BT Group Carbon Abatement Methodology

2024

BT Group

Contents

1 Introduction

BT Group is the UK's leading provider of fixed and mobile telecommunications and related secure digital products, solutions and services. The company also provides managed telecommunications, security and network and IT infrastructure services to customers across 180 countries.

We have been a leader on sustainability and climate action for over thirty years and have a target to be a net zero carbon emissions business by end of March 2031 for our own operations, and by the end of March 2041 for our supply chain and customer emissions (all Scope 3 emissions).

Acting on climate change has never been more important. In 2015, 196 parties adopted the Paris Agreement, aligning on aiming to limit global warming to 1.5°C above pre-industrial levels. Since then, the Intergovernmental Panel on Climate Change (IPCC) has shown the importance of limiting warming to a maximum of 1.5°C. To achieve this goal, global greenhouse gas emissions need to halve every decade, reaching net zero by 2050.

BT Group has a role to play, not only in reducing our own end-to-end emissions, but also in providing products and services that help our customers and wider society to transition to a low carbon economy. Between 2013 and 2019, we delivered on a commitment to achieve a '3:1 Net Positive ratio' – enabling our customers to avoid three times the emissions of our own end-to-end carbon footprint.

Building on this success, we're continuing our focus on providing products and services which enable carbon reduction, and set a new carbon abatement target in 2021 - to help our customers avoid 60 million tonnes of cumulative carbon emissions (carbon dioxide equivalent, or CO2e, emissions) by the end of March 2030.

To achieve this goal, we'll drive shifts to growth technologies such as full fibre broadband (or FTTP, Fibre to the Premises), mobile 4G/5G solutions, cloud computing and the Internet of Things (IoT).

As part of this goal, we've included the following considerations:

- the methodology and case studies represent the best available data to us at the time of publication, and we recognise the need to periodically update the methodology and our case studies as information and available data evolve
- the methodology and abatement target have been developed based on previous work we've undertaken in this area while conducting literature and peer reviews
- we take into account new emerging technology solutions
- rebound effects have been considered, acknowledged and documented and are quantified where possible
- in recognition that this is a complex area to accurately measure, we're sharing our methodology and case studies to drive transparency in the hope of stimulating further learning, and we welcome any feedback

This document outlines our approach to calculating the abatement impact of the following impact areas and technologies:

Impact area	Enabling technology and application
Remote working	Full fibre broadband Business collaboration tools (Global Voice) Virtual Events
E-commerce (online shopping)	Full fibre broadband 4G/5G mobile connectivity
Healthcare	Digital (Virtual Care) Full fibre broadband (virtual consultations)
Transportation	4G/5G mobile connectivity (personal navigation and public transport apps) Internet of Things (IoT) (Telematics) Digital (Electric Vehicle (EV) charging)
B2B network management	Software-Defined Wide Area Networks (SD-WAN) B2B cloud services

Section 2 of this document provides an overview of our general approach to calculating carbon abatement, including the key components and principles that underpin our methodology.

Section 3 provides detail on how the methodology has been applied to the technologies we assessed to determine their abatement impact. Throughout this document, we use the terms 'technology' and 'applications' to describe the products or services that we sell to our consumer and business customers.

2 Methodology overview

Stakeholders increasingly recognise that in parallel to asking companies to demonstrate how they are reducing their own emissions, there is a critical need to understand and measure how their products and services are helping society to decarbonise. Assessments of carbon abatement will help ensure that capital shifts to more sustainable solutions, while also accelerating the scale-up and adoption of those solutions. [1]

While there is growing evidence that the abatement impact of information and communications technology (ICT) is significant and accelerating, there is currently no official or standardised calculation methodology. To ensure our approach aligned with leading practice and emerging techniques, we assessed our previous carbon abatement work and conducted an extensive literature review covering more than 30 academic and non-academic papers.

We also considered the methodologies and latest thinking published by a range of other peers and industry organisations including:

- AT&T: 10x methodology (2017) and global progress updates
- Vodafone: Connecting for Net Zero: Addressing the climate crisis through digital technology (2021)
- AWS: The Carbon Reduction Opportunity of moving to Amazon Web Services (2019)
- Liberty Global: Connecting a sustainable future: The power of Gigabit connectivity (2022)
- GeSI: SMARTer2030 – ICT Solutions for 21st Century Challenges (2015)
- GSMA: The Enablement Effect: The impact of mobile communications technologies on carbon emission reductions (2019)
- Huawei: Green 5G: Building a Sustainable World (2020)

In the absence of a standardised calculation framework, the literature review identified leading practice for approaching variables such as baseline selection, rebound effects and allocation from the existing methodologies outlined below:

- Mission Innovation: Avoided Emissions Framework (2020)
- WRI: Estimating and Reporting the Comparative Emissions Impacts of Products (2019)
- ICCA & WBCSD: Addressing the Avoided Emissions Challenges (2013)
- ILCA: Guidelines for Assessing the Contribution of Products to Avoided Greenhouse Gas Emissions (ILCA) (2015)
- GeSI: Evaluating the carbon reducing impacts of ICT (2010)
- ITU: Methodology for Environmental Life-Cycle Assessment of Information and Communication Technology Goods, Networks and Services (2014)

In particular, our methodology incorporates many of the principles, definitions and guidance documented in Mission Innovation's Avoided Emissions Framework (2020), which was developed with input from BT Group. References for all documents included in our review are found in Appendix A.

This document will be updated periodically to account for additional technologies and improved data sources that support the methodology.

[1] Mission Innovation and Net Zero Compatible Innovations Initiative (2020)

2.1 General methodology

Our carbon abatement calculations provide an estimation of the greenhouse gas (GHG) emissions, calculated in CO2e, that are avoided or reduced through the use of BT Group's products and services. This is done by comparing the emissions from a 'before' (or baseline) scenario, with those from the 'after' (or technology-enabled) scenario. The baseline scenario represents the most likely process that would have occurred without the enabling technology. For example, the most likely alternative to shopping for clothing, groceries or household goods online is physically travelling to a store.

Carbon abatement is achieved when the activities included in the enabled scenario have been assessed to result in an incremental, net positive impact over the baseline scenario. When calculating the impact of the enabled scenario, the technology's direct solution emissions and rebound effects – which are described in more detail below – must also be considered. Our methodology calculates the total carbon abatement impact of a technology application as follows:

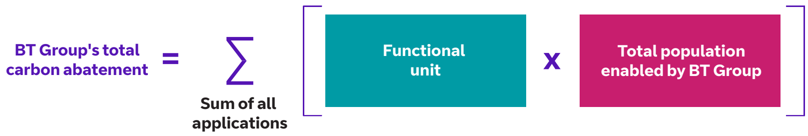
Total net carbon abatement = [Enabling effects] – [Direct solution emissions] – [Rebound effects]

Figure 1: Components of the total carbon abatement calculation
Source: Avoided Emissions Framework

Our carbon abatement calculations are carried out at the individual application level. Each application is assessed by determining a carbon abatement factor, or 'functional unit', that reflects the net avoided emissions per unit of the solution implemented. The functional unit describes the system boundaries in which the baseline scenario can be compared to the enabling solution. They are clearly defined, measurable, and include a description of quantity and time period. For comparison purposes, all the functional units used in our calculations are expressed over an annual period. For example, the functional unit used for online shopping is the 'average carbon abatement (in kg CO_2e) per e-commerce user per year'.

To calculate the total carbon abatement for a given application, over a specific time period, the functional unit is multiplied by the total population enabled by BT Group. The impact of each technology application is then aggregated to provide a portfolio-level impact assessment.

Figure 2: Calculation of total carbon abatement, using functional units
Source: Avoided Emissions Framework



Each of the technologies and applications included in our calculations were selected on the basis that they are likely to achieve net avoided emissions today, and/or are important contributors to our future growth. This has allowed us to focus data collection and methodological developments on the areas that are likely to make the most significant contribution to our cumulative emissions target. Over time, we will expand the number of enabling technologies and applications that are included in our calculations. At present, with the exception of digital workplace tools, our calculations only measure the net avoided emissions resulting from the use of our products and services in the UK.

2.2 Key methodological components

Enabling effects

Enabling effects are the emissions that are avoided as a result of using a specific technology. These effects are further divided into primary and secondary enabling effects.

Primary enabling effects are those that cause an immediate reduction of emissions (compared to the baseline scenario) as a result of the technology being implemented. It is leading practice to include all primary enabling effects in carbon abatement calculations if they can be quantified. Our current methodology incorporates at least one primary effect per application, but there is scope to include additional primary effects in the future if data becomes available.

Secondary enabling effects, or indirect effects, tend to have an impact over a longer time period and require a number of assumptions to be made. This includes the abatement impact's correlation to the enabling technology, the likelihood of these impacts occurring, and the scale of technology adoption. Secondary effects have been excluded from our calculations, but have been acknowledged and documented where relevant following leading practice (as per the documents referenced at the beginning of this section).

We have also identified instances where the enabling effects of more than one technology could potentially overlap. To avoid double-counting, functional units and technology boundaries have been clearly defined, and conservative assumptions have been included in the calculations. For example, secondary data on internet usage patterns have been incorporated to make a distinction between the online shops that are likely to be made at home using full fibre broadband versus those made on a 4G/5G mobile connection.

Direct solution emissions

Direct emissions are the life cycle emissions of the technology that is causing the enabling effect. The ITU defines these as 'direct environmental effects associated with the physical existence of an ICT solution, i.e., the raw materials acquisition, production, use and end-of-life treatment stages, and generic processes supporting those including the use of energy and transportation.'[3] The emissions that are specifically related to the manufacturing of a technology are known as 'embodied emissions'. Direct emissions (and embodied emissions in particular) are difficult to quantify and require a comprehensive Life Cycle Assessment encompassing manufacture, operation, maintenance and end of life to quantify accurately. We have estimated the embodied emissions of the devices used in our SD-WAN solutions, but do not have the data available to do so for our other in-scope technologies. This might be assessed in future iterations of BT Group's carbon abatement model.

Rebound effects

Rebound effects occur when the efficiencies created by an enabling technology are offset, often unintentionally, by greater consumption of resources, products or services with an emissions impact. For example, the convenience of shopping online may result in consumers buying more items and/or shopping more frequently than they would if they could only shop at a physical store. These 'extra' shops will have an emissions impact linked to the increased parcel deliveries.

Rebound effects have been included in the calculation of avoided emissions in two instances where they are considered to be significant and can be quantified. This includes the increase in energy used when working from home, and the increase in parcel deliveries resulting from online purchases. Where other potential rebound effects have been identified but are not quantifiable, they have been described qualitatively.

2.3 Guiding principles

To ensure alignment to leading practice, our methodology uses the following principles:

Data quality

The data used in abatement calculations should reduce bias and uncertainty as far as practicable by using the best quality data available. The data included in our calculations are either primary, secondary or modelled. Priority is given to primary data from BT Group or our customers (via surveys or case studies), but where this is not available secondary data from credible sources are used. Where multiple secondary sources were found for a single input, the source with the highest temporal and geographical representativeness was selected. In cases where data from equally representative sources conflicted, the most conservative figures were used to avoid overestimating our impact.

