# Carbon Footprint of Social Media (and other popular platforms)

## Lecture Series on Sustainability in Computer Science

Andreas Uhl

Department of Artificial Intelligence and Human Interfaces
Paris Lodron University of Salzburg, Austria

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# Footprints to determine Sustainability

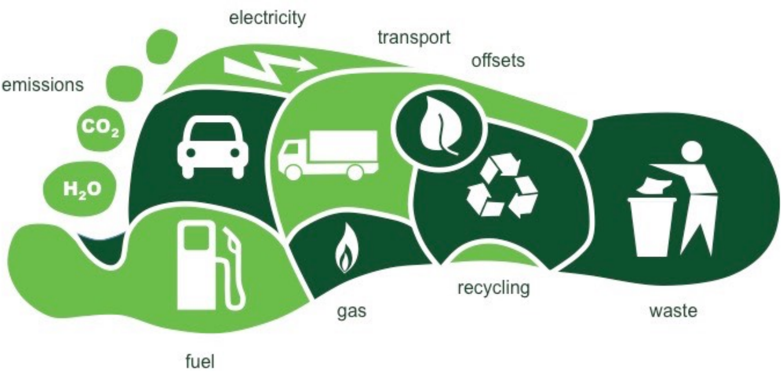
Different types of footprints are used to assess the impact of human society on the earths resources:

- Carbon footprint (aka greenhouse gas footprint)
- Water footprint
- Land footprint
- Material footprint

# Carbon Footprint: Definition

The carbon footprint (or greenhouse gas footprint) serves as an indicator to determine the total amount of greenhouse gases emitted from an activity, product, company or country. Carbon footprints are usually reported in tons of emissions (CO2-equivalent) per unit of comparison; such as per year, person, kg protein, km travelled and alike. For a product, its carbon footprint includes the emissions for the **entire life cycle** from the production along the supply chain to consumption and disposal.
In the context of climate change mitigation activities, the carbon footprint can help distinguish those economic activities with a high footprint from those with a low footprint.
In the definition of carbon footprint, some scientists include only CO2, but more commonly several of the important greenhouse gases are included. The various greenhouse gases are made comparable by using carbon dioxide equivalents over a relevant time scale, like 100 years. Thus, the terms “greenhouse gas footprint” or “climate footprint” are sometimes used alternatively.

# Carbon Footprint: Examples




Annual CO2 emissions (t per person as of 2021): Australia 15.1, Austria 7.2, Canada 14.3, China 8.0, France 4.7, Germany 8.1, India 1.9, Kuwait 25.0, Tanzania 0.2, US 14.9[1].

[1] https://ourworldindata.org/co2-emissions

# Carbon Footprint: Greenhouse Gas Protocol

The GHG Protocol is a group of standards that are the most common in GHG accounting. These standards reflect a number of accounting principles, including relevance, completeness, consistency, transparency, and accuracy. ISO published the ISO 14064 standards suite for greenhouse gas accounting and verification in 2006.

The standards divide emissions into three scopes:

- **Scope 1** covers all direct GHG emissions within a corporate boundary (owned or controlled by a company). It includes fuel combustion, company vehicles and fugitive emissions.
- **Scope 2** covers indirect GHG emissions from consumption of purchased electricity, heat, cooling or steam.
- **Scope 3** emission sources include emissions from suppliers and product users (also known as the "value chain"). Transportation of goods, and other indirect emissions are also part of this scope.

# Carbon Footprint: Emissions Scope

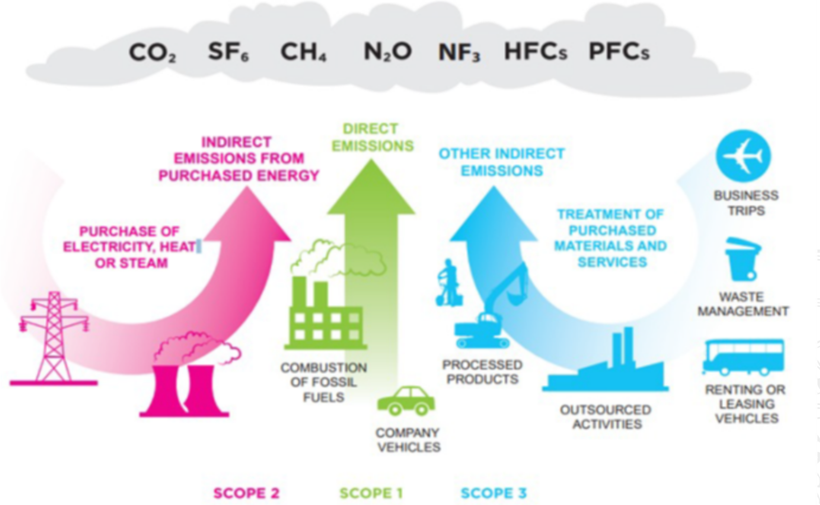



Figure: Types of direct and indirect emissions that need to be considered.

