Carnstone

Carbon emissions of streaming and digital terrestrial television

Carnstone

Executive summary

With the increasing uptake of video streaming services, Ofcom commissioned Carnstone to assess the energy and carbon impacts of this trend.

Carnstone has delivered similar analyses as the convener of the DIMPACT project, as well as the authors of the LoCaT project (see right). The project draws upon the approach of the BBC White Paper 372 – Using behavioural data to assess the environmental impact of electricity consumption of alternate television service distribution platforms.

This analysis furthers the certainty of previous results due to enhanced data provided by Ofcom, offering a clearer view of TV viewing behaviour in the UK. Ofcom also facilitated access to the digital terrestrial television (DTT) network's energy consumption from the UK to provide further certainty in this area.

Our results confirm the results of previous studies (see callout box – right) that TV viewing is a relatively low source of emissions. One hour of viewing TV via terrestrial networks has an energy consumption of 10.6Wh. For streaming, this is 54Wh.

As with other studies, we found that a significant portion of the energy consumption from TV viewing (96% for DTT and 90% for OTT – Over-the-top) is accounted for by in-home devices, when compared to each method's respective distribution networks.

We advise caution about what actions should be taken in light of these results. This study uses an attributional approach which is widely accepted as the best method to understand the energy impact of OTT and DTT services based on today's volume of viewing. However, this approach cannot be used to speculate about how future changes in the delivery networks and user behaviour will impact energy consumption and emissions. Please see page 18 for more details.

Summary of previous work on the emissions of TV

The approach used in this project draws upon similar work completed by the Carnstone team and the wider industry.

Carnstone convenes DIMPACT, an initiative of media and technology companies that are interested in measuring and addressing the emissions of IP-delivered media and entertainment products, such as video streaming. Participating companies measure their emissions using company-specific data on their viewers' behaviour and digital value chain to get tailored estimates, using an agreed upon methodology.

In 2021, DIMPACT engaged the Carbon Trust to produce a White Paper entitled The Carbon Impacts of Video Streaming, which drew upon the DIMPACT approach and presented the results from DIMPACT participants in an anonymised way. This provided the most up-to-date averages for video streaming in Europe.

In addition, the BBC has undertaken studies using a similar methodology to the above to evaluate the impacts of the platforms that they use to distribute their content. The BBC White Paper 372 forms the basis of many of the other studies and has since been peer reviewed in the journal Environmental Impact Assessment Review[1].

Carnstone was also engaged by a consortium of players in the European television market to provide an analysis of the impacts of OTT, DTT and managed IP-delivered TV (IPTV) across Europe. This project, entitled the LoCat Project (Quantitative study of the GHG emissions of delivering TV content) created high-level estimates across different countries in Europe.

[1] https://doi.org/10.1016/j.eiar.2021.106661

Introduction

Climate change and increasing energy costs have come to the front of companies', of policy makers' and of wider society's agenda. As a result, the energy and greenhouse gas (GHG) emissions impacts of many everyday activities are coming into question. This includes streaming, where there have been varying estimates of the impact. When conflated with the continued growth of streaming services, this explains why many stakeholders are interested in gathering reliable estimates of the energy and carbon impacts of streaming and other TV viewing methods.

As such, Ofcom has engaged Carnstone to provide an up-to-date estimate of the energy and GHG impacts of streaming and digital terrestrial television in the UK. The objectives of this study were simple: build upon the existing approaches to measuring the energy and emissions impacts of TV viewing for DTT and OTT by using a comprehensive set of UK-specific data.

Using the results, we have provided a discussion about the key findings, and the areas for further investigation.

Approach

The approach to measuring the energy consumption and GHG emissions of OTT and DTT viewing aligns with the methodology of previous studies, with additional data sources provided by Ofcom. This provided more confidence in the outputs for the UK specifically. Given that we draw upon other studies, we have not outlined our methodology in full, but have cross-referenced these studies where appropriate. We have focussed this section on sharing the data sources used to develop this estimate.

Overall modelling approach

To measure the GHG emissions associated with each delivery method we adopted an attributional life-cycle assessment (LCA) approach, consistent with the BBC White Paper 372, the LoCaT project and DIMPACT project. We first mapped each of the functional processes that take place to deliver TV content, then assigned variables and parameters to model the behaviour of TV delivery methods.

Functional units

We considered two functional units as part of the analysis:

1. The energy consumption and GHG emissions attributed to one device hour of DTT and OTT in the UK in 2021. This is expressed in Wh/h or ‘Wh per device hour’.
2. The annual energy consumption and GHG emissions attributed to all device hours of DTT and OTT in the UK in 2021. This is expressed in GWh.

The first unit normalises the data by device hour to allow for easy comparison. The second metric was used to provide an overall estimate of the scale of energy and GHG emissions attributed to each viewing method across the UK. For both units, ‘device hours’ was chosen, as the devices used in each system are what consume energy, and makes explicit the fact that shared viewership (multiple people viewing content on the same device) is taken into account.

In some cases, this report references TV viewership per household, and viewing per person. This is because a significant amount of the viewership data available to us was tracked at either the household or individual level. For example, the total number of households that use DTT, or the average number of daily viewing hours per person. The latter does not factor in any shared viewership so, as such, we reference calculations in units per household to show our intermediate steps to determine the ‘device hour’ estimates for the two functional units above.

System boundaries

For both OTT and DTT, we modelled the energy consumption of the systems required to deliver and view television content. This includes the network transmission, data centres and content delivery networks (CDN), and end-user devices. The components of the system modelled are in line with the previous studies. We have outlined these system boundaries for DTT and OTT in Figure 1.