Where secondary data was not available, conservative assumptions were used. Given the lower level of confidence in assumptions (compared to primary or secondary data) a degree of caution has been taken when interpreting the calculated impacts. In line with leading practice, assumption ranges have been stress tested where required, and all assumptions were reviewed with internal product teams. All data sources and a description of the basis of our assumptions have been clearly documented.

[3] ITU Methodology L 1480
Enabling the Net Zero transition

Future solutions

Inherently, there will be greater uncertainty when predicting the future carbon abatement impact of our technologies. We use emissions factors that are adjusted over time to reflect the projected decarbonisation of the UK electricity grid, and the transition to electric vehicles. We also clearly document where any assumptions or data sources change in future years.

Attribution and allocation

Carbon abatement is often the result of multiple technologies or services working together, making it impossible for one solution alone to claim all the avoided emissions. For example, to work effectively from home, our customers require a reliable, high-speed broadband connection, but also personal ICT equipment such as laptops and smartphones, and remote access to cloud-based servers.

The following guidance on attribution and allocation is found in the Avoided Emissions Framework[4]:

'There is currently no consistent way to allocate avoided emissions, thus it is common practice to attribute all of the avoided emissions to a solution where that solution has a fundamental role in enabling the avoided emissions. The test of a fundamental role may be determined by whether the avoided emissions would only be realised with the existence of the solution (i.e., if the solution did not exist would the avoided emissions still take place?).'

In line with this guidance, all of the technologies included in our methodology are assumed to have a fundamental role in enabling the carbon savings, and therefore the whole carbon abatement from the enabling technology is claimed.

2.4 Summary of steps taken to quantify the net carbon abatement

The below steps were followed to quantify the carbon abatement of the selected BT Group technologies:

1. Identification of the technologies and applications to be assessed

Each of the technologies and applications included in our current calculations were selected on the basis that they were likely to achieve net avoided emissions today, and/or were important contributors to our future growth strategy. We established that the enabling effects did not include a reduction of our own emissions.

2. Establishment of the system boundary, carbon saving mechanisms, and baseline scenarios

For the chosen solutions, we established the mechanism that is causing the enabling effect – for example, reduced travel or energy savings. We also confirmed that the enabling effect could be directly attributed to the technology, meaning the whole carbon abatement can be claimed. Baseline scenarios representing the technology application's most likely alternative were identified to ensure that only the incremental impact of each technology was calculated. Functional units – describing the system boundaries in which the baseline scenarios could be compared to the enabling solution – were clearly defined, and risks of double counting were identified.

[4] Mission Innovation and Net Zero Compatible Innovations Initiative (2020) The Avoided Emissions Framework (AEF), Module 2

3. Documentation of the methodology and identification of the data requirements

Carbon abatement mechanisms, boundaries and calculation methodologies for each technology and application were documented and visualised through the creation of causal models. This enabled the initial methodology and any underlying assumptions to be reviewed and validated by internal product teams and helped us identify the primary and secondary data required for each calculation. These documents have been refined throughout the development of the methodology.

4. Test of the mechanism

At multiple stages, the abatement methodology and data requirements were reviewed by product specialists, both internal and external to BT Group. This process allowed the assumptions and proposed methodology to be tested to ensure they were validated and reasonable.

5. Identification of the studies and determination of the carbon abatement factor

Research was conducted to collect data and studies that provide a quantitative basis for the calculation of the functional unit, including the baseline, enabling effects, direct effects and rebound effects (where this can be quantified). This included primary data, academic studies, other published data and reports, and customer surveys. Over time, methodologies will be refined and examined with case studies and other data sources.

6. Collection of data for volumes and carbon abatement factor

Primary data collection from our product teams and customers was completed to determine the size of the population enabled by each technology. Where BT Group data did not exist or needed to be extrapolated to the end of March 2030, assumptions were made and validated with internal product teams.

7. Calculation of the carbon abatement

The total carbon abatement was calculated by multiplying the carbon abatement factor by the volume for each solution, and then aggregating the results for all the products being assessed. The calculations considered potential overlaps between solutions to ensure there is no double counting of the same avoided emissions being enabled by different solutions.

8. Final documentation and validation of the process

The methodology and calculation process has been fully documented in this report, including the assumptions and data sources.

3 Application of methodology to specific abatement mechanisms and technologies

3.1 Remote working

Technologies that provide individuals with the ability to work remotely (including working from home and virtual attendance at work-related events) can help reduce carbon emissions related to commuting and travelling for work. There may be secondary abatement effects, such as reduction in energy usage required to power devices being used in an office or other work environment.

3.1.1 Fibre to the Premises (FTTP)

BT Group's Full Fibre broadband offering, or fibre to the premises (FTTP), provides ultrafast internet speeds, improved reliability, and the ability to operate multiple devices simultaneously on home broadband. Unlike fibre to the cabinet (FTTC), FTTP broadband is delivered by fibre optic cables directly to consumers' homes, bypassing localised cabinets and eliminating the use of less efficient copper wiring.

Carbon Savings Mechanism (Enabling effects)
The speed and reliability of FTTP is integral in enabling the effective operation of remote work tasks. By providing the ability to work from home, FTTP can help reduce carbon emissions by eliminating the need for a daily commute to a workplace. In addition, FTTP can also help reduce energy consumption in a workplace by reducing the number of computers, lights, and other devices that need to be powered, and by reducing energy related to heating and cooling.

Calculation Methodology
The carbon abatement was calculated as the average annual carbon abatement per homeworker per year multiplied by the number of homeworkers enabled by BT Group's FTTP offering per year, less the increase in emissions from homeworking (heating and office equipment).

The average annual carbon abatement per homeworker per year was estimated as the average number of days working from home per year, multiplied by the proportion of homeworking days enabled by FTTP, multiplied by the emissions per round trip commute to the workplace.

Formula
Carbon abatement (tCO_2e) = [Average annual carbon abatement per homeworker (tCO_2e/homeworker) × Number of homeworkers enabled by BT Group FTTP per year (#/year)] – Emissions from increased home energy use (tCO_2e/year)

Where: Average annual carbon abatement per homeworker (tCO_2e/homeworker/year) = Average number of days working from home per week (#) × Proportion of days working from home enabled by FTTP (%)

× Average emissions per round trip commute to the workplace (tCO_2e/trip)

Functional Unit
Average carbon abatement per homeworker per year.

Assumptions

1. The number of days worked from home per week per homeworker is estimated as a weighted average of days worked from home post COVID-19 from respondents of a survey commissioned by AWA in 2022.
2. The number of working weeks per year is assumed to be 46 in line with the UK average.
3. The number of homeworkers in the UK population for 2022 is taken from the Office of National
4. Statistics: Labour market overview, UK: November 2022. The number of homeworkers is assumed to grow in line with projected UK labour force growth sourced from OECD: Labour force forecast to 2030, with a consistent 33.2% share of the total UK labour force.
5. Total emissions from office working per employee per day is taken as the total emissions from office heating and electricity per employee per working year (sourced from Energise: Working from Home Carbon Emissions) divided by 232 days (UK average number of working days per year).[5]
6. The average number of hours per day working from home per homeworker is assumed to be 8 hours based on the UK average.
7. Total commuting distance (in miles) for each mode of transport is sourced from the Department for Transport Statistics: National Travel Survey 2021. These figures were extended to 2030 without change
8. All emission factors used in the calculation were sourced from Department for Business, Energy and Industrial Strategy (BEIS): Government conversion factors for company reporting of greenhouse gas emissions 2022. The emission factor for ‘average car’ was adjusted to reflect a forecast increase in automotive market share of Battery Electric Vehicles (BEVs) to 2029/30.
9. In the absence of secondary data, the proportion of homeworking days enabled by FTTP (incremental effect of FTTP over previous broadband connection) is assumed to be 30% as a baseline. This share increases by 5% YoY to reflect that these remote working applications will become more data intensive and rely more on increased speed and reliability. As the confidence of this data point remains low, a range of 10-50% has been assigned to allow the user to assess variations in the incremental effect of FTTP on the carbon abatement potential of the application.
10. Primary data on the number of Consumer FTTP lines in the UK were sourced from BT Group. Total UK Consumer FTTP lines are ‘residential only’. Consumer FTTP lines are also residential only and inclusive of connections from BT, EE and Plusnet, along with connections sold to consumers through third-party wholesalers.
11. The number of homeworkers using FTTP is estimated by multiplying the total number of homeworkers in the UK population by the proportion of Consumer broadband lines in the UK that are FTTP. This assumes all homeworkers require a broadband connection to work from home and is reduced to BT Group’s FTTP market share to derive the total number of homeworkers using a BT Group FTTP connection per year.

[5] Department for Transport (2021)
NTS0409: Average number of trips and distance travelled by purpose and main mode

Data sources

Data point	Source
Number of Total UK Consumer FTTP lines	BT Group
Number of BT Group Consumer FTTP lines Total UK Broadband lines	BT Group BT Group
Average number of days working from home per homeworker per week	AWA, 2022
Number of homeworkers in UK population	ONS, 2022
Total emissions from office working per employee	Energise, 2021
Total commuting distance per commuter per year (all modes of transport)	Department for Transport Statistics, 2021
Average number of commutes per commuter per year	Department for Transport Statistics, 2021
Emission factors for all modes of transport	DEFRA,2022

Rebound effects

The following rebound effect was quantified in the carbon abatement calculation for homeworking:

Increase in homeworking energy use

The carbon abatement methodology determined the net increase in CO_2e emissions per homeworker per year resulting from increased home energy consumption by deducting the total emissions from heating and office equipment at the office per homeworker (sourced from Energise: Working from Home Carbon Emissions) from the total emissions from heating and office equipment at home per homeworker (based on emissions factors from BEIS and an average 8-hour UK workday).

Other rebound effects (not quantified)

Several studies indicate homeworking may incentivise hybrid workers to move further away from their employer's premises, increasing commute distance. Whilst this remains a plausible consequence of greater working flexibility, such studies do not typically establish the direction of causality (i.e., do people working from home do so to avoid a longer commute or do they choose to live further from their employee's premises because their employer enables them to do so?)[6]

The inclination of homeworkers to travel more on non-working days due to reduced social interaction and greater time spent at home during the week also remains a possible outcome of greater homeworking. While this effect is not currently investigated in secondary literature, it was identified as a notable potential rebound effect during development of the carbon abatement methodology.

The reduced need for commuting in a personal vehicle may also lead to increased use of the personal vehicle by other household members during working hours in which the personal vehicle would otherwise have been unavailable.

Secondary effects

Requirements for office space are expected to reduce as the flexibility to work from home post-pandemic becomes entrenched.[7] Carbon savings will arise from reduced office energy use (heating, lighting, and office equipment) and dematerialisation (reduced desk/building space).

[6] Hook et al. (2020) A systematic review of the energy and climate impacts of teleworking
[7] Bloomberg (2022) WFH crushes London office needs as 45% of respondents downsize

3.1.2 Global Voice

BT Group facilitates access to global business collaboration programs, including Microsoft Teams, Zoom and Cisco Webex, as well as UK-only platforms (Ring Central and MyCloud). Business customers can purchase licenses providing “seats” for their employees, giving those employees access to a reliable platform on which to collaborate with both internal and external parties, regardless of where employees are located. This collaboration may be in the form of instant messaging, video calls and meetings, shared live documents, and more, reducing the need to work from the office.

