White paper for APWireless and Radius Global Infrastructure

Access to land under the GIA: considerations for regulation

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Contents

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Executive summary

Policy makers must carefully consider intervention in the market for access to land, to ensure outcomes are supportive of digital targets

One objective of the Gigabit Infrastructure Act (GIA) is to speed up, simplify and lower the costs of telecoms networks through regulation of parts of the value chain, including access to land. However, the regulation of the market for access to land could have detrimental effects on its functioning and reduce benefits brought about by investment in this segment. As a result, policy makers should rely on the approach set by the GIA only to solve specific challenges if they arise within the market for access to land. More generally, alternative approaches to regulating access to land, such as light-touch intervention or forbearance, are preferable as they allow for greater market flexibility and a beneficial optimisation of activities between land owners and tower companies and/or mobile network operators.

Potential interventions in the market for access to land, including price intervention, must be carefully considered to ensure unintended or counter-productive outcomes do not arise, as regulation could have detrimental impacts on the broader sector, negatively affecting consumer outcomes, network roll-out and achievement of digital targets. We explain these risks in this paper with reference to the implementation of the Electronic Communication Code (ECC) in the UK.

The access-to-land market for the deployment of mobile networks has been functioning well for many years

Land – both rooftop and ground space – and an effective market for access to land for network deployment and upgrade are fundamental requirements of the mobile telecoms value chain. The mobile industry has developed successfully across Europe over many decades, rolling out multiple networks and technologies, and with increasing access to land. Some industry players have expressed concerns around access to land, however these issues do not appear to be significantly affecting mobile deployment, as:

- prices for access to land represent a small fraction of the overall cost of deploying and operating a mobile network, and
- prices for access to land have typically been flat or negative in real terms over the last few years.

Mobile operators mainly face other challenges in deploying 4G and 5G networks, not related to access to land, as they seek to achieve the Digital Decade targets for widespread availability of high-speed mobile networks.

The land market is fragmented, with many private land owners

Land for mobile networks is supplied to tower companies and mobile network operators by thousands of different land and building owners. A few larger providers such as local authorities exist, but in general the land market is highly fragmented. This diversity and fragmentation creates operational and administrative challenges, as well as network roll-out risks and uncertainties, for tower companies and mobile operators relying on a variety of short- to medium-term rental arrangements.

Lease aggregators have entered the market as digital real-estate investors, bringing a range of benefits and optimised long-term capital funding

Lease aggregators are infrastructure investors, often digital real-estate specialists, focusing on the passive layer of digital infrastructure across different asset classes, including land and rooftops for mobile sites. Lease aggregators typically adopt a very long-term, low-risk approach, targeting stable and predictable cashflows. They bring operational and financial benefits that produce advantages for mobile operators and tower companies, and these efficiencies and optimisations can have a clear positive impact on supporting the achievement of the Digital Decade targets. Through the activity of aggregating individual land leases from multiple land owners into a portfolio to be offered to downstream mobile network operators (MNOs) and tower companies, lease aggregators:

- bring aligned incentives and partnerships between the investors in lease acquisitions and the investors in digital network infrastructure
- minimise the risk of site re-location and churn, thereby reducing the operational, planning, financial and environmental impacts of site moves
- enable long-term visibility and predictability on costs for downstream renters of ground and rooftop land for mobile networks
- realise cost efficiencies, optimise site access, standardise site access contracts, and reduce the administrative efforts of site upgrades and lease renewals
- enable long-term, low-risk capital to be invested in very long life land assets, supporting optimised financing structures for each part of the value chain.

Optimised long-term investments in various passive infrastructures for digital services are on the rise and are sought after by the wider digital infrastructure sector, for assets such as telecoms exchanges, datacentres, mobile masts, dark fibre, etc.

The UK has already applied regulation to access to land for telecoms services, with some unintended consequences. A comparison of the UK to peers suggests that its mobile network performance and deployment have developed less well since

The UK updated its ECC in 2017, which has brought various challenges by disrupting the market for access to land. Hundreds of site access and/or renewal disputes have had negative effects on mobile network deployment, as evidenced by comparison of relevant metrics between the UK and peer countries (Germany, Spain, France, Italy and the USA):

- Opensignal's mobile customer experience data indicates that the UK's mobile network performance and 5G roll-out lag behind those of its peers since 2017, even though key indicators such as market structure, spectrum availability and smartphone penetration show broad alignment between the UK and peer countries.
- The key drivers defining network performance include spectrum efficiency, spectrum allocation and network densification, and many complex factors have an impact on network deployment and performance; however, access to land is a critical enabler for network roll-out and network upgrade.

The table below highlights a comparison between the UK and its peers across a range of critical network performance and infrastructure metrics.

Figure 0.1: Comparison between the UK and five peer countries (Germany, Spain, France, Italy and the USA) [Source: Opensignal, Analysys Mason, 2024]

Metric	Countries	Start year value (rank)	2024 value (rank)	Change (rank change)
4G users' coverage experience[1]	UK	77% (3)	97% (5)	+20% (down 2)
	Peers	75%	98%	+23%
5G users' coverage experience[2]	UK	22% (3)	34% (6)	+12% (down 3)
	Peers	24%	49%	+25%
5G availability[2]	UK	5% (4)	10% (6)	+5% (down 2)
	Peers	9%	19%	+10%
4G download speed[3]	UK	24Mbit/s (4)	32Mbit/s (5)	+8Mbit/s (down 1)
	Peers	24Mbit/s	41Mbit/s	+17Mbit/s
5G download speed[4]	UK	117Mbit/s (4)	124Mbit/s (6)	+7Mbit/s (down 2)
	Peers	117Mbit/s	176Mbit/s	+59Mbit/s
4G base stations per 1000 inhabitants[5]	UK	0.9 (2)	1.3 (6)	+0.4 (down 4)
	Peers	0.8	1.7	+0.9
5G base stations per 1000 inhabitants[6]	UK	0.3 (6)	0.6 (6)	+0.3 (0)
	Peers	0.9	1.2	+0.3

