CO2 (MtCO2) in 2018, equivalent to emissions from France.

The Shift Project: In fact, one of "the figures" (1.6 kgCO_2e for 30 minutes of video) stems from an interview, not from a *Shift Project* publication.

During this interview, at the request of the journalist who asked about the energy consumption of 30 minutes of video, a *Shift Project* collaborator figured out mentally in a snap what would be the average power consumption of viewing 30 minutes of online video, using the Excel spreadsheet in front of him. However, the model is not designed to answer this type of question (it was conceived to assess macroscopic dynamics, on average, and is not applicable to any specific use); it is at this point that the bitrate error (a conversion error from bits to bytes, corresponding to a division by 8 of the bitrate) included in the spreadsheet caused an error on the result for the 30 minutes of video.



Chill your Netflix habit, climate experts say

Issued on: 28/10/2019 - 04:54

Paris (AFP)

Movie nights once required driving to the local video store to rent, rewind and return the latest blockbuster. Now on-demand video content providers offer countless binge-worthy options at the touch of a finger.

But experts say the ease of streaming services comes with a hefty environmental price tag.

Watching a half-hour show would lead to emissions of 1.6 kilograms of carbon dioxide equivalent, said Maxime Efoui-Hess of French think tank the Shift Project. That's equivalent to driving 3.9 miles (6.28 kilometres).

Article from France 24 including the figure on the online video on average and whose title may have misled both other media and G. Kamiya as to the scope of the figure: misleading indeed.

This figure, "impact of 30 minutes of video", was calculated and mentioned only during the interview; it is not related to the data published in our reports, which rely on a different calculation method. On the other hand, the other figures that were quoted in the press are actually taken from the two *Shift Project* reports of 2018 and 2019 and from the corresponding Excel spreadsheets, all available online.

The Shift Project's report continues to influence media coverage, including articles published earlier this month by the Guardian and Thomson Reuters Foundation.

The Shift Project's "3.2kgCO2 per hour" estimate is around eight times higher than a 2014 peer-reviewed study on the energy and emissions impacts of streaming video.

That 2014 study found streaming in the US in 2011 emitted 0.42kgCO2e per hour on a lifecycle basis, including "embodied" emissions from manufacture and disposal of infrastructure and devices. Emissions from operations – comparable in scope to the Shift Project analysis – accounted for only 0.36kgCO2e per hour.

The Shift Project (concerning the bitrate): Correcting the bitrate error (bit-to-byte conversion error, i.e. a division by a factor of 8), our "1byte" model, used for our calculations and available online, yields an impact of 0.40 kgCO_2e per hour of video viewed, which is consistent with this first paper cited by G. Kamiya (*Shehabi, A., et al. (2014). The energy and greenhouse-gas implications of internet video streaming in the United States.*).

The convergence between the two figures reveals that the order of magnitude of the result that our model calculated (i.e. after correction of the bitrate error) is consistent. However, their interpretation still warrants a certain amount of caution: our model is nonetheless not fit for the type of calculation necessary to accurately assess the emissions of a Netflix video (that is, to evaluate the impact of one single use in particular). Moreover, as the article by *Shehabi, A. et al.* dates back to 2014, the validity of this comparison must be reviewed in the light of two opposing trends: the sharp energy efficiency gains allowed by the recent technological advances in data transmission, and the very substantial increase in the average file size of videos, with the spread of high-definition content (HD and UHD).

Because the energy efficiency of data centres and networks is improving rapidly – doubling every couple of years – energy use and emissions today will be even lower.

The Shift Project (concerning networks' energy consumption): The energy efficiency of servers has been improving over the years, so the amount of energy spent to transmit 1 GB is indeed decreasing. However, the estimates for energy consumption published in our 2018 report (Lean ICT, 2018) and the sources it cites suggest two caveats:

- The total energy efficiency of data transmission is increasing by 10 to 15% per year. However, at this point, we should consider that the improvements made on new servers in a data centre do not apply to existing servers (the lifespan of a server is 4 to 5 years).

- With the abrupt increase in the size of videos with each resolution shift (SD to HD, 4K, 8K etc.), the efficiency gain per GB does not directly involve an improvement per hour of video (the file size for a one hour high-resolution video is larger than for a one hour low-resolution video).

Looking at electricity consumption alone, the Shift Project figures imply that one hour of Netflix consumes 6.1 kilowatt hours (kWh) of electricity. This is enough to drive a Tesla Model S more than 30km, power an LED lightbulb constantly for a month, or boil a kettle once a day for nearly three months.

The Shift Project (concerning bitrate): After correction of the bitrate (bit-to-byte conversion error, i.e. a division by 8 of the bitrate), our model indicates 0.77 kWh per hour of video. However, we mention this figure merely on an indicative basis, so as to help understand the importance of the bitrate error in this result, as our model is not designed for this type of calculation (measuring the impact of an individual action). The bitrate error does have a strong impact on the result "power consumption associated with 30 minutes of online video", but it remains trivial with regard to the macro results published in our reports (only 1% error on the total impact of online video). This error has a minimal impact on our macro results for the following reasons:

- The bitrate only serves to convert a video duration into an equivalent volume of data, or vice versa, a volume of data into an equivalent video duration;

- Device power consumption (consumption linked to the length of time the devices run for viewing) is negligible compared to the consumption resulting from network infrastructures (consumption linked to the amount of data that the video represents);

- To compute the result for the "power consumption associated with 30 minutes of online video", as the *Shift* collaborator did upon request by AFP, the duration of the video is converted into a volume of data using the bitrate. Thus, an error on the bitrate induces a significant error on the corresponding volume of data and consequently a significant error (by a factor of 8) on the main consumption category, that of the networks.

- By contrast, for the macro calculations in our reports, we start with the volume of data (taken from Cisco and Sandvine data), and our assumption only serves to convert this volume into viewing time, in order to calculate the device consumption. Thus an error on the bitrate affects only the consumption of the devices, which is trivial (about 1%) at the macro level.

With users collectively watching at least 165m hours per day, the Shift Project figures imply that Netflix streaming consumes around 370 terawatt hours (TWh) per year, which would be comfortably more than the annual electricity demand of the UK.

The Shift Project (concerning bitrate): The 370 TWh result is definitely strongly inconsistent, but it is derived from the extension of a number per unit that is wrong in two respects:

- The figure is impacted by the bitrate error (bit-to-byte conversion error, corresponding to a factor of 8 and involving a major error on the "power consumption for 30 minutes of online video" figure ; however, it affects only marginally – 1% error – our macroscopic results concerning online video in total worldwide, as published in our reports);

- Our model was not designed to perform calculations for any specific individual action or for single players like Netflix, but only for "averaged", macro approaches.

  The figures given by the *Shift* were never intended to assess the consumption of a single specific player, but rather to shed light on the nexus between our digital practices and the infrastructure that supports them, within the digital system. Our approach is macroscopic and therefore involves assumptions that describe the situation "on average", but are in fact unsuitable to rigorously describe a case in particular (e.g. Netflix). While we hadn't expected that our figures could be used this way, we have to face the facts: they have been widely cited to describe particular uses of video streaming, in this case, in the CarbonBrief article, the streaming practices on one specific platform, Netflix.

  Specifically, contrary to the shorthand made in some of the media coverage that followed, our estimate given in the interview did not refer to the specific case of Netflix, but to 30 minutes of video streaming, regardless of the platform or type of streaming use, i.e. to an average of all streaming uses combined. It should therefore be interpreted with all the precautions required when dealing with *average* values.

For comparison, these figures are 800-times larger than figures reported by Netflix (0.45TWh in 2019) and nearly double the estimated electricity use by all data centres globally (198TWh in 2018). It is clear that the Shift Project figures are too high – but by how much?

