DIMPACT

Insight to action on digital carbon impacts

Methodology

Estimating the carbon impacts of serving digital media and entertainment products

Version 1.0

October 2022

Contents

Revision history

Version	Release date	Notes
1.0	October 2022	Initial public release

About this document

This document describes what DIMPACT is, how it works and our methodology. It provides details about the initiative, as well as a repository of the latest thinking.

At a high level, DIMPACT is an initiative of media and technology companies that has come together to understand and measure the greenhouse gas (GHG) emissions of serving digital media and entertainment products. The initiative includes a web-based calculation tool that allows participants to measure these emissions using a standard methodology.

The aims of DIMPACT: why estimate the GHG emissions of digital media and entertainment products?

DIMPACT aims to be a trusted authority on the emissions associated with digital products and services. The tool itself aims to be as comprehensive as possible and enable the most accurate and robust approach available. The initiative aims to improve the overall transparency of the use-phase emissions in these digital value chains and identify emissions hotspots and opportunities for reductions.

Participating companies use DIMPACT and the findings of the initiative to help achieve the following goals:

- Create detailed estimates of the GHG emissions associated with digital media and entertainment products
- Respond to customers', policy makers' and stakeholders' data needs
- Enhance scope 3 greenhouse gas reporting
- Share learnings amongst participants, and get involved in methodological developments
- Drive greater industry transparency and collaboration in the digital value chain

Create detailed estimates of the greenhouse gas emissions associated with digital media and entertainment products

DIMPACT supports media and ICT sector organisations to reliably estimate the use-phase GHG emissions of their digital products and services. DIMPACT uses an attributional life-cycle assessment methodology. The understanding of life-cycle assessments for physical products, such as printed books, vinyl records and DVDs is well established. As many of our DIMPACT participants are now digital-first organisations, with others making the transition this way, using DIMPACT helps to give a comparison of the life cycle of physical products that they are replacing and augmenting.

Respond to customers', policy makers' and stakeholders' data needs

Many DIMPACT participants and media companies are being asked about the impact of their digital services.

This is against a backdrop of media attention about the impacts of our lives switching to digital, IP-delivered content. As a result, we have seen a significant variance in the estimates of such emissions conveyed in the media. This has led to mixed messages for consumers, policymakers and media companies themselves. Many of the estimates have been found to be inaccurate for reasons such as extrapolating current (or outdated) energy or GHG intensity figures (see, for example, the IEA's response to recent media articles). For example, the GHG emissions per gigabyte of data transferred over the internet in a specific year cannot necessarily be used to estimate the emissions associated with future or hypothetical demand.

In addition, we also see unsound uses of attributional modelling approaches (generally used for retrospective reporting) for predicting the consequential impacts of future changes in the media landscape.

For an overview of some of the flaws of ICT energy modelling, we recommend this blog post, based on an academic journal article in Joule by Eric Masanet and Jonathan Koomey.

DIMPACT aims to help clear up such misunderstandings by providing a standardised, up-to-date and organisation-specific approach for estimating the footprint of digital services. The outputs of the tool provide total energy consumption and GHG emissions by device type used for the in-scope services (such as streaming and digital publishing). This provides a product-level – rather than just an organisational-level – footprint.

Enhanced Scope 3 GHG reporting

As mentioned in the previous section, DIMPACT provides a product-level footprint, not an organisational footprint (as is required for corporate reporting). However, the two are not mutually exclusive and the use of the DIMPACT tool provides useful data to input into participants' scope 3 footprints.

Some processes that are within the scope of the DIMPACT model may be within an organisation's own operations – for example, processes run on data centres owned and operated by that organisation. However, it is likely that a majority of the processes lie outside of the organisational boundary and thus are considered scope 3 emissions. The GHG Protocol Corporate Value Chain (Scope 3) Standard specifies 15 categories of Scope 3 emissions, relating to different parts of an organisation's value chain. For DIMPACT, the relevant categories are Category 1: Purchased Goods and Services and Category 11: Use of products sold.

The DIMPACT scope generally takes companies beyond the compulsory scope of activities that require inclusion in scope 3 accounting and target setting. Aside from a few exceptions, DIMPACT participants do not typically sell the devices that their content is viewed on, thus the emissions from devices such as TVs, internet infrastructure and set-top boxes are considered to be indirect use-phase emissions. Indirect use-phase emissions are an 'optional' requirement for inclusion in these organisations' scope 3 inventories and targets, as outlined by the GHG Protocol and Science-Based Targets Initiative Net-Zero Standard (SBTi):

"Indirect use-phase emissions are generated by products that only consume energy indirectly during use over their expected lifetime. Examples of such emissions include the washing and drying of apparel for apparel manufacturers and the cooking and refrigeration of food products for food retailers.

Indirect use-phase emissions are not within the "minimum boundary" for category 11 (use of sold products) and are listed as "optional."

***If companies have significant indirect use-phase emissions and have levers to address them, they are encouraged to estimate these emissions and set an optional target on these emissions**. Despite this, optional scope 3 emissions are not counted towards the two-thirds boundary in near-term science-based targets and 90% boundary in long-term science-based targets." – Science-Based Targets Initiative Net-Zero Standard (p21-22)*

Using the basic processes of the DIMPACT model, Figure 1 outlines how the processes mapped in DIMPACT align with the GHG Protocol's Scope 3 categories. Please note that some media organisations, including some DIMPACT participants also sell devices, are also ISPs, and/or operate their own content delivery networks. In these cases, Figure 1 would require some adjustment. Some of the categories marked as scope 3 would become scope 1 & 2, as these processes would be within their organisational boundary.

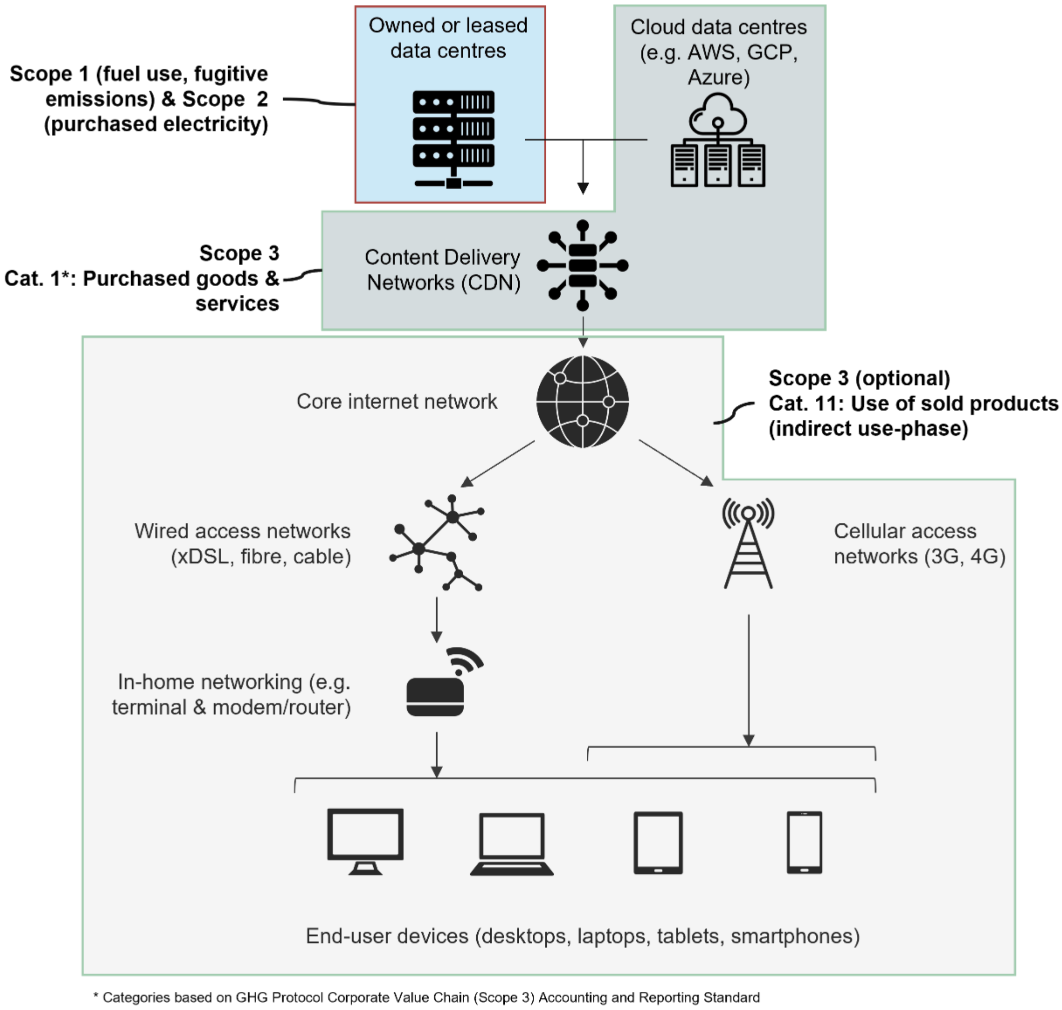

Figure 1. Processes modelled in DIMPACT mapped to a typical digital media organisation

Share learnings amongst participants, and get involved in methodological developments

The companies that have joined DIMPACT proactively engage in the conversation about how to estimate and address the emission from digital media and entertainment products. They are also actively involved in activities and discussions to further enhance and develop the approach and assumptions. DIMPACT provides a platform to explore these challenges and propose new developments. See more in the section: About the DIMPACT initiative.

