Ad Net Zero

Conceptual Framework for Integrating Advertising and Advertised Emissions

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INTRODUCTION: AD NET ZERO

Ad Net Zero marks the advertising industry's response to the climate emergency, a global and pressing issue that impacts every single individual. This crisis demands that every institution should evaluate its own behaviour now, and take steps to deal both with immediate issues, and to set in motion plans to create a more sustainable future. And within the business domain, the entire collective advertising ecosystem is poised to contribute to a global solution, given its designed and unparalleled ability to inform, persuade, shape culture, and guide behaviour (consumption or otherwise).

Importantly, this initiative is concerned with both the internal and external impact of the industry. First, driving the industry to reduce the carbon impact of developing, producing, and running advertising to real net zero. But also in using its role to support businesses in their efforts to operate and grow sustainably, and to support important and needed consumer behaviour change globally. All encapsulated in an industry action plan:

Action 1 Get Your House In Order - Advertising Business Operations
Action 2 Curb Emissions from Advertising Production
Action 3 Curb Emissions from Media Planning & Buying
Action 4 Curb Advertising Emissions Through Awards and from Events
Action 5 Harness Advertising's Power to Support Consumer Behaviour Change

It all begins with an internal look at one's own operations, and agencies as well as other marketing services companies should look to curtail their own carbon emissions. Considering not only the internal emissions (action 1), but also those involved in the production of the work (action 2, e.g. AdGreen providing the needed tools), and in all of the systems involved in the delivery of ads (action 3). As an industry, even the recognition of excellence and incentive systems should be aligned with this effort (action 4).

Although coarsely and hurriedly described now (and in much greater details shortly), these initial steps amount to a large part of all "Advertising Emissions." This is the carbon associated with the provision of advertising services. It is both internal-looking and consistent with taking responsibility for the state of operational impact as well as reduction and mitigation of any waste or misuse of resources.

Action 5 then recognizes the power advertising, both in its ability to guide consumption patterns and to bring about broad behaviour change, which are critical components in a global effort to address the climate emergency. Important, it looks beyond the immediate boundaries of the operation and provision of advertising, to the consequence of the work. It could be the drive for consumption of yet more carbon intensive and polluting products, just as it might lead to widespread adoption of pro-environmental action. Altogether, these external consequences are aggregated into "Advertised Emissions."

In this document we'll examine how the advertising industry, inclusive of advertising businesses, can integrate both Advertising and Advertised emissions into a coherent management framework and use to power of advertising to create a future that is simultaneously commercially and environmentally sustainable, supporting both growth and responsible as well as efficient use of resources.

Why not focus on just Advertised Emissions?

While we recognize that a significant amount of effort has already gone into methodologies for Advertising Emissions and most readers are likely to be interested in new developments around, as well as additional discussions on Advertised Emissions, we have also come to recognize that the explicit division between these discussions is potentially problematic. In fact, these issues motivate the nature of this document as an argument for integration of both Advertising and Advertised Emissions as a holistic and coherent treatment of the carbon issues in our industry, and its impact on society.

One immediate issue that arises is that different companies have developed their own internal (sometimes private and/or proprietary) methodologies for carbon accounting, often connected to corporate pledges towards carbon neutrality. As a result, not only do we have significant duplication of effort, but also non-standardization of approaches, potential for confusion around definitions, and an overall lack of awareness or agreement as an industry. This is just made worse by the sheer complexity of the advertising industry. It's not just ad agencies, media owners and clients. Consider for instance the physical and digital split, and the variety of Martech solutions and tools weaving into the process of getting the right creative in front of the right customer at the right time. Each will contribute, but also carry a cost.

Importantly, there is a significant risk in disconnecting consequences (Advertised Emissions) from the cost of the activity itself (Advertising Emissions). It is similar to engaging in a cost benefit analysis, and only focusing on one side of the equation. Invariably, errors will creep in that decision making process. Advertised Emissions are inherently interesting because they deal directly with behaviour change, and the power of advertising to move populations towards new patterns of consumption. And our aim will be to guide consumption towards both commercial value and carbon reduction; however, to do so blind to the associated costs could see both commercial viability and carbon impact worse-off as a result (i.e., 'overspend' monetarily and in carbon to generate trivial gains in both).

By integrated, we argue that firms will seek to minimize their capital and carbon budgets, while maximizing their commercial results and minimizing the associated carbon impact of that commercial activity. Therefore, our industry will have to manage its activities accordingly.

Why not something as straightforward as Financed Emissions?

The development and introduction of Financed Emissions has often been used as an example of industry-level responsibility and action, as well as a lever to move the advertising industry in a similar path. Therefore, it is worthwhile to have a brief look at what financial institutions have done, and why the advertising ecosystem must handle additional complications to achieve similar goals.

Financed emissions come from Greenhouse Gas (GHG) Protocol standards (Scope 3, category 15), assigning GHG ownership in proportion to the share invested in the investee (company or project generating GHGs). These investments happen as equity, debt, or project financing (making the body of what is called financed emissions), as well as managed investment and client services (leading to alternatively named facilitated emissions, which contain off balance sheet activities).

Additionally, these measures have two goals:

1. Disclosure of what is being funded

2. Measure the institution’s exposure to risk arising from the decarbonization and transition economy

First, we should consider the aspect of ownership. Financed emissions assign ownership (and responsibility) over GHG as proportional to ownership dictated by investment. This is because both equity and debt financing places the bank in a position to claim residual value of the investee, and it directly connects the bank’s revenue stream to the stream of dividends or repayments resulting from the financing operation.

This is a critically important difference between the advertising and finance industry, as the bank is connecting the string of (carbon) costs associated to a string of cash flows arising from the same activity. Additionally, the bank is not necessarily doing so from a purely moral stance, but also because this is a necessary measurement of their risk exposure to carbon costs as well as volatility in carbon-heavy industries.

Should the same be done in the advertising industry? Not exactly. In the advertising industry, no share of ownership takes place, nor does any residual value get reassigned. Brand owners who buy the advertising retain all the future benefits derived from that service. To reassign just the carbon cost of these future benefits to media agencies and media owners would be a severe and significant accounting error.

Additionally, note that the amount of GHG emissions assigned to the investor bank is directly proportional to the equity/debt percentage taken by the investor. This is a very clean and precise attribution that is much more challenging in the advertising domain. For instance, what percentage of the lift in sales observed by the brand owner is directly attributable to the latest advertising campaign? What percentage of the same lift was enabled by pre-existing brand equity (and all previous campaigns)? How far into the future will the shock from this campaign persist and influence other campaigns? How much of this current lift is attributable to media owners? How much to the creative? We’ll address attribution in a future section, but it suffices to say now that we do not have the luxury of simple algebraic attribution.

Overall, suggesting that advertised emissions is possible in the same way as financed emissions creates a very dangerous and false equivalence, be it in terms of costs/benefits or attribution simplicity. That is not to say that the advertising industry has no role to play in the decarbonization of the economy. This entire document is a statement to the fact that it does have the power to help brands, shift consumption and control its own footprint. But we must be vigilant against equivalences drawn to other industries, and therefore must design our own processes.

What about Finance’s Facilitated Emissions?

We mentioned in passing that beyond Financed Emissions, the finance industry has started to have conversations about Facilitated Emissions. These mark the industry’s intent to account for the impact of their off-balance sheet items and services, and the consequences of these on their clients (e.g., capital market transactions or similar commercial fee-earning actions). Alternatively, these are distinguished in temporal terms, such that Financed Emissions represent long term, holding assets, and “stock;” while Facilitated Emissions represent one-off and “flow” activities.

Most of us should recognize a much closer kinship between finance’s Facilitate Emissions and services provided within the advertising industry.

However, it is worthwhile pointing out that at the time of writing Facilitated Emissions are a noted and notable ambition, without any attempts at a methodology nor any implementation. The active discussions around the topic often returning to dangers of double counting and unresolved issues of attribution. Precisely areas that advertising has grappled with for year, and issues we'll tackle here.

MtCO2e will become a cost

We note that as an industry, there has been a perceptible and active avoidance of connecting the metric ton carbon dioxide equivalent (MtCO2e) with the word 'cost.' Instead, it's been positioned as a planning variable, or a tool for goal setting and tracking, or in some cases as something contributing to preparedness towards eventual policy changes. And while it is true that MtCO2e serves as good variable in all these intended uses, we caution that this distancing from carbon-as-a-cost is naïve.

Fundamentally, the metric ton carbon dioxide equivalent will become another dimension of cost structure as soon as <u>anyone</u> in the industry uses it for measurement/reporting. And, under this assumption, we would argue that it works as a cost right now.

We believe that this is an important warning because it will be used as a competitive advantage in the industry (e.g. low MtCO2e channels and firms). It will be a cost that is passed or absorbed across the supply chain (Scope 1,2,3). It will be targeted for progressive cost reduction, and at times it will be accepted even if the cost is high. It will trade-off against other dimensions of cost (£/$, time, etc.), and it will increase the perceived cost of advertising. Some advertisers could be monetarily 'rich' while being carbon 'poor' (for example, big companies with carbon-intensive operations), which could affect their willingness and eventual ability to use certain media mixes and channels due to carbon cost constraints. Others could easily fall in the opposite position, accepting a rather large carbon cost, provided that it comes at a monetary discount.

Here, we note back to our discussion on the need for integrated Advertising and Advertised Emissions to add this additional caveat: a careless or incomplete consideration of the carbon cost and consequence of advertising could lead to a simplistic and disproportionate devaluation of the advertising industry, simply because the 'cost' (monetary plus carbon) of advertising is too high. The tendency to over-simplify complex problems would translate to a coarse multiple-based valuation of advertising activity (e.g., advertising cost is accounted as 1.5x to absorb carbon costs), and commercial performance would suffer in accordance. Instead, we prefer an approach to manage this complexity and to allocate costs and benefits appropriately.

Lastly, it is worth highlighting that we are moving into a world of more complex costs as well as complex benefits from advertising. We are already accustomed to complex benefits: short term, long term, sales-lifts, brand-lifts, etc. All of these arising in some degree from potentially the same set of activities. Now, these gains will be connected to the monetary as well as carbon cost needed to generate them. This reality aligns with our subsequent discussion on attribution (i.e., connecting consequences to their associated activities and costs) and portfolio management of advertising activities (how can advertisers manage their carbon impact and trade off commercial versus carbon consequences).

Hopefully, this also rings as a warning to anyone who's heard "I know that 50% of my ads work, just not which." Similarly, for anyone familiar with the challenges of proper attribution, or measurement of impact in the long term, or capturing adstock, or the aggregation of marketing activities from single exposure to campaign, to multiple campaigns. These are very significant difficulties in the industry, and they will replicate as additional difficulties here with respect to $MtCO_2e$.

Document Organization

Next, we'll turn to general principles and basics on the framework that connects all the emissions attributable to advertising. From there, we will take a much deeper dive into Advertising's own emissions, making use of all the current best practices and available measurements – while also pointing out areas that are rather underdeveloped. We then turn the discussion to advertised emissions and the measurement and accounting of carbon arising from consumption or consumer behaviors in response to ads, including competitive forces and measurement. Next, we introduce a carbon portfolio approach to provide a simpler overview and management of a firm's advertising and advertised emissions and their tradeoffs. We then turn to a discussion on attribution, and new approaches needed to capture the details present in advertising and carbon accounting. Lastly, we close with further integrative discussion, again drawing attention to areas where further development is needed.

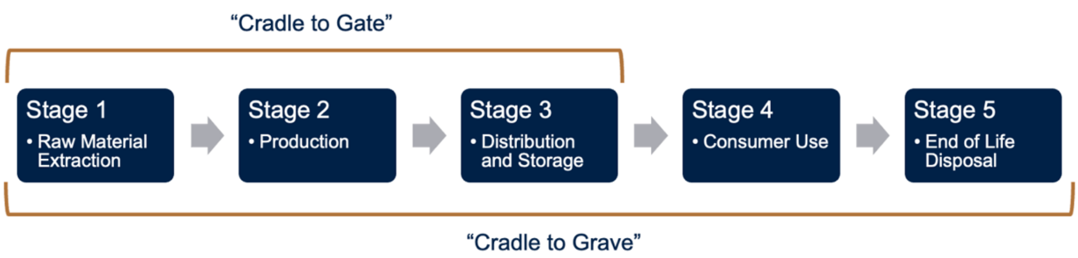
GENERAL PRINCIPLES

Our approach begins from the GHG Protocol Life Stage of how advertising is provisioned, from raw material to disposal after use, consistent with the fundamentals of product life cycle GHG accounting protocols. However, we recognize the complexity of advertising implies not a singular life cycle, but an amalgam as any number of channels might be selected in the provision of advertising services, and every channel will carry a different set of life stages specific to itself. Not only will we have to content with basic divides, like physical versus digital channels of communication, but variances might also exist within channels (for example, presence of programmatic, apps used, device manufacture and age, target audience and region emission heterogeneity). Altogether, to quantify the metric tons of carbon dioxide equivalent ($MtCO_2e$) attributable to a campaign, we will have to capture all of these options.

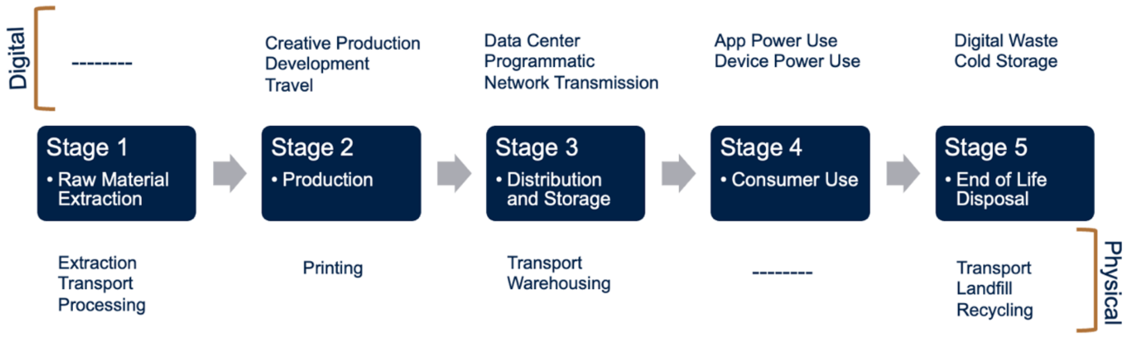
Furthermore, to follow the fundamentals of product lifecycle GHG accounting, we must consider and respect the following principles:

- **Relevance**: Ensure the product Life Cycle Accounting appropriately reflects the GHG emissions of the ad and serves the decision-making needs of users – both internal and external to the company.
- **Completeness**: Account for and report on all GHG emission sources and activities within the stated Life Cycle boundary. Disclose and justify any specific exclusions.
- **Consistency**: Use consistent methodologies to allow for meaningful comparisons of emissions over time. Transparently document any changes to the data, life cycle boundary, methods, or any other relevant factors in the time series.
- **Transparency**: Address all relevant issues in a factual and coherent manner, based on a clear audit trail. Disclose any relevant assumptions and make appropriate references to the accounting and calculation methodologies and data sources used.
- **Accuracy**: Ensure that the quantification of GHG emissions is systematically neither over nor under actual emissions, as far as can be judged, and that uncertainties are reduced as far as practicable. Achieve sufficient accuracy to enable users to make decisions with reasonable assurance as to the integrity of the reported information.

This system seeks to divide the emissions related with a product according to stages, going from raw material extraction (Stage 1) all the way through end-of-life disposal of the product after consumption (Stage 5). The figure bellow shows this basic architecture, highlighting common subsets captured as either “cradle to gate,” meaning the processes from raw materials to product distribution, as well as “cradle to grave” which encompasses all stages.



Like any other industry or product, advertising can be cast in the same process, except that it might not be the neatest replication of stages universally. In the figure below we coarsely overlay digital and physical pathways for stages 1 through 5. We note that digital channels do not have raw material extraction processes present, but are characterized by significant energy usage for the process of a consumer exposure, both in device energy and the power drawn by specific apps. Conversely, physical channels do encounter raw material processes (extraction, transport, and processing), but do not have use emissions for a consumer exposure.



Although coarse, this division clearly highlights the importance of accounting for each channel selected individually and constructing its Stage-level and overall carbon impact as a function of each underlying process.

Channel Taxonomy

Unfortunately, there is a lack of consistency in the taxonomy of media channels in the industry. Given the importance of accounting for and managing the difference in emissions between these channels, the opportunity for confusion is exceptionally high. Therefore, to be explicit, we will be using the organization of media channels and related subchannels as described in the table below:

Media Channels	Sub-channels
TV	• Broadcast, Cable, Addressable TV
VOD	• Streaming
Cinema	• Cinema
Social Media	• Social Media
Digital	• Online Display • Mobile Display • Online Search
Print	• Newspaper, Magazines, Dailies, Community, Business Journals, Consumer, Trade
Out-of-home (OOH)	• PVC/Vinyl Banner • Custom Format – Virgin Paper • Custom Format – Recycled Paper • Lightbox – Back-lit • Telephone Box
Digital OOH	• LED Digital Display – Large Roadside Formats
Radio	• Spot
Digital Audio	• Podcasts/Online Radio

Transient	• Bus & Taxi

Allocation

Allocation is a concept similar to marketing attribution (which we will discuss later), but where attribution is concerned with allocating proportional credit/value for each marketing channel, allocation is instead seeking to split and distribute costs arising from a service that multiple channels share.

In light of carbon emissions, allocation refers to the partitioning of emissions among products where more than one product shares a common process (chapter 9 of the Product Standard). As above, we'll consider how digital and physical channels differ in allocation.

A digital media campaign is defined as the activities associated with storing, targeting and reaching a digital ad through resolution of the ad on the end-user device. Emissions will be allocated based on the ad size and the total data traffic of the component. For example, multiple telecommunication services sharing the same network and multiple channel cloud services (e.g., VOD, digital, database applications) sharing the same data center. For digital ads, allocation involves prorating the usage of the shared component. For example:

- **Use of network**: Allocation based on volume of data traffic, number of ports used or number of subscribers.
- **Use of software**: Allocation based on processing time or quality of data processed.
- **Use of data center**: Allocation based on processing time, quantity of data processed or number of servers used.
- **Overhead energy**: Allocation based on the energy used for cooling information and communication technology (ICT) equipment as well as temperature control of the building, diesel fuel used for backup generators and uninterruptible power supply (UPS) and other ICT infrastructure.

Alternatively, a physical media campaign is defined as the activities associated with material acquisition and preprocessing, production development, printing, transporting and reaching a physical ad through installation. Emissions will be allocated based on the ad area, and allocation involves prorating the usage of transportation activities. For example:

- **Raw material transportation**: Allocation based on the size of the ad, vehicle type and miles transported.
- **Processing and printing**: Allocation based on the size of the ad.
- **Product distribution**: Allocation based on the size of the ad.

Each of the above allocation approaches relies on prorating the shared service according to usage, meaning that for each media channel we must also know the basic unit that we use to measure the size/burden of a given ad using a service. This is termed the function unit.

The functional unit of each media channel in our taxonomy is given in the table below:

Media channel	Functional unit
TV	1 kb of data
VOD	1 kb of data
Cinema	1 kb of data
Social Media	1 kb of data
Digital	1 kb of data
Print	1 cm x 1 cm area
OOH (out of home)	1 cm x 1 cm area
DOOH (digital out of home)	1 kb of data
Radio	1 kb of data
Digital Audio	1 kb of data
Transient	1 cm x 1 cm area

Our calculations, as described earlier will start from this functional units. The functional unit is used to calculate the intensity of the allocatable process. This intensity is then multiplied by the size of the ad to calculate the emissions from a singular ad. The number of ads in the given channel can then be multiplied by the emissions of a single ad to calculate the channel's campaign emissions. And the aggregate of our channels provides the overall campaign emissions.

Data management plan

Calculating the emissions for an ad campaign requires emissions data from the vendors supporting the ad as well as Emission Factors data. Additionally, as emissions data varies year to year, a regular pattern of updates will be necessary. Public data sources, inclusive of sustainability reports and web pages and similar disclosures, can provide much of the needed data. Vendor questionnaires are a valuable additional tool for collecting data that is not publicly available.

Because of the complex nature of media channels, it may sometimes not be possible to obtain primary data outside the reporting companies' ownership or control, or it may not be cost effective for the requested company to collect the data. The Product Standard specifies what may be done to fill data gaps, where primary or secondary data cannot be obtained that are sufficiently representative. Secondary data is defined as data not from specific processes in the given product's life cycle. For advertising, secondary data is the compilation of Emission Factors (e.g., fuels and electricity EFs) to use as a proxy when primary data is not available. In general, some pragmatism is required, as well as caution when using increasing levels of secondary data indicators, as the aforementioned GHG accounting principles of relevancy, accuracy, and transparency might well suffer in this case.

It is worth noting now that we will rely extensively on the measurement ability and quality of our vendors and partners extensively. Without their participation, we will often be reduced to assumptions, and local (or worse global) averages, leading to much less precise estimates of emissions, and weaker overall controls on Advertising and Advertised Emissions.

For a global company, multiple region-specific sources of secondary data may be needed to fill unavailable data gaps. Country-level emissions accounting guidance on secondary regional emission factors should be utilized when identifying secondary data sources. For completeness, the table below provides current country level emission factors for their energy grids, further highlighting the vast differences possible in channel level energy emissions for work does in a large global footprint.

COUNTRY	$kgCO_2e$ per kWh
Argentina	0.3070
Australia	0.7600
Austria	0.1111
Belgium	0.1619
Brazil	0.0617
Bulgaria	0.3721
Canada	0.1200
China	0.5374
Croatia	0.2269
Cyprus	0.6429
Czech Republic	0.4954
Denmark	0.1425
Estonia	0.5986
Finland	0.0953
France	0.0512
Germany	0.3386
Greece	0.4100
Hong Kong	0.7100
Hungary	0.2437
Iceland	0.0001
India	0.7082
Indonesia	0.7177
Ireland	0.3359
Italy	0.3238
Japan	0.4658
Korea	0.4156

COUNTRY	$kgCO_2e$ per kWh
Latvia	0.2156
Lithuania	0.2535
Luxembourg	0.1013
Malta	0.3906
Mexico	0.4314
Netherlands	0.3743
New Zealand	0.1014
Norway	0.0076
Poland	0.7596
Portugal	0.2015
Romania	0.2618
Russian Federation	0.3102
Saudi Arabia	0.5059
Serbia	0.7766
Singapore	0.4080
Slovakia	0.1554
Slovenia	0.2240
South Africa	0.9006
Spain	0.1710
Sweden	0.0056
Switzerland	0.0115
Thailand	0.4420
Turkey	0.3750
United Arab Emirates	0.4041
United Kingdom	0.2123
Unites States	0.4239

ADVERTISING EMISSIONS

Advertising Emissions represent our inward-looking control, and for taking responsibility for the emissions associated with the operation of the advertising industry and for the provision of advertising services to our clients. It is not stated in terms of the entire industry, or a single firm (although it could be aggregated in this way), but rather as the MtCO2e associated with a specific ad or campaign, thus providing a managerially valuable indication of the carbon equivalent burden associated with their activities and providing a needed step towards our calculations of efficiency and returns against MtCO2e (commercial or otherwise).

As described earlier, we will aggregate activities from the smallest possible unit within each sub-process/channel combination all the way up to a campaign level measure, potentially spanning dozens of subchannels and with a global footprint. Specifically, we start from channel-specific functional units. The functional unit is used to calculate the intensity of the allocatable process. This intensity is then multiplied by the size of the ad to calculate the emissions from a singular ad. The number of ads and impressions in the given channel are then multiplied by the emissions of a single ad to calculate the channel's emissions. And the aggregate of our channels provides the overall campaign emissions.

This construction will allow managers to evaluate the value per emission of ads, channel combinations, suppliers, locations and beyond in an exceptional granular approach.