Evidence shows the UK has fallen behind peer countries, with the number of mobile macro sites – an overall measure of land access – being

The Opensignal data in Figure 0.1 clearly shows that for important mobile network metrics, such as 4G/5G coverage, availability, download speeds and base station deployment:

- the UK has fallen to 6th place (out of 6 countries) on most of these metrics
- over the past 3–6 years, the UK's metrics have shown less improvement compared to the average progress seen in peer countries.

Considering access to land, the deployment of macro sites is a reasonable

1 Start year is 2017.

2 Start year is 2020.

3 Start year is 2017.

4 Start year is 2021.

5 Start year is 2018.

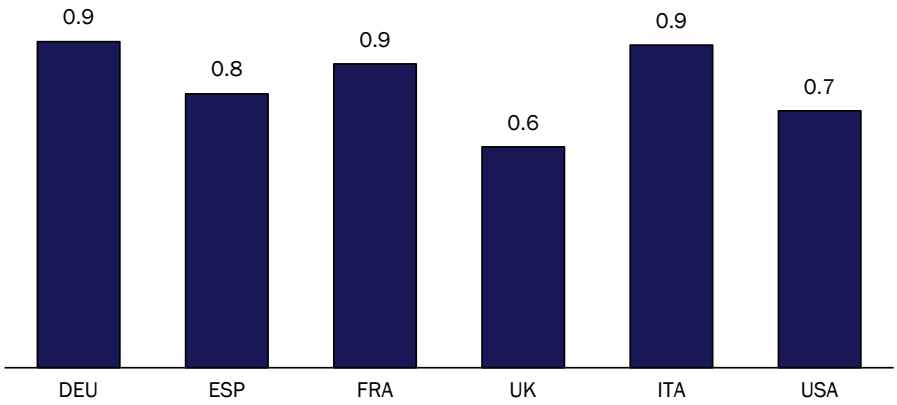
6 Start year is 2023.

the lowest in our benchmark

indicator of how extensive the networks are in terms of presence across the ground and rooftop land locations in each country. More extensive networks will provide better coverage and can offer more capacity.

Figure 0.2 shows that the UK has the lowest number of macro sites across the markets we have compared, when normalised by population.

Figure 0.2: Estimated number of mobile macro sites per 1000 inhabitants [Source: Analysys Mason based on operator websites, analyst reports and tower company publications, 2023–2024]



We recommend careful consideration of intervention in the market for access to land

The GIA is to be implemented and applied in EU Member States in the coming months, and aims to simplify and lower the cost of telecoms networks through regulation. Member States are also encouraged to provide guidance, particularly on the price of access to land. This regulation places requirements on land access negotiations which would not occur in a commercial market situation. We observe that in the UK the implementation of the ECC, which introduced similar land access regulations, has led to hundreds of land access disputes and a significant increase in tribunal referrals (and consequent delays). A comparative analysis of network performance and infrastructure metrics places the UK at the bottom among its peer countries, reflecting a slower pace of development in recent years.

Potential interventions in the market for access to land, including on prices, must be carefully considered as the GIA is implemented. If specific isolated challenges arise, such as landowners demanding 'ransom rents', the GIA could be applied to resolve such issues. However, wider regulation of access to land could have detrimental impacts on the broader sector, negatively affecting consumer outcomes, network roll-out, and achievement of digital targets. Considering that decades of mobile network expansion have been achieved through commercially negotiated access to land, alternative approaches – such as forbearance or lighter-touch regulation – are preferable as they provide greater market flexibility in this crucial aspect of digital infrastructure.

Introduction

This white paper aims to provide European regulators and policy makers with a comprehensive understanding of the land market for mobile telecom infrastructure and the impact of land access regulation, with a focus on lessons learnt from the UK following the introduction of the Electronic Communications Code (ECC) in 2017. It also examines the potential implications for European markets under the forthcoming implementation of the Gigabit Infrastructure Act (GIA).

Drawing on trusted independent data from key sources such as Opensignal, the paper highlights the divergence in market outcomes between the UK and comparable countries during the years of active ECC regulation. Through evidence-based analysis, it explores the dynamics of land access regulation, its broader market impacts, and alternative approaches to reduce implementation risks.

Furthermore, this paper establishes the important role of land aggregators in the European Union (EU)'s digital infrastructure value chain, offering policy makers an informed perspective to support effective regulatory frameworks and foster investment in the digital infrastructure needed to achieve the Digital Decade targets.

The remainder of this document is laid out as follows:

- Section 1 introduces the Digital Decade targets and the Gigabit Infrastructure Act (GIA), outlining its role in seeking to support these objectives
- Section 2 examines the historical performance of mobile infrastructure markets in Europe, introduces the access-to-land market, and highlights concerns raised by stakeholders
- Section 3 explores the role of lease aggregators within the access-to-land market, emphasising their relevance and importance in the digital infrastructure value chain
- Section 4 analyses the mobile infrastructure market in the UK, with a focus on the impact of the ECC on the access-to-land market
- Section 5 compares network performance in the UK to that in other European markets and the United States, using data from Opensignal and Analysys Mason to assess the impact of the regulation of access to land
- Section 6 evaluates the potential effects of the GIA on the access-to-land market and provides recommendations for effective regulatory implementation
- Section 7 summarises the paper's key conclusions.

