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Pathways

Digital infrastructure: Transmitting signals of growth

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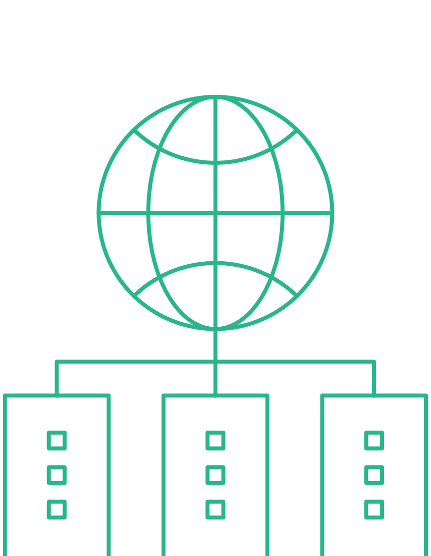
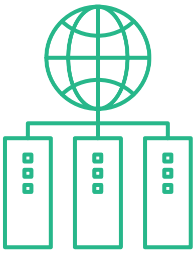
Introduction: Digital infrastructure in a zettabyte world





The opening of the public internet in 1989[1] has had a profound impact on the functioning of modern society and ushered in a period of rapid technological change. More than 4.9 billion[2] people used the internet in 2022, up from 413 million[3] in 2000, representing more than a tenfold increase over two decades. Global internet traffic has experienced dramatic growth, from 36.5 terabytes in 1992 to an estimated 3 zettabytes (a zettabyte contains about one billion terabytes) in 2020, a compound annual growth rate (CAGR) of 92 per cent for 28 years.[4] As data use and creation continue to grow, and the need for reliable high-speed connectivity increases, the demand for new and upgraded digital infrastructure is likely to expand significantly.

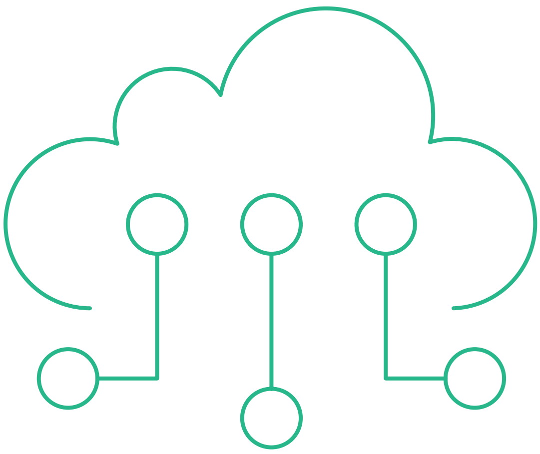
Digital infrastructure assets – data centres, wireline and wireless – play a vital role in enabling everyday activities and promoting economic growth. As a result, institutional investors have been increasingly recognising the critical role of these assets. Between 2010 and 2021, global annual digital infrastructure equity deal volume increased more than tenfold, from $US10.3 billion to $US116 billion.[5] At the same time, the investment universe continues to expand on the back of the constant evolution of use cases that require increased bandwidth and lower latency. Fifth-generation (5G) mobile technology requires densification of networks through the deployment of small cells in addition to towers, while the need for high-speed reliable internet in homes and offices is driving demand for fibre optic connectivity. Complementing the significant growth in consumer connectivity, the digital transformation of enterprises increasingly requires cloud-based applications and data centre services in strategic locations.

1. Refers to the invention of the World Wide Web (WWW) by Tim Berners-Lee.
2. Equivalent to 62.5 per cent of the global population according to Statista, “Global digital population” (January 2022).
3. Our World in Data, “Internet”, accessed on 22 February 2022.
4. World Bank “World Development Report 2021: Crossing Borders”.
5. Compound annual growth rate (CAGR) of 24.6 per cent, based on Inframation database (2021).

This note is split into six sections. In the first section, we analyse digital megatrends – including video streaming, cloud computing, E-commerce, artificial intelligence (AI), and others – that drive demand for digital infrastructure. The second section provides an overview of the digital ecosystem and examines technical aspects of copper, coaxial, and fibre optic cables. It also explains the benefits of the 5G frequency spectrum and discusses the different types of data centres. The third section describes the mechanics of tower carve-outs and how the process can unlock value for infrastructure investors. The fourth section examines the infrastructure spin-off in the wireline segment and its impact on fibre deployments. The fifth section analyses the trends in the data centre market and the drivers behind core and emerging locations. In the sixth and final section, we explore ways to decarbonise digital infrastructure. While digital infrastructure may emit almost as much greenhouse gas (GHG) emissions as the aviation sector,[6] digital infrastructure assets have strong potential to reduce carbon emissions directly through energy efficiency improvements and the sourcing of renewable power, and indirectly by improving the efficiency of other sectors.

6. According to Our World in Data (2020), the aviation sector accounts for 1.9 per cent of global GHG emissions, while digital infrastructure may be responsible for up to 1.8 per cent of global emissions. See details in the sixth section.

Digital megatrends: The Internet of Everything



Since 2010 global internet traffic has increased 15-fold, driven by both consumer and business demand.[7] For consumers, the internet has become an integral part of everyday life: from communication to entertainment, work, and learning. For businesses, the proliferation of data and its intense use, along with the growth of cloud computing, AI, and automation have not only helped to optimise costs and increase efficiency but have also unlocked new growth opportunities.

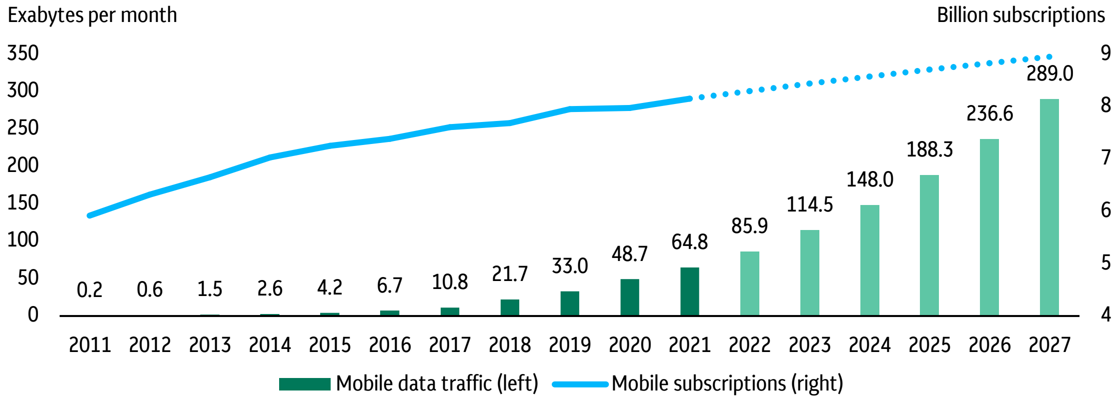
A consequence of the broad-based take-up of digital technologies and rapid growth in data use is an increase in the amount of infrastructure needed to facilitate this growth. The continuous evolution of new use cases leads to the emergence of applications that require increased bandwidth, higher capacity, and lower latency, thus driving the demand for digital infrastructure. For fixed networks, this translates into a need to replace legacy copper wires with fibre optic cables, while for wireless infrastructure, 5G requires both the rollout of fibre and new cell sites to meet the growing demand.

7. International Energy Agency (IEA) (November 2021).

Mobile communications: Data traffic to double by 2024

Global mobile data traffic has grown from 0.2 exabytes (EB) per month in 2011 to 65 EB per month in 2021, a CAGR of 76 per cent[8] over the period. There have been two primary reasons for this growth: the rising number of mobile subscriptions and increasing data traffic per subscription. With mobile penetration maturing, traffic demand per device is expected to be the main driver of future mobile traffic growth. Global monthly average usage per smartphone[9] is forecast to grow fourfold, from an estimated 11.4 GB in 2021 to 41 GB in 2027. This strong growth is likely to be enabled by three drivers: improved device capabilities, growth in data-intensive content (e.g. video streaming), and improvements in digital infrastructure (e.g. availability of 5G). Mobile traffic growth is expected to grow at a CAGR of 28 per cent between 2022 and 2027 (Figure 1).[10]

Figure 1:
Global mobile traffic is forecast to grow strongly on the back of greater consumption of data-intensive content, better infrastructure, and enhanced device capabilities



Source: Ericsson Mobility Report (November 2021).

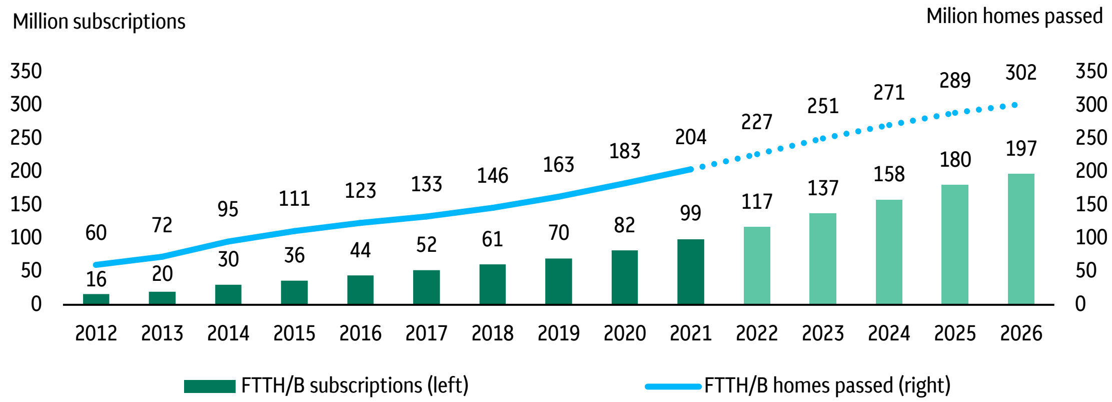
8. Ericsson Mobility Report (November 2021).
9. Smartphones generate most of the mobile data traffic (about 97 per cent).
10. Ericsson Mobility Report (November 2021).

Fixed broadband: Fibre, fibre, fibre

Mobile internet accounts for about half[11] of web traffic worldwide, with the rest of the traffic mainly coming from fixed broadband connections. Fixed broadband networks have seen a significant increase in demand over the past decade as the deployment of fibre optic cable has provided reliable, high-speed internet access for households and businesses. In Europe, fibre-to-the-home (FTTH) subscriptions have increased at a 22.7 per cent CAGR since 2012 (Figure 2). The COVID-19 pandemic drove an uplift in demand, with global fixed data traffic growth of 42 per cent[12] in 2020. In addition, fibre backbone infrastructure is a prerequisite for 5G rollout, as it provides higher bandwidth and lower latency (details in the next section).

Governments worldwide have been actively promoting the deployment of fibre networks as part of their digital agendas to provide very high-speed connectivity to more people and businesses. In the EU, the European Commission has adopted the Connectivity for a European Gigabit Society strategy that aims for access to at least 100 megabits per second (Mbps) for all households and 1 gigabit per second (Gbps) for so-called socio-economic drivers such as schools, universities, hospitals by 2025.[13] By 2030, the EU aims to cover all households with a Gigabit network and all populated areas with 5G under the Digital Decade for Europe plan.[14] In the US, the Infrastructure Investment and Jobs Act signed into law in November 2021 also aims to ensure reliable high-speed broadband access to all citizens.[15]

Figure 2:
Fibre-to-the-home/building (FTTH/B) connections and homes passed in EU27+UK



Source: FTTH Council Europe (September 2021).

11. Statista, "Share of global mobile website traffic 2015-2021" (February 2022).
12. Analysys Mason, "Fixed network data traffic: worldwide trends and forecasts 2020–2026".
13. European Commission, "Connectivity for a European Gigabit Society" (February 2021).
14. European Commission, "Europe's Digital Decade: digital targets for 2030" (March 2021).
15. Reuters, "Biden signs $1 trillion infrastructure bill into law" (November 2021).

Consumer megatrends: Flight to digital

Technological advancements have been driving consumers online for years, but the pandemic has accelerated several trends in consumer behaviour, with many activities shifting to fully online or hybrid formats. While the long-term impact of the pandemic is yet to be fully understood, several key trends are driving an acceleration in data consumption and demand for digital infrastructure.