In order to proceed with these calculations, we must first identify the channels available to us, and describe their unique value chains. Each component step in this chain can then be described by a combination of more general sub-processes with their associated emissions. For example, "production development' is a common step in channels' value chain, and we can describe its component activities/processes: Equipment use, transportation, catering, post-production, etc.

Next, we will describe the 11 media channels and 25 subchannels according to their value chains. We highlight where the "cradle to gate" boundary is defined and indicate the sub-processes/activities that compose our channel life cycles. Then, we will provide detailed calculation for the emissions arising from each of these component activities.

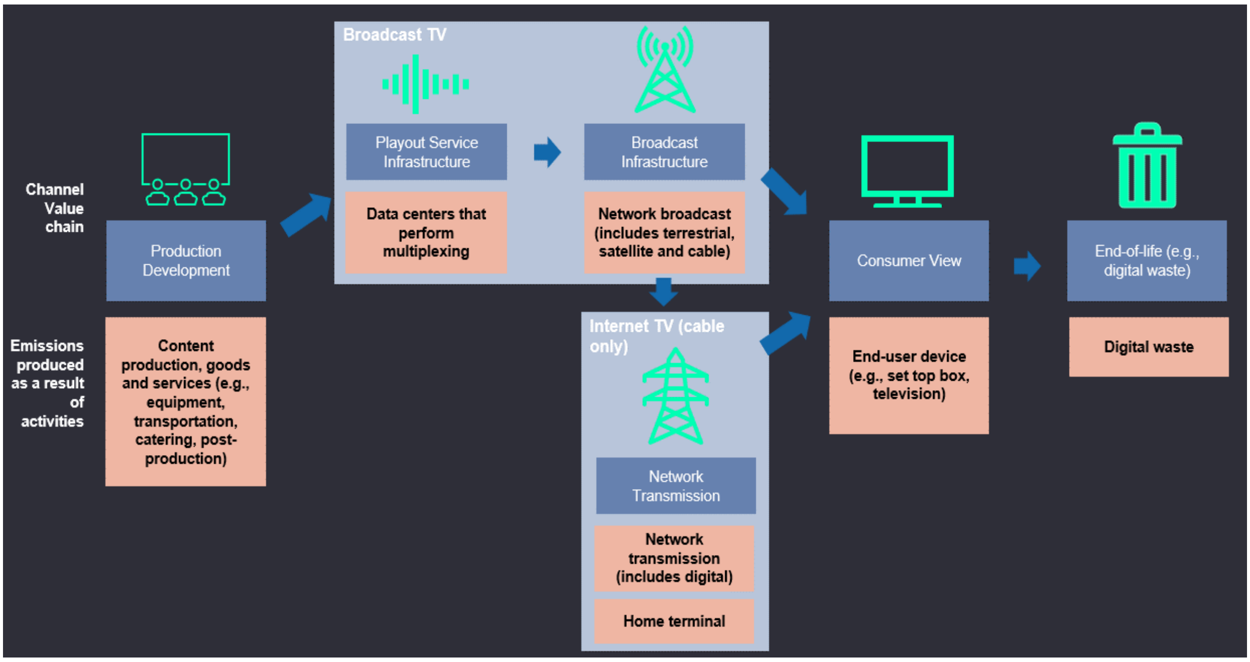
Channel Boundaries and Sub-Processes

TV

For the purposes of this framework, the term TV is defined as the linear "traditional" playout service (broadcast) that delivers live media on a planned schedule. However, if live TV is delivered through a mobile application, a non-linear playout service such as an app is used in addition to this approach. The scope of the TV channel includes the subtype channels of:

- broadcast,
- cable (either delivered via set-top box or internet) and
- addressable TV.

The life cycle stages defined for TV are shown in the figure below (production development, playout services, broadcast infrastructure, network transmission (if live TV is streamed on a mobile device), consumer view and end-of-life). For TV, the cradle-to-gate boundary used in this methodology includes production development, playout services and network transmission.

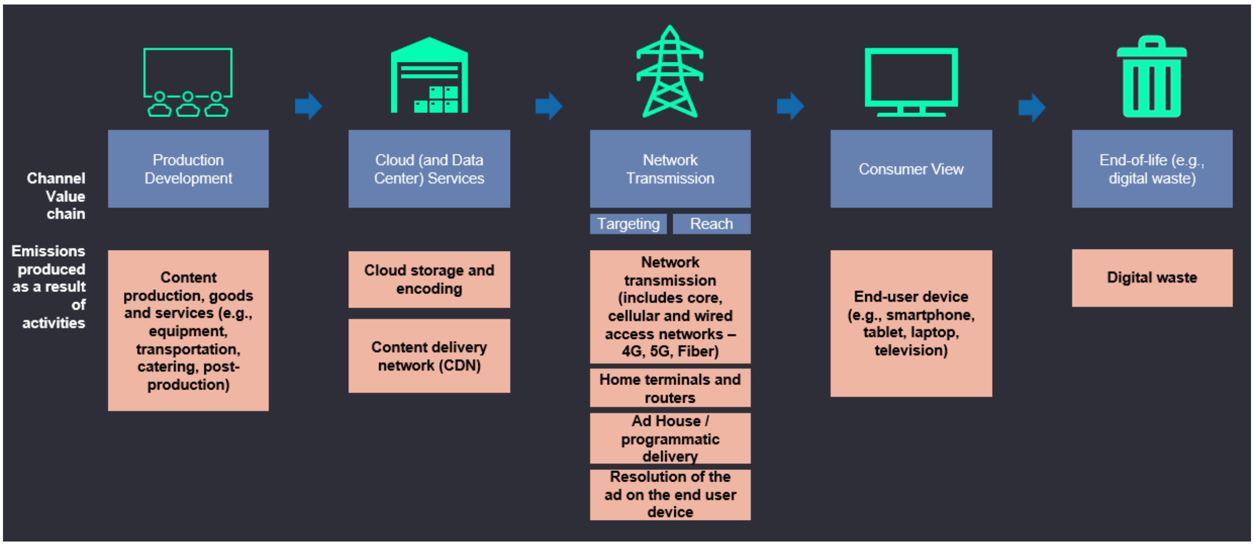


Video on Demand (VOD)

The term VOD is defined as a non-linear playout service that delivers on-demand media via cloud (and data center) services and network transmission infrastructure. Ads reach end users using advanced data to target specific audiences. The scope of the VOD channel includes the subtype channel of:

- streaming

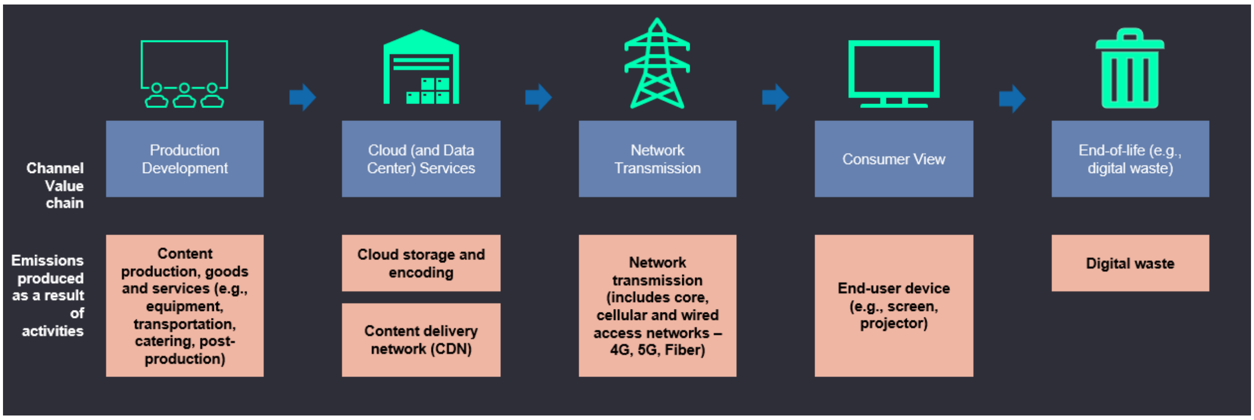
The five life cycle stages defined for digital are shown in the figure below (production development, cloud (and data center) services, network transmission, consumer view and end-of-life). For VOD, the cradle-to-gate boundary used in this methodology includes production development, cloud (and data center) services and network transmission.



Cinema

The term cinema is defined as the non-linear playout service infrastructure that delivers digital video media.

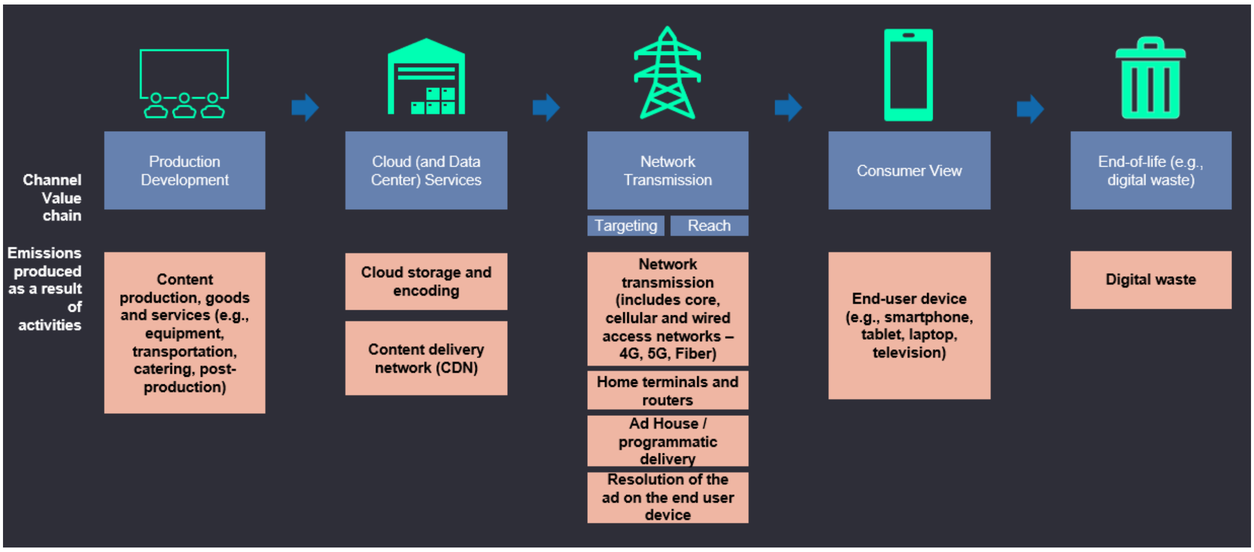
The five life cycle stages defined for cinema are shown in the figure below (production development, cloud (and data center) services, network transmission, consumer view and end-of-life). For cinema, the cradle-to-gate boundary used in this methodology includes production development, cloud (and data center) services and network transmission.



Social Media

The term social media is defined as a multiplatform mobile application that delivers ads to end users via cloud (and data center) services and network transmission infrastructure. Ads reach end users using advanced data to target specific audiences. The social media channel includes mobile and web-based platforms.

The five life cycle stages defined for social media are shown in the figure below (production development, cloud (and data center) services, network transmission, consumer view and end-of-life). For social media, the cradle-to-gate boundary used in this methodology includes production development, cloud (and data center) services and network transmission.

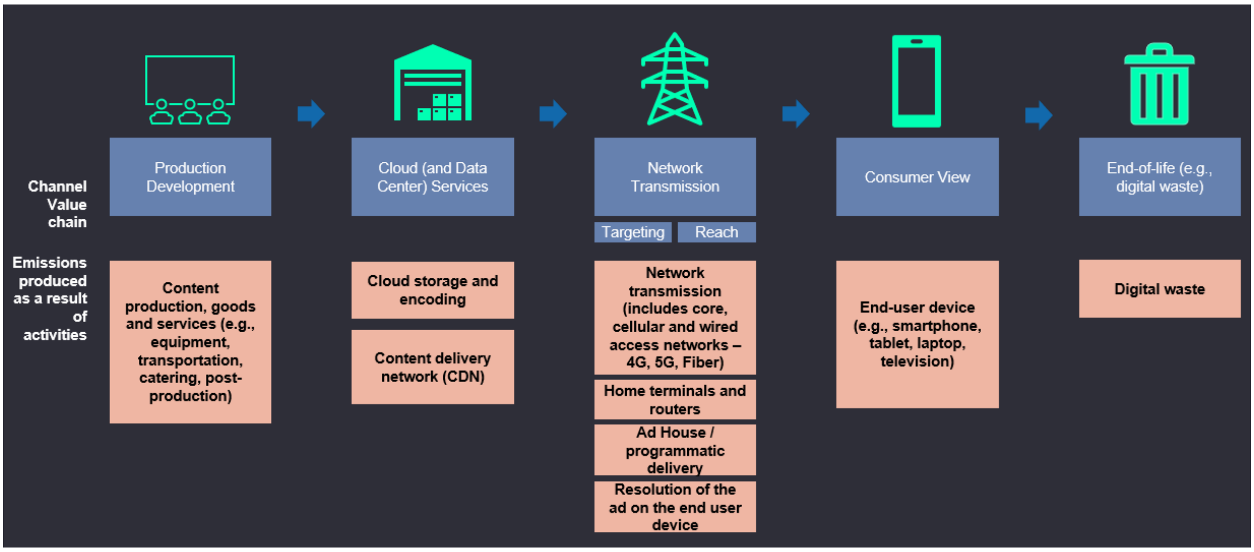


Digital

The term digital is defined as ads delivered on digital devices (e.g., smartphone, tablet and laptop) to end users via cloud (and data center) services and network transmission infrastructure. Ads reach end users using advanced data to target specific audiences. The scope of the digital channel includes the subtype channels of:

- online display,
- mobile display and
- online search.

The five life cycle stages defined for digital are shown in the figure below (production development, cloud (and data center) services, network transmission, consumer view and end-of-life). For digital, the cradle-to-gate boundary used in this methodology includes production development, cloud (and data center) services and network transmission.

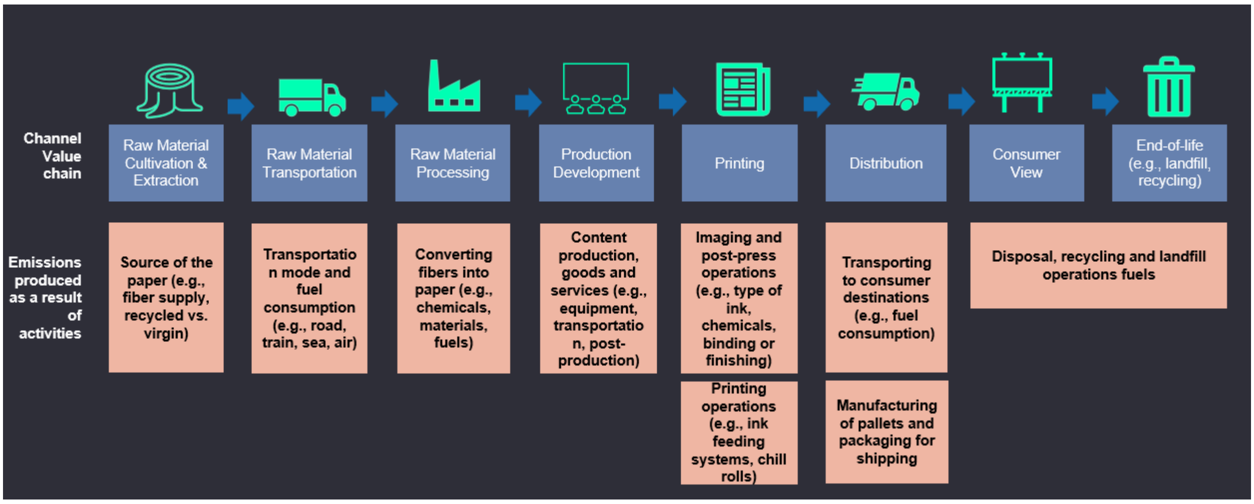


Print

The term print is defined as the activities in which physical advertisements undergo to be placed onto magazine or newspaper outlets. The scope of the print channel includes the subtype channels of:

- newspaper and
- magazine.

The seven life cycle stages defined for print are shown in the figure below (raw material cultivation & extraction, raw material transportation, raw material processing, printing, distribution, consumer view and end-of-life). For print, the cradle-to-gate boundary used in this methodology includes raw material cultivation & extraction, raw material transportation, raw material processing, printing and distribution.

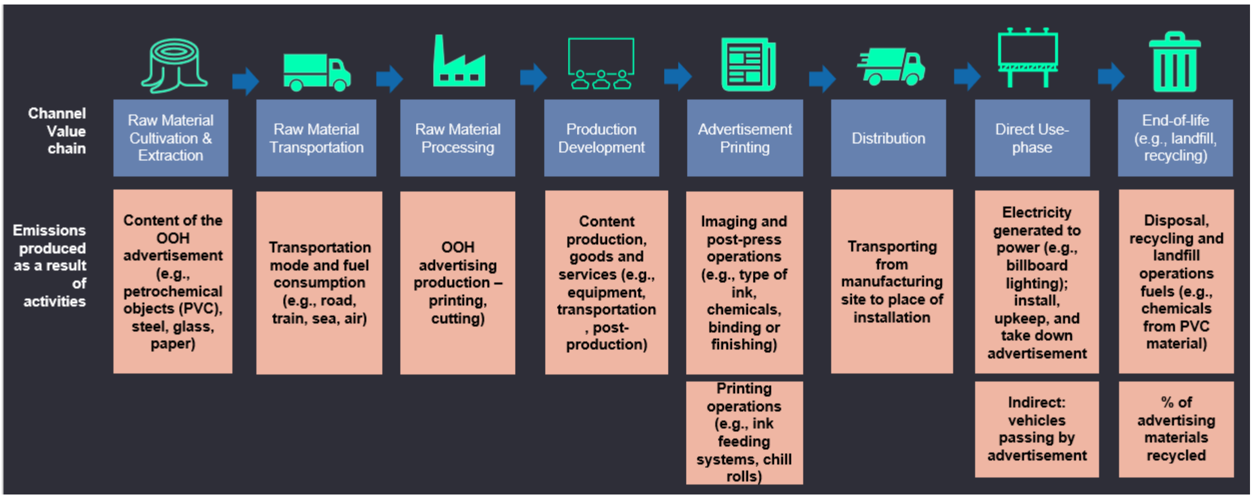


Out-of-Home (OOH)

The term OOH is defined as physical media that is placed in stationary public locations. The scope of the OOH channel includes the subtype channels of:

- PVC/vinyl banner,
- custom format virgin and recycled paper,
- lightbox – backlit and
- telephone box.

The seven life cycle stages defined for OOH are shown in the figure below (raw material cultivation & extraction, raw material transportation, raw material processing, printing, distribution, direct use-phase and end-of-life). For OOH, the cradle-to-gate boundary used in this methodology includes raw material cultivation & extraction, raw material transportation, raw material processing, printing, and distribution.

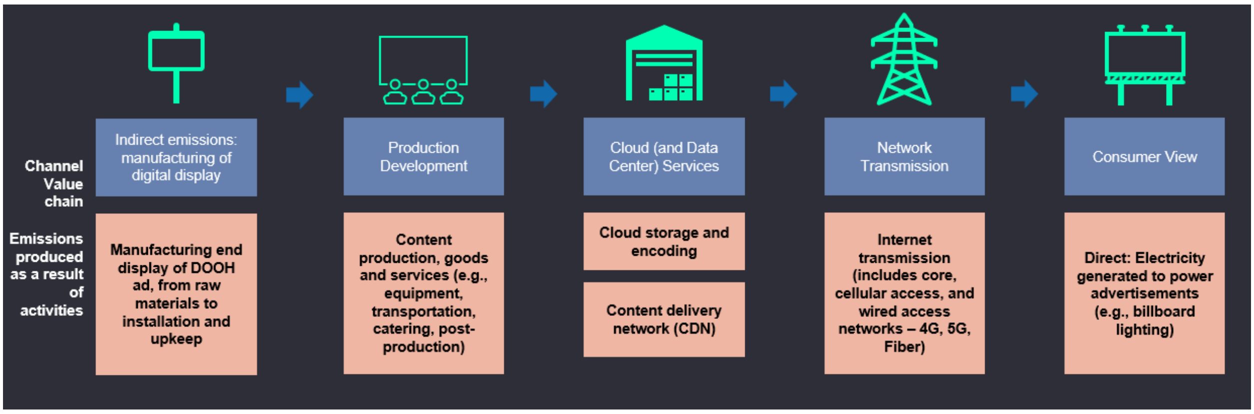


Digital Out of Home (DOOH)

The term DOOH is defined as digital media that is placed in public locations. The scope of the DOOH channel includes the subtype channels of:

- LED digital display – large roadside formats.

The four life cycle stages defined for DOOH are shown in the figure below (production development, cloud (and data center) services, network transmission and consumer view). For DOOH, the cradle-to-gate boundary used in this methodology includes production development, cloud (and data center) services and network transmission.

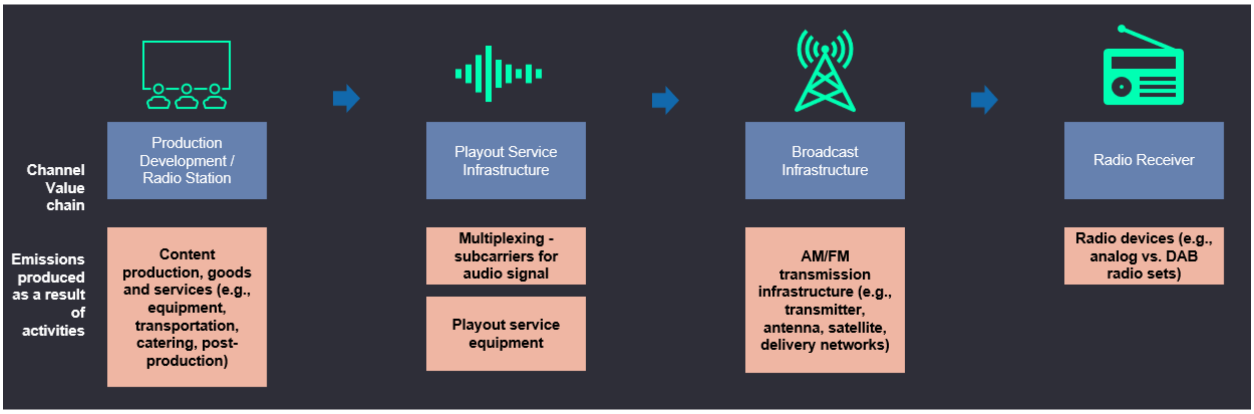


Radio

The term radio is defined as the linear playout service infrastructure that delivers live radio media on a planned schedule. The scope of the radio channel includes the subtype channel of:

- spot.

The four life cycle stages defined for radio are shown in the figure below (production development, playout service infrastructure, broadcast infrastructure and radio receiver). For radio, the cradle-to-gate boundary used in this methodology includes production development, playout service infrastructure and broadcast infrastructure.

