DIMPACT

Insight to action on digital carbon impacts

DIMPACT

Draft Paper

"Literature Review and Policy Principles for Streaming and Digital Media Carbon Footprinting"

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You can read more about DIMPACT here.

Introduction

DIMPACT was established to support companies to estimate and address the greenhouse gas (GHG) emissions from serving digital media and entertainment products. As these products use data centres and data transmission networks for processing and distributing digital content, companies that are part of DIMPACT are committed to identifying and supporting the implementation of actions that reduce the Information, Communication and Technology (ICT) sector's energy consumption and carbon footprint.

When thinking about the emissions of the ICT sector, it is important to consider both the 'enabling effects' of the sector to drive the decarbonisation of carbon-intensive industries[1], as well as the energy and carbon impacts of the activities of the sector itself. Whilst the former is important, this paper focuses on the latter as it is closely aligned with the goals of DIMPACT and its participants. As The Climate Group's analysis showed long ago, the 'enabling effects' of ICT to drive decarbonisation of carbon-intensive industries outweigh the carbon footprint by orders of magnitude.

That said, because climate change has reached such a critical point, an "all-of-society approach" (UN Environment Programme) is called for and we are committed to working across the value chain to reduce the sector's contribution to global greenhouse gases. We understand that the energy consumption of data centres and networks currently represents about 2-3% of global electricity consumption, driving 0.6% of total GHG emissions.[2] However, we want to put into context the reality that:

1. **The digital industry is more efficient than other industries** and is, therefore, further on track to meet global decarbonisation goals as compared to other sectors such as Aviation, International Shipping, Cement, and others.[3] When it comes to individual actions, we also know that activities such as reducing food waste and changing energy sources in our homes are more impactful than changing behaviours relating to the digital sector.[4] Individual actions on changing behaviours related to the use of digital products and services are comparatively less urgent, hence, system-wide changes (driven by collaboration) are key to decarbonising the digital sector.
2. So much of our world depends on digital services, and fortunately, **society's expanded reliance on digital services has not resulted in significant increases in**

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[1] For example: Smart technologies and controls systems to minimise industrial and built environment emissions, real-time load balancing to maximise renewables use on grids, smart mobility and logistics, etc

[2] Per IEA, Data Centers & Networks, "The data centres and data transmission networks that underpin digitalisation accounted for around 300 Mt CO2-eq in 2020 (including embodied emissions), equivalent to 0.9% of energy-related GHG emissions (or 0.6% of total GHG emissions)." Note that this is 2-3% of global electricity usage; 1-1.5% each for Data Centres and Networks.

[3] Per IEA resources, the following sectors are less on track to meet global sustainability goals than Data Centers & Networks (0.9% of global energy-related emissions): Cement, Building Envelopes (6% of global emissions), Chemicals, Aviation, International Shipping (2% of global emissions), Pulp & Paper, etc.

[4] Project Drawdown

overall sectoral energy demand. We must still strive for efficiency everywhere (especially from screens and personal devices), but increased demand for digital services has not caused proportional growth in energy consumption or carbon emissions.

3. There are complexities in the relationship between data traffic, energy consumption, and carbon emissions that require **careful consideration before making real-world decisions, due to modelling and data access limitations**. Actions towards decarbonisation should therefore be driven by stakeholder-specific evidence and state-of-the-art data, to avoid potential unintended adverse consequences. As an industry, we are actively seeking improved data for decision-making to address this.

Some DIMPACT participants are considered part of the ICT sector - or have segments of their business that fall in this category - whereas others are wholly part of the Entertainment and Media sectors. Therefore different participants will have varying levels of operational control of ICT activities. However, what they have in common is a goal to understand how their actions and broader influence can impact the end-to-end impacts of delivering digital content.

We know that climate change and energy security concerns are driving many countries to identify ways to reduce their reliance on fossil fuels and lower their carbon footprint. The digital sector and those that rely on the digital sector for delivering their products and services should therefore be focused on ensuring that we make the most high-impact and responsible changes to support these efforts, grounded in strong data and holistic evidence.

This paper is split into two parts. Part 1 outlines the policy suggestions that we have reached based on DIMPACT's experience and review of the literature. Part 2 summarises the latest technical and methodological thinking on digital emissions, upon which the policy recommendations are based.