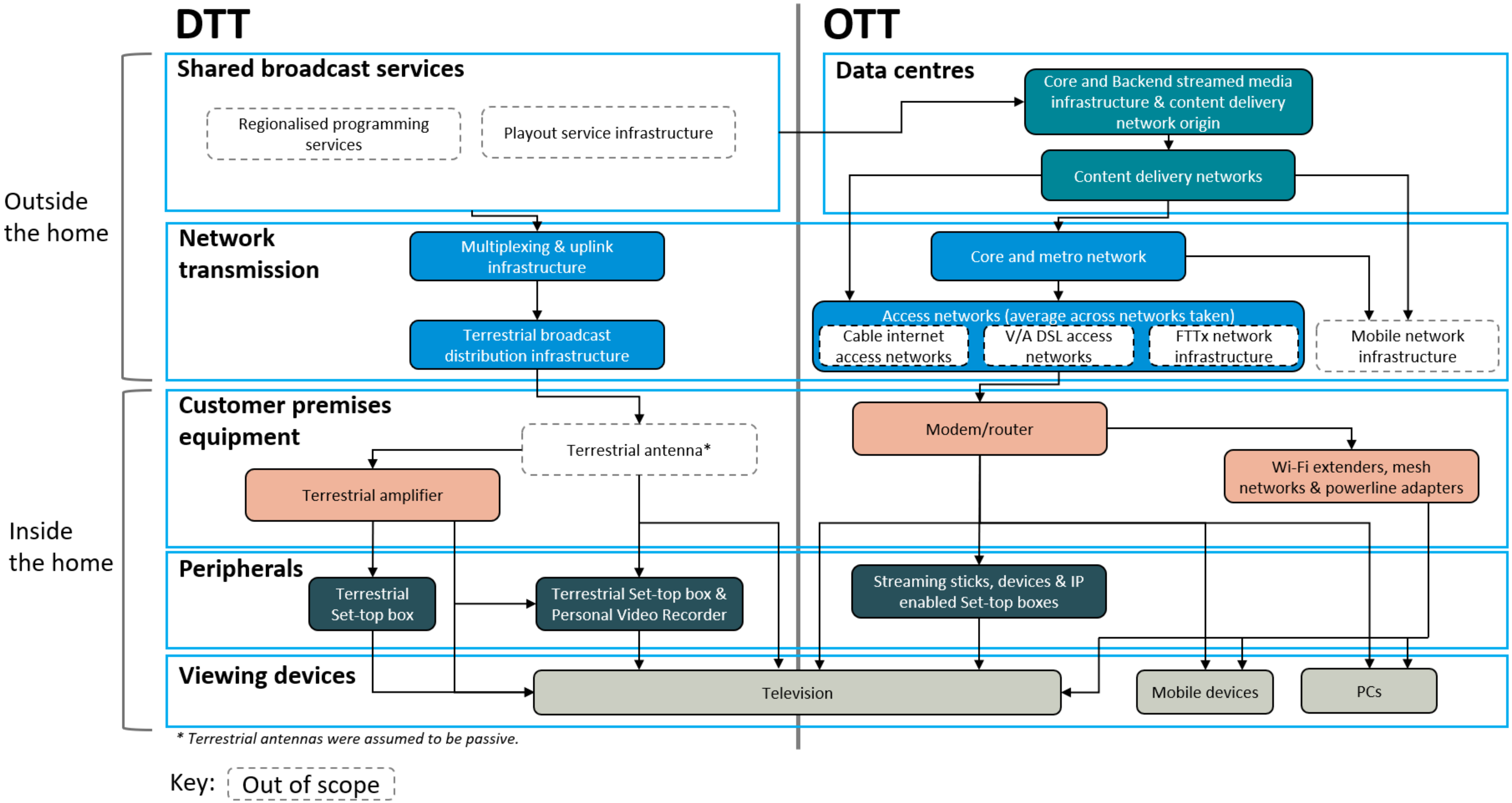

Figure 1. System diagram of DTT and OTT components considered in the study

The main notable difference in the boundaries in this project when compared to the earlier BBC work was that the 'shared broadcast services' were not considered in this study. Firstly, these processes were assumed to be shared between DTT and OTT, thus may not enable a comparison between the two. Secondly, the BBC found these shared broadcast services to be <1% of the overall footprint of their services, thus we considered these to be *de minimis*.

Notable exclusions to this study include the following:

- **Embodied and end-of-life emissions:** Embodied emissions are the emissions produced in the raw material extraction, manufacturing and transportation of the equipment required to view TV content. End-of-life emissions are those that are produced when equipment is disposed of, recycled, or refurbished and re-sold. We have followed the approach of other studies, that consider the use-phase only – for simplicity but also as reliable estimates of the embodied emissions are difficult to come by. The LoCaT report (2021), which uses a methodology very similar to the one applied in this study, briefly covers the challenges of estimating embodied emissions, and provides some consideration on what its scale represents.
- **Production of TV content:** TV content production sat outside the boundaries of this assessment, because generally content produced may be viewed across all delivery methods. For example, content on live TV may be viewed via DTT, but the same content may be viewed via a video on demand streaming platform later. Therefore, it made sense to exclude this in order to compare the parts of DTT and OTT that differ from one another.
- **Enabling effects of television viewing:** Enabling effects are the opportunities that a service may have to avoid emissions in other sectors beyond the system boundaries. For example, those viewing an on-demand movie may be less likely to drive a car to a shop to purchase a DVD. Depending on the distance travelled, the emissions saved from not driving is likely to be greater than the emissions from viewing the movie via a streaming service. However, we excluded any analysis of enabling effects as this is in line with the *GHG Protocol Product Standard,* which specifies that these effects should be excluded from evaluating the GHG footprint of a product or service.
- **Consideration of renewable energy procurement in the value chain:** We're aware that many companies operating networks and data centres in the UK often use renewable energy to power these data centres – via electricity procurement and on-site generation[2]. These companies generally apply the recommendations of the GHG Protocol Sector 2 guidance to 'dual report' their emissions. This specifies that companies should report their emissions in two ways: (1) Market-based: Taking into account this renewable energy procurement; and (2) Location-based: in a way that assumed the grid average in the country/region where they operate. For this analysis we have chosen the location-based approach. This means that we used the average emissions from energy generation in the UK for 2021 – as provided by the Department for Business, Energy and Industrial Strategy (BEIS).
- **Mobile network transmission:** Viewing of content using mobile networks was not considered specifically in this analysis because the goal of the study was to compare viewing *inside* the home. For households that used broadcast video on demand (BVoD) and subscription video on demand (SVoD) platforms, it was assumed that almost all viewing in the home used fixed-line networks to view content.

Estimating viewership of DTT and OTT platforms

Understanding viewing behaviour was important to develop an overall estimate of the scale of viewing using DTT and OTT. For DTT, the total viewing hours of content transmitted was also required to apportion the energy consumption per hour for the terrestrial transmission network.

For this, we needed to understand how viewers in the UK were viewing content. We worked with Ofcom to draw upon an extensive set of data points to do this. Households in the UK receive broadcast content TV differently, with Cable, Satellite, DTT and IPTV platforms available. To model the energy consumption for OTT and DTT only, we needed to understand both the average viewing hours and the usage of different platforms.

[2] For example, Sky reports that for their own operations in 2021, 100% of their electricity consumption was from renewable sources (link). For DTT networks, Arqiva reported that they purchase 99% of their electricity for network transmission and offices from renewable energy contracts in 2021 (see p60 of Arqiva's 2021 Annual Report). For the internet backbone, BT (including Openreach) reported in 2021 that they procure 100% renewable electricity (see p18 of BT Group's Manifesto Report 2022).

To do this, we used Ofcom's Media Nations Report 2022, which estimated the average time individuals in the UK spend watching different content. For 2021, this is outlined in Figure 2 below. We also noted that 2021 and 2020 were atypical years in terms of TV viewership, due to the impacts of the COVID-19 pandemic lockdowns. To run a sense-check of our numbers, we also ran a sensitivity analysis using 2019 viewership figures but holding network transmission parameters constant. This can be found in Appendix B: Scenario analysis results.

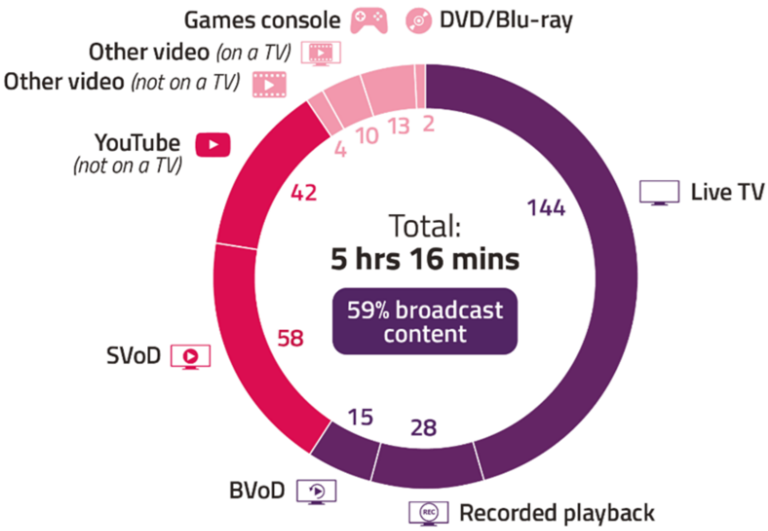

Figure 2. Average minutes of viewing per day in the UK, all individuals, all devices. Source: Ofcom estimates of total audio-video viewing. Modelled from BARB, Comscore and TouchPoints data, via Ofcom Media Nations Report 2022 (p5)

We then worked with Ofcom to map each of the slices of the total viewing hours to the platforms and devices used, to understand what proportion of each segment of pie chart related to OTT and DTT. Note that for this analysis, we were only interested in exploring TV-like content. Thus, we excluded the following segments of the above chart from our analysis:

- Other video
- YouTube (not on a TV)
- Other video (on a TV)
- Other video (not on a TV)
- DVD
- Games console

For those segments that were within scope, we mapped the relevant platforms to the relevant segments of the chart, as outlined in Table 1 below.