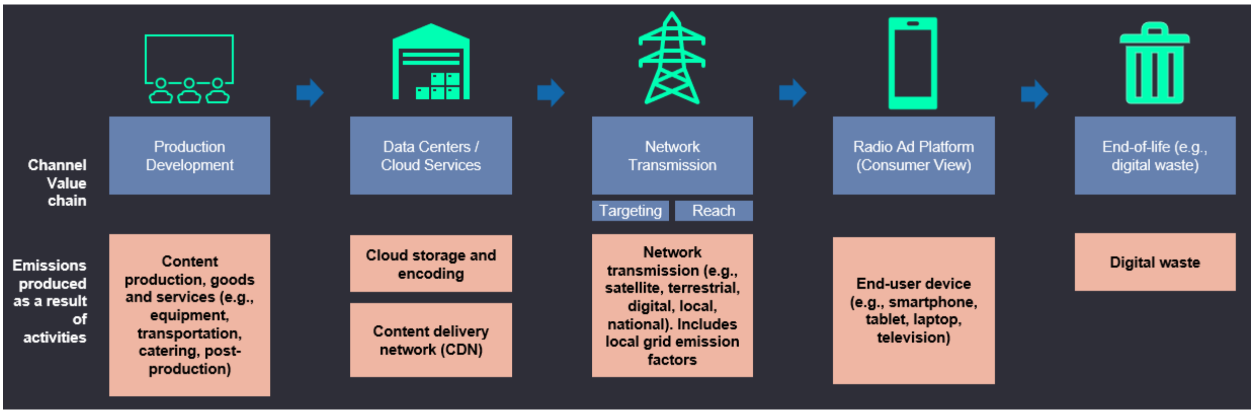


Digital Audio

The term digital audio is defined as non-linear playout services that deliver audio media via cloud (and data center) services and network transmission infrastructure. The scope of the digital audio channel includes the subtype channel of:

- podcasts and
- online radio.

The five life cycle stages defined for digital audio are shown in the figure below (production development, cloud (and data center) services, network transmission, radio ad platform and end-of-life). For digital audio, the cradle-to-gate boundary used in this methodology includes production development, cloud (and data center) services, network transmission and radio ad platform).

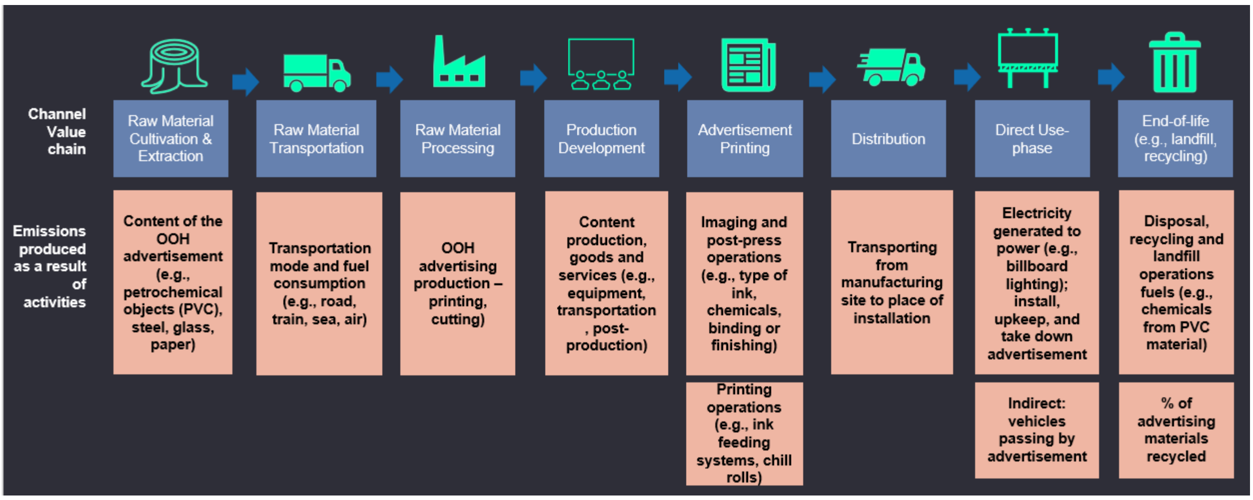


Transient

The term transient is defined as physical media that is placed on or within vehicles or within transit stations; it does not include bus shelters. The scope of the transient channel appendices includes the subtype channels of:

- bus,
- train and
- taxi.

The seven life cycle stages defined for transient are shown in the figure below (raw material cultivation & extraction, raw material transportation, raw material processing, printing, distribution, direct use-phase and end-of-life). For transient, the cradle-to-gate boundary used in this methodology includes raw material cultivation & extraction, raw material transportation, raw material processing, printing, and distribution.



Individual Processes

Now we describe the technical calculations involved with accounting for ad emissions through channel value chain stages. The intent of this section is to provide the methods to account for the attributable processes in the value chain, which are reference in the above channel value chain descriptions.

The processes described are given in the table below:

Value chain stage	Applicability by channel:										
	TV	Cinema	Social	Digital	VOD	Print	OOH	Transient	DOOH	Radio	Digital Audio
Production Development	X	X	X	X	X	X	X	X	X	X	X
Cloud and Data Centers	-	X	X	X	X	-	-	-	X	-	X
Network Transmission	X	X	X	X	X	-	-	-	X	X	X
Raw Material Production	-	-	-	-	-	X	X	X	-	-	-
Printing	-	-	-	-	-	X	X	X	-	-	-
Physical Distribution	-	-	-	-	-	X	X	X	-	-	-
Playout Services	X	-	X	-	-	-	-	-	-	X	X
Mobile Application	-	-	X	X	X	-	-	-	X	-	X

Production development

Production development is defined as the creative, production and post-production activities involved in creating an advertisement. The AdGreen Carbon Calculator (AdGreen) was developed in partnership with external industry stakeholders to calculate the emissions associated with motion, stills and audio projects within advertising campaigns. This tool calculates the ad production emissions. The tool is free to use and is easily accessible, with wide adoption in the industry. And rather than replicate effort, as well as in building on successful implementations, we will adopt this approach for our calculations as well.

Cloud (and data center) services

Cloud services is a term used to encapsulate the delivery of a digital service. Emissions associated with the use of cloud services are attributable to its use of data centers, networks and end-user devices. These services are commonly used in media to deliver on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction (Mell & Grance, 2011). Due to the diversity and complexity of cloud service transactions and the lack of a standardized approach to separating transactions, this methodology uses the same energy load on IT hardware (The Carbon Trust, 2017), based on the functional unit of one kilobyte (1 kB) for a given service). In addition, virtual machine utilization is included within cloud and data center energy consumption and is not accounted for separately.

Based on the vendor ownership or lease of cloud and data centers, there are two options for calculating the emissions associated with their utilization of cloud services.

Owned cloud infrastructure

Source:	Information needed:	Abbreviated as:	Unit:
Vendor	Annual data center IT infrastructure energy consumption	Annual reported data center energy	MWh
	Annual data center scope 1 emissions	Data center scope 1 emissions	mt CO_2e
	Annual data center scope 2 (market-based method (MBM)) emissions	Data center scope 2 (MBM) emissions	mt CO_2e
	Annual power usage effectiveness (PUE)	PUE	Unitless
	Annual total quantity of data processed	Total data traffic	kB
	Location(s) of data center(s)	(Used to identify grid EF)	Unitless

If the vendor, or cloud service provider, has calculated their emissions intensity, inclusive of embodied emissions of IT infrastructure, it is recommended that the vendor's intensity be used in lieu of a separate calculation of emissions intensity. This would be used in a similar way to utility companies that may provide market based Emission Factors for customers. An example of cloud services emissions intensity would be the ratio of total cloud service emissions per annual quantity of data processed. The following methodology is recommended to support vendors that do not calculate their emissions intensity.

In the absence of vendor emissions intensity data, the preferred approach is to request that the vendor calculate and provide the annual energy consumption of its IT infrastructure for the specified (likely most recent) reporting year. Do not include the energy and emissions from a vendor’s office facilities.

In addition to requesting the annual cloud infrastructure energy consumption, the PUE ratio should be requested. The PUE is a metric that represents the ratio between the total facility power (fixed plus variable) and the IT equipment power (variable) of a data center. It is used to allocate the total overhead energy (i.e., non-IT energy of the data center mechanical and electrical infrastructure). If no PUE is available, use the most recent year's global average PUE. In 2021, the global average PUE was 1.57 (Bizo, Ascierto, Lawrence, & Davis, 2021), meaning data center facility functions added 57% to the energy use of IT equipment. The typical use-stage energy use per year is then calculated by:

$$\boldsymbol{Annual\ IT\ equipment\ energy}\ (MWh) = \frac{Annual\ reported\ data\ center\ energy\ (MWh)}{PUE}$$

Equation 1

Knowing the energy associated with the IT equipment, excluding data center facility overhead energy, the emissions of the IT equipment can be calculated using a region-specific (e.g., country-level) purchased electricity EF, similar to those provided previously. If there is uncertainty regarding the location of the cloud infrastructure, the global average purchased electricity EF should be used. The use-stage IT equipment emissions can be calculated by:

$$\boldsymbol{IT\ equipment\ emissions}\ (mt\ CO_2e) = Annual\ IT\ equipment\ energy\ (MWh)\ x\ grid\ EF\ (\frac{mt\ CO_2e}{MWh})$$

Equation 2

Once the use-stage IT equipment emissions have been calculated, the ratio method[1] can then be used to approximate the embodied emissions associated with the equipment powering the cloud services. The recommended ratio used is [25/135] for the data center. This ratio is based on an extensive dataset, which combined primary and secondary data for operational (use-stage) energy consumption and life cycle GHG emissions from approximately 100 of the major global ICT and Entertainment and Media (E&M) manufacturers, operators, and service providers (Malmodin, Jens; Lunden, Dag, 2018). Using this ratio, the embodied emissions can be calculated by:

$$\begin{aligned}&\boldsymbol{Embodied\ IT\ equipment\ emissions}\ (mt\ CO_2e)\\ &\quad = Use\ stage\ IT\ equipment\ emissions\ (mt\ CO_2e)\ x\ Use\ stage\ emissions\ ratio\ (\frac{25}{135})\end{aligned}$$

Equation 3

The total cloud service emissions are calculated by adding:

$$\begin{aligned}&\boldsymbol{Total\ cloud\ services\ annual\ emissions}\ (mt\ CO_2e)\\ &\quad = Data\ center\ scope\ 1\ emissions\ (mt\ CO_2e)\\ &\quad + Data\ center\ scope\ 2\ (MBM)\ emissions\ (mt\ CO_2e)\\ &\quad + Embodied\ IT\ equipment\ emissions\ (mt\ CO_2e)\end{aligned}$$

Equation 4

The vendor total annual quantity of data processed is used to create an emissions intensity for cloud services:

$$\boldsymbol{Annual\ cloud\ services\ emissions\ intensity}\ (\frac{mt\ CO_2e}{kB}) = \frac{Total\ cloud\ services\ (mt\ CO_2e)}{Total\ data\ traffic\ (kB)}$$

Equation 5

Lastly, the emissions intensity is multiplied by the size of the ad to calculate the attributable emissions of cloud services:

$$\boldsymbol{Cloud\ services\ emissions}\ (mt\ CO_2e) = Emissions\ intensity\ \left(\frac{mt\ CO_2e}{kB}\right)\ x\ Ad\ size\ (kB)$$

Equation 6

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[1] The ratio method is a calculation approach using secondary data, termed life cycle stage ratio modelling, which is used to calculate embodied emissions of ICT hardware with reasonable levels of confidence (The Carbon Trust, 2017).

Leased cloud infrastructure

Source:	Information needed:	Abbreviated as:	Unit:
Campaign planner	Cloud services spend for the media campaign	Cloud services spend on media campaign	USD
Vendor	Annual cloud services spend	Annual provider spend	USD
Vendor's cloud services provider	Annual quantity of data processed	Total quantity of data processed	kB

For instances in which the vendor is leasing cloud infrastructure and the secondary vendor is both known and has operational data available, their vendor-based emissions intensity should be used, as described above.

If no vendor-based emissions intensity is available, the exact or approximated spend on the media campaign should be used to calculate the cloud service emissions. The campaign spend on cloud services should be calculated by multiplying the campaign spend by an Environmentally Extended Input-Output (EEIO) database factor that represents the emissions from this service. If this spend is not available, it can be calculated using annual provider spend and total quantity of data processed. The US EPA Supply Chain Database EEIO factor for 'Data processing and hosting' is recommended. See the table below for EPA Supply Chain Emission Factors (published in 2020) for data processing and hosting (Ingwersen & Li, 2020).

BEA Industry Code	Commodity Name	Substance	Unit	Supply Chain Emission Factors with Margin
518200	Data processing, hosting and related services	Carbon dioxide	Kg CO_2/2018 USD purchaser price	0.126
518200	Data processing, hosting and related services	Methane	Kg CH_4/2018 USD purchaser price	0.001
518200	Data processing, hosting and related services	Nitrous oxide	Kg N_2O/2018 USD purchaser price	0.000
518200	Data processing, hosting and related services	Other GHGs	Kg CO_2e/2018 USD purchaser price	0.008

The EF is calculated using the above table and the most recent global warming potential (GWP) factors. At the time of writing, the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report GWP factors were the most recent publication.

Gas	GWP
CH_4	27.9

N_2O	273

$$\boldsymbol{EEIO\ EF}\ \left(\frac{kg\ CO_2e}{2018\ USD\ purchaser\ price}\right) = 0.126\ \left(\frac{kg\ CO_2}{2018\ USD\ purchaser\ price}\right) x\ 1 + 0.001\ \left(\frac{kg\ CH_4}{2018\ USD\ purchaser\ price}\right) x\ CH_4\ GWP + 0.0\ \left(\frac{kg\ N_2O}{2018\ USD\ purchaser\ price}\right) x\ N_2O\ GWP + 0.008\ \left(\frac{kg\ CO_2e}{2018\ USD\ purchaser\ price}\right)$$

Equation 7

The EEIO EF using the AR6 is $0.000188\ \frac{mt\ CO_2e}{2018\ USD\ purchaser\ price}$.

As the most recent publication of the US EPA supply chain database data is for 2018 purchaser price, using the Consumer Price Index (CPI) inflation factor to convert the cloud service spend to that of the EF. When calculating the emissions of 2021 cloud service spend, modify the spend by the rate inflation increased (e.g., from 2018 to 2021) before multiplying by the EEIO EF.

$$\boldsymbol{Spend - based\ cloud\ services\ emissions}\ (mt\ CO_2e) = Cloud\ services\ spend\ on\ media\ campaign\ (Current\ year\ USD)\ x\ CPI\ Factor\ \left(\frac{2018\ USD}{Current\ year\ USD}\right) x\ 0.000188\ \left(\frac{mt\ CO_2e}{2018\ USD\ purchaser\ price}\right)$$

Equation 8

The spend-based cloud services emissions are divided by the total quantity of data to calculate the emissions intensity. This intensity is then multiplied by the ad size to calculate the cloud services emissions for the size of the ad.

$$\boldsymbol{Cloud\ service\ emissions}\ (mt\ CO_2e) = \frac{Spend - based\ cloud\ service\ emissions\ (mt\ CO_2e)}{Total\ quantity\ of\ data\ (kB)}\ x\ Ad\ size\ (kB)$$

Equation 9

Network transmission

Network transmission is the communication of data between the cloud infrastructure and the end users (consumers) through the broader internet. This service uses telecommunications network services, which is a series of points or nodes interconnected by communication paths, to take the ad from storage to audience targeting through reach.

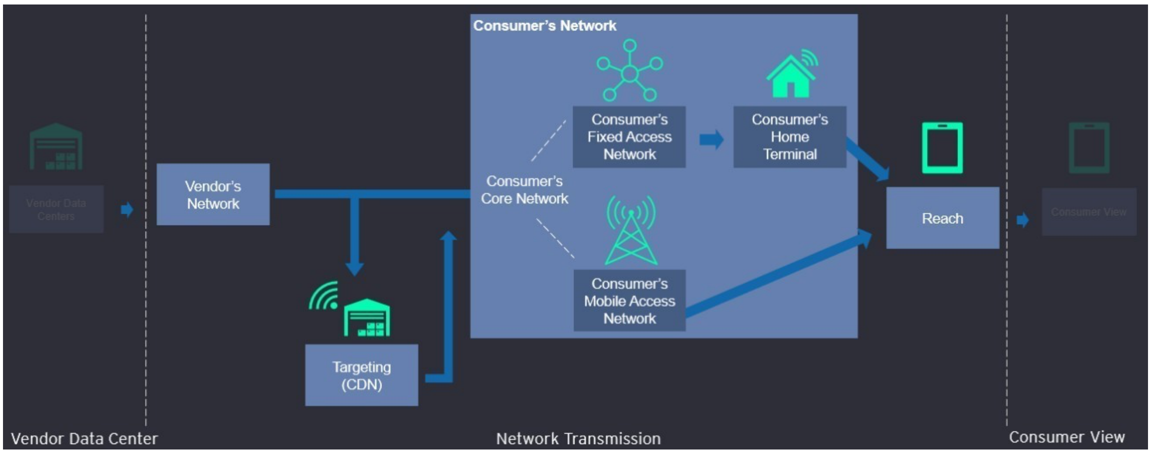
In simplest cases, the emissions associated with network transmission are from the internet access infrastructure. In more complex cases, the emissions include transportation to and from, as well as the operation of, content delivery networks (CDNs). Energy consumption within networks is not linearly proportional to data volume (Malmodin, Jens; Lunden, Dag, 2018). At present, there are two proposed approaches to estimating network transmission (The Carbon Trust, 2021):

1. *Conventional approach*: uses data volume transferred for network emissions allocation
2. *Transmission network power model*: uses Malmodin's power model, which estimates baseload and dynamic contributions, for network emissions allocation

The conventional approach was selected for use in this methodology as The Carbon Trust states that the transmission network power model is "relatively nascent with open questions and uncertainty that currently restrict it from being used as an alternative for organizational footprinting" (The Carbon Trust, 2021).

Due to uncertainty of the network transmission type, the operators used by end consumers and rapidly changing technological innovation (e.g., transitioning from a fixed-line router to a 5G mobile broadband hub), there is difficulty in estimating network energy. The emissions from network infrastructure may be calculated by using an energy intensity factor for the combined core networks and fixed telephony, fixed broadband and/or mobile access networks (expressed in kilowatt-hour (kWh) per data volume) of a network operator and multiplying this by the size of the ad and a region-specific electricity EF.

For our purposes, the network transmission process has been broken down into the following steps:



The total network emissions encompass the vendor and consumer's network. Within the consumer network, there is a core network and an access network. Within the access network, there are two types: fixed access and mobile access. Fixed access networks transmit data through point-to-point wireless communication devices or systems (e.g., building to building or tower to building). Mobile access networks transmit data through cellular towers to enable data transmission through a portable, mobile internet connection.

Typically, core and access networks are operated by the same company. If not stated otherwise by the network operator, emissions provided by the network operator are for both the core and fixed access networks. When the breakdown of emissions between core and fixed access networks is unknown, the ratio of the market share (by country) of the two broadband access networks is used to allocate the emissions.

The home terminal network is also a part of the consumer network. The home terminal network only applies when the consumer data is passing through a fixed access network, not a mobile access network. Therefore, those emissions from the consumer fixed access network, as allocated by market share, are used to calculate the home terminal network emissions.

The following sections describe the methodology used to calculate the emissions attributable to each step, which are then added to describe the total network transmission emissions:

$$\begin{aligned}\boldsymbol{Total\ network\ transmission}\ (mt\ CO_2e) \\ &= Vendor's\ network\ (mt\ CO_2e) + Targeting\ (mt\ CO_2e) \\ &+ Consumer's\ network\ (mt\ CO_2e) +\ Reach\ (mt\ CO_2e)\end{aligned}$$

Equation 10

Vendor's network

Source:	Information needed:	Abbreviated as:	Unit:
Vendor's network operator	Vendor's name	n/a	Unitless
	Annual energy consumption of IT infrastructure	Energy consumption of IT infrastructure	MWh
	Annual PUE	PUE	Unitless
	Annual scope 1 emissions	Network services scope 1 emissions	mt CO_2e
	Annual scope 2 (MBM) emissions	Network services scope 2 (MBM) emissions	mt CO_2e
	Annual operator network traffic	Total network traffic	kB
Vendor	Country of vendor's network operator	(Used to identify grid EF)	Unitless

The core network used by the vendor is either self-operated (e.g., Microsoft) or operated by a third party. If the network operator provides an emissions intensity, inclusive of embodied emissions of network infrastructure, it is recommended that the vendor's intensity be used in lieu of alternative calculations. This would be used similar to how utility companies may provide market-based EFs for customers. An example of network operator emissions intensity would be the ratio of total network service emissions per annual operator traffic. The following methodology is suggested to support vendors that do not calculate their emissions intensity.

In the absence of a provided network operator emissions intensity, the preferred approach is to use the high-level service platform method by requesting that the vendor provide the name of their network operator. With this information, the vendor's network operator's most recent sustainability report should be researched to identify their annual network operator electricity consumption (e.g., Gigawatt-hour (GWh), Gigajoule (GJ)) of IT infrastructure, network traffic (e.g., Petabyte (PB)) and market-based operational emissions (MtCO_2e). If this information is not publicly available, it is recommended that the vendor request this information directly from their network operator.

The annual IT infrastructure energy consumption for the most recent reporting year of the vendor's network operator is requested to calculate the use-stage emissions. This should not include the energy and emissions from the network operator's office facilities (exactly as assumed previously).

In addition to annual energy consumption, the PUE ratio should be requested. The PUE is a metric that represents the ratio between the total facility power (fixed plus variable) and the IT equipment power (variable) of a data center; although developed to be used for data center, this ratio may be used for other facility types (The Carbon Trust, 2017). It is used to allocate the total overhead energy (i.e., non-IT energy of the network infrastructure mechanical and electrical infrastructure). If no PUE is available, the most recent year global average PUE is recommended. In 2021, the global average PUE was 1.57 (Bizo, Ascierto, Lawrence, & Davis, 2021). The typical use-stage energy use per year is then calculated by:

$$\boldsymbol{Annual\ IT\ equipment\ energy}\ (MWh) = \frac{Energy\ consumption\ of\ IT\ infrastructure\ (MWh)}{PUE}$$

Equation 11

Knowing the energy associated with the IT equipment, excluding network infrastructure facility overhead energy, the emissions of the IT equipment can be calculated using a region-specific (e.g., country-level) purchased electricity EF. If there is uncertainty regarding the location of the network infrastructure, the global average purchased electricity EF should be used. The use-stage IT equipment emissions can be calculated by:

$$\boldsymbol{Use\ stage\ IT\ equipment\ emissions}\ (mt\ CO_2e) = Annual\ IT\ equipment\ energy\ (MWh)\ x\ grid\ EF\ (\frac{mt\ CO_2e}{MWh})$$

Equation 12

Using the use-stage IT equipment emissions, apply the ratio method to approximate the embodied emissions associated with the equipment powering the network services. The recommended ratio is [25/75] for the network infrastructure. Using this ratio, calculate the embodied emissions:

$$\boldsymbol{Embodied\ IT\ equipment\ emissions}\ (mt\ CO_2e) = \frac{Use\ stage\ IT\ equipment\ emissions\ (mt\ CO_2e)}{Use\ stage\ emissions\ ratio\ (\frac{25}{100})}\ x\ [1 - Use\ stage\ emissions\ ratio\ \left(\frac{25}{100}\right)]$$

Equation 13

The vendor's network operator total network service emissions are calculated by adding:

$$\begin{aligned}\boldsymbol{Total\ network\ services\ emissions}\ (mt\ CO_2e) &= Network\ services\ scope\ 1\ emissions\ (mt\ CO_2e)\\ &+ Network\ services\ scope\ 2\ (MBM)\ emissions\ (mt\ CO_2e)\\ &+ Embodied\ IT\ equipment\ emissions\ (mt\ CO_2e)\end{aligned}$$

Equation 14

The vendor's network operator total annual quantity of data processed is used to create a network operator emissions intensity:

$$\boldsymbol{Emissions\ intensity}\left(\frac{mt\ CO_2e}{kB}\right) = \frac{Total\ network\ services\ emissions\ (mt\ CO_2e)}{Total\ network\ traffic\ (kB)}$$

Equation 15

Lastly, the emissions intensity is multiplied by the size of the media ad to calculate the attributable emissions of vendor's network services:

$$\boldsymbol{Emissions}\ (mt\ CO_2e) = Emissions\ intensity\left(\frac{mt\ CO_2e}{kB}\right)\ x\ Ad\ size\ (kB)$$

Equation 16

A similar process shall be performed for the consumer's network operator.