Drive greater industry transparency and collaboration, enabling rapid decarbonisation

Whilst many of the emissions of digital products and services may fall outside the required scope 3 boundary, the organisations involved in DIMPACT are not washing their hands of these emissions. DIMPACT assessments allow organisations to pinpoint their use-phase emissions hotspots associated with their digital media and entertainment products (which may sometimes be 'blind spots'), which helps to engage with their value chain. We believe that collaborative engagement is best to understand the opportunities for media organisations to influence these emissions – either directly through product design, or indirectly by encouraging value chain participants to abate and neutralise such emissions.

You can read more about how we are engaging with the wider industry in the section: About the DIMPACT initiative.

Methodology

DIMPACT uses an attributional life-cycle assessment approach, which aims to align with the GHG Protocol Product Standard and draws upon the GHG Protocol ICT Sector Guidance. This approach involves mapping the functional processes in the delivery of digital media content (the processes considered in-scope are outlined below) and then parametrising each of these processes.

Developing the DIMPACT methodology

DIMPACT progresses prior academic and industry research, and it consolidates it into a standard model and methodology. Notably, the DIMPACT approach draws upon the analysis completed by the BBC and the University of Bristol, which in turn pulled together a corpus of modelling techniques proffered by academia and industry. This research has been peer-reviewed and published in the journal "Environmental Impact Assessment Review".

This work was tailored to the BBC, so the development of DIMPACT aimed to generalise the approach to be applicable to a wider range of companies. This involved in-depth engagement with the participants about the structure of their systems – this engagement continues today as new participants join the initiative.

In broad terms, the three major questions that we asked during the development phase were:

- What does the technical architecture of your systems look like?
- What is the scale of usage of each component, and how does this scale with increased/decreased utilisation?
- How do you measure the behaviour of your audiences/viewers, and what does this look like (e.g., device types used, typical means of connectivity, offline vs online usage, etc.)?

This allowed us to develop our process maps and computational models of the components of the system to generate an estimate of the system as a whole. The final models developed were abstracted and generalised to be applicable to similar companies using each of the modules. The term "module" refers to each application of the DIMPACT approach. Currently, we have developed modules for:

- Digital publishing
- Video streaming
- Online banner advertising (further development ongoing)

We then developed the web-based user interface to take the inputs from participating companies to run their assessments.

Our method for the video streaming module was also presented in the white paper, the Carbon Impacts of Video Streaming, which was authored by the Carbon Trust. This document has some crossover with this white paper but is broadened to cover the other modules covered by DIMPACT.

The scope and boundaries of the DIMPACT model

The processes mapped and measured within DIMPACT fall into three high-level categories, regardless of the digital service being measured. These are outlined in Table 1 below.

Table 1. Summary of the typical processes modelled in DIMPACT (note that these will vary by module and organisation)

Data centre processes (varies by module, but examples provided below)	**Internet network infrastructure**	**End-user devices (varies by module)**
• Content ingestion & uploading • Encoding and transcoding • Storage • CDN Origin • User analytics services • Hosting services • [other module-specific processes]	• Core internet network • Metro networks • Access networks • Content Delivery Networks (CDNs) • Customer premises equipment (CPE) – modem routers, Wi-Fi repeaters, etc.	• Televisions • Laptops • Set-top boxes • Computers & monitors • Tablets • Smartphones • Smart speakers

Process boundaries

The production phase of content is excluded from the process boundary of the DIMPACT model. There are other industry initiatives, such as Albert and AdGreen, that focus on the production, travel, and editing required to produce content.

A caveat to this is that for some publishing organisations, content production is so intertwined with the operational and distribution systems that exclusion becomes impractical. This is especially the case where content authoring and management are highly integrated and for academic peer review platforms.

We also exclude corporate functions that are not directly related to content management and distribution. For example, HR systems, back-office administration, corporate business travel, and so forth.

Emissions scope boundaries

DIMPACT's initial objective is to measure use-phase emissions at a minimum. Use-phase emissions are those that result from the electricity and energy consumption of equipment used to process, transfer, and view content. What is excluded from this minimum boundary are the emissions from the raw material extraction, manufacturing, transport and installation of the equipment and devices used to serve and view digital content. These are known as 'embodied emissions. The tool supports adding wider boundaries if desired, including embodied emissions. If publishing data or results, participants should be clear if these boundaries are met or exceeded.

Some studies have estimated the proportion of embodied emissions in the entire life cycle of ICT equipment, such as the estimates presented in Figure 2. Whilst these high-level estimates do not provide specific estimates of the services used by DIMPACT participants, they give a rough idea of the proportion of life-cycle stage ratios. This helps to understand how the results may differ if embodied emissions were included. It is important to note that these ratios will change based on the carbon intensity of the electricity grid where the equipment and devices are used and manufactured.

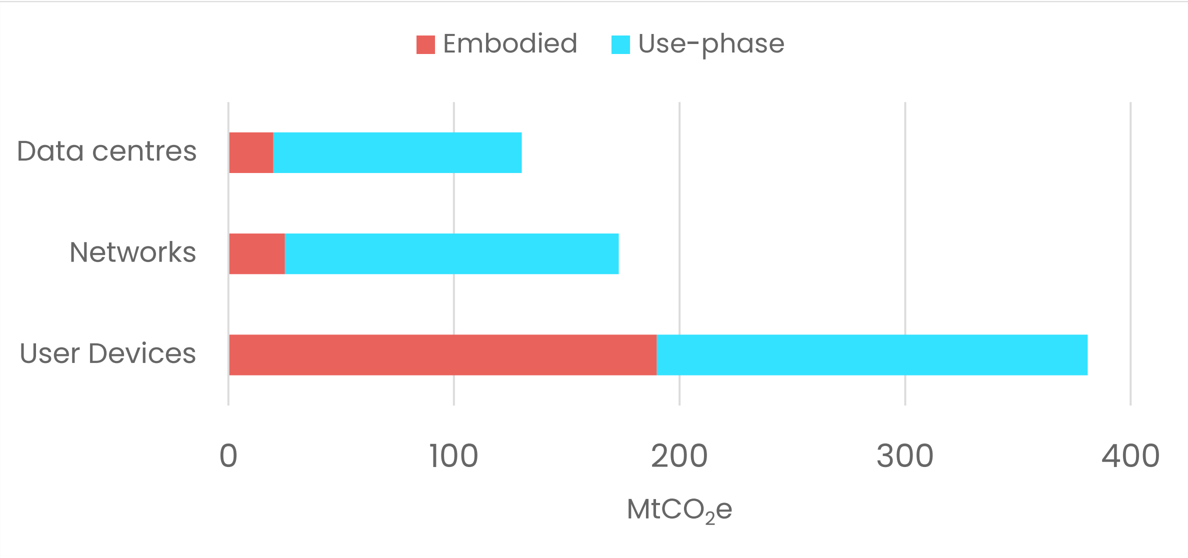

Figure 2. Breakdown of emission in the ICT Sector, by component (Source: Adapted from [Malmodin, 2020](#) – see slide presented at 6:30)

The GHG Protocol ICT Sector Guidance also provides typical life-cycle ratios of ICT equipment by device category, which are summarised in Table 2. These are largely in agreement with the results presented in Figure 2. Note that televisions are not included here, as these are part of the Entertainment and Media sector.

Table 2. Typical life cycle ratios of ICT equipment (Source: Adapted from GHG Protocol ICT Sector Guidance, Table 5.9 and 5.10, Section 5)

Type of equipment	Use phase	Embodied
LED/LCD monitors	20%	80%

Type of equipment	Use phase	Embodied
Mobile phones & personal computers	30%	70%
Set-top Box	80%	20%
Home gateways and modems (CPE)	80-85%	15-20%
Routers & switches (business to business)	85-90%	5-10%

By default, the tool uses location-based emissions factors for converting electricity to carbon emissions. These only include the emissions from electricity generation, not well-to-tank and transmission and distribution losses (see below). However, carbon intensities of electricity generation can be set by the user, so the tool can also be used for market-based estimates. We recommend that companies analysing market-based emissions also evaluate and report location-based emissions in parallel to be in line with best practices outlined in the Greenhouse Gas Protocol Scope 2 Guidance (See Table 1.1, p12).

In future developments, we plan to also include the option to incorporate transmission and distribution (T&D) losses for electricity generation, as well as the well-to-tank (WTT) emissions for extracting, refining and transporting fuel for use in electricity generation. This is in line with the Greenhouse Gas Protocol ICT Sector Guidance (p23, Section 1). If users want to include these using the current model, they can adjust the emissions factor fields in the model. If this is the case, we suggest that this should be stated when presenting the results.