The Shift Project (concerning bitrate): As already mentioned, this 370 TWh figure is indeed strongly inconsistent, but results from the extension of a value per unit that is wrong in two respects:

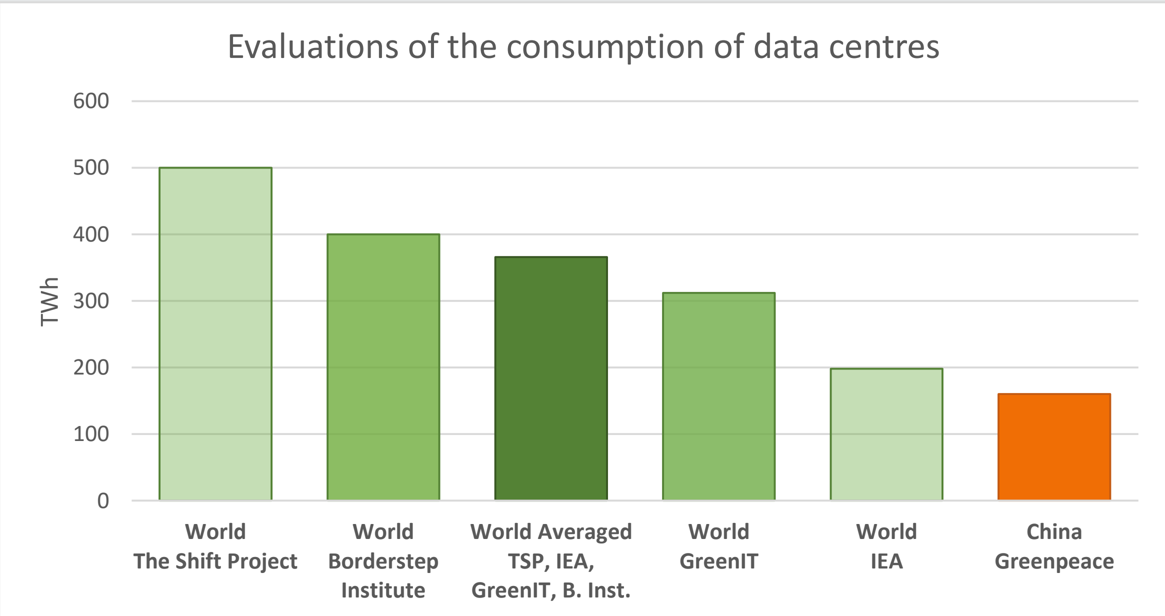
- The figure is impacted by the bitrate error (bit-to-byte conversion error, corresponding to a factor of 8 and involving a major error on the "power consumption for 30 minutes of online video" figure; however, it affects only marginally – 1% error – our macroscopic results concerning online video in total worldwide, as published in our reports). By correcting the bitrate error, the *average* figure given by the *Shift* for 30 minutes of video would only be 100 times higher than the one given by the specific platform Netflix;

- Our model was not designed to calculate the impact of individual actions in particular or of single players in particular like Netflix, but only for "averaged", macro approaches.

The Shift Project (concerning networks' energy consumption): The IEA estimate for the energy consumption of data centres worldwide in 2018 is 198 TWh, which is lower than other studies:

- The 2019 GreenIT study estimates data centres consumption at about 300 TWh;
- A study by the Borderstep Institute sets it around 400 TWh in 2018 (*Hintemann, R. (2020). Data centers 2018. Efficiency gains are not enough: Data center energy consumption continues to rise significantly. Berlin: Borderstep Institute*);
- Our 2018 report estimates it at around 500 TWh;

- A study based on measurements in China (*Greenpeace East Asia and the North China Electric Power University (2019). Powering the Cloud: How China's Internet Industry Can Shift to Renewable Energy*) mentions 160 TWh for Chinese data centres alone.



Comparisons of data centre consumption estimates in the world, China and Europe in 2018, according to several studies. Sources: The Shift Project, IEA, GreenIT.fr, Greenpeace East Asia, Borderstep Institute.

The comparison of these studies suggests that the IEA data likely underestimates the consumption of data centres globally. The large discrepancies between the various estimates call for a comparison of the modelling approaches, extrapolations and measurements. This is what we are currently undertaking with the update of our results (interim report published in January 2020).

Flawed assumptions

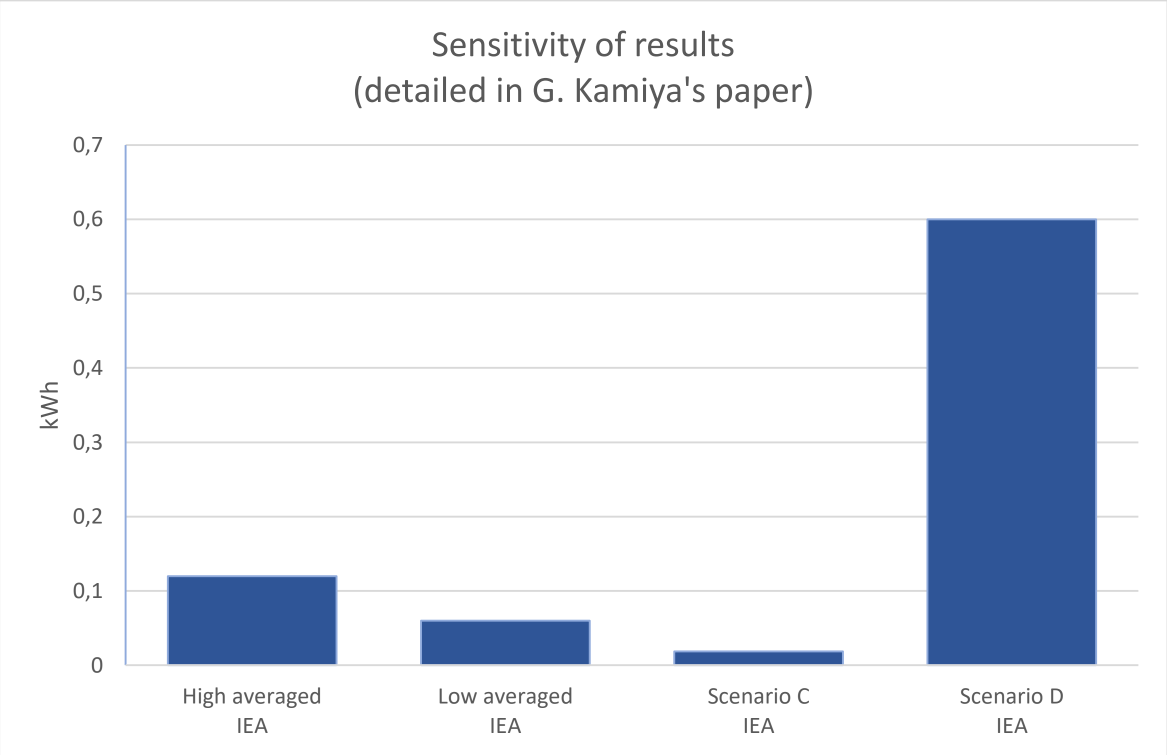
The assumptions behind the Shift Project analysis (largely based on a 2015 paper) contain a series of flaws, which, taken together, seriously exaggerate the electricity consumed by streaming video.

The Shift Project (concerning networks' energy consumption): in order to correctly interpret the discrepancies between the data from various sources (IEA, *The Shift Project*, Greenpeace East-Asia, GreenIT, etc.), it is essential to keep in mind the margins of uncertainty inherent to Kamiya's own work.

- There is a factor of 2 between the *lowest* (0.12 kWh or 28 gCO_2e per hour of video) and *highest* figures (0.24 kWh or 57 gCO_2e per hour) of the *average* range given by G. Kamiya;

- In Kamiya's model, we also find a factor of 32 between the data for his *lowest* consumption *extreme* scenario (SD video watched on smartphone via Wifi – 0.037 kWh per hour) and his *highest* consumption *extreme* scenario (4K video watched on smartphone via the 4G network – 1.199 kWh per hour).

The intrinsic sensitivity of G. Kamiya's modelling leads to uncertainties and ranges of values that span factors of 2 to 32. These – as explicitly detailed by G. Kamiya in his paper – are due to the high sensitivity of this type of results to the assumptions and parameters chosen (devices, resolution, type of network, etc.). This is fully consistent with the uncertainties observed when modelling the power consumption of digital systems, and is indicative of the extent of the uncertainties inherent to any modelling.



Charting of the uncertainties observed by G. Kamiya during his modelling. There is a factor 2 difference between the mean estimates (« Low averaged IEA » et « High averaged IEA »), and a factor 32 between the extreme estimates (« Scenario C IEA » and « Scenario D IEA) Source: IEA, analyses presented in the CarbonBrief article, values for 30 minutes viewing.

First, it overestimates bitrate, the amount of data transferred each second during streaming, apparently assuming a figure of 24 megabits per second (Mbps), equivalent to 10.8 gigabytes (GB) per hour. This is six times higher than the global average bitrate for Netflix in 2019 (around 4.1 Mbps or 1.9 GB/hr, excluding cellular networks) and more than triple the transfer rate of high-definition (HD, 3 GB/hr). Other typical transfer rates are 7 GB/hr for ultra-high definition (UHD/4K) and 0.7 GB/hr for standard definition (SD).

The Shift Project: On the basis of our 3 Mbps assumption (average for online video in general), but after correcting the bit/byte error (bit-to-byte conversion error), we obtain: 1.4 GB/hr, a result that is consistent with the figures provided by G. Kamiya.

(In part, this difference stems from a stated assumption of 3Mbps apparently being converted in error to 3 megabytes per second, MBps, with each byte equivalent to eight bits.)

