REPORT

Alibaba Cloud's Carbon Benefits

A study on enabling effects of Alibaba's internet data centres

15 August 2022

ABOUT THE REPORT

Acknowledgments

The Carbon Trust authored this report based on an impartial analysis of primary and secondary sources.

This report was commissioned by Alibaba Cloud. For the avoidance of doubt, this report expresses independent views of the authors.

About the Carbon Trust

We are a trusted, expert guide to Net Zero, bringing purpose led, vital expertise from the climate change frontline. We have been pioneering decarbonisation for more than 20 years for businesses, governments and organisations around the world.

We draw on the experience of over 300 experts internationally, accelerating progress and providing solutions to this existential crisis. We have supported over 3,000 organisations in 50 countries with their climate action planning, collaborating with 150+ partners in setting science-based targets, and supporting cities across 5 continents on the journey to Net Zero.

CARBON TRUST

The Carbon Trust's mission is to accelerate the move to a decarbonised future.

Authors:

Tina Tingyu He

Senior Associate

tina.he@carbontrust.com

Roman Ziqing Chen

Senior Analyst

roman.chen@carbontrust.com

Ruiheng Jin

Analyst

ruiheng.jin@carbontrust.com

With additional technical support from Beatriz Fialho da Silva, Veronika Thieme, and Matt Anderson.

Contents

Tables

Figures

Abbreviations

AWS	Amazon Web Services
BAU	Business-as-usual
HDD	Hard disk drive
ICT	Information and communications technology
IDC	Internet data centre
ITU	International Telecommunication Union
kWh	kilowatt-hour
PUE	Power usage effectiveness
SDD	Solid-state drive

EXECUTIVE SUMMARY

With the rapid digitisation of the modern economy, the data centre sector is expected to grow in the coming years to meet the increasing demand for data processing and storage, and as such, the associated greenhouse gas emissions will also increase. The International Telecommunication Union[1] forecasts that these emissions may reach 141.5 million metric tonnes by 2030, up by nearly 30% compared to the 2020 level. The sector undoubtedly faces steep challenges to align with the Paris Agreement trajectory.

Meanwhile, emerging technologies such as cloud computing has significant potential to enable its customers to avoid emissions, as it allows computing resources to be aggregated and achieve greater energy efficiency than traditional, on-premise data centres owned by organisations to support internal operations. Previous studies on Amazon Web Services[2] and Microsoft Azure[3], for example, have attempted to quantify such carbon benefits for users switching from on-premise equivalents. As Alibaba deploys cloud computing technologies to power its cloud services in China and worldwide, there is increasing interest to understand the extent to which Alibaba Cloud can enable its customers to avoid emissions.

This study aims to improve the understanding of the carbon abatement Alibaba Cloud enabled for its China-based customers compared to continuing to use in-house data infrastructure. Following *Scope 3+ Emissions Reduction: A New Methodology for Corporate Climate Actions Beyond Value Chains* developed by Alibaba Group and CEC, and *The Avoided Emissions Framework* developed by the Carbon Trust, we compared Alibaba internet data centres' upstream, use phase, and downstream emissions with those of an on-premise equivalent scenario, where data are processed and stored in off-cloud servers run by internal data centres.

The results show that Alibaba Cloud, when running on Alibaba's owned internet data centres (IDC) in China, can help avoid 85.5% of the emissions for China-based users switching from on-premise equivalents. The largest carbon savings come from improved power usage effectiveness (PUE) and reduced power draw of servers during a data centre's use phase. Further efforts should be devoted to investigating Alibaba Cloud's carbon benefits when their leased data centres are considered and at a global scale.

[1] ITU (2020). Recommendation ITU-T L.1470: Greenhouse gas emissions trajectories for the information and communication technology sector compatible with the UNFCCC Paris Agreement.

[2] 451 Research (2019). The Carbon Reduction Opportunity of Moving to Amazon Web Services.

[3] Microsoft (2020). The carbon benefits of cloud computing.

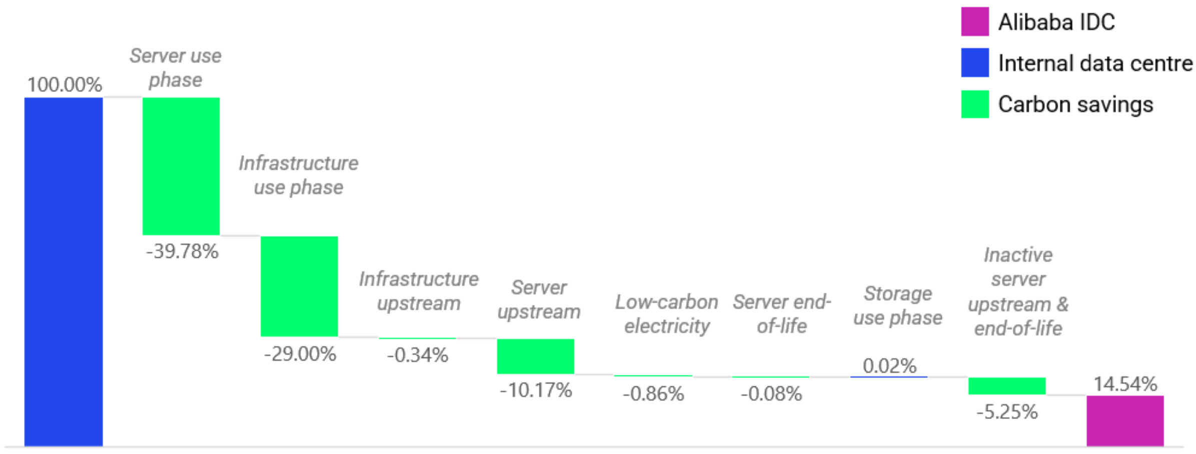

Figure 1: Alibaba IDCs' carbon benefits compared to internal data centres

1. INTRODUCTION

1.1. Data centres' energy consumption is on the rise and faces steep challenges for decarbonisation.

With the increasing use of data in our ever connected and digitised economy, data centres are expanding significantly, and with it comes the rapid growth in energy consumption. The International Telecommunication Union (ITU), the specialised agency under the United Nations coordinating global affairs related to the information and communication technology (ICT) sector, estimated that data centres in 2020 accounted for around 2% of the electricity consumed and 0.4% of greenhouse gas emitted globally[4].

As the data centre sector is expected to continue growing in the years to come, its greenhouse gas emissions can also grow significantly if decarbonisation measures do not take place. By 2030, the sector's absolute emissions are expected to increase by 10% in a business-as-usual scenario[5]. This trend poses significant challenges to a world already urgently in need of fast and deep emissions reduction to stay on track with goals set out by the Paris Agreement (see Figure 2).