Table 1. Mapping viewing hours to different platforms and devices

Viewing segment	Platforms included	Devices included	Notes
Live TV	• Cable • Satellite • DTT • IPTV (linear) • OTT (live)	• TVs • Set-top-boxes (STBs) • Relevant peripherals (for live BVoD on TVs)	Live BVoD viewed on non-TV devices included in BVoD.
Recorded playback	• Cable • Satellite • DTT • IPTV (linear)	• TVs • Set-top-boxes (STBs)	For recorded playback, it was assumed that all content was viewed with a set-top box.
BVoD	• OTT, excluding live OTT viewed on TV sets	• All devices (including smartphones, tablets, and computers) • Relevant peripherals	Live OTT viewed on TV sets was included in Live TV.
SVoD	• OTT	• All devices (including smartphones, tablets, and computers) • Relevant peripherals	This also includes live streaming on SVoD platforms.

For live TV and recorded playback, we estimated the proportion of hours viewed via DTT based on the proportion of households that view content using DTT. Ofcom was able to provide figures for the total minutes of DTT viewing in households (device hours) across the total UK population. This figure was used directly in the calculations.

Table 2. Calculation of device viewing hours for DTT

Household type	A) Households (HH) (million)	B) Daily device hours (per household)	C) Total device hours (million)
All DTT	17.08	3.65	22,776
Source	Barb/Ofcom's Communications Market Report 2022	Calculated (C)/(A)	Barb/Ofcom's Communications Market Report 2022

For OTT, we apportioned the segment of live TV viewing based on Ofcom expert input. A further step was required for OTT to understand the device mix of viewership, as streaming can occur on devices such as computers, laptops and smartphones, as well as televisions.

Table 3. Calculation of viewing hours for OTT

Parameter	BVOD	SVOD	OTT	Source
A) Households (million)	15.86	19.10	23.67	Calculated using BARB Establishment Survey Q4 2021, IPA TouchPoints 2021
B) People (million)	37.43	45.08	55.87	Calculated using average HH size (from ONS)
C) Daily viewing hours (per person)	0.4	1.3		Ofcom Media Nations, BARB
D) Total viewing hours (millions)			26,904	Calculated
E) Device hours on TV (millions)			12,868	Calculated
F) Device hours on non-TV devices (millions)			6,726	Calculated
G) Total device hours (millions)			19,594	Calculated

The model accounted for households/viewers having access to BVOD-only, SVOD-only or both. It also considered that the daily viewing times (Figure 2) are the average for all the UK population, so the viewing time was adjusted to reflect the time for a BVOD or SVOD viewer. The total hours watched by SVOD viewers and by BVOD viewers was added to get the total hours of OTT watched. The total hours of SVOD watched was calculated by multiplying the average daily hours of SVOD watched per person by the number of SVOD individual viewers, who could be SVOD-only viewers, or SVOD+BVOD viewers. The same is true for the total number of BVOD hours watched. As SVOD+BVOD viewers (those that consume TV through both) watch SVOD and BVOD, it is appropriate to include them in both calculations.

The Ofcom Media Nations report found that 75% of OTT viewing in 2021 was on a TV and the rest on non-TV devices (laptops, computers, smartphones and tablets).

To estimate the device viewing hours on TVs, we considered that TV watched in households of more than one person will have some shared viewing. This is an assumption used in previous studies where Carnstone has applied a similar methodology.

- 1.0 viewers for one-person households
- 1.5 viewers for two-person households
- 2.0 viewers for three-person and four-person households
- 2.5 viewers for five-person and six-person households
- 3.0 viewers for seven or more person households

The average for UK households was 1.57 viewers per household. This was consistent with the methodology used in the BBC White Paper.

For the hours watched on other devices it was a simplifying assumption that these personal devices had negligible shared viewership. The TV hours adjusted for shared viewing and the non-TV hours were added to obtain the total number of OTT device hours.

Estimating the energy consumption of system components

We then modelled each of the systems within the boundaries. Many of the processes in the modelling required an attribution method as the processes are shared with other services. Table 4 and Table 5 summarise the key assumptions and parameters for OTT and DTT viewing, respectively.

Table 4. OTT modelling parameters and assumptions

Device type	Attribution method	Source	Assumptions & comments
Data centres and CDN	**1.3Wh/h viewing** Energy consumption per hour of viewing (Watts per hour).	Carbon Trust White Paper[3] – based on averaged data across a selection of DIMPACT participants.	Analysis completed for video on demand only, not live streaming.
Network transmission (core and fixed-line access networks)	**0.0065 kWh/GB[4]** Energy consumption per gigabyte of data transferred (kWh/GB).	Derived from Aslan et. Al. (2018)[5] using regression analysis presented in the Carbon Trust White Paper.	Carbon Trust regression analysis was used to estimate the intensity of the internet networks in 2020. We have not extrapolated further to 2021 to be conservative.
Customer Premises Equipment (CPE), includes terminals, modem routers and in-home networks	Typical modem, terminal and in-home networking energy over a month, divided by the average monthly data consumption per household (453GB/household/month).	Refer to Appendix A for modem, router and extender power estimates Proportion of households with in-home networking provided by Ofcom. Average monthly data consumed per household provided in the UK included in Ofcom Connected Nations Report 2021.	It is assumed that modem routers are 'always on' and have a constant energy consumption regardless of data transmission. This assumption is backed up by Malmodin (2020)[6], who found minimal uplift in power consumption of modem routers with increased data consumption.
Data transmission rates	**3.6 Mbps** (Average video streaming bitrate including HD and SD content).	Average bitrate source from Netflix ISP Speed Index for Nov/Dec in 2021.	This is likely to vary by OTT platform, especially those with a higher viewership of UHD content.
Viewing device and peripherals	Time-based approach based on viewing hours and power consumption of devices, with standby allocation.	Typical power consumption of peripherals provided in Appendix A. Proportion of devices used discussed elsewhere in this paper.	Standby allocated based on the estimated OTT viewing as a percentage of overall viewing.

[3] The Carbon Trust (2021) "The Carbon Impacts of Video Streaming", (link), refer to Table 3 on p43
[4] Please note that kWh/GB figures can only be used for retrospective allocation purposes, and cannot be used to estimate the instantaneous change in impacts of increasing or decreasing data volumes. For an explanation of this, please refer to the Conclusions and limitations section.
[5] Aslan, J., Mayers, K., Koomey, J.G. and France, C. (2018), "Electricity Intensity of Internet Data Transmission: Untangling the Estimates". Journal of Industrial Ecology, 22: 785-798 (link)
[6] Malmodin, J., 2020: "The power consumption of mobile and fixed network data services - The case of streaming video and downloading large files". Electricity Goes Green, Berlin, 1 September 2020 (link)

Table 5. DTT modelling parameters and assumptions

Device type	Attribution method	Source	Assumptions & comments
Network transmission (DTT infrastructure)	Total UK network energy consumption.	Network energy consumption provided by Arqiva.	Data includes power required to operate transmitters, as well as uplinks and multiplexing. It excludes maintenance vehicles, fugitive refrigerant gases and back-up generators.
Terrestrial antenna amplifier	Fully allocated to DTT, including when television is not being viewed.	Power consumption included in Appendix B. It was assumed that 20% of DTT households required an antenna amplifier, as per BBC study.	It was assumed that the antenna amplifier is 'always on', which is in line with the approach taken in the BBC White Paper.
Viewing device and peripherals	Time-based approach based on viewing hours and power consumption of devices, with standby allocation.	Typical power consumption of peripherals provided in Appendix B.	Standby allocated based on the estimated OTT viewing as a percentage of overall viewing.

Estimating GHG emissions

The energy consumption was then converted to GHG emissions using the GHG intensity of electricity generation factors for the UK in 2021, published by the Department for Business, Energy and Industrial Strategy. Figure 8 presents the GHG equivalent for the results presented previously. We included the GHG emissions from electricity generation, transmission & distribution losses (T&D) and well-to-tank (WTT) emissions to account for the full value chain emissions of electricity in the UK. The emissions factors used are outlined in Table 6.