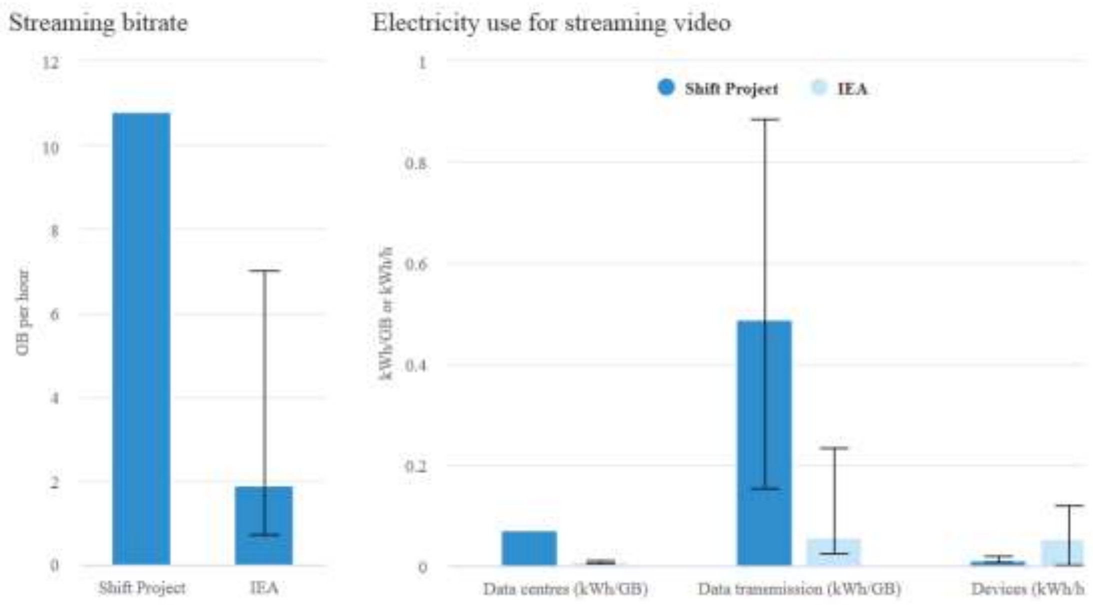
The Shift Project (on the bitrate): The mistake was made when designing the model, which was elaborated for *The Shift Project* report on the impact of video (2019). Of course, this macroscopic model had been subject to sensitivity tests (i.e. tests that check the impact of each assumption on the final results). However, these tests did not reveal the bit/byte error, because it only impacts the contribution of the devices in the macroscopic model, which is negligible overall (1% error on the macro results). This explains why it has initially gone unnoticed in the calculation tool.

While the bitrate error strongly affects the "power consumption associated with 30 minutes of online video", it remains negligible on the macroscopic results published in our reports (only 1% error on the total impact of online video). This is explained by the following factors:

- The bitrate only serves to convert a video duration into the equivalent volume of data, or vice versa, a volume of data into an equivalent video duration;
- The power consumption of devices (consumption linked to the length of time the devices run for viewing) is negligible compared to the consumption resulting from network infrastructures (consumption linked to the amount of data that the video represents);
- To compute the result for the "power consumption associated with 30 minutes of online video", as the *Shift* collaborator did upon request by the AFP, the duration of the video is converted into a volume of data using the bitrate. Thus, an error on the bitrate induces a significant error on the corresponding volume of data and consequently a significant error (by a factor of 8) on the main consumption category, that of the networks.
- By contrast, for the macro calculations in our reports, we start from the volume of data (taken from Cisco and Sandvine data) and our hypothesis only serves to convert this volume into viewing time, in order to calculate the consumption of the devices. Thus an error on the bitrate affects only the consumption of the devices, which is trivial (about 1%) at the macro level.

This error does not impact the overall results published in the 2019 report (not by chance, but because the impact of this assumption is negligible, which is proven by the sensitivity tests). Nevertheless, the error has had consequences: the online spreadsheet was used by a *Shift Project* employee to mentally perform a quick calculation during an interview, in response to a question for which the model is in fact inadequate (the model is not intended to precisely compute any single action in particular), leading to a major error in the AFP brief cited later on by various media; the error was spotted by G. Kamiya, who quite rightly pointed it out in his article on CarbonBrief; this gave him the opportunity to investigate further the assumptions suggested by *The Shift Project*. These consequences confirm the fact that our model is suitable for a macro approach ("total impact of online video in the world") but not for the computation of single individual actions ("impact of a 30-minute online video").

The chart below shows each of three ways that the Shift Project overestimated electricity use for streaming video – such as the bitrate – and one area where it underestimated the actual figure. These other errors are described in the text below the chart.



Estimates of data and electricity use for streaming video from the Shift Project and this analysis. Left chart: bitrate, in GB per hour. Right chart: electricity use in data centres (kWh/GB), data transmission networks (kWh/GB) and devices used for viewing (kWh per viewing hour). Source: the Shift Project and IEA analysis. Chart by Carbon Brief using Highcharts.

Second, I estimate that the Shift Project analysis overestimates the energy intensity of data centres and content delivery networks (CDN) that serve streaming video to consumers by 7- to 18-fold, relative to figures derived from 2019 Netflix electricity consumption data, Cisco traffic data and IEA analysis.

The Shift Project (on the energy consumption of networks): The difference between estimates on the data centres consumption accounts for only about 10% of the discrepancies between the figures proposed by the *Shift* and G. Kamiya.

- Our figures represent a global average for data centres in general, and were never intended to be applied to a single specific case. This is especially true for Netflix, which relies on its own, strongly optimized infrastructure.
- We do not know at this stage what figures the article alludes to when it mentions their incompatibility with Cisco and IEA data. A discussion with G. Kamiya is needed to clarify this point.

Third, my analysis shows the Shift Project overestimates the energy intensity of data transmission networks by 6- to 17-fold. This is the result of high energy-use assumptions for various access modes – for example, 0.9 kWh/GB for "mobile" compared to my estimate of 0.1-0.2 kWh/GB for 4G mobile in 2019. The Shift Project also assumes a higher share of data transfer through more energy-intensive mobile networks compared to WiFi, which it puts at one-third of the total compared to less than 10% based on Netflix data.

The Shift Project (on the energy consumption of networks): our estimate of the consumption of networks (as presented in our 2018 report and the associated calculation tools) is 478 TWh in 2017 (consistent with the GreenIT estimate, 418 TWh in 2018 – the difference between the two being negligible for this order of magnitude, 10^{14} Wh) and the estimate for traffic is approximately 1388 EB in 2017, which yields an average energy efficiency of approximately 0.3 kWh/GB.

- For the mobile network, our figure is approximately 0.8 kWh/GB in 2017, with a strong year-on-year improvement depending on the 4G/3G distribution;

- These figures, (i.e. the power consumption associated with the load on network infrastructure for data transfer), are the most important in comparing our approach with G. Kamiya's: as mentioned above, 90% of the discrepancy stems from this figure (once the bitrate error is corrected). In this instance, we need to have the exact sources of G. Kamiya's estimates in order to understand the differences in assumptions and approach. We are in touch with G. Kamiya to clarify these points;

- Our figures do not overvalue the IEA's estimates for network consumption linked to in G. Kamiya's article: the IEA mentions 172 TWh for the mobile network in 2018, TSP estimates 97 TWh in 2017 in its "Forecast Model" of the 2018 report;