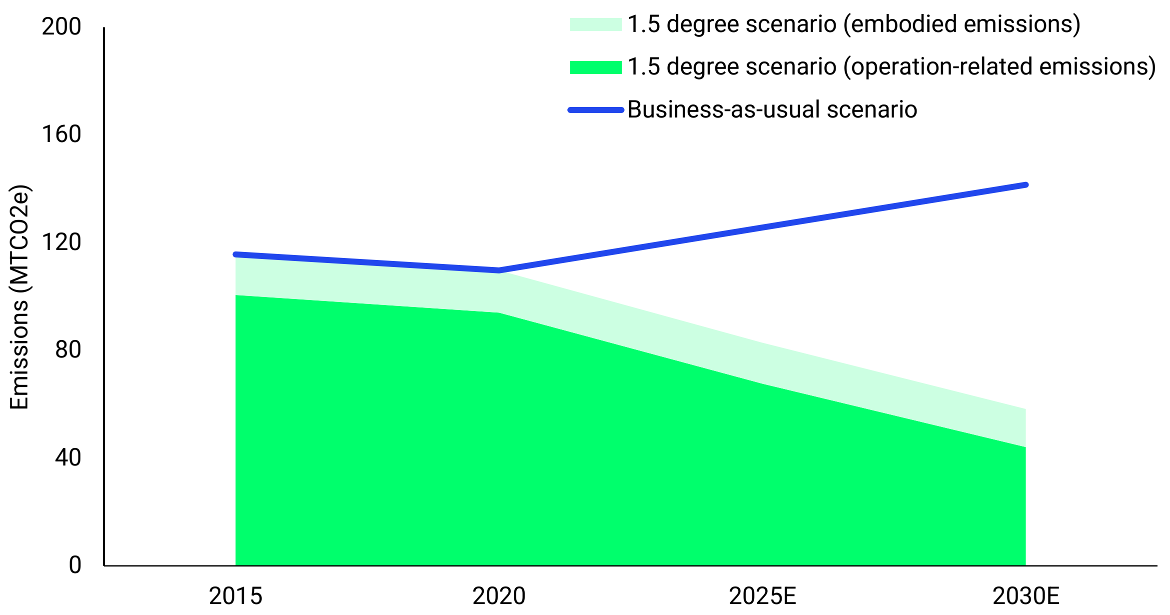

Figure 2: Data centres' emissions trajectories, 2015 to 2030[6]

[4] ITU (2020). Recommendation ITU-T L.1470: Greenhouse gas emissions trajectories for the information and communication technology sector compatible with the UNFCCC Paris Agreement.

[5] A business-as-usual scenario here refers to the scenario in which the energy mix of grid electricity remains unchanged from the current level. In this scenario, the increase in emissions result from increased electricity consumption, which is affected by a combination of trends such as consolidation, virtualization, hardware development, cloudification and Power Usage Effectiveness (PUE) development.

[6] Analysis from ITU (2020)

1.2. Cloud computing data centres can offer significant benefits in cutting down energy use and consequently greenhouse gas emissions.

To address the climate crisis, reducing the sector's own carbon footprint is only one part of the equation in achieving net zero – innovative solutions are urgently needed to enable the rapid reductions in emissions while meeting the world's needs[7] . As data centres play an ever more important role in our economy, companies that can supply low-carbon data processing and storage services hold significant potential in enabling their customers to avoid emissions, thus reducing the overall carbon footprint.

Cloud computing has emerged in recent years as a new computing paradigm that can significantly increase data centres' energy efficiency compared to conventional, on-premise data centres. Through aggregating computing resources, large-scale data centres coupled with cloud technologies can better manage the overall power consumption. As previous studies such as Accenture (2011)[8] explained (see Figure 3), cloud computing achieves this chiefly in three ways: dynamically provisioning computing capacity, multi-tenancy, and improved server utilisation.

1. **Dynamic provisioning:** On-premise data centres are commonly over-provisioned with active IT equipment to ensure peak business demands are met. Cloud computing enables computing resources to be dynamically provisioned, which optimises the matching of server capacity with actual demand.
2. **Multi-tenancy:** As the cloud serves multiple users at the same time, demand patterns become flattened, thus requiring less additional capacity to meet the overall peak demand, which in turn reduces the overhead for individual users.
3. **Server utilisation:** Cloud computing enables servers to run at high utilisation levels, meaning that the same demand can be done by fewer servers when compared to on-premise equivalents. Even though power use per server may increase according to the increased level of utilisation, it is still more energy efficient to run fewer highly utilised than more servers at low utilisation, because servers do not draw power perfectly proportional to their utilisation and still require power at low utilisation or even during idle periods.

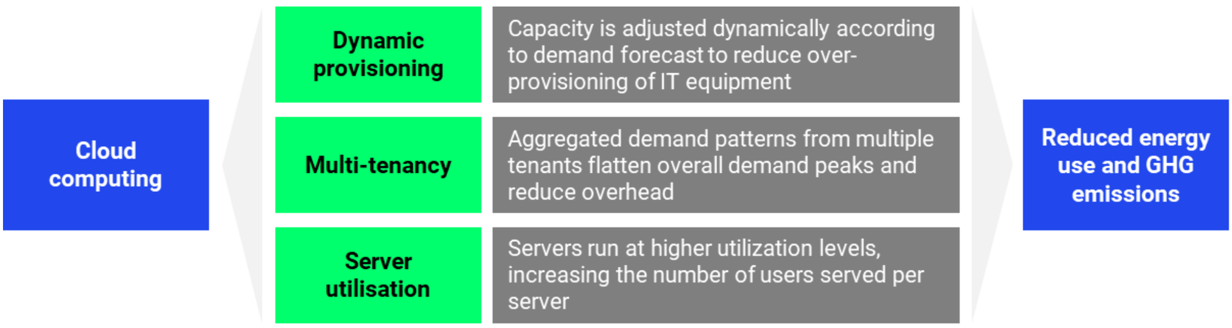

Figure 3: Cloud computing's carbon benefits[9]

---

[7] Stephens & Thieme (2020). The Avoided Emissions Framework. Mission Innovation.

[8] Accenture (2010). Cloud Computing and Sustainability: The Environmental Benefits of Moving to the Cloud.

[9] Adapted from Accenture (2010).

To date, selected cloud computing service providers have published studies on how their solutions are creating carbon benefits to their customers, that is, enabling them to create net enabled carbon abatement by switching from the less efficient, on-premise alternatives to their solutions. For example, a 2019 study commissioned by Amazon Web Services (AWS)[10] found that moving to AWS would result in a 72% reduction in carbon emissions from their enterprise baseline, whereas a 2020 Microsoft study[11] found that Azure Compute is 52 to 79% more energy efficient than its on-premise equivalent.