Part 1

Policy Principles

The digital sector is evolving rapidly, which has left room for unanswered questions, concerns, and speculation about the energy and carbon emission trends of our expanded reliance on digital services. Due to the complexity of this industry and the lack of predictive models that can be used to assess future impacts, it is difficult to prescribe a comprehensive set of specific actions or requirements on any sub-portion of the digital sector or its consumers.

To drive the most impact, we should look at actions across the entire digital sector that will enable energy and carbon reductions, as well as ways to better model the net impacts of such actions. We recommend the following guiding principles for interested stakeholders and policymakers, built upon extensive research by industry and academic experts[5] (which is summarised in Part 2 of this paper):

Principle 1: Expand access to shared, contemporary data

1. **Enable standardised data sharing across the digital sector** through data reporting and aggregation protocols. This will enable better holistic decision-making and ensure the use of relevant data that best represents the current state of the rapidly-evolving digital sector. Data and methodologies should be standardised across operators so that metrics can be aggregated to understand the impacts across the sector without compromising competitive information. Data should be collected in a way that allows for better demand forecasting.
2. **Leverage contemporary data (less than 1-2 years old) to help inform future decisions in a rapidly changing sector.** Researchers cite "Improving industry data sharing" and "Exercising restraint" in drawing conclusions from old or incomplete data as top priorities for policymakers and industry analysis.[6] They demonstrate[7] that the lack of up-to-date data may lead us to make faulty assumptions with potentially negative consequences. The industry has a role to play in regularly providing up-to-date information to avoid such issues.

Principle 2: Ensure appropriate modelling for short- and long-term decision making

1. **Conduct additional research on demand response (peak vs off-peak internet use)**, i.e. the time-variable throughput of data traffic through the digital sector and network, and account for the network's baseload of energy (for mobile and fixed networks). This will enable better real-world modelling and will help us better understand long-term trends that current models are not capable of predicting.
2. **Use appropriate modelling for changes to the digital sector energy use** in a way that reflects the energy dynamics of these systems**.** Models such as the Power Model are most appropriate for understanding the short-term impacts of changes to delivering

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[5] IEA section "Enact policies to encourage energy efficiency, demand response and clean energy procurement", Joule article, Koomey and Masanet

[6] Joule article, Koomey and Masanet; Science Magazine, Masanet et. al.

[7] Joule article, Koomey and Masanet

content via internet networks because they account for real-world circumstances like baseload electricity of infrastructure and demand response. Additional study is needed to develop long-term predictive models for the future energy needs of the digital sector.

Principle 3: Institute energy efficiency incentives for devices and infrastructure

1. **Promote energy-efficient devices and infrastructure**,[8] including TVs, data servers, data centre cooling, networks, and in-home devices, especially for devices that are powered on all the time, even when idle. Media and entertainment companies can play an indirect role by influencing their value chain partners to adopt more efficient technology - and, to a smaller degree, a direct influence on the energy consumption of certain user devices. Increasing the efficiency of screen devices will have the greatest impact on reducing the end-to-end energy consumption of streaming and other digital activities.
2. **Incentivize efficient device and infrastructure *utilisation***. As a general principle[9], the fewer connected devices we use, the more efficiently the digital sector operates. For example, network technology that reduces the need for personal infrastructure (i.e. Wi-Fi routers in every home), may reduce overall energy consumption.

Principle 4: Prioritise broad availability of Low Carbon and Renewable Energy

1. **Invest in low-carbon and renewable energy infrastructure**, so that corporations can set and achieve sustainability goals and accelerate the transition to low-carbon electricity. Because most digital sector use-phase emissions come from the electricity usage of data transmission and consumption (embodied emissions, whilst still important, are lower), we can reduce ICT emissions by 80% through the usage of renewable electricity.[10] The industry can play an important decarbonisation role by procuring credible, high-impact renewable electricity. This is an important place to start, but we also note that embodied emissions will become more important as electricity generation decarbonises globally.
2. **Enable low-cost renewable energy for at-home usage; this will drive the most impact for video streaming.** End-user devices represent the majority of streaming-related use-phase emissions, so the greatest carbon footprint reduction will come from renewable energy usage within consumers' homes.