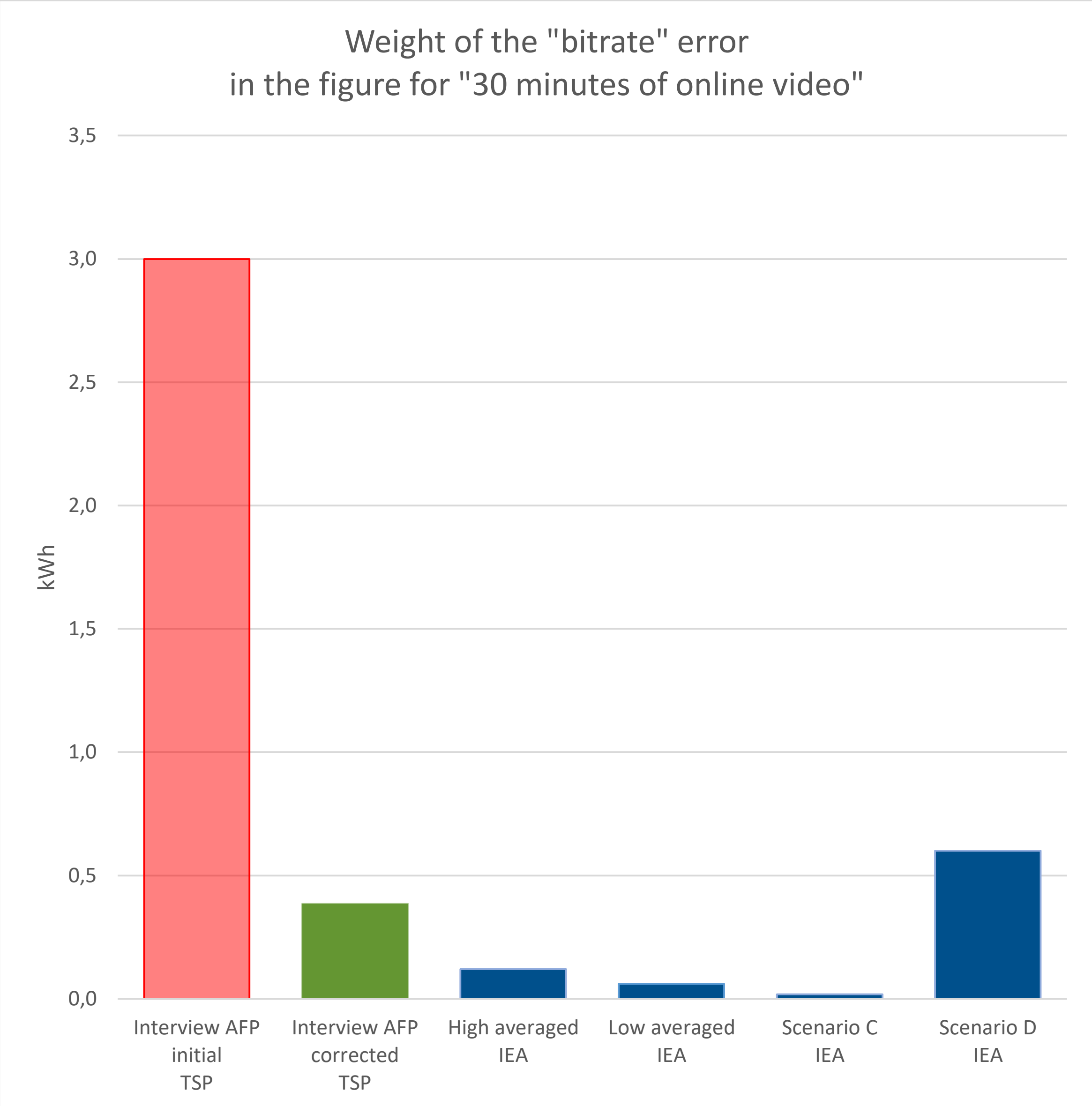
- Our figures are a world average for all networks and were never intended to be applied to a specific case such as Netflix. Thus, the distribution of flows over the different networks for Netflix uses are indeed not taken into account in our calculations.

However, the Shift Project underestimates the energy consumption of devices by some 4- to 7-fold, because it assumes that viewing occurs only on smartphones (50%) and laptops (50%). According to Netflix, 70% of viewing occurs on TVs, which are much more energy-intensive than laptops (15% of viewing), tablets (10%), and smartphones (5%).

The Shift Project (on the energy consumption of networks): As for data centres and networks, our data correspond to a global average for all devices and were never intended to be applied to a specific case such as Netflix. Thus the distribution of flows according to the type of devices for Netflix uses are indeed not taken into account in our calculations.

Taken together, my analysis suggests that streaming a Netflix video in 2019 typically consumed 0.12-0.24kWh of electricity per hour, some 25- to 53-times less than estimated by the Shift Project, as shown in the chart, below left. The results are highly sensitive to the choice of viewing device, type of network connection and resolution, as shown in the chart, below right.

The Shift Project (on the bitrate):

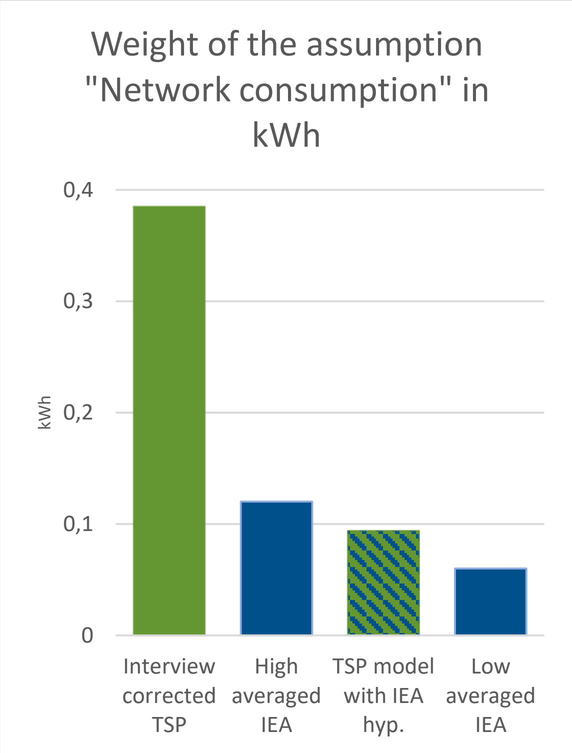


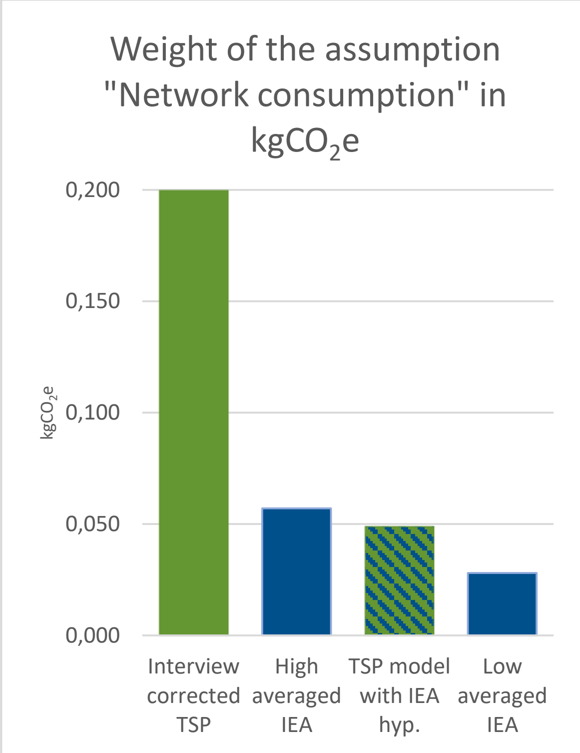
Impact of the bitrate error correction (bit-to-byte conversion error) on the difference between The Shift Project's and G. Kamiya's models. The correction reduces the difference between the two approaches by 90%. "Interview initial TSP": figure taken from the interview with The Shift Project employee (3 kWh or 1.6 kgCO2e per 30 min.). "Interview corrected TSP": figure calculated using The Shift Project model and assumptions, but correcting for the conversion error in the bitrate (0.4 kWh or 200 gCO2e per 30 min.). "High averaged IEA": high value of the average range calculated by G. Kamiya (0.12 kWh or 57 gCO2e per hour). "Scenario C IEA": G. Kamiya's estimate for the 'smartphone, WIFI and low definition' viewing scenario (0.018 kWh per 30 min.). "Scenario D IEA": estimate by G. Kamiya for the viewing scenario 'on smartphone, in 4G and ultra-high definition (4K)' (0.60 kWh per 30 min.).

After correction of the bitrate (bit-to-byte conversion error, corresponding to a division by 8 of the bitrate), our model yields 0.4 kWh per 30 minutes, i.e. 3 to 6 times G. Kamiya's estimates. This is to be compared with the fact that his own estimates vary by a factor of 2 (between averaged values) to 32 (between extreme scenarios) due to the uncertainties in his modelling.

The bitrate error (bit-to-byte conversion error, which amounts to dividing the bitrate by 8) accounts for nearly 90% of the discrepancy noted in the CarbonBrief article.

The Shift Project (on the energy consumption of networks):





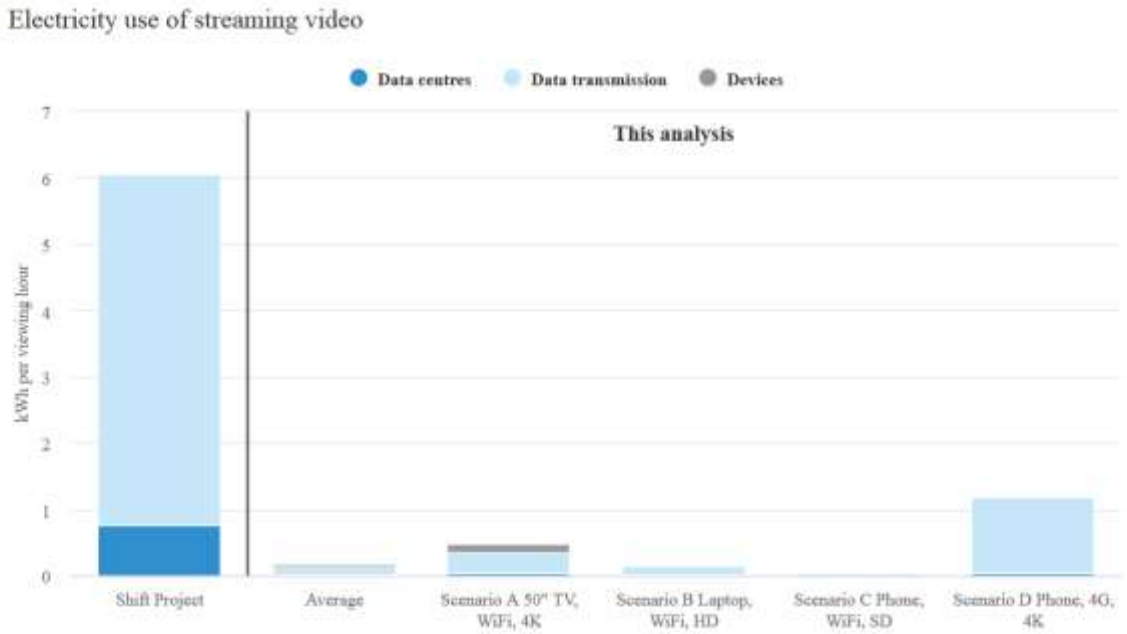
Effect of the bitrate error correction (bit-to-byte conversion error) on the difference between The Shift Project's and G. Kamiya's models. The correction reduces the difference between the two approaches by 90%. "Interview corrected TSP": figure calculated using The Shift Project model and assumptions, but correcting for the conversion error in the bitrate. "High averaged IEA": high value of the averaged range calculated by G. Kamiya. "Low averaged IEA": low estimate of the averaged range calculated by G. Kamiya. " TSP model with IEA hyp.": figure calculated using The Shift Project's model and assumptions, but correcting for the bitrate conversion error and replacing The Shift Project's assumption regarding the network power consumption (0.488 kWh/GB) with G. Kamiya's (0.058 kWh/GB).