1.3. This study aims to improve the understanding of the carbon abatement Alibaba Cloud can enable for its customers compared to on-premise equivalents.

In 2021, Alibaba launched its carbon neutrality action report, committing to powering Alibaba Cloud with 100% clean energy by no later than 2030. By scaling its cloud-based solutions to a wider customer base – especially those who have relied on traditional, on-premise data facilities – Alibaba Cloud holds significant potential to reduce energy use and carbon footprint for its customers. It is in this context that the Carbon Trust was commissioned to conduct this study and establish a credible basis for quantifying Alibaba Cloud's carbon saving potential. This study assessed the energy saved and enabling effects for a China-based user switching to Alibaba Cloud from its on-premise equivalents.

1.4. Limitations of study

There are two major limitations of this study. First, though Alibaba Cloud is a global product that runs on servers in owned and leased data centres worldwide, this study only considered the IDCs owned by Alibaba in China, as data on leased data centres' power use effectiveness were not easily available. As Alibaba has direct control over these IDCs, they are likely to be more energy efficient than the leased data centres due to design choices made at the early stage. Thus, the findings may not be representative of Alibaba Cloud's carbon benefits at a global scale. Second, as Alibaba Cloud deploys a mix of owned and leased data centres in China to service China-based users, findings based on the owned IDCs are likely to also overestimate the carbon benefits for China-based users. For the avoidance of doubt, the carbon benefits or enabling effects described in this report refer specifically to enabled carbon abatement for a China-based user switching to Alibaba Cloud powered by its owned IDCs. Further studies will consider Alibaba Cloud product at a global scale where region-specific parameters will be adopted in calculation, and enablement factors will be generated to represent individual regions when measuring the carbon benefits of Alibaba Cloud compared to on-premises data centres.

[10] 451 Research (2019). The Carbon Reduction Opportunity of Moving to Amazon Web Services.

[11] Microsoft (2020). The carbon benefits of cloud computing.

2. METHODOLOGY

2.1. This study aligns with the *Scope 3+ Emissions Reduction: A New Methodology for Corporate Climate Actions Beyond Value Chains* and *The Avoided Emissions Framework* when calculate Alibaba Cloud's carbon benefits.

To date there is not yet an internationally uniform guidance on calculating the environmental benefits of ICT solutions, though efforts by the European Union are underway to establish relevant science-based methods[12]. *Scope 3+ Emissions Reduction: A New Methodology for Corporate Climate Actions Beyond Value Chains* [13] published by Alibaba Group and China Environmental United Certification Centre (CEC in short), together with *The Avoided Emissions Framework (2020)* [14]developed by the Carbon Trust have developed broad framework and methodologies that help corporates to measure carbon benefits. Following methodologies suggested in these two reports, this study defines Alibaba Cloud's carbon benefits, otherwise referred to as 'carbon savings' or 'enabled carbon abatement' in this report, as "reductions in emissions caused indirectly by a product… where a product provides the same or similar function as existing products in the marketplace, but with significantly less GHG emissions"[15].

The basis of the methodology is that the carbon benefits (i.e., net enabled carbon abatement) are calculated by comparing the GHG emissions from a business-as-usual (BAU) baseline scenario with those from a solution-enabled scenario to demonstrate the benefit of the solution to reduce overall system level GHG emissions.

$$Net\ avoided\ emissions = BAU\ baseline\ emissions - emissions\ of\ the\ solution\ enabled\ scenario$$

It should be noted that as one makes the switch from on-premise data centres to Alibaba Cloud, new emissions, otherwise known as "rebound effects", may occur. For example, because of technological advancement and massive efficiency gains, the cost of switching to cloud computing data centres is driven down, which may attract companies to bring more data processing to the cloud and consequently result in significant spikes in the service demand and power consumption. This study did not address these rebound effects due to the uncertainty in quantifying them.

---

[12] Global e-Sustainability Initiative (2022). The European Green Digital Coalition gets a boost by top Associations: Laying the foundational work for the digital and green twin transitions.

[13] Alibaba Group and CEC 2022. *Scope 3+ Emissions Reduction: A New Methodology for Corporate Climate Actions Beyond Value Chains*

[14] Stephens & Thieme (2020). The Avoided Emissions Framework. Mission Innovation.

[15] GHG Protocol Product Standard – see chapter 11, sections 11.2 and 11.3.2.

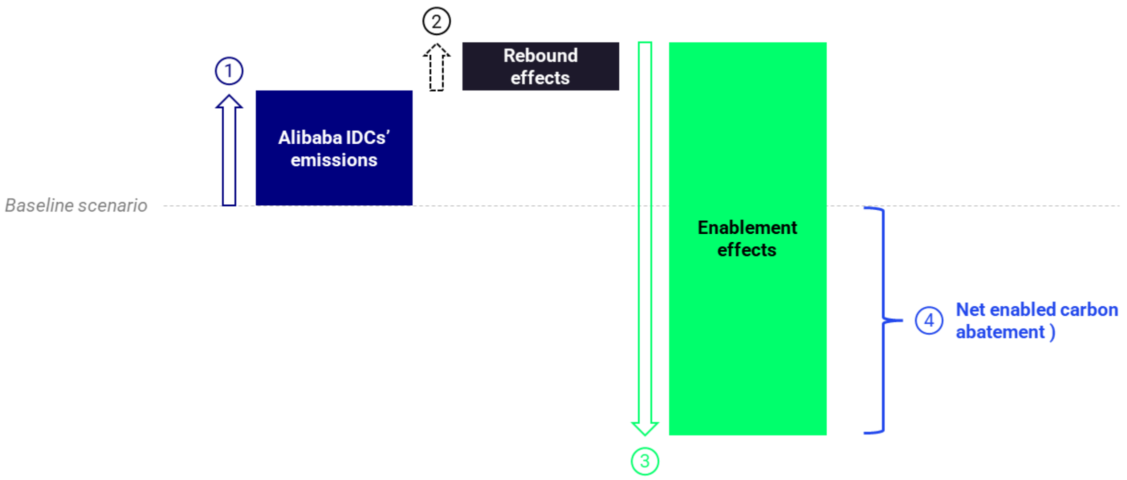

Figure 4: Framework for quantifying Alibaba IDCs' enabled carbon abatement

As suggested by *Scope 3+ Emissions Reduction: A New Methodology for Corporate Climate Actions Beyond Value Chains*, a baseline or BAU scenario determines the carbon emissions levels in the absence of a solution/intervention, and there is often more than one alternative solution/intervention under a BAU scenario. When establishing the baseline of cloud computing, three reference scenarios, namely internal data centre, service provider and hyperscale, defined in the Shehabi et al (2016)[16]were used to represent different space types of on-premise data centres.