- **Video sharing and streaming.** Video accounts for the largest share of traffic generated on smartphones, amounting to 69 per cent of all mobile data traffic in 2021. Video mobile traffic is forecast to grow at a CAGR of 29.9 per cent to 2027[16] (Figure 3). The growth is expected to be driven by longer viewing times, new types of streaming (e.g. virtual reality), and enriched video content across social media platforms.
- **E-commerce.** Online shopping accounted for 18 per cent of the global retail market in 2020. Strong tailwinds – urbanisation, the ease of internet banking, and growth in fixed and mobile subscriptions – are forecast to increase the share of e-commerce to 25 per cent[17] in 2025 (Figure 4), adding to data consumption and demand for digital infrastructure.
- **Online learning.** E-learning was rising in popularity before the COVID-19 pandemic, but growth, particularly in professional training, has accelerated since 2020. Employer provision of online learning to employees increased fivefold in 2020,[18] while the overall e-learning market is forecast to grow at a 24 per cent CAGR from now until 2026.[19]
- **Virtual health.** The COVID-19 pandemic has accelerated the demand for telehealth. After an initial spike, telehealth adoption has stabilised at around 17 per cent[20] of all outpatient visits, above the pre-pandemic 11 per cent adoption rate. Growing investment in the sector, technological innovation, and emerging business models all point to accelerating demand for telehealth, which will in turn increase demand for fast and reliable digital infrastructure.
- **Hybrid working.** While the full effect of the pandemic's impact on long-term working patterns is yet to settle, estimates suggest that 20 to 25 per cent[21] of the workforce may be working from home between three and five days a week. This will likely add another layer of demand, accelerating the need for FTTH.

16. Between 2022 and 2027, according to Ericsson Mobility Report (November 2021).
17. Statista, "E-commerce as percentage of total retail sales worldwide from 2015 to 2025" (August 2021).
18. World Economic Forum, "These 3 charts show the global growth in online learning" (January 2022).
19. Statista, "Size of the global e-learning market in 2019 and 2026, by segment" (June 2020).
20. McKinsey, "Telehealth: A quarter-trillion-dollar post-COVID-19 reality?" (April 2021).
21. McKinsey, "The future of work after COVID-19" (February 2021).

Figure 3:
Video mobile traffic is forecast to grow at a CAGR of 29.9 per cent from 2022 to 2027

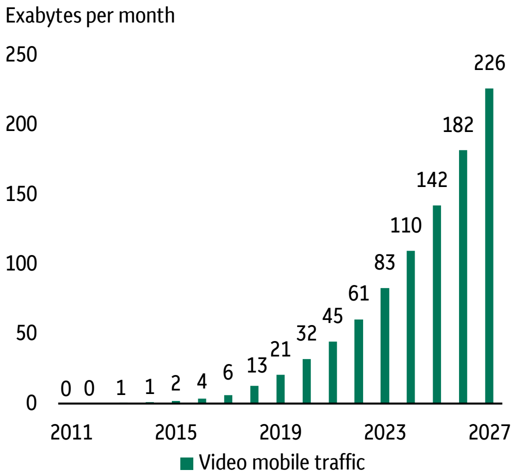
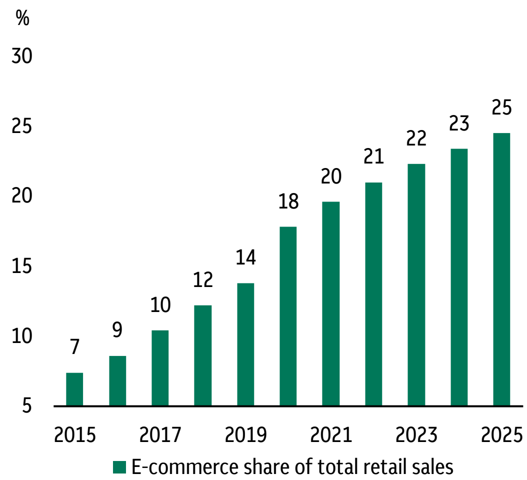


Figure 4:
E-commerce is expected to account for 25 per cent of global retail sales in 2025



Sources: Ericsson Mobility Report (November 2021), Statista (August 2021).

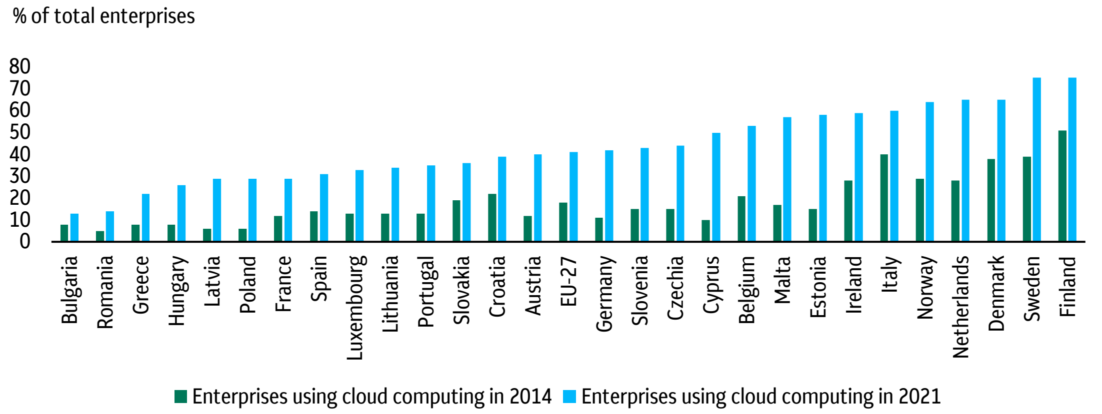
Enterprise demand: Mass migration to the cloud unlocks new potential

Businesses have been increasingly relying on cloud computing for storing and processing data instead of using on-premise servers. In the EU, the proportion of enterprises using cloud computing has increased from 18 per cent to 41 per cent between 2014 and 2021 (Figure 5).[22] The cloud is a large network of servers that can deliver software and services over the internet or dedicated private networks. In many cases, using cloud computing is cost-efficient as it does not require building out and maintaining on-premise information technology (IT) infrastructure. According to McKinsey, businesses may reduce IT overhead costs by up to 40 per cent and incidents by up to 70 per cent[23] by using the cloud, providing significant upside to employee productivity. This large-scale development of these cloud computing resources has been a key source of demand for data centre capacity.

22. Eurostat database on cloud computing services (February 2022).
23. McKinsey, “Cloud adoption to accelerate IT modernization” (April 2018).

With cloud computing enabling more efficient data storage and processing, the use of big data has become more affordable and scalable. As companies are able to collect more real-time data, there is an increased demand for data-driven solutions to analyse consumer trends. Evolving techniques using AI can enhance big data analytics and provide greater insights to businesses. For example, natural language processing (NLP) – a branch of AI – uses algorithms to analyse human communications on social media and provide valuable insights into customer acquisition, retention, and engagement. According to the International Business Machines Corporation (IBM) Global AI Adoption Index 2021, 43 per cent of businesses reported an acceleration in AI rollout due to the COVID-19 pandemic.[24] As AI applications grow, there could be a very rapid increase in synthetic data generation. Synthetic data refers to data that are artificially generated by algorithms and statistical techniques to complement real-world data.

Figure 5:
Cloud adoption by EU businesses has grown from 18 per cent of enterprises to 41 per cent over seven years



Source: Eurostat database on cloud computing services (2021).

Another source of enterprise data generation is expected to come from the Internet of Things (IoT) – objects with embedded sensors and software connected to the internet. Fibre networks and 5G rollouts are expected to accelerate IoT deployments. The number of IoT devices is forecast to grow at a CAGR of 22.3 per cent and reach 30.9 billion units in 2025,[25] with industrial IoT growth driven by a rise of smart building, smart utilities, and smart manufacturing.[26] The rise of the IoT is expected to grow hand in hand with industrial robotics. Although similar to IoT, industrial robots can also perform actions based on collected data, thus offering businesses increased efficiency, reduced costs, and shortened production times.

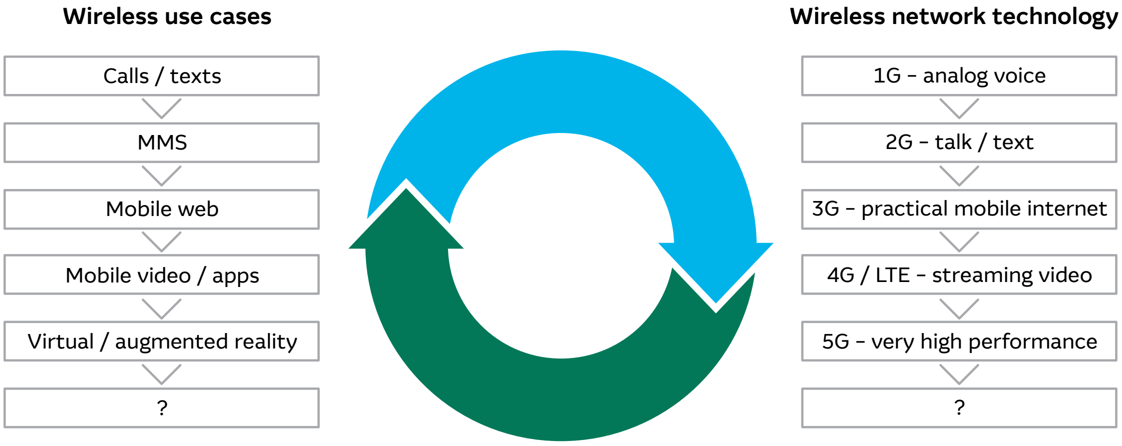
24. IBM, "Global AI Adoption Index 2021".
25. Statista, "Internet of Things (IoT) and non-IoT active device connections worldwide from 2010 to 2025" (November 2020).
26. GSMA, "The mobile economy 2019".

With computing and storage available, and increased analytical capacity based on new data from IoT, businesses are increasingly seeking more sophisticated data solutions such as digital twins. A digital twin is a virtual representation of a physical object that allows businesses to test and run simulations before starting construction of a site or introducing a new production line. In 2020, the digital twin market was valued at $US3.1 billion but is estimated to reach $US48.2 billion by 2026, thereby growing both data consumption and generation.[27]

Data demand: Resilience to economic downturns

The dynamic within the digital sector has been for new use cases to drive demand for data and bandwidth, which has in turn led to increased demand for faster and better infrastructure. When delivered, this new infrastructure then spawns another round of use case innovation, and the cycle starts again. The historical evolution of mobile networks is a good example (Figure 6). First-generation (1G) wireless technology was introduced in the 1980s and led to the wide adoption of mobile phone calls. As the system neared capacity, analog telecommunications were replaced by digital signals (2G), which were more reliable and secure. Improved capabilities then allowed the development of new features such as short message service (SMS) as well as sharing multimedia files. With each consecutive generation (3G, 4G and 5G), new capabilities expanded the universe of use cases, leading to stronger data growth and the subsequent need to upgrade existing digital infrastructure as networks reached capacity.

Figure 6:
The virtuous circle of data and network growth

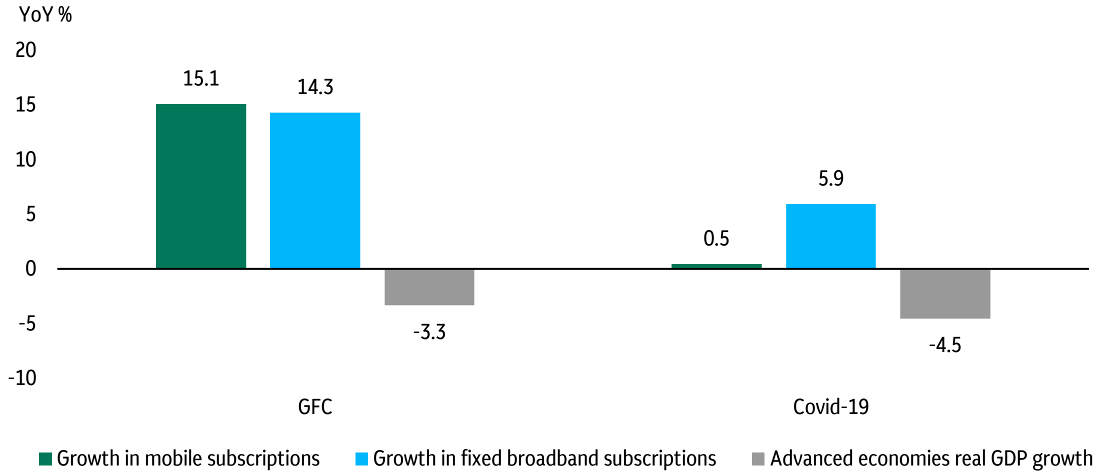


Source: Macquarie Asset Management (May 2022).