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[8] Science Magazine, Masanet et. al.

[9] ENGIE Impact

[10] Ericsson

Part 2

Technical and methodological summary

In this section, we summarise some of the latest thinking on the wider context of GHG impacts of digital emissions, the current methodologies used to estimate the emissions of digital products and services, as well as some of the solutions. We also outline the limitations of these methodologies, and how improved data and collaboration can potentially address these limitations.

However, it is important to first outline the three main opportunities to reduce the digital sector's use-phase carbon emissions from providing digital media and entertainment over the Internet:

1. **Energy Efficiency** across all energy-consuming devices in the value chain, including data centres, network infrastructure, and home devices such as wifi routers, TVs, laptops and peripherals (set-top-boxes, streaming sticks, etc.). Home devices consume the most energy (by far) in the use phase of streaming, making them an important priority[11]. This can be achieved with energy efficiency design of the devices and, to a smaller degree, the software and content that runs on those devices.
2. **Holistically optimising digital content delivery**. This includes consolidating data centres and content distribution networks into efficient facilities with efficient hardware, and increasing the energy efficiency and utilisation of network infrastructure.
3. **Low-carbon Energy** implementation wherever possible, especially for the individual consumer and the screen they're using. Many corporations in the digital sector already pursue opportunities for renewable energy procurement at scale, but individual consumers in some geographies currently have less access to similar opportunities. Expanding general affordable access to clean energy is especially important because at-home devices are the main source[12] of use-phase energy consumption and carbon emissions in delivering digital media and entertainment products.

Section A: Global and Industry Context

The following context[13] is important to remember as we seek effective solutions to decrease global energy demand and carbon emissions:

1. **Digitalization is happening in every aspect of our lives, not just digital media and entertainment, and enables dematerialization.** Digital technologies are increasingly replacing legacy physical products such as print media and DVDs, which require the mining of materials, processing and distribution. Digital options are generally

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[11] Carbon Trust, page 52. The Carbon Trust does not account for lifecycle and manufacturing emissions, which should also be powered by renewable energy where possible

[12] Carbon Trust, page 52

[13] These findings are expected to hold, globally. However, more work needs to be done to understand the nuances between countries, especially in the Global South, in terms of how user behaviour changes, differing rates of digitalisation, and technologies used impacts energy consumption and GHG emissions.

understood to be less carbon-intensive[14].

2. **Streaming has a relatively small energy and carbon impact as an entertainment activity,** especially compared to other daily activities; one hour of video streaming (use-phase) emits about as much as microwaving four bags of popcorn, or three boils of an electric kettle in the UK[15]. While we are committed as an industry to reducing the energy and carbon impacts of the digital sector, r, it's important to remember that one hour of video streaming emits less carbon than driving a petrol car 300 metres,[16] i.e. approximately 23 seconds of driving on a residential street[17].
3. **The expansion of the digital sector is happening quickly, mainly in terms of its capacity to handle more users and more data, *not* in terms of the energy consumption and carbon emissions of the sector.** Demand for digital content has grown over time, but fortunately, the digital sector's energy consumption has remained relatively flat due to significant Improvements in the sector's energy efficiency. While it is still a critical goal of the sector to reduce absolute energy consumption and emissions, technological efficiencies so far have largely prevented growth in energy usage of the digital sector overall.

The scale of efficiency in the digital sector, despite data and user growth, is important to discuss. ISPs are demonstrating significant efficiency improvements, and many are additionally committed to rapid decarbonisation through the procurement of renewable energy. For example, T-Mobile, Vodafone Europe, and BT Group (including Openreach, the UK's core internet backbone) already procure 100% renewable electricity[18].

Many ISPs already report that despite network demand increases, their relative energy consumption is decreasing[19]. BT Group's energy consumption (~90% from network operations[20]) has reduced on average by 1.5% per year over the past five years, despite increases in data traffic[21]. TalkTalk in the UK reported that their emissions intensity by bandwidth decreased from 7MT CO_2e/Gbps[22] to 5MT CO_2e/Gbps between 2020 and 2021[23]. T-

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[14] See, for example Nair, Auerbach and Skerlos (2019), "Environmental Impacts of Shifting from Movie Disc Media to Movie Streaming: Case Study and Sensitivity Analysis" (Source) and Science Direct's overview of the concept of dematerialisation.