Specifically, this study adopts "the most widely used scenario approach "[17] to determine the scenario that best reflect the market situation. As the 2020 market penetration of cloud computing in China is 7.5%[18], internal data centres, which are traditional facilities owned by business and institutions to support their internal administrative and general operations, were deemed as the major target to be replaced by cloud computing services and therefore considered as the baseline scenario in emission abatement measurement.

We also measured the carbon benefits of Alibaba Cloud when compared to the average service provider and hyperscale data centre scenarios. Results of these comparisons are presented in Appendix 1, as there is no credible data indicating the level of renewable electricity use in these scenarios, which render the results less robust.

---

[16] Shehabi et al (2016). United States Data Center Energy Use Report. Ernest Orlando Lawrence Berkeley National Laboratory.

[17] Alibaba Group & CEC (2022*). Scope 3+ Emissions Reduction: A New Methodology for Corporate Climate Actions Beyond Value Chains. The Avoided Emissions Framework (2020)*

[18] Market penetration was calculated by comparing the 2020 market scale of cloud computing and total IT expenditure in China. Data retrieved from *2022 China Cloud Computing Blue Book* developed by CCIA and *The IT Expenditure* released by *Gartner* in 2020.

2.2. A lifecycle approach was applied to estimate Alibaba Cloud's data centres' carbon footprint, covering upstream, use phase, and downstream emissions.

Based on *Scope 3+ Emissions Reduction: A New Methodology for Corporate Climate Actions Beyond Value Chains*, and *The Avoided Emissions Framework* (2020), Emissions reduction from a solution/intervention is the overall change in emissions across every phase of a product or service's lifecycle using the LCA approach.

Previously, data centre service providers such as AWS and Microsoft have published studies on the carbon benefits enabled by their respective products (see Table 1). Generally, a product's cradle-to-grave carbon footprint covers the following lifecycle stages: raw material production and distribution; product manufacturing; distribution and retail; the use phase; and lastly, disposal and recycling.[19] At the sectoral level, ITU's report on ICT sector emissions trajectories largely corresponds to the lifecycle boundary definition, including emissions of the data centre supply chain, manufacturers, operator's overhead, and electricity consumption.[20]

Table 1: Overview of the AWS and Microsoft studies

Service provider	Emission boundary	Analysis
aws	Embodied facility + Embodied IT + [CORE ENERGY CARBON MODEL: Grid - offset by renewable purchases x PUE x IT efficiency]	• Both studies prioritised the data centre's use phase emissions in their models. • Both studies took into consideration emissions related to manufacturing of the IT equipment. • The AWS study did not consider servers' emissions in the upstream (i.e. transportation) nor in the downstream (i.e. end-of-life treatment). • The Microsoft study considered the embodied emissions of the IT equipment but not those of the data centre infrastructure.
Microsoft	 Raw material extraction and assembly → Transportation → Use → End of life disposal	

Prioritising the most material lifecycle stages and considering data availability, this study included the following emissions associated with data centres.

1. **Upstream emissions:** The emissions associated with the IT equipment (including inactive servers) and data centre infrastructure, such as from materials, manufacturing, construction, and/or transportation processes, before the data centre is in operation.

2. **Use phase emissions:** The emissions from IT equipment during a data centre's use phase, including that of servers and storage devices, as well as power consumed to maintain the operations of the data centre infrastructure (e.g. for purposes of cooling, lighting, controls).

---

[19] British Standards Institution (2011). Publicly Available Standard 2050: Specification for the assessment of the life cycle greenhouse gas emissions of goods and services.

[20] ITU (2020). Recommendation ITU-T L.1470: Greenhouse gas emissions trajectories for the information and communication technology sector compatible with the UNFCCC Paris Agreement.

3. **Downstream emissions:** The emissions associated with the IT equipment (including inactive servers) from disposal and recycling processes at the end-of-life stage.

Table 2 provides an illustrative summary of the emissions included in this study's boundary when assessing Alibaba Cloud's carbon benefits. Detailed approaches and assumptions used to model these emissions are provided in Appendix 1:.

Table 2: Alibaba Cloud's emission boundary summary[21]

		Raw material production and distribution	Product manufacturing	Upstream transportation	Use phase	Disposal and recycling
IT equipment	Servers	No	Yes	Yes	Yes	Yes
	Inactive servers[22]	No	Yes	Yes	No	Yes
	Data storage drives	No	No	No	Yes	No
Data centre infrastructure		Yes	Yes	Yes	Yes	No

[21] Other IT equipment typically deployed in a data centre, such as the networking device, is deemed immaterial in terms of their energy consumption compared to that of servers and data storage equipment. Additionally, relevant network energy use data is limited to establish reference scenarios. Thus the networking equipment was not included within the boundary of this study.

[22] Inactive servers (also referred to as comatose or "zombie" servers) represent obsolete or unused servers that consume electricity but provide no useful information services.

3. FINDINGS

3.1. China-based internal data centres are estimated to emit as much as 6.9 times more than Alibaba IDCs, all else being equal.

All things equal, China-based internal data centres’ emissions are estimated to be 687.9% of those of Alibaba’s owned IDCs (Figure 5). This means there can be significant carbon benefits for China-based businesses and institutions to switch from their existing internal data infrastructure to Alibaba Cloud.