27. IBM, "What is a digital twin?"

This structural dynamic is unrelated to the economic cycle and so has meant that data use has proved resilient to economic shocks and downturns. For example, during the global financial crisis (GFC), when the advanced economies contracted by 3.3 per cent, mobile and fixed broadband subscriptions grew by 15.1 and 14.3 per cent respectively (Figure 7). Similarly, in 2020, when the advanced economies shrank by 4.5 per cent due to the COVID-19 pandemic, mobile and fixed subscriptions grew by 0.5 and 5.9 per cent respectively.[28]

Figure 7:
Digitalisation has proven resilient during economic downturns



Sources: Statista, OECD, IMF (May 2022). Global financial crisis (GFC) refers to the calendar year of 2009. COVID-19 refers to the calendar year of 2020.

28. In fact, digitalisation is one of the drivers of economic growth. Empirical evidence suggests that broadband adoption has contributed on average 0.3 per cent per annum to gross domestic product (GDP) growth over the past 15 years.

Future applications: Autonomous driving, Industry 5.0, and the Metaverse

Global data generation is expected to reach 181 zettabytes per year in 2025, up from 2 zettabytes in 2010, a CAGR of 35 per cent.[29] Beyond 2025, the virtuous cycle of data and network growth described above is likely to lead to a future with numerous data-intensive applications such as autonomous vehicles, smart cities, and connected aircraft. Each of these use cases is expected to generate terabytes (TB) of data per day. For example, an aircraft may generate 5 TB of maintenance and operational data per day, while a smart factory may generate 1 petabyte (1,000 TB) per day as information is collected about thousands of individual processes.[30]

The UK Office of Communications (Ofcom) identified several future applications that may shape the internet of the future. These include Industry 5.0, the Metaverse, the Internet of Senses (IoS) and others.[31] Industry 5.0 – the fifth industrial revolution[32] – refers to the collaborative production and manufacturing based on successful human and machine interaction. The Metaverse is a virtual shared environment in which people can interact with other people within a computer-generated space. The IoS – still far from being implemented – refers to the virtual world that allows multisensory digital experience, i.e. gives an augmented sense of smell, touch, and taste in addition to vision and sound. Altogether, these applications could have profound and transformative effects for digital infrastructure over the coming decades.

29. Refers to the total amount of data created, captured, copied, and consumed globally, according to Statista (June 2021).
30. Intel (February 2017).
31. Ofcom, “Internet Futures Spotlight on the technologies which may shape the Internet of the future” (July 2021).
32. Since the first Industrial Revolution in the mid-18th century.

Digital ecosystem: Data centres, wireline and wireless infrastructure

Digital infrastructure comprises physical assets such as buildings, cables, and masts that enable the transfer, use, and storage of data. It excludes IT equipment such as servers, computers, laptops, and routers that belong to end users. This section provides an overview of the digital infrastructure ecosystem, focusing on its three main components: data centres, wireline infrastructure, and wireless infrastructure.

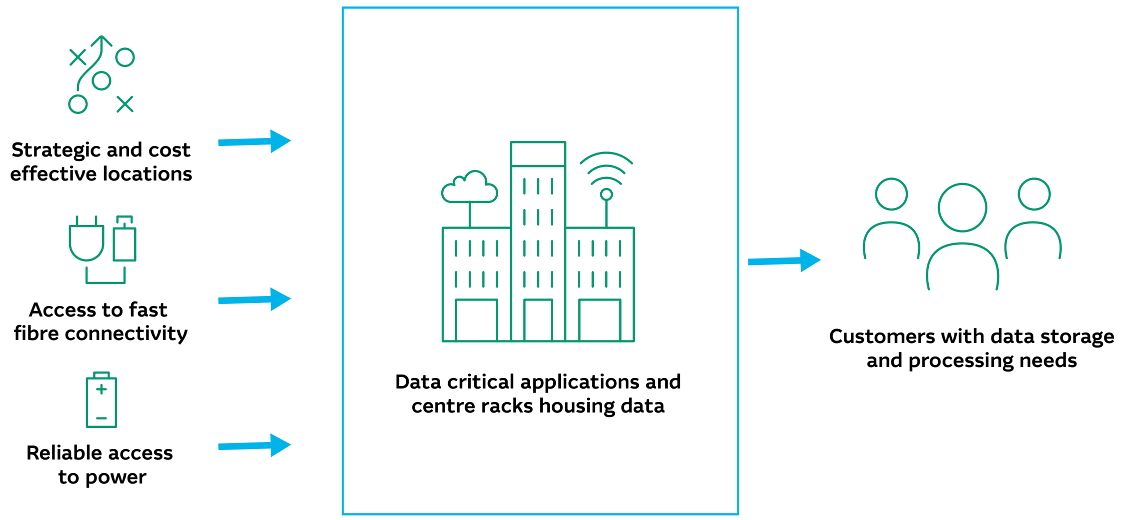
Data centres: All roads lead to the cloud

Data centres are purpose-built physical facilities that provide space, power, and fibre connectivity for business-critical equipment used to store and process data (Figure 8). Data centres sit at the heart of digital infrastructure – they perform data computation, processing, and storage. Every time someone accesses the cloud (e.g. to watch a movie online), they access a server in a data centre somewhere in the world. For example, it is estimated that about 70 per cent[33] of the world's internet traffic passes through data centres in Ashburn, Virginia, outside of Washington DC in the US. As applications become increasingly connected, there is also a multiplier effect: for every bit of data that travels the network from data centres to end users, another five bits of data[34] are transmitted within and among data centres.

33. Digital Tech, "Data Center Alley: Why 70% of Internet Traffic Flows Through Ashburn, Virginia" (May 2019).
34. International Energy Agency, "Data Centres and Data Transmission Networks" (November 2021).

Data centres are not a novelty. In fact, they have been around for many decades and were previously known as "mainframes".[35] Mainframes (and in fact any sort of server) were in effect mini-data centres located inside the premises of an enterprise in spaces ranging from closets to server rooms. However, with growing performance, reliability and security requirements, businesses have been increasingly outsourcing "in-house" data centres to third-party providers. Leasing rather than owning a data centre also helps enterprises reduce their costs related to building, operating, and maintaining data centres. Data centre operators do not own IT equipment (e.g. servers), but they are responsible for meeting significant infrastructure requirements, primarily related to providing power and cooling to servers. These include power systems, uninterruptible power supplies (UPS), ventilation, cooling systems, fire suppression, backup generators, and connections to external networks.[36]

Figure 8:
Data centres provide space, power, and fibre connectivity to customers



Source: Macquarie Asset Management (May 2022).

35. Cisco, "Infrastructure evolution: from mainframes to cloud applications", accessed on 20 February 2022.
36. Cisco, "What is a data center?", accessed on 20 February 2022.

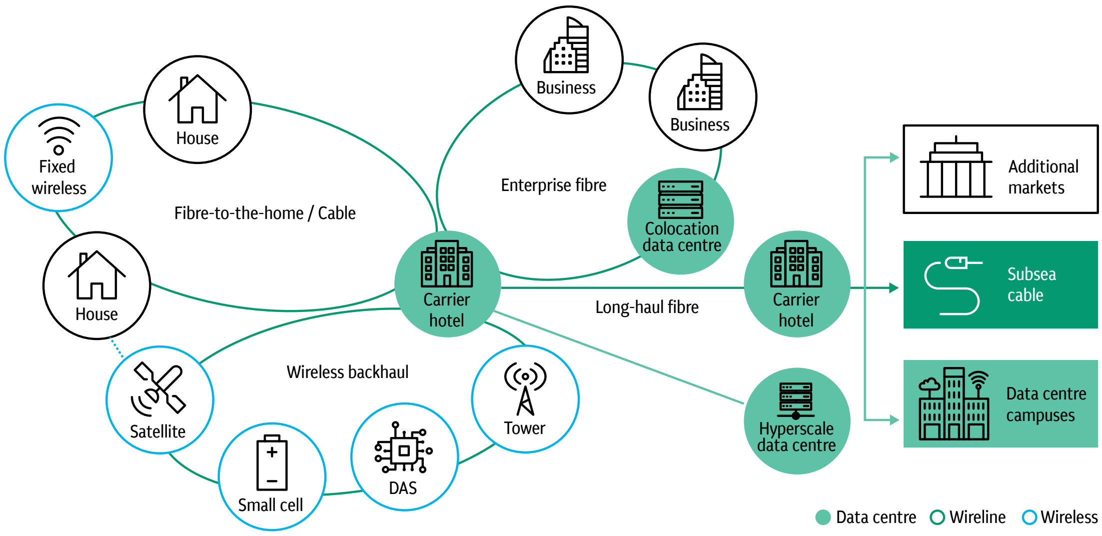
Data centres typically differ by their business model:

- **Carrier hotels.** These are physical sites where network and cloud service providers can directly connect to one another's fibre and network infrastructure. They are typically located in central urban locations and are of paramount importance for global connectivity as they help route traffic between different providers.
- **Hyperscale data centres.** These are data centres designed to meet the needs of large-scale, sophisticated, data-intensive businesses, typically in the information and communications technology (ICT) sector, but often including more traditional businesses with intensive IT needs, such as banks or airlines.
- **Colocation data centres.** These smaller-scale data centres are more focused on providing service to non-IT businesses that have smaller technology footprints and less sophisticated needs.
- **Edge data centres.** These small facilities are located closer to the end user in order to provide low-latency service. There is a limited use case today, but going forward we expect the demand for edge data centres to accelerate, driven by the demand from next-generation applications such as autonomous vehicles that require low latency to operate effectively (read on for further details on latency).

Wireline infrastructure: The backbone of all communications

Wireline infrastructure transmits data traffic over a physical network of cables. It provides the backbone of all communications as it connects data centres, businesses, homes, and telecommunication towers in one digital ecosystem (Figure 9). Wireline communication can happen over a twisted pair[37] (often called "copper"), coaxial,[38] or fibre optic cable. The copper access network was originally built to provide voice services, with broadband services added later to function in parallel. However, with data use growing rapidly in recent years, the inherent capacity limitations of electrical signals over long distances means legacy networks can no longer meet consumer and business demand, which has driven demand for high-capacity fibre optic networks that transmit data using light.

Figure 9:
Wireline infrastructure physically connects digital infrastructure assets



Source: Macquarie Asset Management (May 2022).

37. A twisted pair is a type of copper cable with two insulated copper wires twisted together.
38. A coaxial cable is a type of copper cable built with a metal shield to block signal interference. Coaxial is a technology originally deployed for the transmission of analog television services, where the traffic stream is shared between all users on the same coaxial cable.

In digital infrastructure, it is important to differentiate between two main concepts: bandwidth and latency. Bandwidth refers to how much data (i.e. volume) is transmitted in a given amount of time. A greater number of megabits per second and a larger amount of data being delivered per unit of time will enable the user to download and upload data faster and improve their experience. If one person is streaming a video and another is working remotely in the same home, a higher bandwidth will provide a better experience than a lower bandwidth. Fibre may offer up to 500 times[39] more bandwidth than legacy copper networks (Figure 10).

Latency is a term used to describe delay time. In a network, latency measures the time it takes for data to get to its destination across the network. This encapsulates actual transmission time (i.e. the speed of light in a fibre optic cable) and delays caused by routers and other network equipment. Low latency is becoming increasingly important for a rising number of real-time applications and a growing amount of video content. According to Ofcom observations, full fibre networks currently provide up to three times[40] lower latency on average than copper networks (Figure 11).

Figure 10:
Fibre can offer up to 500 times more bandwidth than legacy copper networks...