# Water Footprint

A water footprint of an individual, community, product or business is an environmental indicator that measures the volume of fresh water needed to produce the goods and services demanded by society. We discriminate three types:

1. **Blue Water Footprint** refers to the volume of water that has been sourced from surface or groundwater resources (lakes, rivers, wetlands) and has either evaporated (for example while irrigating crops), or been incorporated into a product or taken from one body of water and returned to another.
2. **Green Water Footprint** refers to the amount of water from precipitation that, after having been stored in the root zone of the soil (green water), is either lost by evapotranspiration (evaporation + transpiration) or incorporated by plants.
3. **Gray Water Footprint** refers to the volume of water that is required to dilute pollutants (e.g. industrial discharges, untreated municipal wastewater) to such an extent that the quality of the water meets agreed water quality standards.

# Land and Material Footprints

- **Land footprint** is the real amount of land, wherever it is in the world, that is needed to produce a product, or used by an individual, organisation or by a nation. For example, in a report by *Friends of the Earth Europe* from 2016, the land footprint of the EU was estimated to 269 million of hectares, i.e. 43% more than the agricultural land available in the EU. 73% of this land footprint was due to the consumption of animal products and the rest to vegetable oils and plant-based products.
- **Material footprint** is a consumption-based indicator of resource use. It enumerates the link between the beginning of a production chain (where raw materials are extracted from the natural environment) and its end (where a product or service is consumed).

# Life Cycle Analysis/Assessment

Life cycle analysis/assessment (LCA) is a method used to evaluate the environmental impact of a product through its life cycle encompassing extraction and processing of the raw materials, manufacturing, distribution, use, recycling, and final disposal.

An LCA study involves a thorough inventory of the energy and materials (i.e. carbon, water, land, material footprints) that are required across the industry value chain of the product, process or service, and calculates the corresponding costs to the environment. LCA thus assesses cumulative potential environmental impacts.

Widely recognized procedures for conducting LCAs are included in the 14000 series of environmental management standards of the ISO, in particular, in ISO 14040 and ISO 14044 standard suites.

# Life Cycle Analysis: Illustration

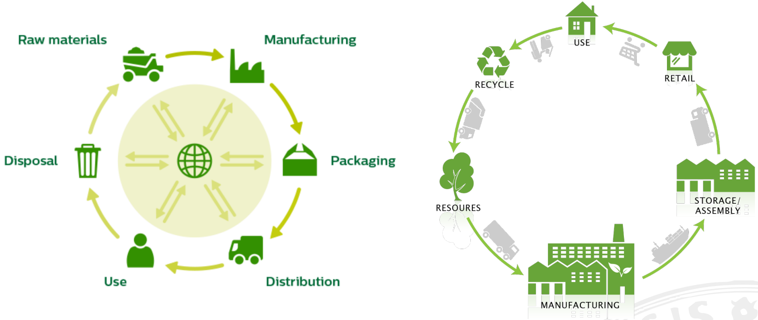



Figure: Two ways to illustrate the product life cycle.

In social media applications and activities, a considerable amount of devices is involved – no matter which exact model is used, a modelling of product life cycle for e.g. internet routers, cables, data centers, and end user devices is difficult !!

# Footprints in Internet Usage

As one of the few exceptions, a recent study[2] tries to look beyond the carbon footprint only, and also illustrates the impact of deployments in different countries.

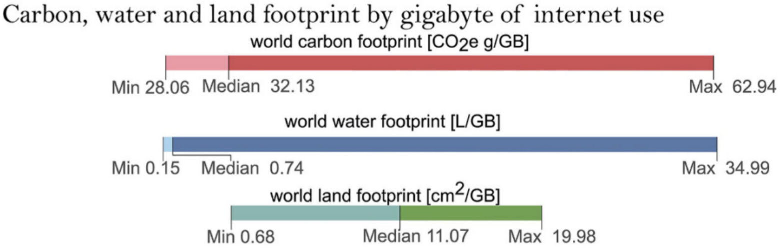



Figure: Carbon, water, and land footprints of internet usage.

[2] Renee Obringer et al. "The overlooked environmental footprint of increasing Internet use". In: *Resources, Conservation and Recycling* 167 (Apr. 2021), p. 105389. DOI: 10.1016/j.resconrec.2020.105389.

