Title: **Understanding the Full Emissions Impact from Internet Traffic**
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Background

With the amount of traffic flowing on the internet, we have no great way of measuring the overall emissions impact of an end-to-end bit. Numerous estimates and assumptions can be made; however, power grids, hardware, components, and physical deployments are only sometimes created equal concerning emissions value. As traffic increases across the internet, we see a continued increase in power consumption and the need for more hardware, components, and physical deployments. With this continued growth, we need expanded capabilities to measure the impact of the broader internet on the planet and the effects of new and emerging technologies.

As we continue to build out the world wide web, the global community will be met with increased challenges, such as infrastructure being deployed in already taxed grids, producing hardware and components for speed vs. consequence consideration, or even sourcing raw materials in already heavily affected areas of the world coming with an unknown environmental and biodiversity impact. As a group of concerned internet professionals, we must be ready for the future and develop a way to better understand the planetary effect of the bit end to end.

Challenge

As traffic demand and power consumption increase, we need a reliable way to measure emissions output against consumption across the web. Unfortunately, this challenge limits our ability to determine the full emissions impact of the web on modern society. Except for some power-related measurements, we need a consistent way to measure end-to-end lifecycle emissions across all parts of the web to provide consistent and accurate measurements targeted at the total emissions impacts of a bit.

Concept

There are many ways to solve the end-to-end emissions impact of a bit today. However, there is no one size fits all, and in some cases, we may need to estimate to get closer to reality. More detailed analysis and increased traceability could provide much-needed control to decide how we apply the measurement criteria for each bit consumed. Across the web, there are generally three distinct areas of impact, they include:

- power
- products (racks, hardware, servers, switches, Etc.)
- physical (buildings, location interconnects, grid, Etc.)

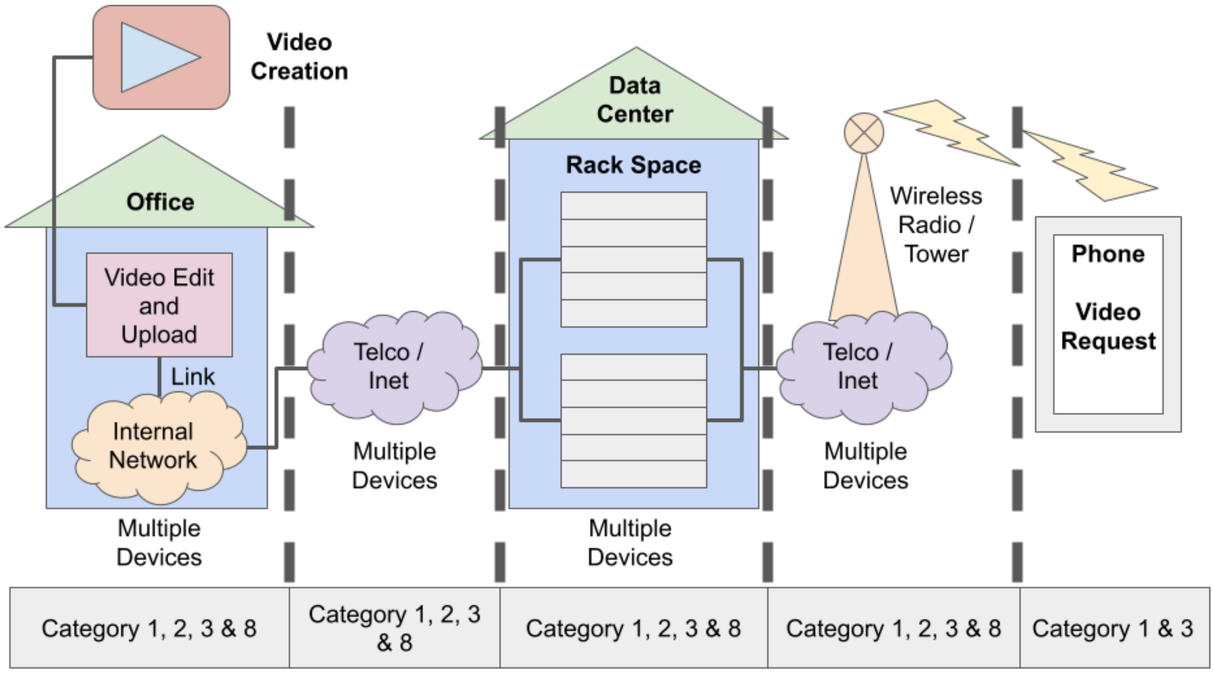
Each of these categories plays a vital role in emissions impact in understanding the lifecycle of a bit. As we break it down, there are many intersections of impact here, detailed under the Greenhouse Gas Protocol (GHGP). Since a bit is an indirect power consumer, most emissions impact would be qualified under the Scope 3 emissions standard. As this gets distilled down to the more granular components that affect the bit, we end up with the following categories for consideration:

Emissions Category	Impact	bit Connection
Category 1	Purchased Goods and Services	Rack Space (Data Center), Monitoring, Devices
Category 2	Capital Goods	Servers, Switches, Hardware, Racks, Components and Accessories
Category 3	Fuel and Energy Related Activities	Result of Energy Consumption including Generator Use, Related PUE, Transmission and Distribution Losses
Category 8	Upstream Leased Assets	Interconnect, Bandwidth, Transit

From a chain of custody perspective, since the bit is not the direct cause of power in this instance, it is the underlying device to support the traffic flow. Therefore, all measurement categories should fall under Scope 3 from a GHGP perspective.

Emissions Values

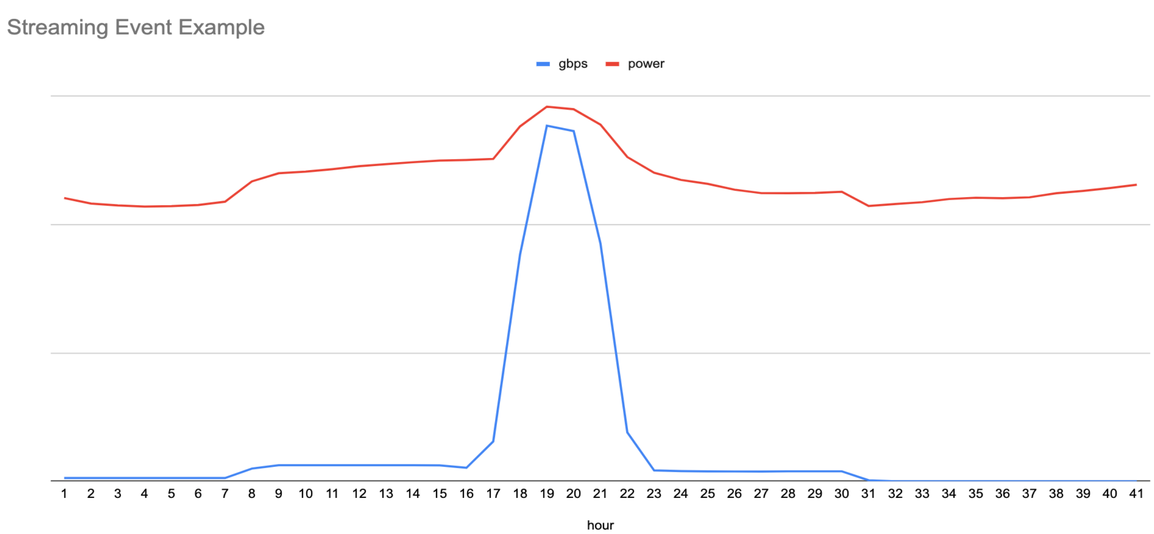
In order to better understand the emissions value of the bit, these categories would have to be pulled apart to understand their individual emissions values and determine whether they are fixed values (cradle to grave under each category) or dynamic under categories 1, 3, and 8. In addition, bits would have to pair against a relative max capacity, hardware, and the various devices helping to push traffic across the web to get closer to an actual value. The graphic below illustrates the components found across the internet from when this example highlights a video being created to when it is viewed, with applied categories across the chain.