Table 6. Emissions factors of electricity generation used in the study

Emissions factor	Conversion factor used (kg CO2e/kWh)	Definition
GHG intensity of electricity generation	0.21233	The emissions of the electricity provided to the grid that is purchased by the user.
Transmission and distribution losses	0.01879	Emissions associated with grid losses (the energy loss that occurs in getting the electricity from the power plant to the organisations that purchase it).
Well-to-tank emissions factors	0.05529 (Generation) 0.00489 (T&D Losses)	Emissions for electricity are those emitted in the upstream of the electricity production (e.g., the extraction and refining of the gas if the electricity comes from a power plant).
Total	**0.29130**	Final conversion factor used.

Results

Viewership of OTT and DTT

The audience surveys in the study show that households that use different TV distribution methods tend to have different viewing patterns. This is the case for DTT vs OTT. While OTT has a higher penetration in terms of number of households that use one or more of these services[7], the profile of the DTT households shows that a typical household (across DTT only and mixed households) watches 3.7 hours of TV per day, which is more than the figure for the typical OTT household. This results in more hours of content viewed using DTT transmission, when compared to viewing via OTT platforms. These are shown in Figure 3 and Figure 4.

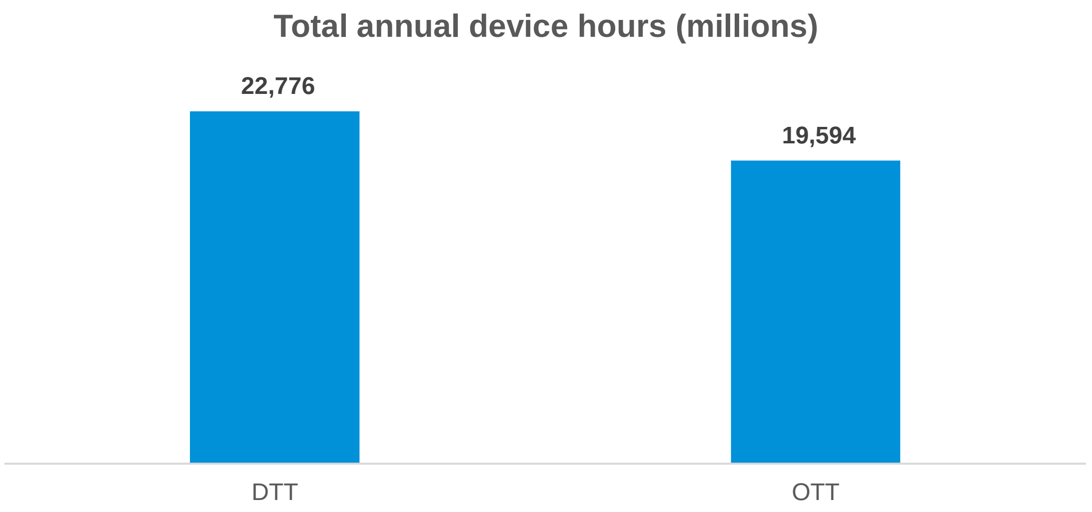

Figure 3. Outcome of the viewership analysis

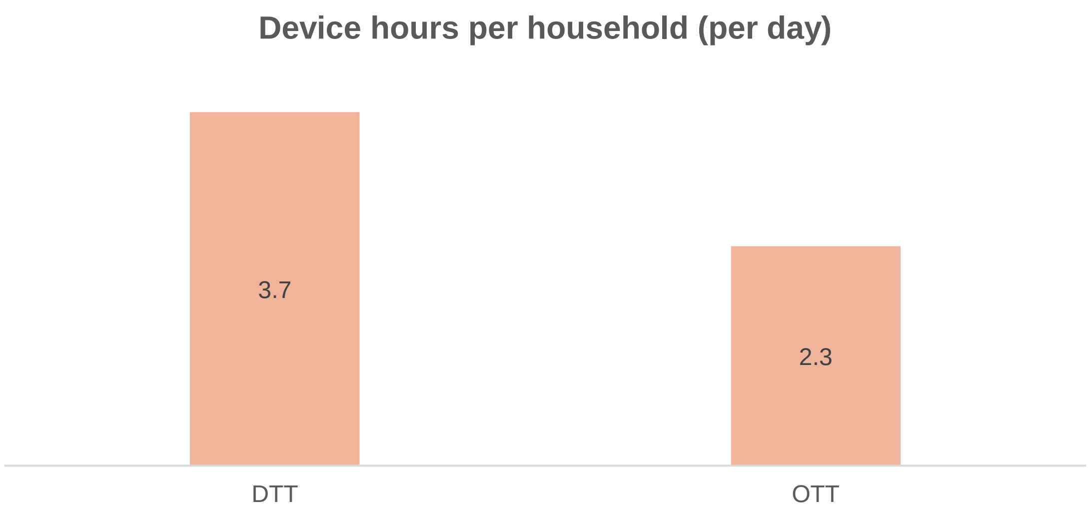

Figure 4. Device hours per household

[7] 60% of HH have a TV connected to DTT (BARB Establishment survey), 92% of people watch TV over OTT on either BVOD or SVOD forms (estimates based on BARB Establishment Survey Q4 2021, IPA TouchPoints 2021).

Energy consumption and GHG emissions of OTT and DTT

The main functional unit that was analysed in this study is the energy consumption per device hour. This is represented by how many Watt-hours (Wh) have been consumed to deliver the TV content for each hour that a viewing device is displaying it. As previously explained, this is the energy consumed from the point that the content is broadcasted or streamed up to the point when it is displayed on the viewing device. The results are outlined Figure 5 and Figure 8.

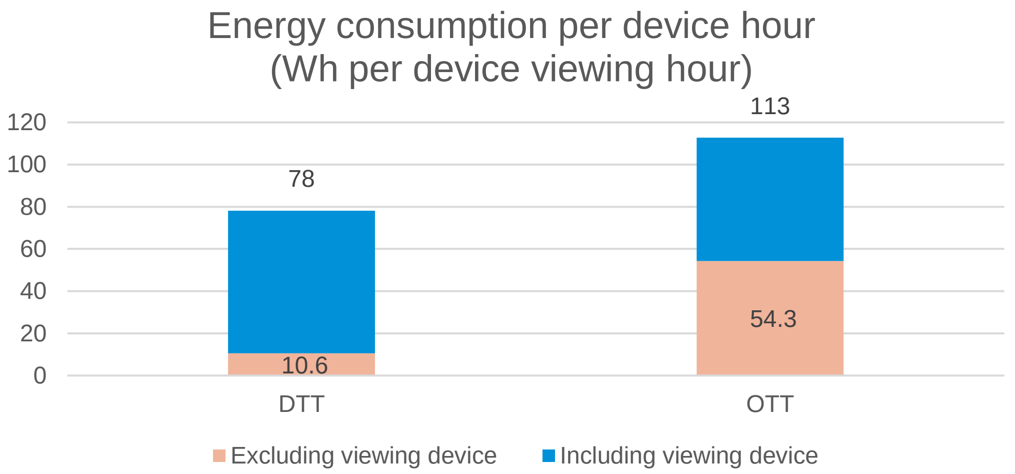

Figure 5. Energy consumption per device viewing hour

This figure is 44% higher for OTT (113Wh) when compared to DTT (78Wh). However, a large proportion of this is explained by the viewing device (the portion in blue above), which does not isolate the underlying differences between the two methods. Whilst the energy consumption for the viewing device is high for both, it is worth noting that for OTT this figure is lower (58Wh vs 68Wh). The reason is that, unlike DTT, OTT platforms are available on smaller devices such as smartphones, tablets and laptops among others. These devices tend to have a lower energy requirement. When the viewing device is excluded, the energy consumption per device hour for OTT (54.3Wh) is five times higher than that for DTT (10.6Wh).

Figure 6 and Figure 7 below show the breakdown of both DTT and OTT energy consumption by device hour, broken down by system component.