# Looking at different Deployment Countries

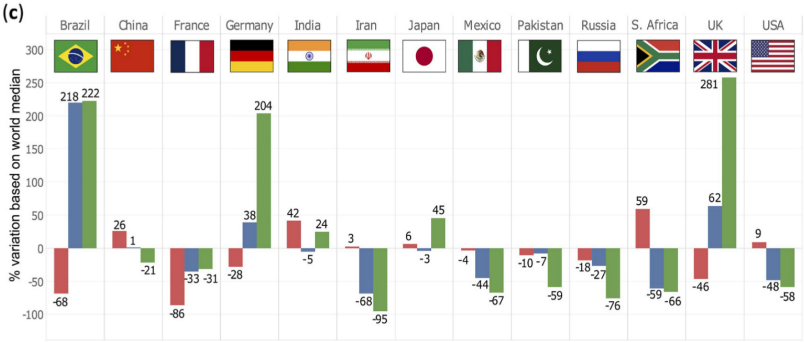



Figure: Deviation of the environmental footprints of a unit of electricity used for data processing and/or transmission (!!! restriction to electricity here !!!) within select countries from the world median environmental footprints, calculated based on each country's energy mix. The large ranges of footprint values are mainly attributable to the variation in energy production technologies and efficiencies around the world.

# Impact of Changing Application Settings I

| | | Carbon Footprint ($g\ CO_2e$/hour) | Water Footprint (L/hour) | Land Footprint ($cm^2$/hour) |
|---|---|---|---|---|
| **Before** | Streaming, HD | 440.58 | 5.20 | 77.48 |
| | VC, Video On | 157.34 | 1.86 | 27.67 |
| **After** | Streaming, SD | 62.94 | 0.74 | 11.07 |
| | VC, Video Off | 6.29 | 0.07 | 1.11 |

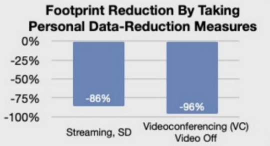



Figure: Impact of personal data-reduction measures.

Example 1: A common streaming service requires 7 GB per hour of streaming in high video quality (Ultra HD or 4k), having a carbon footprint of 441g CO2 e/h (global median), assuming streaming four hours a day would result in a monthly carbon footprint of 53 kg CO2e. However, by lowering the video quality from HD to standard, the monthly footprint would drop to 2.5 kg CO2e, saving the emissions of driving a car from Baltimore to Philadelphia (150 km). If 70 million streaming subscribers do so, we see a monthly reduction in 3.5 million t of CO2e – the equivalent of eliminating 1.7 million t of coal, or 6% of the total monthly US coal use.

# Impact of Changing Application Settings II

Example 2: A standard videoconferencing service uses about 2.5 GB/h and has a carbon footprint of 157 g CO2e/hr. Assuming 15 1-hour meetings a week, their monthly carbon footprint would be 9.4kg CO2e. Simply turning off the video, however, would reduce the monthly emissions to 377g CO2e. This would save the emissions of charging a smart phone each night for over 3 years (1151 days). If 1 million videoconference users were to make this change, they would collectively reduce emissions by 9023 t of CO2e in one month, the equivalent emissions of powering a town of 36,000 people for one month via coal.

# History of Comparing Media: Here is the News !

One of the first topics when comparatively discussing environmental impact of media types was to assess the impact of printing technology vs. electronic versions of such media:

1. Comparing the consumation of a newspaper in printed form and tablet-based e-paper reading[3]
2. Comparing the consumation of news via newspaper, on-line newspaper and broadcast television[4]

In the following, we will look at the latter in more detail.

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[3] Åsa Moberg et al. "Printed and tablet e-paper newspaper from an environmental perspective — A screening life cycle assessment". In: *Environmental Impact Assessment Review* 30.3 (2010), pp. 177–191. ISSN: 0195-9255. DOI: https://doi.org/10.1016/j.eiar.2009.07.001.

[4] Inge Reichart. "The Environmental Impact of Getting the News". In: *Journal of Industrial Ecology* 6 (July 2002), pp. 185–200; R. Hischier and I. Reichart. "Multifunctional electronic media - traditional media". In: *The International Journal of Life Cycle Assessment* 8 (2003), pp. 201–208.