Carbon Savings Mechanism (Enabling effects)
BT Group’s Global Voice service allows customers’ employees to easily access a reliable platform for collaboration from wherever they are located. The ability to continue to work efficiently with colleagues and clients is instrumental in enabling employees to work from home. By providing this ability, Global Voice can help reduce carbon emissions by eliminating the need for a daily commute to a workplace. In addition, Global Voice can also help reduce energy consumption in a workplace by reducing the number of computers, lights, and other devices that need to be powered, and by reducing energy related to heating and cooling.

Calculation Methodology
The carbon abatement was calculated as the average annual carbon abatement per homeworker per year multiplied by the number of homeworkers enabled by BT Group’s Global Voice offering per year, less the increase in emissions from homeworking (heating and office equipment).

The average annual carbon abatement per homeworker per year was estimated as the average number of days working from home per year, multiplied by the proportion of homeworking days enabled by Global Voice, multiplied by the emissions per round trip commute to the workplace.

As Global Voice provides business collaboration tools globally, different assumptions have been made depending on the region of the end user (i.e., the employee using the “seat” purchased by a business customer). These are further detailed in the Assumptions section below.

Formula
Carbon abatement (tCO_2e) = [Average annual carbon abatement per homeworker (tCO_2e/homeworker) × Number of homeworkers enabled by Global Voice per year (#/year)] – Emissions from increased home energy use (tCO_2e/year)

Where: Average annual carbon abatement per homeworker (tCO_2e/homeworker/year) = Average number of days working from home per week (#) × Proportion of days working from home enabled by Global Voice (%) × Average emissions per round trip commute to the workplace (tCO_2e/trip)

Functional Unit
Average carbon abatement per homeworker per year.

Assumptions

1. The number of working weeks per year is assumed to be 46 for all regions, in line with the UK average.
2. The number of homeworkers in the UK population for 2022 is taken from the Office of National Statistics: Labour market overview, UK: November 2022. The number of homeworkers is assumed to grow in line with projected UK labour force growth sourced from OECD: Labour force forecast to 2030, with a consistent 33.2% share of the total UK labour force.
3. All emission factors used in the calculation were sourced from Department for Business, Energy and Industrial Strategy (BEIS): Government conversion factors for company reporting of greenhouse gas emissions 2022. The emission factor for 'average car' was adjusted to reflect a forecast increase in automotive market share of Battery Electric Vehicles (BEVs) to 2029/30.

For homeworkers in the UK:

1. The number of days worked from home per week per homeworker is estimated as a weighted average of days worked from home post COVID-19 from respondents of a survey commissioned by AWA in 2022.
2. Total commuting distance (in miles) for each mode of transport is sourced from the Department for Transport Statistics: National Travel Survey 2021. These figures were extended to 2030 without change
3. The proportion of homeworkers that are simultaneously enabled by BT Group's FTTP service (see above) are considered to have already been captured by the methodology, and are therefore excluded from the Global Voice figures. This is done by taking the inverse of BT Group's market share for FTTP as a conservative approximation of the proportion of homeworkers using BT Group's services that have not yet been counted.

For homeworkers in the US:

1. The number of days working from home per homeworker per year is estimated based on 2022 data published by the World Economic Forum.
2. The average commute distance for employees living in the US was taken from average statistics published for 2021 by the US Government's Bureau of Transportation Statistics.

For homeworkers in the EU:

1. The commute distance travelled uses the same assumptions as UK homeworkers, with an uplift factor applied to account for additional days worked in the office on average. This data was obtained from a 2023 CESifo survey.

Data sources

Data point	Source
Number of Total UK Consumer FTTP lines	BT Group
Number of BT Group Consumer FTTP lines Total UK Broadband lines	BT Group BT Group
Average number of days working from home per homeworker per week - UK	AWA, 2022
Average number of days working from home per homeworker per week – US	World Economic Forum, 2022
Average number of days working from home per homeworker per week - EU	CESifo, 2023
Number of homeworkers in UK population	ONS, 2022
Total commuting distance per commuter per year (all modes of transport) – UK and EU	Department for Transport Statistics, 2021
Total commuting distance per commuter per year (all modes of transport) – US	Bureau of Transportation Statistics, 2021
Average number of commutes per commuter per year	Department for Transport Statistics, 2021
Emission factors for all modes of transport	DEFRA, 2022

Rebound effects

The rebound effects caused by increased rates of working from home are discussed in section 3.1.1 above with regards to FTTP.

Secondary effects

The secondary effects caused by increased rates of working from home are discussed in section 3.1.1 above with regards to FTTP.

3.1.3 Virtual Events

BT Group offers Virtual Events services specifically Microsoft Teams Live Event, Zoom Webinar and Webex Webinar. Virtual Events solutions allow customers to run seamless, effective online events where otherwise events may be held in person.

Carbon Savings Mechanism (Enabling effects)

The enablement of online events through BT Group's Virtual Events services allows BT Group customers to communicate and work remotely. The transition from an in-person event to a virtual equivalent can reduce travel, resources and energy consumption during the planning, preparation and execution of the event, as well as accommodation for overnight stays.

Calculation Methodology

The carbon abatement methodology assumes a transition from in-person to virtual events. This is calculated as the carbon abatement per participant, multiplied by the number of virtual conference participants avoiding an in-person meeting per year. The carbon abatement per participant is calculated as the difference between the carbon footprint of an in-person and a virtual event. The total number of virtual conference participants avoiding an in-person meeting is calculated by multiplying the number of events by the number of participants per event and applying reduction factors, considering that not all virtual conferences replace travel to meetings (meeting avoidance factor) and that even when a virtual meeting does replace travel, it does not necessarily do so for everyone (participants avoiding travel factor).

Formula

Carbon abatement (tCO_2e) = Carbon abatement per participant (tCO_2e/participant) × Total number of virtual conference participants avoiding an in-person meeting (#/year)

Where: Carbon abatement per participant (tCO_2e/year/participant) = Carbon footprint of in-person conference per participant (tCO_2e/participant) - Carbon footprint of virtual conference per participant (tCO_2e/participant)

And: Total number of virtual conference participants avoiding an in-person meeting (#/year) = Total number of virtual events (globally) (#) × Meeting avoidance factor (%) × Average number of attendees per event (#) × Participants avoiding travel factor (%)

Functional Unit

Average carbon abatement per participant per year.

Assumptions

1. This BT Group service will be available from March 2023 onwards, so its impact is not included in calculations made in 2021/22 or 2022/23.
2. Not all virtual conferences replace travel to meetings; for example some virtual conferences may not be essential, but are held due to the ease of doing so. The meeting avoidance factor (the share of in-person meetings that can be replaced due to Digital Workplace Tools) is assumed to remain static from 2023 to 2030, and was informed by existing BT Group data of past events held in-person.
3. When a virtual meeting does replace travel, it does not necessarily do so for everyone. The proportion of participants avoiding travel factor is assumed to remain static from 2023 to 2030.
4. Based on a 2021 optimisation study, avoided emissions includes emissions from transportation, video-conferencing technology, and auxiliary emissions from resource and energy consumptions, such as conference planning and preparation, execution, catering, and accommodation during the conference.
5. The 2021 optimisation study results consider different scenarios for transport mode (car, rail and plane) and for travel distances (up to 10,000 km) based on different hub locations on a global scale.
6. Forecast number of virtual events for 2023/2024 is based on historical data from BT Group's legacy managed event service.
7. Forecast number of virtual events from 2024 to 2030 is based on market growth projections.
8. There will be the same number of attendees per event (130 average number) from 2023 to 2030.
9. Assumptions around grid decarbonisation and transition to Electric Vehicles (EVs) not included. The carbon abatement per participant is not-UK specific, therefore we cannot apply a UK decarbonisation rate or assumptions about the UK's transition to EVs as with other applications.

Data sources

Data point	Source
Carbon footprint of in-person and virtual conference per participant	Tao, Y., Steckel, D., Klemeš, J.J. and You, F., 2021. Trend towards virtual and hybrid conferences may be an effective climate change mitigation strategy. Nature communications, 12(1), pp.1-14.
Meeting avoidance and participants avoiding travel factors	Assumption based on literature review and validated with BT Group in line with existing data of past events held in-person.
Market growth	Wainhouse Research, 2022. Market Sizing & Forecast - 2022 Cloud Engagement Solutions and Services.
Number of virtual events and participants	BT Group data

Rebound effects
Fewer trips, especially overseas, due to avoided attendance to in-person events, may result in more time and company budget to increase local travel for similar events.

Secondary effects
As the number of in-person events for business purposes resulting in travel is reduced, the use of and need for company cars diminishes. The total number of vehicles owned by a company may consequently also decrease, resulting in a long-term reduction in emissions from the manufacture of new vehicles. Similarly, this could contribute to a reduced number of new aircraft manufactured, as overall passenger numbers decline.

3.2 E-Commerce

Technologies that allow users to shop online or via mobile applications can help reduce carbon emissions through the reduction of personal travel, as postal deliveries of e-commerce purchases replace individuals' physical trips to stores. As delivery vehicles service all deliveries on a given route, this is a more efficient mechanism for the movement of goods than individuals travelling separately to stores.

3.2.1 FTTP

As noted above, FTTP provides improved speed, reliability, and efficiency to broadband customers.

Carbon Savings Mechanism (Enabling effects)
The use of online and app-based shopping has increasingly replaced physical shopping trips with postal deliveries, resulting in a reduction in personal travel. The speed and reliability of FTTP broadband is expected to boost this capability, particularly at rural premises where previously slower connection speeds (e.g., fibre to the cabinet) have limited customers' access to online shopping.

Calculation Methodology
The carbon abatement was calculated as the average annual carbon abatement resulting from online shopping per user per year multiplied by the number of e-commerce users enabled by BT Group FTTP per year, less the increase in emissions from parcel delivery services per user per year.

The average annual carbon abatement due to online shopping using FTTP per user per year was estimated as the average number of online shops resulting in home delivery per user per year, multiplied by the proportion of online shops enabled by FTTP, multiplied by the emissions per physical shopping trip per user.

Formula

Carbon abatement (tCO_2e) = [Average annual carbon abatement due to online shopping per user per year (tCO_2e/user/year) × Number of e-commerce users enabled by BT Group FTTP per year (#)] – Increase in CO_2e emissions from parcel deliveries (tCO_2e/year)

Where: Average annual carbon abatement due to online shopping per user per year (tCO_2e/user/year) = Average number of online shops resulting in home delivery per user per year (#) × Proportion of online shops that are enabled by FTTP (%) × Proportion of online shops done on FTTP rather than a mobile network (%) × Emissions per shopping trip per user (tCO_2e)

Functional Unit

Average carbon abatement per e-commerce user per year.