Annex A presents the Opensignal methodology, describing the different customer experience and network metrics and explaining how the data was collected.

1 The EU has ambitious targets for its Digital Agenda which it is seeking to support through new regulation

1.1 Connectivity targets are defined by the EU's Digital Decade Policy Programme 2030, which includes mobile and fixed coverage ambitions together with 10 000 edge nodes

Telecoms coverage targets in the EU have been defined as part of the wider digital targets included in the EU's Digital Decade Policy Programme 2030,[7] as follows:

> "*all end users at a fixed location are covered by a gigabit network up to the network termination point, and all populated areas are covered by next-generation wireless high-speed networks with performance at least equivalent to that of 5G, in accordance with the principle of technological neutrality;*" and
> "*at least 10 000 climate-neutral highly secure edge nodes are deployed in the Union, distributed in a way that guarantees access to data services with low latency (i.e. a few milliseconds) wherever businesses are located*".

Other targets in the programme refer to the digital skills of the EU population, the environmental sustainability of networks, the digital transformation of businesses and the digitalisation of public services.

Meeting the telecoms coverage targets will be a significant challenge, especially in large and populous markets, which will require substantial investments and growth in digital infrastructure, in all of its forms. The EC estimates that EUR200 billion of additional investment will be required to ensure full gigabit coverage across the EU as well as 5G coverage in all populated areas.[8] The relevance of achieving the connectivity targets for EU competitiveness and the investment gap to get there have been endorsed by the Letta[9] and Draghi[10] reports.

1.2 Mobile targets will be underpinned by three key improvements to existing networks

Coverage targets for mobile (wireless) networks set by the EU Digital Decade Programme, and counted in terms of network points of presence (PoPs), will be mainly addressed through three key network actions:

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7 European Union (19/12/2022), *Decision (EU) 2022/2481 of the European Parliament and of the Council*.

8 European Commission (27/09/2023), *First report on the State of the Digital Decade calls for collective action to shape the digital transition*.

9 Enrico Letta (April 2024), *Much more than a market – Speed, Security, Solidarity, Empowering the Single Market to deliver a sustainable future and prosperity for all EU Citizens.*

We note that the Letta report mentions a "considerable investment gap" and "growing connectivity investment gap", but does not refer to the amount of EUR200 billion.

10 Mario Draghi (September 2024), *The future of European competitiveness*.

- upgrade of existing PoPs
- deployment of capacity PoPs
- deployment of coverage PoPs.

Access to land has an impact on each of these actions, as outlined in Figure 1.1.

Figure 1.1: Main types of site upgrades and their impact on the Digital Decade targets [Source: Analysys Mason, 2025]

Site deployment	Description	Impact on Digital Decade targets	Impact of access to land on deployment
Upgrade of existing PoPs	Upgrade of existing PoPs to a new and improved technology such as 5G	• Higher download/upload speeds and lower latency, improving network quality • Higher capacity, improving network congestion • Improving energy efficiency supporting the sustainability targets	• New equipment (5G) will be needed, potentially occupying additional land or rooftop space • Requires permission and/or facilitation of access so that the access seeker can perform upgrades
Deployment of capacity PoPs	Increased capacity through densification of already covered areas with additional PoPs	• Improves network capacity in high-traffic areas, reducing network congestion and improving user experience	• Occupying additional land or rooftop space on an existing (shared) site or a completely new site • Deployment on an existing (shared) site requires permission and/or facilitation of access • Deployment of a new site requires a new plot of land and thus a new lease/land purchase agreement
Deployment of coverage PoPs	Deployment of new PoPs to improve coverage	• Expands coverage to uncovered areas, typically in rural or remote areas, including transport routes	

1.3 The EU has introduced a new policy, the GIA, designed to support mobile network roll-out improvements, including through regulation of access to land

The EU's Gigabit Infrastructure Act (GIA)[11] replaces the 2014 Broadband Cost Reduction Directive (BCRD), aiming to ensure faster, cheaper and simpler roll-out of gigabit networks, and addressing hurdles identified by the European Commission (EC) such as expensive and complex procedures for network deployment. The GIA is explicitly designed to support Digital Decade targets such as ensuring EU-wide access to fast gigabit connectivity and fast mobile data by 2030.

11 European Union (08/05/2024), *Regulation (EU) 2024/1309 of the European Parliament and of the Council*.

To facilitate the roll-out of fixed and mobile very high-capacity networks (VHCNs)[12] for electronic communications, the following entities and elements will be regulated according to the GIA:

- **Network operators**: electronic communications networks but also networks of gas, electricity, heating and water, as well as transport services, including railways, roads, ports and airports.
- **Physical infrastructure**: hosting network equipment, such as "pipes, masts, ducts, inspection chambers, manholes, cabinets, antenna installations, towers and poles, […] buildings [and] street furniture".

More specifically, the GIA introduces the following measures to streamline network deployment:

- **Shared use of infrastructure**: encouraging the shared use of ducts and poles for deploying VHCNs to optimise resources and reduce costs.
- **Co-deployment and co-ordination of civil works**: enhances collaboration between telecoms operators and public civil works to reduce disruptions and expedite broadband expansion (representing the only instances where network operators, other than electronic communications networks, are regulated).
- **Administrative streamlining**: reducing bureaucratic hurdles and improving efficiency.
- **Equipping buildings with high-speed-ready infrastructure**: encouraging the installation of high-speed-ready infrastructure in new buildings (or buildings undergoing major renovation works) and ensuring access to this infrastructure to facilitate broadband deployment and adoption.