Enabling effects of digital media and entertainment products

Enabling effects are not considered directly in the DIMPACT approach. Enabling effects are the opportunities that a service may have to avoid emissions in other sectors. For example, the transition from printed to digital newspapers may reduce the emissions from the pulp and paper industry, as well as the printing and transport sectors. Similarly, the uptake of video conferencing may reduce the need for business travel.

The GHG Protocol Product Standard specifies that "offsets and avoided emissions are both classified as actions that occur outside the boundary of the product's lifecycle." Thus, these emissions "should not be deducted from the product's total inventory results but may be reported separately." Therefore, DIMPACT recommends that participants and those interested in digital products and services also consider their wider enabling effects in addition to the emissions of delivering these services. However, an approach to estimating these enabling effects is not covered by DIMPACT.

When presenting results, we encourage digital emissions to be placed within the context of other activities, in order to understand the magnitude of the results.

Modelling system components with DIMPACT

The three system categories outlined in Table 1 are modelled in DIMPACT differently, and each requires different inputs when conducting modelling. The below sections summarise the modelling for each of these processes.

Data centre processes

For each module, the functional diagrams for DIMPACT provide a fairly comprehensive checklist of processes that organisations may use to provision, process and distribute their content. The functional diagrams are produced by working with the relevant technical teams from the DIMPACT participants. They are designed to be a general and comprehensive map of the likely components in each case.

In general, we have found that data centre processes (excluding CDNs) do not scale linearly with viewership. As such, we recommend gathering primary data from those who own that process, as it is the most reliable way to capture the required data.

The scale of emissions from data centre processes for video streaming was found to be relatively low when compared to other processes. Analysis of DIMPACT participants' assessments by the Carbon Trust (see p found that data centres used 1.3Wh per hour of streaming. This is compared with 100Wh per hour for a Television. However, these proportions may be different for other digital products and services where increased computational power is needed to serve content, and smaller devices are more commonly used.

Because of the very wide variety of approaches, technologies, and services used to provide the back-end data centre components of a digital service, we advise organisations to first engage with their suppliers to gather this information. As such, in most cases, the DIMPACT model simply asks for total energy (kWh/month) or GHG emissions (kgCO2e/month) for each of the component services.

Where the use-phase electrical energy (kWh/month) values are provided there is an additional input for the estimated carbon intensity of the electricity used by the data centre or service. The use-phase GHG emissions are calculated based on Equation 1.

Equation 1. Use-phase GHG emissions of data centre components

*Data centre component use-phase GHG emissions = electrical energy per period (kWh/period) * carbon intensity electricity used (kgCO2e/kWh)*

The carbon or electrical energy values may be derived in several ways depending on how the components operate. This is summarised in Table 3.

Table 3. Types of data centres used and typical data sources

Type of data centre	Examples	Typical data sources to estimate emissions
Owned or leased data centres	• Premises data centres • Colocation data centres	• Direct from your own organisation if the facilities are owned or leased
Hosted Infrastructure as a Service (IaaS)	• Microsoft Azure • Google Cloud Platform (GCP) • Amazon Web Services (AWS)	• Direct from the IaaS/SaaS service provider • Estimated from operational and billing information • Environmentally Extended Input-Output (EEIO) factors
Software as a service (SaaS) and/or platform as a service (PaaS)	• User analytics & recommendation tools • Encoding providers	

Many of the services that participants use run via third-party cloud IaaS providers, such as Amazon Web Services (AWS), Google Cloud Platform (GCP) and Microsoft Azure. Some of these organisations are beginning to share customer-level emissions data, and we recommend that participants request and review these reports as part of running a DIMPACT assessment. Alternatively, we have produced a Supplier Data Request Form that can be used to request this information – available on the Resources section of the DIMPACT website.

Currently, we have seen that data from providers may not include both location-based and market-based emissions or may be aggregated to include carbon offsetting. In addition, these may or may not include data on their own Scope 3 emissions. Many of these discrepancies may be explained by the fact that there is no cross-industry standard that is available to these vendors for such reporting.

The DIMPACT team has not reviewed or verified these approaches in detail and supports the standardisation or certification of such approaches. We encourage cloud services providers to share both location-based and market-based emissions as well as clear documentation of their assessment methodologies. The methodology is important because it will outline what is and is not included in their assessments and what data and modelling have been used to make their estimates. We are also encouraged to see many of these providers working with their customers to reduce their footprint.

We are currently exploring how we can model these processes based on other usage metrics. For example, types of virtual computer instances and amounts of storage. However, there are other tools that allow you to obtain estimates based on this kind of activity data, such as administration consoles and billing metrics. A team at ITV developed and evaluated this approach in 2019/20 based on the metrics of Virtual CPU hours (vCPU hours per period) and Storage Hours (Terabyte hours per period). This approach has now been more widely explored and an example of its implementation is cloudcarbonfootprint.com which provides useful documentation on their approach.

A note on data granularity

The experience of DIMPACT participants is that generally one cloud service provider is used to run most of the processes that are in-scope for DIMPACT. As such, the emissions data provided by this provider may not be broken down into the individual processes that are outlined in the DIMPACT model.

For the purposes of reporting, there is no need to break this data down any further, and the data received can be lumped in the 'Other' field in the model, with notes added accordingly.

If your goal is to understand which processes are most energy-intensive, you may wish to break this data down further. Some cloud service providers may be able to provide this data at the instance level, which is tagged in a way that enables mapping emissions or energy consumption to each process in DIMPACT. We recommend engaging with your provider to see if this level of data is available.

For each process that is relevant to you, we recommend that you engage with the supplier or internal team if this process is owned and operated by your organisation.

Internet distribution infrastructure

DIMPACT estimates the use-phase networking energy consumption of a given service using a data volume allocation approach. This is aligned with the GHG protocol to model the energy consumption of the internet attributed to a given service. The model does not include embodied emissions, or the emissions caused by internet infrastructure providers' activities outside of directly powering the network (e.g., stores, company vehicles and offices).

We use an intensity figure to estimate the energy of the internet consumed to transfer a specific volume of data, as per Equation 2. For a discussion on the intensity factors used, as well as their limitations, please see the section below: Internet energy consumption.

$$\text{Internet energy consumption} = \text{data volume transferred (GB)} * \text{intensity (kWh/GB)}$$

Equation 2. Calculation of energy consumption of internet infrastructure

Data volume transferred

The DIMPACT model estimates the data volume transferred based on company-specific information that is input into the tool. This data is sourced from companies' historical aggregated user analytics data over a specified time period, and (where available) the corresponding host server access logs combined with estimates of data volume transferred per interaction. The specific inputs are discussed further in the End-user devices section.

The user analytics and system logs are generally obtained from participants' internal systems teams and user analytics tools or 3rd party services such as Google or Adobe Analytics.

In general, 3rd party user analytics services and your own user analysis tools will focus on human users. They will generally exclude non-human users, such as bots, spiders and crawlers who visit your site and harvest content for a variety of purposes. See below for more details.

The data volumes are then calculated using the below Equations, depending on the service being modelled.

Equation 3. Estimating data volume transferred for webpages and mobile apps

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For webpages and mobile apps:

*Data volume transferred = mean data volume per pageview * number of pageviews per period*

*Data volume transferred = mean data volume per app session * number of app sessions per period*

Equation 4. Estimating data volume transferred for downloads

For downloads (publishing module only):

*Data volume transferred = mean data volume per download * number of downloads per period*

Equation 5. Estimating data volume transferred for streamed video

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For streamed video:

*Data volume transferred = mean bitrate of content served * duration of content served per period*

Currently excluded but under investigation: non-human end-users

In most cases, for the current DIMPACT modules, the majority of user requests and data transferred will be from human users. However, there is also access by non-human users such as bots, crawlers and spiders. These can be categorised as:

- *Known-legitimate bots.* For example, search engines, link tracking, and service monitoring bots. These are often part of a company's own monitoring, or actively encouraged to enhance search engine optimisation.
- *Bad bots.* For example, hacking attempts or illegal content harvesting.
- *Legitimate-but-problematic bots.* For example, content harvesting but meeting licence conditions when harvesting, or badly written bots that make more requests than needed.

DIMPACT has not yet fully investigated the impacts of bots on the data volumes transferred by services and the impacts they could have on the DIMPACT results. Nor have we addressed the question of allocation for who is responsible for their energy consumption – both in terms of the network energy consumption and the processing and storage.

This presents a challenge because of the myriad behaviours of these bots, in terms of the types of requests made, and the amount of content gathered (e.g., full webpage versus headers, or even simply receiving an error message).

Understanding the scale of these bots requires further investigation. We are currently working with some DIMPACT partners to provide more clarity.

Because different devices may have different data volumes per interaction, or video bitrates, data volumes are estimated per device type (e.g., tablet, smartphone, computer). The model then aggregates the data volumes transferred across all device types transferred over the assessment period.