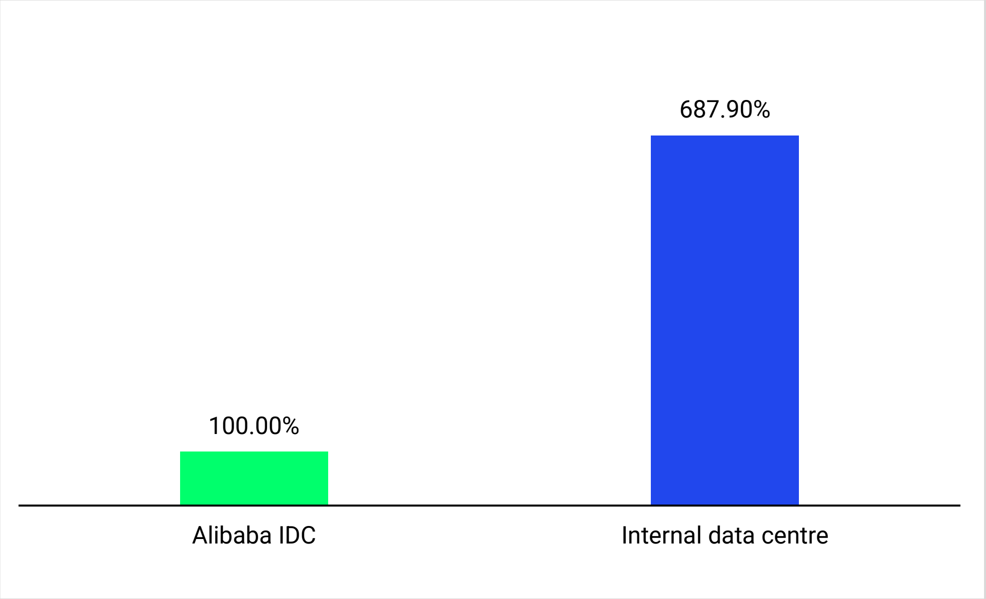

Figure 5: Alibaba IDCs' carbon benefits compared to internal data centres

3.2. Largest carbon savings come from the use phase, followed by those in the upstream; low-carbon electricity procurement is expected to further increase Alibaba Cloud’s carbon saving potential.

The switch to Alibaba Cloud powered by Alibaba’s owned IDCs can enable a China-based user to avoid 85.5% of the emissions associated with its current use of on-premise data centres (see Figure 6). Specifically, reduced server power use, which is driven by cloud computing as outlined in Figure 3 is the largest driver for carbon savings, accounting for 39.8% of total emissions avoided. The second largest source of enabled carbon abatement (29.0%) comes from improved PUE during the use phase. This is followed by reduced upstream emissions associated with the servers, which accounts for 10.2%, and reduced inactive-server embodied emissions (5.2%).

Finally, as Alibaba IDCs partly procure electricity from low-carbon sources[23], this contributes a further 0.9% of carbon savings compared to internal data centres[24]. This ratio is expected to grow in the coming years as Alibaba scales its clean energy purchase.

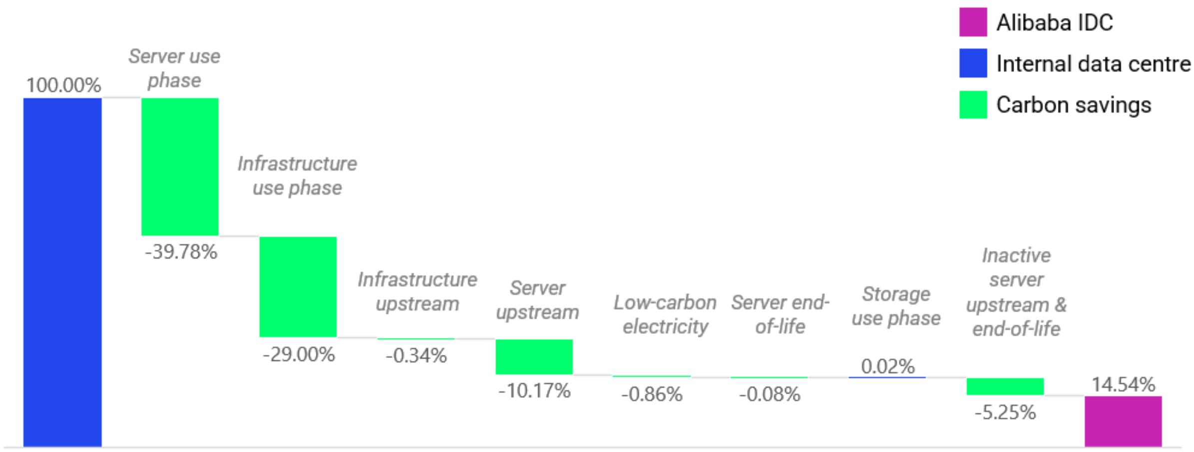

Figure 6: Drivers of Alibaba IDCs' carbon benefits

[23] In 2020, Alibaba purchased renewable electricity certificates and sourced electricity from natural gas plants. These have been collectively referred to as low-carbon electricity procurement.

[24] Given the state of renewable electricity market in China, this study assumed that the average internal data centre did not procure renewable electricity in the baseline year.

Appendix 1: Comparison with Other Scenarios

Following the same approach as Shehabi et al (2016), this study also investigated Alibaba Cloud's carbon benefits against the following reference scenarios:

1. **Service provider data centre scenario:** Facilities that provide data processing and/or storage as a core service of businesses, such as communication and social media companies. These data centres are often configured for more specialised and predictable operations.

2. **Hyperscale data centre scenario:** Large warehouse-size data centres that have emerged with the growth in cloud platforms, mobile devices, social media, and big data.

For a customer switching from an average service provider data centre, Alibaba Cloud can help achieve up to 75.9% of carbon savings, out of which 36.3% are from the server use phase, while infrastructure use phase accounts for 26.9%, followed by server upstream embodied emissions (9.3%) See Figure 7 for a detailed breakdown. Similarly for a customer switching from an average hyperscale data centre, Alibaba Cloud can help avoid up to 60.0% of the emissions, out of which 33.1% are from the server use phase, while infrastructure use phase accounts for 16.8%, followed by server upstream emissions at 8.5%. See Figure 8 for a detailed breakdown. It should be noted though that these comparisons do not consider renewable electricity usage, which may significantly skew these results given the increasing ambition levels of service providers and hyperscale data centres to power their services with renewables.

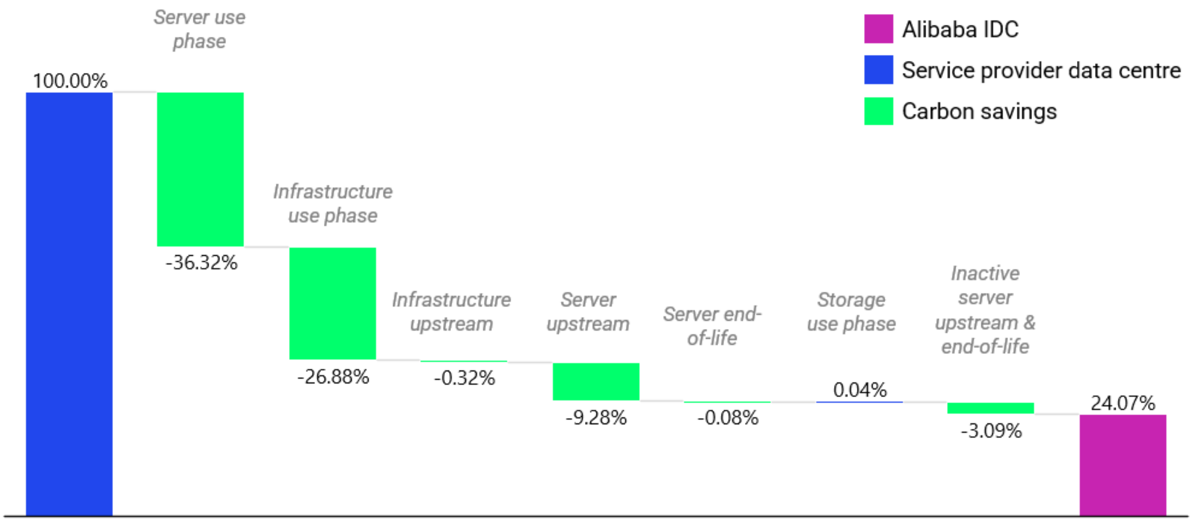

Figure 7: Alibaba IDCs' carbon benefits compared to service provider data centres