The GIA also addresses issues related to access to land in relation to telecoms networks. Paragraph 15 of the preamble states that:

> "*To ensure continuity of service and predictability for the planned deployments of associated facilities, legal persons who are […] holders of rights over land […] on which facilities are planned to be or have been installed […] should negotiate in good faith access to the land and inform national regulatory authorities about their agreements, including the negotiated price, which where appropriate should reflect market conditions. To facilitate such negotiations, Member States could provide guidance, in particular on the price for access to the land.*"

Article 3 (Access to existing physical infrastructure) further stipulates that:

12 VHCNs as defined by the EU's Electronic Communications Code are "either an electronic communications network which consists wholly of optical fibre elements at least up to the distribution point at the serving location, or an electronic communications network which is capable of delivering, under usual peak-time conditions, similar network performance in terms of available downlink and uplink bandwidth, resilience, error-related parameters, and latency and its variation;"

"*legal persons […] who manage lease contracts on behalf of land owners, and operators, shall negotiate access to such land in good faith, including on the price, which where appropriate shall reflect market conditions in accordance with national contract law.*"

And:

"[…] *owners of private commercial buildings […] are to meet reasonable requests for access to those buildings, including their rooftops, with a view to installing elements of VHCNs or associated facilities under fair and reasonable terms and conditions, and at a price reflecting market conditions…*[provided that the building is in a defined remote or rural area, and there are no other nearby networks or other suitable host building]."

Article 13 (Dispute settlement) states that:

"Without prejudice to the possibility to refer the case to a court, any party shall be entitled to refer to the competent national dispute settlement body established pursuant to Article 14 a dispute that may arise:

a) *where access to existing infrastructure is refused or agreement on specific terms and conditions, including price, has not been reached within one month from the date of receipt of the request for access under Article 3…*"

"Taking full account of the principle of proportionality, the national dispute settlement body referred to in paragraph 1 shall issue a binding decision to resolve the dispute at the latest: within four months from the date of the receipt of the dispute settlement request, with respect to disputes referred to in paragraph 1, point (a)…"

As outlined above, it will be the responsibility of a competent national authority, such as the national regulatory authority (NRA) for telecoms, to determine and apply the terms of the GIA in accordance with national law. The wording of the GIA that such dispute settlement body can issue binding "*fair and reasonable terms and conditions, including price*" appears to be open to wide interpretation by relevant authorities, as discussed later in this report. However, it is worth noting that EU law is based on a number of principles and fundamental rights, which are recognised by European case law and must be considered in relation to regulation of access to land. These include **proportionality**[13] (which is referenced directly in Article 13) and the **freedom to conduct a business**,[14] within the rules set by legislators:

- Proportionality requires that measures adopted by EU institutions must be appropriate and necessary to achieve the objectives pursued by the legislation, and they should not exceed what

13 Article 5(4) Treaty on the functioning of the European Union; Article 5, Protocol (No 2) Treaty on the Functioning of the European Union; affirmed by ECJ in series of cases including Federation Charbonnière (C8-55), Internationale Handelsgesellschaft (C11-70), Fedesa (C331-88), Swedish Match (C201-03) and Digital Rights Ireland (C293-12).

14 See: Sky Österreich GmbH v Österreichischer Rundfunk (Case C-283/11), Alemo-Herron and Others v Parkwood Leisure Ltd (Case C-426/11), AGET Iraklis AE v Minister for Labour, Social Security and Social Solidarity (Case C-201/15).

is necessary to achieve those objectives. When there is a choice between several appropriate measures, the least onerous option should be selected, and the disadvantages caused by the measures should not be disproportionate to the aims pursued.

- The freedom to conduct a business includes the right to engage in economic or commercial activity, freedom of contract, and free competition. These can be limited by law, as long as these limitations respect the essence of those rights and freedoms, and comply with the principle of proportionality. Such limitations must be necessary and genuinely meet objectives of general interest recognised by the EU or the need to protect the rights and freedoms of others.[15]