The figure for the power consumption of network infrastructures (kWh/byte of data transferred) accounts for 90% to 100% of the remaining differences.

In other words, if we stick to our computation methodology after correcting the bitrate error, simply replacing our figure (0.488 kWh/GB) by that of G. Kamiya (0.058 kWh/GB – see 1st figure of the article) in our modelling yields results that are within the validity interval defined by G. Kamiya:

- 0.094 kWh/30 min (within the IEA range: 0.06 to 0.12 kWh/30 min);
- 0.049 $kgCO_2e$/30 min (within the IEA range: 0.028 to 0.057 $kgCO_2e$/30 min).

This means that the scientific discussion primarily lies within this hypothesis (network infrastructure power consumption, i.e. the number of kWh/byte of data transferred). This is precisely our goal when updating our scenarios' results, as planned in our new research on digital issues, of which an interim report was published last January. The other assumptions have interesting, though much less decisive effects on the final result.



Average electricity use per hour of streaming video (kWh) according to the Shift Project (leftmost bar) and this article's analysis (second left bar). A series of scenarios for viewing device, network connection and video resolution are also shown on the right. Source: the Shift Project and IEA analysis. Chart by Carbon Brief using Highcharts.

For example, a 50-inch LED television consumes much more electricity than a smartphone (100 times) or laptop (5 times). Streaming through 4G mobile networks consumes about four times as much electricity than through WiFi.

The The Shift Project: We fully agree with these qualitative analyses, and this is the focus of our 2018 report:

- The "Référentiel Environnemental du Numérique (REN)" (Environmental Repository of the Digital System), which summarises the evaluations for the consumption of various types of devices.

- The "1byte" model, discussed here, in which we find the same magnitude of difference between WIFI and 4G (the mobile network consuming an estimated six times more than WIFI).

Because phones are extremely energy efficient, data transmission accounts for nearly all the electricity consumption when streaming through 4G, especially at higher resolutions (Scenario D). Streaming an hour-long SD video through a phone on WiFi (Scenario C) uses just 0.037 kWh – 170 times less than the estimate from the Shift Project.

The Shift Project (on the energy consumption of networks): We fully agree with these qualitative analyses, as our models reveal the same predominance of network infrastructure consumption in the total, particularly with regard to the consumption of devices (this massive predominance of "network" consumption over "device" consumption explains why the bitrate error made when translating our model into our computation tool was not revealed by the sensitivity tests, as it has no significant influence – 1% error – on the results of our report).

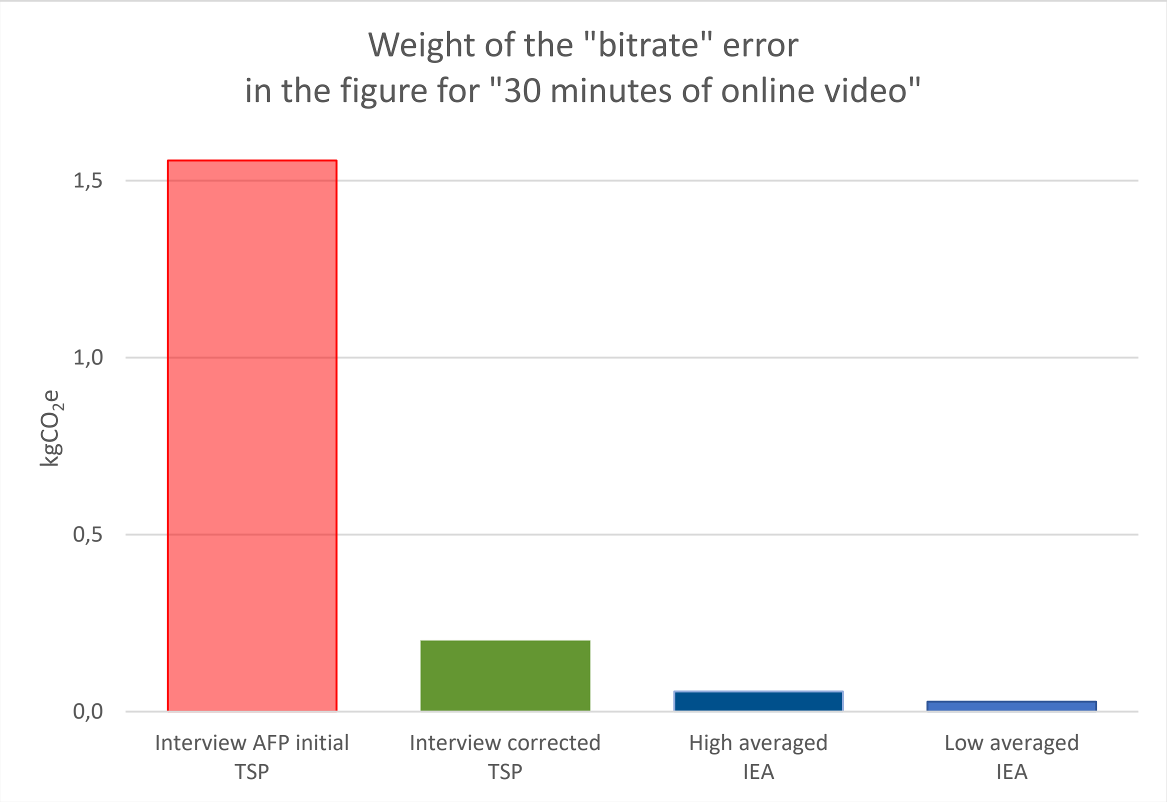
Modest footprint

The carbon footprint of streaming video depends first on the electricity usage, set out above, and then on the CO2 emissions associated with each unit of electricity generation.

As with other electricity end-uses, such as electric vehicles, this means that the overall footprint of streaming video depends most heavily on how the electricity is generated.

Powered by the current global average electricity mix, streaming a 30-minute show on Netflix would release 0.028-0.057kgCO2e (28-57 grammes, second column in the chart, below). This is some 27- to 57-times less than the 1.6kg figure from the Shift Project (leftmost column), which was compared with driving four miles (6.4 kilometres).

The Shift Project (on the bitrate):



Impact of the bitrate error correction (bit-to-byte conversion error) on the difference between The Shift Project's and G. Kamiya's models. The correction reduces the difference between the two approaches by 90%. "Uncorrected TSP": figure taken from the interview with The Shift Project employee. "Corrected TSP": figure calculated using The Shift Project model and assumptions, but correcting for the conversion error in the bitrate. "High averaged IEA": high value of the averaged range calculated by G. Kamiya. "Low averaged IEA": low estimate of the averaged range calculated by G. Kamiya.

After correction of the bitrate (bit-to-byte conversion error, corresponding to a division by 8 of the bitrate), our model yields 0.4 kgCO_2e per hour, i.e. 4 to 7 times G. Kamiya's estimates. This is to be compared with the fact that his own estimates vary by a factor of 2 (between averaged values) to 32 (between extreme scenarios) due to the uncertainties in his modelling.