Consumer's network

Source:	Information needed:	Abbreviated as:	Unit:
Consumer's network operator	Vendor's name	n/a	Unitless
	Annual energy consumption of IT infrastructure	Energy consumption of IT equipment	MWh
	Annual PUE	PUE	Unitless
	Annual scope 1 emissions	Network services scope 1 emissions	mt CO_2e
	Annual scope 2 (MBM) emissions	Network services scope 2 (MBM) emissions	mt CO_2e
	Annual network traffic	Total network traffic	kB
Vendor	Country of vendor's network operator	(Used to identify grid EF)	Unitless

The annual IT infrastructure energy consumption for the most recent reporting year of the consumer's network operator is requested to calculate the use-stage emissions. This should not include the energy and emissions from their office facilities.

In addition to requesting the annual network infrastructure energy consumption, the PUE ratio should be requested. If no PUE is available, the most recent year global average PUE is recommended. In 2021, the global average PUE was 1.57 (Bizo, Ascierto, Lawrence, & Davis, 2021). The typical use-stage energy use per year is then calculated by:

$$\boldsymbol{Annual\ IT\ equipment\ energy}\ (MWh) = \frac{Energy\ consumption\ of\ IT\ equipment\ (MWh)}{PUE}$$

Equation 17

Knowing the energy associated with the IT equipment, excluding network infrastructure facility overhead energy, the emissions of the IT equipment can be calculated using a region-specific (e.g., country-level) purchased electricity EF. If there is uncertainty regarding the location of the network infrastructure, the global average purchased electricity EF should be used. The use-stage IT equipment emissions can be calculated by:

$$\boldsymbol{Use\ stage\ IT\ equipment\ emissions}\ (mt\ CO_2e) = Annual\ IT\ equipment\ energy\ (MWh)\ x\ grid\ EF\ (\frac{mt\ CO_2e}{MWh})$$

Equation 18

Once the use-stage IT equipment emissions have been calculated, the ratio method can then be used to approximate the embodied emissions associated with the equipment powering the network services. The recommended ratio used is [25/75] for the network infrastructure. Using this ratio, the embodied emissions can be calculated by:

$$\boldsymbol{Embodied\ IT\ equipment\ emissions}\ (mt\ CO_2e) = \frac{Use\ stage\ IT\ equipment\ emissions\ (mt\ CO_2e)}{Use\ stage\ emissions\ ratio\ (\frac{1}{25})}\ x\ [1 - Use\ stage\ emissions\ ratio\ \left(\frac{1}{25}\right)]$$

Equation 19

The consumer’s network operator total network service emissions are calculated by adding:

$$\boldsymbol{Total\ network\ services\ emissions}\ (mt\ CO_2e) = Network\ services\ scope\ 1\ emissions\ (mt\ CO_2e) + Network\ services\ scope\ 2\ (MBM)\ emissions\ (mt\ CO_2e) + Embodied\ IT\ equipment\ emissions\ (mt\ CO_2e)$$

Equation 20

The consumer’s network operator total annual quantity of data processed is used to create a network operator emissions intensity:

$$\boldsymbol{Consumer\ operator\ emissions\ intensity}\ \left(\frac{mt\ CO_2e}{kB}\right) = \frac{Total\ network\ services\ emissions\ (mt\ CO_2e)}{Total\ network\ traffic\ (kB)}$$

Equation 21

The emissions intensity is multiplied by the size of the ad to calculate the attributable emissions of vendor’s network services:

$$\boldsymbol{Consumer\ network\ operator\ emissions}\ (mt\ CO_2e) = Consumer\ emissions\ intensity\ \left(\frac{mt\ CO_2e}{kB}\right)\ x\ Ad\ \mathrm{size}\ (kB)$$

Equation 22

Home terminal (router)

Source:	Information needed:	Abbreviated as:	Unit:
Consumer	Terminal/router model	Router	Unitless

For internet-based service platforms, the consumer's access network type (either fixed or mobile) will not be available when planning a media campaign. Therefore, it is recommended that a regional assumption of fixed versus mobile access networks used by consumers be established. The Ofcom International Broadband Scorecard: 2021 (Ofcom, 2021) is used to estimate regional fixed access network market share; several countries are provided in the table below:

Country	Market share of fixed network access	Data consumption per month (GB)
France	61%	112.4
Germany	62%	79.9
Italy	58%	53.6
Spain	63%	82.1
United Kingdom	66%	174.8
United States of America	87%	147.6

Although it is not discernable at this time to allocate consumer's network operator emissions intensity by access network type, it is recommended that the additional energy associated with home terminals or home routers be added proportionately with the fixed broadband market share. To estimate this, the assumption of a 10 Watt (W) router operated 24 hours per day (The Carbon Trust, 2021) is used to calculate the energy consumed by the router per hour:

$$\boldsymbol{Home\ router\ energy}\left(\frac{Wh}{day}\right) = Router\ power\ demand\ (W)\ x\ \left(\frac{24\ hours}{day}\right)$$

Equation 23

For a 10W router, the daily energy use can be estimated at 10 Watt-hours (Wh) per day. Using the Ofcom average household data consumption, the router energy can then be allocated to data transmitted:

$$\boldsymbol{Home\ router\ energy\ intensity}\left(\frac{kWh}{kB}\right)$$
$$= Router\ energy\left(\frac{Wh}{day}\right)\ x\ \frac{1}{Country\ average\ data\ consumption}\left(\frac{month}{GB}\right)x\left(\frac{30\ days}{1\ month}\right)x\left(\frac{1\ GB}{1{,}000{,}000\ kB}\right)x\ \left(\frac{1\ kW}{1{,}000\ W}\right)$$

Equation 24

The 10W router in the United Kingdom would be calculated to consume 1.72 Wh/GB or 0.00000000172 kWh/kB. The region-specific purchased electricity grid factor is then used to calculate the emissions of the home router per kilobyte of data processed.

$$\textbf{Home router emissions intensity}\left(\frac{mt\ CO_2e}{kB}\right) = Router\ energy\ intensity\left(\frac{kWh}{kB}\right) x\ grid\ EF\left(\frac{mt\ CO_2e}{kWh}\right)$$

Equation 25

Lastly, the home router emissions intensity is multiplied by the size of the media ad allocated to the fixed network access market share to calculate the additional emissions of consumer's fixed access network services:

$$\textbf{Home router use phase emissions}\ (mt\ CO_2e) = Router\ emissions\ intensity\left(\frac{mt\ CO_2e}{kB}\right) x\ Ad\ size\ (kB)\ x\ Fixed\ access\ market\ share\ (\%)$$

Equation 26

Once the use-stage home router emissions have been calculated, the ratio method can then be used to approximate the embodied emissions associated with the home router equipment. The recommended ratio used is [80/20] for the home router. Using this ratio, the embodied emissions can be calculated by:

$$\textbf{Embodied router emissions}\ (mt\ CO_2e) = \frac{Use\ stage\ home\ router\ emissions\ (mt\ CO_2e)}{Use\ stage\ emissions\ ratio\ (\frac{80}{100})}\ x\ [1 - \text{Use stage emissions ratio}\ (\frac{80}{100})]$$

Equation 27

The use-stage and embodied emissions are then added to calculate the total home router emissions (as part of the consumer network emissions):

$$\textbf{Home router emissions}\ (mt\ CO_2e) = Use\ phase\ router\ emissions\ (mt\ CO_2e) + embodied\ router\ emissions\ (mt\ CO_2e)$$

Equation 28

Network transmission proxy sources – alternative calculation based on public sources

If network operator data for vendor or consumer energy consumption and data traffic is unavailable, proxy sources have been identified to be used

For network transmission emissions that are via the internet, the estimations provided by The Carbon Trust's "conventional approach" are recommended as proxies for this stage of the value chain as they are the most recent estimations that utilize data transmission metrics.

Network transmission stage	Use-stage energy intensity (kWh/GB)
Vendor's network operator	0.0065[2]

[2] Intensity derived for 2020, Carbon Trust calculated from Aslan et. al, 2018 using linear regression

Network transmission stage	Use-stage energy intensity (kWh/GB)
Consumer's network operator	0.1065[3]
Home router	0.025[4]

The Cisco Annual Internet Report can be used to estimate a region-specific network transmission rate for both fixed and mobile subscribers. These can be used in lieu of network operator annual traffic to calculate an energy consumption intensity factor.

Region	Average Fixed Broadband speed (Mbps) - 2022	Average Mobile Broadband speed (Mbps) - 2022
Global	97.8	35.9
Asia Pacific	137.4	39.0
Latin America	51.5	24.8
North America	126.0	50.6
Western Europe	105.6	54.4
Central and Eastern Europe	77.8	36.1
Middle East and Africa	34.9	20.3

As this report is published annually, and the ICT sector efficiency changes rapidly, it is recommended that the most recent Cisco publication be used when estimating broadband speeds. For example, for 2022 estimates, it is recommended to use the Cisco report published in 2021 until the 2022 report is published. It is then recommended to use the 2022 report for the data on 2022.

The energy intensity ratios and network transmission rates can then be used to calculate region-specific Emission Factors for the network transmission using the size of the ad.

Vendor's network operator emissions

The annual network traffic for vendor operators is calculated for the selected region by:

$$\boldsymbol{Annual\ network\ traffic}: \boldsymbol{vendor\ network\ operator}\ (GB) = \ Region\ average\ network\ speed, fixed\ (Mbps)\ x \left(\frac{0.45\ \frac{GB}{hour}}{1\ Mbps}\right) x \left(\frac{24\ hours}{1\ day}\right) x \left(\frac{365\ days}{1\ year}\right)$$

Equation 29

The emissions attributable to the vendor network operations are calculated using the size of the media ad:

3 Combined fixed network (0.0065 kWh/GB)[6] and mobile network (0.1 kWh/GB (Pihkola et. al, 2018)) intensities from (The Carbon Trust, 2021)

4 (The Carbon Trust, 2021)

$$\boldsymbol{Use - stage\ emissions}\ (mt\ CO_2e) = \ Vendor\ use\ stage\ network\ operator\ energy\ intensity\ \left(0.0065\frac{kWh}{GB}\right) x$$
$$Annual\ network\ traffic\text{: } vendor\ network\ operator\ (GB)\ x\ grid\ EF\ (\frac{mt\ CO_2e}{kWh})$$

Equation 30

Once the use-stage emissions of the vendor's network operator have been calculated, the ratio method can then be used to approximate the embodied emissions associated with the equipment powering the network services. The recommended ratio used is [25/75] for the network infrastructure. Using this ratio, the embodied emissions can be calculated by:

$$\boldsymbol{Embodied\ vendor's\ network\ operator\ emissions}\ (mt\ CO_2e) = \frac{Use\ stage\ vendor\ network\ operator\ emissions\ (mt\ CO_2e)}{Use\ stage\ emissions\ ratio\ \left(\frac{25}{100}\right)}\ x\ [1 - Use\ stage\ emissions\ ratio\ \left(\frac{25}{100}\right)]$$

Equation 31

The vendor's network operator total network service emissions are calculated by adding:

$$\boldsymbol{Total\ network\ services\ emissions}\ (mt\ CO_2e) = Use\ stage\ network\ operator\ emissions\ (mt\ CO_2e) + Embodied\ vendor\ network\ operator\ emissions\ (mt\ CO_2e)$$

Equation 32

The vendor's network operator total annual quantity of data processed is used to create a network operator emissions intensity:

$$\boldsymbol{Emissions\ intensity}\ \left(\frac{mt\ CO_2e}{kB}\right) = \frac{Total\ network\ services\ emissions\ (mt\ CO_2e)}{Annual\ network\ traffic\ (kB)}$$

Equation 33

Lastly, the emissions intensity is multiplied by the size of the media ad to calculate the attributable emissions of the vendor's network services:

$$\boldsymbol{Vendor\ emissions}\ (mt\ CO_2e) = Emissions\ intensity\ \left(\frac{mt\ CO_2e}{kB}\right)\ x\ Ad\ size\ (kB)$$

Equation 34

Consumer's network operator emissions

The annual network traffic for consumer's operators is calculated for the selected region by:

$$\boldsymbol{Annual\ network\ traffic: consumer\ network\ operator}\ (GB) = Region\ average\ speed, fixed\ (Mbps)\ x \left(\frac{0.45\ \frac{GB}{hour}}{1\ Mbps}\right) x \left(\frac{24\ hours}{1\ day}\right) x \left(\frac{365\ days}{1\ year}\right)$$

Equation 35

Next, the emissions attributable to the consumer's network operator operations are calculated using the size of the media ad:

$$\boldsymbol{Use - stage\ emissions}\ (mt\ CO_2e) = Consumer's\ use\ stage\ network\ operator\ energy\ intensity\ \left(0.0065\frac{kWh}{GB}\right) x\ Annual\ network\ traffic: consumer's\ network\ operator\ (GB)\ x\ grid\ EF\ \left(\frac{mt\ CO_2e}{kWh}\right)$$

Equation 36

Once the use-stage emissions of the consumer's network operator have been calculated, the ratio method can then be used to approximate the embodied emissions associated with the equipment powering the network services. The recommended ratio used is [25/75] for the network infrastructure. Using this ratio, the embodied emissions can be calculated by:

$$\boldsymbol{Embodied\ consumer's\ network\ operator\ emissions}\ (mt\ CO_2e) = \frac{Use\ stage\ consumer's\ network\ operator\ emissions\ (mt\ CO_2e)}{Use\ stage\ emissions\ ratio\ \left(\frac{25}{100}\right)}\ x\ [1 - Use\ stage\ emissions\ ratio\ \left(\frac{25}{100}\right)]$$

Equation 37

The consumer's network operator total network service emissions are calculated by adding:

$$\boldsymbol{Total\ network\ services\ emissions}\ (mt\ CO_2e) = Use\ stage\ network\ operator\ emissions\ (mt\ CO_2e) + Embodied\ vendor\ network\ operator\ emissions\ (mt\ CO_2e)$$

Equation 38

The consumer's network operator total annual quantity of data processed is used to create a network operator emissions intensity:

$$\boldsymbol{Emissions\ intensity}\ \left(\frac{mt\ CO_2e}{kB}\right) = \frac{Total\ network\ services\ emissions\ (mt\ CO_2e)}{Annual\ network\ traffic\ (kB)}$$

Equation 39

Lastly, the emissions intensity is multiplied by the size of the media ad to calculate the attributable emissions of vendor's network services:

$$\boldsymbol{Consumer\ emissions}\ (mt\ CO_2e) = Emissions\ intensity\ \left(\frac{mt\ CO_2e}{kB}\right)\ x\ Ad\ size\ (kB)$$

Equation 40

Consumer's home terminal emissions

Once the transmission emissions associated with (1) the vendor's network operator, (2) consumer's network, and (3) home router have been calculated (see processes above for details) the network transmission is calculated by adding them:

$$\begin{aligned}\boldsymbol{Network\ transmission\ emissions}\ (mt\ CO_2e) \\ &= vendor\ network\ emissions\ (mt\ CO_2e) + consumer\ network\ emissions\ (mt\ CO_2e) \\ &+ home\ router\ emissions\ (mtCO_2e)\end{aligned}$$

Equation 41

Targeting

Source:	Information needed:	Abbreviated as:	Unit:
Content Delivery Network (CDN) operator	Vendor's name	n/a	Unitless
	Annual energy consumption of IT infrastructure	Energy consumption of IT equipment	MWh
	Annual PUE	PUE	Unitless
	Annual scope 1 emissions	CDN scope 1 emissions	mt CO_2e
	Annual scope 2 (MBM) emissions	CDN scope 2 (MBM) emissions	mt CO_2e
	Annual network traffic	Total network traffic	kB
Campaign planner	Country of targeted customer	(Used to identify grid EF)	Unitless

Programmatic advertising uses a process called targeting to deliver impressions to a pre-defined audience through the use of a CDN. The CDN, also referred to as an AdHouse, is the physical location where the targeting operations occur. This is a form of advertising that automates the buying and selling of ad space in real-time based on predetermined bid specifications such as the demographics of the intended consumer. From an emissions perspective, a CDN operates similarly to a data center. If programmatic advertising is used within the media campaign, the attributable emissions can be similarly calculated.

The annual IT infrastructure energy consumption for the most recent reporting year of the CDN's network operator is requested to calculate the use-stage emissions. Again, this should not include the energy and emissions from their office facilities.

In addition to requesting the annual network infrastructure energy consumption, the PUE ratio should be requested. If no PUE is available, use the most recent year's global average PUE. In 2021, the global average PUE was 1.57 (Bizo, Ascierto, Lawrence, & Davis, 2021). The typical use-stage energy use per year is then calculated by:

$$\boldsymbol{Annual\ IT\ equipment\ energy}\ (MWh) = \frac{Energy\ consumption\ of\ IT\ equipment\ (MWh)}{PUE}$$

Equation 42

Knowing the energy associated with the IT equipment, excluding CDN facility overhead energy, the emissions of the IT equipment can be calculated using a region-specific (e.g., country-level) purchased electricity EF. If there is uncertainty regarding the location of the cloud infrastructure, the global average purchased electricity EF should be used. The use-stage IT equipment emissions can be calculated by:

$$\boldsymbol{IT\ equipment\ emissions}\ (mt\ CO_2e) = Annual\ IT\ equipment\ energy\ (MWh)\ x\ grid\ EF\ (\frac{mt\ CO_2e}{MWh})$$

Equation 43

Once the use-stage IT equipment emissions have been calculated, the ratio method can then be used to approximate the embodied emissions associated with the equipment powering the CDN. The recommended ratio used is [25/135] for a data center, which is most similar to a CDN. This ratio is based on an extensive dataset, which combined primary and secondary data for operational (use-stage) energy consumption and life cycle GHG emissions from approximately 100 of the major global ICT and Entertainment and Media (E&M) manufacturers, operators and service providers (Malmodin, Jens; Lunden, Dag, 2018). Using this ratio, the embodied emissions can be calculated by:

$$\boldsymbol{Embodied\ IT\ equipment\ emissions}\ (mt\ CO_2e) = Use\ stage\ IT\ equipment\ emissions\ (mt\ CO_2e)\ x\ Use\ stage\ emissions\ ratio\ (\frac{25}{135})$$

Equation 44

The total CDN emissions are calculated by adding:

$$\boldsymbol{Total\ CDN\ annual\ emissions}\ (mt\ CO_2e) = CDN\ scope\ 1\ emissions\ (mt\ CO_2e) + CDN\ scope\ 2\ (MBM)\ emissions\ (mt\ CO_2e) + Embodied\ IT\ equipment\ emissions\ (mt\ CO_2e)$$

Equation 45

The total annual quantity of data processed by the CDN is used to create an emissions intensity:

$$\boldsymbol{Annual\ CDN\ emissions\ intensity}\ (\frac{mt\ CO_2e}{kB}) = \frac{Total\ CDN\ emissions\ (mt\ CO_2e)}{Total\ network\ traffic\ (kB)}$$

Equation 46

Lastly, the emissions intensity is multiplied by the size of the ad to calculate the attributable emissions of targeting services:

$$\boldsymbol{Targeting\ emissions}\ (mt\ CO_2e) = CDN\ emissions\ intensity\ \left(\frac{mt\ CO_2e}{kB}\right)\ x\ Ad\ size\ (kB)$$

Equation 47

If data is unavailable for the CDN, the spend-based approach used previously can be used to calculate attributable emissions by considering the CDN to be a leased data center. Alternatively, if the media campaign is of a video, the DIMPACT data center and CDN operation intensity of 1.3 Wh/hour of video duration can be used to calculate the attributable emissions along with the duration of the ad. This intensity would be used in place of both the cloud services emissions 0 and the targeting emissions. The DIMPACT intensity can be calculated as follows:

$$\boldsymbol{Emissions\ from\ data\ center\ and\ targetting}\ (mt\ CO_2e)$$
$$= 1.3\ \left(\frac{Wh}{hour}\right)\ x\ Ad\ duration\ (seconds)\ x\ \left(\frac{1\ hour}{3{,}600\ s}\right)\ x\ \left(\frac{1\ kW}{1{,}000\ W}\right) x\ grid\ EF\ \left(\frac{mt\ CO_2e}{kWh}\right)$$

Equation 48

Reach

When an ad is loaded, the energy used is roughly proportional to the amount of data transferred. Using the internet speed, the amount of time the ad takes to load can be calculated. As it is unknown if fixed or mobile broadband access will be used, a weighted regional average is recommended.

$$\boldsymbol{Weighted\ average\ broadband\ speed}\ (Mbps)$$
$$= Regional\ market\ share, fixed\ (\%)\ x\ Regional\ fixed\ broadband\ speed\ (Mbps)$$
$$+\ Regional\ market\ share, mobile\ (\%)\ x\ Regional\ mobile\ broadband\ speed\ (Mbps)$$

Equation 49

The weighted average regional broadband speed is then used to calculate the time to upload the ad.

$$\boldsymbol{Time\ to\ load}\ (hour)$$
$$= \frac{1}{Weighted\ average\ broadband\ speed\ (Mbps)}\ x\ \left(\frac{1\ Mbps}{0.000125\ GBps}\right)\ x\ Ad\ \text{size}\ (kB)\ x\ \left(\frac{1\ GB}{1{,}000{,}000\ kB}\right) x\ (\frac{1\ hour}{60\ s})$$

Equation 50

Knowing the time to upload, the energy of the device can then be calculated if the device is known. If the consumer device is unknown, the representative device mix created by The Carbon Trust (The Carbon Trust, 2021) for streaming devices can be used as a proxy. If the specific model of the device is not known, the power draw can be estimated using the power consumption assumptions used by The Carbon Trust that has been reproduced below:

Device type	Power Draw (W)	Comment	Source
Android phone	1	Samsung Galaxy S9, has 11.55Wh battery with up to 16 hours lifetime when watching videos	Fixit for battery Wh, Samsung for battery lifetime
iPhone	1	Assuming ~11Wh battery and 10h of battery life if streaming	Apple, 2021a, Apple, 2021b
Desktop computer	115	Desktop and monitor	Singh et al., 2019
Laptop	22	Portable computer	Singh et al., 2019
Normal TV	100	Conservative estimate for 2020 offering, but reasonable considering older TVs are used to watch Netflix	ENGIE analysis using Best Buy best sellers (Singh et al., 2019)
Smart TV	100	Conservative estimate for 2020 offering but reasonable considering older TVs are used to watch Netflix	ENGIE analysis using Best Buy best sellers (Singh et al., 2019)
Gaming Console	89	Sony PlayStation 4	Mills, 2015, NRDC, 2014 and Singh et al., 2019
Set-Top Box	18	STBs with DVR using reported installed base of all STBs in the US	D+R International, 2020
Cinema motor*	322	Not included in Carbon Trust report	Cam Stage Major Pro C, 5M to 7M wide (Cam Stage, 2017)

The time for the ad to upload onto the device is then used to calculate the energy expended by the device during the upload:

$$\boldsymbol{Device\ Energy}\ (kWh) = Device\ Power\ Draw\ (W)\ x\ \left(\frac{1\ kW}{1{,}000\ W}\right) x\ Time\ to\ load\ (hour)$$

Equation 51

The emissions associated with this energy consumption are calculated by multiplying the device energy consumption by the region-specific grid factor of the consumer.

$$\boldsymbol{Device\ emissions}\ (mt\ CO_2e) = Device\ energy\ (kWh)\ x\ grid\ EF\ \left(\frac{mt\ CO_2e}{kWh}\right)$$

Equation 52

It is assumed that the energy associated with the device operating system software usage is included in the calculated power consumption of the device and that 100% of impressions are delivered.