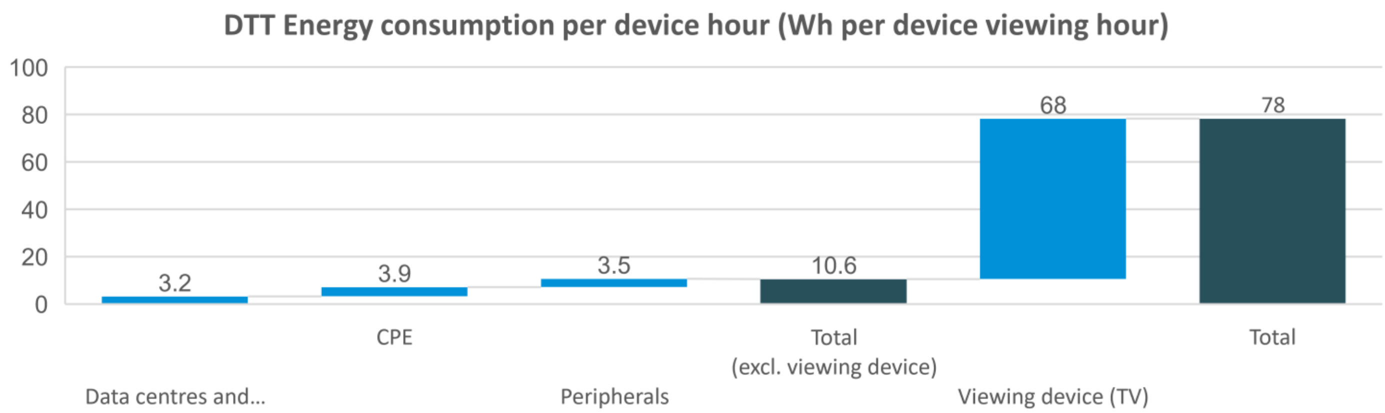

Figure 6. DTT energy consumption per device hour

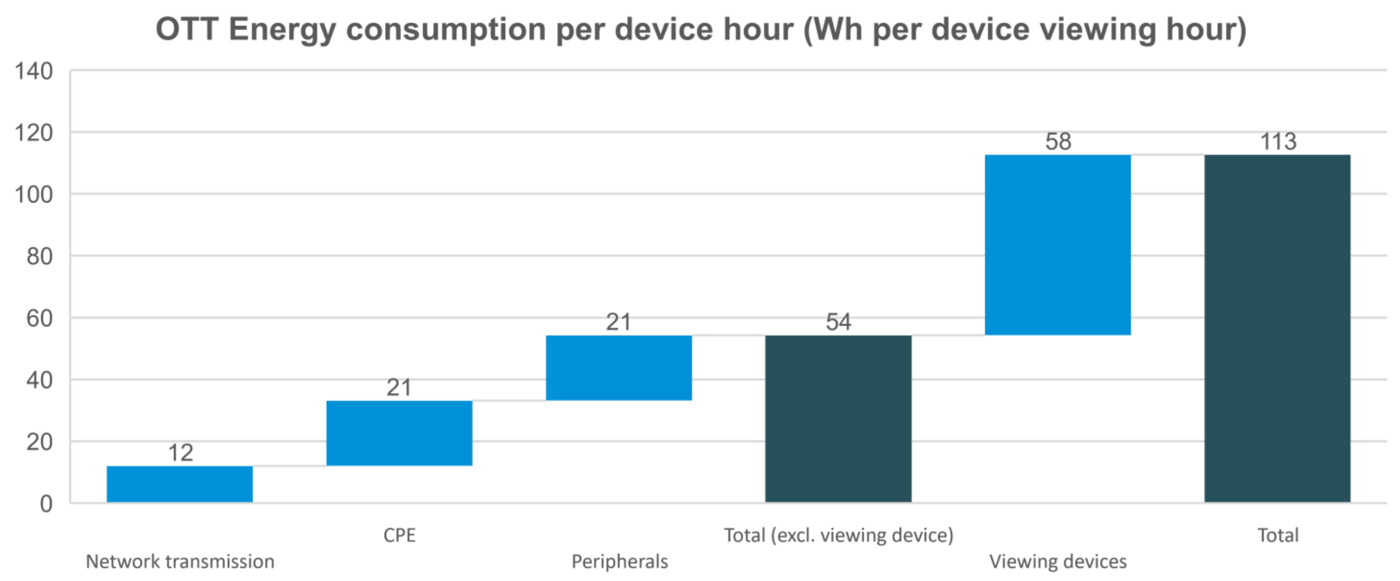

Figure 7. OTT energy consumption per device hour[8]

The energy consumption was then converted to GHG emissions, as outlined in the Approach section. Figure 8 presents the estimated GHG emissions per device hour.

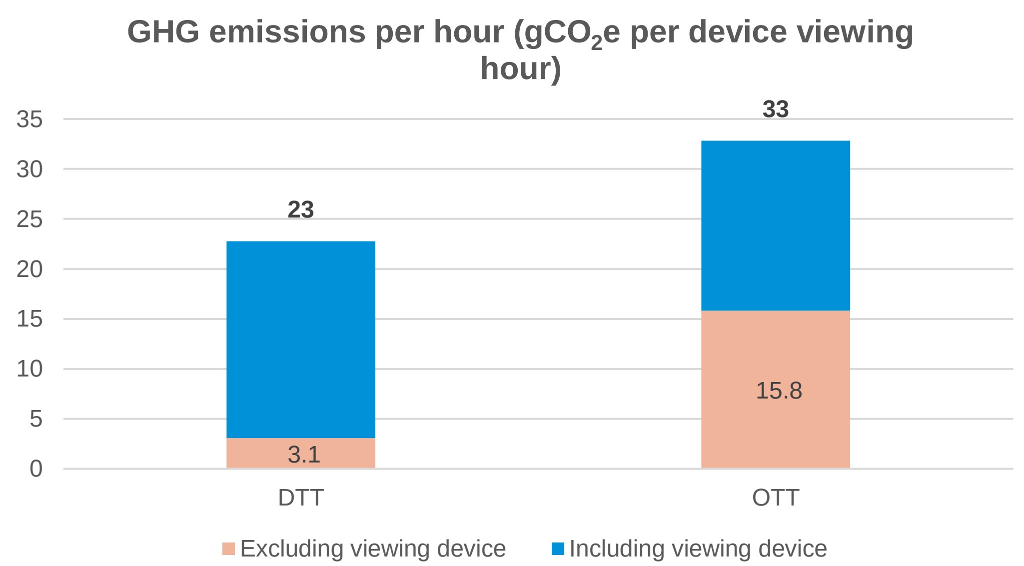

Figure 8. GHG emissions per device hour

The second of the functional units observed in this study is the annual energy consumption for the whole UK. This figure gives a sense of scale considering the number of device hours watched through each delivery method. The two figures below present the total annual energy consumption for DTT and OTT content distribution respectively. Figure 9 shows that, even when the hours of OTT watched are less than those of DTT, its higher energy intensity means its total energy consumption is more than four times the energy consumption of DTT. A more energy intensive network transmission (infrastructure) and the reliance on customer premises equipment (CPE) and viewing peripherals, bumps up the energy consumption for OTT.

[8] Network transmission includes the energy consumption per device hour for data centres.