Assumptions

1. Each online purchase attributed to FTTP is a direct replacement for a physical shopping trip.
2. Primary data on the number of Consumer FTTP lines in the UK were sourced from BT Group. Total UK Consumer FTTP lines are 'residential only'. BT Group Consumer FTTP lines are also residential only and inclusive of BT, EE and Plusnet connections, along with connections sold to consumers through third-party wholesalers.
3. Total shopping distance (in miles) per year for each mode of transport and the average number of shopping trips per user per year were sourced from the Department for Transport Statistics: National Travel Survey 2021. Values from the National Travel Survey 2019 were used for 2022/23 to account for a post-COVID recovery in physical shopping trips and aligned with historical trends over the past ten years to 2029/30.
4. The average number of online shops resulting in home delivery per user per year is sourced from a survey with a sample size of approximately 22,000 commissioned by the IPC, in which respondents were asked how often they purchased physical goods online.[8] Growth in the average number of online shops was indexed to forecast revenue from e-commerce from 2021/22 to 2030/31.
5. All emission factors used in the calculation were sourced from Department for Business, Energy and Industrial Strategy (BEIS): Government conversion factors for company reporting of greenhouse gas emissions 2022. The emission factor for 'average car' was adjusted to reflect a forecast increase in automotive market share of EVs to 2030.
6. The number of e-commerce users in the UK population is estimated from data provided by the Office for National Statistics (ONS), showing approximately 87% of UK adults shopped online in 2020. Data on the 2020 and forecast 2030 UK population is sourced from ONS and OECD respectively. The UK adult population (taken as individuals over the age of 16) is assumed to grow in line with the total UK population, at 0.32% per year to 2030. The methodology therefore does not account for an aging UK population.
7. The proportion of online shopping enabled by FTTP (incremental effect of FTTP over previous broadband connections) is assumed to be 30% as a baseline. This share increases by 5% YoY to reflect that these applications may become more data intensive in future and rely more on increased speed and reliability. As the confidence of this data point remains low, a range of 10-50% has been assigned to allow the user to assess variations in the incremental effect of FTTP on the carbon abatement potential of the application.
8. The number of UK users shopping online using FTTP is estimated by multiplying the total number of e-commerce users in the UK population by the proportion of Consumer broadband lines in the UK that are FTTP. This is then reduced to BT Group's FTTP market share to derive the total number of e-commerce users on a BT Group FTTP connection per year.
9. To distinguish between online purchases made using mobile data and FTTP (and to prevent double counting with 4G/5G e-commerce), the proportion of online shops made using FTTP was estimated based on research from U-Switch and incorporated into the calculation methodology.

[8] IPC (2021) IPC Cross Border E-commerce Shopper Survey

Data sources

Data point	Source
Number of Total UK Consumer FTTP lines	BT Group
Total UK Broadband lines	BT Group
Average number of online purchases resulting in home delivery per user per year	IPC, 2021
Average number of shopping trips per user per year	Department for Transport Statistics, 2021
Total distance travelled for shopping per user per year	Department for Transport Statistics, 2021
Emission factors for all modes of transport and emissions per parcel delivery drop	DEFRA, 2022
Proportion on online shops made using FTTP rather than mobile data	U-Switch, 2023

Rebound effects

The following rebound effect was quantified and included in the carbon abatement calculation: Increase in emissions from parcel delivery drops.

Increase in emissions from parcel delivery drops

The average emissions per parcel delivery drop were sourced from an article published by ABTS logistics[9] outlining the environmental impact of home deliveries. This is then multiplied by the average number of online shops per user per year to determine the rebound effect, which is deducted from the total carbon abatement per user per year. Over time, the rebound effect from increased parcel deliveries is likely to reduce as delivery companies transition to electric vehicles. However, this is not currently reflected in our methodology.

Other rebound effects (not quantified)

Whilst it remains plausible that the convenience of e-commerce may result in an increased number of purchases made online versus physical shopping trips, reliable secondary data to quantify this effect is not currently available.

Secondary effects

Studies predict increases in e-commerce will continue to incite new distribution strategies, with businesses becoming more 'demand responsive'.[10] This is expected to lower aggregate product inventories (dematerialisation), with a subsequent reduction in warehouse space as companies move to shipping directly to customers.

9 ABTS Logistics (2009) Shopping trip or home delivery: which has the smaller carbon footprint?

10 Lake (2008) The Impacts of e-Work and e-Commerce on Transport, the Environment and the Economy

3.2.2 4G/5G Mobile Networks

4G networks operate on Long Term Evolution (LTE) technology, which offers faster data speeds, better network capacity, and improved call quality. 5G networks operate on the latest 5G technology, which provides faster data speeds, lower latency, and higher network capacity than 4G, offering high-speed data connectivity to customers across the country.

Carbon Savings Mechanism (Enabling effects)
4G and 5G mobile networks with greater data transfer speeds than legacy networks (such as 3G) have facilitated users to shop online in instances where broadband connectivity is unavailable, and the speed of previous mobile networks was inadequate (such as when travelling or in remote locations). The carbon abatement methodology therefore included carbon savings associated with online shopping using 4G and 5G mobile data, in addition to FTTP.

Calculation Methodology
The carbon abatement was calculated as the average annual carbon abatement resulting from online shopping per user per year, multiplied by the number of e-commerce users enabled by BT Group's 4G and 5G networks per year, less the increase in emissions from parcel delivery services per user per year.

The average annual carbon abatement resulting from online shopping per user per year was estimated as the average number of online shops resulting in home delivery per user per year, multiplied by the emissions per physical shopping trip per user.

Formula
Carbon abatement (tCO_2e) = [Average annual carbon abatement due to online shopping per user per year (tCO_2e/user/year) × Number of e-commerce users enabled by BT Group 4G and 5G networks per year (#)] – Increase in CO_2e emissions from parcel deliveries (tCO_2e/year)

Where: Average annual carbon abatement due to online shopping per user per year (tCO_2e/user/year) = Average number of online shops resulting in home delivery per user per year (#) × Emissions per shopping trip per user (tCO_2e)

Functional Unit
Average carbon abatement per e-commerce user per year.

Assumptions

1. Each online purchase made using 4G or 5G is a direct replacement for a physical shopping trip.
2. Primary data on the number of 4G and 5G mobile users in the UK, and BT Group's 4G and 5G customer base was sourced from BT Group. The mobile user base is 'Consumer' only (both for total UK users and BT Group users).
3. Total shopping distance (in miles) per year for each mode of transport and the average number of shopping trips per user per year were sourced from the Department for Transport Statistics: National Travel Survey 2021. Values from the National Travel Survey 2019 were used for 2022/23 to account for a post-COVID recovery in physical shopping trips and aligned with historical trends over the past 10 years to 2029/30.
4. The average number of online shops resulting in home delivery per user per year is sourced from a survey with a sample size of approximately 22,000 people commissioned by the IPC, in which respondents were asked how often they purchased physical goods online.[11] Growth in the average number of online shops was indexed to forecast revenue from e-commerce from 2021/22 to 2030/31.
5. To distinguish between online purchases made using mobile data and FTTP (and to prevent double counting with 4G/5G e-commerce), the proportion of online shops made using FTTP was estimated based on research from U-Switch and incorporated into the calculation methodology.
6. All emission factors used in the calculation were sourced from Department for Business, Energy and Industrial Strategy (BEIS): Government conversion factors for company reporting of greenhouse gas emissions 2022. The emission factor for 'average car' was adjusted to reflect a forecast increase in automotive market share of EVs to 2030.
7. The number of e-commerce users in the UK population is estimated from data provided by the Office for National Statistics (ONS), showing approximately 87% of UK adults shopped online in 2020. Data on the 2020 and forecast 2030 UK population is sourced from ONS and OECD respectively. The UK adult population (taken as individuals over the age of 16) is assumed to grow in line with the total UK population, at 0.32% per year to 2030. The methodology therefore does not account for an aging UK population.
8. The total number of 4G and 5G users enabled by BT Group is inclusive of 4G and 5G connections provided directly by BT Group to consumers, as well as connections provided to consumers via third-party wholesalers.
9. The number of 4G and 5G e-commerce users enabled by BT Group to shop online using a mobile network is calculated as the total number of 4G and 5G users enabled by BT Group, multiplied by the percentage of 4G and 5G users shopping online in the UK.

Data sources

Data point	Source
Number of 4G and 5G users enabled by BT Group	BT Group
Total 4G and 5G users in the UK	BT Group
Average number of online purchases resulting in home delivery per user per year	IPC, 2021
Average number of shopping trips per user per year	Department for Transport Statistics, 2021
Total distance travelled for shopping per user per year	Department for Transport Statistics, 2021
Emission factors for all modes of transport and emissions per parcel delivery drop	DEFRA, 2022

[11] IPC (2021) IPC Cross Border E-commerce Shopper Survey

Rebound effects
Rebound effects for e-commerce using 4G and 5G mobile data are considered to be the same as for FTTP, including increased emissions from parcel delivery services and a potential increase in the number of online purchases made due to the convenience of online shopping when compared to physical shopping trips.

Secondary effects
Secondary effects for e-commerce using 4G and 5G mobile data are considered to be the same as for FTTP, including dematerialisation from reduced company product inventories and a reduction in commercial warehouse and high street shopping space.

3.3 Healthcare

BT aims to work with healthcare partners to build smarter, safer, more efficient services for everyone. Our digital solutions and full fibre broadband give patients access to the healthcare services they need remotely, safely and conveniently, outside of a hospital setting.

3.3.1 Virtual Care

BT helps deliver virtual care solutions, using Artificial Intelligence (AI) to enable community healthcare professionals and patients to capture reliable health information in real time and assess the risk of conditions worsening quickly. The technology is used across care homes and community nursing wards.

Carbon Savings Mechanism (Enabling effects)
BT's Virtual Care solutions enable users to acquire information on patients and manage treatments outside of hospitals. The resulting early identification of risks and patient deterioration not only reduces the need for hospital admission, but also prevents avoidable GP callouts.

Calculation Methodology
The carbon abatement calculation comprises the following applications:

1. Reduced hospital admissions: Calculated as the average number of hospital admissions per Virtual Care user per year multiplied by the percentage of admissions avoided, multiplied by the average emissions per hospital admission.
2. Reduced GP callouts: Calculated as the average number of GP callouts per user per year multiplied by the percentage of GP callouts avoided, multiplied by the average emissions per GP callout.