For web and mobile app content, the data volumes are estimated for *content received by the end-user* for a service rather than the data served by the host organisation to the user. That is because webpages and app content for a single pageview or app session may be served from many different servers/data centres. In addition, there may be other services such as user analytics and advertising brand protection or auditing services.

We work with DIMPACT participants to help them estimate the mean data volumes or bitrates for the calculation, as this may not be straightforward and may vary between participants. This can be done by a sampling of web pages or app sessions on different kinds of devices or by estimating appropriate weighted average bitrates for video streaming.

Those input variables are discussed further in the End-user devices section.

Internet energy consumption

Internet energy consumption is estimated by DIMPACT using the approach described in the Greenhouse Gas Protocol ICT Sector Guidance (Chapter 4, p26), which uses a single intensity metric based on the data transferred in kWh/GB, with different values for fixed-line and cellular (mobile) networks.

> *"The internet emissions may be calculated by using an energy intensity factor for the internet (expressed in kWh/GB) and multiplying this by the data transferred (in GB) and an electricity emission factor (in kg CO_2e / kWh)." – GHG Protocol ICT Sector Guidance (Chapter 4, p26)*

Fixed line includes different kinds of access networks used. For example, Fibre to the Cabinet (FTTC), Fibre to the Premises (FTTP), ADSL, or Cable that connect homes and premises to the core of the internet.

Please note that using kWh/GB intensity figures are not suitable for estimating the future or instantaneous change in energy consumption of internet network transmission

Using an intensity metric based on data volumes (kWh/GB) can only be used to attribute the product or service's share of the internet's energy consumption over a defined period in the past using actual estimated (not hypothetical) data volumes, such as for GHG accounting and reporting. Therefore, the intensity figures presented in this section cannot be used to speculate on hypothetical and/or future energy consumption as a result of changing data consumption, especially for high-bitrate activities.

This is because the intensity factors used:

- Are based on average data transmission and power consumption over a defined historical period, and thus do not factor in the dynamic relationship between the energy consumption of the internet infrastructure based on changes to data volumes; and
- Are likely to change in the future. As Figure 3 demonstrates, historic trends show network energy intensity halving every two years as data transmission has significantly increased due to improved efficiency or the internet infrastructure's ability to serve higher data volumes using a similar amount of energy. IEA analysis shows a moderate increase in energy consumption between 2015 and 2021 whilst data volumes transmitted have increased by 750% in the same period.

This view is shared by our Expert Advisory Panel, who are challenging DIMPACT to develop a broadly accepted model for internet transmission and CPE that does reflect these dynamics. This is especially important for high bitrate activities such as video streaming, video conferencing and large downloads, where the use of a kWh/GB figure incorrectly implies a significant increase in network energy consumption. Evidence from Malmodin (2020) suggests that internet network energy consumption has only a small incremental instantaneous increase as a result of higher data transmission, and is not directly proportional to data volumes transmitted.

A possible solution, as used by the IEA, Ericsson and discussed by the Carbon Trust, is to switch to a time-based approach to modelling network energy for high bitrate activities. This may more accurately reflect the instantaneous impact for causal modelling. For further discussion of this concept, please refer to the Reporting versus causal modelling section, as well as the Expert Advisory Panel discussion.

The intensity values currently available are assumed to be global averages. These figures are derived from a top-down analysis of an infrastructure's total energy use divided by its total data volume transferred over a full calendar year. As such, it is important to note that its use is only valid for attributional and not consequential or enabling assessments. The global nature of this figure also presents uncertainty, particularly for participants with users concentrated in fewer countries.

Cellular network intensities are generally found to be higher than fixed line networks but are particularly debated. In practice, they will vary by the type of access network, country and other factors. However, reliable country-specific data is not currently available, and the use of the overall average global value is most widely used.

The proportion of traffic transferred over cellular networks is estimated via inputs from the DIMPACT participant - discussed further in the End-user devices section.

Whilst different studies measure this differently, the energy intensity per bit of data transferred has been found to be decreasing year on year, as shown in Figure 3 below. These decreases have historically been exponential with the kWh/GB intensity halving for fixed-line networks about every two years and cellular networks a bit more quickly – although there is large uncertainty. Trends are due to two main factors 1) increasing data transferred per year and 2) increasing efficiency of the network equipment and network architectures. In very rough terms the energy use for the networks (kWh/year) is stable or slowly increasing over time while the data volumes (GB/year) transferred grow exponentially – driving the roughly net exponential decrease in energy per GB (kWh/GB).

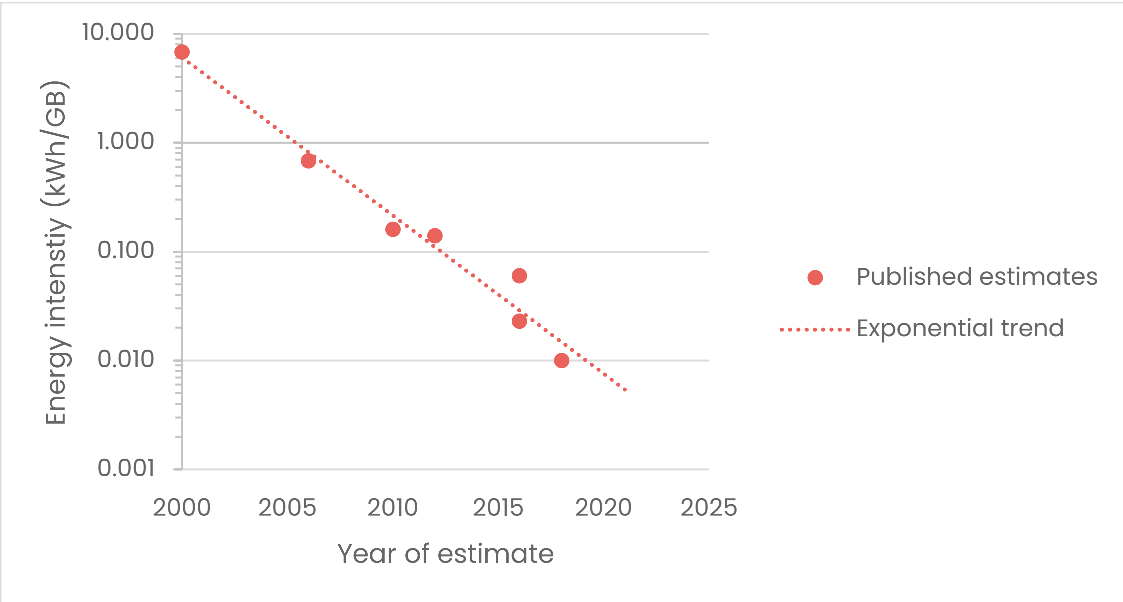

Figure 3. Estimates of energy intensity of fixed-line networks (kWh/GB) – LOG scale (adapted from [Aslan et al, 2018](#))

However, the years 2019 to 2021 have been highly unusual with vastly increased home working and other changes due to the Covid-19 pandemic, significantly increasing internet traffic. Data is becoming available for those years, but the trends are not yet clear, and data may need updating retrospectively as the situation becomes clearer.

We plan to update our figures periodically as more data becomes available – either through academic studies or directly from Internet Service Providers (ISPs). In addition, we are exploring alternative methodologies for quantifying the energy consumption of networks, including expressing the energy consumption as the Watts per subscriber as per the Power Model outlined in the Carbon Trust White Paper (see Section 5.3), drawing upon Jens Malmodin's research. Watts per subscriber data may become available through industry or policy initiatives. For example, Arcep – the French telecommunications regulator – is starting to gather data from major French ISPs.

Table 4. Summary of internet network energy intensities used in DIMPACT

	Fixed-line networks	**Cellular networks**
Intensity figure	0.006 kWh/GB for year 2020 Based on Aslan et al (2018) see below.	Range 0.1 – 1.0 kWh/GB (2020) After review of the available data the Carbon Trust used a value of 0.1 kWh/GB based on Pihkola (2018) in their Whitepaper 'Carbon impact of video streaming' (2021)
Scope	• Backhaul/Metro/Core network • Access network	Data available varies but would ideally include (as Pihkola et al 2018): • Backhaul/Metro/Core network • Access network
Exclusions	• CDNs (included elsewhere) • CPE (included elsewhere) • Data centres (included elsewhere) • Undersea cables	• CDNs (included elsewhere) • Undersea cables
Source	Aslan, J., Mayers, K., Koomey, J.G. and France, C. (2018), Electricity Intensity of Internet Data Transmission: Untangling the Estimates. Journal of Industrial Ecology, 22: 785-798. https://doi.org/10.1111/jiec.12630	Modelling based on corporate reporting and Pihkola et al (2018) 'Evaluating the energy consumption of mobile data transfer – from technology development to consumer behaviour and life cycle thinking'. Sustainability, 10(7), p2494. https://doi.org/10.3390/su10072494

The carbon footprint of the networks is estimated using Equation 6 below.