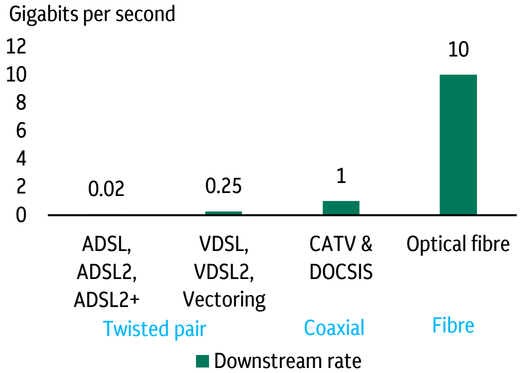
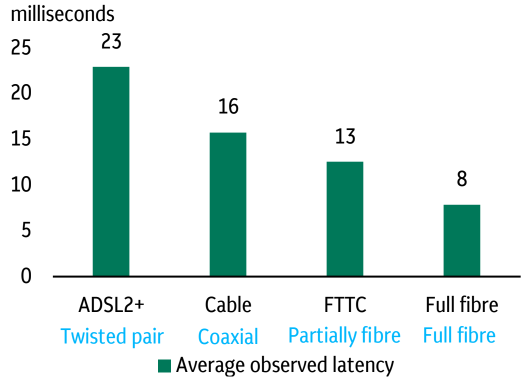


Figure 11:
...while also providing lower latency (less delay time)



Sources: European Commission, "Broadband technology comparison", and Ofcom report, "UK Home Broadband Performance" (March 2021). Notes: ADSL = Asymmetric digital subscriber line; VDSL = Very high-speed digital subscriber line; CATV = Cable television; DOCSIS = Data over cable service interface specifications. DOCSIS here refers to DOCSIS 3.0. Lower latency (less delay) is better than higher latency.

39. Based on European Commission, "Broadband technology comparison", accessed on 22 February 2022.
40. Based on observations by Ofcom, "UK Home Broadband Performance" (March 2021).

The complexity of the fibre optic network mainly depends on the end-user type (home or enterprise), type of fibre installation (full fibre or partial with copper), and geographical coverage (metro area, long-haul, or subsea):

- **Fibre-to-the-home (FTTH)** refers to the full fibre connection between the residential customer and the network provider. FTTH has superior signal conservation over long distances and offers higher bandwidth compared to other technologies.
- The connection may also be a **mix of fibre optic and copper cables**. For example, fibre-to-the-building (FTTB) refers to an installation where a fibre optic cable enters a point in a building, after which the copper cables bring the signal to each individual home. In a fibre-to-the-cabinet (FTTC) installation the fibre optic cable connects to the street cabinet, with copper cables extending the connection further to individual homes.
- **Enterprise fibre** refers to fibre optic cables that connect businesses to their data centres, office buildings, industrial parks, or any dedicated points. With large enterprises increasingly seeking sophisticated, custom network solutions, we believe enterprise fibre is likely to expand rapidly.
- **A metro fibre network** is typically built in a ring architecture around a metropolitan area and connects data centres, enterprises, and homes within the same city.
- **Long-haul fibre networks** enable efficient transmission of large amounts of information over long distances, connecting cities and countries. With major technology companies increasingly seeking to boost capacity on strategic routes over and above current supply, we anticipate that the demand for long-haul fibre should increase over the coming years.
- **Subsea cables** are laid on the seabed and play an essential role in connecting continents. Approximately 99 per cent[41] of international internet traffic travels through cables under the sea. The longest undersea cable is South-East Asia - Middle East - Western Europe 3 (SEA-ME-WE 3), which stretches over 24,000 miles and connects 33 countries.[42]

41. World Economic Forum, “This map shows how undersea cables move internet traffic around the world” (November 2016).
42. Submarine Cable Networks, “SEA-ME-WE 3”, accessed on 20 February 2022.

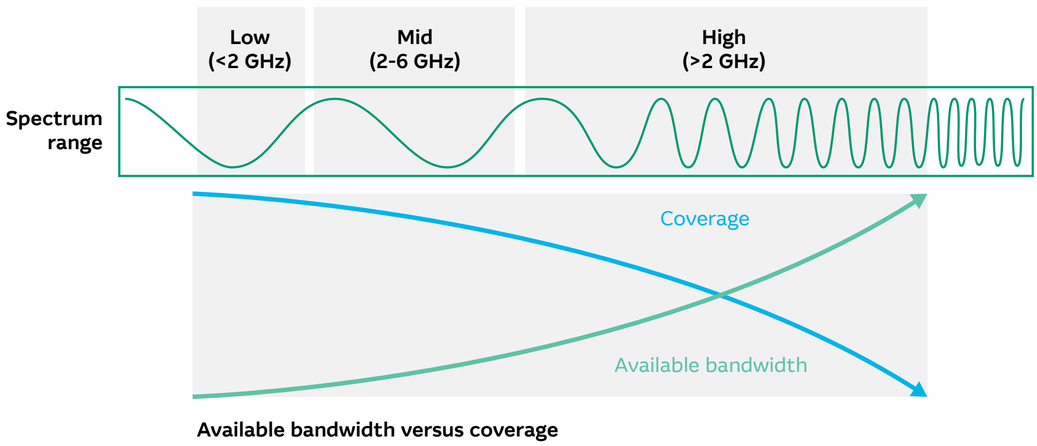
Wireless infrastructure: Small cells as 5G's missing puzzle pieces

Wireless infrastructure refers to physical assets such as mobile towers that use radio frequencies to transmit data. A mobile phone network is divided into geographic areas or "cells", with a mobile tower mast at the centre of each cell. The mobile tower transmits and receives a local radio frequency with which mobile phones can interact. The available bandwidth is then shared by all users in the same cell. Due to their elevated positions and clear lines of sight, purpose-built towers are the most efficient way to propagate signals, providing around 1-2 miles of coverage, and remain the preferred method for building out wireless infrastructure.

Wireless networks are heavily reliant on wireline infrastructure. In fact, all mobile internet traffic eventually goes through wireline infrastructure such as fibre optic networks. For example, a digital photo sent to New York from a mobile phone in Paris first travels to the nearest tower using wireless, but then uses a network of cables, including a subsea cable, to deliver the photo to the person in New York.

Going forward, the interlinkages between wireline and wireless are expected to strengthen. A successful rollout of 5G mobile technology requires significant fibre infrastructure deployment. The main factor behind 5G's capability to deliver superior performance is that 5G uses a combination of radio frequencies, including low bands, mid bands, and high bands. The physics of radio waves means that lower frequencies are better for delivering wider coverage to end users, while higher frequencies have greater capacity to carry data but provide less coverage (Figure 12).

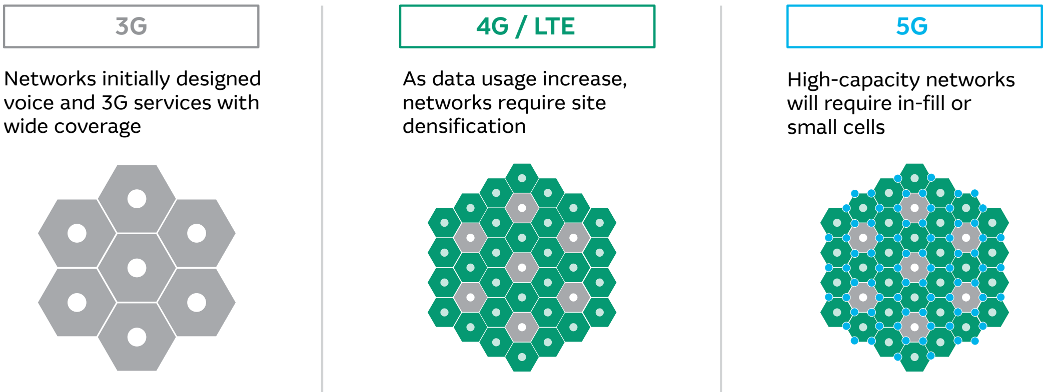
Figure 12:
Higher frequency waves used by 5G have greater bandwidth but provide less coverage and thus require denser infrastructure



Source: Nokia, "Spectrum explained" (January 2021).

Higher frequencies therefore create the need for small cells (Figure 13) – small-scale antennas – that can complement coverage provided by towers, propagating the signal on shorter distances in the range of 30 to 1,000 feet.[43] Small cells can be embedded into existing urban installations such as lighting fixtures or bus shelters and require dense fibre infrastructure. In addition to small cells, mobile network coverage can be densified in high-traffic buildings or venues (e.g. airports, sports stadiums) using indoor distributed antenna systems (DAS). We believe that towers are expected to remain the core infrastructure of wireless networks, while emerging technologies will fill coverage gaps.

Figure 13:
Small cells are expected to complement tower coverage, requiring more sites and more fibre



Source: CTIA – The Wireless Association (June 2019).

43. Macquarie Asset Management analysis based on market data.

Wireless Infrastructure: Unlocking value in towers

In recent years, telecom companies have been divesting their infrastructure such as towers and fixed-line networks. As the industry moves away from the traditional vertically integrated telecom model, new infrastructure-focused companies have emerged, creating a large opportunity for private infrastructure investors. The most widely adopted model is one of independent tower companies (TowerCos). This section explores the fundamental drivers of telecom separation in the wireless segment, the value proposition of TowerCos, and the outlook of this rapidly growing sector in Europe and the US.

Tower carve-outs: Understanding the mechanics

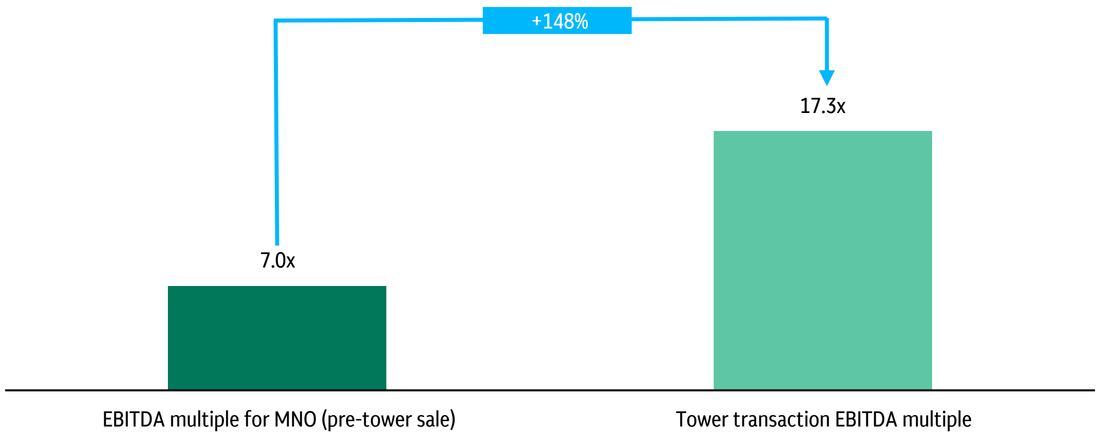
Over the recent decade, the market for mobile network operators (MNOs) has gone through a structural realignment, with many operators selling their tower portfolios. This has resulted in the emergence of an independent TowerCo market. Under this separation model, a TowerCo owns "passive" infrastructure such as towers, shelters, and access facilities, while an MNO owns "active" equipment such as antennas, radio units, and fibre connections. TowerCos then lease tower site space, power, and related services to MNOs, allowing both groups to focus on their core businesses.

There are several benefits from carving out tower infrastructure assets into a separate entity. From the MNO perspective, they can generate substantial proceeds from divestments of tower portfolios, reduce debt, and optimise their capital structures. This is particularly applicable for MNOs that have accumulated a high level of debt and are looking to raise capital to roll out 5G technology. From the TowerCo perspective, the carve-out may allow for more than one MNO or wireless operator to be on the same tower, thus increasing profitability per tower. According to an Ernst & Young (EY) study, the tenancy ratio – the average number of operators sharing tower infrastructure – is higher for an independent TowerCo (tenancy ratio of 2.4) than for an MNO-controlled tower (tenancy ratio of 1.3).[44] By focusing on its core business, a tower operator can help direct resources to increase efficiency, optimise locations, and improve services to clients (wireless operators).