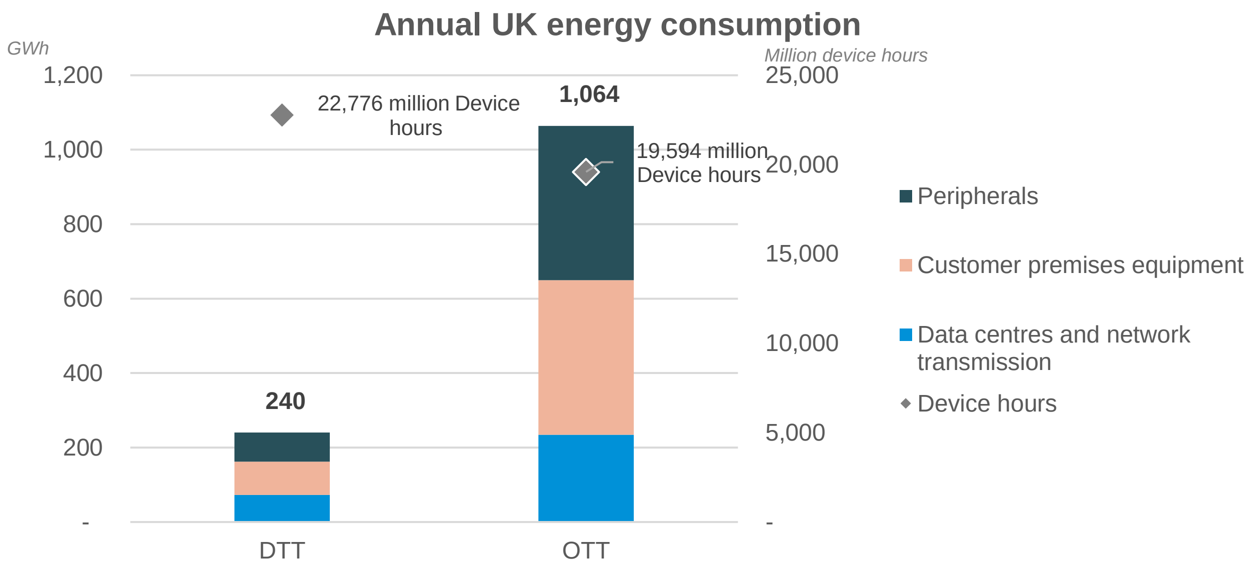

Figure 9. Total UK annual energy consumption, broken down by system component

However, Figure 10 shows that when the viewing device is included in the total energy consumption, the annual energy consumption of DTT is not far from the figure for OTT. This was primarily driven by the higher number of hours of content viewed via DTT (as shown in Figure 3). It is also driven by the fact that OTT, unlike DTT, can be viewed on smaller devices such as smartphones, tablets and laptops. Therefore, the weighted average viewing device power consumption was lower for OTT than DTT. It is worth noting there is some uncertainty and variability in terms of viewing devices, as a breakdown of viewership of non-TV devices was estimated based on survey data, as opposed to directly measured.

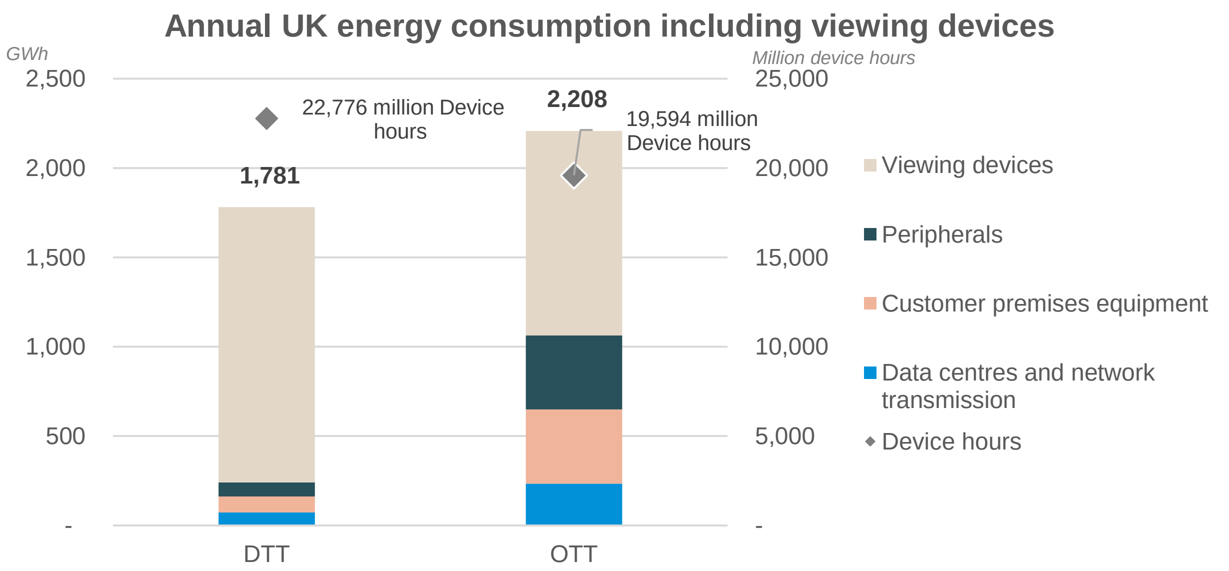

Figure 10. Total UK annual energy consumption including the viewing devices, broken down by system component

Figure 11 shows more clearly the proportions for the different components of DTT and OTT. Both OTT and DTT have a relatively well-distributed energy consumption along the three different components into which the system (excluding the viewing device) is broken down. For both delivery methods, the majority of emissions occur inside the viewer's home.

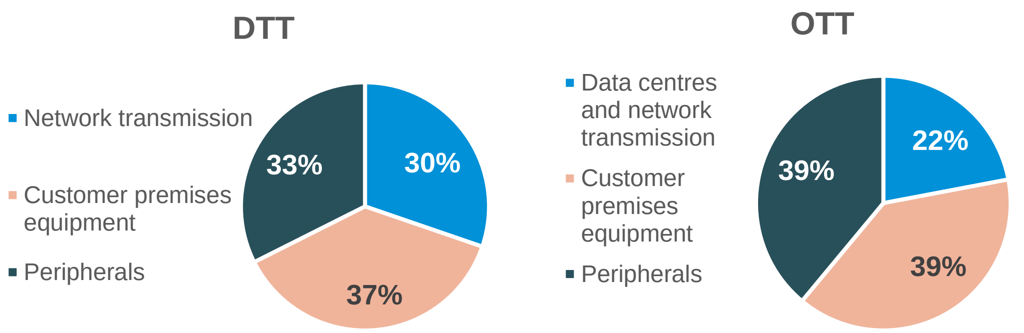

Figure 11. Energy consumption distribution by components (excluding the viewing device)[9]

Comparison of the results to other estimates

The results of this report are consistent with other recently published studies that use an attributional methodology. There are differences derived from different data sources and context. For example, the Carbon Trust White Paper shows results for Europe, not just the UK. However, overall, these differences are not substantial and show a similar ratio between DTT and OTT viewing, as shown in Figure 12.

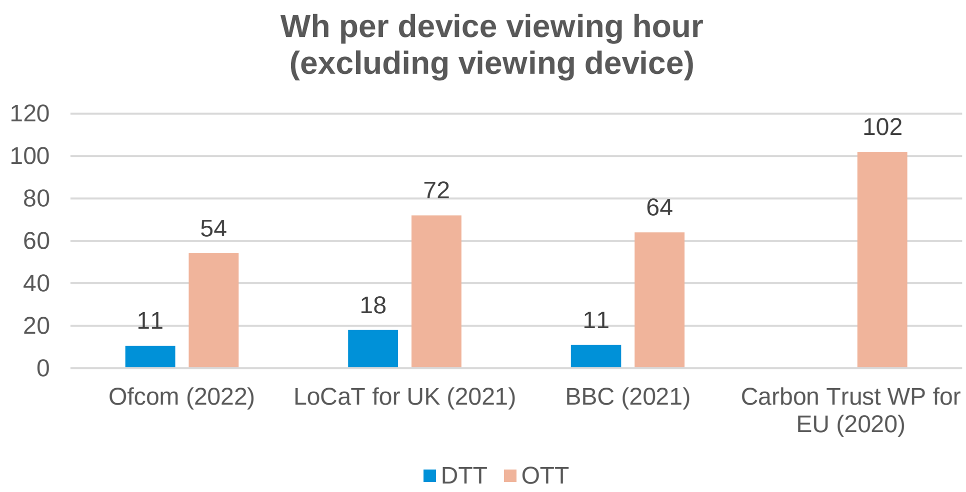

Figure 12. Comparing the results of the study to previous studies (no viewing device)[10,11,12]

[9] Note that 'customer premises equipment' for DTT refers to antenna amplifiers, as per the system diagram shown in Figure 1.
[10] Carnstone (2020), "Quantitative study of the GHG emissions of delivering TV content", The LoCaT Project (link)
[11] Schien, Daniel, et al (2020), "Using Behavioural Data to Assess the Environmental Impact of Electricity Consumption of Alternate Television Service Distribution Platforms", BBC Research and Development (link)
[12] "Carbon impact of video streaming", Carbon Trust (link)

Sensitivity analysis results – considering 2019 viewership

Data on TV viewership (Ofcom Media Nations report, see Figure 2) suggests that 2020 and 2021 were atypical years for TV viewing due to the change in behaviour brought about by the COVID-19 pandemic. The study has used (where available) 2021 data. Therefore, a scenario analysis was undertaken to understand the impact if TV viewership was to rebound to pre-pandemic patterns. Comparing both years, this difference was reflected primarily in the viewership patterns (i.e., hours of TV watched, internet data consumption). Therefore, the model was re-run, updating only:

- The hours of TV watched (Ofcom Media Nations)
- TV/broadband owners' universe (Ofcom Media Nations. BARB)
- Total data volume per connection in Gigabytes (Ofcom Connected Nations)

All other parameters were kept constant. Notably, parameters such as the proportion and types of peripherals used may have changed during the pandemic as consumers upgraded their TV sets, but this was not able to be tracked as part of this study. Similarly, the pandemic may have increased the prevalence of shared viewership, but this was not able to be factored in due to a lack of data.