# Defining what we look at: System Boundary

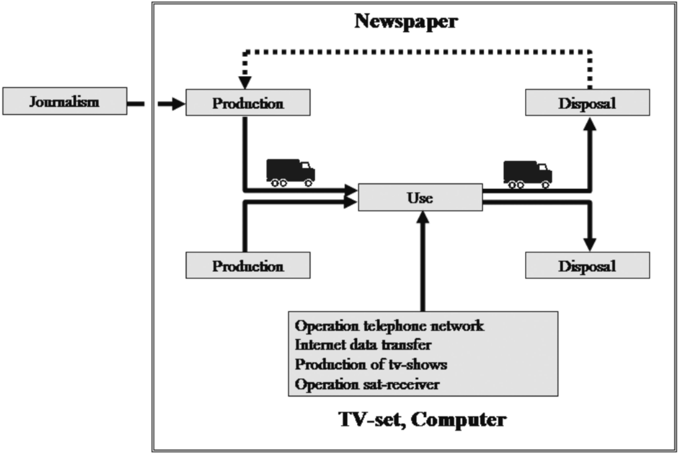


Figure: System boundary for environmental analysis of news delivery: We do NOT consider environmental costs of journalism and recycling of electronic waste, but we do consider paper recycling here.

# Modelling of the Entire System

When trying to assess environmental imapct (which done using the method of "environmental scarcity" in Ecopoints, emphasizing energy consumption and its related air emissions, although some emissions to water and land are also evaluated), one is confronted with a highly complex system to be modelled.

- The majority of modelling is taken from various existing sources: lifetime and energy consumption of devices, disposal and recycling of newspaper, disposal of electronic waste, manufacturing of newspaper, manufacturing of electronic devices, etc.
- Only user behaviour when consuming news is experimentally investigated and further used in modelling; also length of typical news items.

# Results: 1 News item

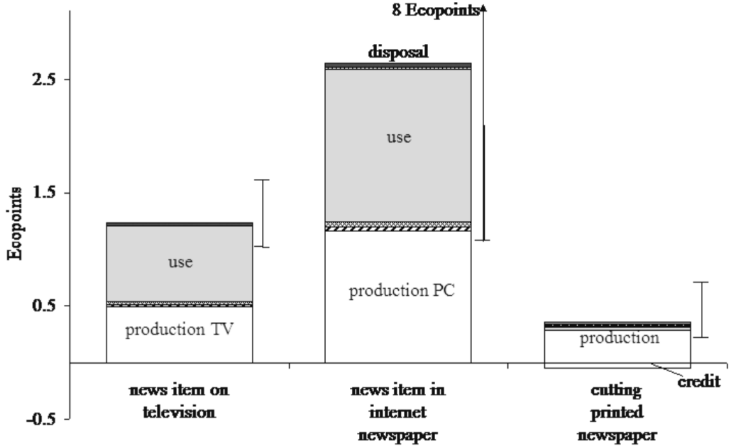


Figure: Environmental impact of reading or listening to a **single** news item, disaggregated into life-cycle stages. Thin bars to the right of each bar indicate the total potential environmental impact when taking the potential variance of news items, including user variability, into account.

# Results: Daily News

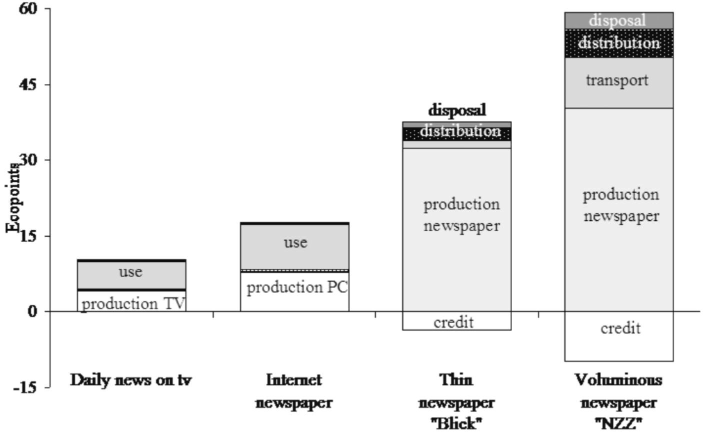


Figure: Environmental impact of reading or listening the daily news, disaggregated by life-cycle stages. The credit is for energy recovered from burning part of the waste paper which is disposed of together with household waste in incineration plants.

# Results: Looking @ Details

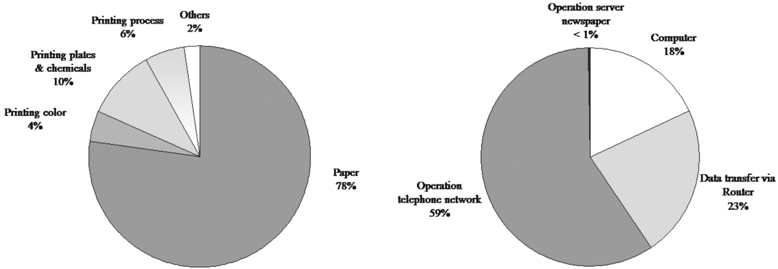


Figure: Environmental impact for (left) the production phase of the newspaper life cycle as well as (right) the use phase only for reading an on-line newspaper. Note that operation of the telephone network consumes over half of the power.