Equation 6. Estimating the carbon emissions of internet energy consumption

*Carbon Footprint (kgCO2e/period) = Carbon intensity of electricity (kgCO2e/kWh) * Electrical energy used in data transfer in period (kWh/period)*

Currently, in the DIMPACT modules, the carbon intensity of electricity is a single value. For those organisations with audiences across multiple countries, we work with them to develop a weighted mean for the electricity carbon intensities of the relevant countries or regions.

Content delivery networks

In many digital services, the majority of digital media content is delivered to end-users via Content Delivery Networks (CDNs). CDNs are services that duplicate, and cache (temporary store) high-demand data provided by service providers (e.g., TV streaming companies, news media, popular web content, etc.) so that it is geographically closer to users than would be the case if it were stored on a single data centre location. The goal is to provide a higher quality of service to users regardless of location or scale of demand. It is also a necessity for the functioning of the internet, as it reduces traffic in the metro and core networks.

Most large digital services use CDNs for serving some of their content. As with data centre services, CDN service providers may be able to provide an estimate of customer-level energy use and/or carbon footprint of the service they provide. Just like data centre services in DIMPACT, a value can be inputted for the total GHG emissions footprint or electrical energy use combined with an estimated carbon intensity for the electricity.

Alternatively – depending on the DIMPACT module – the footprint can be estimated via a data volume served by the CDNs and an estimate of the energy intensity (kWh/GB served) from the study 'Evaluating Sustainable Interaction Design of Digital Services: The Case of YouTube, CHI '19 conference'.

The default value used is from public data that is over two years old, and the value for intensity may vary significantly by application and provider, so we advise teams to contact the provider, if possible, only using the default if this data is not available. As part of our broader industry engagement, we are looking to engage with major CDN providers to update these figures from primary industry data.

In the video streaming module, the model assumes that all streaming is via CDNs. Based on our experience working with the relevant DIMPACT participants, we found that this assumption is likely to be realistic. This is calculated as it is for the internet transmission – from end-user device data. The current version of the publishing module gives a choice of an estimate of the proportion of overall data volume that flows through CDNs or a total data volume.

In the case where the energy use of the CDNs is estimated using the default intensities, this is calculated using Equation 7.

Equation 7. Estimating energy consumption allocation of CDNs

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*Electrical energy used in CDN services in period (kWh/period)= Electrical Energy intensity of CDN Services (kWh/GB) * Data volume served by CDN service per period (GB per period)*

The data volume served variable in the equation above is generally calculated based on user analytics data (page weights and/or bitrates on each device).

From there, the GHG emissions are estimated using Equation 8. This equation also applies if users enter a pre-measured electricity consumption value.

Equation 8. Estimating the GHG emissions of CDNs

*GHG emissions (kgCO2e/period) = Carbon intensity of electricity (kgCO2e/kWh) * Electrical energy used in CDN services in period (kWh/period)*

Where more than one CDN is used, the values for each should be combined – carbon footprint or energy – and entered for the service as a whole.

Customer premises equipment

Customer premises equipment (CPE) is networking equipment, such as modems, Wi-Fi routers and range extenders on the customer premises. This equipment is likely to be used to provide households and organisations with a wide variety of services delivered via the internet. Thus, we must allocate a share of the energy consumption of this equipment to the service.

The widely accepted approach, which is recommended by the GHG Protocol ICT sector guidance, is to allocate energy and GHG emissions to a particular service based on its share of data transferred – which is similar to the allocation approach used for internet networks. For domestic networks, the allocation to services is based on the share of the total data volume transferred through the equipment in a period for that service.

Allocating this way means that a service using a high proportion of the data volume will be allocated a larger share of the footprint than one with a lower data volume. Home networking equipment energy use may vary quite considerably from country to country, as does the total data volume used by households.

Estimates of the total data volumes per household are publicly available for a selection of countries. The main source of data used in DIMPACT is the Ofcom International Broadband Scorecard. This data provides the total data volume used per capita within a given country. We estimate the total data volume per household, based on the average number of people per household, per country. For the UK, Ofcom provides this information in their Media Nations Report. For 2021, this was 453GB/household. A summary of values for different countries is outlined in Appendix 1 – Data consumption per household.

We work with participants to estimate data consumption for markets where published data is not available, with the longer-term intention of encouraging an expansion of reporting on data volumes in more markets.

In the DIMPACT tool, we estimate the data volume transferred for the service by aggregating the data volumes for each kind of device outlined in the End-user devices section below. This is similar to the approach used to calculate the data volumes transmitted via IP networks, as explained in the section Data volume transferred above.

The mean energy per unit of data (kWh/GB) is derived from an estimate of mean power (Watts) used by the customer base's devices divided by an estimate of the total data volume used by households in the customer base. This allocates a portion of the router's power to the service being assessed. Studies, such as Malmodin (2020) have suggested that the power consumption of CPE is essentially constant regardless of the data being processed. Therefore, instantaneously, data usage does not cause a significant uplift in the power of CPE. As such, this approach can only be used for attributional assessments, not to evaluate the instantaneous or consequential uplift in power consumption in CPE due to a user consuming content.

Finally, the associated carbon footprint is calculated based on the share of users (see above) in different countries to account for the different carbon intensities of electricity generation in different countries. A weighted average should be used based on the grid carbon intensities and the number of users in each country. Currently, this is done within the tool for the publishing module, but this must be done outside the tool for video streaming.

The calculations used will vary by module have the form:

Equation 9. Estimating the total energy of CPE

*Total mean energy of CPE per period per premises (kWh/period) = Mean power of CPE on premises (kW) * Duration of period (hours per period)*

Equation 10. Estimating energy intensity for CPE

Mean Electrical Energy used by CPE per GB (kWh/GB) = Total mean energy of CPE per period per premises (kWh/period) / Total mean data volume used per premises per period (GB/period)

Equation 11. Allocating energy consumption for CPE

*Estimated CPE electrical energy allocated to service (kWh/period) = Mean Electrical Energy used by CPE per GB (kWh/GB) * Data volume transferred over fixed-line networks per period (GB/period)*

Equation 12. Estimating GHG emissions for CPE

*Carbon Footprint (kgCO2e/period) = Carbon intensity of electricity (kgCO2e/kWh) * Estimated CPE electrical energy allocated to service (kWh/period)*

Currently, the DIMPACT model only includes domestic networking equipment. We are currently investigating whether there is a material difference in the impacts of non-domestic networking (e.g., universities organisations), and the data and parameters required to add this to the modelling.

End-user devices

For most digital services assessed by DIMPACT participants, and in other studies, the majority of the energy and use-phase carbon footprint is caused by end-user devices. For that reason, we encourage participants to focus on this section when completing an assessment.

As part of running an assessment, organisations provide company-specific data for each type of device (smartphone, tablet, computer, TVs, STB, etc.) that is applicable to the organisations' audience. This enables the estimation of both energy consumption, and subsequently the use-phase GHG emissions. These are estimated using Equation 13 and Equation 14 below. For end-user devices, unlike the internet and CPE, energy consumption is allocated based on time, using primary data on the amount of time the service is typically used.

Equation 13. Energy consumption of end-user devices

Device energy consumption (kWh) = Duration of service (W) x Power consumption of device (hrs) / 1000 (W/kWh)

Equation 14. GHG emissions of end-user devices

GHG emissions (kgCO_2e) = Energy consumption (kWh) GHG emissions factor for electricity used in users' homes (kgCO_2e/kWh)*

User-device data inputs are typically sourced from user analytics teams within participating companies. This input section of the tool is also used to gather the data necessary to estimate the data volumes transferred across CPE, internet distribution infrastructure, and CDNs, as referenced in the sections above.

The specific inputs vary by module. Data is input per device type, as behaviour data inputs and data volumes may vary depending on which device is being used to access the service. For each module, we have a table of all input requests which is available upon request. These inputs are summarised in Table 5 below.

Table 5. End-user device inputs

<table>
<tr><th>Publishing module</th></tr>
<tr><td>For each device type (tablet, computer, smartphone):
• Number of web page views, app pageviews/sessions and/or downloads
• Mean duration of use by the user per pageview/session
• The proportion of views/sessions per country, based on locations of end-users
• An estimate of the mean power of the type of end-user device (see below)
• An estimate of the proportion of computer viewing that occurs on laptops vs desktops
• Mean data volume for each view/session for each device type
• Bitrate of embedded video
• Number of downloads (and average file size)
For Smart Phones and Tablets the proportion of use over cellular networks (used for network energy calculations – see above)</td></tr>
<tr><th>Video streaming</th></tr>
<tr><td>For TVs:
• Number of households that use a TV to view the service
• Proportion of viewing on primary (typically larger) vs secondary (typically smaller) TVs.

For TVs and Set-Top Boxes:
• (optional) Estimated service device hours as a proportion of total device hours – required if standby is to be included

For each device type (tablet, computer, smartphone, TV, STBs, streaming devices, games consoles):
• Unique number of devices used to access the service
• Total number of service hours per day
• Proportion of viewing over fixed line and cellular networks
• Average bitrate of content, per connection type (fixed & cellular)
• Estimated proportion of viewing on primary vs secondary TVs</td></tr>
</table>

End-user device energy and GHG emissions are estimated using the below equations.