Formula
1. Reduced hospital admissions

Average annual carbon abatement per Virtual Care user per year (tCO_2e) = [Average number of hospital admissions per Virtual Care user per year (#/user/year) × Percentage of hospital admissions avoided per user per year (%) x Average emissions per hospital admission per user per year (tCO_2e/user/year)

Where: Average emissions per hospital admission per user per year (tCO_2e/user/year) = [Average length of hospital stay (days) x Average emissions per patient per day in hospital (tCO_2e/user/day)] + [Average distance travelled to hospital per admission (km) x Ambulance emission factor (tCO_2e/km)]

2. Reduced GP callouts

Average annual carbon abatement per Virtual Care user per year (tCO_2e) = Average number of GP callouts per Virtual Care user per year (#/user/year) × Percentage of GP callouts avoided per user per year (%) x Average emissions per GP callout (tCO_2e/callout)
Where: Average emissions per GP callout (tCO_2e/callout) = Average distance travelled by a GP per callout (km) x Average car emission factor (tCO_2e/km)]

Functional Unit
Average annual carbon abatement per Virtual Care user per year

Assumptions

1. All emission factors used in the calculation were sourced from the Department for Business, Energy and Industrial Strategy (BEIS): Government conversion factors for company reporting of greenhouse gas emissions 2022. The emission factor for 'average car' was adjusted to reflect a forecast increase in automotive market share of EVs to 2030.
2. The average number of hospital admissions per Virtual Care user per year is sourced from a study by Quality Watch (2015) on hospital admissions from care homes. This is assumed to stay constant to 2029/30.
3. The percentage of admissions avoided by Virtual Care is sourced from a case study from Feebris (2023) into hospitalisation rates among care home residents in the UK. To remain conservative, this is assumed to remain constant to 2029/30 however it remains likely that as Virtual Care solutions improve, this rate will increase.
4. The average distance travelled per hospital admission is sourced from a study from Quality Watch (2014), examining the distances from home to hospital for emergency hospital care in the UK. This is assumed to stay constant to 2029/30.
5. The average length of hospital stay is sourced from the OECD (2023). It remains highly likely that the length of hospital stays will vary considerably among patients, and is likely to be longer among the target population for Virtual Care solutions (care home residents and patients with chronic health conditions). This is assumed to stay constant to 2029/30.
6. The average emissions per person per day spent in hospital is sourced from Carbon Brief (2021). This is assumed to stay constant to 2029/30.
7. The percentage of GP callouts avoided by Virtual Care is sourced from a case study from Feebris (2023) into hospitalisation rates among care home residents in the UK. This is assumed to remain constant to 2029/30.
8. The average number of GP callouts per user per year (pre-Virtual Care) was sourced from the Australian Institute for Health and Welfare (AIHW) which suggests care home residents see a GP twice a month. As this data includes both GP visits and external trips to see GPs, it was assumed that 50% of visits were at the care home.
9. The distance travelled per GP callout was sourced from a study by Jordan et al, 2004 exploring the geographical accessibility of health services in urban and rural areas of Southwest England. This was kept constant with the figures used in the application 'E-Health' for consistency.

Data sources

Data point	Source
Average number of hospital admissions per Virtual Care user per year	Quality Watch, 2015
Percentage of admissions avoided by Virtual Care	Feebris, 2023
Average distance travelled per hospital admission	Quality Watch, 2014
Average length of hospital stay (pre-Virtual Care) per admission	OECD, 2021
Average emissions per person per day spent in hospital	Carbon Brief, 2021
Percentage of GP callouts avoided by Virtual Care	Feebris, 2023
Average number of GP callouts per user per year (pre-Virtual Care)	RACGP, 2020
Emission factors for ambulance and average car	DEFRA, 2022
Number of Virtual Care users enabled by BT	BT Group
Number of Virtual Ward users enabled by BT	BT Group

3.3.2 FTTP-enabled virtual consultations

As noted above, FTTP provides improved speed, reliability, and efficiency to broadband customers.

Carbon Savings Mechanism (Enabling effects)
Virtual consultations (e-health) via video conferencing technology, replacing the need for patients to travel to in-person appointments. The number of virtual consultations has increased significantly due to social distancing restrictions enforced due to COVID-19, and is expected to persist as a product of modernisation in the healthcare sector. Improved connectivity through use of FTTP will continue to boost the adoption of virtual consultations, particularly in areas where previously slow, unreliable broadband connections had prevented its use.

Calculation Methodology
The carbon abatement methodology was calculated as the average annual carbon abatement per e-health user per year multiplied by the number of e-health users enabled by BT Group FTTP per year.

The average annual carbon abatement per e-health user per year was estimated as the average number of e-health consultations per user per year, multiplied by the proportion of e-health consultations enabled by FTTP, multiplied by the emissions per physical consultation trip per user.

Formula
Carbon abatement (tCO_2e) = Average annual carbon abatement per e-health user per year (tCO_2e/user/-year) × Number of e-health users enabled by BT Group per year (#/year)

Where: Average annual carbon abatement per e-health user per year (tCO_2e/user/year) = Average number of e-health consultations per user per year (#/year) × Proportion of e-health consultations enabled by FTTP (%) × Emissions per GP visit (tCO_2e/visit)

Functional Unit
Average carbon abatement per e-health user per year.

Assumptions

1. The carbon abatement methodology assumes that each virtual consultation attributed to FTTP is a direct replacement for an in-person consultation requiring travel.
2. Primary data on the number of Consumer FTTP lines in the UK was sourced from BT Group. Total UK Consumer FTTP lines are 'residential only'. BT Group FTTP lines are also residential only and inclusive of BT, EE and Plusnet connections, along with connections sold to consumers through third-party wholesalers.
3. The average number of virtual consultations per e-health user per year was sourced from a report provided by OECD on the use of teleconsultations.
4. The emissions per GP visit were sourced from a study by Carbon Brief on calculating the carbon footprint of the NHS in England. This is assumed to stay constant to 2030.
5. Data on the 2020 UK population is sourced from ONS. The UK adult population (taken as individuals over the age of 16) is assumed to grow in line with the total UK population at 0.32% per year to 2030.
6. The percentage of adults using e-health services (5%) was sourced from a 2020 survey by Statista, which also showed that 58% of respondents would 'definitely consider' using digital health services to prevent the spread of Covid-19. We would expect Covid-19 to have a positive impact on e-consultation usage, and therefore assume that uptake will increase to 10% by 2030.
7. The proportion of virtual consultations enabled by FTTP (incremental effect of FTTP over previous broadband connection) is assumed to be 30% as a baseline. This share increases by 5% YoY to reflect that these applications may become more data intensive in future and rely more on increased speed and reliability. As the confidence of this data point remains low, a range of 10-50% has been assigned to allow the assessment of different variations in the incremental effect of FTTP on the carbon abatement potential of the application.
8. All emission factors used in the calculation were sourced from Department for Business, Energy and Industrial Strategy (BEIS): Government conversion factors for company reporting of greenhouse gas emissions 2022. The emission factor for 'average car' was adjusted to reflect a forecast increase in automotive market share of EVs to 2030.

Data sources

Data point	Source
Number of Total UK Consumer FTTP lines	BT Group
Number of BT Group Consumer FTTP lines	BT Group
Total UK Broadband lines	BT Group
Average number of virtual consultations per e-health user per year	OECD, 2020
Average emissions per GP visit	Carbon Brief, 2021
Adult (18 and over) population in the UK	ONS, 2021
Percentage of adults using e-health services	Statista, 2020

Rebound effects

Increased home energy use for virtual consultations is considered negligible. No other material rebound effects were identified.

Secondary effects

Increased use of e-health services could lead to a reduction in the number of local practices and healthcare facilities. In parallel with other applications contributing to reduced personal travel, virtual consultations have the potential to reduce traffic congestion.

3.4 Transportation

3.4.1 Private Navigation on 4G/5G Networks

As noted above, 4G and 5G networks offer faster and more reliable connectivity to customers across the UK.

Carbon Savings Mechanism (Enabling effects)
4G and 5G technologies improve the performance of navigation apps on mobiles by providing faster download and upload speeds, lower latency, and increased network capacity. This results in faster and more accurate mapping, real-time traffic updates, and improved GPS location accuracy, which enhances the user experience of using navigation apps. As more people use mobile apps - enabled by faster 4G and 5G services - the accuracy of the navigation apps will continue to improve.

Navigation apps such as Waze, Google Maps, and Apple Maps use real time data to optimise routes for users, taking into account factors such as traffic congestion and road closures. These apps can help to reduce fuel consumption by minimising the time cars spend on the road, resulting in fewer emissions from cars idling in traffic. In addition, the widespread adoption of electric vehicles (EVs) can further reduce emissions as they produce zero emissions while driving. The use of navigation apps can also help EV drivers plan their routes to include charging stations, which can alleviate range anxiety and encourage more people to adopt EVs.

As the adoption of 4G and 5G mobile networks becomes more widespread, the use of these apps, along with use of EVs, is expected to further decrease emissions. Overall, the use of 4G/5G networks in navigation has the potential to reduce carbon emissions from transportation.

Calculation Methodology
The carbon abatement was calculated as the average annual carbon abatement resulting from use of navigation apps while driving per user per year multiplied by the number of users enabled by BT Group 4G and 5G networks per year.

The average annual carbon abatement resulting from use of navigation apps per user per year was estimated as the average distance travelled per user per year using conventional vehicles and EVs, multiplied by the respective fuel saving factor of the vehicle used.

Formula
Carbon abatement (tCO_2e) = Average annual carbon abatement due to use of navigation app per user per year using conventional vehicle (tCO2e/conventional user/year) + Average annual carbon abatement due to use of navigation app per user per year using electric vehicle (tCO_2e/EV user/year) × Number of users enabled by BT Group 4G and 5G networks per year (#/year)

Where: Average annual carbon abatement per user per year using conventional vehicle (tCO_2e/conventional user/year) = Average distance travelled per year (km) ÷ Average fuel economy of conventional vehicle (km/litre) × fuel saving factor (%) × Emission factor of fuel (tCO_2e/litre)

Average annual carbon abatement per user per year using electric vehicle (tCO_2e/EV user/year) = Average distance travelled per year (km) ÷ Average energy economy of battery electric vehicle (km/kWh) × Energy saving factor (%) × Emission factor of UK grid electricity (tCO_2e/kWh)

Functional Unit
Average carbon abatement per navigation app user per year.

Assumptions
1. Average distance travelled (in miles) per year - using private transport was sourced from the Department for Transport Statistics: National Travel Survey 2021.
2. Average fuel economy of conventional vehicle and energy economy of BEV considered to estimate annual fuel and energy consumption was sourced from the Department for Transport.
3. Primary data on the number of 4G and 5G mobile users in the UK was sourced from BT Group.
4. All emission factors used in the calculation were sourced from the Department for Business, Energy and Industrial Strategy (BEIS): Government conversion factors for company reporting of greenhouse gas emissions 2022. The emission factor for 'average car' was adjusted to reflect a forecast increase in automotive market share of BEVs to 2030.
5. The total number of 4G and 5G users enabled by BT Group is inclusive of 4G and 5G connections provided directly by BT Group to consumers, as well as connections provided to consumers via third-party wholesalers.
6. The number of 4G and 5G users enabled by BT Group to use navigation apps while driving is calculated as the total number of 4G and 5G users enabled by BT Group, multiplied by the percentage of 4G and 5G users using navigation while driving in the UK.
7. The percentage of users using navigation apps on a mobile device while driving is sourced from a survey conducted by a car finance provider in UK.[12] As the confidence of this data point remains low, a range of 10-30% has been assigned to allow the assessment of different levels of navigation app uptake. We assume a conservative (3%) year on year increase in use of navigation technology using a mobile device; this reflects 2022 research projecting that the public transport market size will grow at a CAGR of 10% by 2028.[13]
8. The proportion of journeys for which navigation apps are used was sourced from a study by Knapper et al, 2015 in which the use of portable navigation systems in everyday driving was assessed. As the confidence of this data point remains low, a range of 20-30% has been assigned to allow the assessment of different levels of navigation app usage.