# Results: Reading Time and Energy Mix

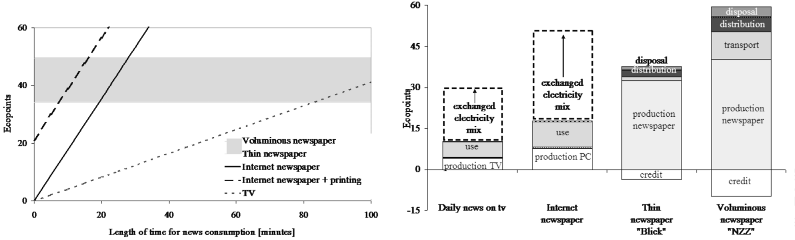


Figure: Influence of (left) length of time for news consumption and (right) the electricity mix (Swiss mix replaced by average European mix) on the environmental impact.

# History of Comparing Media: Streaming vs. DVD

The rapid growth of streaming video entertainment has received attention starting with 2010, as a possibly less energy intensive alternative to the manufacturing and transportation of digital video discs (DVDs and BluRays).
A 2014 study[5] utilizes a life-cycle assessment approach to estimate the primary energy use and greenhouse-gas emissions associated with video viewing through both traditional DVD methods (4 different business models are considered) and online video streaming.
This discussion is a prototype one, when assessing the dematerialization associated with replacing physical goods or activities with equivalent services provided through the internet, where streaming music and video entertainment are prominent examples (others are e.g. utilizing teleconferencing to reduce business travel and on-line dating).

[5] Arman Shehabi, Ben Walker, and Eric Masanet. "The energy and greenhouse-gas implications of internet video streaming in the United States". In: *Environmental Research Letters* 9.5 (2014), p. 054007.

# Considered DVD/BluRay Usage Scenarios

Streaming video in this study is limited to content typically found on DVDs/BluRays, such as full-length movies or television programs.

For DVD/BluRay usage scenarios, the following are considered:

- "Mail Rented" represents a Netflix model for mail service subscriptions, where DVDs are mailed directly to the consumer from centralized warehouses.
- "Store Rented" represents brick-and-mortar DVD stores (e.g., Blockbuster) or kiosks (e.g., Redbox) where the consumer travels a short distance to pick up **and return** rental discs.
- "Mail Purchased" represents DVDs purchased online and mailed directly to the consumer (e.g., via Amazon).
- "Store Purchased" represents DVDs purchased from a brick-and-mortar store (e.g., Walmart).

# DVD Video Consumption

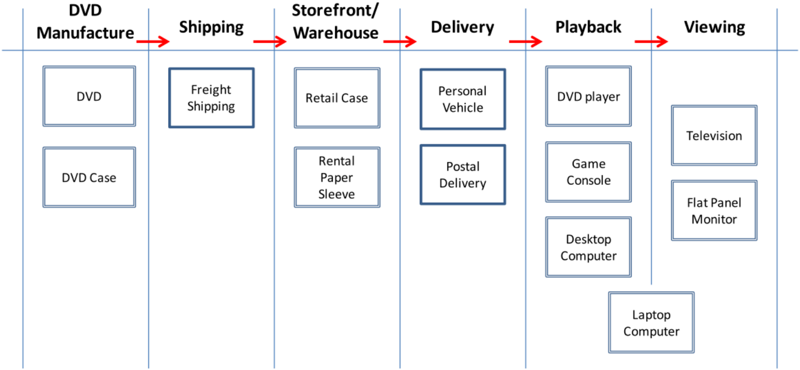


Figure: System diagram of DVD viewing analysis. Boxes with double lines represent components where embodied energy and embodied CO2e emissions are also included in the analysis.