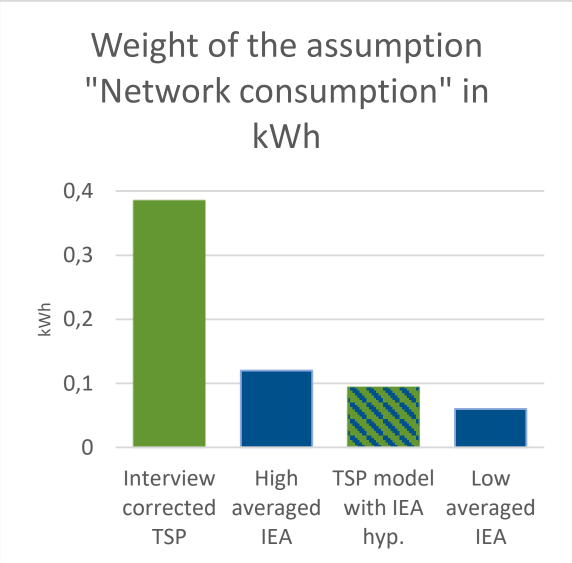
The bitrate error (bit-to-byte conversion error, which amounts to dividing the bitrate by 8) accounts for nearly 90% of the discrepancy noted in the CarbonBrief article:

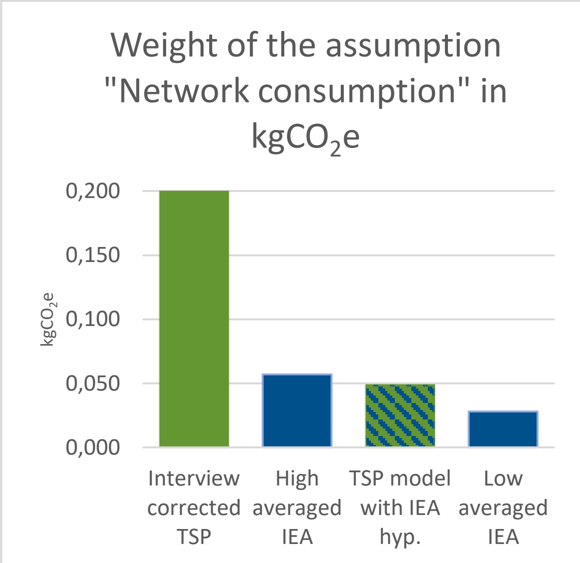
- The discrepancy between the emissions calculated by G. Kamiya for a 30-minute video and the emissions figure from the interview with The Shift Project contributor (including the bitrate error) is 1.500 to 1.529 kgCO_2e;
- Once the bitrate error is corrected, the difference between the two calculations is only 0.143 to 0.172 kgCO_2e.

This bitrate error is therefore the main cause of discrepancy between the results obtained by G. Kamiya and by *The Shift Project*. This is because this error strongly impacts the "power consumption associated with 30 minutes of online video", but remains negligible at the macro level on the results published in our reports (only 1% error on the total impact of online video). This is explained by the following factors:

- The bitrate only serves to convert a video duration into the equivalent volume of data, or vice versa, a volume of data into an equivalent video duration;
- The power consumption of devices (consumption linked to the length of time the devices run for viewing) is negligible compared to the consumption resulting from network infrastructures (consumption linked to the amount of data that the video represents);
- To calculate the figure for the "power consumption associated with 30 minutes of online video", as the *Shift* collaborator did upon request by AFP, the duration of the video is converted into an equivalent volume of data using the bitrate. Thus, an error on the bitrate induces a significant error on the corresponding volume of data and consequently a significant error (by a factor of 8) on the main consumption, that of the networks.

By contrast, for the macro calculations in our reports, we start from the volume of data (taken from Cisco and Sandvine data) and our hypothesis only serves to convert this volume into viewing time, in order to compute the consumption of the devices. Thus an error on the bitrate affects only the consumption of the devices, which is trivial (about 1%) at the macro level.





Impact of the bitrate error correction (bit-to-byte conversion error) on the difference between The Shift Project's and G. Kamiya's models. The correction reduces the difference between the two approaches by 90%. "Interview corrected TSP": figure calculated using The Shift Project *model and assumptions, but correcting for the conversion error in the bitrate. "High averaged IEA": high value of the averaged range calculated by G. Kamiya. "Low averaged IEA": low estimate of the averaged range calculated by G. Kamiya. "TSP model with IEA hyp.": figure calculated using The Shift Project's model and assumptions, but correcting for the bitrate conversion error and replacing The Shift Project's assumption regarding the network power consumption (0.488 kWh/GB) with G. Kamiya's (0.058 kWh/GB).*

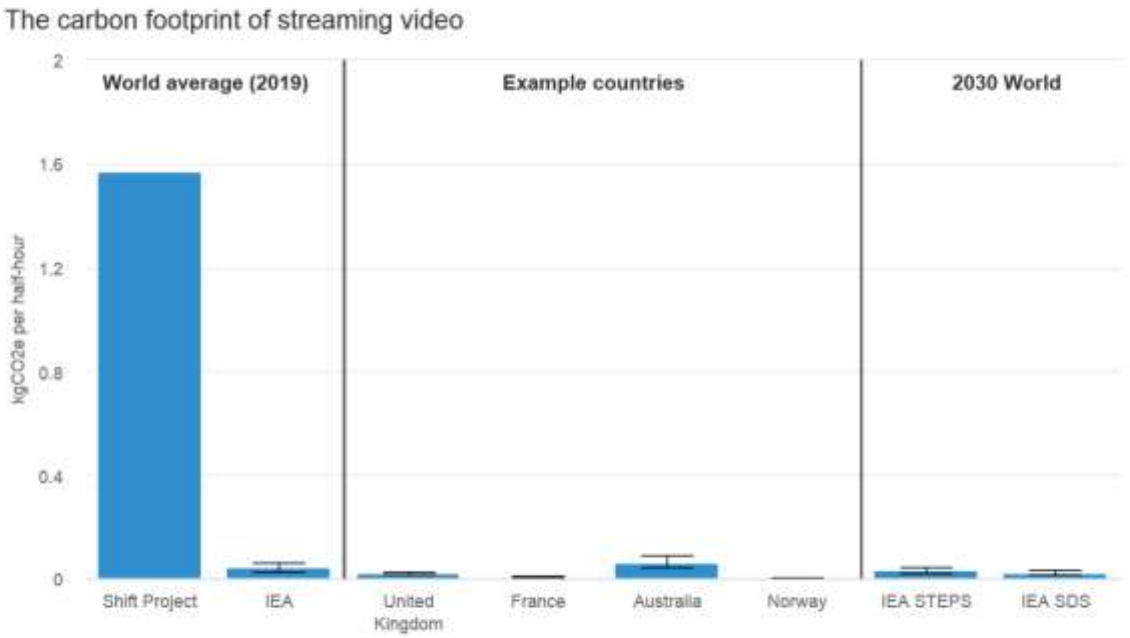
The figure corresponding to the power consumption of network infrastructures (kWh/byte of data transferred) accounts for 90% to 100% of the remaining differences.

In other words, if we stick to our computation methodology after correcting the bitrate error, simply replacing our figure (0.488 kWh/GB) by that of G. Kamiya (0.058 kWh/GB – see 1st figure of the article) in our modelling yields results that are within the validity interval defined by G. Kamiya:

- 0.094 kWh/30 min (within the IEA range: 0.06 to 0.12 kWh/30 min)
- 0.049 kgCO2e/30 min (within the IEA range: 0.028 to 0.057 kgCO2e/30 min)

This means that the scientific discussion deals primarily with this hypothesis (power consumption of the network infrastructure, i.e. the number of kWh/byte of data transferred). And this is exactly the goal of the updating of our scenarios' results, as planned recently in our new research on digital issues, and published in January in the interim report. The other assumptions have interesting, though much less decisive effects on the final result.

G. Kamiya's results were obtained using a global mix of 467 to 474 gCO_2e/kWh, which is an updated version of the IEA figures we also used for our calculation, which are therefore in agreement: 519 gCO2e/kWh – the differences between these three values are indeed small enough to be insignificant, given the uncertainties on the assessments of power generation carbon intensities, depending on electricity mixes.



Global average carbon emissions per half-hour of streaming video (kgCO2e) according to the Shift Project (leftmost bar) and this article's analysis (second left bar). A series of scenarios for country-level electricity systems and future global pathways are also shown on the right. Source: the Shift Project and IEA analysis. Chart by Carbon Brief using Highcharts.

To put it in context, my updated estimate for the average carbon footprint of a half-hour Netflix show is equivalent to driving around 200 metres in a conventional car.

The Shift Project (on the bitrate): After correction of the bitrate (bit-to-byte conversion error), our model yields 0.200 $kgCO_2e$ per 30 minutes of video. With an emission factor of about 200 gCO_2e/km (consistent with the factor chosen by G. Kamiya, probably between 140 and 285 gCO_2e/km), we obtain an equivalence of about 1 km by car, i.e. 5 times G. Kamiya's estimate.