[15] Based on comparisons made by the IEA and Netflix

[16] Carbon Trust

[17] 300m = 0.19 miles; 0.19 miles / 30 mph = 0.0063 hrs; 0.0063 hrs * 3600 s/hr = 23 seconds

[18] As mentioned above, it is important that low-carbon electricity is available to everyone in order to decarbonise the end-to-end digital value chain, therefore companies should procure renewable energy in a way that provides 'additionality' which induces more renewable electricity for all. We acknowledge that there is an ongoing debate about renewable energy accounting methods, which is not in the scope of this paper.

[19] Pg 21-23 GSMA

[20] BT energy efficiency initiatives

[21] DIMPACT analysis of the ESG Addendum to the BT Group plc Manifesto Report 2022

[22] MT CO_2e/Gbps = metric tonnes of carbon dioxide equivalent / Gigabits per second of capacity

[23] Data provided to DIMPACT by TalkTalk

Mobile has a public goal[24] to "Achieve a 95% reduction in energy consumption (MWh) per petabyte (PB) of data traffic by 2030," similar to Telefonica's[25] goal of reducing energy consumption by 90% from 2015 to 2025. Research by Dr Koomey and Dr Masanet shows that Network operator Telefonica (Spain) more than tripled data traffic while energy use stayed roughly constant over that same period.[26]

Data centres are improving too. The efficiency of computing devices in data centres at peak output has historically increased at rapid rates[27]. A study[28] published by Masanet et. al. shows that the global electricity consumption of data centres increased by 6% from 2010 to 2018, whereas compute instances (virtual machines running in the cloud) increased by 550% over the same time period. This means that "Expressed as energy use per compute instance, the energy intensity of global data centres has decreased by 20% annually since 2010, a notable improvement compared with recent annual efficiency gains in other major demand sectors (e.g., aviation and industry), which are an order of magnitude lower."

Furthermore, ICT infrastructure is evolving faster than research and projections can keep up with; we've seen rapid efficiency gains in hardware, but we also see growing demand from computation-intensive activities like AI, machine learning, etc. Making definitive assumptions about energy consumption and carbon footprint implications of the sector based on old data and/or simple attributional models can therefore lead to erroneous estimates.[29]

Section Takeaway:

1. Digitalization is a global reality, and though it is pervasive in our lives, the relative energy and carbon impact of individual digital activities like video streaming is relatively small.
2. The digital sector is rapidly and steadily becoming more efficient and is a global leader in procuring renewable energy. This means that energy and carbon footprint data can quickly become outdated; old data cannot be used to predict long-term trends.
3. Energy consumption by networks and data centres has remained relatively constant despite increased demand for services, thanks to efficiency gains in data centres and network technologies.

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[24] Page 56 of T-mobile 2021 report

[25] Telefonica's short, medium and long term goals matrix

[26] Joule article, Koomey and Masanet. New report from Telefonica indicates that "Since 2015, we have managed to stabilise energy consumption, reducing it by 2.4% even though the traffic managed by our networks has increased more than 5.1 times"

[27] See Koomey, J., & Naffziger, S. (2016, November 28). Energy efficiency of computing: What's next? Electronic Design (Source) and Koomey, J. G., Berard, S., Sanchez, M., & Wong, H. (2011). Implications of Historical Trends in The Electrical Efficiency of Computing. IEEE Annals of the History of Computing, 33(3), 46-54 (Source).

[28] Science Magazine, Masanet et. al.

[29] Joule article, Koomey and Masanet

Section B: Recap of Carbon Trust White Paper

The Carbon Trust white paper showed conclusively that the emissions for internet uses like streaming are concentrated in the consumer use phase (i.e. devices and other on-premise peripherals) but companies representing all phases of the internet value chain are working to optimise and decarbonize where possible.

The Carbon Trust study was developed by convening best-available data from across the industry to understand the use-phase carbon impacts of the video streaming value chain, via the Average Data Attributional Method (the DIMPACT model). This study finds that the conservative[30] European average emissions attributable to video streaming are 55 gCO2e per device hour,[31] roughly equivalent to 3 boils of an electric kettle in the UK. These findings don't take into account the benefits of renewable energy usage by data centres and network providers,[32] which is further discussed later in this section.