44. Estimates from Ernst-Young-Parthenon, "The economic contribution of the European tower sector" (February 2022).

In addition, financial valuations for tower infrastructure businesses tend to be higher than for MNOs. Tower infrastructure typically has low operational risks and is based on long-term contracts that support the visibility and stability of cash flow generation. Based on Standard & Poor's (S&P) data, the average EV/EBITDA multiple for a tower sale transaction has had a premium of 148 per cent,[45] compared to the pre-sale valuation of the MNOs (Figure 14). Higher equity valuations mean standalone tower companies may have access to more capital to expand networks, unlocking growth opportunities. According to Fitch Ratings, the investment-grade threshold for an independent TowerCo funds from operation (FFO) net leverage is around 6.7x, while for a large European MNO it is around 4.0x-4.5x.[46] The higher allowed leverage is due to the stability and visibility of the cash flows that underpin the tower operator business model.

Figure 14:
An average tower sale transaction has had a valuation premium of 148 per cent, compared with the pre-sale MNO valuation



Source: Based on S&P, "Why Telecom Companies Across Europe Are Selling Their Towers" (October 2019).

45. S&P, "Why Telecom Companies Across Europe Are Selling Their Towers" (October 2019). Average calculation includes multiples for tower-only transactions and excludes blended multiples. EV/EBITDA = enterprise value to earnings before interest, taxes, depreciation, and amortisation.
46. Fitch Ratings, "Mergers Could Accelerate European Tower Sector Evolution" (February 2021).

European TowerCo market: Global precedents hint at growth ahead

In Europe, the trend of outsourcing towers to independent operators has been relatively slow compared to other regions (Figure 15) because tower ownership has often been perceived by MNOs as a sign of network quality. As a result, European MNOs have historically preferred to keep control of critical tower infrastructure by creating joint ventures (JVs) and MNO-controlled tower companies (as majority shareholders). But with the advent of 5G this is changing. The much denser network requires significant capital investment, driving the industry to separate out the towers infrastructure to capitalise on greater access to debt capital that such a separation allows. In Europe, around 35 per cent[47] of towers are owned by independent TowerCos, which is well below the US, where this share is 90 per cent. If Europe follows the US path, there could be substantial growth ahead.

High population density in Europe – 112 people per square kilometre (compared with 36 in the US)[48] – has historically allowed multiple sets of towers to overlap each other in urban areas. Rationalisation of tower locations – where instead of two towers in the same location only one tower is kept – may result in reduced costs. Currently, about 48 per cent of European towers are either controlled or owned by MNOs (Figure 16), particularly in countries such as Germany, Spain, Italy, and the Nordics. Growth through network consolidation may be possible on the back of continued tower disposals by MNOs in these markets.

Figure 15:
Independent TowerCos own 35 per cent of towers in Europe, well below other regions...

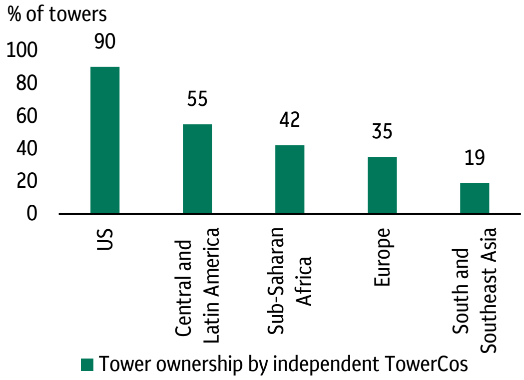
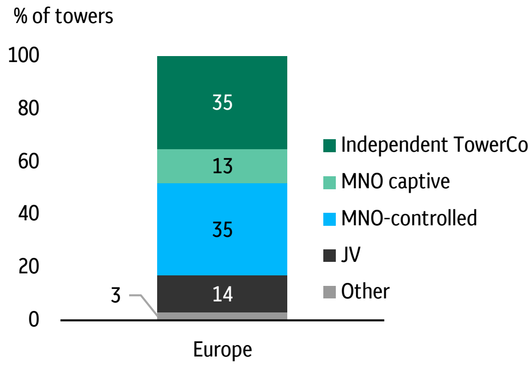


Figure 16:
...suggesting potential market growth as MNOs continue outsourcing tower infrastructure



Source: Ernst & Young - Parthenon study, "The economic contribution of the European tower sector" (February 2022). Notes: "MNO captive" refers to towers owned by MNOs.

47. Estimates from Ernst-Young-Parthenon, "The economic contribution of the European tower sector" (February 2022).
48. World Bank population density estimates (2020).

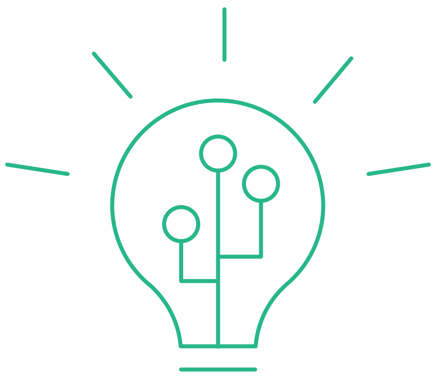
US TowerCo market: Mature market with greenfield prospects

The US TowerCo market is characterised as a more mature and more consolidated market compared with other regions, with independent TowerCos accounting for 90 per cent of tower ownership. As a result, the growth in the US market is likely to be mostly organic, driven by demand for new towers and the further lease-up of existing sites. Wireless operators are likely to increasingly require new sites to support 5G services, as each new antenna will require space on the tower to which it is fixed.

According to estimates, 5G technology is likely to require 3 to 10 times the number of existing cell sites.[49] In addition to towers, these new sites are likely to take the form of small cells and in-building solutions. According to Bloomberg Intelligence, leading US mobile carriers have started to boost their capital expenditures (capex), with industry spending likely to rise 16.2 per cent in 2022, up from 11.1 per cent in 2021.[50]

49. Deloitte, “5G: The chance to lead for a decade” (2018).
50. Bloomberg Intelligence, “Tower Company Growth Gets a Boost From 5G Deployments” (March 2022).

Wireline infrastructure: Fixed network separation and fibre opportunities



Similar to the TowerCo dynamics that we have described, telecom operators have also been spinning off their fixed-line infrastructure businesses. This has led to the emergence of a new segment: pure network-infrastructure players (NetCos). As a separate entity with a strong infrastructure profile, a fixed-line NetCo typically has improved access to capital, lower borrowing costs and better growth prospects. Such characteristics imply favourable positioning of NetCos for fibre deployment. This section explores the benefits of network separation and its implications for fibre investments growth in Europe and fibre-related opportunities in the US.

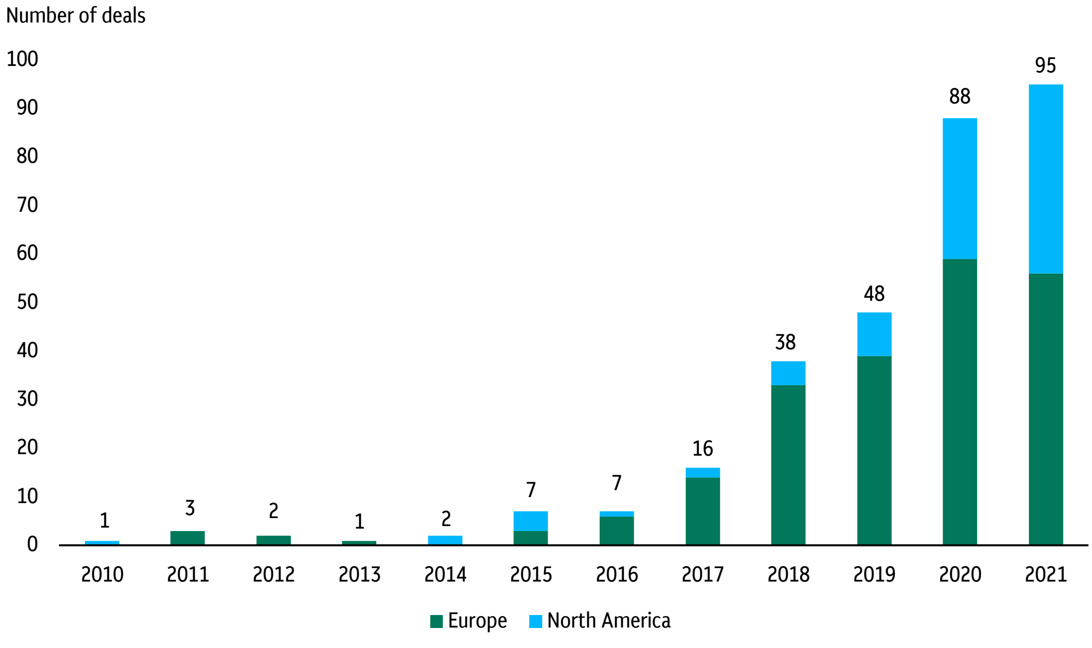
NetCos separation: A trigger to investments in fibre

Integrated telecom operators are companies structured as a one-stop shop. Put simply, the company operates the infrastructure business and also offers corresponding retail services to consumers. These companies often have network assets with solid infrastructure characteristics. As with the wireless market, there is a growing trend of splitting an integrated telecom operator into a NetCo and a customer-facing communications service provider (ServCo), or even more commonly, operators rolling out new infrastructure such as fibre through a pure NetCo with open access business models.

The separation may create benefits for both the NetCo and the ServCo. The ServCo can focus on improving customer service to retail customers. The NetCo can increasingly operate on an open-access wholesale model and provide infrastructure to many ServCos rather than one, leading to improved network monetisation. Having an infrastructure profile can also help the NetCo get improved capital access from long-term investors and potentially lead to lower borrowing costs to finance capex. This is particularly important in light of 5G and FTTH requiring fibre network densification, where the payback period on fibre investments may be more than 10 years. Long-term contracts with a few large wholesale customers tend to support the visibility and stability of cash flows, a feature particularly attractive to infrastructure investors.

The separation of traditional telecom operators into a NetCo and a ServCo as well as the deployment of modern fibre through open-access NetCos has created an opportunity for infrastructure investors to capitalise on the market demand for fibre connectivity. The total number of transactions across Europe and North America increased from just one in 2010 to 95 in 2021, with European deals accounting for most of the activity (Figure 17). Overall, total deal volume has increased from $US139 million in 2010 to $US42.5 billion on 2021.[51]

Figure 17:
Fibre-related infrastructure transactions in Europe and North America have accelerated



Source: Inframation database (May 2022).

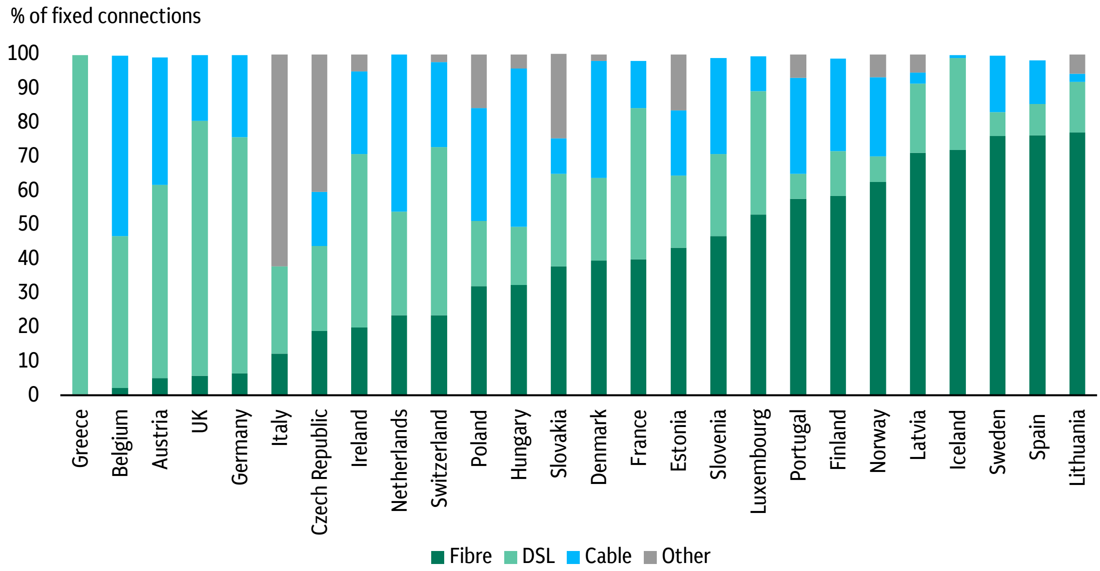
51. Inframation database (March 2022).