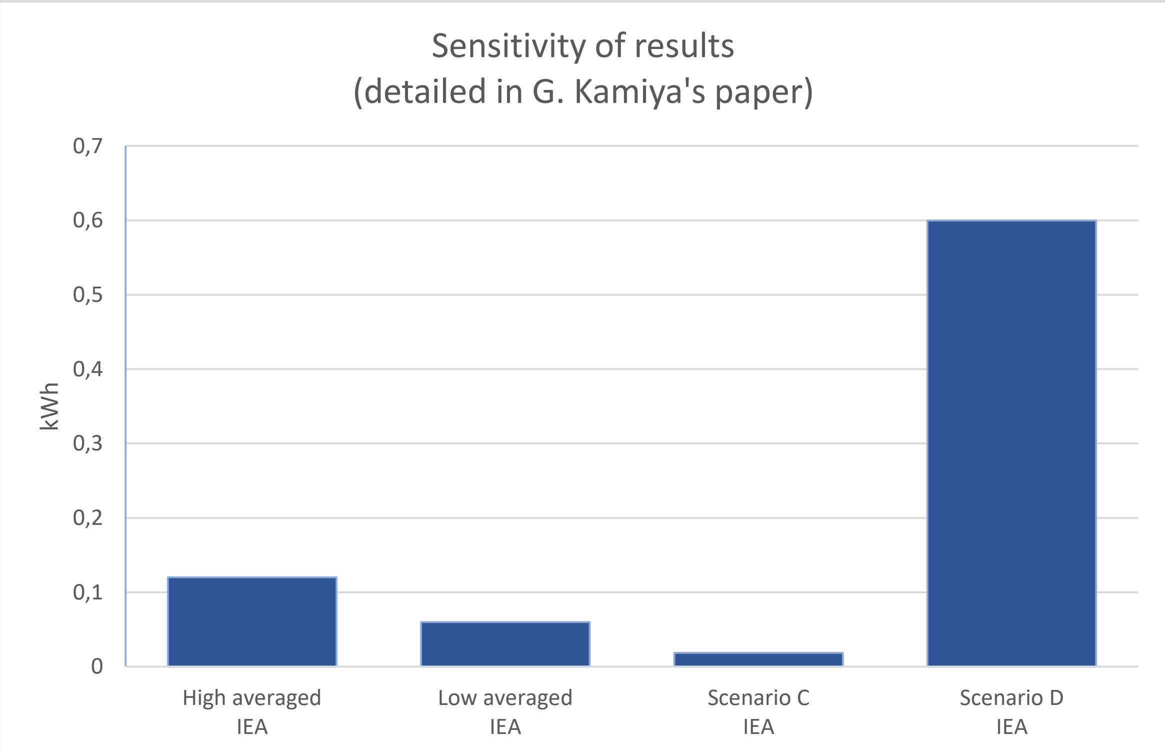
This discrepancy is to be compared with the variations between G. Kamiya's own estimates, which vary from a factor 2 (between averaged values) to 32 (between extreme scenarios), due to the intrinsic uncertainties in his modelling (this is fully consistent with the uncertainties observed when modelling the power consumption of digital systems). One also ought to bear in mind that our model is not designed to measure the impacts related to particular actions, but to perform macroscopic assessments for which average assumptions make sense.

The Shift Project (concerning networks' energy consumption): in order to correctly interpret the discrepancies between the data from various sources (IEA, *The Shift Project*, Greenpeace East-Asia, GreenIT, etc.), it is essential to keep in mind the margins of uncertainty inherent to Kamiya's own work.

- There is a factor of 2 between the lowest (0.12 kWh or 28 gCO_2e per hour of video) and highest figures (0.24 kWh or 57 gCO_2e per hour) of the *average* range given by G. Kamiya;

- In Kamiya's model, we also find a factor of 32 between the data for his *lowest* consumption extreme scenario (SD video watched on smartphone via Wifi – 0.037 kWh per hour) and his *highest* consumption extreme scenario (4K video watched on smartphone via the 4G network – 1.199 kWh per hour).

The intrinsic sensitivity of G. Kamiya's modelling leads to uncertainties and ranges of values that span factors of 2 to 32. These – as explicitly detailed by G. Kamiya in his paper – are due to the high sensitivity of this type of results to the assumptions and parameters chosen (devices, resolution, type of network, etc.). This is fully consistent with the uncertainties observed when modelling the power consumption of digital systems, and is indicative of the extent of the uncertainties inherent to any modelling.



Charting of the uncertainties observed by G. Kamiya during his modelling. There is a factor 2 difference between the mean estimates (« High averaged IEA » and « Low averaged IEA »), and a factor 32 between the extreme estimates (« Scenario C IEA » and « Scenario D IEA ») Sources: IEA, analyses presented in the CarbonBrief article, values for 30 minutes viewing.

But as the chart above shows, this figure depends heavily on the generation mix of the country in question. In France, where around 90% of electricity comes from low-carbon sources, the emissions would be around 4gCO2e, equivalent to 20 metres of driving.

Using country average emission factors may still overestimate emissions, particularly from data centres. Technology firms operating large data centres are leaders in corporate procurement of clean energy, accounting for about half of renewable power purchase agreements in recent years.

The Shift Project: Once again, our approach is global and averaged, and thus does not take into account variables such as data centres' geographical locations. Since it is impossible to define an average data path, as it depends too heavily on the infrastructure that supports the use considered (e.g., Netflix), we chose to centre our approach on a global average, in line with the goal of our modelling: to correctly describe macroscopic dynamics. However, it is not applicable as such to a specific case like the consumption of Netflix content in France.

While data centres increasingly run on renewable energy, this should not preclude a reflexion about the development of practices:

- The purchase of "green" electricity does not mean that the data centres are supplied directly with renewable energy; it simply allows the financing of new sources of renewable generation. However, this has a positive effect on net emissions only if the construction of each low-carbon power plant leads to the decommissioning of one high-carbon power plant.

The fast and massive extension of uses leads to the expansion of the underlying physical infrastructures: network infrastructures, data centres, devices, etc. However, for digital equipment, the production phase is often predominant (for example 90% of a smartphone's emissions over its lifetime are related to its production).

The electricity mix is also rapidly decarbonising in many parts of the world. For instance, the emissions intensity of electricity in the UK fell by nearly 60% between 2008 and 2018. Compared to 2018 levels, global emissions intensity of electricity falls by around one-fifth by 2030 in the IEA Stated Policies Scenario and by half in the Sustainable Development Scenario.

The Shift Project: The CarbonBrief and IEA articles mention the future decrease in the carbon intensity of electricity production and uses the scenarios of the World Energy Outlook published by the International Energy Agency to support this assumption.

However, one should bear in mind that, as this is the case with most scenarios, the IEA results must be interpreted with great caution, particularly in view of the limitations associated with the assumptions and underlying models.

As recalled in the conclusions of our report "Energy-Climate Scenarios: Assessment and Instructions for Use" carried out with Afep in 2019, there are many such limitations: the GDP is assumed to be growing, ignoring both the effects of the energy transition and of adaptation to climate change; energy efficiency is assumed to improve at a rate never observed historically (around 3%/year vs. 1%/year between 1980 and today); the rebound effect is not taken into account (or only marginally), although it strongly, or even completely, limits efficiency gains; and finally, the major disruptions (political, societal, environmental) that will inevitably affect our future are not taken into account.

While it is more crucial than ever to reduce the carbon intensity of electricity production, tremendous efforts still lay ahead. This is why, among other reasons, we stick to fairly conservative assumptions.

Digital efficiency

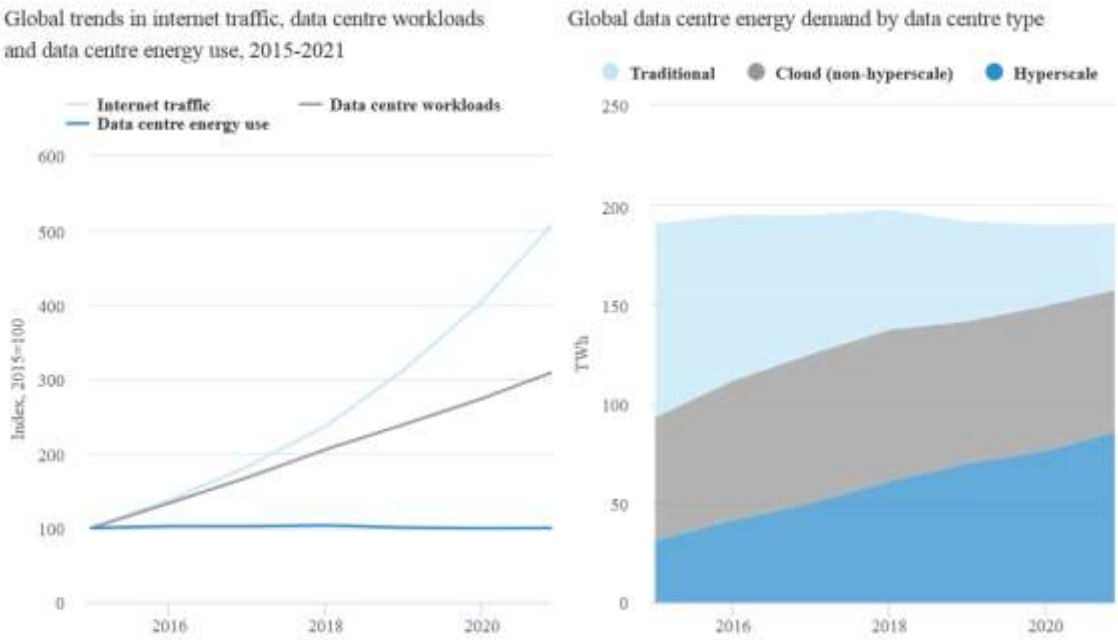
Although the carbon footprint of streaming video remains relatively modest, it might still seem reasonable to expect the overall impact to rise, given exponential increases in usage.