This top-level 55g figure helps us understand how much of the digital sector's total carbon emissions are attributable to video streaming. Specifically for networks, attribution of total energy was done on the basis of *network traffic*. The Carbon Trust researchers attributed network energy to video streaming over a fixed time in the past, proportional to the amount of streaming-related data passing through the system. Notably, this study could have been derived from a different metric besides network traffic, such as the number of internet subscribers or time.

Because it utilises the Average Data Attributional Method based on network traffic, the DIMPACT model and Carbon Trust findings can therefore provide us with:

1. **A model** for attributing historical, system-level carbon emissions to video streaming, based on (a) streaming-related data centre energy consumption, (b) streaming-related network data traffic, and (c) power consumption from screens and connected devices.
2. **A key finding** that end-user devices are the main driver of use-phase emissions.[33]

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[30] George Kamiya (International Energy Agency [IEA]) published a global average estimate of 56-114gCO2e/hour in February 2020 in Carbon Brief. The assumptions and methods were updated in November 2020, including to incorporate Jens Malmodin's time-based assumptions to estimate network energy use for high bitrate services (see Power Model discussion in Part 3). The central estimate was revised down from 82 gCO2e/hour in the original February 2020 analysis to 36 gCO2e/hour.

[31] Device hour is the emissions from a device streaming content for an hour. It doesn't consider the number of people viewing.

[32] "Hyperscale data centre operators in particular lead in corporate renewable energy procurement, mainly through power purchase agreements (PPAs). In fact, Amazon, Microsoft, Meta and Google are the four largest purchasers of corporate renewable energy PPAs, having contracted over 38 GW to date (including 15 GW in 2021)." - IEA

[33] Carbon Trust Table 4, page 52

Data centres contribute <1% and networks contribute ~10% to emissions, which means that the remainder comes from energy consumed by user devices, including TVs, internet modems and WiFi routers.

3. **A general observation** that shared infrastructure (data centres, networks) have a lower relative energy consumption per user compared to highly distributed devices (personal devices like wifi routers, TVs, TV peripherals, etc.)

In contrast, due to the underlying model assumptions, the Carbon Trust findings cannot provide insight into the digital sector's carbon emissions as a result of *actions and changing behaviours* associated with video streaming. Therefore, the Carbon Trust analysis does not definitively provide us with:

1. **A quantitative model** that accounts for the base load of internet networks, and the fact that they are always on[34]
2. **The real-world implications** of peak demand vs off demand[35] internet usage for video streaming
3. **A comprehensive view** of what actions and behaviours can be taken by content providers, network operators, and data centre providers to impact the net environmental impacts across the entire system (good or bad)

Section Takeaway:

1. The Carbon Trust study findings, based on the DIMPACT Model, provide valuable insights into the emissions hotspots of a typical video stream (excluding the additional positive impacts of known renewable energy usage)
2. However, alternative modelling types must be utilised in order to understand potential changes to the system, such as changing video stream resolution

Section C: Appropriate Modelling for Evidence-based Policymaking

Two typical allocation methodologies have been applied so far to allocate the energy consumption and emissions of data transmission networks: Allocating based on average data volumes (the Average Data Method), and allocating based on time (the Power Model).

These methodologies represent our best available (though still imperfect) approaches for (a) approximating corporate and digital sector GHG accounting, and (b) for decision-making

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[34] The DIMPACT model is attributional and does not use the power model approach. However, the Carbon Trust discussion section does provide information about implications of factoring base load into quantitative modelling and a consequential analysis

[35] Schien, Preist & Shabajee (2022), "Rethinking Allocation in High-Baseload Systems: A Demand-Proportional Network Electricity Intensity Metric", Position Paper for IAB workshop on Environmental Impact of Internet Applications and Systems (link)

about decarbonisation activities in the use phase of streaming. As described in this section, the Average Data Method is best suited for attributing system-level energy in historical GHG accounting, because it ensures that 100% of the networks' historical energy consumption is allocated to each company or service using networks. The Power Model, in contrast, is currently our best option to compare the networks' power consumption for different scenarios. It allows us to see what does and doesn't change in the system given a specific action, and it helps focus us on high-impact decarbonisation interventions in a holistic system approach (rather than disproportionately drawing attention to lower-impact changes like reduced video resolution streaming over fixed networks).