Raw material production

Source:	Information needed:	Abbreviated as:	Unit:
Vendor	Vendor's name	n/a	Unitless
	Paper fiber content (i.e., percentage virgin, recycled or mixed) or material type (e.g., PVC vinyl or plastic)	n/a	Unitless
	Weight of ad	Ad weight	kg
Campaign planner	Size of ad	Ad size, area	cm^2

Raw material extraction and transportation are used for the production of print media and include the sub-processes of:

- raw material cultivation and extraction,
- transportation and
- processing.

These phases are part of physical ads' (e.g., newspapers, magazines, OOH and transient) life cycle. Although specific activities within these phases may differ by channel, the attributable processes to which the ad is produced remain relatively the same.

Primary vendor data should be prioritized over the utilization of industry or peer averages. The following sections provide the methodology to calculate emissions when activity data within each of the value chain phases is available. If activity data is not available, the latest DEFRA EFs or region-specific EFs, in the "material use" category are recommended.

At a minimum, the ad size, material type and weight are needed to calculate non-digital media emissions. However, if only the ad size is not known, we can estimate it based on print type-dimensions (Specle, 2022), as given in the table below:

Size of media	Dimensions width (mm) x height (mm)	Area (cm^2)
Full Page Broad Sheet	597 x 375	2,238.8
Half Page Broad Sheet	298.5 x 187.5	559.7
Double Page Spread	550 x 338	1859.0
Full Page	264 x 338	892.3
Half Page Horizontal	264 x 170	448.8
Half Page Vertical	149 x 338	503.6
Quarter Page	134 x 160	214.4
Eighth Page	160 x 66	105.6
Twelfth Page	105.16 x 89.25	93.9
Bookend	338 x 111	375.2
TV Strip	504 x 46	231.8

Size of media	Dimensions width (mm) x height (mm)	Area (cm^2)
Cover Wrap	550 x 343	1,886.5

If a vendor does not have specifications for the weight of the ad product, the paper weight intensity by media type (Poster Print Genius, 2020) provided in the table below contains common industry averages that can be used to estimate ad weight.

Print media	Weight per area intensity (kg/m^2)
Newspaper	0.105
Magazine	0.145
Billboard	0.300

The newspaper and magazine weights are a result of the average weight range for lightweight paper and that of a typical magazine flyer weight. The billboard weight is based on the average range of heavier prints intended for paints and denser coatings.

The ad weight is then calculated using the weight per area intensity:

$$\boldsymbol{Ad\ weight}\ (\mathbf{kg}) = \text{Ad size}\ (\text{cm}^2)\ \text{x Weight per area intensity} \left(\frac{\text{kg}}{\text{m}^2}\right) \text{x} \left(\frac{\text{m}^2}{10{,}000\ \text{cm}^2}\right)$$

Equation 53

The ad size and weight are used throughout the physical ad emissions calculation methodology sections.

Raw material cultivation and extraction

Source:	Information needed:	Abbreviated as:	Unit:
Vendor	Vendor's name	n/a	Unitless
	Annual scope 1 emissions	Vendor scope 1 emissions	mt CO_2e
	Annual scope 2 (MBM) emissions	Vendor scope 2 (MBM) emissions	mt CO_2e
	Annual quantity of pulp (dry basis) processed	Vendor production quantity	kg

If the vendor has an applicable emissions intensity, it is recommended that the vendor's intensity be used. This would be used similar to how utility companies may provide market-based EFs for customers. An example of raw materials cultivation and extraction emissions intensity would be the ratio of the vendor's scope 1 and scope 2 emissions per annual weight of raw materials processed. The following methodology is recommended to support vendors that do not calculate their emissions intensity.

In the absence of a vendor emissions intensity, request the vendor's annual Scope 1 and Scope 2 (market-based method) emissions of their raw material cultivation and extraction operations and quantity of pulp processed for the specified (or most recent) reporting year. This information is used to create a raw material cultivation and extraction intensity:

$$\boldsymbol{Raw\ material\ cultivation\ and\ extraction\ intensity}\ \left(\frac{mt\ CO_2e}{kg}\right) = \frac{Vendor\ scope\ 1\ emissions\ (mt\ CO_2e) + Vendor\ scope\ 2\ emissions\ (mt\ CO_2e)}{Vendor\ production\ quantity\ (kg_{dry\ basis})}$$

Equation 54

This intensity is multiplied by the weight of the ad to calculate the attributable emissions of raw material cultivation and extraction:

$$\boldsymbol{Raw\ material\ cultivation\ and\ extraction\ emissions}\ (mt\ CO_2e) = Raw\ material\ cultivation\ and\ extraction\ intensity\left(\frac{mt\ CO_2e}{kg}\right)\ x\ Ad\ weight\ (kg)$$

Equation 55

Raw material transportation

Transportation of raw materials includes the transportation activities between cultivation and extraction to paper mill processing. Common methods of raw material transportation include:

- rail,
- road and
- marine.

For each method of distribution used in the transportation of the ad, the accompanying information should be obtained from vendor primary or secondary data. Three methods are provided for use on available primary data. Only one method should be used per segment of the transportation. For example, if the raw materials are transported via van and both the fuel consumption and distance traveled are known, use this method to calculate the associated emissions. Do not use both methods and double count the associated emissions

Transportation calculation

Method 1: fuel-based

Source:	Information needed (for each method of distribution used):	Abbreviated as:	Unit:
Vendor	Vendor's name	n/a	Unitless
	Vehicle type	(Used to identify EF)	Unitless
	Fuel type	(Used to identify EF)	Unitless
	Amount of fuel consumed during transport	Total volume of fuel consumed	Liters or m^3

Source:	Information needed (for each method of distribution used):	Abbreviated as:	Unit:
	Dedicated or shared mode of transport	(Used for applicability)	Unitless
	Vehicle weight capacity	Shipment weight	kg
Campaign planner	Weight of ad	Ad weight	kg

If a dedicated mode of transport is used and the volume of fuels and electricity (if an electric vehicle) are known, the emissions can be calculated. Fuel-specific emission factors can be found within the annually published DEFRA GHG reporting: conversion factors report within the 'Fuels' tab (UK Government (DEFRA), 2022) contains some example fuels that may likely be used.

Activity	Fuel	Emission factor (kg CO_2e/liter[5])	Emission factor (kg CO_2e/kWh) (Gross CV)
Liquid fuels	Diesel (average biofuel blend)	2.51233	0.23686
	Diesel (100% mineral)	2.70553	0.25338
	Petrol (average biofuel blend)	2.19352	0.22980
	Petrol (100% mineral)	2.33969	0.24158
	Marine gas oil	2.77539	0.25836
Gaseous fuels	Natural gas (100% mineral)	2.03473*	0.18438

Using the fuel-specific EF, the fuel-based transportation emissions are calculated:

$$\boldsymbol{Emissions\ from\ transportation\ method\ 1}\ (mt\ CO_2e)$$
$$= \frac{Total\ volume\ of\ fuel\ consumed\ (liters)\ x\ Fuel\ specific\ EF\ \left(\frac{kg\ CO_2e}{liter}\right)\ x\ \left(\frac{1\ mt}{1{,}000\ kg}\right)}{Shipment\ weight\ (kg)}\ x\ Ad\ weight\ (kg)$$

Equation 56

Method 2: distance-based

Source:	Information needed (for each method of distribution used):	Abbreviated as:	Unit:
Vendor	Vendor's name	n/a	Unitless
	Vehicle type	(Used to identify EF)	Unitless
	Fuel type	(Used to identify EF)	Unitless
	Distance transported	Distance traveled	km

[5] *Note that for natural gas the emission factor denominator is in cubic meters instead of liters.

Source:	Information needed (for each method of distribution used):	Abbreviated as:	Unit:
	Dedicated or shared mode of transport	(Used for applicability)	Unitless
	Vehicle weight capacity	Shipment weight	kg
Campaign planner	Weight of ad	Ad weight	kg

If a dedicated mode of transport is used for ground transportation and the volume of fuels and electricity (if an electric vehicle) is not known, the distance traveled, vehicle type and shipment weight are used to calculate the ad's emissions.

Distance-based EFs can be found within the annually published DEFRA GHG reporting: conversion factors report within the 'Delivery vehicles' tab (UK Government (DEFRA), 2022) contains some example fuels that may likely be used.

Activity	Type	Fuel	Emission factor (kg CO_2e/km)
Vans (trucks)	Class I (up to 1.305 tonnes)	Diesel	0.1467
	Class II (1.305 to 1.74 tonnes)	Diesel	0.18315
	Class III (1.74 50 3.5 tonnes)	Diesel	0.26529
	Average (up to 3.5 tonnes)	Diesel	0.24116
	Class I (up to 1.305 tonnes)	Petrol	0.19987
	Class II (1.305 to 1.74 tonnes)	Petrol	0.19821
	Class III (1.74 50 3.5 tonnes)	Petrol	0.31306
	Average (up to 3.5 tonnes)	Petrol	0.21047

Using the vehicle and fuel-specific EF, the distance-based transportation emissions are calculated:

$$\boldsymbol{Emissions\ for\ method\ 2}\ (mt\ CO_2e) = \frac{Distance\ travelled\ (km)\ x\ Vehicle\ specific\ EF\ \left(\frac{kg\ CO_2e}{km}\right)\ x\ (\frac{1\ mt}{1{,}000\ kg})}{Shipment\ weight\ (kg)}\ x\ Ad\ weight\ (kg)$$

Equation 57

Method 3: weight-based

Source:	Information needed (for each method of distribution used):	Abbreviated as:	Unit:
Vendor	Vendor's name	n/a	Unitless
	Vehicle type	(Used to identify EF)	Unitless
	Fuel type	(Used to identify EF)	Unitless

	Distance transported	Distance traveled	km
Campaign planner	Weight of ad	Ad weight	kg

If a dedicated mode of transport is used and the volume of fuels is not known, the distance traveled, vehicle type and ad weight are used to calculate the associated emissions. Fuel-specific emission factors can be found within the annually published DEFRA GHG reporting: conversion factors report within the 'Fuels' tab (UK Government (DEFRA), 2022) contains some example fuels that may likely be used.

Activity	Type	Fuel	Emission factor ($kg\ CO_2e$/tonne.km)
Rail	Freight train	Not specified	0.02782
Cargo ship	Bulk carrier, average	Not specified	0.00354
	General cargo, average	Not specified	0.01323
	Container ship, average	Not specified	0.01614
	Vehicle transport, average	Not specified	0.03858
Vans (trucks)	Class I (up to 1.305 tonnes)	Diesel	0.81485
	Class II (1.305 to 1.74 tonnes)	Diesel	0.6292
	Class III (1.74 50 3.5 tonnes)	Diesel	0.59232
	Average (up to 3.5 tonnes)	Diesel	0.60261

Using the activity, vehicle and fuel-specific EF, the weight-based emissions are calculated:

$$\boldsymbol{Emissions\ from\ transportation\ method\ 3}\ (mt\ CO_2e) = Distance\ travelled\ (km)\ x\ Ad\ weight\ (kg)\ x\ \left(\frac{tonne}{1{,}000\ kg}\right)\ x\ Fuel\ specific\ EF\ \left(\frac{kg\ CO_2e}{tonne.km}\right)\ x\ (\frac{1\ mt}{1{,}000\ kg})$$

Equation 58

When the methods of raw material transportation have been identified and attributable emissions quantified for each method used, the total transportation emissions are found by adding all method emissions.

Raw material processing

Source:	Information needed:	Abbreviated as:	Unit:
Vendor	Vendor's name	n/a	Unitless
	Annual scope 1 emissions	Vendor scope 1 emissions	$mt\ CO_2e$
	Annual scope 2 (MBM) emissions	Vendor scope 2 (MBM) emissions	$mt\ CO_2e$
	Annual quantity of media processed	Vendor production quantity	kg

A paper mill is used to process the cultivated and extracted materials into usable media to get them to the stage that they can be sent to printing. If the vendor has an emissions intensity, it is recommended that the vendor's intensity be used. An example of raw material processing emissions intensity would be the ratio of the vendor's scope 1 and scope 2 emissions per annual weight of raw materials processed. The following methodology is recommended to support vendors that do not calculate their emissions intensity.

In the absence of a vendor emissions intensity, request the vendor's annual Scope 1 and Scope 2 (market-based method) emissions of their raw material processing operations and quantity of media processed for the specified (or most recent) reporting year. If multiple vendors are utilized, or the specific vendor is not identifiable from a variety used, a weighted average based on the amount purchased from each vendor should be used. This information is used to create a paper mill emission intensity:

$$\boldsymbol{Paper\ Mill\ Emission\ Intensity}\ (\frac{mt\ CO_2e}{kg}) = \frac{Vendor\ scope\ 1\ emissions\ (mt\ CO_2e) + Vendor\ scope\ 2\ emissions\ (mt\ CO_2e)}{Vendor\ production\ quantity\ (kg)}$$

Equation 59

This intensity is multiplied by the weight of the ad to calculate the attributable emissions of raw material processing:

$$\boldsymbol{Raw\ material\ processing\ emissions}\ (mt\ CO_2e) = Raw\ material\ processing\ intensity \left(\frac{mt\ CO_2e}{kg}\right) x\ Ad\ weight\ (kg)$$

Equation 60

Lastly, combine the raw material cultivation and extraction, transportation and processing emissions to calculate the total raw material production emissions of the ad:

$$\begin{aligned}\boldsymbol{Raw\ material\ production\ emissions}\ (mt\ CO_2e) &= raw\ material\ cultivation\ and\ extraction\ emissions\ (mt\ CO_2e)\\ &+ raw\ material\ transportation\ emissions\ (mt\ CO_2e)\\ &+ raw\ material\ processing\ emissions\ (mt\ CO_2e)\end{aligned}$$

Equation 61

Raw material production proxy sources

Source:	Information needed:	Abbreviated as:	Unit:
Campaign planner	Weight of ad	Ad weight	kg
	Paper fiber content (i.e., percentage virgin, recycled or mixed) or material type (e.g., PVC vinyl or plastic)	Material	Unitless

If primary vendor data is unavailable for one or more of the raw material phases, an EF may be used until vendor data becomes available. The paper and board virgin and recycled content EFs for the raw material cultivation and extraction, transportation and processing are combined into one EF and can be found in the annually published DEFRA GHG conversion factors report within the 'Material Use' tab. The latest DEFRA factors are provided as an example in the table below. The primary material production (virgin source) and the closed-loop (recycled source) source EFs for three types of materials are provided.

		Virgin source	Recycled source
Activity	**Material**	**kg CO_2e per tonnes**	**kg CO_2e per tonnes**
Paper	Board (78% corrugate, 22% cartonboard)	821.23	718.54
	Mixed (25% paper, 75% board)	881.19	731.28
	Paper	919.4	739.4
Plastic	PVC (incl. forming)	3,413.08	2,489.67
	Average plastics	3,116.29	2,326.53

Once the material content of the paper sourced for the ad is identified, the production emissions can be calculated.

$$\begin{aligned}&\boldsymbol{Raw\ material\ production\ emissions}\ (mt\ CO_2e)\\ &= Ad\ weight\ (kg)\ x\ Material\ source\ EF\ \left(\frac{kg\ CO_2e}{kg}\right)\ x\ (\frac{1\ mt}{1{,}000\ kg})\end{aligned}$$

Equation 62

An alternative to using the production EF is to create a regional vendor database of raw material production providers using the methods outlined in this section. This information can be gathered by leveraging the peer's latest CDP and sustainability reports and assessing regional disclosure of emission intensity ratios.

Printing

Source:	Information needed:	Abbreviated as:	Unit:
Vendor	Vendor's name	n/a	Unitless
	Annual scope 1 emissions	Vendor scope 1 emissions	mt CO_2e
	Annual scope 2 (MBM) emissions	Vendor scope 2 (MBM) emissions	mt CO_2e
	Annual amount (in area) of media printed	Vendor production quantity	cm^2

Printing is the process of creating the ad in the form that it will be viewed by the end consumer. If the vendor has an emissions intensity, it is recommended that the vendor's intensity be used. An example of printing emissions intensity would be the ratio of the vendor's scope 1 and scope 2 emissions per annual production quantity. The following methodology is recommended to support vendors that do not calculate their emissions intensity.

In the absence of a vendor emissions intensity, request that the vendor calculate and provide their annual Scope 1 and Scope 2 (market-based method) emissions of their printing operations and quantity of media printed for the specified (or most recent) reporting year. The Scope 1 emissions must include the volatile organic compound (VOC) emissions associated with the use of solvents (i.e., inks) during the printing processes. If multiple vendors are utilized, or the specific vendor is not identifiable from a variety used, a weighted average based on the amount purchased from each vendor should be used. This information is used to create a printing emission intensity:

$$\boldsymbol{Printing\ Emission\ Intensity}\ (\frac{mt\ CO_2e}{cm^2}) = \frac{Vendor\ scope\ 1\ emissions\ (mt\ CO_2e) + Vendor\ scope\ 2\ emissions\ (mt\ CO_2e)}{Vendor\ production\ quantity\ (cm^2)}$$

Equation 63

This intensity is multiplied by the size of the ad to calculate the attributable emissions of printing:

$$\boldsymbol{Printing\ emissions}\ (mt\ CO_2e) = Printing\ intensity\left(\frac{mt\ CO_2e}{cm^2}\right) x\ Ad\ size\ (cm^2)$$

Equation 64

If no vendor-based emissions intensity is available, the exact or approximated spend on printing is used to calculate the attributable emissions. Multiply the campaign spend on printing by an EEIO database factor that represents the emissions from this service. If this spend is not available, it can be estimated using annual printing spend and total quantity of print processed. The US EPA Supply Chain Database EEIO factor for 'Printing' (Ingwersen & Li, 2020) is recommended.

BEA Industry Code	Commodity Name	Substance	Unit	Supply Chain Emission Factors with Margin
323110	Printing	Carbon dioxide	Kg CO2/2018 USD purchaser price	0.379
323110	Printing	Methane	Kg CH4/2018 USD purchaser price	0.001
323110	Printing	Nitrous oxide	Kg N2O/2018 USD purchaser price	0.000
323110	Printing	Other GHGs	Kg CO2e/2018 USD purchaser price	0.004

The EF is calculated using the above table and the most recent global warming potential (GWP) factors. At the time of writing, the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report GWP factors were the most recent publication .

Gas	GWP
CH_4	27.9
N_2O	273

$$\boldsymbol{EEIO\ EF}\ \left(\frac{kg\ CO_2e}{2018\ USD\ purchaser\ price}\right) = 0.379\ \left(\frac{kg\ CO_2}{2018\ USD\ purchaser\ price}\right) x\ 1 + 0.001\ \left(\frac{kg\ CH_4}{2018\ USD\ purchaser\ price}\right) x\ CH_4\ GWP + 0.0\ \left(\frac{kg\ N_2O}{2018\ USD\ purchaser\ price}\right) x\ N_2O\ GWP + 0.004\ \left(\frac{kg\ CO_2e}{2018\ USD\ purchaser\ price}\right)$$

Equation 65

The EEIO EF using the AR6 is

$$0.000411\ \frac{mt\ CO_2e}{2018\ USD\ purchaser\ price}$$

As the most recent publication of the US EPA supply chain database data is for 2018 purchaser price, use the Consumer Price Index inflation factor to convert the printing spend to that of the EF. When calculating the emissions of 2021 printing spend, modify the spend by the rate inflation increased (e.g., from 2018 to 2021) before multiplying by the EEIO EF.

$$\boldsymbol{Spend - based\ printing\ emissions}\ (mt\ CO_2e) = Printing\ spend\ (Current\ year\ USD)\ x\ CPI\ Factor\ \left(\frac{2018\ USD}{Current\ year\ USD}\right) x\ 0.000188\ \left(\frac{mt\ CO_2e}{2018\ USD\ purchaser\ price}\right)$$

Equation 66

Lastly, the spend-based printing emissions are divided by the total number of ads printed to calculate the ad printing emissions.

$$\boldsymbol{Printing\ emissions}\ (mt\ CO_2e) = \frac{Spend - based\ printing\ emissions\ (mt\ CO_2e)}{Total\ ads\ printed\ (\#)}$$

Equation 67

Physical Distribution

Distribution of a physical ad includes the transportation and storage activities between ad manufacturing to where the consumer views the ad. Common methods of distribution include:

- air transport,
- rail transport,
- road transport,
- marine transport and
- warehousing/storage.

Ownership of distribution activities may vary significantly between and within channels; however, the information needed to assess this phase of the value chain is relatively straightforward. For additional information on calculating the weight of the ad, see the Processes for Raw Material Production. And for alternative transportation, refer to the previous transport calculations.

Warehousing and storage

Source:	Information needed (for each method of distribution used):	Abbreviated as:	Unit:
Vendor	Vendor's name	n/a	Unitless
	Facility annual scope 1 emissions	Warehouse scope 1 emissions	mt CO_2e
	Facility annual scope 2 (MBM) emissions	Warehouse scope 2 (MBM) emissions	mt CO_2e
	Facility location	(Used for grid EF)	Unitless
	Facility type	(Used for energy intensity estimate)	Unitless
	Facility size	Facility size	m^2
	Number of days stored	Time stored	days

If the ad requires warehousing or storage, the annual facility emissions and the total days of ad storage are requested. If the facility energy consumption or emissions are unavailable, the size of the storage facility is used to calculate the annual energy consumption using the Building Energy Efficiency Survey (BEES) intensity factors for electricity and natural gas. The table below contains the most recent annual energy intensity values for commercial storage operations, published for the time period of 2014 to 2015 (Department for Business, Energy & Industrial Strategy, 2016).

Storage sub-sector	Purchased electricity energy intensity (kWh/m2) (Median)	Fuel energy intensity (kWh/m2) (Median)
Large Distribution Warehouses	**47.08**	**15.69**
Stores	**32.32**	**5.29**
Warehouses	**31.54**	**26.68**

For each type of energy source identified, the fuel-specific EF should be used to calculate the associated emissions. At a minimum, electricity should be identified; however, both electricity and natural gas are typically energy sources for storage operations. Storage and warehousing emissions are calculated using the following equation:

$$\textbf{Emissions from warehousing method 1}\ (mt\ CO_2e) = \frac{Warehouse\ scope\ 1\ emissions\ (mt\ CO_2e) + Warehouse\ scope\ 2\ emissions\ (mt\ CO_2e)}{Facility\ size\ (m^2)}\ x\ \frac{Time\ stored\ (days)}{365\ (days)}\ x\ Ad\ size\ (cm^2)\ x\ (\frac{m^2}{10{,}000\ cm^2})$$

Equation 68

When energy consumption and area of a storage facility are unavailable, the intensities can be used to provide an estimated energy consumption per facility. The associated emissions can then be calculated using fuel and region (for purchased electricity) EFs to create an emissions intensity:

$$\textbf{Emissions intensity for method 2}\ \left(\frac{mt\ CO_2e}{m^2}\right) = Purchased\ electricity\ energy\ intensity\ \left(\frac{kWh}{m^2}\right)\ x\ Region\ specific\ EF\ \left(\frac{mt\ CO_2e}{kWh}\right) + Fuel\ energy\ intensity\ \left(\frac{kWh}{m^2}\right)\ x\ Fuel\ EF\ \left(\frac{mt\ CO_2e}{kWh}\right)$$

Equation 69

The ad size and number of days stored are then multiplied by the emissions intensity to calculate the associated emissions.

$$\textbf{Emissions from warehousing method 2}\ (mt\ CO_2e) = Emissions\ intensity\ \left(\frac{mt\ CO_2e}{m^2}\right) x\ \frac{Time\ stored\ (days)}{365\ (days)}\ x\ Ad\ size\ (cm^2)\ x\ (\frac{m^2}{10{,}000\ cm^2})$$

Equation 70

When the methods of the ad distribution have been identified and attributable emissions quantified for each method used, the total distribution emissions are found by combining them.