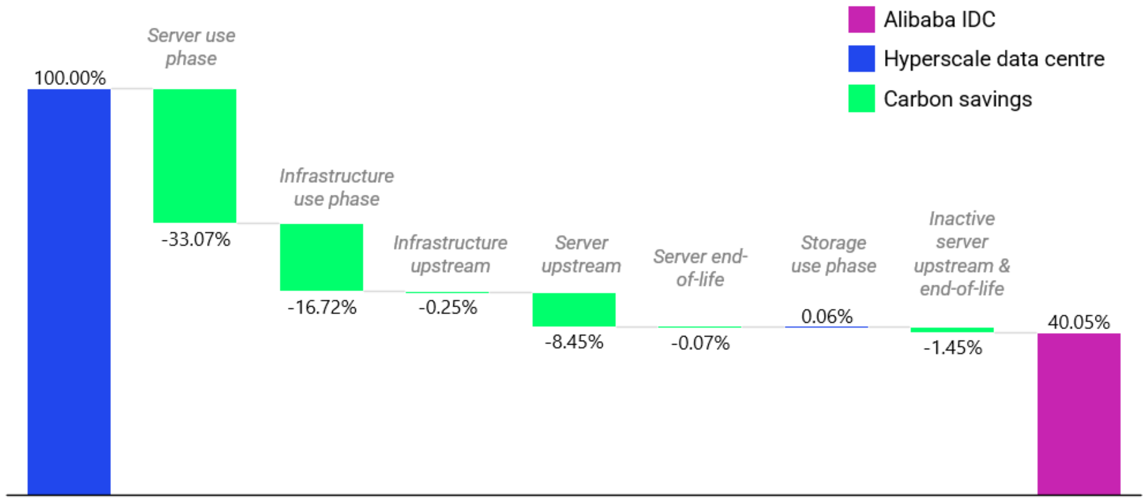

Figure 8: Alibaba IDCs' carbon benefits compared to hyperscale data centres

Appendix 2: Further Notes on the Methodology

Figure 9 summarises the overall modelling approach and the key parameters used to calculate emissions from the main sources associated with data centres within this study's boundary. Shehabi et al (2016) was referenced extensively for this study, including the modelling approach for server, storage, and data centre infrastructure-related use phase emissions and relevant key assumptions.

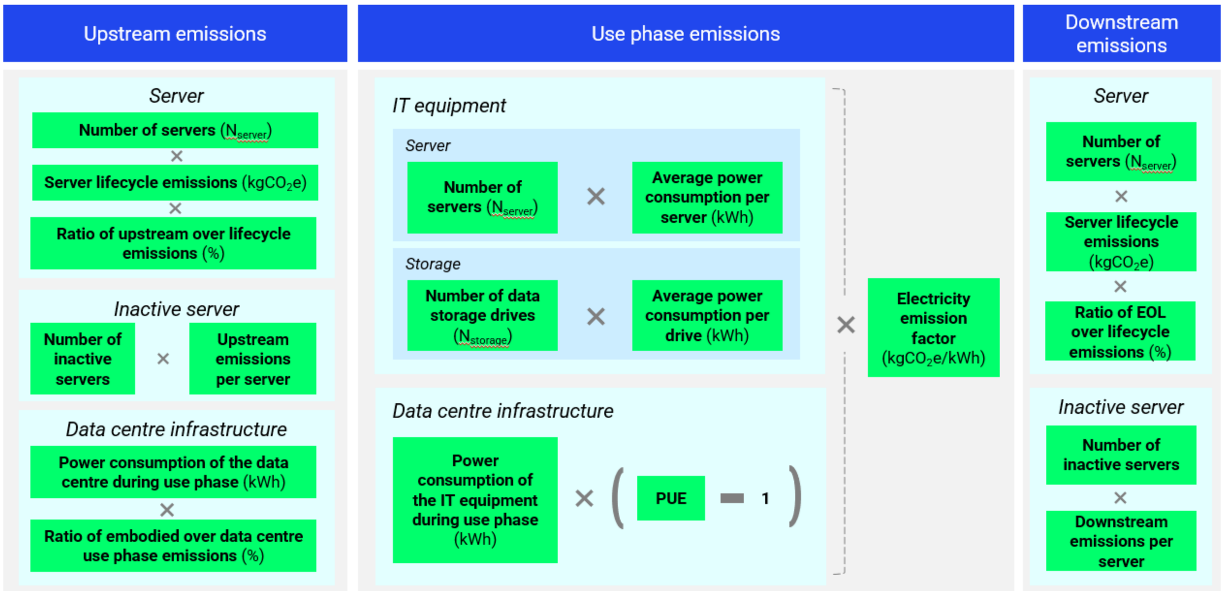

Figure 9: Overview of modelling approach

When modelling Alibaba IDCs' emissions, this study relied on product- and data centre-level data to ensure that the approach would remain consistent between Alibaba Cloud and the reference scenarios so that results are comparable. Emissions associated with Alibaba IDCs under this approach are not to be mistaken as actual carbon footprinting results, which should ideally be calculated by using actual energy use data. The Carbon Trust did not verify nor assure the accuracy of the proprietary data provided by Alibaba Cloud.

Modelling approach to use phase emissions

Three key sources of energy consumption during a data centre's use phase were considered: power consumption of servers, data storage drives, and the infrastructure needed to maintain a data centre's operation (e.g. cooling, lighting, controls).

Emissions from power consumption of servers are calculated using the following formula:

$$Emission_{server}^{use} = \left(N_{server} \times E_{server}^{avg} \right) \times EF_{elect} \qquad (1)$$

Where $Emission_{server}^{use}$ = emissions of server power consumption during use phase

N_{server} = number of servers

E_{server}^{avg} = average power consumption per server

EF_{elect} = emission factor for electricity

Assuming the server specifications across different scenarios do not differ in a material way, the number of servers meeting the same data demand would still vary, as servers under different scenarios are utilised at different rates. As servers draw power during idle periods and hence do not have perfect power-proportionality, i.e., using a percentage of maximum power when running at the same percentage of utilisation, low server utilisation adversely affects a data centre's power consumption. Conversely, when server utilisation is improved, such as by way of server consolidation, the number of servers needed to meet the same demand will reduce, which will in turn improve energy efficiency.