[12] Motor Finance Online (2022) 40% of UK motorists rely on a satnav when driving
[13] Million Insights (2022) Global Navigation App Market Size, Share Report, 2021-2028

Data sources

Data point	Source
Number of 4G and 5G users enabled by BT Group	BT Group
Total 4G and 5G users in the UK	BT Group
Average annual distance travelled using private transport	Department for Transport Statistics, 2021
Average fuel economy of conventional vehicle	Department for Transport Statistics, 2021
Average energy economy of battery electric vehicle	Electric Vehicle database, 2022
Fuel saving factor	Lei et al, 2018
Total number of conventional vehicles in UK as of March 2022	Department for Transport, 2022
Total number of battery electric vehicles in UK as of March 2022	Department for Transport, 2022
Percentage decrease in fuel economy due to improved technology	IEA, 2019
Emission factors for fuel and UK grid electricity	DEFRA, 2022
Proportion of journeys for which navigation apps are used	Knapper et al, 2015

Rebound effects
Increased travel in private cars due to efficiency of navigation tools.

Secondary effects
Not identified.

3.4.2 Public Transportation using 4G/5G Networks

Carbon Savings Mechanism (Enabling effects)
The use of public transport apps – such as Citymapper, Tube Map, UK Bus checker, Trainline UK and Google Maps – provides access to real-time information on public transport services, incentivising greater use of public transport and encouraging travellers to switch from private to public modes of transport. The abatement effect from real-time public transport apps is expected to grow with the increased use of 4G and 5G mobile networks.

Navigation apps can disincentivise personal vehicle use by providing real-time traffic information that helps users make more informed decisions about their transportation options. Additionally, navigation apps that provide information on parking availability and costs can also encourage people to use alternative modes of transportation.

Calculation Methodology
The carbon abatement was calculated as the average annual carbon abatement per commuter using different modes of public transport instead of private transport per year, multiplied by the number of users enabled by BT Group 4G and 5G per year.

The average annual carbon abatement per commuter per year was estimated as the emissions resulting from the average distance travelled using private transport less the emissions due to decreased use of private transport plus the emissions arising from the use of different modes of public transport.

Formula
Carbon abatement (tCO_2e) = Average annual carbon emissions due to use of private transport per commuter per year (tCO_2e/commuter/year) - Average annual carbon emissions due to decreased use of private transport per commuter per year (tCO_2e/commuter/year) + Average annual carbon emissions due to increased use of public transport per commuter per year (tCO_2e/commuter/year) × Number of 4G and 5G users enabled by BT Group per year (#/year)

Where: Average annual carbon emissions resulting from use of private transport per commuter per year (tCO2e/commuter/year) = Average distance travelled per commuter per year using private vehicle (km) × emission factor (tCO_2e/km)

Average annual carbon emissions resulting from use of public transport per commuter per year (tCO_2e/commuter/year) = Average distance travelled per commuter per year using different mode of public transport (km) × emission factor of different modes of transport (tCO_2e/km)

Functional Unit
Average carbon abatement per public transport app user per year

Assumptions
1. Average distance travelled (in miles) per year using private transport as driver or passenger – weighted average was sourced from the Department for Transport Statistics: National Travel Survey 2021
2. Average distance travelled (in miles) per year using public transport (all modes of transportation) – weighted average was sourced from the Department for Transport Statistics: National Travel Survey 2021
3. Primary data on the number of 4G and 5G mobile users in the UK was sourced from BT Group.
4. All emission factors used in the calculation were sourced from Department for Business, Energy and Industrial Strategy (BEIS): Government conversion factors for company reporting of greenhouse gas emissions 2022. The emission factor for 'average car' was adjusted to reflect a forecast increase in automotive market share of EVs to 2030.
5. The percentage of total population using mobile device apps to use public transport is assumed to be 20%. As the confidence of this data point remains low, a range of 10-30% has been assigned to allow the assessment of different levels of public uptake of transport apps. We assume a conservative (2%) year on year increase in the usage rate of public transport apps; this reflects 2020 research projecting that the public transport market size will grow at a CAGR of 8% by 2027 (due, in part, to use of transport apps).[14]
6. The frequency that public transport is used instead of private vehicles due to apps (15%) has been sense-checked using responses to a BT Group customer survey. As the confidence of this data point remains low (due to low response rate), a range of 10-20% has been assigned to allow the assessment of different levels of public transport usage. We assume a conservative (2%) year on year increase in the rate at which public transport is used in place of private transport; this reflects 2020 research projecting that the public transport market size will grow at a CAGR of 8% by 2027 (due, in part, to use of transport apps).[15]
7. The total number of 4G and 5G users enabled by BT Group is inclusive of 4G and 5G connections provided directly by BT Group to consumers, as well as connections provided to consumers via third-party wholesalers.
8. The number of 4G and 5G users enabled by BT Group to use real-time public transport apps is calculated as the total number of 4G and 5G users enabled by BT Group, multiplied by the percentage of 4G and 5G users using public transit apps.

[14] Akre, Sejal (2020) Public Transport Market Research Report: Information by Type (Bus, Light Rail, Regional Taxi, Metro and Tram), Application (City and Rural) and Region - Forecast till 2030
[15] ibid

Data sources

Data point	Source
Number of 4G and 5G users enabled by BT Group	BT Group
Total 4G and 5G users in the UK	BT Group
Average annual distance travelled using private transport	Department for Transport Statistics, 2021
Average annual distance travelled using different modes of public transport	Department for Transport Statistics, 2021
Emission factors for all modes if transport	DEFRA, 2022

Rebound effects
By making public modes of transportation more convenient and accessible, apps might increase usage among people who would have otherwise not travelled at all (e.g., to avoid sitting in traffic in their personal vehicle) or would have used lower emitting modes of transportation such as walking or cycling, but this effect has not been quantified.

Secondary effects
Not identified.

3.4.3 Telematics - Internet of Things (IoT)

IoT telematics solutions can collect, store, and analyse vehicle and roadway condition data using GPS technology, artificial intelligence (AI), and onboard diagnostics. Providing this data to fleet owners and managers can lead to reduced fuel consumption, and consequently emissions, through route optimisation and improved vehicle maintenance, driver operation, and cargo management.

Carbon Savings Mechanism (Enabling effects)
Vehicle telematics can help reduce fuel or energy consumption, by encouraging improved driver behaviours (more fuel-efficient driving techniques and speeds), as well as more efficient routing and logistics.

Calculation Methodology
Methodology 1 (currently used - based on secondary data):
The carbon abatement is calculated as the average emissions per vehicle multiplied by a fuel saving factor, multiplied by the number of vehicle telematics connections enabled by BT Group per year.

The average emissions per vehicle is derived from the average annual distance travelled per vehicle multiplied by the emissions factor for a given vehicle type.

Methodology 2 (for future use if primary data becomes available):
The carbon abatement can be calculated as the fuel saved per petrol or diesel vehicle and the energy saved per electric car vehicle multiplied by the relevant emission factors, multiplied by the number of vehicle telematics connections enabled by BT Group per year.

Formula
Methodology 1
Carbon abatement (tCO_2e) = Average emissions per vehicle (tCO_2e /vehicle) × Fuel saving factor (%) × Number of vehicle telematics connections enabled by BT Group per year (#/year)

Where: Average emissions per vehicle (tCO_2e/vehicle) = Annual distance travelled per vehicle (km/year/-vehicle) × Emission factor of vehicle type (tCO_2e/km)

Methodology 2
Carbon abatement (tCO2e) = Fuel/energy saved per vehicle (litre or kWh/year/vehicle) × Emission factor (tCO2e/litre or kWh) × Number of vehicle telematics connections enabled by BT Group per year (#/year)

Functional Unit
Average carbon abatement per vehicle telematics connection per year.

Assumptions
1. Studies as referenced in the GSMA Enablement Effect report[16] give a range of 5% to 15% for the fuel saving factor, depending on the vehicle type. As the type of vehicles and the specific system is unknown at this stage, an assumption of a typical 10% for the fuel saving factor is made.
2. Vehicles covered by the technology are unknown, however they will typically be commercial vehicles (vans), therefore a conservative assumption is to use an average van emission factor. However, it is considered that there will also be a percentage of private vehicles connected to telematics, using an average car emission factor. It is assumed that 90% of the fleet connected to telematics will be vans (diesel) and 10% private cars (mix of petrol, diesel and plug-in hybrid vehicles).
3. It is assumed that by 2030, 20% of the UK car and van fleet will be BEVs. See Appendix 2 for additional details on how this is calculated.

Data sources

Data point	Source
Average annual distance travelled per vehicle	Department for Transport, 2022. RFS0112: Average annual vehicle kilometres (loaded, empty and total) by type and weight of vehicle.
Fuel saving factor	GSMA, 2019. The Enablement effect: The impact of mobile communications technologies on carbon emission reductions.
Number of vehicle telematics connections enabled by BT Group per year	BT Group data
Emission factor for vehicle type	DEFRA and BEIS, 2022. UK Government GHG Conversion Factors for Company Reporting.

Rebound effects
More efficient travelling may result in more trips and an increase in the number of new vehicles, but this effect has not been quantified.

[16] GSMA (2019) The Enablement Effect:
The impact of mobile communications technologies on carbon emission reductions

Secondary effects
Avoided emissions are likely to result from reduced wear and tear on highway infrastructure and reduced maintenance. There could also be a reduction in emissions from the manufacture of new vehicles, resulting from more efficient use of vehicles and lower overall demand for new or replacement vehicles.

3.4.4 Electric Vehicle Charging Infrastructure

Using EVs rather than cars with traditional petrol-or diesel-powered engines has become a mainstream avenue by which consumers are shifting towards lower carbon lifestyles. EVs are either partially or fully powered by electricity, reducing the need for the burning of fossil fuels in a standard internal combustion engine. The EV charging infrastructure pilot run by BT Group will be able to be used by a range of different EV brands and vehicle types, operating as roadside public infrastructure (by utilising existing BT Group street furniture and converting these to charge points).

Accelerating the EV transition

Carbon Savings Mechanism (Enabling effects)
Access to EV charging infrastructure has been identified as a major consideration for individuals when deciding whether to buy an EV for their next vehicle.[17] EV charging infrastructure therefore reduces carbon emissions to the extent it enables the replacement of a petrol/diesel car with an EV.

Calculation Methodology
The carbon abatement is calculated as the difference in the annual carbon emissions between an average EV and an average petrol/diesel car, multiplied by the number of additional EVs on the road (as replacements of petrol/diesel cars).

The difference in the annual carbon emissions between an average EV and an average petrol/diesel car is calculated as the average emissions in an average petrol/diesel car less the average emissions of an EV.

Formula
Carbon abatement (tCO_2e) = Increase in EVs on road due to BT Group charge points (number/year) * Difference in average emissions between a petrol/diesel car and an EV car (tCO_2e/year)

Where: Difference in average emissions between a petrol/diesel car and an EV car (tCO_2e/year) = Weighted average emissions of a petrol/diesel car per year (tCO_2e/year) – Average emissions of an EV per year (tCO_2e/year)

Functional Unit
Actual functional unit: Average carbon abatement per additional BT Group roadside EV charge point per year.