Playout services

Playout services encompass broadcasting and internet processes, including the equipment and software required to convert and deliver media to an external environment. There are two types of playout services, linear and non-linear. Linear encompasses “traditional” broadcasting processes, such as those for broadcast TV, AM/FM radio and satellite radio, which deliver live media on a planned schedule. The methodology for broadcast TV (i.e., terrestrial, cable and satellite) and broadcast radio (i.e., analog and satellite radio) are detailed in the following section. If a mobile application is used to stream live TV, the process for “Mobile Application” must be included as an additional stage.

Non-linear playout includes media content that is not delivered as part of a pre-planned schedule. Non-linear playout encompasses digital services, such as VOD, cinema and internet radio via cloud services and network transmission and is included within Network Transmission. This type of media format uses mobile applications, which result in an additional step in the ad’s value chain. The subsequent section on “Mobile Application” describes how the emissions resulting in the consumer use of an app are included within the digital media ad value chain.

Linear playout (broadcast)

Source:	Information needed:	Abbreviated as:	Unit:
Vendor	Vendor's name	n/a	Unitless
	Annual energy consumption of IT infrastructure	Energy consumption of IT equipment	MWh
	Annual PUE	PUE	Unitless
	Annual scope 1 emissions	Playout service scope 1 emissions	mt CO_2e
	Annual scope 2 (MBM) emissions	Playout service scope 2 (MBM) emissions	mt CO_2e
	Annual quantity of data processed	Total quantity of data processed	kB
Campaign planner	Country of targeted customer	(Used to identify grid EF)	Unitless
Broadcast network	Vendor's name	n/a	Unitless
	Annual energy consumption of IT infrastructure	Energy consumption of IT equipment	MWh
	Annual PUE	PUE	Unitless
	Annual scope 1 emissions	Broadcast scope 1 emissions	mt CO_2e
	Annual scope 2 (MBM) emissions	Broadcast distribution scope 2 (MBM) emissions	mt CO_2e
	Annual broadcast traffic	Total broadcast traffic	kB
Campaign planner	Country of targeted customer	(Used to identify grid EF)	Unitless
	Ad duration	Ad duration	seconds
Creative production	Ad bitrate	Ad bitrate	kbps

If the vendor or broadcast network provides an emissions intensity, inclusive of embodied emissions of IT hardware, it is recommended that the intensity be used. An example of broadcast network emissions intensity would be the ratio of the vendors scope 1 and scope 2 emissions of network infrastructure per annual network traffic. The following methodology is recommended to support vendors that do not calculate their emissions intensity.

Broadcast occurs in two stages, linear playout services and broadcast network distribution. If a vendor operates both playout services and broadcast distribution, separation between energy consumption within each stage does not need to be performed. If two separate operators are used, the emissions intensity should be calculated separately and then combined.

Linear playout services

Linear playout services use equipment and software required for encoding and multiplexing processes that convert the media content into a distributable form (British Broadcasting Corporation (BBC), 2020). The playout service infrastructure is the physical location where the coding and multiplexing occur. From an emissions perspective, a playout service operates similarly to data center services.

The annual IT infrastructure energy consumption for the most recent reporting year of the playout service operator is requested to calculate the use-stage emissions. This should not include the energy and emissions from their office facilities. In addition to requesting the annual infrastructure energy consumption, the PUE ratio should be requested. If no PUE is available, use the most recent year's global average PUE. In 2021, the global average PUE was 1.57 (Bizo, Ascierto, Lawrence, & Davis, 2021). The typical use-stage energy use per year is then calculated by:

$$\boldsymbol{Annual\ IT\ equipment\ energy}\ (MWh) = \frac{Energy\ consumption\ of\ IT\ equipment\ (MWh)}{PUE}$$

Equation 71

Knowing the energy associated with the IT equipment, excluding playout service facility overhead energy, the emissions of the IT equipment can be calculated using a region-specific (e.g., country-level) purchased electricity EF. If there is uncertainty regarding the location of the cloud infrastructure, the global average purchased electricity EF should be used. The use-stage IT equipment emissions can be calculated by:

$$\boldsymbol{IT\ equipment\ emissions}\ (mt\ CO_2e) = Annual\ IT\ equipment\ energy\ (MWh)\ x\ grid\ EF\ (\frac{mt\ CO_2e}{MWh})$$

Equation 72

Once the use-stage IT equipment emissions have been calculated, the ratio method can then be used to approximate the embodied emissions associated with the equipment powering the playout services. The recommended ratio used is [25/135] for a data center, which is most similar to a playout service. Using this ratio, the embodied emissions can be calculated by:

$$\begin{aligned}&\boldsymbol{Embodied\ IT\ equipment\ emissions}\ (mt\ CO_2e)\\&\quad = Use\ stage\ IT\ equipment\ emissions\ (mt\ CO_2e)\ x\ Use\ stage\ emissions\ ratio\ (\frac{25}{135})\end{aligned}$$

Equation 73

The total playout service emissions are calculated by adding:

$$\begin{aligned}&\boldsymbol{Total\ playout\ service\ annual\ emissions}\ (mt\ CO_2e)\\&\quad = Playout\ service\ scope\ 1\ emissions\ (mt\ CO_2e)\\&\quad + Playout\ service\ scope\ 2\ (MBM)\ emissions\ (mt\ CO_2e)\\&\quad + Embodied\ IT\ equipment\ emissions\ (mt\ CO_2e)\end{aligned}$$

Equation 74

The total annual quantity of data processed by the playout service is used to create an emissions intensity:

$$\textbf{Annual playout service emissions intensity}\ \left(\frac{mt\ CO_2e}{kB}\right) = \frac{Total\ playout\ service\ emissions\ (mt\ CO_2e)}{Total\ network\ traffic\ (kB)}$$

Equation 75

Lastly, the emissions intensity is multiplied by the size of the ad to calculate the attributable emissions of playout services:

$$\textbf{Playout service emissions}\ (mt\ CO_2e) = Playout\ service\ emissions\ intensity\ \left(\frac{mt\ CO_2e}{kB}\right)\ x\ Ad\ size\ (kB)$$

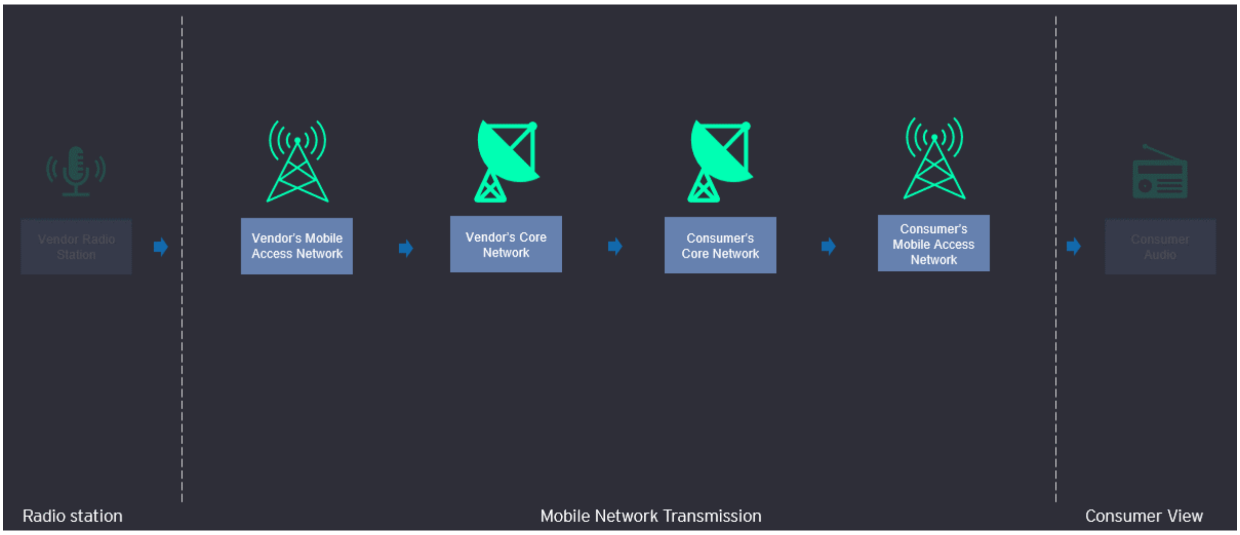
Equation 76

If data is unavailable for the playout service, the spend-based approach suggested previously can be used to calculate attributable emissions by considering the playout service to be equivalent to a leased data center.

Broadcast distribution

Broadcast TV is distributed using an antenna or cable infrastructure.

Analog (AM/FM) and satellite radio are broadcasts that follow mobile network transmission processes. Mobile radio receivers operate through the air and, therefore, do not use fixed access networks. The below figure illustrates the radio broadcast infrastructure.



In the absence of a vendor emissions intensity, use the high-level service platform method, which is performed by requesting the vendor provide their broadcast operator. With this information, the broadcast operator's most recent sustainability report can be researched to identify their annual broadcast operator electricity consumption (e.g., GWh, GJ) of IT infrastructure, broadcast traffic (e.g., PB) and market-based operational emissions ($MtCO_2e$). If this information is not publicly available, it is recommended that the vendor request this information from their broadcast operator.

Vendor's broadcast operator

The vendor's broadcast operator annual energy consumption of the IT infrastructure for the most recent reporting year is requested to calculate the use-stage emissions.

In addition to requesting the annual broadcast infrastructure energy consumption, the PUE ratio is requested. The PUE is a metric that represents the ratio between the total facility power (fixed plus variable) and the IT equipment power (variable) of a data center. It is used to allocate the total overhead energy (i.e., non-IT energy of the network infrastructure mechanical and electrical infrastructure). If no PUE is available, the most recent year global average PUE is recommended. In 2021 the global average PUE was 1.57 (Bizo, Ascierto, Lawrence, & Davis, 2021). The typical use-stage energy use per year is then calculated by:

$$\boldsymbol{Annual\ IT\ equipment\ energy}\ (MWh) = \frac{Energy\ consumption\ of\ IT\ equipment\ (MWh)}{PUE}$$

Equation 77

Knowing the energy associated with the IT equipment, excluding broadcast infrastructure facility overhead energy, the emissions of the IT equipment can be calculated using a region-specific (e.g., country-level) purchased electricity emission factor. If there is uncertainty regarding the location of the broadcast infrastructure, the global average purchased electricity emission factor should be used. The use-stage IT equipment emissions can be calculated by:

$$\boldsymbol{IT\ equipment\ emissions}\ (mt\ CO_2e) = Annual\ IT\ equipment\ energy\ (MWh)\ x\ grid\ EF\ (\frac{mt\ CO_2e}{MWh})$$

Equation 78

Once the use-stage IT equipment emissions have been calculated, the ratio method can then be used to approximate the embodied emissions associated with the equipment powering the broadcast services. The recommended ratio used is [25/75] for the network infrastructure, as broadcast is a type of network. Using this ratio, the embodied emissions can be calculated by:

$$\begin{aligned}\boldsymbol{Embodied\ IT\ equipment\ emissions}\ (mt\ CO_2e) \\ = \frac{Use\ stage\ IT\ equipment\ emissions\ (mt\ CO_2e)}{Use\ stage\ emissions\ ratio\ (\frac{25}{100})}\ x\ [1 \\ - Use\ stage\ emissions\ ratio\ \left(\frac{25}{100}\right)]\end{aligned}$$

Equation 79

The vendor's network operator total network service emissions are calculated by adding:

$$\begin{aligned}\boldsymbol{Total\ broadcast\ services\ emissions}\ (mt\ CO_2e) \\ = Broadcast\ operator\ scope\ 1\ emissions\ (mt\ CO_2e) \\ + Broadcast\ operator\ scope\ 2\ (MBM)\ emissions\ (mt\ CO_2e) \\ + Embodied\ IT\ equipment\ emissions\ (mt\ CO_2e)\end{aligned}$$

Equation 80

The vendor's broadcast operator total annual quantity of data processed is used to create a broadcast operator emissions intensity:

$$\textbf{Broadcast emissions intensity}\ \left(\frac{mt\ CO_2e}{kB}\right) = \frac{Total\ broadcast\ services\ emissions\ (mt\ CO_2e)}{Total\ broadcast\ traffic\ (kB)}$$

Equation 81

Lastly, the emissions intensity is multiplied by the bit rate (kilobits per second (kbps)) and duration (seconds) of the media ad to calculate the attributable emissions of vendor's broadcast services:

$$\textbf{Broadcast emissions}\ (mt\ CO_2e) = Emissions\ intensity\ \left(\frac{mt\ CO_2e}{kB}\right)\ x\ Ad\ bit\ rate\ \left(\frac{kb}{s}\right) x\ Ad\ duration\ (s)\ x\ (\frac{1\ kB}{8\ kb})$$

Equation 82

A similar process shall be performed for the consumer's broadcast operator.

<u>**Consumer's broadcast operator**</u>

The consumer's broadcast operator annual energy consumption of the IT infrastructure for the most recent reporting year is requested to calculate the use-stage emissions. This should not include the energy and emissions from their office facilities.

In addition to requesting the annual broadcast infrastructure energy consumption, the PUE ratio is requested. If no PUE is available, the most recent year global average PUE is recommended. In 2021, the global average PUE was 1.57 (Bizo, Ascierto, Lawrence, & Davis, 2021). The typical use-stage energy use per year is then calculated by:

$$\textbf{Annual IT equipment energy}\ (MWh) = \frac{Energy\ consumption\ of\ IT\ equipment\ (MWh)}{PUE}$$

Equation 83

Knowing the energy associated with the IT equipment, excluding broadcast infrastructure facility overhead energy, the emissions of the IT equipment can be calculated using a region-specific (e.g., country-level) purchased electricity emission factor. If there is uncertainty regarding the location of the broadcast infrastructure, the global average purchased electricity emission factor should be used. The use-stage IT equipment emissions can be calculated by:

$$\textbf{IT equipment emissions}\ (mt\ CO_2e) = Annual\ IT\ equipment\ energy\ (MWh)\ x\ grid\ EF\ (\frac{mt\ CO_2e}{MWh})$$

Equation 84

Once the use-stage IT equipment emissions have been calculated, the ratio method can then be used to approximate the embodied emissions associated with the equipment powering the broadcast services. The recommended ratio used is [25/75] for the network infrastructure, as broadcast is a type of network. Using this ratio, the embodied emissions can be calculated by:

$$\textbf{Embodied IT equipment emissions}\ (mt\ CO_2e) = \frac{Use\ stage\ IT\ equipment\ emissions\ (mt\ CO_2e)}{Use\ stage\ emissions\ ratio\ (\frac{1}{25})}\ x\ [1 - Use\ stage\ emissions\ ratio\ (\frac{1}{25})]$$

Equation 85

The consumer's broadcast operator total broadcast service emissions are calculated by adding:

$$\textbf{Total broadcast services emissions}\ (mt\ CO_2e) = Broadcast\ operator\ scope\ 1\ emissions\ (mt\ CO_2e) + Broadcast\ operator\ scope\ 2\ (MBM)\ emissions\ (mt\ CO_2e) + Embodied\ IT\ equipment\ emissions\ (mt\ CO_2e)$$

Equation 86

The consumer's broadcast operator total annual quantity of data processed is used to create a broadcast operator emissions intensity:

$$\textbf{Consumer operator emissions intensity}\ \left(\frac{mt\ CO_2e}{kB}\right) = \frac{Total\ broadcast\ services\ emissions\ (mt\ CO_2e)}{Total\ broadcast\ traffic\ (kB)}$$

Equation 87

The emissions intensity is multiplied by the bit rate and duration of the ad to calculate the attributable emissions of vendor's broadcast services:

$$\textbf{Consumer broadcast operator emissions}\ (mt\ CO_2e) = Consumer\ emissions\ intensity\ \left(\frac{mt\ CO_2e}{kB}\right)\ x\ Ad\ bit\ rate\ \left(\frac{kb}{s}\right) x\ Ad\ duration\ (s)\ x\ (\frac{1\ kB}{8\ kb})$$

Equation 88

Once the broadcast transmission emissions associated with the vendor's broadcast operator and the distribution emissions associated with the consumer's broadcast operator have been calculated, the broadcast transmission is calculated by adding them:

$$\textbf{Broadcast transmission emissions}\ (mt\ CO_2e) = vendor\ broadcast\ emissions\ (mt\ CO_2e) + consumer\ broadcast\ emissions\ (mt\ CO_2e)$$

Equation 89

If broadcast operator emissions and annual broadcast traffic are unavailable

Practitioners are encouraged to identify the top five linear broadcast providers within satellite, cable and terrestrial networks for both vendors and consumers. Follow the instructions calculate the operators' emissions. Once the top providers' emissions intensities have been estimated, use the average to calculate the total network services emissions.

The network transmission estimations provided by The Carbon Trust's "conventional approach" are recommended to be used as proxies for this stage of the value chain as they are the most recent estimations available that utilize data transmission metrics. See section 0 for details.

Mobile application

Source:	Information needed:	Abbreviated as:	Unit:
Campaign planner	Size of ad	Ad size	kB
Consumer	End-user device	n/a	Unitless

Application software is any program, or number of programs, designed for end-users (Janalta Interactive, 2020). A multiplatform mobile application (app) is a specific type of software application designed to run on a mobile device, although it can also be run on a personal computer (PC) or laptop through an internet browser (Janalta Interactive, 2020). Mobile applications provide additional opportunities to reach consumers beyond traditional broadband and web-based platforms. How the software is designed to request and process data has the opportunity to significantly impact the amount of energy used by the viewing device (The Carbon Trust, 2017).

Mobile applications use additional energy to exchange the data that makes up the app's newsfeed. The energy consumption of 10 social media apps was measured (Derudder, 2021) in October 2021 using the app's battery draw. The results of this assessment are in the table below:

Mobile app	Energy consumption of newsfeed (mAh/min)	Exchanged data on newsfeed (MB/min)
YouTube	8.58	3.09
Twitter	8.90	6.28
Twitch	8.92	6.87
Facebook	9.05	11.15
LinkedIn	10.28	15.34
Snapchat	10.83	17.26
Instagram	11.04	32.46
Pinterest	11.48	40.65
TikTok	12.36	96.23
Reddit	15.81	100.00

In addition to the energy associated with the network transmission reach already discussed, if an app is used, there are additional emissions associated with the app data exchange that occurs during the reach phase. These emissions are to be added to the ads network emissions. The additional emissions are calculated by:

$$\textbf{App time to load}\ (hour) = \frac{1}{App\ data\ exchange\ \left(\frac{MB}{min}\right)}\ x\ \left(\frac{1\ hr}{60\ min}\right)\ x\ \left(\frac{1\ MB}{1{,}000\ kB}\right)\ x\ Ad\ size\ (kB)$$

Equation 90

Knowing the time to upload, the energy of the app can then be calculated if the consumer device is known. If the device is unknown, the representative device mix created by The Carbon Trust (The Carbon Trust, 2021) for streaming devices can be used as a proxy. If the device type is known but the specific model of the device is unknown, the power draw can be estimated using the power consumption assumptions used by The Carbon Trust.

The time for the data exchange on the app to occur is then used to calculate the energy expended by the device during the upload:

$$\textbf{App energy}\ (kWh) = Device\ power\ draw\ (W)\ x\ \left(\frac{1\ kW}{1{,}000\ W}\right)\ x\ App\ time\ to\ load\ (hour)$$

Equation 91

The emissions associated with this energy consumption are calculated by multiplying the app energy consumption by the region-specific grid factor of the consumer.

$$\textbf{App data exchange emissions}\ (mt\ CO_2e) = Device\ energy\ (kWh)\ x\ grid\ EF\ \left(\frac{mt\ CO_2e}{kWh}\right)$$

Equation 92

The app data exchange emissions are added to the network reach emissions and should be calculated for each app to which the ad is delivered.

Consumer use (View)

The Product Standard defines the use-stage as beginning when the consumer takes possession of a product and ending when the product is discarded for transport to a waste treatment or recycling location (Greenhouse Gas Protocol, 2011). The use-stage is defined within this methodology as the energy and time associated with a consumer view of the ad. This use definition assumes that the ad is already uploaded (i.e., pixels on page), distributed (i.e., mailed) or posted (i.e., billboard hung) to the location the consumer is targeted.

High-level methodology overviews are provided below for assessing the consumer view of digital and physical ads.

Digital and audiovisual consumer view

Source:	Information needed:	Abbreviated as:	Unit:
Campaign planner	Expected view duration	Ad duration	seconds
	Consumer viewing platform used (digital only)	Web browser, app	Unitless
Consumer	End-user device	Device type	Unitless

Consumer view of a digital ad involves energy associated with viewing device operation (including the device operating system software) for the period of time to review the ad and the viewing platform (i.e., browser or app) utilized. The digital consumer view emissions are calculated by adding the device emissions and viewing platform emissions. To calculate device emissions, obtain the power consumption of the device model. Smartphone manufacturers typically publish battery capacity in milliamp-hours (mAh). This amp-hour rating can then be used to estimate power draw by identifying the device's operating (or nominal) voltage. As the operating voltage may be difficult to locate for battery-operated devices, specifically smartphones. As a rule of thumb, if the operating voltage of a smartphone is unavailable, lithium-ion smartphone batteries typically operate at around 3.8 Volts (Battery University, 25) and devices that source their electricity directly from an outlet use the voltage of the country in which they are located. Additional examples of device operating voltages are in the table below:

Device type	Voltage (V)
Smartphone	3.8
Tablet	3.7
Desktop computer	230
Laptop	10.8
Normal TV	230
Smart TV	230
Gaming Console	230
Set-Top Box	230

The voltage is then used to calculate the device energy consumption intensity:

$$\boldsymbol{Device\ energy\ intensity} \left(\frac{kWh}{s}\right) = \frac{Device\ capacity\ (mAh)\ x\ Device\ operating\ voltage\ (V)\ x\ \left(\frac{A}{1{,}000\ mA}\right) x\ \left(\frac{kW}{1{,}000\ W}\right)}{Daily\ battery\ life\ (hours)}\ x\ \left(\frac{hr}{3{,}600\ s}\right)$$

Equation 93

It is assumed that the operating energy intensity includes the energy use of the device operating software. The energy intensity of the hosting website itself has been accounted for in the vendor cloud services and network transmission stages of the ad's life cycle.

The device energy intensity is then multiplied by the ad duration to calculate user device energy consumption:

$$\boldsymbol{Device\ view\ emissions}\ (mt\ CO_2e) = Device\ energy\ intensity \left(\frac{kWh}{s}\right) x\ Ad\ duration\ (\mathrm{sec})\ x\ grid\ EF \left(\frac{mt\ CO_2e}{kWh}\right)$$

Equation 94

Next, determine whether the media content is viewed through a web page or app (i.e., the content viewing platform). If the consumer is using a web page, the energy consumption of web browser navigation should be added to the consumer view emissions. The energy consumption of navigation of 10 web browsers was measured by Greenspector (Philippot, 2021) in January 2021. The following table summarizes the results and should be updated annually (when the annual report is published).

Web browser	Energy consumption of navigation (mAh)
DuckDuckGo	24
Yandex	24
Firefox Focus	24.5
Vivaldi	25.5
Samsung	25.5
Opera	26
Firefox Nightly	27
Kiwi	27
Ecosia	27
Chrome	28
Brave	29.5
Edge	33
Firefox	33
Qwant	34
OperaMini	39
Mint	42

The device power draw is then calculated using the device power voltage, similar to the device intensity calculated above.

$$\boldsymbol{Browser\ energy}\ (kWh) = Browser\ capacity\ (mAh)\ x\ Device\ operating\ voltage\ (V)\ x\ \left(\frac{A}{1{,}000\ mA}\right) x\ \left(\frac{kW}{1{,}000\ W}\right)$$

Equation 95

The browser emissions are then calculated by multiplying the browser energy consumption with the region-specific emission factor:

$$\boldsymbol{Browser\ emissions}\ (mt\ CO_2e) = Browser\ energy\ (kWh)\ x\ grid\ EF\ \left(\frac{mt\ CO_2e}{kWh}\right)$$

Equation 96

If the consumer is using a playout service such as an app, the following section shall be included and added to the device view emissions. The Greenspector energy consumption of newsfeed intensity can be used to calculate the energy of viewing the ad within the app newsfeed.