The server's power draw may vary across brands and models, though we could not meaningfully differentiate server power performance across different scenarios due to the lack of relevant data. Thus, we used the average performance figures based on publicly available data of 89 server models from 2019 to 2021[25].

To calculate the average power consumption per server, the following formulae were followed[26]:

$$m = P_{server}^{max} \times (1 - DR) \tag{2}$$

Where m = slope of utilisation verus power line
P_{server}^{max} = maximum server wattage
DR = dynamic range of server (fraction of max power used at idle)

$$P_{server}^{avg} = P_{server}^{max} - m \times (1 - u_{server}^{avg}) \tag{3}$$

Where P_{server}^{avg} = average server wattage
P_{server}^{max} = maximum server wattage
m = slope of utilisation verus power line
u_{server}^{avg} = average server utilisation

$$E_{server}^{avg} = P_{server}^{avg} \times H \tag{4}$$

Where E_{server}^{avg} = average power consumption per server
P_{server}^{avg} = average server wattage
H = total running hours of the server

Separately, to calculate the number of servers that could be consolidated in the reference scenarios, the following formulae were followed:

$$N_{server}^{con} = \frac{u_{server}^{post} - u_{server}^{overhead}}{u_{server}^{pre}} - \frac{1}{r_{server}^{pre}} \tag{5}$$

---

[25] Standard Performance Evaluation Corporation. SPECpower_ssj2008 Results. Accessed on 29 September 2021 from https://www.spec.org/power_ssj2008/results/.

[26] As acknowledged in Shehabi et al (2016), in the absence of data on utilisation rates for servers, this approach assumes a linear relationship between server utilisation and power consumption, while the actual relationship is generally non-linear, resulting in a loss of accuracy in modelling energy use at an average utilisation level.

Where N_{server}^{con} = number of servers that can be consolidated into one
u_{server}^{post} = post-consolidation server utilisation
$u_{server}^{overhead}$ = consolidation utilisation overhead
u_{server}^{pre} = pre-consolidation server utilisation
r_{server}^{pre} = fraction of pre-conslidation servers that are non-inactive

$$N_{server}^{i} = N_{server}^{con} \times N_{server}^{Ali} \quad (6)$$

Where N_{server}^{i} = number of servers in reference scenario i
N_{server}^{con} = number of servers that can be consolidated into one
N_{server}^{Ali} = number of Alibaba IDCs' servers

Alibaba IDCs' target server utilisation was 98%, which was used as the post-consolidation server utilisation rate when compared with the reference scenarios. Different server utilisation rates and non-inactive rates of per-consolidation servers were assumed for the reference scenarios (see Table 3), and a 5% of consolidation utilisation overhead was assumed across scenarios to account for applications that must be run on the server to balance multiple workloads.

Table 3: Server utilisation assumptions for the reference scenarios[27]

Scenario	Average server utilisation	Non-inactive rate of pre-consolidation servers
Internal data centre	15%	70%
Service provider data centre	25%	80%
Hyperscale data centre	50%	90%

Emissions from power consumption of data storage equipment are calculated using the following formula:

$$Emission_{storage} = (N_{storage} \times P_{storage}^{avg}) \times EF_{elect} \quad (7)$$

Where $Emission_{storage}$ = emissions from power consumption of data storage equipment
$N_{storage}$ = number of data storage drives installed
$P_{storage}^{avg}$ = average power consumption per drive
EF_{elect} = emission factor for electricity

The data storage equipment is disaggregated by type to reflect the difference in storage equipment use across scenarios. The two most common types, hard disk drive (HDD) and solid-state drive (SSD), are

[27] Shehabi et al (2016). United States Data Center Energy Use Report. Ernest Orlando Lawrence Berkeley National Laboratory.

considered[28]. The average wattage per disk is assumed to be 6.5W per HDD and 6W per SSD[29]. The following use profiles are assumed for each reference scenario:

Table 4: Data storage equipment assumptions for the reference scenarios[30]

Scenario	HDD use	SSD use
Internal data centre	52.2%	47.8%
Service provider data centre	52.2%	47.8%
Hyperscale data centre	52.2%	47.8%

Emissions from data centre infrastructure power consumption are calculated using the following formula:

$$Emission_{infra}^{use} = EF_{elect} \times E_{IT}^{use} \times (PUE - 1) \tag{8}$$

Where $Emission_{infra}^{use}$ = emissions from data centre infrastructure power consumption

EF_{elect} = emission factor for electricity (other energy sources, such as diesel, are considered immaterial and hence excluded from calculation)

E_{IT}^{use} = power consumption of the IT equipment during use phase

PUE = data centre's power use effectiveness

For the reference scenarios, the following assumptions were applied:

Table 5: PUE assumptions for the reference scenarios

Scenario[31]	PUE[32]
Internal data centre	1.63
Service provider data centre	1.60

[28] China Academy of Information and Communications Technology (2020). Research report on data storage technology of the next generation.

[29] Shehabi et al (2016). United States Data Center Energy Use Report. Ernest Orlando Lawrence Berkeley National Laboratory.

[30] The breakdown of HDD versus SSD use in the service provider scenario is based on the estimated global output volume of the two drive types in 2020, available at Qianzhan (2021). Based on our interview, data centres make procurement decisions based on storage performance, capacity, price, and speed of the storage equipment, and there is no fixed preference attached to each scenario types. Therefore, the same ratio is applied when calculating the enablement impact on storage

[31] Classification of data center types from Shehabi et al (2016).

[32] PUE values extrapolated from China Green Data Center Development Report (2020). The report published empirical data on average PUE of data centres of various sizes in China. The classification from Shehabi et al. (2016) is applied to group those data centres into 3 scenarios, and the average PUEs are calculated.

Hyperscale data centre	1.40

Modelling approach to upstream emissions

Upstream emissions of IT equipment are calculated using the following formula:

$$Emission_{IT}^{embodied} = \frac{Emission_{IT}^{lifecycle} \times R_{IT}^{embodied}}{Lifespan_{IT}} \quad (9)$$

Where $Emission_{IT}^{embodied}$ is the upstream emissions of IT equipment
$Emission_{IT}^{lifecycle}$ is the lifecycle emissions of IT equipment
$R_{IT}^{embodied}$ is the ratio of IT equipment's upstream over lifecycle emissions
$Lifespan_{IT}$ is the average lifespan of IT equipment

This study only covered servers for IT equipment-related upstream emissions, as Alibaba Cloud reported no use of other types of IT equipment. Based on publicly available lifecycle analysis results, the ratio of a server's upstream emissions over its lifecycle emissions is assumed to be 20.32%, including 19.64% for manufacturing and 0.68% for transportation.[33] It should be noted that raw material-related emissions were not accounted for due to the lack of such relevant information.