European fixed network: Key markets remain underserved in fibre

There is a substantial opportunity in the FTTH rollout in Europe. Several countries such as Germany, the UK, Italy, Belgium, and Austria – which together account for half of European GDP[52] – remain underserved in terms of high-speed connections, although coverage has grown significantly in recent years and there are investment plans to deploy fibre at scale in coming years (Figure 18). In Germany, fibre optic accounts for 6.4 per cent of total fixed broadband connections, while copper accounts for 69.4 per cent, presenting growth and upgrade potential for network providers. These markets are also well placed for a rapid fibre rollout. Their dense populations improve rollout economics, while their relatively high GDP per capita means there is plenty of capacity to pay.

Moreover, the European telecom market is supported by a transparent regulatory framework. Adopted in 2018, the European Electronic Communications Code (EECC)[53] aims to improve the broadband coverage of all EU countries. It stimulates investment in very high capacity fixed and mobile networks through regulatory incentives with a strong focus on enabling wholesale-only operators. In addition, European last-mile access is often supported by a "fair and reasonable" cost-based regulatory pricing framework, which facilitates transparency and predictability of revenue for prospective investors.

Figure 18:
Key European markets remain heavily underserved in terms of high-speed internet



Source: OECD, "OECD broadband statistics update" (June 2021).

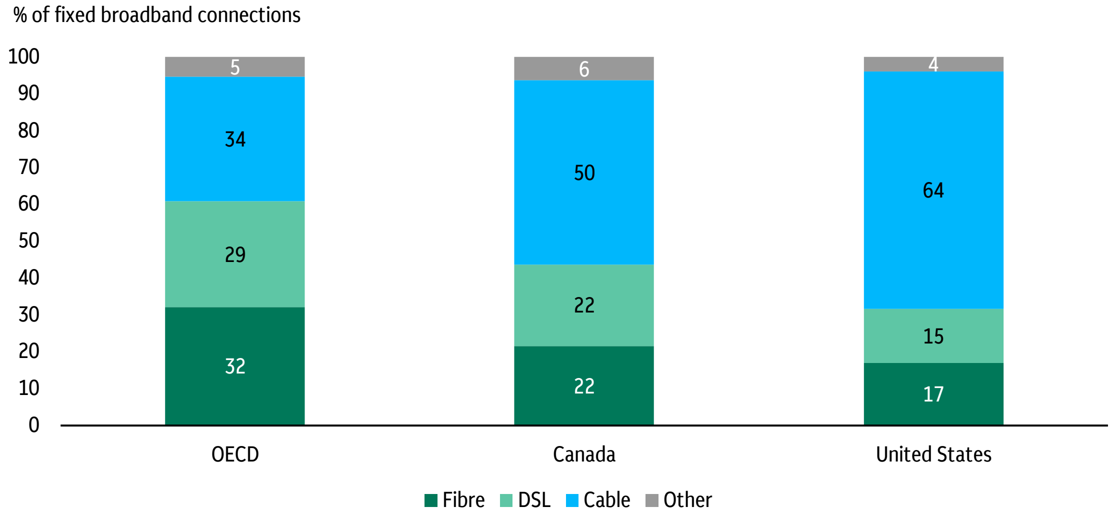
52. Nominal GDP of Austria, Belgium, Germany, Italy, and the UK, accounted for 51.3% of the EU27+UK nominal GDP in 2020.
53. Directive (EU) 2018/1972 of the European Parliament and of the Council of 11 December 2018.

US fibre market: Growth lies beyond FTTH

In the US, the telecommunications market has historically been dominated by cable providers. Cable accounts for 64 per cent of total fixed broadband connections in the US, which is substantially above the average of 34 per cent in OECD markets (Figure 19). This means that, compared with Europe where the legacy networks are mainly twisted-pair copper, the FTTH rollout in the US faces greater competition from cable networks. Despite this, there is significant momentum for new FTTH networks in the US as customers seek higher bandwidth and reliability along with improved customer service. Enterprise and wholesale fibre providers in the US have also seen significant demand growth as MNOs connect cell sites and a wide variety of customers, from hospitals to cloud providers, seek dedicated custom network solutions.

The US government is also increasingly supporting the fixed network build-out, particularly from a national level in historically underserved rural areas where low population density undermines the economics of broadband deployment. The Infrastructure Investment and Jobs Act that passed into law in November 2021 includes $US65 billion of spending on broadband deployment and adoption.[54] The funding – in the form of federal grant programs – is expected to flow to the states, which would then award them to qualifying projects.

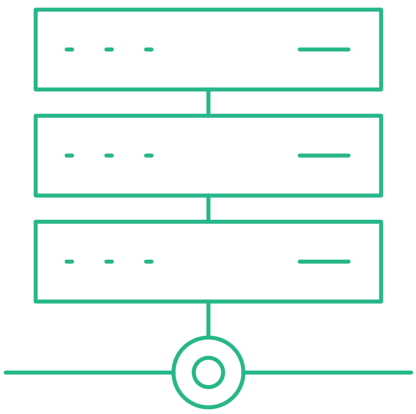
Figure 19:
The North American fixed broadband market historically has been dominated by cable



Source: OECD, "OECD broadband statistics update" (June 2021).

54. Reuters, "Biden signs $1 trillion infrastructure bill into law" (November 2021).

Data centres: Edge computing and demand



Data centres have evolved in terms of how they are used. In the past they were primarily used for storage or as backup sites and were often located on the same premise as the enterprise. Modern data centres are used to host cloud-based applications and provide services to businesses outsourcing their growing computing needs. To date, data centre markets have concentrated in Tier I locations in Europe and the US, underpinned by economic drivers. However, there is an emerging trend of locating computing capacity closer to end users as new real-time applications require low latency. This drives new demand outside of Tier I locations, often in smaller markets, expanding the potential investment universe.

Data centres: A sector increasingly recognised for its infrastructure characteristics

In recent years, data centres have become increasingly recognised as essential service providers with attractive infrastructure characteristics. The business model is often based on medium-to-long-term contracts, ranging from one to five years for colocation data centres and up to 10 years or more for hyperscale data centres. Fibre connectivity, access to reliable power supply, and proximity to end users and internet hubs limit the number of suitable locations and act as strong barriers to entry. At the same time, technical expertise and high switching costs typically result in having “sticky customers”, particularly in the case of carrier hotels. In addition, data centre contracts often include price escalators, potentially acting as an inflation hedge for institutional investors. All these characteristics have contributed to the increased interest in data centres as an infrastructure sector.

The unlisted data centre market has grown rapidly since 2015, with global transactions rising from four to 73 over six years (Figure 20).[55] In value terms, global transactions have increased from $US0.5 billion in 2015 to $US23.2 billion in 2021, with North American and European markets accounting for more than 70 per cent of deals (Figure 21). North America is a more mature and consolidated market with several large players, while Europe remains more fragmented. This is reflected in the average deal size, with deals in the US averaging $US781.2 million compared with $US266 million in Europe.

Figure 20:
The unlisted data centre market has accelerated since 2015...

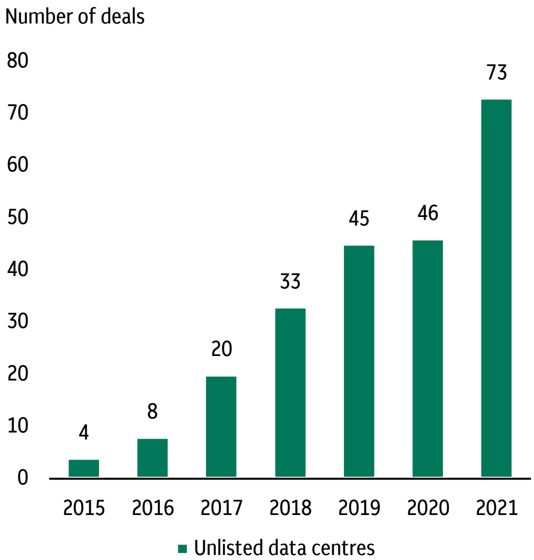
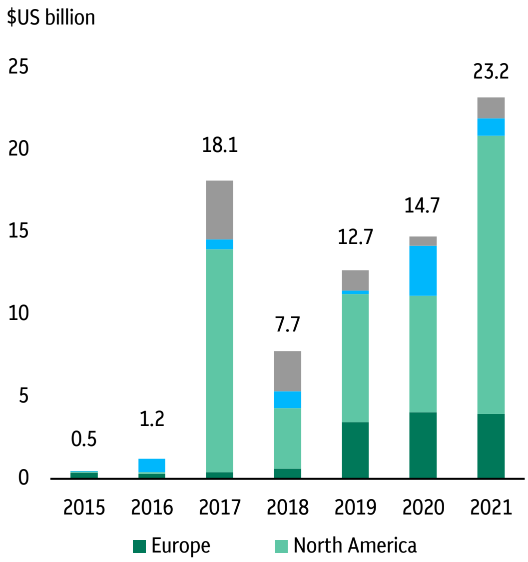


Figure 21:
...with North America and Europe accounting for the bulk of deals



Source: Inframation database (March 2022). Past performance is not indicative of future results.

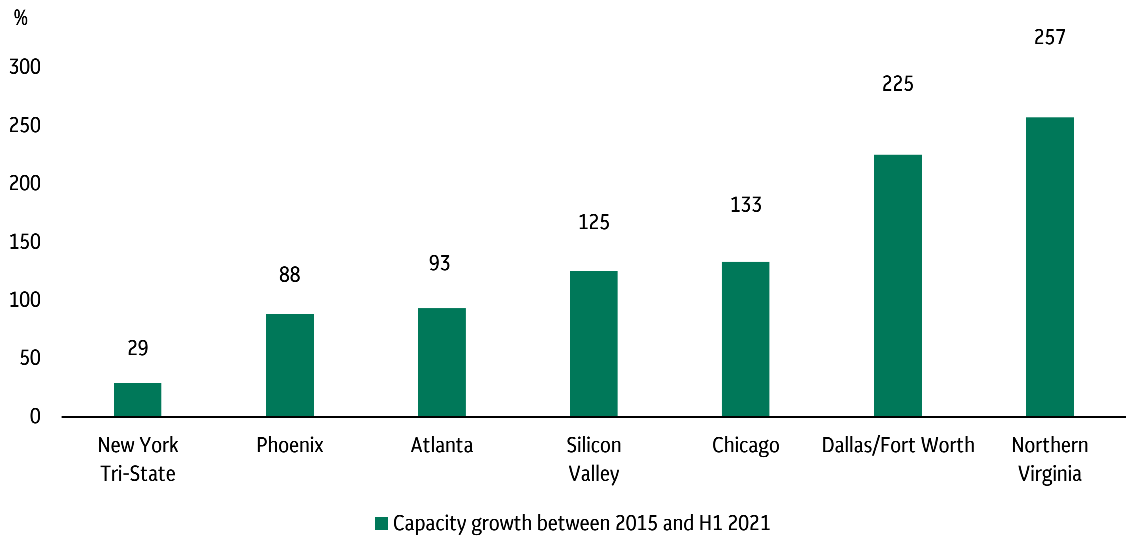
55. Inframation database (March 2022).

US data centres: The largest market with strong growth

The US accounts for more than 40 per cent[56] of all data centres and dominates the global data centre market. Over the past six years, the market has experienced strong growth (Figure 22), particularly across Tier I markets such as Northern Virginia, San Francisco, Dallas, Phoenix, Chicago, and New York. For example, Northern Virginia – the world's largest data centre hub – is home to more than 2.8 gigawatts (GW) of data centre capacity. To put this in perspective, it is equivalent to the amount required to power approximately 1.2 million average US houses.[57]

Historically, data centres were concentrated in markets where the technology and telecom giants had a strong presence. However, as edge computing and connectivity become drivers of data centre locations, many content companies are increasingly moving servers closer to end users residing outside of traditional market hubs. This increases the demand for data centre space in emerging locations such as Portland, Minneapolis, and Charlotte. Despite these shifts, in terms of the outlook the key requirements remain the availability of fibre connectivity, access to reliable power sources, presence of cloud providers, and stability of local government policies.