Equation 15. Estimating service duration of end-user devices

Mean service duration per period on device type *= Number of views/sessions per period (no) * Mean duration per view/session*

Or

Mean service duration per period on device type *= duration as measured by user analytics systems directly*

Equation 16. Estimating end-user device energy

End-user device energy for device type *= Mean power of device type (W) * mean service duration per period on device type (hrs per period)*

Equation 17. Estimating GHG emissions from end-user devices

End-user device carbon footprint for device type *= End-user device energy for device type * Carbon intensity of electricity (kgCO2e/kWh)*

The end-user device average power (Watts) for a service will be *service dependent* and the input values should ideally take account of the service energy intensity and the device demographics. See below for some examples.

The power (Watts) used by laptops varies significantly depending on models, workload and whether they are connected to an external monitor. Different types of service may be used by different types of users and on different types of devices (e.g., netbooks Vs full laptops), all with different power requirements. For example, the mean power for non-intensive uses (e.g., web-browsing non-video content) may be about 15W, where for more intensive services it may be over 50W.

Our own measurements on laptops for video conferencing services indicate that, for a specific video conference service the average power on two sample laptops (Mac and Windows computers) was approximately 20W higher when in a video call than at baseline power, which was around 10W. That is approximately 200% over the baseline power. The baseload power would be roughly the short idle power as used in Energy Star and EU Energy Certificate measurements.

Regarding demographics in earlier work, we have found that using BARB data (BARB actively monitor and survey TV viewing behaviours) from the UK that TV viewers, who watch via different platforms (digital terrestrial, satellite, cable) have different size TVs on average – and so different power consumptions as TV power use is correlated with screen size with power use varying by up to 18% between platforms.

A further example of user device demographics is the power consumption differences using laptops with or without external monitors. Laptops on their own are generally low power – approximately 15W in short idle state (e.g., reading a static webpage). However, for some services, a significant proportion of their users may use an external monitor. If a 24-inch external monitor is used, this may add about 17W. Larger 27-inch monitors could be higher at an estimated 25W. In addition, the laptop itself may also need more power to drive the monitor. Our initial measurements indicate that this varies by device but may be of the order of 6W.

There may also be variation in the power consumption of televisions based on whether peripherals are being used to view the content (for example, streaming on an app on a STB). Anecdotal evidence suggests that when peripherals are used, the television acts only as a display panel, and may reduce its power consumption when the computational power required to process content is being done on a peripheral device. However, this has not been confirmed via systematic testing. Therefore, the DIMPACT model currently assumes a flat value for simplicity.

There may also be variations by country. Some DIMPACT organisations have been able to obtain survey or user analytics data about the types of devices used by their users. We recommend talking to the DIMPACT team about which values to use.

The DIMPACT tool provides example power values for estimating average device energy consumption, as outlined in Table 5 below. Note that these are possible upper and lower bounds, not minimum and maximum values. These can be used for initial estimates, but we recommend that participants look to investigate further based on the above, to determine organisation-specific values. We are currently exploring options to undertake our own device testing to validate some of these values and understand the dynamics of device power under different scenarios.

Table 6 Typical average power values for end-user devices

Device type	**Typical average power ranges (W)**		**Source / assumptions**
	Lower	**Upper**	
Primary television	40	120	EU Energy Label Database / Energy Star Database BARB Data for UK (typical TV sizes)
Secondary television	30	60	EU Energy Label Database / Energy Star Database BARB Data for UK (typical TV sizes)
Television (standby)	0.5		EU energy labelling requirements
Modem/router	9	15	Variable by ISP (Internet Service Provider) Access Network type and capabilities.
Set-top box (STB) on Power	8	20	Assumes a complex STB that has recording capabilities and is likely to be connected to the internet.
Set-top box (STB) standby Power	0.5	15	Varies depending on the functionality of the STB.
Tablet	5.5		BBC White Paper 372 (2020)
Smartphone	1	2	Carbon Trust White Paper (lower bound). Upper bound may be used as a conservative estimate.
Desktop & Monitor	77	100	Depending on service and likely device demographics
Laptop	15	30	Depending on service and likely device demographics

The carbon intensity of electricity (kgCO2e/kWh) for end-user devices, varies by module. Currently, the Video Streaming module has a single electrical carbon intensity for all end-user devices – this should be a weighted average of the values for different countries by proportions of users. In the publishing module, users have the option to complete this calculation within the tool by listing the proportions of their views per country.

As noted above, there are multiple different data sources for the carbon intensity of electricity generation (kgCO2e/kWh) for a given country in any given year. We recommend that the values used for DIMPACT should be the same as those used for an organisation's other GHG reporting and target setting. These values are generally available sustainability teams or consultants.

Standby allocation approaches

In addition to energy use due to electrical devices being switched on and in use, energy is also consumed when devices are in a standby state (i.e., not in use but awaiting user interaction). There has been much work over recent years to reduce the impact of standby power, including legislation such as the Ecodesign rules for simple set-top boxes.

In general, including standby energy for scope 3 reporting is optional (as these are indirect use-phase emissions – see discussion in the Enhanced Scope 3 GHG reporting Section). However, for some types of digital service standby energy can be significant, and we offer an option in the tool to model this for TVs and STBs in the video streaming module.

Standby power is excluded for other types of devices, such as computers, tablets and smartphones. This is because these devices are used for a wide variety of digital services and generally have very low standby power usage – therefore the allocation of standby to any particular service would be very small and likely considered negligible (or *de minimis* in carbon reporting terms). For that reason, we currently do not recommend that standby energy consumption of devices aside from televisions and STBs should be included as in-scope.

In contrast, STBs and TVs are used primarily for TV, video viewing and audio streaming, so any particular service provider may have a significant proportion of the overall use. In addition, larger 'complex' STBs can have significant standby power values which add up to a significant proportion of the energy use or carbon footprint of the device.

Overall, the approach to the allocation of standby energy and carbon emissions to a particular service is in proportion to the duration of use of the device used by that service.

In the equations below, the Carbon intensity of electricity (kgCO2e/kWh) is a weighted mean of the intensities for countries in proportion to usage in each country.

Equation 18. Estimating overall standby power of end-user devices

*Total mean standby energy of device per period (kWh/period) = Mean power device in standby mode (kW) * Duration of device in standby mode per period (hours per period)*

Equation 19. Allocating standby power to a given service

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*Allocated standby energy to service per period (kWh/period) = Total mean standby energy of device per period (kWh/period) * [Total duration of use by service per period / Total duration of use for all services per period]*

Equation 20. Estimating the GHG emissions of allocated standby power

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*Allocated standby carbon footprint (kgCO2e/period) = Allocated standby energy to service per period (kWh/period) * Carbon intensity of electricity (kgCO2e/kWh)*

Summary of data input requirements for DIMPACT participants

DIMPACT uses a combination of primary data and general estimates to model the GHG emissions of digital media and entertainment products. The data inputs and parameters are summarised in the table below.

Data input sources, by model component

	Data centres & back-end processes	Internet distribution infrastructure	User devices	Emissions factors for electricity generation
DIMPACT input	Module-specific system architecture diagrams, outlining expected processes and scope	Internet network intensity (kWh/GB) CDN energy intensity (kWh/GB)	Typical power consumption of devices (W)	Publicly available emissions factors (AIB, government sources) *Guidance on choice of factors for each model component provided to participants on an ad hoc basis*
Participant input	Energy consumption of GHG emissions for data centre processes. Obtained directly from suppliers, or estimated using relevant tools (as per below)	• [Optional] Energy/GHG data obtained directly from CDN providers OR • [Optional]Total data served by CDN	• Audience locations • Device types • Viewing hours & data • Service data volumes Service-specific device energy consumption (refer to the End-user devices section)	• Licensed emissions factors (e.g., IEA) • Weighted average emissions factors (if audience is located in multiple countries) • Intensity factors from utility providers
Complementary tools & data sources	Cloud service provider calculators Cloudcarbonfootprint.org EEIO factors (to be used as a last resort)		Tools for estimating page weights. Proxy estimates for video bitrate can be obtained from Netflix's ISP Speed Index.	International Energy Agency UK BEIS Greenhouse Gas Reporting Conversion Factors (includes well-to-tap emissions factors)

Participant results from DIMPACT modelling runs

There is no requirement for DIMPACT participants to publish their results. However, we are delighted that many of our participants have taken it upon themselves to publish their results. Below we outline some of the publicly available results published by our participants.