However, there have already been major improvements in the efficiency of computing, described by "Koomey's Law". This law describes trends in the energy efficiency of computing, which has doubled roughly every 1.6 years since the 1940s – and every 2.7 years since 2000. A similar trend has been observed in data transmission networks, with energy intensity halving every two years since 2000.

Coupled with the short lifespans of devices and equipment, which hastens turnover, the efficiency of the overall stock of devices, data centres and networks is improving rapidly.

For example, increasingly efficient IT hardware (following Koomey's Law) and a major shift to "hyperscale" data centres have helped to keep electricity demand flat since 2015 (chart, below right). Data centres worldwide today consume around ~1% of global electricity use, even while internet traffic has tripled since 2015 and data centre "workloads" – a measure of service demand – have more than doubled (chart, below left).

The Shift Project: Energy efficiency gains are likely to plateau; even today, they do not compensate for the increase in digital uses. The energy consumption of the world's digital system (including production and use) is currently increasing by 9% per year.



Left: Trends in internet traffic, data centre "workloads" and data centre energy use, 2015-2021, relative to 2015=100. Right: Global data centre energy demand by data centre type (terawatt hours). Source: IEA. Chart by Carbon Brief using Highcharts.

As well as changes that are invisible to the consumer, there are also obvious trends in the technology seen everyday. Devices are also becoming smaller and more efficient, for example, in shifts from CRT to LCD screens, and from personal computers to tablets and smartphones.

> ***The Shift Project:*** Miniaturisation does not automatically mean a systematic reduction of associated emissions: again, the production phase is dominant, and the trends of equipment downsizing do not result in a linear decrease in embodied energy or emissions.

Rising demand

Set against all this is the fact that consumption of streaming media is growing rapidly. Netflix subscriptions grew 20% last year to 167m, while electricity consumption rose 84%.

Many new video streaming and cloud gaming services have also launched in recent months. Particularly noteworthy is the rapid growth in video traffic over mobile networks, which is growing at 55% per year. Phones and tablets already account for more than 70% of the billion hours of YouTube streamed every day.

The ease of accessing streaming media is leading to a large rebound effect, with overall streaming video consumption rising rapidly. But the complexity of direct and indirect effects of digital services, such as streaming video, e-books, and online shopping, make it immensely challenging to quantify the net environmental impacts, relative to alternative forms of consumption.

> ***The Shift Project***: We fully agree with G. Kamiya's views that the rebound effect plays a major role in the dynamics of our digital systems, and that it is impossible to quantify precisely its effects today at the level of digital practices (substitution effects, competition between uses, direct and indirect rebound effects, etc.).

Moreover, emerging digital technologies, such as machine learning, blockchain, 5G, and virtual reality, are likely to further accelerate demand for data centre and network services. Researchers have started to study the potential energy and emissions impacts of these technologies, including blockchain and machine learning.

It is becoming increasingly likely that efficiency gains of current technologies may be unable to keep pace with this growing data demand. To reduce the risk of rising energy use and emissions, investments in RD&D for efficient next-generation computing and communications technologies are needed, alongside continued efforts to decarbonise the electricity supply.

The Shift Project: We fully agree with G. Kamiya's conclusions on the importance of studying the possible effects of the deployment of new technologies such as 5G, Artificial Intelligence etc. This is one of the focal points of our ongoing work, as published last January in our interim report.

Broader context

Streaming video is a fairly low-emitting activity, especially compared to driving to a cinema, for instance. As consumers, we can further reduce our environmental footprint by streaming at lower resolutions, using smaller devices and screens, as well as connecting through WiFi instead of mobile networks. Replacing devices less often can also help, since production accounts for more than two-thirds of the lifecycle carbon emissions of mobile devices, and electronic waste is a growing problem across the world.

The Shift Project: We fully endorse these recommendations, which are also included in our 2018 report and/or our 2019 report on online video.

Technology companies can continue to play a big role in reducing the environmental impact of streaming, including through further efforts to increase energy efficiency – both in the near-term with new technologies and developing next-generation technologies – and investing in renewable energy to power their data centres and networks.

Sustainable design and coding could also help, such as further improving video compression. A recent study explored the potential energy and emission reductions of shifting YouTube music videos to audio only when playing in the background.

The Shift Project: We fully agree with these recommendations, which are included in our online video publications, such as our "Guide for reducing the weight of videos". However, to achieve net reductions in energy consumption, these efforts to improve compression must be integrated into overall reduction strategies.

It is important to keep in mind the scale of emissions from digital technologies compared to other sectors, with digital technologies accounting for around 1.5% of global carbon emissions.

The Shift Project: According to our previous reports, digital technologies account for nearly 4% of global emissions. This is in line with the study carried out by GreenIT.fr, which evaluates their share at 3.8% of global emissions in 2019.

All sectors and technologies are needed to help achieve the goals of the Paris Agreement and digital technologies are no exception. In fact, digital technologies, such as AI, could help accelerate climate action. But, without sound climate policies, AI could end up just helping to make oil extraction cheaper or extending the lifetime of coal plants.

What is indisputable is the need to keep a close eye on the explosive growth of Netflix and other digital technologies and services to ensure society is receiving maximum benefits, while minimising the negative consequences – including on electricity use and carbon emissions.

The Shift Project: We fully agree with these observations, which are in line with the idea of digital sobriety as advocated by *The Shift*: digital restraint is meant to preserve the most valuable assets of digital technology, by making it compatible with climate and energy constraints, so that it becomes the tool that we need to meet these challenges.

The objective of our research on online video has been to reaffirm this stance, as explicitly stated in our report, as well as in the executive summary and the subsequent media campaigns: if we are to build a digital system that is durable and compatible with the constraints that affect it, we should consider why our digital practices are developing in this manner. We should study the trends that underline the development of our infrastructures, in order to curb their evolution and to secure their resilience.

Instead of relying on misleading media coverage, this will require rigorous analysis, corporate leadership, sound policy and informed citizens.

The Shift Project: We also endorse this recommendation: the complexity of the issues at stake requires the mobilisation of the widest possible rigorous and constructive research task force.

The qualitative approach has to give way to a quantitative discussion, so we can eventually monitor our digital systems in a way that is compatible with the constraints that affect them: constraints on resources, reduction of **net** emissions and energy consumption from all sectors, etc. This quantitative debate is currently getting underway, notably thanks to discussions on assumptions and models such as this one between G. Kamiya of the IEA and *The Shift Project*. Indeed, this was one of the main goals of *The Shift*'s publications on the environmental impact of digital technology.

However, there is a need to work on better ways to diffuse information; this is crucial for building the collective debate we are urging (as explained in detail in our report on online video), so that "information diffusion" no longer means "simplification". The issues are complex (both for the technical complexity of digital systems, and for the complex intricacies between the evolution of practices and the development of infrastructures), and the responses will also be complex, for they must be systemic.

Methodology and sources

The analysis of the carbon intensity of streaming video presented in this piece is based on a range of sources and assumptions, calculated for 2019 or the latest year possible.

- Bitrate: global weighted average calculated based on subscriptions by country and average country-level data streaming rates from Netflix in 2019; resolution-specific bitrates from Netflix.
- Data centres: low estimate based on Netflix reported direct and indirect electricity consumption in 2019, viewing statistics and global weighted average bitrate (above); high estimate based on 2019 cloud data centre IP traffic from Cisco and energy use estimates for cloud and hyperscale from IEA.
- Data transmission networks: calculations based on Aslan et al. (2018), Schien & Priest (2014), Schien et al. (2015), and Andrae & Edler (2015), and weighted based on Netflix viewing data by devices.
- Devices: smartphones and tablets: calculations based on Urban et al. (2014) and Urban et al. (2019), iPhone 11 specifications (power consumption and battery capacity), and iPad 10.2 specifications; laptops: Urban et al. (2019); televisions: Urban et al. (2019) and Park et al. (2016), and weighted based on Netflix viewing data by devices.
- Carbon intensity of electricity: based on IEA country-level and global data, and 2030 scenario projections.

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The Shift Project

The Shift Project is a think tank that works in favor of a post-carbon economy. A non-profit association in the general interest and guided by the requirement for scientific rigor, our mission is to enlighten and influence debate on energy transition in Europe. Our partners are large companies that wish to make energy transition their priority.


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