All embodied emissions, including upstream and end-of-life emissions, are divided by the respective assumed lifespan (Table 6) of the equipment of infrastructure to account for the carbon savings in one year.

Table 6. Assumed lifespan for servers and data centre infrastructure

Subject	Lifespan (yr)
Servers	4[34]
Data centre infrastructure	20[35]

Upstream emissions of inactive IT equipment are calculated using the following formula:

$$Emission_{inactive\ IT}^{embodied} = \frac{\frac{Emission_{IT}^{embodied}}{\#\ of\ IT} * \#\ of\ inactive\ IT}{Lifespan_{inactive\ IT}} \quad (10)$$

Where $Emission_{inactive\ IT}^{embodied}$ is the upstream emissions of inactive IT equipment
$Emission_{IT}^{embodied}$ is the upstream emissions of active IT equipment
$\#\ of\ IT$ is the number of active IT equipment

[33] Dell (n.d.). Product carbon footprints. Accessed from https://corporate.delltechnologies.com/en-us/social-impact/advancing-sustainability/sustainable-products-and-services/product-carbon-footprints.htm#tab0=3.

[34] Shehabi et al (2016). United States Data Center Energy Use Report. Ernest Orlando Lawrence Berkeley National Laboratory.

[35] ITU (2020). Recommendation ITU-T L.1470: Greenhouse gas emissions trajectories for the information and communication technology sector compatible with the UNFCCC Paris Agreement

$\# \, of \, redun \, IT$ is the number of inactive IT equipment

$Lifespan_{inactive \, IT}$ is the average lifespan of inactive IT equipment

The upstream emissions, i.e., manufacturing and transportation emissions, of an inactive server are assumed to be the same as those of a active server. For the reference scenario, the number of inactiveinactive servers is derived from the active rate of pre-consolidation servers (Table 3). For Alibaba's owned data center, the number of inactiveinactive servers is provided.

Upstream emissions of data centre infrastructure are calculated using the following formula:

$$\boldsymbol{Emission_{infra}^{embodied} = (Emission_{IT}^{op} + Emission_{infra}^{op}) \times R_{infra}^{embodied}} \quad (11)$$

Where $Emission_{infra}^{embodied}$ is the upstream emissions of the data centre infrastructure

$Emission_{infra}^{op}$ is the use phase emissions of the data centre infrastructure

$R_{infra}^{embodied}$ is the ratio of data centre infrastructure's upstream over use phase emissions

As power consumption data for the data centre infrastructure were not available for the reference scenarios, a high-level extrapolation was done to model the relevant emissions by applying a ratio of 10%[36] to the use phase emissions of a data centre.

Modelling approach to downstream emissions

Emissions from end-of-life treatment of decommissioned IT equipment (only considering decommissioned servers) are calculated using the following formula:

$$Emission_{IT}^{eol} = \frac{N_{IT} \times Emission_{IT}^{LCA} \times R_{LCA}^{eol}}{Lifespan_{IT}} \quad (12)$$

Where $Emission_{IT}^{disposal}$ = emissions from the disposal of decommissioned IT equipment

N_{IT} = number of decommissioned IT equipment

$Emission_{IT}^{LCA}$ = lifecycle emissions of the IT equipment

R_{LCA}^{eol} = ratio of the IT equipment's end-of-life treatment-related over lifecycle emissions

$Lifespan_{IT}$ = the average lifespan of IT equipment

This study only covered servers for IT equipment-related end-of-life emissions, as Alibaba Cloud reported no use of other types of IT equipment. Based on publicly available lifecycle analysis results, the percentage of a server's end-of-life emissions is assumed to be 0.17% of its lifecycle emissions.[37]

Emissions from end-of-life treatment of decommissioned inactive IT equipment (only considering decommissioned servers) are calculated using the following formula:

$$\boldsymbol{Emission_{inactive\,IT}^{eol} = \frac{\frac{Emission_{IT}^{eol}}{\# \, of \, IT} * \# \, of \, inactive \, IT}{Lifespan_{inactive\,IT}}} \quad (13)$$

Where $Emission_{inactive\,IT}^{eol}$ = the disposal emissions of decommissioned inactive IT equipment

---

[36] ITU (2020). Recommendation ITU-T L.1470: Greenhouse gas emissions trajectories for the information and communication technology sector compatible with the UNFCCC Paris Agreement

[37] Dell (n.d.). Product carbon footprints. Accessed from https://corporate.delltechnologies.com/en-us/social-impact/advancing-sustainability/sustainable-products-and-services/product-carbon-footprints.htm#tab0=3.

$Emission_{IT}^{eol}$ = the disposal emissions of active IT equipment

$\# \, of \,\, IT$ is the number of active IT equipment

$\# \, of \,\, redun \, IT$ is the number of inactive IT equipment

$Lifespan_{redun \, IT}$ is the average lifespan of inactive IT equipment

It is also assumed that the end-of-life emissions for an inactive server is the same as its active counterpart.

Appendix 3: Data Quality

This study follows the data quality guidelines prescribed in *Scope 3+ Emissions Reduction: A New Methodology for Corporate Climate Actions Beyond Value Chains*, and *The Avoided Emissions Framework* (2020) .

Four major principles below were considered in data source selection:

- **Relevance:** Data source should offer relevant information about the geographic location and should have an appropriate level of granularity required for calculation.
- **Timeliness:** Data source should reflect up-to-date market conditions. As far as possible, data in the current reporting year should be used. If such data is unavailable, previous year's data can be accepted.
- **Credibility**: The reporting company should reference multiple credible sources of data, preferably from official sources, followed by industry sources. If neither is available, the company may refer to publicly released academic papers and reports.
- **Conservativeness**: When there are significant deviations between sources, the company should take the data that gives the most conservative estimates

To avoid choosing data or assumptions that are biased, this study compared multiple sources and choose the source(s) with the most relevant time and geographic information. All data sources, assumptions and relevant justifications that were used in calculations were documented and clearly referenced.

carbontrust.com

+44 (0) 20 7170 7000

The Carbon Trust is a company limited by guarantee and registered in England and Wales under Company number 4190230 with its Registered Office at: 4th Floor, Dorset House, 27-45 Stamford Street, London SE1 9NT.

Published in the UK: 2022