Table 7. A selection of publicly available participant model run results

Module	**Organisation**	**Results**	**Geographical coverage**
Video streaming	BBC (iPlayer)	33g CO_2e per device hour 109Wh per device hour (viewing on all devices)	UK
	Netflix	Well under 100g CO_2e per hour streamed	Global
	Carbon Trust White Paper (using DIMPACT method)	56g CO_2e per hour 188Wh per hour (viewing on TVs only)	Europe average
Digital publishing	Schibsted (Scope 3 reporting, p42)	Emissions from digital newspapers in 2021: External data centres (location-based): 120 tCO_2e Internet infrastructure: 24tCO_2e End-users: 393 tCO_2e Total: 537 tCO_2e (Paper used for physical newspapers: 6,612 tCO_2e)	Nordics

These results suggest that, when compared to other everyday activities, the GHG emissions from accessing digital content are relatively low. For example, the Carbon Trust White Paper estimate of 55g CO_2e per hour is approximately the equivalent of driving a car 250m or microwaving 3.5 bags of popcorn. For digital publishing, Schibsted's results show that the emissions are an order of magnitude lower than those for paper used for print publishing. It is important to note here that the usage metrics of digital versus print were not available to compare the two on a per unit basis.

One important thing to note is that varying estimates are often caused by differing data inputs and assumptions that organisations are making to complete their modelling. For example, one company may find that its audience base is less likely to have larger devices, therefore the power consumption is lower. Some audiences may be more likely to view content via cellular networks and fixed-line networks, which will impact the results. A good example of a discussion on differences in results is provided by the BBC in their blog article.

From insight to action: how can media companies reduce the footprint of their digital value chain?

Once companies have completed their modelling, they will have a better understanding of the scale emissions from their product or service, and understanding of the 'hot spots' of emissions, and (ideally) a greater understanding of how their value chain partners are measuring and addressing these emissions.

The natural next question then becomes: 'what do we do next to reduce these emissions?' This is not necessarily a straightforward question, as the methods used to account for emissions (for, say, the purposes of GHG reporting) cannot be used to understand the impacts that any interventions will have on the entire system. We discuss these limitations in the below section.

This does not necessarily answer the question of 'what can we do?' but provides a word of warning for stretching the current DIMPACT approach beyond its capabilities to make future projections of emissions or evaluate interventions. We then provide some thoughts on what can be done in the absence of detailed guidance on how product and service architecture and design can reduce emissions.

Reporting versus causal modelling

Much of the uncertainty faced by those interested in what they can do to reduce the footprint is due to the difference in approaches used to retrospectively account for carbon emissions for a given digital product or services, versus how to quantify the system-wide impacts of energy consumption based on an intervention or future trends. DIMPACT uses an attributional life-cycle assessment approach, which is useful for the former. As such we use proxies such as data volumes to allocate the emissions that a given service is responsible for over a given time period in the past.

However, as discussed earlier in this document, the internet and devices such as modem-routers do not behave in a way where energy consumption increases linearly with data transmitted. In fact, throughout the Covid-19 pandemic, many ISPs and mobile providers found that the increase in traffic resulted in a negligible increase in any consumption across their networks. See, for example, this article from the GSMA. As such we advise strongly against making claims of "emissions saved" by interventions such as reducing data loads. Similarly, the attributional methodology such as the current intensity metrics used in DIMPACT (kWh/GB) cannot be used to estimate the instantaneous or future impacts of changes to viewing behaviour, or company or policy interventions.

In life-cycle analysis terms, this issue embodies the key distinction between attributional and consequential analysis. In the simplest terms, an attributional approach sets clear boundaries of an assessment scope, and assigns emissions that a given service are 'responsible' for. The consequential approach must consider all systems (and associated emissions sources) that are affected by a future change, against a counterfactual baseline. A comparison of these approaches is outlined in more detail in Table 8.

Table 8. Comparison of attributional versus consequential methods. Adapted from Brander (2021)

Feature	**Attributional (currently used by DIMPACT)**	**Consequential**
Accounting purpose	Allocating responsibility to entities for emissions arising from activities for reporting and/or tracking emissions over time	Quantifying system-wide change in emissions (or removals) caused by a decision or intervention
Boundary setting principles	Fixed boundaries, determined by normative rules	Boundary determined by the intervention of interest (to include all affected systems)
Type of change that can be accounted for	Change relative to a base year/period	Change relative to a predicted counter-factual baseline
Retrospective or prospective	Retrospective (generally)	Prospective, to assess impact of future decisions (generally)
Outputs	Physically measurable quantity of GHG emissions	Estimated change in GHG emissions caused by a specific decision or intervention
Example use-cases relevant to DIMPACT	A streaming company wishes to extend their scope 3 reporting to include their share of ISP traffic and in-home devices used to view their products (indirect-use phase)	A digital media organisation wants to evaluate the impact of switching all of their video content to UHD

Both approaches are important, but they answer different questions. Currently DIMPACT has been able to shed light on the allocation approach, given that we were able to set clear boundaries for the assessment, and parametrise each of the in-scope components. There is more work to be done in developing a robust framework for analysing the consequential impacts of changes made by organisations or customers.

We are currently exploring how we can implement a credible causal (consequential) assessment methodology, but acknowledge that this may require further academic research, primary data and engagement with value chain participants such as ISPs, data centre providers and device manufacturers.

What can actually be done?

It is understandable that the above section may leave you wondering what can actually be done to reduce the carbon footprint. This is especially the case as digital media companies may not have significant levels of control over some parts of their value chains. For example, the types of devices that are used for viewing their content are largely a customer choice. However, we have identified two areas where DIMPACT participants can take action, either individually or through DIMPACT.

Engage with value chain partners

Much of the emissions of serving digital media and entertainment products occur outside the direct control of DIMPACT companies. DIMPACT participants have spent a lot of time engaging with these value chain partners to understand the GHG impacts of these partners. This has increased transparency across the sector, which is a positive step forward.

As may have become apparent from the methodology section of this document, we recommend that DIMPACT participants gather primary data from their value chain partners where possible, as well as information about their sustainability programmes and targets.

Generally, these emissions hotspots are within the homes of users. For device manufacturers setting science-based and net-zero targets, this means that these emissions are likely to be included in any scope 3 targets (direct use-phase of products sold).

However, as an initiative, we are not washing our hands of this, and are engaging with manufacturers to understand the proportion of these devices covered under certified product-level, science-based and net-zero targets. Where there are significant gaps in this coverage, we will engage these manufacturers to understand their progress in developing and delivering ambitious reductions and energy efficiency targets for devices. We also intend to support the development of product-level standards that aim to reduce and credibly neutralise the emissions of these user devices.

For those value chain participants that are closer to the organisations, such as cloud service providers and CDNs, we recommend you engage with these providers directly to understand their sustainability credentials, and request environmental data attributed to the services you purchase from them. For DIMPACT participants, we have a standard data request form that you can share with these organisations, available upon request.

Understanding where system-level reductions can be made

This is an opportunity for DIMPACT participants to engage in cross-sector collaboration between digital media providers and ISPs, CDNs and IaaS providers to understand the implications of system-wide changes that impact energy consumption. This could be either on the demand side: what are the energy implications of a large and sudden step-change in data traffic? Or the supply side: how can the architecture of delivering content be changed to reduce energy consumption, and what are the implications of this in terms of latency, quality, reliability, and so forth?

DIMPACT Expert Advisory Panel involvement in the methodology

The DIMPACT expert advisory panel currently consists of the following members:

- George Kamiya, Digital/Energy Analyst at the International Energy Agency
- Dr. Arman Shehabi, Research Scientist in the Energy Analysis and Environmental Impacts Division of the Energy Technologies Area at Lawrence Berkeley National Laboratory
- Professor Eric Masanet, Energy System Analysis, Climate Change Mitigation, Sustainable Manufacturing, Data Centers & ICT, at UC Santa Barbara
- Jens Malmodin, Senior Specialist Environmental Impacts and Life Cycle Analysis at Ericsson Research
- Dr. Daniel Schien (Chair), Senior Lecturer in Computer Science, Department of Computer Science Systems Centre Cabot Institute for the Environment, The University of Bristol

The next page discusses their primary challenge with the DIMPACT methodology, and the way in which companies are estimating the impacts of their digital products and services.

In addition, the Panel challenged us on whether there was a way for DIMPACT participants to use a standard approach to estimating emissions from their use of data centres, which would allow for comparability between companies. The Panel also thought it would be worth including some typical figures for data centre emissions, for companies to sense-check against their own data that DIMPACT participants collect.

Whilst offering multiple ways to estimate data centre emissions allows for flexibility for participants in completing assessments using the data that they have available; we agree with this challenge. We will continue to work with cloud service providers to understand their calculation and attribution methodologies and encourage standardisation in their GHG reporting to customers. We have also added some typical values for data centre energy consumption to this document, which was aggregated from select DIMPACT participants as part of the Carbon Trust White Paper.

Key Outcomes of the DIMPACT Expert Advisory Panel Review

In July 2022, the newly formed Expert Advisory Panel met with the DIMPACT team to discuss the methodology presented in this document. The Panel were asked to provide challenge to the DIMPACT team on the methodology outlined in this document.