The capacity intensity of the mobile app is used with the device operating voltage to calculate the power consumption per minute.

The device voltage is then used to calculate the mobile app power consumption in kilowatt-hours per second.

$$\textbf{App energy intensity}\left(\frac{kWh}{s}\right) = App\ capacity\ intensity\left(\frac{mAh}{min}\right) x\ Device\ voltage\ (V)\ x\ \frac{A}{1{,}000\ mA}\ x\ \left(\frac{kW}{1{,}000\ W}\right) x\ \left(\frac{min}{60\ s}\right)$$

Equation 97

The emissions associated with the energy consumption of the app are calculated by multiplying the app energy intensity, duration of the ad and the region-specific grid factor of the consumer.

$$\textbf{App emissions}\ (mt\ CO_2e) = App\ energy\ intensity\left(\frac{kWh}{s}\right) x\ Ad\ duration\ (sec)\ x\ grid\ EF\left(\frac{mt\ CO_2e}{kWh}\right)$$

Equation 98

These steps should be performed for each viewing combination.

Lastly, the emissions from the device and the browser or app are added to calculate the total consumer view emissions:

$$\textbf{Total digital view emissions}\ (mt\ CO_2e) = Device\ emissions\ (mt\ CO_2e) + Browser\ emissions\ (mt\ CO_2e) + App\ emissions\ (mt\ CO_2e)$$

Equation 99

Audio consumer view

Source:	Information needed:	Abbreviated as:	Unit:
Campaign planner	Expected view duration	Ad duration	seconds
Consumer	End-user device	Device type	Unitless

Consumer view of an audio ad involves the energy associated with viewing device operation for the period of time to listen to the ad. To calculate the emissions of the device, obtain the power consumption of the listening device model. The power consumption is then used the calculate the device energy consumed by multiplying the power draw by the ad duration:

$$\textbf{Device Energy}\ (kWh) = Device\ Power\ Draw\ (W)\ x\left(\frac{1\ kW}{1{,}000\ W}\right) x\ Ad\ duration\ (sec)\ x\ \left(\frac{hour}{3{,}600\ s}\right)$$

Equation 100

The device emissions are then calculated by multiplying the device energy consumption with the region-specific emission factor:

$$\textbf{Device emissions}\ (mtCO_2e) = Device\ energy\ (kWh)\ x\ grid\ EF\left(\frac{mt\ CO_2e}{kWh}\right)$$

Equation 101

Physical consumer view

Source:	Information needed:	Abbreviated as:	Unit:
Installation vendor	Electronic devices (by model), power demand and amount of time operated	Activity power demand	Watts, seconds
Maintenance/ upkeep vendor	Transport of personnel fuel consumption	Volume of fuel consumed	Liters
	Electronic devices (by model), power demand and amount of time operated	Activity power demand	Watts, seconds
Lighting vendor	Wattage, number of light bulbs and hours per day operation	Activity power demand	Watts
Signage vendor	Power demand of signage (e.g., electronic display) and hours per day operation	Activity power demand	Watts, hours
	If flashes between several ads, the amount of time daily the ad is displayed	Activity duration	days
Takedown vendor	Transport of personnel fuel consumption	Volume of fuel consumed	Liters
	Electronic devices (by model), power demand and amount of time operated	Activity power demand	Watts, seconds
Campaign planner	Number of days operating	Activity duration	days

Consumer view of physical ads involves the energy associated with the installation, maintenance, lighting, electronic display (for digital OOH only) and takedown activities. For dedicated moving displays such as a fly-by banner, the fuel consumption will be needed.

For activities using electronic devices, such as lighting, electronic displays and use of power tools, the power demand will be necessary along with the activity duration (e.g., once or daily and total days during campaign).

$$\boldsymbol{Activity\ energy}\ (kWh) = Activity\ power\ demand\ (W)\ x\ \left(\frac{kW}{1{,}000\ W}\right)\ x\ Activity\ time\ \left(\frac{hours}{day}\right)\ x\ Activity\ duration\ (days)$$

Equation 102

The activity emissions are then calculated by multiplying the activity energy consumption with the region-specific emission factor:

$$\boldsymbol{Activity\ emissions\ from\ electric\ devices}\ (mt\ CO_2e) = Activity\ energy\ (kWh)\ x\ grid\ EF\ \left(\frac{mt\ CO_2e}{kWh}\right)$$

Equation 103

For activities powered by fuels, the energy consumption will be calculated by multiplying the fuel consumption by the most recent DEFRA fuel emission factors. For example, if 25 liters of motor gasoline was used during personnel transport activities for the maintenance and takedown operations, the liters are to be multiplied by the DEFRA motor gasoline emission factor.

$$\boldsymbol{Fueled\ activity\ emissions}\ (mt\ CO_2e) = Volume\ of\ fuel\ used\ (liters)\ x\ Fuel\ EF\ \left(\frac{mt\ CO_2e}{liter}\right)$$

Equation 104

All activities associated with a consumer view of the physical ad during the campaign display duration are then summed to calculate the total consumer view emissions.

$$\begin{aligned}\boldsymbol{Physical\ view\ emissions}\ (mt\ CO_2e) \\ = \sum Electric\ device\ activit(ies)\ emissions\ (mt\ CO_2e) \\ + Fueled\ activit(ies)\ emissions\ (mt\ CO_2e)\end{aligned}$$

Equation 105

End-of-life treatment

Source:	Information needed:	Abbreviated as:	Unit:
Campaign planner	Number of delivered impressions	Delivered impressions	Number
	Number of viewed impressions	Viewed impressions	Number
	Ad material composition by weight	Material type	tonne

The Product Standard defines waste as an output of a process that has no market value (Greenhouse Gas Protocol, 2011). The resulting waste from ad campaigns is defined as the digital waste (includes audio) associated with advertisements that are not viewed and the physical waste of the discarded paper or portion of the out of home advertisement that is not reusable (e.g., the ad on a vehicle, not the vehicle itself).

The end-of-life phase of a digital ad consists of the emissions associated with delivered impressions that were not viewed by the consumer. To calculate this, the difference between delivered and viewed impressions are multiplied by the cloud services, data center, network transmission and app exchange (if applicable) emissions per ad.

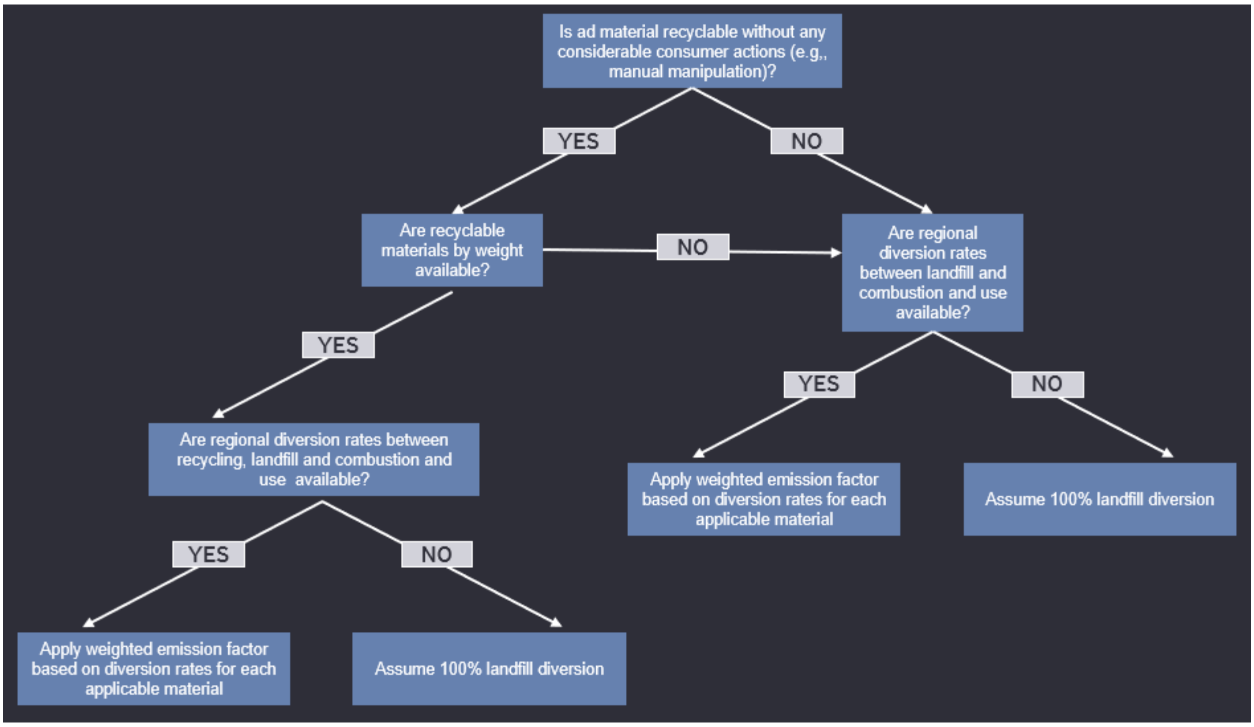
$$\begin{aligned}\boldsymbol{Digital\ waste\ emissions}\ (mt\ CO_2e) \\ = Delivered\ impressions\ (\#) \\ - Viewed\ impressions\ (\#)\ x\ [Cloud\ services\ and\ data\ center\ emissions\ \left(\frac{mt\ CO_2e}{Ad}\right) \\ + Network\ transmission\ emissions\ \left(\frac{mt\ CO_2e}{Ad}\right) \\ + App\ data\ exchange\ emissions\ \left(\frac{mt\ CO_2e}{Ad}\right)]\end{aligned}$$

Equation 106

The end-of-life phase of a physical ad consists of the emissions associated with treating the ad after the campaign has ended or the ad has been discarded by the consumer. There are several options for end-of-life treatment depending on the material of the ad. The table below shows a country-level example if the end-of-life treatment options by material type (Waste and Resources Action Programme (WRAP), 2021)).

	Treatment applicability by material type					
End-of-life treatment type	**Paper**	**Plastic**	**Electrical equipment**	**Metal**	**Glass**	**Clothing**
Reuse (as-is)			X			X
Open-loop recycling[6]		X	X	X	X	
Closed-loop recycling[7]	X	X		X	X	X
Combustion	X	X	X	X	X	X
Composting	X					
Landfill	X	X	X	X	X	X

The applicability of end-of-life treatment types should be assessed using the following decision tree:



Multiple sources may exist to assess the data availability for regional waste treatment in Europe and other regions. An example of obtaining this information is to use the DEFRA UK Statistics on Waste publication (Department for Environment, 2021). The data published in 2021 has been reproduced in the table below. Furthermore, additional sources of information include the European

[6] Open loop recycling offsets the raw material extraction and refining stage for the material that is substituted (i.e., material to product) (Waste and Resources Action Programme (WRAP), 2021). This is not applicable for a media ad.
[7] Closed loop recycling offsets the raw material extraction and refining stage for the material recycled (i.e., material to material) (Waste and Resources Action Programme (WRAP), 2021)

Environment Agency indicators for the category of resource efficiency, and waste may be used to identify country-level diversion rates for recycling, combustion, composting and landfilling.

	Treatment rate by material type in the UK in 2018 (2021 publication)					
End-of-life treatment type	Paper	Plastic	Electrical equipment[8]	Metal	Glass	Clothing
Closed-loop recycling	99.78%	88.37%	99.20%	99.99%	97.69%	98.44%
Combustion	0.00%	0.52%	0.00%	0.00%	0.00%	0.00%
Landfill	0.13%	11.11%	0.80%	0.01%	1.62%	1.56%

The emissions from the end-of-life treatment of the ad are then calculated for each material within the ad using the most recent DEFRA WRAP emission factors (Waste and Resources Action Programme (WRAP), 2021).

$$\boldsymbol{End\ of\ life\ treatment\ emissions}\ (mtCO_2e)$$
$$= \sum Material\ weight\ (tonnes)\ x\ WRAP\ EF\ \Big[Recycling\ rate\ (\%)\ x\ Recycling\ EF\ \left(\frac{kg\ CO_2e}{tonne}\right) x \left(\frac{1\ mt}{1{,}000\ kg}\right)$$
$$+\ Combustion\ rate\ (\%)\ x\ Combustion\ EF\ \left(\frac{kg\ CO_2e}{tonne}\right) x \left(\frac{1\ mt}{1{,}000\ kg}\right)$$
$$+\ Composting\ rate\ (\%)\ x\ Composting\ EF\ \left(\frac{kg\ CO_2e}{tonne}\right) x \left(\frac{1\ mt}{1{,}000\ kg}\right)$$
$$+\ Landfill\ rate\ (\%)\ x\ Landfill\ EF\ \left(\frac{kg\ CO_2e}{tonne}\right) x \left(\frac{1\ mt}{1{,}000\ kg}\right)\Big]$$

Equation 107

If a region-specific diversion rate for a non-landfill treatment type is unavailable, assume '0' in the above equation. The sum of the non-landfill diversion rates and the landfill diversion rate must equal one.

[8] The discarded equipment EWC-STAT description was used for this material type (Waste and Resources Action Programme (WRAP), 2021).

ADVERTISED EMISSIONS AND BEHAVIOUR CHANGE

We now move from the internal processes of carbon accounting across the various advertising channels to the external consequence of advertising on society more broadly. Here, we'll examine the carbon consequence of why advertising is used by a variety of companies and institutions, both in terms of commercial shifts and other advantages to be gained. We will consider influencing consumption patterns as well as other opinions and associated behaviours in a targeted group of people.

So far, the advertising industry (and ecosystem) has handled the carbon consequence of advertising's external impact under the banner of "Advertised Emissions," which worked as a catch-all category for any and all external-related emissions. For clarity, this version of advertised emissions connects the exposure to advertising to increase in demand, and this increase in demand with increase in manufacturing. It then argues that all associated manufacturing, transport, usage, and product lifetime emissions are linked back to the advertising ecosystem. We've noted some issues with this conceptualization in our introduction, so let it suffice here to point out that assigning the multi-stage and multi-dimensional costs of the economy to advertising is an accounting mistake that will create a bad system of incentives where long term benefits flow in one direction and long-term costs in another. Unfortunately, a coarse view, and a coarse measure of such an influential industry will lead to bad sustainability/conservation consequences.

That is not to say that the consequence of advertising on society is to be ignored. The conversation around Advertised Emissions has been core in recognizing and cementing the role of the industry as a facilitator to shift consumption as well as sustainability behaviours, and the associated need to consider its full impact. However, to fulfil this purpose, we will adopt a more specific set of definitions around the external consequence of advertising:

Def.: Consumption Emissions
Carbon emissions connected to the use of products and services as well as their disposal (stages 4 and 5 of GHGP)

Def.: Advertised Emissions
Consumption emissions attributable to the influence of an advertisement.

Def.: Incremental Advertised Emissions
Novel and differential (positive or negative) consumption emissions attributable to the influence of an advertisement.

Def.: Displaced Advertised Emissions
Existing consumption emissions that shifted from one unique entity (organization/brand/product/region) to another, due to the influence of an advertisement.

First, by considering Consumption Emissions, we restrict our analysis and view to the stages 4 and 5 of the Greenhouse Gas Protocols, or the 'unusual' gate-to-grave component of a product's journey. This is a correspondence to purchase decisions, usage patterns, re-purchase cycles, and similar constructs that advertising is called upon to manipulate in one way or another. It is then separated from supply-side components of operation that are the purview of the acting firm, from sourcing or manufacturing through its distribution. Obviously, demand (natural or influenced by advertising) is going to be connected to supply, but generally through a filter of decision making on the firm's side. As such, by focusing on consumption emissions, we focus on our direct impact, rather than internal decisions taken by other industries on the basis of our performance. We avoid one instance of double counting by allowing them to consider the carbon cost of their own internal processes and decisions.

From consumption, we turn to Advertised Emissions. In our discussion, we will restrict these to the consumption we can attribute to advertising activity. This is a recognition that despite its power to drive consumption, not all consumer decision making is taking place as a direct function of advertising activity. However, we also recognize that this is too broad a concept for good managerial action, which leads to the introduction of our two final definitions: incremental advertising emissions, which captures the difference in emissions brought about by advertising (note that we are not assigning or assuming a direction, thus leaving space for activities that help the sustainability effort, not just that harm it), and displaced advertised emissions, which capture the competitive aspect of demand shifts.

These final two concepts should align cleanly with traditional demand management in day-to-day operations. We are accustomed to discussions on growth, and greater specificity on where growth comes from. Incrementality captures this aspect of growth and connects the aim and consequences of advertising by considering the same aspects of lift in performance and lift in consumed carbon. Similarly, most immediately recognize that business growth does not equate to an unchecked and perpetual growth in a category, much less the overall economy. Growth for one specific company will most often come from the loss of business by a competitor, thus leading to a market share shift. By considering the displaced advertising emission we accompany this shift in share of rewards with a commensurate shift in carbon attribution.

Importantly, the joint consideration of these more detailed aspects of advertised emissions opens up a traditional market playbook that could lead to really positive sustainability outcomes. For example, consider instances of positive cannibalization, and what it would mean for a net-zero effort. In this instance, we aim to replace demand in one older offering with a new product, and let's assume with higher unit profit margin, as well as lower unit Consumption Emissions. This shift accomplishes both a higher level of financial performance as well as a lower environmental impact relative to the previous status quo. Incrementality and Displacement both matter significantly in order to create the right system of incentives in the marketplace.

This is particularly meaningful when we start considering the relative strength of advertising in its ability to shift consumption behaviours, both in the short term and long term, as well as the knock-on effect it has on likelihoods of shifting market share in the same time frames.

There have been numerous studies examining the overall impact of advertising on sales, as well as additional studies seeking to summarize (via meta-analyses) these findings into a cohesive snapshot. And given the timelines involved, we are also able to speak a little about the dynamics in this environment. In a 1984 meta-analysis of 128 econometric models describing the elasticity in advertising (% change in ads leading to % change in sales), the authors (Gert, Farley and Lehmann) find that advertising had an elasticity of 0.22 in the short term, and 0.41 in the long term. Later, in a 2011 follow up study considered 56 published studies in a meta-analysis, and these authors (Sethuraman, Tellis, and Briesch) find that short-term and long-term elasticities had diminished to 0.12 and 0.24, respectively.

Combined, these results lead us to two important generalizations. First, there is a declining power of advertising to driving sales (and therefore underlying behaviours) over time. These analyses cover a period from the early 1960s to the late 2000s, which is a period of tremendous growth in the amount of advertising; consider, for example, that global ad spend has approximately doubled between the decade between the end of these studies and now. It is hardly surprising that the amount of noise and competition for audiences has had a marked impact. Secondly, in both meta-analyses the long-term impact of advertising vastly outperforms its short-term impact. This should cause concern to anyone seeking to simplify the attribution of performance or carbon consequence to a give advertising activity, as most of the effects are not going to be simple time concurrent.

As an additional piece of data, a more recent work published by Dall'Olio and Vakratsas (2022) considers the impact of creative optimization on short and long-term advertising elasticities on sales. They find that adjusting creative can improve short term by and additional 0.04 to 0.07 (33-58% improvement), and long-term performance by 0.08 to 0.15 (33-62.5%). Making creative a massive component in getting the most return (commercial/behavioural) for a given level of input (monetary/carbon).

Additionally, and relatedly, we know that market share position and overall stability is a function of time. In the immediate (concurrent) to mid-term, market shares across industries appear rather static, with large incumbent companies retaining their positions. However, in the longer term, market shares are very volatile. Historically, only 23% of firms that have held the number 1 position in market share in their categories have remained in position, with 16% falling further down than number 10, and 28% eventually failing and disappearing entirely (Golder 2000). This provides additional evidence that marketing activity impacts long term performance, and builds on previous actions/results.

Altogether, consumer shifts will largely be non-concurrent with advertising campaign shifts, and we will need to consider multi-period, multi-iteration, and sequential attribution of advertising campaigns. We will address the need to attribution and issues with current approaches later, but it is important to recognize that just doing **more** advertising is likely to be inefficient and relatively costly in terms of CO_2e (higher net advertising emissions facing a decline 'exchange rate' for outcomes). Creative content, execution, rebalancing of media allocation (thus lowering advertising emissions associated with a given return level) are likely to have a much better outcome and better outcome to CO_2e ratio. However, to have a clear control on returns, we need some better measures on behaviour shift (thus augmenting sales). We turn to that next.

Quantifying Behaviour Change

We are interested in quantifying the likelihood that various groups will take a certain action, be it commercial (e.g. visit a specific shop, buy a product), or sustainability-related (e.g. recycle packaging, reduce water or energy usage), and we would like to extend this measurement to an analysis of our ability to influence these events. However, the likelihood that a person will behave in a specific way is often underpinned by un-observable characteristics that vary across a population. There are a variety of abilities, knowledge, motivations and beyond that will remain hidden from us, and will result in variance in how individuals respond to stimuli.

Therefore, we will leverage an approach of psychometrics to measure the likelihood that individuals will behave in the way we're interested in, without directly observing these underlying dimensions, but rather estimating a range and distribution of behaviours, as well as our ability to shift these patterns.

The Behavioural Response Function

Here we will define the behavioural response function (BRF); a simple function that gives the probability that a person, having a given underlying latent predisposition, will take an action. For simplicity's sake we will be equating this unobserved layer to a person's predisposition to the action, or their knowledge level. This equivalent to the suggestion that the more knowledge you have about the climate crisis, the more likely you are to take a pro-environmental action. It would also be similar to high brand equity (un-observed within the individual) is connected to a higher chance of positive reaction to brand activation. At its most basic, the higher we infer someone's predisposition to action, the higher the assumed likelihood of the associated action.

Importantly, we will consider each action taken as individual events, such that they can be stated in simple dichotomous statements: yes/no, acted/did not act, succeeded/failed, etc. From a data and modelling perspective allows us to work in a straightforward world where the desired action takes a value of 1, or 0 otherwise, fitting nicely in a logistic model.

In order to describe the behavioural relationship fully, we will need more than the latent predisposition. Our BRF model will have three additional parameters, modifying the traditional logistic model such that:

$$p(K) = b + \frac{1-b}{1+e^{-c(K-i)}}$$

Equation 108

giving us the probability **p** that someone with a predisposition/knowledge level of **K** will take the action that we are interested in (note that **K** is handled as a sample drawn from a normal distribution; is both unit free and infinite in both positive and negative directions, centred at zero).

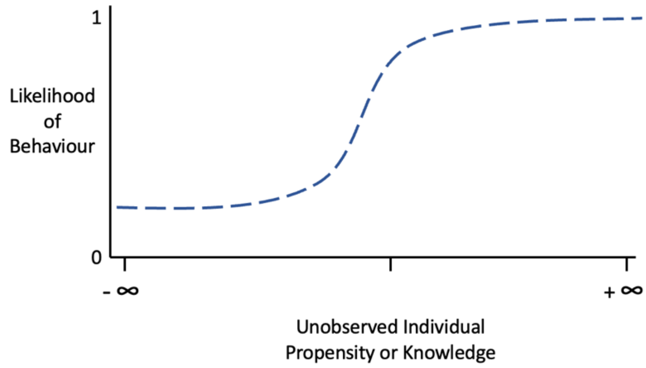
The additional parameters control the shape of the distribution we're interested in. and can be interpreted in the following way:

i – Indifference point. This is the location where individuals are exactly 50/50 on taking the action or not (note that this is the point where the slope below is maximized).