The Average Data Method, DIMPACT Model in Carbon Trust Study:

The Average Data Method can only be used to determine how much of the total ICT sector's energy should be attributed to a single activity that happened in the past. The Carbon Trust whitepaper uses the DIMPACT model to attribute total energy used by internet networks to a single activity (one video stream to one user) on the basis of data volume.

Due to its design, this model cannot be used to determine the real-world consequence of a change , i.e. varying levels of data volume. Using the model in such a way will artificially show proportional increases in energy consumption due to increased data volume in the network portion of the model, as it does not take into account the fact that approximately 80% of total electricity in fixed networks comes from base load.[36] In reality, network infrastructure components are constantly consuming baseload power, and the correlation between energy consumption and average data traffic at the system level has not been shown in the published data from network operators.[37]

Time Allocation Method, The Power Model:

Jens Malmodin has offered an alternative method to assessing and allocating the energy of networks to a given service. This approach more closely reflects the observed immediate response between data transmission rates and energy. As such, the Power Model gives a better sense of the short-term marginal change in network energy consumption based on changes in data volume transfers (e.g. switching a video stream from 4K to SD).

This Power Model acknowledges that there is a high baseload energy required to keep ICT networks running for all its users, whether or not data is flowing through it; baseload energy is allocated by the time duration of usage and the number of subscription lines. For each subscription line, the Power Model accounts for network baseload energy usage based on how long the internet is being used. It also estimates the marginal energy uplift above this baseload. This is estimated (for fixed line networks) at +0.02W/line when browsing the web (lower data volumes) vs. +0.2W/line when streaming Netflix (4 Mbps). For the latter, this

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[36] Chan et. al.

[37] Malmodin 2022

translates to a mere 1% marginal increase over the base load power of 18W induced by 10x higher data throughput.[38]

Whilst the Power Model is useful for understanding the instantaneous impacts of increases in energy consumption based on data volume, it does not take into account that, over longer timeframes, the provisioning of network capacity is driven by peak data volumes. We cannot use this model to predict long-term trends, but historical trends have demonstrated that technological efficiency gains have offset demand growth for many years.

Covid-19 as a real-world case study:

The effect of the Covid-19 pandemic on networks is a real-world example that helps us understand the importance of modelling decisions. The pandemic lockdowns pushed more people online, increasing global network data traffic. However, we know based on actual data that this increase in network traffic had minimal impact on network electricity consumption.[39] For example, Dr Koomey and Dr Masanet observed that "Telefonica's data traffic jumped by 45% in 2020 due in part to COVID (compared to 2019), with no reported increase in network energy use. Models displaying the effect of increased short-term data demand that fail to account for non-proportionality between energy and data flow in network equipment risk yielding inflated environmental-impact results."[40]

If we had tried to use the Average Data Method to estimate the effect of Covid-19 on network energy consumption, we would have wrongly predicted a spike in network energy consumption corresponding to network utilisation. This is because the Average Data model is not well-suited for predicting the impact of changes to the system (like increased network usage). On the other hand, the Power Model more accurately reflects short-term real-world impacts, because it accounts for the network's baseload power that is constant no matter the volume of transferred data.

Three years later, the longer-term impact of the Covid-19 disruption remains far below the linear increase that the average data method would predict. For example, Telefonica reported flat absolute electricity consumption in 2022 relative to 2021, and a 10% decline in electricity use per petabyte of data, in the continuity of its 2021 performance relative to 2020.[41] Researchers in the field expected this limited impact given the reality that networks today have significant spare capacity (global average utilisation <30%).[42] As Jens Malmodin's studies of trends in the last decade demonstrate, "Historic data shows data rates and data

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[38] Malmodin 2020, starting pg 87, figure 7. See Section 3 "Generic Power Model" for further description.