15 See *Charter of Fundamental Rights of the European Union*, Article 16 and Article 52(1).

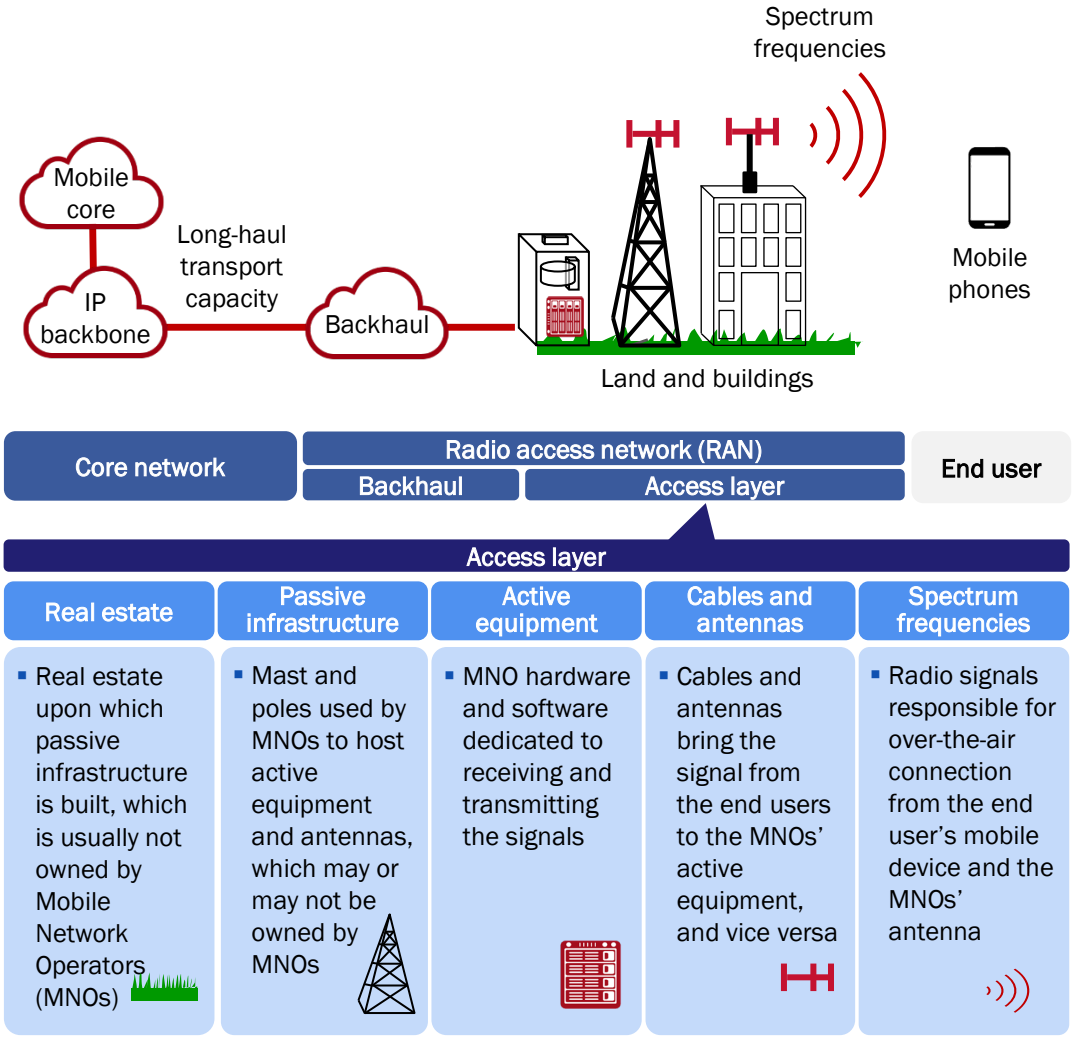
2 The access-to-land market for the deployment of mobile networks has been functioning well for many years

2.1 Access to land is a key part of the telecoms value chain

'Land' is referred to as the area where a mobile radio site is located, which may be ground (for ground-based towers), rooftops (for rooftop sites), buildings (other than rooftops, such as wall mounts) and street furniture (lampposts, bus stops, etc.).

Figure 2.1 illustrates the role of land within the mobile network.

Figure 2.1: Illustrative overview of mobile network architecture [Source: Analysys Mason, 2025]



Land can be seen as the most passive layer of the telecoms infrastructure and, as such, is an integral part of the telecoms value chain. The land market is very fragmented and telecoms operators, tower companies and infrastructure investors access land to secure space for mobile network infrastructure.

2.2 The mobile industry has developed successfully across Europe, rolling out multiple networks and technologies, and with increasing access to land over many decades

Over the last 35 years, in all telecoms markets across EU Member States, the UK and the USA,[16] between three and four mobile network operators (MNOs) have emerged (see Figure 2.2).

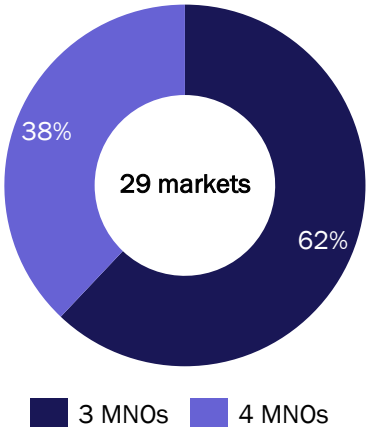
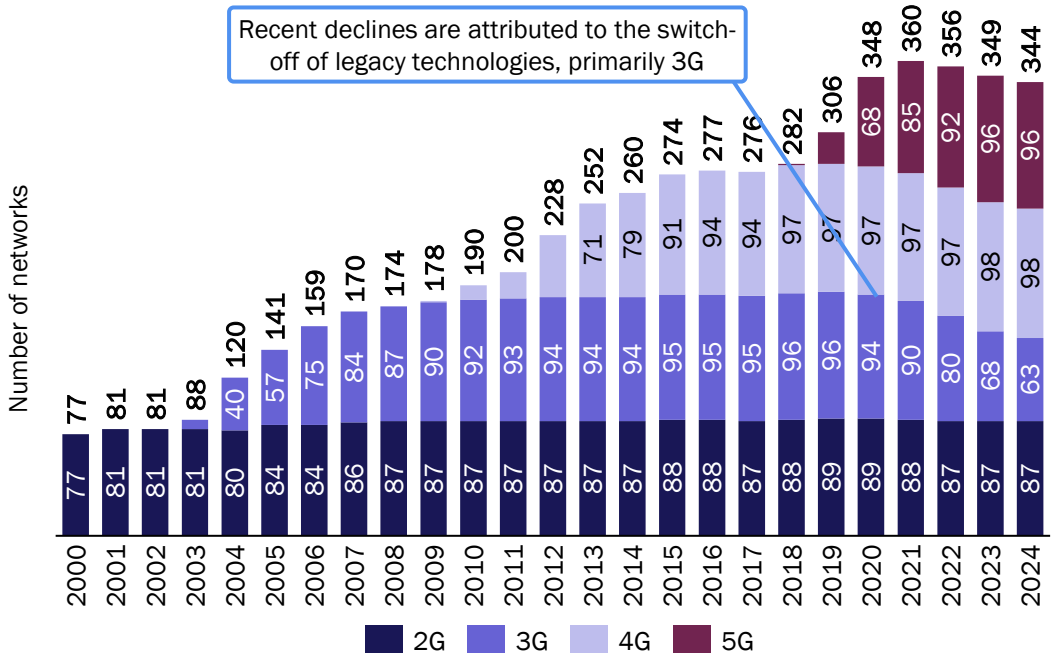