# Streaming Video Consumption

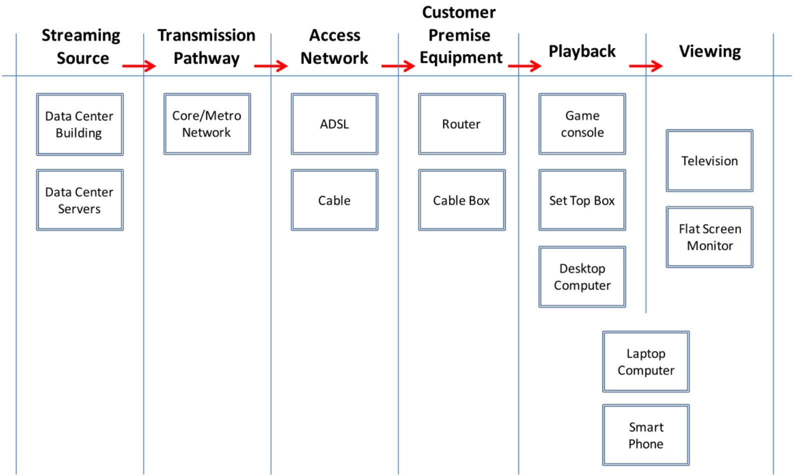


Figure: System diagram of streaming analysis. Boxes with double lines represent components where embodied energy and CO2e emissions are also included in the analysis.

# Results

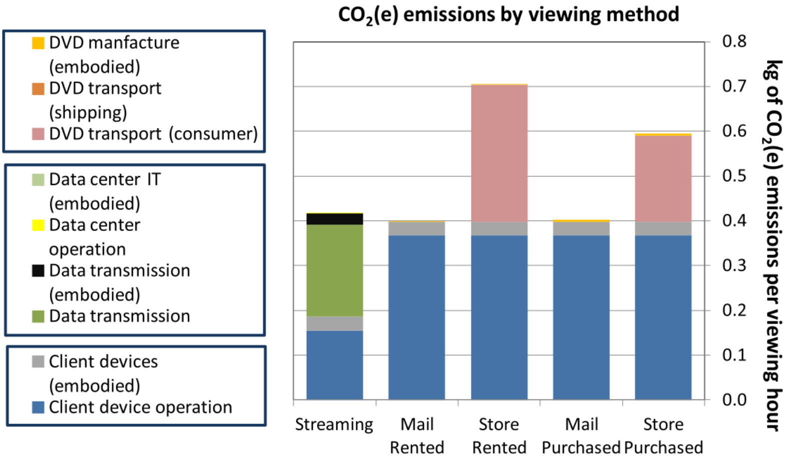


Figure: Estimated per viewing hour CO2e emissions associated with US video streaming and DVD viewing variants.

# Looking @ Variability Details

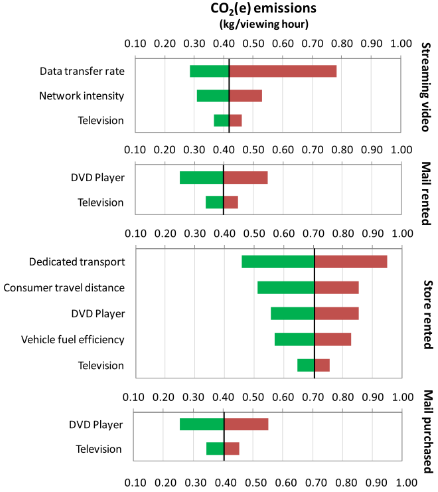


Figure: Range of US average CO2e emissions per hour of video viewing under different sensitive input assumptions.

System component input parameters are listed on the vertical axes – We notice that many components have a surprisingly high impact on the overall result – e.g. data transfer rate, consumer travel distance, dedicated transport, vehicle fuel efficiency, etc.

# ICT Carbon Footprint Calculations and their Politics

In 2020, the electricity consumed by information and communication technologies (ICT) was calculated variously to generate 1.4% to 3.8% of global greenhouse gas emissions[6] (this is higher than the 1.9% of the airline industry). About $1/3$ of that, or 1% of global greenhouse gas emissions, has been attributed to streaming video: VoD platforms, YouTube, pornography, live streaming, videos embedded in social media, and games.

With the pandemic, internet traffic spiked by 40%. Over 15% of that traffic was YouTube, and 11% was Netflix – this despite the fact that both those companies, as well as PlayStation, reduced resolution to standard definition in order to cope with demand.

By one estimate, ICT will constitute 15% of global electricity consumption by 2040. These figures illustrate why different stakeholders might follow very different political interests when it comes to studies wrt. ecologic footprints of various media types.

[6] Laura U. Marks and Radek Przedpełski. "The Carbon Footprint of Streaming Media: Problems, Calculations, Solutions". In: *Film and Television Production in the Age of Climate Crisis: Towards a Greener Screen.* Ed. by Pietari Kääpä and Hunter Vaughan. Cham: Springer International Publishing, 2022, pp. 207–234.