The results from the analysis, summarised below in figures 13 and 14, show the energy consumption (in absolute and per-hour terms) of DTT viewing to remain stable across the two years being considered. However, the absolute energy consumption of OTT services was 27% higher in 2021 than it was in 2019. This was largely driven by a 62% increase in the number of OTT viewing hours. It is important to note here that the increase in viewing hours is not linearly proportional to the increase in absolute energy consumption. Consequentially, the absolute energy consumption of OTT services grew at a slower rate than the viewing hours (27% versus 62%) leading to a 21% decrease in the per-device hour energy consumption of OTT services.

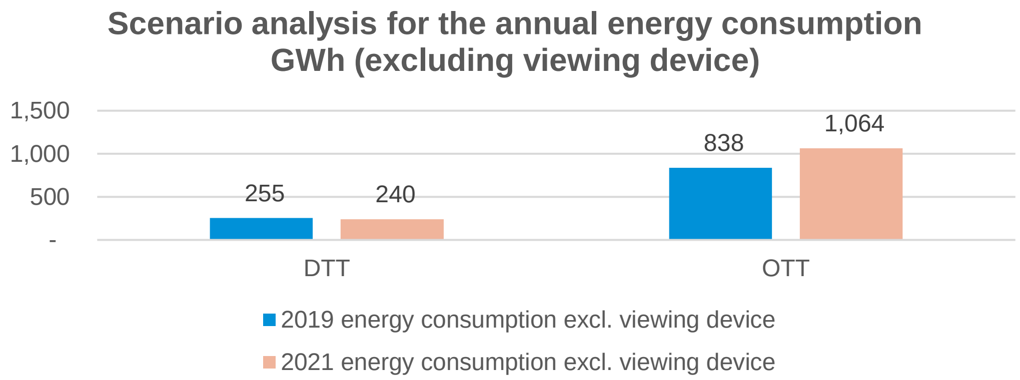

Figure 13. Scenario analysis for 2019 viewership patterns

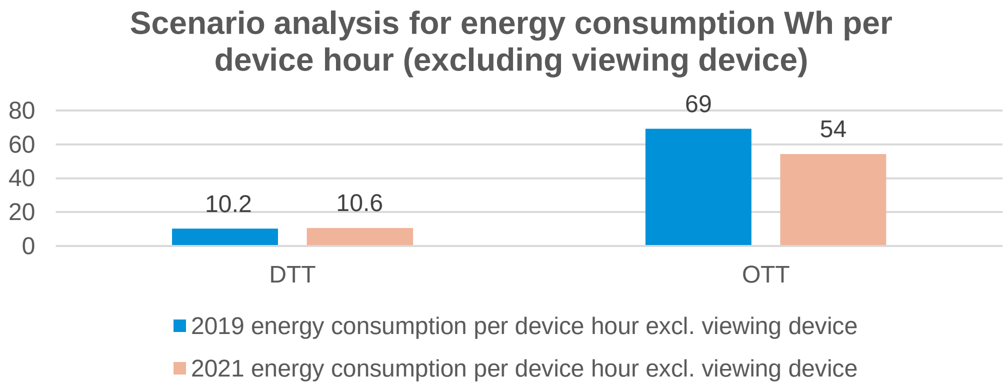

Figure 14 Scenario analysis for 2019 viewership patterns (per device hour)

Conclusions and limitations

The results of this analysis confirm the results of other similar studies. A key finding was that a considerable proportion, approximately 89% for OTT and 96% for DTT, of the energy consumption occurred within the home, concentrated around viewing devices and in-home networks.

Comparison of DTT and OTT

When comparing DTT to OTT, we found that DTT has it attributed a lower energy consumption per hour of viewing. This was due to the higher energy consumption attributed to customer premises equipment (modem/routers and other in-home networking) in the OTT model, as well as increased use of peripherals for OTT viewing. Energy consumption of network transmission outside the home was also higher for streaming. However, there is less certainty regarding the energy consumption of the network transmission for OTT services, as the current intensity metric is a global figure based on academic studies.

An important limitation of the approach and findings of this study

The approach used in this analysis was selected because it is the most established approach for understanding the energy consumption and GHG emissions that DTT and OTT were responsible for in 2021. It cannot, however, be used to understand the impacts of future trends (such as a rapid switch to streaming) or intervention (such as switching off part or all of one TV delivery method). This is an important distinction that we explain in further detail below.

OTT and DTT both use infrastructure and devices that are also used by other services. DTT uses terrestrial networks, which are shared with radio and other data services. OTT uses the internet infrastructure and in-home equipment, which are shared with a wide range of other services, such as video conferencing, web browsing, online gaming and e-commerce. For each system we have used established attribution approaches to estimate the GHG emissions that OTT and DTT were responsible for. For the case of internet transmission and in-home networking equipment, we used our estimate of the proportion of data transmitted over the internet that was OTT to allocate the energy consumption that this activity is responsible for.

However, this data attribution method cannot be used to estimate the future system-wide impacts caused by interventions or changes in any given system. This is because allocation does not explicitly account for the system dynamics of these shared services, what is driving changes in a given system, or the knock-on effects that may initially be outside of the study boundary. The ability to estimate the future impacts caused by system changes requires a consequential approach, which considers such dynamics and requires a counterfactual baseline. A comparison of allocation and consequential methods is outlined in Table 7.

In summary, attributional and consequential approaches are both important, but answer different questions. We chose to use an attribution methodology in this study, because there is an established approach to applying this method and it gives a robust estimate on historical emissions that a given service is responsible for over a given period. This provides a baseline and an understanding of the hotspots in the value chain scale. The consequential approach can then be used to understand how trends and interventions will impact future emissions across all affected emissions sources. The challenges and complexities of developing an agreed upon counterfactual baseline, and access to primary data to help understand the dynamics of network transmission, remain a barrier to developing a robust consequential model and requires further study.

Table 7. Comparison of the attributional and consequential modelling approaches, adapted from Brander (2021)[13]

Feature	Attributional method (used in this study)	Consequential method
Accounting purpose	Allocating responsibility to entities for emissions arising from activities for reporting and/or tracking emissions over time.	Quantifying system-wide change in emissions (or removals) caused by a decision or intervention.
Boundary setting principles	Fixed boundaries, determined by normative rules.	Boundary determined by the intervention of interest (to include all affected systems).
Type of change that can be accounted for	Change relative to a base year/period.	Change relative to a predicted counter-factual baseline.
Retrospective or prospective	Retrospective (generally).	Prospective, to assess impact of future decisions (generally).
Outputs	Physically measurable quantity of GHG emissions.	Estimated change in GHG emissions caused by a specific decision or intervention.
Relevant example applications	Estimating the emissions that TV delivery is responsible for over a given period (as is conducted in this study).	• Evaluating the impacts of switching off all or part of a transmission network (including the need for viewers to purchase new devices transition to use another network). • Evaluating the impacts of an accelerated switch to UHD content on streaming platforms.