Figure 2.2: Number of MNOs per country, including EU Member States, the UK and the USA [Source: Analysys Mason, TeleGeography, 2025]

MNOs have also progressively upgraded their mobile networks to new technologies in waves, keeping pace with the development of successive generations (2G, 3G, 4G, 5G), as shown in Figure 2.3. This includes the deployment of new antenna technologies using new spectrum bands as they are auctioned and become available to the MNOs, e.g. 5G massive multiple-input and multiple-output (MIMO) antennas. Over time, legacy technologies become suboptimal and their spectrum is refarmed to support new technologies, for example the 3G switch-offs started in recent years. The addition of multiple generations in parallel, and newer generations using higher frequency (smaller cell coverage) bandwidths, has resulted in an increasing need for access to additional land for more sites, as well as larger site footprints for electronics.

16 The USA is described as having three major nationwide MNOs in Verizon, T-Mobile and AT&T.

Figure 2.3: Number of network generations over time in the EU, UK and USA [Source: Analysys Mason, 2025][17]



Despite having to roll out new technologies regularly, the three or four MNOs present in each country have, to a very large degree, managed to access land to deploy their networks and offer near-ubiquitous population coverage, as illustrated for the EU in Figure 2.4.

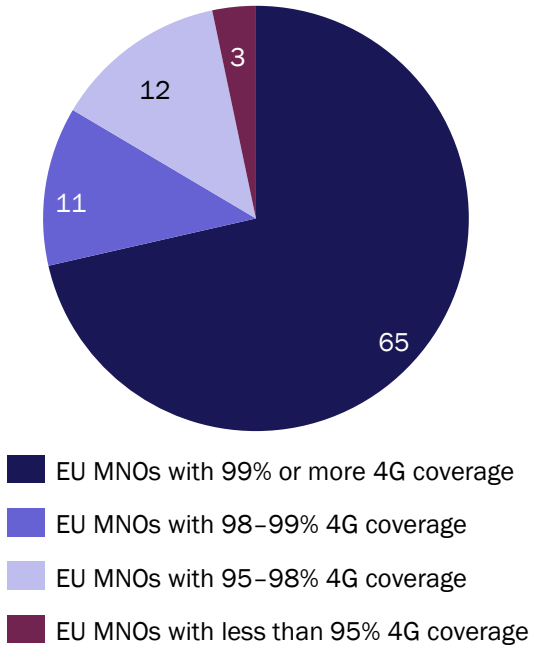


Figure 2.4: EU MNOs by 4G population coverage (Q2 2023) [Source: © GSMA Intelligence 2023]

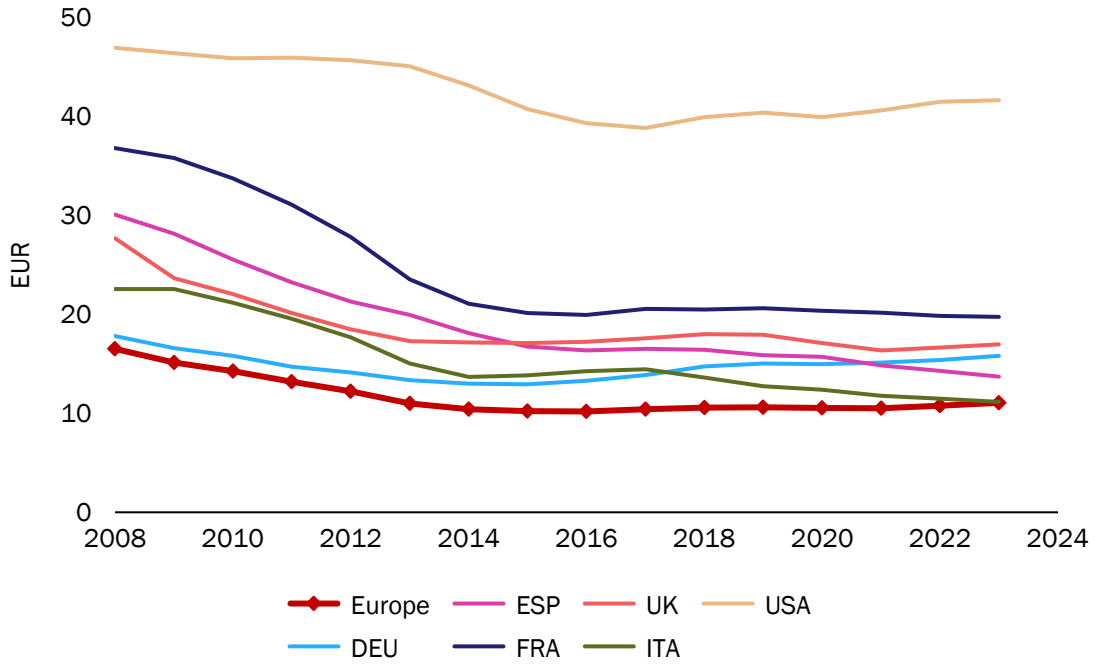
17 The figure aggregates the total number of networks per technology for all operators in the selected markets.