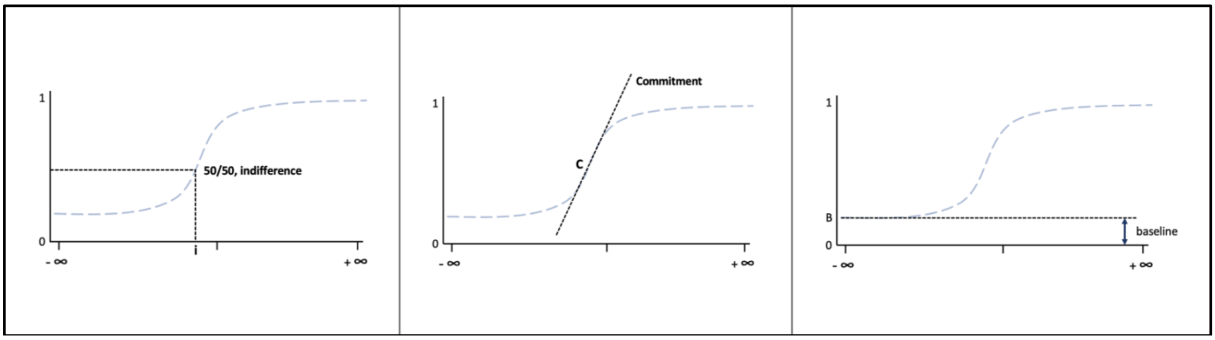
c – Commitment. It gives the rate at which changes in knowledge/predisposition result in changes in the odds of the given behaviour. A number closer to zero suggests very gradual increasing commitment (grey spaces exist). A vertical line (with undefined value) suggests an all-or-nothing division between doers and not-doers (the world is black-or-white). This is the (maximum) slope of the cumulative distribution.

b – Baseline. This provides us with a potential for a non-zero chance of an action, even for individuals with the lowest possible predisposition/knowledge.

Altogether, these parameters generate the following behavioural curve that describes a specific measured group, organized at increasing levels of **K** on the x axis, and associated p(**K**) on the y axis.



The location and use of the three estimated parameters (**i, c, b**) can be seen below.



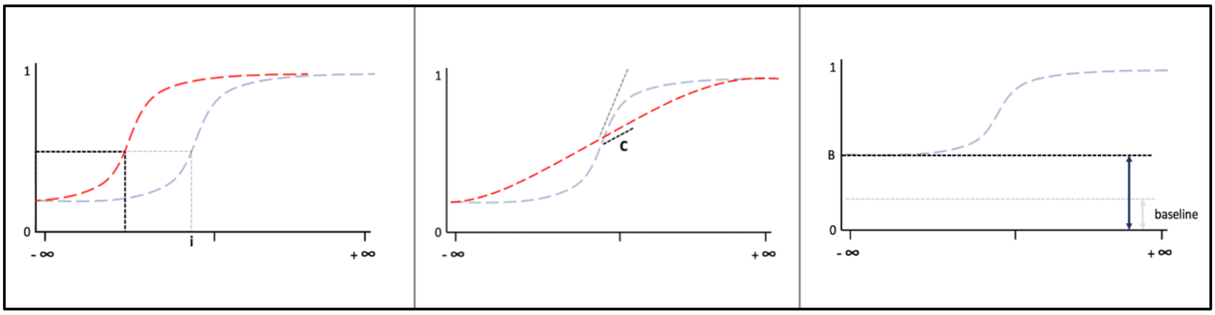
The **C** parameter stretches the horizontal scale, the **i** parameter shifts the horizontal scale, and the **b** parameter compresses the vertical scale from [0,1] to [**b**,1].

For illustration, let's assume that we are investigating vegan food decisions in England as a response to the climate emergency. We might view the left extreme values of **K** (- infinity) to capture climate-deniers, while right extreme values (+ infinity) capture eco-warriors. Assuming a value of zero for **b**, climate deniers would simply never demand any vegan options since p(-infinty) = 0, and eco warriors would choose vegan options on every occasion, as p(+infinity) = 1.0. Meanwhile, the rest of England consumers would exist in between these extremes, with varying probabilities of picking a vegan option, depending on individual predisposition/knowledge (**K**) and as described by **c**, a measure of the gap between our climate deniers and eco warriors.

Testing Interventions

As presented, the Behavioural Response Function is a static, descriptive tool. It, importantly, captures the heterogeneity of individuals, and describes the odds of activity for a group. However, our aim is to investigate the change in these patterns of behaviour, and to quantify the impact of advertising on these behaviours.

First, to build intuition, we'll look at the role each parameter has in reshaping the behavioural curve that describes our target group. The following table depicts shifts in the previously shown curve, along each individual parameter:



As we can see, a reduction in **i** shifts the entire curve to the left and keeps all else equal. It still captures the same indifference point, where individuals of a given knowledge level or predisposition are as likely to take the specific action as they are not (50% chance of action). However, this indifference is taking place at a much lower **K**.

Turning to our commitment parameter **c**, a reduction in value translates in a much more gradual shift from “low probability of action” to “high probability of action,” marking a move away from a stricter all-or-nothing type of commitment. Interestingly, we should note that this shift is accompanied by gains in individuals below the indifference point, and losses in those above. And it is likely that context will dictate when we want higher or lower levels of commitment (for instance, gradual shifts might be helpful in early adoption, followed by higher commitment to lock in later, already-adopted positive behaviours).

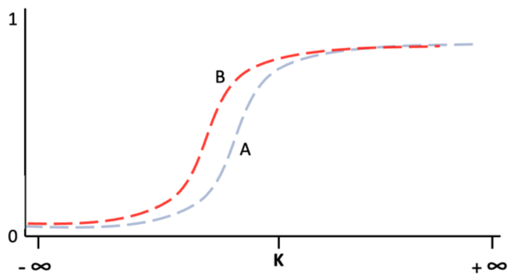
Lastly, our baseline **b** raises the floor on the entire curve, setting a new minimum probability of the desired behaviour, regardless of **k**.

Next, we need to move beyond this description of a singular group towards a contrast between the curves describing two groups. The choice of the groups will depend on the question and analysis being done, but the entire playbook of market test/control testing should open up here.

The immediate choice is a population exposed to an ad campaign contrasted with a control group that is otherwise identical. Alternatively, we can examine the same group, before and after an in-market intervention.

To be explicit, once the design and question is clear, and the group(s) are identified we can: (1) collect dichotomous data on behaviour (observed, stated intent, etc), (2) estimate a Behavioural Response Function, with 3 parameters (i, c, b) for each group, (3) generate a behavioural curve for each group.

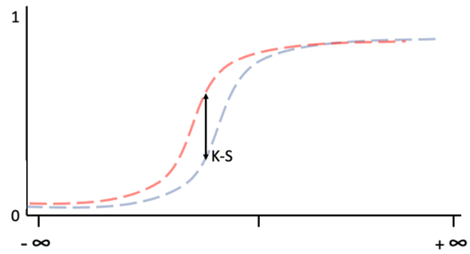
From this point, we can visually inspect the impact of our action as in the figure below, describing the differences between groups ‘A’ and ‘B.’



However, we can now go a bit farther and test the significance and quantify this impact.

Kolmogorov-Smirnov (K-S) test

In order to test whether there is a statistically significant difference between the two probability distributions described in our behavioural curves we use the (two-sample) Kolmogorov-Smirnov test. In this approach we will be examining the distance between these two empirically generated distribution functions ('A' and 'B'). It is worth noting that the K-S test picks the location of greatest difference between the two curves, which is additionally helpful in this case, as it highlights in which (if any) value range of **K** our advertising had the most impact; those with lowest predisposition, highest, or somewhere in the middle (the figure below highlights this process).



For completeness, the Kolmogorov-Smirnov statistic is given by:

$$D_{n,m} = \max_{x} |A_n(x) - B_m(x)|$$

Equation 109

Where A is the first group distribution we're interested in, having a sample size on *n,* and B is the second group distribution, itself having a sample size of *m*.

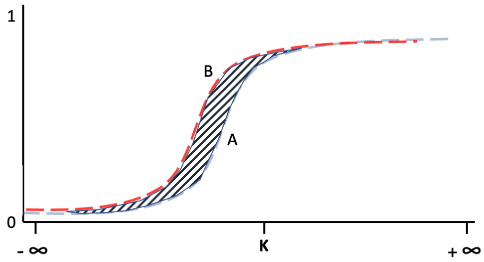
We can then be 95% confident that these distributions are not the same if,

$$D_{n,m} > 1.358 \sqrt{\frac{n+m}{n \times m}}$$

Equation 110

Difference of areas under the curve

If we want another measure of the overall impact we have by shifting the behaviour of our group, we can calculate the difference between the area created by the new behavioural curve and that created by the original or control curve. Otherwise known as the Signed Area, this incremental gain is shown in the figure below:



This difference is defined as:

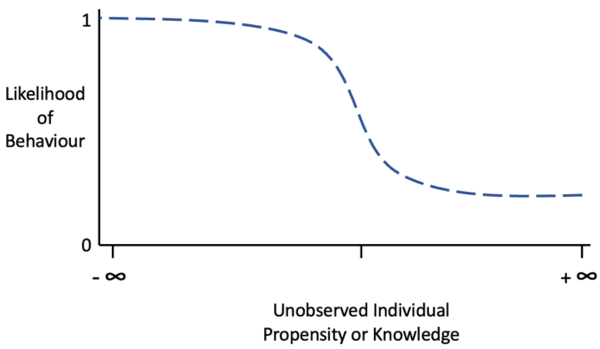
$$\int_{-\infty}^{+\infty} \big(B(x) - A(x)\big)\, dx$$

Equation 111

Note that this difference is finite provided that our baseline parameters **b** are equal in each behavioural curve. However, in cases where the baseline shifts, and **b** values are unequal, the area itself becomes infinite. To address this issue, the integral above can be adjusted to be done between two finite points in the **K** scale (e.g. either -4/+4, or -3/+3), provided that we believe we are capturing the bulk of individuals within this restricted range (i.e. the most extreme values of **k** represent few outliers).

Why is my Commitment parameter negative?

There are occasions where an estimated Behavioural Response Function will have a negative value for the commitment parameter **c**, leading to a descriptive curve similar to the one shown in the figure below. The implication is that the greater someone's Knowledge (**k**) the LESS likely they are to take the indicated action. This will be common in cases of undesirable activities, or negative brand equity (where greater knowledge leads to lower demand/consumption).



While not inherently problematic, simply re-stating the problem or behaviour or reverse coding the activity variable will return the curve to our familiar format. For example, the likelihood that an individual "will continue using the same energy supplier in next 12 months" will have a negative **c** for a given audience, while having a positive **c** for "will seek a green-energy supplier in the next 12 months." Overall, it is capturing the same information, but showing it differently.

PORTFOLIO MANAGEMENT AND TRADE-OFFS

Having established the carbon equivalent cost of advertising activities (Advertising Emissions) and quantified the behavioural consequence of those initiatives (Advertised Emissions), we can bring those concepts together in what should be a natural cost/benefit analysis, considering the effort and costs associated with driving a specific outcome.

It is worth noting that this trade-off concept is hardly new in sustainability. For example, even as early as 1996 BASF has conducted its own eco-efficiency analysis, describing a product in terms of a ratio of its environmental impact to its economic impact, and more recently it has added a social impact dimension to this analysis. However, follow up publications have questioned the validity and clarity of these trade-offs (Heijungs 2022). Others have suggested a more direct business linkage by using Return on Carbon, given as the ratio of gross profit to total metric tons of carbon-dioxide equivalent used, or the sum of scopes 1, 2 and 3 (Fairchild 2020). Together, they form a sensible measure of efficiency, by looking at how much economic benefit a firm has generated per unit of a precious resource ($mtCO_2e$). Inverse variants, like environmental intensity (carbon emission per economic unit), or deltas of each measure above are also pervasive in practice, all operating under the banner of eco-efficiency.

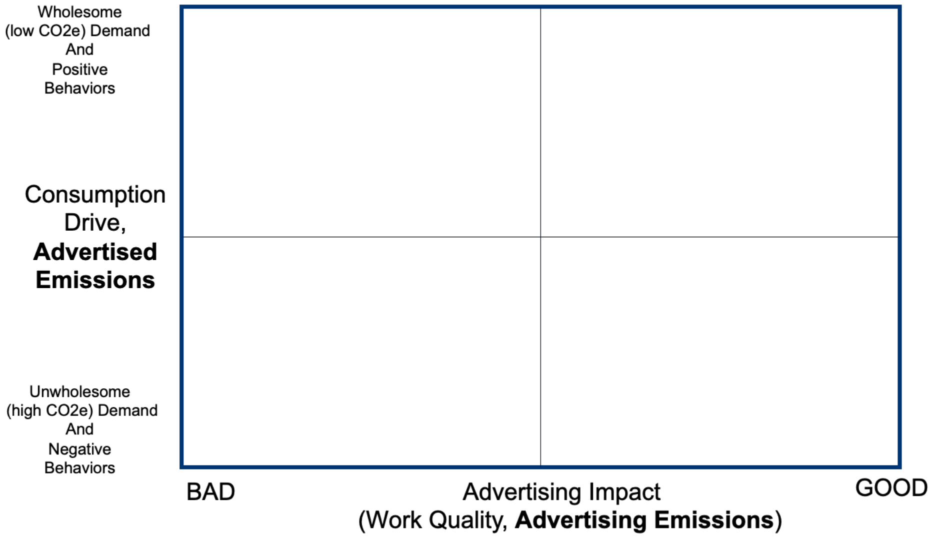
We could certainly apply the same Return on Carbon logic in advertising by looking strictly at the commercial value generated by an activity, and the precise combination of Advertised Emissions involved in its creation and execution. However, as we noted before, our industry is both uniquely positioned to do more, and capable of influencing consumption and other decision making beyond its own footprint. As such, we can consider more complex combinations of monetary and carbon costs, leading to combinations of monetary as well as carbon consequences.

In order to build intuition in the process and connect to more immediate business practices we will initially simplify this trade-off analysis by collapsing our complex, multi-dimensional cost structures into a singular and necessarily crude dimension. We will then repeat the same for the benefits arising from the advertising activity.

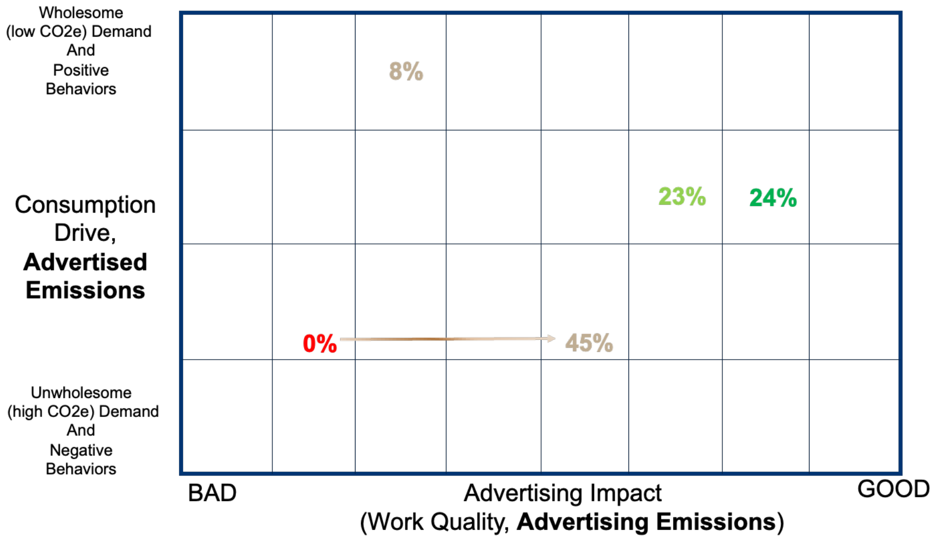
In terms of costs and economic benefit gained, we will assume a simultaneous effective and efficient scale. All of advertising emissions collapses into this one continuum. We will consider that on the lowest end of the scale (i.e. bad work), we would be given ineffective and poorly executed advertising that does a rather poor job of 'moving the needle' of its target KPI, and does so inefficiently, being on the highest end of associated carbon cost and advertising emissions to do so. Truly a worst-on-all-aspects experience with advertising. However, on the other extreme end of the scale (i.e. good work), we are met with very high quality work, that is exceptionally well executed, delivering effective and significant lifts on its intended KPI, and doing so efficiently, at a very low carbon cost in advertising emissions.

We will then similarly collapse our outcome/consequence (Advertised Emissions) components into a single linear dimension. On the extreme negative side we should expect very large levels of associated 'unwholesome' demand, consumption and disposal of products that have a very large $mtCO_2e$ attached to it, and a rise in negative, undesirable behaviours (anti-environment, antisocial, etc). On the opposite, extreme positive side of our Advertised Emissions scale we should expect very large levels of 'wholesome' demand, consumption and disposal of products with much lower associated $mtCO_2e$, and positive behaviours that lead of sustained sustainability practices and lower overall carbon utilization.

Staged against one another, these simplified Advertising versus Advertised dimensions give rise to a straightforward 2-by-2 to assist on the evaluation of existing activities, and identification of problematic areas in need of improvement along on (or both) dimensions. As example of this trade-off matrix is shown in the figure below:



Of course, most sizeable firms are hardly engaged with a singular advertising initiative or campaign at a time. Given the international footprint of companies, it is almost a guarantee that the same execution will have different values in our two simpler dimensions (accounting for localized responses and variance in local power grid emission factors, for example). As such, we should consider plotting our various efforts and costs on this frame, forming a picture of the overall contribution and impact of the firm. An example of such a plot with percentage of activity is given below:



In the example above, we have a firm whose product might be particularly carbon intensive. It is reliant on one main campaign to drive commercial success, but the nature of the consumption/use of its product, this main effort is on the lower end of our outcomes dimension capturing Advertised Emissions. In order to address this issue, but respecting commercial needs, the firm is able to move this main effort (45% of ad spend) toward better Advertising Emissions, maybe rebalancing its media plan and gaining greater efficiency. The core product is still problematic, and the firm will likely need to address this internally in the future, but at least it is spending less carbon to generate business and sustain itself. So, what of the remaining 55%? We see that 8% is dedicated to a campaign leading to really positive behaviours; however, the Advertising Emissions associated with this effort are not great. Lastly, our final two campaigns score much higher marks, generating positive behaviour change at much more efficient rates. The ultimate result of this portfolio being realized is a mathematical exercise. How much of Advertised Emissions are incremental? How much is displaced? Do these shifts lower the overall $mtCO_2e$ in the firm's industry as a result? Is this gain sufficient to offset the Advertising Emission cost associated with creating this shift?

The example above is simple but illustrative of the process and advantages of organizing both Advertising and Advertised Emissions, along with its descriptive components in order to quantify the net $mtCO_2e$ consequence of advertising, accounting for the cost of manipulating a market, and recognizing the $mtCO_2e$ value of shifting the probability that certain populations will take an action in the future (commercial or sustainability-related).

ATTRIBUTION AS THE CONNECTION

We have previously alluded to the fact that, just as in traditional marketing activities, precise attribution will be critical in proper management of emissions in the advertising industry and its impact beyond. Attribution exists precisely as the descriptive and accounting connection between the costs of the activity (Advertising Emissions) and its consequence (Advertised Emissions). Without it, we will have an entirely disjointed where benefits do not flow to the appropriate costs, and reality devolves into a well-known 'wild west' of claims, or managerial irresponsibility taking the shape of statements like "I know half of my marketing works, just not which half." Additionally, as we know the long-term consequence of advertising is much larger than the immediate (and more easily attributable), the problem is not only important, but more difficult than immediately apparent.

We will not develop and introduce an appropriate method for attribution here, as it is beyond the immediate scope of this framework, other than to point to its absolute necessity. It will; however, briefly discuss attribution models, the currently used state of art approach, and describe why it is unfit for purpose, hopefully further motivating a movement away from simplistic and flawed attribution towards better methodologies.

An attribution model is described as a systematic approach to evaluating the impact the touch points of an advertising campaign have on key performance indicators. Attribution models can generally be described as narrative focused or variable focused. Here, we consider two types of variable focused attribution applied to click-stream data:

1. Fractional attribution: this approach assigns a predetermined value to each touch point. Examples of fractional attribution include First and Last click attribution. These algorithms are typically simple to implement and fast to compute but can lack meaningful conclusions.
2. Data-driven: determines the value of each combination of touch points from a data set then finds the incremental value of each touch point via the Shapley value.

Data-driven models are heralded as state-of-the-art and have received much attention in recent years, and likely make up the bulk of attribution services purchased in practice. Since the purpose of multi-touch attribution is to systematically evaluate the impact of touch points of an advertising campaign on key performance indicators; there are several properties which should be met in order to obtain a desirable attribution model: (1) permits touch point sequencing and repetition; (2) provides granular scoring of touch points; (3) adheres to current marketing theory, such that touch points can exhibit complementarity and cross effects; (4) determines scores without bias; (5) yields verifiable outcomes; and (6) admits easily measurable error.

Unfortunately, the Shapley value, which underpins widespread "data-driven' attribution models does not satisfy of these six conditions in general.

First, a brief explanation of how the Shapley method is currently employed. A common approach to applying the Shapley value is with the aid of a predictive model. The strategy is to define a probability that a given touch points in the group of all touch points being used/considered will lead to conversion (assuming this is our KPI). Alternatively, we can ourselves define a valuation function with respect to some KPI such that sub-grouping of touch points will sum up to the revenues.

For brevity in this discussion, we will focus on a few of the critical issues and where they might be particularly troublesome when considering carbon-related attribution.

First, we will consider the failure to address sequencing. The Shapley value determines the payoff of each group of touchpoints where the group itself is an unordered collection without repetition. In the case of a customer journey, touch point sequencing is crucial for conversion. Moreover, a customer may encounter the same touch point more than once on their path to the final action/KPI (e.g. conversion). Regardless of the care taken in constructing the valuation function, this information is lost when the Shapley value is applied. And while sequencing is crucial in marketing, the inability to understand repetition could prove to be an enormous issue with carbon accounting, as each interaction will add to the Advertising Emissions. Simply, it is not just an issue of turning a channel on or off, but rather when, where and how often it is used. Current data-drive attribution cannot handle this requirement.

Next, we consider its ability to capture the functionality of marketing channels. The Shapley value is a unique payoff function which is efficient, symmetric, and linear. This linearity criterion is a rephrasing of the original condition proposed by Shapley which was called the law of aggregation, or an assumption that this attribution functions like a “competitive” game. A competitive game is defined as a game in which a player’s payout is independent of another player’s contribution. That is, one player’s loss does not cause another player to receive a lower payout. However, this assumption flies in the face of modern marketing understand, which assumes channels can influence each other’s performance both in terms of complementarities and cross-media effects, forming the basis for integrated marketing communications. In summary, the Shapley value assumes the touch points are working competitively when marketing research has shown that touch points can work cooperatively.

Lastly, we should point out the issue of verifiability. As we noted earlier, the Shapley value is implemented by either a predictive model or by generating a valuation function. However, it is worth noting that there is no ‘correct’ valuation function. In fact, absolutely any valuation function will yield a Shapley value attribution. Or, if we chose to work backwards, any desired final attribution can be created by a pre-determined valuation model. That is, our “data-driven” model can be constructed in order to give absolutely any attribution answer we desire (a fact known to and stated by Shapley when the measure was introduced). In short, there is no ground truth, and results can be manipulated (although we would not suggest that they are, merely that they can be).

Altogether, this discussion is meant to highlight what we see as a significant issue and barrier to a proper management of the advertising industry’s impact, and the carbon consequence of its actions. We have previously described a fine-grained measure of Advertising Emissions, down to minutiae inside of each channel composing part of a given campaign. The implication is that we should re-organize and favor specific channels and combinations that minimize our Advertising Emissions. However, how are we to do this without the knowledge of the function of that channel? The implication of its inclusion on performance? Or, ultimately, its contribution to a specific behaviour change we desire (Advertised Emissions). Appropriate attribution is crucial in appropriately managing the interplay between Advertised and Advertising Emissions, and there remains an enormous amount of improvement possible in how we implement these models.

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