Revenue functional unit: Average carbon abatement per additional GBP revenue from roadside charge points.

[17] Gifford (2022) 'The importance of charging infrastructure to the electric vehicle revolution'

Assumptions

1. EVs purchased will be replacing a petrol/diesel car that was nearing the end of its useful life and would otherwise have been replaced with another petrol/diesel car.
2. The average distance driven in a vehicle per year does not vary between an EV and a petrol/diesel car.
3. The journal Environmental Research Letters quotes a study estimating that for every additional standard roadside EV charger, there will be 0.72 new EVs on the road per year.[18] This study was undertaken in Germany, but we have assumed that the findings are applicable to the UK.
4. Average emissions for different vehicle types were calculated by applying emission factors sourced from Transport & Environment to vehicle mileage statistics from the UK Government's Department for Transport.
5. A weighted average emissions factor was calculated for the average petrol/diesel car, using the emissions factors of these vehicle types and data on the proportion of petrol and diesel cars licensed in the UK from the UK Government's Department for Transport and Driver and Vehicle Licensing Agency.

Data sources

Data point	Source
Number of new EV cars on road per additional charge point	S. Sommer & C. Vance, 2021. Do more chargers mean more electric cars? Environmental Research Letters, Volume 16, Number 6.
Average emissions of an EV or petrol/diesel car per year	Y. Gimbert, 2022. How clean are electric cars? Transport & Environment. Department for Transport, 2022. Vehicle mileage and occupancy – Statistical data set. UK Department for Transport and Driver and Vehicle Licensing Agency, 2023. Vehicle licensing statistics data tables – Statistical data set.
BT Group charge points installation and growth	BT Group data
BT Group utilisation and energy usage at charge points	BT Group data

Rebound effects

The following potential rebound effects have been identified but are not quantified in the model due to a lack of supporting data:

- Embodied carbon potentially being greater for an EV than a standard petrol/diesel car
- Increase in overall emissions where EVs are purchased by a first-time car owner (i.e., not directly replacing a petrol/diesel car)

Secondary effects

None identified.

[18] Sommer & Vance (2021) 'Do more chargers mean more electric cars?'

Improved energy mix of on-street EV chargers

Carbon Savings Mechanism (Enabling effects)
BT Group's EV charge points will aim to provide access to 100% renewable electricity. This will reduce users' carbon emissions, as the average roadside EV charger in the UK is not 100% renewable and will therefore carry a higher carbon footprint per charge.

Calculation Methodology
The carbon abatement is calculated as the emissions saved per charge at a BT Group charge point (in comparison to the UK average) multiplied by the number of EV charges per year at BT Group charge points.

The emissions saved per charge point at a BT Group charge point is calculated as the average emission factor of an average alternative charge point, less the emission factor of a BT Group 100% renewable charge point.

Formula
Carbon abatement (tCO_2e) = Number of EV charges per year at BT Group charge points (number) x Energy used per charge (kWh) x Difference in emissions factor of BT Group charge point and an average charge point (tCO_2e/kWh)

Difference in emissions factor of BT Group charge point and an average charge point (tCO_2e/kWh) = Emissions factor of an average charge point (tCO_2e/kWh) - Emissions factor of a BT Group 100% renewable charge point.

Functional Unit
Actual functional unit: Average carbon abatement per additional BT Group roadside EV charge point per year.

Revenue functional unit: Average carbon abatement per additional GBP revenue from roadside charge points.

Assumptions
1. The energy mix of BT Group charge points is 100% renewable. This is verified through the purchase of legitimate Renewable Energy Certificates for the energy used to power charge points.
2. The emissions factor for a 100% renewable charge point is 0 tCO2e/kWh.
3. The UK grid emissions factor is sourced from the Green Book, published by the UK Government's Department for Energy Security and Net Zero and Department for Business, Energy and Industrial Strategy.
4. The emissions factor of an average charge point is a function of the market share of roadside EV charge point providers in the UK, whether those providers use 100% renewable energy or not, and the UK grid factor. A weighted average is calculated by applying an emissions factor of nil for the proportion of the market that provide 100% renewable energy at charge points, and attributing the grid factor for the remaining market proportion.
5. Where a competitor does not state they use 100% renewable energy for their charge points, we assume they use standard grid electricity.
6. There will not be significant changes to the existing network market share for EV charge points.

Data sources

Data point	Source
Emissions factor for average UK roadside EV charge point	Zapmap, 2023. EV charging statistics 2023. Competing EV charging providers' 100% renewability claims, sourced by desktop research into individual providers identified in Zapmap's EV charging statistics. UK Department for Energy Security and Net Zero and Department for Business, Energy & Industrial Strategy, 2023. Green Book.
BT Group market share	BT Group data
BT Group utilisation and energy usage at charge points	BT Group data

Rebound effects
None identified.

Secondary effects
None identified.

3.5 B2B network management

3.5.1 Software-Defined Wide Area Network (SD-WAN)

Software-Defined Wide Area Network (SD-WAN) is a technology that simplifies the management and operation of a wide area network (WAN). SD-WAN uses software to create a virtualised network overlay on top of physical network infrastructure, making it more agile and flexible. This overlay network extends an organisation's network to Infrastructure as a Service (IaaS) and multi-cloud environments, shifting some computing power from devices to the cloud and requiring smaller and lower energy consuming devices on organisation's sites. Using SD-WAN, organisations can quickly connect to all company data centres, core and campus locations, branches, colocation facilities, cloud infrastructure, and remote workers.

Carbon Savings Mechanism (Enabling effects)
In an SD-WAN environment, virtualisation is used to optimise the routing of traffic across a wide area network by using software to manage the routing of traffic across multiple connections. These connections may include broadband, mobile, and Multi-Protocol Label Switching (MPLS). This allows organisations to improve network performance and reduce costs. The potential benefit of using virtualisation in an SD-WAN network is the ability to use smaller and less energy intensive devices on premises. By using virtualisation to move some of the computing power of multiple physical routers into the cloud, organisations can have lighter and more efficient physical on-premises devices connecting to the network. This can result in energy and materials savings, as well as a reduction in costs.

Calculation Methodology

The carbon abatement is calculated in two parts and summed together:

- The average energy consumption of routers used in traditional WAN networks, which will be replaced by a one-edge device with an SD-WAN, less the average energy consumption of a one-edge device used with SD-WAN, multiplied by the emission factor for electricity use; plus
- The average embodied carbon of routers used in traditional WAN networks, which will be replaced by a one-edge device with an SD-WAN, less the average embodied carbon of a one-edge device used with SD-WAN.

The methodology uses revenue as the functional unit, meaning the carbon abatement calculation through the formula outlined above is then divided by the revenue per device (from actual/historical data) and then multiplied by the SD-WAN revenue forecast for a given future year.

Formula

Carbon abatement (tCO_2e) = Average annual carbon abatement per device (tCO_2e/year) / Average annual revenue per SD WAN device (£/year) x Total SD WAN revenue (£)

Where: Average annual carbon abatement per device (tCO_2e/year) = Average annual carbon savings from reduced energy consumption (tCO_2e/year) + Average annual carbon savings from embodied emissions in hardware (tCO_2e/year)

Average annual energy savings (kWh/year) = Energy consumption from legacy WAN devices replaced (kWh/year) – Energy consumption of SD WAN device (kWh/year)

Average annual carbon savings from reduced energy consumption (tCO_2e/year) = Average annual energy savings (kWh/year) x Emission factor for electricity in UK (tCO_2e/kWh)

Average annual carbon savings from embodied emissions in hardware = [Total embodied emissions from legacy WAN devices replaced (tCO2e) / Lifespan of device (years)] – [Total embodied emissions of SD WAN device (tCO_2e) / Lifespan of SD WAN device (years)]

Functional Unit

Average carbon abatement per revenue unit (£) per year.

Assumptions

1. The approach considers two types of customers, depending on the SD-WAN solution employed:
   - Thin edge (VMware): Saves more hardware and energy due to moving more computing power to the cloud, so the devices require lower computing power and therefore smaller, more consolidated boxes.
   - Thick edge (Cisco, Fortinet, Nokia): Save some hardware and energy in comparison to WAN, as some computing power is moved to the cloud. However, this solution requires higher computing power at edge than thin edge, and therefore bigger boxes.
2. The average legacy WAN router used is the Cisco ASR 1000 series.
3. For the thin edge solution, the VMware SD-WAN Edge device is installed. For the thick edge solution, the Cisco 4000 Family Integrated Services Routers are installed.
4. Average power consumption of a legacy WAN router is 560 watts.
5. Average power consumption of an SD-WAN thin edge device is 30 watts, with an average weight of 1.3 kg.
6. Average power consumption of an SD-WAN thick edge device is 250 watts, with an average weight of 8.75 kg. This assumption is based on the median of all Cisco 4000 Family Integrated Services Routers.
7. Routers and SD-WAN devices operate continuously without any downtime, throughout the year.
8. All emission factors used in the calculation were sourced from the Department for Business, Energy and Industrial Strategy (BEIS): Government conversion factors for company reporting of greenhouse gas emissions 2022.
9. Primary data on the revenue generated from of SD-WAN in the UK was sourced from BT. Revenue data was attributed to thin edge and thick edge solutions according to the number of SD WAN devices sold and the cost ratio between the two solutions.
10. The embodied emissions of an average server in UK are used for calculations on the basis that legacy WAN routers and SD-WAN devices have on average the same types of components as a server The embodied emissions of all devices (both legacy WAN routers and SD-WAN devices) were estimated as a ratio of the embodied emissions of an average server in UK per weight.

Data sources

Data point	Source
Average weight of a legacy WAN router	CISCO datasheet
Average weight of SD-WAN thin edge devices	VMware SD-WAN Edge platform specifications
Average power consumption and weight of SD-WAN thick edge devices	CISCO datasheet
Average embodied emissions of a server in UK	Dell PowerEdge R640 estimated carbon footprint
Average weight of a server	Dell EMC PowerEdge R640 Technical Specifications
Average embodied emissions of devices	Calculated using the average embodied emissions of a server per one kilogram (from the two rows above)
Emission factors for UK grid electricity	DEFRA, 2022

Rebound effects

Not identified.

Secondary effects

Not identified.

3.5.2 B2B Cloud Services Computation Aggregation

Businesses use public cloud infrastructure as it gives them the ability to flexibly scale resources to track workload demand. Moving workloads to public cloud infrastructure also presents businesses with the opportunity to dramatically reduce the environmental footprint of their IT operations.

Carbon Savings Mechanism (Enabling effects)
BT Group's Cloud Connect Direct service provides direct connectivity to third party cloud providers (i.e., Microsoft Azure, Amazon Web Services). By providing this direct connectivity, BT Group is enabling companies to use cloud services, replacing the use of in-house computing infrastructure. Through this move, the customer will benefit from greater server utilisation and improved Power Usage Effectiveness (PUE). This can have the consequence of lower energy use and carbon emissions.

Calculation Methodology
The carbon abatement methodology assumes that a customer moves to public cloud from a typical mix of private cloud and dedicated IT. This is calculated as the average annual carbon abatement per customer, multiplied by the number of customers connected to public cloud enabled by BT Group per year.