Opportunities for further investigation

Understanding the interaction of viewing devices and peripherals

In this analysis, we considered how the use of peripherals affected the energy consumption of TV viewing. For the proportion of viewing via STBs and streaming sticks, the power consumption of these devices was added to the energy consumption of the television. We did not consider how the energy consumption of the TV itself may be affected by its connectivity to another device. For example, if a TV is connected to a STB, the TV is only acting as a viewing device, and is not processing the incoming signal. As the TV in this instance is doing less, it may consume less power – partially offsetting the energy consumption of the STB.

Further device testing is required to understand the interplay between different combinations of devices to confirm the above and revisit the assumption of this study. The outputs of such analysis could spark further investigations amongst device manufacturers about opportunities to improve efficiency of devices and enable informed advice to customers about how to reduce their own impact.

[13] Brander, J (2020), "The most important GHG accounting concept you may not have heard of: the attributional-consequential distinction", GHG Management Institute (link)

Building on the modelling with industry data

A key area of uncertainty in the modelling is the energy intensity of the internet network. Unlike the DTT networks, this is not owned by one operator, therefore wider engagement and more in-depth analysis is required to gather this information in a way that is useful. Currently the relevant organisations' corporate greenhouse gas reporting does not provide the level of granularity to understand the intensity of their networks. Encouraging the industry to come together to agree to reporting this data in a comparable format, and in way that can be aggregated to provide a robust estimate of the overall network intensity would significantly improve the estimates in studies such as this.

Developing an approach to modelling that reflects the dynamics of the internet infrastructure

As outlined earlier in this section, the attribution approach in this study cannot be used to estimate the impacts of future changes in any component of the system modelled. This is because retrospective allocation does not necessarily use metrics that take the dynamics of that component and wider system into account. As such, there is a need to develop agreed models and methodologies to enable such assessments.

For example, emerging evidence suggests that data volume is not correlated with energy consumption, at least not instantaneously. For example, CPE is generally 'always on' and its power consumption may not significantly change, regardless of the data being transmitted through the device. Some evidence suggests that this is the same for the internet infrastructure[14]. Gathering primary data, including time-based data on the energy profiles of devices and infrastructure will help to build an understanding of the instantaneous impacts of such changes, which will lead to more sophisticated models.

This would also help understand the approaches that could be used by network operators and device manufacturers to reduce the energy consumption of the components used along the value chain for delivering TV content.

Understanding the energy implications for an increase in peak demand

As has been mentioned in other studies and from our work with ISPs, network capacity planning is primarily driven by forecasts in future peak traffic demand. Building networks capable of meeting higher peak demand is likely to have energy and GHG emissions implications. Whilst more capacity may require more new infrastructure, the equipment that replaces the existing infrastructure may be more efficient, reducing the energy impacts in the use-phase. Further primary data from ISPs and those in the value chain (such as infrastructure and CDN providers) would help enable estimates of future emissions that could input into a causal model.

Furthermore, work is needed to understand which products and services are driving peak demand, or whether higher-bandwidth services are updated or enhanced to take advantage of greater capacity that is achieved by improved efficiency, (this is known as Jevon's Paradox). This complexity means that it is currently difficult to attribute the future emissions of the internet to any given service. Industry collaboration to unpick the causal relationships between the uptick in demand for services and emissions would help all organisations within the sector to better understand their emissions and ultimately achieve their emissions reduction targets.

Overlaying the sustainability commitments and performance of system components

As the transmission networks, data centres and CDNs required to deliver TV content generally powered by electricity for their energy, the GHG emissions of these activities depend on the generation mix of the electricity purchased. A key lever for organisations that own these processes is to procure or generate renewable electricity. As mentioned earlier in this report, many organisations responsible for delivering TV content – either via the internet or terrestrial transmission – are actively procuring renewable electricity. However, this was not considered in this analysis. Understanding the market-based emissions of the transmission infrastructure in the UK would provide another view of the impacts of TV viewing.

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[14] For an in-depth discussion about the limitations of data-based allocation methods for internet energy attribution, see: Malmodin, J,(2020), "The power consumption of mobile and fixed network data services - The case of streaming video and downloading large files", Electricity Goes Green, Berlin, 1 September 2020 (link)

Appendix A: Power consumption of devices

The table below outlines the power consumption of the devices modelled in this analysis.

Device type	Device category	Power consumption (W)	Sources	Comments
Complex STB	Peripheral	**18**	Carbon Trust WP Table 10	
Simple STB		**5**	Expert judgement	
Antenna amplifier	Customer premises equipment	**3**	Expert judgement	
Modem router		**10.5**	Malmodin (2020)[15]	For typical equipment
Powerline adapter		**3**	https://homenetworkgeek.com/do-powerline-adapters-use-a-lot-of-electricity/	
Mesh networks		**6.5**	Expert judgement	
Network extender		**6**	https://re-rockspace-local.com/how-much-power-does-wifi-extender-use/	
Smartphones	Viewing device	**1**	Carbon Trust WP Table 10	
Tablet		**3.24**	Market research	
Laptop		**68.5**	Carbon Trust WP Table 10	
Television		**65.6** **(100 for Smart TV)**	Multiple, Ofcom for TV ownership in the UK Smart TV: Carbon Trust WP Table 10	The average consumption for TVs at different sizes were taken to estimate the average for the UK

[15] Malmodin, J., 2020: "The power consumption of mobile and fixed network data services - The case of streaming video and downloading large files". Electricity Goes Green, Berlin, 1 September 2020 (link)

Appendix B: Scenario analysis results

Metric	**Year**	**DTT**	**OTT**	**Units**
Total Device hours	*2019*	24,958	12,114	million device hours
Total Device hours	2021	22,776	19,594	million device hours
Device hours per household	*2019*	3.72	1.40	device hours
Device hours per household	2021	3.65	2.27	device hours
Total energy consumption incl. TV	*2019*	1,949	1,530.30	GWh
Total energy consumption incl. TV	2021	1,781	2,208	GWh
Total energy consumption excl. TV	*2019*	255	838	GWh
Total energy consumption excl. TV	2021	240	1,064	GWh
Energy consumption incl. TV per device hour	*2019*	78.1	126.3	Wh per device hour
Energy consumption incl. TV per device hour	2021	78.2	112.7	Wh per device hour
Energy consumption excl. TV per device hour	*2019*	10.2	69.1	Wh per device hour
Energy consumption excl. TV per device hour	2021	10.6	54.3	Wh per device hour

Appendix C: Detail on viewership calculations for OTT

Parameter	BVOD	SVOD	OTT	Source
A) Households (million)	15.86	19.10	23.67	BARB Establishment Survey Q4 2021, IPA TouchPoints 2021
B) People (million)	37.43	45.08	55.87	Calculated using average HH size (from ONS)
C) Daily viewing hours (per person)	0.4	1.3		Ofcom Media Nations, BARB
D) Total viewing hours (millions)			26,904	Calculated: (B x C for BVOD) + (B x C for SVOD)
E) Device hours on TV (millions)			12,868	Calculated: (D / shared viewers) x 75% (from Ofcom Media Nations, proportion watched on TV)
F) Device hours on non-TV devices (millions)			6,726	Calculated: (D / shared viewers) x 25% (from Ofcom Media Nations, proportion not watched on TV)
G) Total device hours (millions)			19,594	Calculated: E+ F

Version control

Version number	Version release date	Notes
1.0	October 28th 2022	Original release
2.0	July 22nd 2024	The figures for DTT viewership were updated. Ofcom has modified their methodology for looking at the DTT household (device) hours extracted from the original 2019/2021 data, along with updated values for numbers of DTT households. This has simplified the calculations and eliminated the need for some of the previous assumptions. This improved approach reduced the number of DTT device hours compared to version 1.0, which had minimal impact on the resulting energy consumption per device hour but caused a corresponding reduction in the total energy consumption for DTT. *Note: Carnstone Partners Limited, the consultancy commissioned in 2022 by Ofcom to deliver this study, was acquired by SLR Consulting Limited in May 2023. As of the date of the release of this version in 2024, the team involved in this study has been fully integrated into SLR and the Carnstone name is no longer in use.*

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