# The Difficulty of Tackling the Carbon Footprint of Streaming Media

A survey of 22 ICT carbon footprint calculators and nine calculators specifically for streaming video[7] revealed several issues:

- Definition of system boundary is hard and done diversely.
- Concerning data centres, networks, and devices, should the embodied energy (energy involved in manufacture) and disposal energy be included ? This is significant, as e.g. in small devices like mobile phones, 90% of the electricity consumption occurs before they reach the consumer.
- What about the pollution in mining and disposal?
- Different methods in data collection on system modelling.

Throughout the literature, the disparity among result figures is enormous. A surprising degree of cherry-picking is seen when identifying data, modelling resource consumption, and prediction.

[7] Stephen Makonin et al. "Calculating the Carbon Footprint of Streaming Media: Beyond the Myth of Efficiency". In: *Eighth Workshop on Computing within Limits 2022*. LIMITS. June 2022.

# Politics and More

"We quickly realized that much of the literature on the subject used figures from previous documents, very often without cross-referencing them with others, and without taking precautions regarding the limits of their validity"[8].

"As we researched more deeply, these issues turned out to reflect not only the regular turnover of scientific findings but also ideological agendas. We began to identify alliances, rifts, and tribes among the engineers studying this topic."

[8] Marks and Przedpełski, "The Carbon Footprint of Streaming Media: Problems, Calculations, Solutions".

# The Case: The Shift Project (TSP) vs. International Energy Agency (IEA)

The Shift Project (TSP) developed an exhaustive calculator to assess the carbon footprint of streaming media[9], concluding that streaming video contributes 1% of global greenhouse gas emissions, this was supported by other studies[10].
Those findings made a splash in popular media, with coverage by the BBC, The Guardian, the New York Post, and other media.
This quickly drew a rebuttal from George Kamiya, an analyst for the IEA, which is oddly mean-spirited in tone[11].
Instead of simply critizising the science behind TSP findings, he deploys language, charts, and hyperlinks intended to downplay the carbon footprint of ICT and discredit TSP in the eyes of a layperson[12].

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[9] https://theshiftproject.org/en/home/

[10] Makonin et al., "Calculating the Carbon Footprint of Streaming Media: Beyond the Myth of Efficiency".

[11] https://www.iea.org/commentaries/the-carbon-footprint-of-streaming-video-fact-checking-the-headlines

[12] Marks and Przedpełski, "The Carbon Footprint of Streaming Media: Problems, Calculations, Solutions".

# IAE Unfair Play

- The focus of IEA is set on Netflix: Netflix is unusually energy efficient and its content is hosted on content distribution networks near the end user. Thus, this is misleading.
- The argumentation plays with artificial distinctions of data centers and servers (which are seen as cloud-based IT equipment but not data centers) thereby minimizing the energy usage of streaming for data centers.
- Based on a confusion of megabits and megabytes of a TSP member in an interview, Kamiya multiplied all TSP's calculations by eight and produced a chart that makes TSP look ridiculous.

So why is the IEA, the planet's most influential voice on energy policy, so determined to demolish TSP ("this little French think tank"[13]) ? Why does it need to reassure the public that the energy consumption of streaming media is not a concern?

[13] Marks and Przedpełski, "The Carbon Footprint of Streaming Media: Problems, Calculations, Solutions".

# Comparing TSP to IEA and others

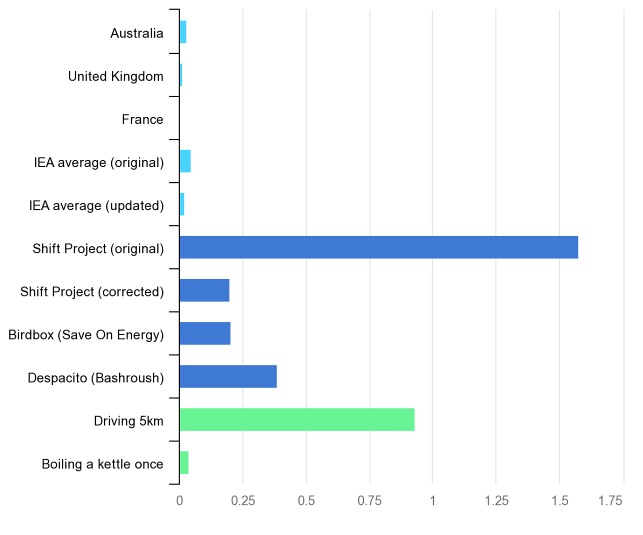
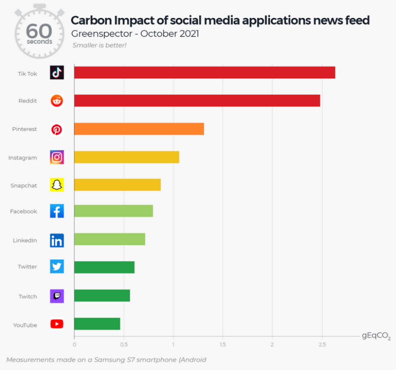