The average annual carbon abatement per customer is calculated as the annual energy used per customer (prior to cloud services), multiplied by an emission factor for electricity less the equivalent annual energy used per customer (post cloud services), multiplied by an emission factor.

Formula
Carbon abatement (tCO_2e) = Average annual carbon abatement per customer (tCO_2e /year/customer) x Number of customers connected to public cloud enabled by BT Group per year (#/year)

Where: Average annual carbon abatement per customer (tCO_2e/year/customer) = [Annual energy used per customer (before) (kWh/year/customer) x Emission factor for electricity (customer) (tCO_2e/kWh)] – [Equivalent annual energy used per customer (after) (kWh/year/customer) x Emission factor for electricity (cloud provider) (tCO_2e/kWh)]

Customer's site (before public cloud scenario)
As explained in the assumptions below, an equivalent number of Virtual Machines (VM) was estimated, so that the energy consumption in the before and after scenario could be comparable.

Number of physical servers = 100 (assumed)

Equivalent number of virtual machines (VM) before public cloud (#) = Proportion of Dedicated IT servers (%) x Number of physical servers (100) + Proportion of Private Cloud servers (%) x Number of physical servers (100) x conversion ratio.

Conversion ratio = Private Cloud utilisation rate (%) / Dedicated IT utilisation rate (%)

- Server energy per year (kWh/server/year) = Server power (kW) x annual running hours (hours)
- Total annual servers energy (kWh/year) = Proportion of Dedicated IT servers (%) x Number of physical servers (100) x Server energy per year (kWh/server/year) x Dedicated IT PUE + Proportion of Private Cloud servers (%) x Number of physical servers (100) x Server energy per year (kWh/-server/year) x Private Cloud PUE
- Energy per customer server per year before cloud (kWh/ server/year) = Total annual servers energy (kWh/year) / Number of physical servers (100)
- Energy per VM per year before cloud (kWh/VM/year) = Total annual servers energy (kWh/year) / Equivalent number of virtual machines before public cloud (#)
- Annual energy used per customer (before) (kWh/year/customer) = Energy per customer server per year (kWh/server/year) x Number of physical servers on customer's site before migration to public cloud (#/customer)

Public cloud (after public cloud scenario)

Number of physical servers = 1 (assumed)

Equivalent number of virtual machines (VM) after public cloud (#) = Number of physical servers (1) x conversion ratio

Conversion ratio = Public Cloud utilisation rate (%) / Dedicated IT utilisation rate (%)

- Total annual servers energy (kWh/year) = Number of physical servers (1) x Server energy per year (kWh/server/year) x Public Cloud PUE
- Energy per public cloud server per year after cloud (kWh/ server/year) = Server energy per year (kWh/server/year) x Number of physical servers (1)
- Energy per VM per year after cloud (kWh/VM/year) = Total annual servers energy (kWh/year) / Equivalent number of virtual machines after public cloud (#)
- Equivalent annual energy used per customer (after) (kWh/year/customer) = Energy per VM per year after cloud (kWh/VM/year) x (Equivalent number of virtual machines before public cloud / Number of physical servers (100) (#number/server)) x Number of physical servers on customer's site before migration to public cloud (#/customer)

Functional Unit

Average carbon abatement per customer per year.

Assumptions

1. For the purpose of calculations, a notional number of physical servers (before migration to public cloud) was converted to an equivalent number of virtual machines so that the carbon saving per virtual machine could be calculated and used to compare the position before and after the migration to public cloud scenarios.
2. For dedicated IT, one virtual machine maps to one physical server.
3. Before the migration to public cloud, it is assumed that each customer would have a typical split between dedicated IT and private cloud computing of 60% / 40%.
4. It is assumed that servers run 24x7 throughout the year.
5. Weighted average server power consumption is 295 Watts.
6. Average server utilisation is assumed to be:
   - Dedicated IT – 15%
   - Private Cloud – 40%
   - Public Cloud 65%.
7. PUEs are assumed to be:
   - Customer dedicated PUE = 2
   - Customer private cloud PUE = 1.8
   - Public Cloud PUE = 1.2.
8. Studies indicate that the number of physical servers per enterprise may range from 1 - 100, depending on the number of employees. As the size of the different customers varies, an assumption of 51 physical servers per enterprise before migration to public cloud is made, based on the median value of the above range.
9. It is assumed that customers are UK based and therefore the UK grid electricity emission factor is used.
10. Electricity emission factors for cloud providers were calculated based on provider's average annual energy consumption during computation, storage, networking, memory usage, PUE and average emission factors of the grid electricity of different regions where the provider's data centres are located (calculation process described in Appendix B).

Data sources

Data point	Source
Proportion of Private Cloud servers	451 Research, 2019. The Carbon Reduction Opportunity of Moving to Amazon Web Services. Commissioned by Amazon Web Services.
Dedicated IT, Private and Public cloud utilization rate and PUE	CDP and Verdantix, 2019. Carbon Disclosure Project Study 2011 – Cloud Computing – The IT Solution for the 21st Century.
Typical server power	Weighted average using data from: Department of Energy/Berkeley Lab Centre of Expertise for Energy Efficiency in Data Centres (COE)
Number of physical servers on business's site	Applied Computer Research, Inc, 2011. Identifying IT Markets and Market Size by Number of Servers.
Emission factor for UK electricity	DEFRA and BEIS, 2022. UK Government GHG Conversion Factors for Company Reporting.
Emission factor for cloud providers (Microsoft Azure and AWS)	Calculated using data from: Thoughtworks, 2021. Cloud carbon footprint

Rebound effects
Not identified.

Secondary effects
Research indicates that carbon benefits may also arise in the form of lower embodied emissions when moving workloads to the cloud, as opposed to building their own infrastructure capacity. Hyperscale data centres are leaner and better utilised, and hyperscale supply chains for servers are highly optimised for lower use of materials, which in effect lowers the energy required to produce systems. In addition, cloud providers tend to use higher-performance processors than businesses because they can monetise them more effectively, so they require fewer servers to deliver the same overall performance. The reduction in embodied emissions could be added to the carbon abatement calculations in the future, if the impact is estimated as significant and data is available.

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Appendix B Additional detail on calculation of emissions factors

Calculation of third-party cloud provider emission factor

Estimating CO_2e emissions for cloud compute and storage services, as well as networking and memory usage, depends on various factors such as the specific cloud provider, the location of their data centres, the energy mix used to power them, the efficiency of the data centres, and the usage patterns of the services. To estimate the CO_2e emissions for cloud compute and storage services, the cloud provider's own publicly reported emissions data should be used, if available. Some cloud providers disclose their carbon footprint and related information, such as the total emissions generated by their data centres and the percentage of renewable energy used to power them.

The methodology used to estimate the carbon footprint of cloud services, based on the user's own data inputs such as the number of servers, storage capacity, and network usage. It is important to note that the estimates generated by these methods are approximations and may not reflect the exact emissions of a specific cloud provider.

Energy estimates:

- Energy consumption during computation (based on server utilisation): When a server is idle, it consumes some power to run basic functions such as maintaining network connections. This is known as the "minimum power" or "base power" consumption. As the server utilisation increases, the amount of power consumed also increases to accommodate the additional processing and memory requirements.
  - Average energy consumption during computation = Min Power + 50% (Average Utilization rate) x (Max Power - Min Power) x operating hours
- Energy consumption due to storage: The energy consumption due to storage can vary depending on the type of storage technology being used, such as hard disk drives (HDD) and solid-state drives (SSD). The estimated storage coefficient for HDD storage is 0.65 Watt-Hours per Terabyte-Hour and for SSD is 1.2 Watt-Hours per Terabyte-Hour.
  - Average energy consumption due to storage = Storage (TB-hr) x Storage coefficient (Wh/TB-hr)
- Energy consumption due to networking: The electricity used to power the internal network, such as switches, routers, and other networking equipment, is generally considered to be relatively small because the internal network is typically not responsible for the majority of the data processing and storage in a system. The energy consumption of the internal network can vary depending on the specific type and configuration of the networking equipment being used, as well as the amount of network traffic. Given these assumptions, the smallest coefficient available is 0.001 kWh/GB.
  - Average energy consumption due to Networking = Networking (GB) x Networking coefficient (kWh/GB)
- Energy consumption due to memory usage – to estimate the energy consumption of memory is to use the idle power consumption of the memory devices such as Dynamic Random-Access Memory DDR4 or DDR5. The estimated memory coefficient based on the average power consumption per GB memory is 0.000392 kWh/GB
  - Average energy consumption due to Memory usage = Memory (GB) x Memory coefficient (kWh/GB)
- Power Usage Effectiveness of data centre – After estimating the average energy consumption for compute, storage, networking and memory usage, it is necessary to multiply this by the cloud provider's Power Usage Effectiveness (PUE) to estimate the total energy consumption of the data centre. Here are the cloud provider PUEs being used – 1) AWS: 1.135, 2) GCP: 1.1, 3) Azure: 1.185

Carbon estimates:

- By using publicly available data on the emission factors for a given electricity grid and the cloud provider's data centre region, calculate the estimated CO_2e emissions for a specific amount of energy usage.
  - Average annual energy consumption of single cloud provider = Average energy consumption during computation + Average energy consumption due to storage + Average energy consumption due to Networking + Average energy consumption due to Memory usage + Data centre's PUE of cloud provider
  - Average annual carbon emissions = Average annual energy consumption × Emission factor of grid electricity (specific to region where data centre is located)
  - Carbon intensity = Total emissions due to all data centres (tCO_2e) / Total energy consumed by all data centre (kWh)
- Once a business has an estimate of the emissions associated with its usage of a cloud provider's services, the company can proportion the emissions due to the cloud provider based on their usage. This can be done by calculating the proportion of the cloud provider's total emissions that are attributed to the business's use of their services.
- For example, if a business's usage of a cloud provider's services is responsible for 1% of the provider's total emissions, then the business can say that 1% of the provider's total emissions is due to their usage.

Calculation of emission factor for transitioning from conventional car to battery electric vehicle

As of March 2022, there are approximately 37 million conventional petrol and diesel cars and vans on UK roads, compared to 450,000 BEVs. It is estimated that by 2030, up to 10 million vehicles, will be BEVs. The Committee on Climate Change (CCC) estimates that BEVs will comprise between 27-37% of the car and van fleet by 2030 in UK.[19]

Based on the above, an assumption is made that the composition of the average fleet will shift from 99% conventional vehicles and 1% BEVs in 2022, to 72% conventional vehicles and 20% BEVs in 2030. The average car emission factor, which is used in the glidepath calculations for the transition to BEVs, is adjusted accordingly.

- Average emissions due to conventional vehicle = Number of conventional cars × total distance travelled × Emission factor of an average car ($kgCO_2e/km$)
- Average emissions due to battery electric vehicle = Number of battery electric vehicles per × total distance travelled × Emission factor of battery electric vehicle ($kgCO_2e/km$)

This estimation assumes that the adoption rate of BEVs will continue to increase at a steady pace without any significant disruptions or barriers. It is also estimated that each year approximately 42% conventional vehicles will be replaced by BEVs.

[19] HM Government, 2022, Taking charge: the electric vehicle infrastructure strategy

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