Figure 22:
Strong capacity growth observed across key US data centre markets between 2015 and 1H 2021



Source: CBRE Research, CBRE Data Center Solutions, 1H 2021.

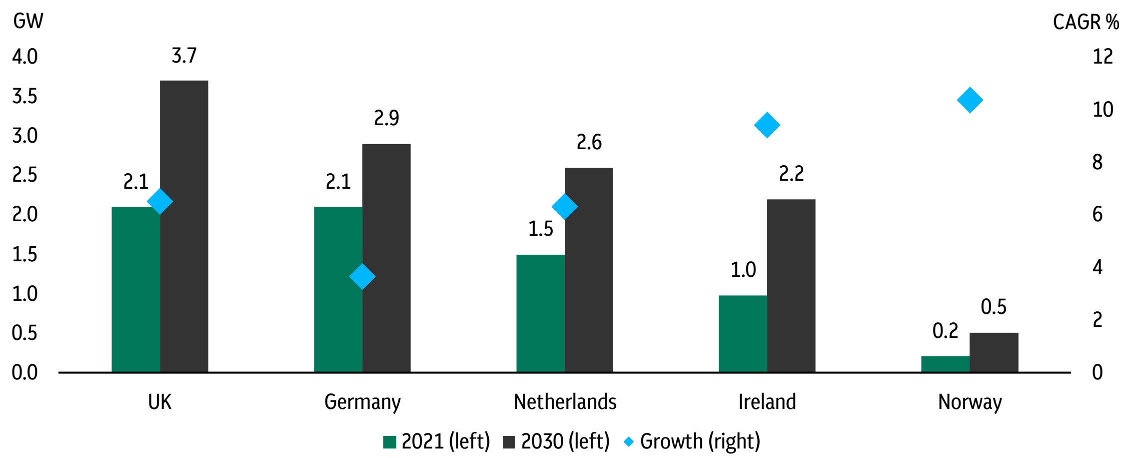
56. Statista, "Number of data centers worldwide in 2022, by country" (January 2022).
57. Under the assumptions that an average U.S. household consumes about 11,000 kWh per year (according to the US Energy Information Administration) and 55 per cent capacity factor of nominal data centre capacity.

European data centres: Policy support and data regulation create demand tailwinds

In Europe, in addition to strong corporate demand to digitalise, demand for data centre services is also supported by EU policy. The EU's "Digital Decade" initiative has a target of 75 per cent[58] of EU companies using cloud or artificial intelligence technology by 2030, up from the adoption level of 41 per cent in 2021. In addition, EU General Data Protection Regulation (GDPR) rules are expected to prompt enterprises to outsource data centres to third-party providers and GDPR-compliant cloud solutions. Policy support and greater transparency and trust in the European cloud computing market are expected to increase take-up of the cloud and, thus, data centre services in Europe. At the same time, the supply growth of data centres is likely to be constrained. For example, in 2019 the Amsterdam area saw a year-long ban on new data centre build, followed by several policies dictating new data centre locations and total capacity.[59] This demand-supply dynamic can put upward pressure on data centre valuations and support their pricing power, particularly in strategic locations.

European data centre capacity is currently concentrated in the FLAP-D area (Frankfurt, London, Amsterdam, Paris, and Dublin). However, as edge computing requires the processing of information closer to end users, growth in the data centre market is expected to accelerate in Tier II markets such as Berlin, Milan, Madrid, Warsaw, and Vienna.[60] Overall, established locations are expected to grow at around a 7.2 per cent CAGR to 2030 (Figure 23), while the growth across emerging locations may be higher still.

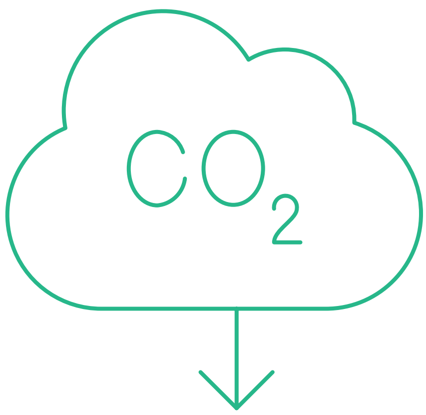
Figure 23:
Key European data centre locations are expected to grow by 7.2 per cent on average



Source: BloombergNEF, "Data Centers and Decarbonization" (October 2021).

58. European Commission, "Europe's Digital Decade: digital targets for 2030" (March 2021).
59. BloombergNEF "Data Centers and Decarbonization" (October 2021).
60. Data Centre Magazine, "Emerging data centre hubs for 2021" (December 2020).

Net zero world: Decarbonising digital infrastructure



Digital infrastructure generates almost as much GHG emissions as the aviation industry.[61] With data traffic growing rapidly, digital infrastructure may increasingly consume more power and contribute to a larger share of emissions. To limit global warming to 1.5C compared with pre-industrial levels,[62] fixed networks, data centres, and mobile networks will need to reduce GHG emissions by about 45 per cent[63] by 2030. For data centres and wireless networks, there is a wide range of sustainable solutions from improving energy efficiency to sourcing renewable power. For fixed networks, the replacement of legacy copper wires with more efficient fibre optic cables may result in a substantial reduction of emissions. In addition to direct emission reduction potential, digital infrastructure may also have an "enablement effect" by helping reduce carbon emissions in other sectors.

61. According to Our World in Data (2020) data, the aviation sector accounts for 1.9 per cent of global GHG emissions. Digital infrastructure may account for up to 1.8 per cent of global emissions under an assumption that digital infrastructure accounts for 46 per cent of the ICT sector, where the ICT sector emits up to 3.9 per cent of global emissions.
62. For more details on the challenges of decarbonisation, see our recent paper, "Pathways – The path to net zero: The challenges and opportunities for real assets investors" (November 2021). The report can be found here.
63. In line with the ICT sector emissions reduction requirements.

Digital infrastructure's emission reduction potential

The ICT sector contributes up to 3.9 per cent[64] of global GHG emissions, equivalent to up to 1.9 Gt CO_2 equivalent per year. The rapid growth of the ICT sector suggests that the industry could be responsible for as much as 14 per cent[65] of global emissions by 2040. To meet the 1.5C Paris Agreement target, the ICT sector will need to reduce its carbon emissions and accelerate its decarbonisation efforts. A new standard[66] developed by the International Telecommunication Union (ITU) highlights that the ICT industry will need to reduce GHG emissions by 45 per cent[67] from 2020 to 2030 to align with the Paris Agreement.

Within the ICT sector, user devices are responsible for 54 per cent of emissions, with digital infrastructure accounting for the remainder (Figure 24). This suggests that digital infrastructure is responsible for up to 1.8 per cent of global emissions. Data centres account for the largest share of ICT infrastructure GHG emissions, followed by mobile and fixed networks. According to the ITU standard, fixed networks, data centres, and mobile networks should reduce GHG emissions by 54 per cent, 38 per cent, and 36 per cent,[68] respectively by 2030 (Figure 25):

Figure 24:
Digital infrastructure generates about 46 per cent of total ICT sector emissions...

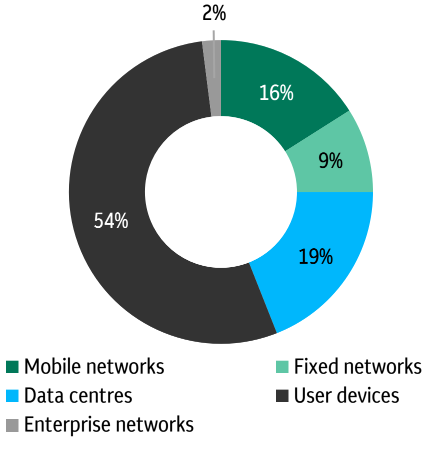
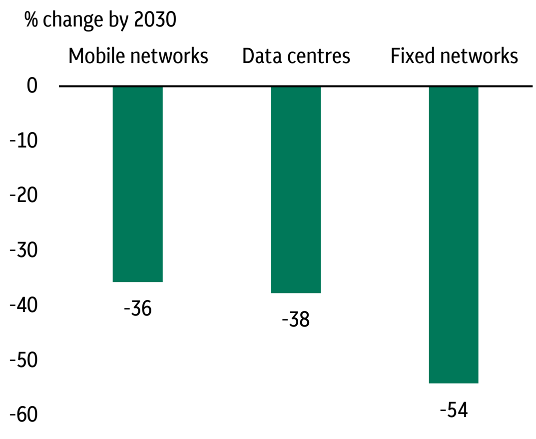


Figure 25:
...which should be reduced to align with the Paris Agreement target



Source: ITU, SBTi, GSMA, and GeSI's Recommendation ITU-T L.1470 on "Greenhouse gas emissions trajectories for the information and communication technology sector compatible with the UNFCCC Paris Agreement" (January 2020).

64. Freitag et al (September 2021) estimates that the ICT's share of emissions could be between 2.1 per cent and 3.9 per cent, while peer-reviewed studies estimate the share to be between 1.8 per cent and 2.8 per cent of global GHG emissions.
65. European Commission, "Supporting the Green Transition" (February 2020).
66. A collaboration between the ITU, Science Based Targets initiative (SBTi), GSM Association (GSMA), and Global Enabling Sustainability Initiative (GeSI) has developed a recommendation ITU-T L.1470 on "Greenhouse gas emissions trajectories for the information and communication technology sector compatible with the UNFCCC Paris Agreement" (January 2020).
67. ITU, "ICT industry to reduce greenhouse gas emissions by 45 per cent by 2030" (February 2020).
68. ITU, SBTi, GSMA, GeSI (January 2020).

Multiple ways data centres can reduce carbon emissions

Data centres are energy-intensive assets. The global data centre industry consumes about 1 per cent[69] of global final electricity demand. With data growth accelerating, data centres may increasingly consume larger amounts of power, putting pressure on electricity grids. For example, in Ireland, estimates suggest power demand from data centres may account for 24 per cent[70] of electricity consumption by 2030 (Figure 27).

One major way data centres can reduce GHG emissions is by improving their efficiency. Power usage effectiveness (PUE) is a key performance indicator that measures the energy efficiency of a data centre. A PUE of 1.0 is the theoretical most efficient performance, and implies the facility draws only the power needed to supply the underlying server equipment. Traditional "in-house" data centres typically have a PUE of about 2.0, while hyperscale data centres have a PUE of around 1.2.[71] Thus, outsourcing data centre services to more efficient service providers may result in higher efficiency of power usage and reduced power consumption. Specialised data centre operators typically invest in innovative solutions to improve energy efficiency. Some utilise the excess heat generated by servers. Innovative cooling solutions play an important role as they can help reduce both power and water consumption, which can in turn reduce operating costs.

Another way to reduce GHG emissions is to use renewable power sources. Data centres may enter into corporate power purchase agreements (PPAs) with renewable energy suppliers. However, to ensure around-the-clock operation, data centres cannot rely on intermittent solar or wind. Renewable PPAs for clean power thus tend to be on a net energy usage basis, and only rarely on a time-matched basis. This implies that the data centres still rely on fossil power plants to remain available around the clock. To reduce fossil fuel-based electricity reliance energy storage can be deployed. This allows the time shifting of produced clean energy to times of demand, thus removing much of the reliance on fossil-based power generation. There is a wide range of energy storage options. Hydropower plants are particularly popular in this regard because the dams provide the energy storage. Additionally, hydropower tends to be well priced. In recent years, battery storage has been gaining traction, while hydrogen is expected to play an increasingly important role in the years ahead.

69. In 2020. IEA, "Data Centres and Data Transmission Networks" (November 2021).
70. BloombergNEF, "Data Centers and Decarbonization in Europe" (October 2021).
71. Nature, "How to stop data centres from gobbling up the world's electricity" (September 2018).

Additional decarbonisation potential exists by using data centre flexibility to align energy demand with clean energy availability. Several approaches exist, including deferring tasks that are not time sensitive (load shifting), or – thanks to the ease of transmitting data – executing the task at a different data centre that at the time has clean energy available (location shifting).