Figure: CO2 emissions associated with a half-hour show on Netflix in 2019 (IEA chart)

# Finally: Comparing Social Media



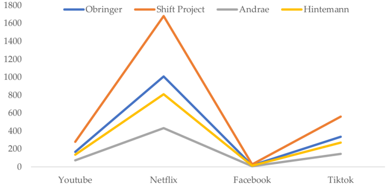




Figure: Comparison of social media generated CO2e in (left) 60 seconds (Greenspector) vs. (right) one hour (Sustainability).

# Social Media: Hourly Use

Table: Comparing hourly use (g CO2e).

| *Platform* | *Greenspector* | *MDPI Sustainability* |
|---|---|---|
| YouTube | 27.6 | [72 - 280] |
| Facebook | 47.4 | [7.2 - 28] |
| TikTok | 157.8 | [144 - 560] |

Results produced by Greenspector[14] and a recent study published in MDPI Sustainability[15] (VERY confused paper !).

[14] https://greenspector.com/en/social-media-2021/

[15] Altanshagai Batmunkh. "Carbon Footprint of The Most Popular Social Media Platforms". In: *Sustainability* 14.4 (2022).

# Social Media Footprint: What does it mean ?

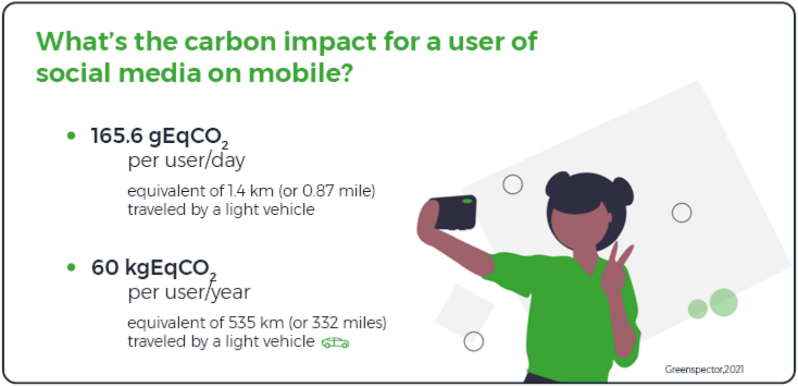



Figure: Comparing social media generated CO2e with driving a car.

Compute your own social media footprint (based on Greenspector): `https://www.comparethemarket.com.au/energy/features/social-carbon-footprint-calculator/`

# Social Media Footprint: Bad Examples do not help

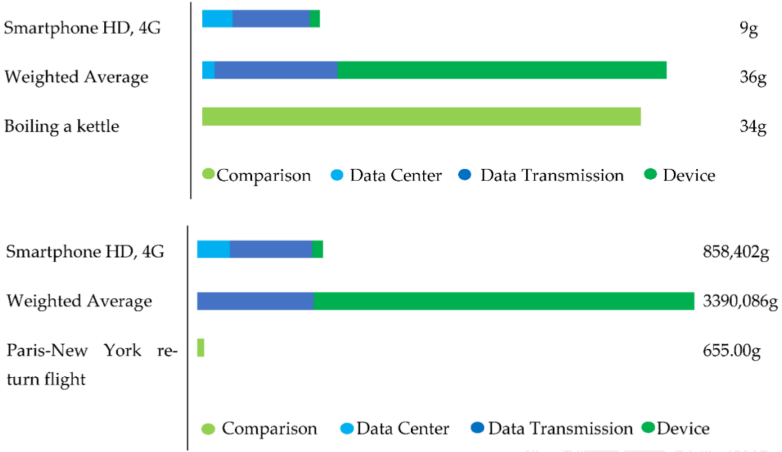



Figure: $CO_2e$ for one hour (top) and one day (bottom) streaming, respectively. Return flight Paris - New York is 1900 kg $CO_2e$.

# Conclusions

## Observations

- Literature on the topic is scarce.
- Modelling requires enormeous background knowledge (or trust in external resources).
- Several papers exhibit obvious shortcomings & mistakes.
- People / organisations involved often have a political / economical / ecological agenda.
- Results often reveal surpringly high ecological footprints and easy ways to reduce those.

$\Longrightarrow$ Solid and reproducible research in this field is required to raise the awareness that (i) social media consumption does have a non-negligible ecological footprint and that (ii) even changing individual settings can make a large difference.