Over this long period and through the multiple technological upgrades mentioned above, access to land has not been identified as a significant burden or obstacle by mobile operators, policy makers, regulators or industry experts.

2.3 Mobile operators face a range of challenges

Mobile telecoms markets in Europe have been characterised by very competitive market structures over the past 30 years, with up to four MNOs per market and a multitude of mobile virtual network operators (MVNOs). As a result, price rivalry between MNOs has resulted in sustained average revenue per user (ARPU) decreases across European markets as well as in the USA. ARPUs have stabilised somewhat in European markets since 2015 (as shown in Figure 2.5), although they have continued to fall in some markets in recent years. ARPUs are shown here on a nominal basis, suggesting ARPU decreases in real terms would be more significant. Low revenue can reduce the MNOs' abilities to invest.

Figure 2.5: Monthly ARPU per country over time (excl. IoT SIMs)[18] [Source: Analysys Mason, 2025]



Simultaneously, mobile operators regularly face significant capex demands in order to deploy new technologies. In the UK, Three UK and Vodafone for example have announced that "MergeCo (the new merged entity) intends to invest over GBP6 billion in the first five years, and GBP11 billion over a ten-year plan, to create a best-in-class 5G network"[19] on top of any investment already made since the launch of 5G in 2019. The procurement of spectrum licences also requires a significant capex investment: in the UK in 2021, EE invested GBP280 million in 20MHz of 5G spectrum in the 700MHz

18 The European average includes all 27 Member States.

19 Vodafone (14/06/2023), *Merger of Vodafone UK and Three UK to create one of Europe's leading 5G networks*.

band and GBP168 million in 40MHz of 5G spectrum in the 3.6–3.8GHz band.[20] While in the same year in Spain, Vodafone paid EUR350 million for 20MHz of 5G spectrum in the 700MHz band.[21]

High capex demands combined with decreasing or stable ARPUs have resulted in unfavourable financial positions for mobile operators, and this is likely to hamper their ability to fully achieve EU digital targets.[22]

2.4 Prices for access to land represent a small element in relation to the overall cost to roll out and operate a mobile network

As previously estimated by Analysys Mason in its report on "Land providers in the context of the European Commission's planned Gigabit Infrastructure Act",[23] (see Figure 2.6 below) land costs account for 6–15% of an MNO's overall network expenses, and an even smaller percentage when significant retail operating costs are included. By comparison, the network costs associated with the radio access network electronics and towers represent on average 21% and 26% respectively, and can be as high as 27% and 47% in certain markets. It is also noted that, following the carve-out of passive infrastructure to 'tower companies' (discussed further in Section 3.1), there is in many cases an intermediary between MNOs and land providers. The presence of this intermediary may result in any price adjustments associated with regulation under the GIA not effectively flowing through to MNOs and end-user prices.

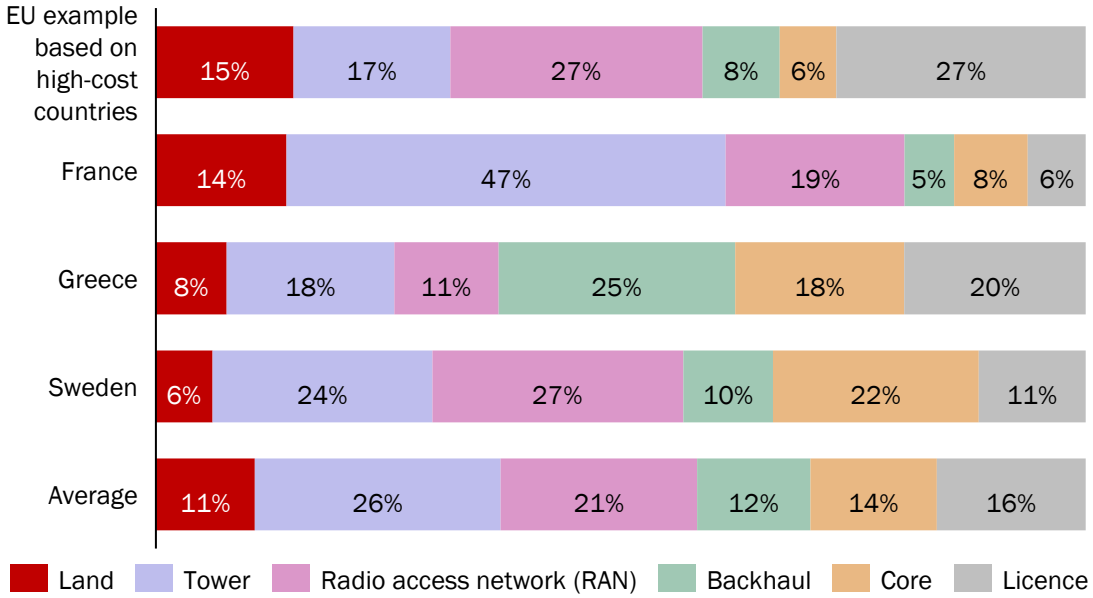
20 OFCOM (17/03/2021), *Ofcom spectrum auction: principal stage results*.

21 Vodafone (22/07/2021), *Vodafone Spain acquires 2x10 MHz of spectrum to expand 5G services*.

22 European Commission (27/09/2023), *First report on the State of the Digital Decade calls for collective action to shape the digital transition*.