Each hop across the example of creating a video has an emissions value in terms of power. This impact could also be physical or virtual (supplier goods and services). In order to understand the full impact of the bit, a baseline for some of the more static values will need to be developed, including those components that do not have a direct power impact, such as racks, buildings, and various materials used to support the network operation. Physical and virtual is in addition to power which will need to be considered by location to apply relevant emissions factors for an accurate view of the impact. Across the bit flow, local grid and location information will need to be gathered to understand emissions lifecycle impact.

CDN Power Example

Using a high-level Content Delivery Network (CDN) example, the power-related impact from a live event targets power used in time series. As the event ramps up, power consumption increases across the hardware, as detailed in the graph below.



This graph illustrates that the event causes the hardware to increase power consumption during the event to handle the traffic. In addition, it is expected to see a moderate power increase across the entire path those bits travel to handle the increased load. Therefore, the increased power load would be seen across the entire diagram in the sample video creation image above. The emissions values would fluctuate depending on where those bits are being served due to the increased power across server, switch, router, and DWDM to support the increased traffic load.

In addition to the dynamic power value change due to traffic changing, there are static values relating to emissions impact to support the event known as physical or embodied emissions on the GHGP. In the CDN example, embodied emissions would come from the physical footprint needed to power the traffic. Typically, the embodied emissions impact is based on the useful life of all products needed to power that traffic such as hardware, racks, PDU and building locations used across that chain. Today most products in the hardware value chain could vary in useful life depending on the type of component. Generally speaking, most components could have anywhere from 3 to 7 years of useful life, with the exception of buildings, depending on the component, technology, vintage, Etc. Below, is sample high-level math is based on a 5-year useful life across 8760 hours in a year off of an average global emissions factor.

Embodied Rack Value by Hour	**Total Embodied Value Metric Tons CO2e**
Server	~ 0.000009615902939 Per Hour
Rack	~ 0.000001671859589 Per Hour
PDU	~ 0.000000214590751 Per Hour
Accessories	Varies Depending on Component
Switch, Router, DWDM	~ 0.00000004377225452 Per Hour

These values will vary greatly depending on location, material source, and manufacturing location. However, to get a closer comparison to what is happening hourly, this is the estimated embodied value based on the 5-year useful life over 8760 hours in a year.

To illustrate math at the most superficial level in the CDN example, we will break down this equation in watt-hours and use hours.

Power used across devices to emissions:
*server + PDU + switch + router + DWDM = total wh * EF = Power EF CO2e*

Then we add the embodied values to get to a complete number of total emission impact as illustrated in the equation below:

Embodied emissions impacted by equipment time hours used:
*((server count * EF) + (PDU count * EF) + (switch count * EF) + (router count * EF) + (DWDM * EF) + (accessories count * EF)) * hours used = Embodied EF CO2e*

Then we add both totals to get a total emissions impact, dynamic and static, based on the hardware hours used. This approach to measurement will get us closer to the actual impact vs just using power as the unit of measurement alone.

Open Challenges

1. This approach uses high-level estimates and views in a typical end-to-end bit transaction. More granular research would be needed to develop a hierarchical view into the total emissions impact due to power consumption and physical use.
2. Emissions factors are relatively easy to apply to power consumption based on location and now even a point in time with emerging measurement technology; however, as we think of an end-to-end infrastructure like what is across the web, it is relatively complicated to apply time-based impact to some of the more static values such as those detailed in category 2 of the GHGP as an example. Some assumptions and high-level logic may need to be applied in order to get a more consistent real value
3. Understanding location mapping of traffic will be critical relative to power consumption, market congestion, and potential emissions impact during different times of the day. This impact will have a direct impact on emissions.
4. Emissions measurement fluctuate based on the market and could differ from origin to end device. Environmental tagging may need to be considered to understand the scope and impact fully.
5. Not all bits may be created equal from a power or embodied emissions perspective.

Conclusion

There are many ways we can approach being more sustainable across the internet. Tying the internet's environmental impact to traffic more closely will help quantify our overall impact in a way that engineers and end users can more easily consume. Giving a more realistic view of emissions impact could help more people make conscious decisions when making choices in their day-to-day transitions across the web. The full emissions impact against bit flow will help future-proof a more sustainable web for all.