Their primary challenge to the methodology was the use of average historic data volumes to allocate energy consumption of the internet transmission networks and CPE. The below outlines this challenge:

As discussed in the Internet energy consumption section, data allocation (kWh/GB) approaches do not reflect the real-world dynamic relationship between usage and energy consumption. This is discussed in the Carbon Trust White Paper on video streaming, Jens Malmodin's 2021 conference paper at Electronics Goes Green, and the IEA's analysis on video streaming. These papers propose a time-based approach to allocating network emissions, especially for high-bitrate activities. As such, by using such intensity factors, the wider community may use these to incorrectly speculate on an increase or decrease in energy consumption due to increased data consumption.

DIMPACT is aware of these shortcomings, but have continued to use the data allocation approach for the following reasons:

- The DIMPACT tool is currently used for retrospective reporting, not causal modelling (See Reporting versus causal modelling above), and we make this clear in this document to participants when completing model runs. It cannot be used to evaluate changes such as reducing data volumes transferred.
- The DIMPACT approach is built upon methods that use the current approach which are currently in line with the GHG Protocol ICT Sector Guidance. We have not yet applied, tested or implemented alternative methods to these methods, and thus this document reflects the current state of the DIMPACT approach.

As such, we cannot declare that the Advisory Panel completely fully agrees with the current DIMPACT approach. Their challenge has, however, helped us develop some actions for the future development of the DIMPACT approach. In response, we will:

- Work with the Panel to explore new modelling approaches for internet energy consumption, based on the state-of-the-art research and industry analysis.
- Where required, encourage further publication of the approach and sense-check proposals to test that any proposed updates are broadly accepted.
- Engage the standard setters for product-level GHG accounting, especially those focussed on ICT, to gather their views on any proposed updates to the methodology; and
- Work with DIMPACT participants to compare modelling results between the current and updated approaches, to gain a view of materiality of the changes.

We intend to report on any updates to the methodology as a result of these actions.

About the DIMPACT initiative

Background

DIMPACT is a collaborative project convened by Carnstone with the support of the University of Bristol and leading media companies.

The project was born out of the Responsible Media Forum (RMF) to take the complexity out of calculating the greenhouse gas (GHG) emissions associated with serving digital media and entertainment products. The RMF (RMF) is a long-standing collaborative initiative run and managed by Carnstone.

After a successful pilot phase ending in the summer of 2020, the DIMPACT tool is now available on a yearly subscription model. The project also fosters close collaboration between participants to develop industry standards and influence key stakeholders (e.g., device manufacturers, or cloud service providers).

Vision

DIMPACT aims to become the leading authority on measuring, reducing and contextualising the greenhouse gas (GHG) emissions caused by delivering digital media and entertainment products.

DIMPACT wants to provide access to the most advanced tool for conducting the life-cycle assessment of digital media products, as well as participation in a knowledge-sharing community that enables increased transparency and collective action with the digital value chain.

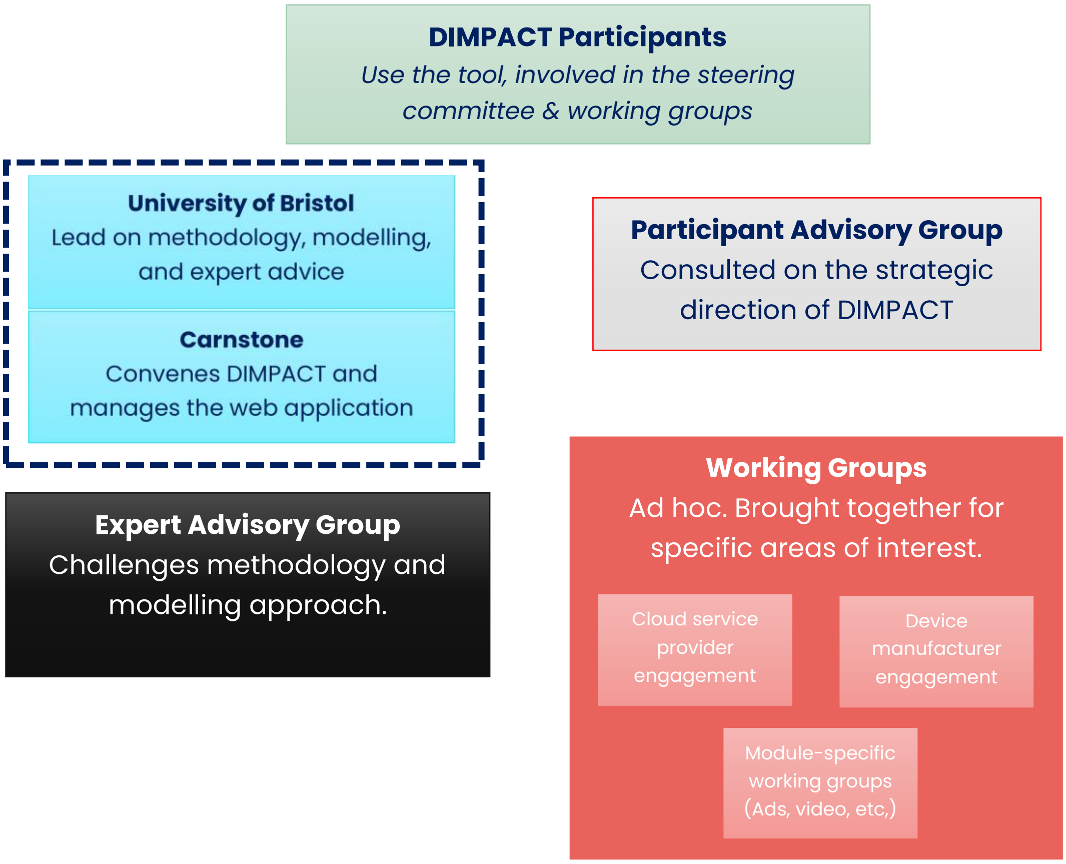
How the initiative is managed

DIMPACT is owned and run by Carnstone, with a technical research partnership with the University of Bristol's Computer Science Department. DIMPACT is underpinned by a governance structure described in the graph below.

1. The **DIMPACT Participant Advisory Group** offers non-binding advice on the strategic direction of DIMPACT, the development and prioritisation of future features, and collaborations with external stakeholders. The Group is made up of a selection of DIMPACT participants that is representative of the sectors, sizes, and interests in the group. The Terms of Reference of the Steering Committee are available upon request.

2. The **Working Groups** are convened on an ad hoc basis to serve the needs and ambitions of the DIMPACT participants and the wider industry – e.g., influencing device manufacturers, or engaging with cloud services providers.

3. The **Expert Advisory Group** has been formed to provide counsel and challenge on the DIMPACT methodology and modelling. The Panel is made up of recognised academics and industry experts with in-depth knowledge of life-cycle assessment or energy modelling approaches for ICT infrastructure and IP-delivered services ("Panellists"). The Panel also acts as a two-way learning opportunity between industry, academia and thought leaders to advance the research agenda and dissemination of current best practices. The Terms of Reference of the Expert Advisory Panel are available upon request.



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List of acronyms & glossary

AIB	Association of Issuing Bodies
AWS	Amazon Web Services
CDN	Content delivery network
E&M	Entertainment and media
EEIO	Environmentally Extended Input-Output
GHG	Greenhouse gas
IaaS	Infrastructure as a service
ICT	Information, communication & technology
ISP	Internet service providers
Module	Refers to each application of the DIMPACT model (e.g., video streaming, digital publishing, banner advertising)
PaaS	Platform as a service
SaaS	Software as a service
SBT	Science-based target
SBTi	Science Based Targets Initiative
T&D	Transmission and distribution losses
WTT	Well-to-tank emissions, from extraction, refining and transportation of primary fuels before their use in the generation of electricity.

Appendix 1 – Data consumption per household

Data consumption per household allows us to attribute the energy of the customer premises equipment (e.g., modem router) to a given service based on the monthly data volume of that service when compared to the total data volume.

All data below is for the latest year available, which is 2020. Except for the UK, which is for 2021. This data is updated annually, so we recommend using this data for 2021 reporting.

Table 9 Monthly data volume by country

Country	Data volume per capita (GB/capita/month)	People per household	Data volume per household (GB/HH/month)
United Kingdom	N/A (provided directly by Ofcom)		**453**
South Korea	153.0	2.5	**382.5**
Canada	148.2	2.5	**370.5**
United States	147.6	2.6	**383.8**
New Zealand	112.7	2.7	**304.3**
France	112.4	2.3	**258.5**
Sweden	102.8	2.0	**205.6**
Singapore	99.4	3.3	**328.0**
Australia	95.6	2.5	**239.0**
Ireland	91.3	2.6	**237.4**
Spain	82.1	2.5	**205.3**
Germany	79.9	2.0	**159.8**
Netherlands	78.4	2.1	**164.6**
Portugal	77.0	2.5	**192.5**
China	63.9	2.62	**167.4**
Italy	53.6	2.3	**123.3**
Japan	20.2	2.4	**120.5**

Data volume per capita data is sourced from Ofcom International Broadband Scorecard 2021, with the exception of the UK which is sourced from the UK Media Nations Report.

People per household data is sourced from Population Reference Bureau (2020), with the exception of European Countries, which was sourced from Eurostat.