[39] Schien, Shabajee and Preist, "Rethinking Allocation in High-Baseload Systems: A Demand-Proportional Network Electricity Intensity Metric." (Source)

[40] Joule article, Koomey and Masanet

[41] Telefonica annual report, page 308 table 2.1.7 and page 319

[42] TeleGeography Global Internet Research Service, Figure 2

traffic have kept increasing exponentially (slowing down slowly) while power consumption has decreased per subscription or line."[43] Similarly, the IEA also states that "Data-intensive services may only have limited impacts on energy use in the near term since energy use does not increase proportionally with traffic volumes."[44]

Areas of Future Investigation: Peak Demand and Network Type

In order to gain a more holistic picture of the emissions from networking, we still need to improve our current modelling methodologies. The following future areas of study can help us understand the longer-term consequential impacts of network usage:

Peak Demand: The DIMPACT Model generalises for average use, and does not account for the differences in peak vs not-peak network usage. Numerous experts point to this limitation, recognizing that its effects are not well known and should be more carefully studied before drawing any conclusions from existing models. Schien et. al.[45] propose an alternative methodology for establishing an energy intensity metric that "redistributes [the] burden of baseline power consumption proportional to data throughput" by reallocating the energy of the baseload to periods of peak demand, thereby accounting for the influence of bandwidth demand on real-world scenarios. Additionally, the IEA[46] notes that "the average energy consumption of video streaming is fairly low compared with other everyday activities, with end-user devices such as televisions consuming the majority. But if streaming and other data-intensive services add to peak internet traffic, the build-out of additional infrastructure to accommodate higher anticipated peak capacity could raise overall network energy use in the long run."

This suggests that we cannot just consider the instantaneous or short-term impacts of increasing data volumes and peak traffic. We need to also understand how longer-term changes in traffic may impact network energy consumption and emissions, as well as affect the sector's ability to decarbonise.

To address these uncertainties, cross-sector collaboration will be necessary in order to understand:

- Whether future networking equipment technology will offer greater ability to dynamically scale power consumption with utilisation;
- What drives peak demand, and how different stakeholders in the value chain can collaborate to encourage demand shifting, i.e. better utilising networks to prevent peak events and capacity constraints; and

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[43] Malmodin 2020, starting pg 87

[44] Data Centers & Networks

[45] Schien, Preist & Shabajee (2022), "Rethinking Allocation in High-Baseload Systems: A Demand-Proportional Network Electricity Intensity Metric", Position Paper for IAB workshop on Environmental Impact of Internet Applications and Systems (link)

[46] IEA

- How we can more accurately model the longer-term energy and carbon impacts of a peak event causing network operators to build capacity in their networks.

Network Type: All digital sector energy and carbon emission models today are limited by a lack of data on the influence of network type. This uncertainty comes in part from rapidly evolving network technology. For fixed networks, we know that energy loads today are generally unaffected by system-wide data traffic. In contrast, for mobile networks, it is currently very difficult to attribute usage to individual users, and existing studies today show mixed results on the pros and cons of mobile versus fixed networks. As the IEA states, "Mobile data traffic is also projected to continue growing quickly, quadrupling by 2027… Although 5G networks are expected to be more energy efficient than 4G networks, the overall energy and emissions impacts of 5G are still uncertain."[47]

To address these uncertainties, we are keen to determine if:

- Network providers are able to provide up-to-date data that will help address the uncertainties in current modelling. These include:
    - Power per subscriber (Watts per subscriber line) for each connection type (e.g. FTTH, xDSL) in a standardised format
    - Power consumption of networks during peak-, average- and low-traffic scenarios
    - Equivalent usage metrics (total data volume per household, number of subscribers per connection type, peak capacity)
- Replacing legacy network equipment (e.g. 3G, copper) with newer technology (e.g. 5G, fibre) impacts total network energy consumption, or if the efficiencies created simply offset usage growth.
- Data can be standardised across countries and operators, to understand the difference in energy intensities and absolute energy consumption between countries.

Section Takeaway:

1. Every model requires assumptions; using an inappropriate model for certain scenarios can yield a biased and oversimplified answer to a complex topic.
2. The Average Data Method should not be used for modelling the impacts of changes to a system in the short-term, such as changing video stream resolution or reducing page weights of websites; instead, the Power Model should be used.
3. Additional research is still required to understand the energy consumption and carbon emissions effects of peak vs off-peak network demands, and of fixed vs mobile network types.

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[47] IEA