The electricity consumed in data centres ultimately ends up as heat that needs to be evacuated from the building. Cooling can account for up to 40 per cent of the energy demand of a data centre.[72] This, however, is highly climate dependent. Locating data centres in colder climates can significantly cut the need for cooling energy. Advances in cooling systems also promise a lowering of energy demand and its associated emissions. Plus, chillers are moving away from high global warming potential (GWP) refrigerants, lowering the impact of refrigerant leakages.

Figure 26:
Rising internet traffic typically leads to higher data centre workloads...

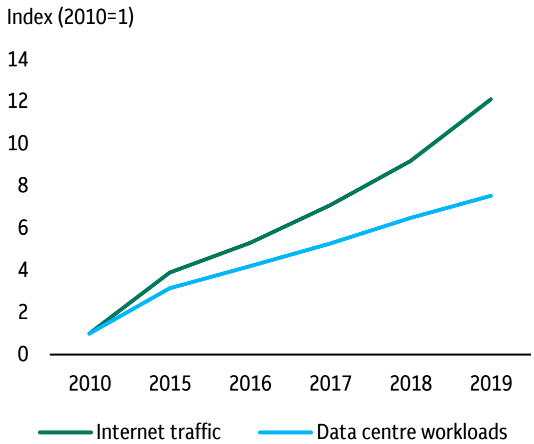
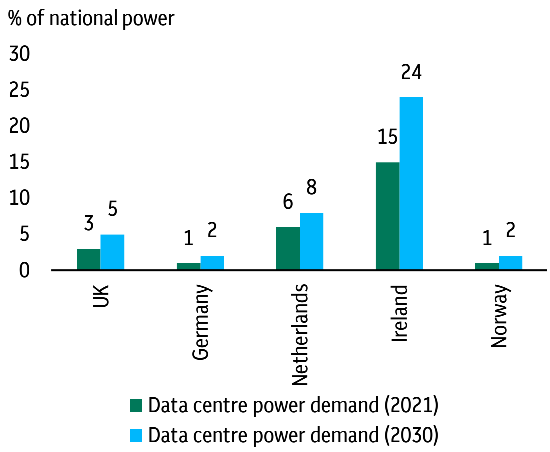


Figure 27:
...putting pressure on data centres' power consumption



Sources: IEA, "Tracking Data Centers and Data Transmission Networks 2020" (June 2020), and BloombergNEF, "Data Centers and Decarbonization in Europe" (October 2021).

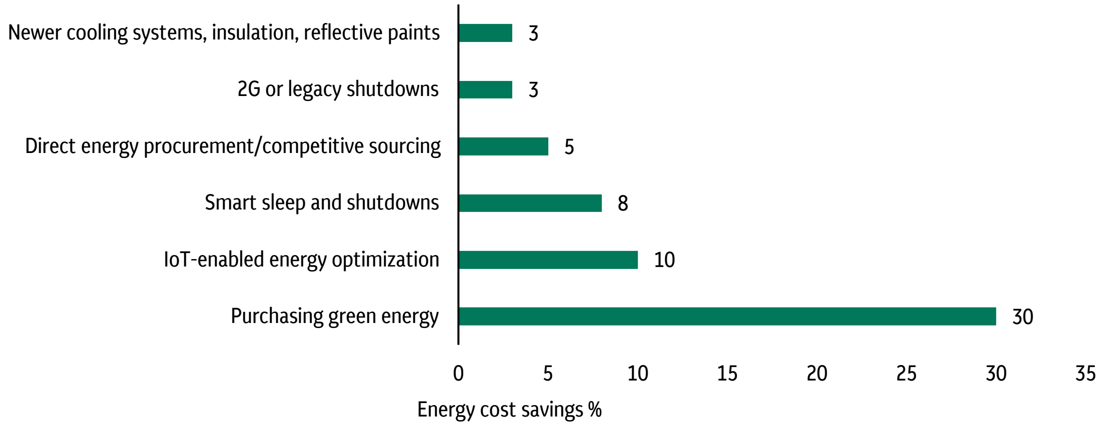
72. European Commission, "Cooler data centres help take the heat off electric bills" (August 2021).

Rapid increases in mobile data traffic will require greater focus on energy savings

The rollout of 5G technology is likely to put upward pressure on energy consumption. 5G is estimated to need up to 90 per cent[73] less energy per bit of data compared with 4G, partly due to shorter average distances between towers and users and partly due to advances in technology. But this energy efficiency gain will likely be offset or exceeded by the expected increase in mobile data traffic. It is estimated that a 5G network may use over 140 per cent more power than 4G with a similar coverage area.[74]

To limit the growth in power consumption from denser infrastructure, both MNOs and TowerCos are likely to need to optimise their power usage. A McKinsey study suggests that a wide range of techniques can be deployed to reduce energy consumption and, if applied simultaneously, may result in a more than 50 per cent reduction in energy consumption (Figure 28). Procuring renewable energy, including the on-site installation of solar panels and high-capacity batteries, may have the most significant impact from an energy saving perspective (up to 30 per cent).[75] Smart meters, including IoT-enabled sensors, may help monitor, measure, and optimise processes, contributing to significant improvements in energy efficiency.

Figure 28:
Potential techniques to reduce energy consumption of mobile networks



Source: McKinsey, "The case for committing to greener telecom networks" (February 2020).

73. GSMA, "Mobile Net Zero: State of the Industry on Climate Action 2021" (April 2021).
74. Analysys Mason, "Green 5G: Building a sustainable world" (July 2020).
75. McKinsey, "The case for committing to greener telecom networks" (February 2020).

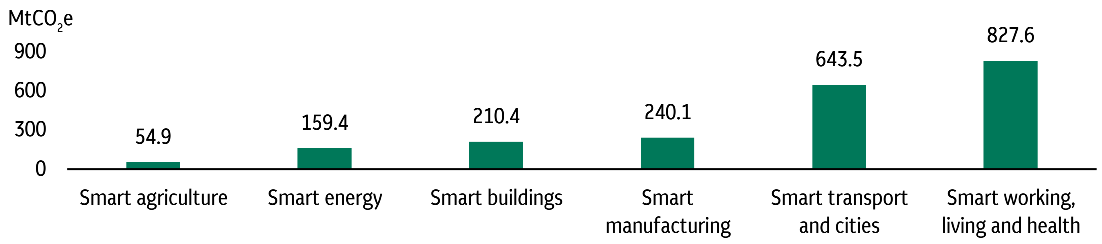
Environmental benefits lie across the lifecycle of fibre optic

Fibre optical networks provide multiple advantages over copper networks. Not only do they allow significantly higher data throughput rates but when it comes to operating fixed networks, a fibre optic cable is also about 85 per cent more energy-efficient than legacy copper wires.[76] This is partly due to the signal traveling further without the need for a repeater. Fibre networks also achieve the lowest GHG emissions for high-speed internet compared with wireless networks.[77] Especially where fibre optics can replace copper networks without the need for trenching works by reusing existing conduits, replacement of copper lines is beneficial due to the reduction in energy usage.

The "enablement effect" of digital infrastructure

The direct solutions discussed above to address the sector's current and future emissions are crucial to reducing its overall carbon footprint and enabling the world to reach net zero by 2050. But the sector may also have an important role to play in other sectors by improving their efficiency and facilitating behavioural changes that lower emissions. This is often referred to as the "enablement effect". By enabling mobile banking, online shopping, and video-calling, and promoting a circular economy through shared accommodation and shared transport, digital infrastructure allows more efficient and flexible use of resources and fewer GHG emissions. Estimates of the size of this effect vary but an estimate by GSMA[78] suggests that the enabling impact of global mobile networks was around 2,135 MtCO$_2$e in 2018 for total mobile network-related emissions of 220 MtCO$_2$e, with the largest impacts on working, living, and health (Figure 29). According to other estimates, mobile communications enabled a 1.4 billion MWh reduction in electricity and gas consumption, equivalent to powering 70 million US households for a year.[79] This implies that digital infrastructure, despite its energy use, can be at the base of net emissions reductions due to the enablement effect. In the mobile network, this emission reduction is practically 10t of CO_2 avoided per tonne emitted.

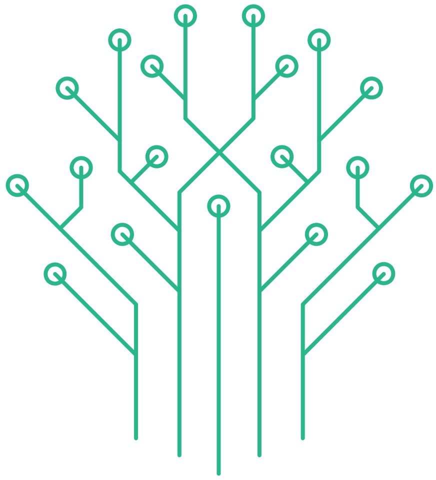
Figure 29:
The "enablement effect" of mobile network helped avoid 2,135 MtCO$_2$e in 2018



Source: GSMA, "The Enablement Effect: The impact of mobile communications technologies on carbon emission reductions" (December 2019).

76. World Bank Development Report 2021.
77. Assessing the emissions footprint of the fibre networks relative to other fixed broadband options in New Zealand (2021)
78. "The Enablement Effect", GSMA 2019.
79. 2018 data. GSMA, "The Enablement Effect: The impact of mobile communications technologies on carbon emission reductions" (December 2019).

Conclusion: Ecosystem densification and data growth



In this paper we have examined digital infrastructure with a focus on the topics most relevant for investors: the key drivers of data demand from consumers and businesses; the digital ecosystem and the physics of fixed-line cables; the 5G radio spectrum and need for small cells; the value creation of the split of telecom operators into independent tower companies (TowerCos) and fixed-line network operators (NetCos); the data centre market and the direction of its growth; and the carbon footprint of digital infrastructure and ways to reduce emissions.

There are several key conclusions from this analysis:

- **Data growth.** Since 2010, global internet traffic has increased 15-fold, driven by both consumer and business demand.[80] The COVID-19 pandemic has fast-tracked digital transformations by businesses and internet adoption by consumers. As data from new applications such as IoT, AI, and automation continue to grow, the need for reliable high-speed connectivity increases, creating powerful tailwinds for digital infrastructure.
- **Infrastructure investors.** Global digital infrastructure equity deal volume has increased more than tenfold in the last 11 years,[81] representing strong investor appetite to complement their portfolios with digital infrastructure assets. At the same time, the investment universe continues to expand on the back of the constant evolution of use cases that require increased bandwidth and lower latency.
- **Digital ecosystem.** The three main components of digital ecosystem – data centres, wireline and wireless – are closely interlinked. Data centres sit at the heart of digital infrastructure and perform data computation, processing, and storage. Wireline infrastructure is the backbone of all communications which connects data centres, businesses, homes, and mobile towers over a physical network of cables, while wireless infrastructure enables mobile connectivity.

80. IEA (November 2021).
81. Inframation database (2021).

- **Telecom market split.** Over the past decade, vertically integrated telecom companies have been divesting their infrastructure businesses such as towers and fixed-line networks. This has resulted in the emergence of new infrastructure players: TowerCos and NetCos. As independent entities, they may get better access to capital, lower borrowing costs, and more attractive valuations from long-term investors. We believe such characteristics favourably position TowerCos and NetCos to capitalise on growing demand for tower sites and fibre connectivity, unlocking value and opportunities for investors.
- **Data centres.** Cloud adoption and outsourcing of computing needs drive the demand for cloud-based applications and data centre services. Historically, data centres were concentrated in markets where the technology and telecom giants had a strong presence. However, as edge computing and connectivity become drivers of data centre locations, many content companies are increasingly moving servers closer to end users residing outside of traditional market hubs.
- **Net zero emissions.** Digital infrastructure may be responsible for up to 1.8 per cent of global GHG emissions. With data traffic growing rapidly, digital infrastructure may increasingly consume more power and contribute to a larger share of emissions. To limit global warming to 1.5C, fixed networks, data centres, and mobile networks will need to reduce GHG emissions by about 45 per cent by 2030. The solutions may include direct procurement of renewable power, use of innovative cooling systems, improved energy efficiency, shutdown of legacy technology (copper wires, 2G/3G), energy use optimisation, and other solutions.

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Pathways

For more information, or to speak to the author of this issue, Aizhan Meldebek, CAIA, please contact your Macquarie Asset Management Relationship Manager.