23 Analysys Mason (27/09/2023), *Land providers in the context of the European Commission's planned Gigabit Infrastructure Act*.

Figure 2.6: Cost of land and other items as a proportion of an MNO's network costs (annualised capex and opex in 2023 from regulators' LRIC models and benchmarks of land rents) [Source: European Commission,[24] Arcep,[25] EETT,[26] PTS,[27] Analysys Mason,[28] 2023]



In recent years, Europe has witnessed the emergence of the 'towerco model', in which MNOs carve out their passive infrastructure into separate companies that take on the functions related to the ownership and management of passive infrastructure that were previously the responsibility of the MNOs. Many of these separate tower companies have then been partially or fully divested by the MNOs as part of long-term sale-and-leaseback agreements, creating an intermediary party in the relationship between MNOs and landowners. Tower holdings by ownership in Europe are shown in Figure 2.7.

24 See https://digital-strategy.ec.europa.eu/en/library/finalisation-mobile-cost-model-roaming-and-delegated-act-single-eu-wide-mobile-voice-call

25 See www.arcep.fr/uploads/tx_gspublication/modele-TA-mobile-consultation_publique-avril17.rar

26 See https://www.eett.gr/anakinosis/diexagogi-dimosias-diavoyleysis-anaforika-me-tin-epikairopoiisi-toy-technooikonomikoy-monteloy-bottom-up-pure-lric-gia-ton-kathorismo-ton-anotaton-timon-ton-ypo-rythmisi-telon-termatismoy-kliseon-se-k/

27 See https://pts.se/sv/bransch/telefoni/konkurrensreglering-smp/prisreglering/kalkylarbete-mobilnat/gallande-prisreglering/

28 In each of the four LRIC models, we subtracted the cost of land, based on benchmarks in various European countries collected by Analysys Mason from public sources and confidential datapoints, from the annualised cost of towers.

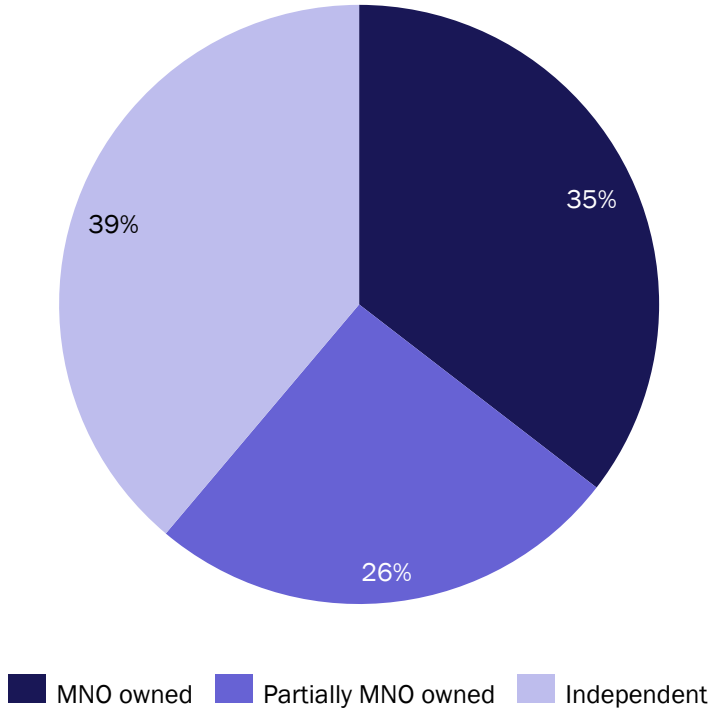


Figure 2.7: Tower holdings in Europe by ownership [Source: Analysys Mason, 2023]

In recent years, many of the EU's largest MNOs have created subsidiaries of tower companies with varying levels of divestment (see Figure 2.8), many of which have been acquired by a relatively small number of investors, resulting in the development of several pan-European tower companies with high market shares (see Figure 2.9).

Figure 2.8: Overview of the tower strategies of the five largest MNOs by number of SIMs, in Europe [Source: Analysys Mason, operator reports, press search, 2023]

MNO	EU market share (% of SIMs)	EU markets of operation	Tower strategy
Vodafone	15%		Vodafone carved out its tower infrastructure assets into Vantage Towers in 2019–21 before launching an IPO for ~20% ownership. In 2022, Vodafone further reduced its stake in Vantage Towers, entering into a co-control partnership with a consortium comprising KKR and GPI
Orange	12%		Orange carved out its tower infrastructure into a separate entity, TOTEM, in 2021. It is fully owned and operated by Orange, with no sale plans announced so far

MNO	EU market share (% of SIMs)	EU markets of operation	Tower strategy
Deutsche Telekom	11%		Deutsche Telekom carved out its towers in Germany and Austria into GD towers, in which it sold a majority stake in 2023. It may go on to carve out its towers in other markets in a similar way
Iliad	7%		Iliad sold its towers in Italy and France to Cellnex in 2019, and in Poland in 2020, also to Cellnex
Telefónica	7%		Telefónica sold its Telxius Towers division to ATC in 2021

Figure 2.9: Overview of main European tower companies [Source: Analysys Mason, tower company reports, press search, 2023]

Tower company	No. of EU sites	EU market share (% of total sites)	EU markets of operation	Ownership	Key anchor tenants
Cellnex	~95 000	21%		Cellnex is a publicly listed company	Cellnex has anchor tenancies from a range of major MNOs including Iliad, Telefónica Bouygues Telecom, and H3G
Vantage Towers	~69 000	16%		Vantage Towers is 89% owned by the co-control partnership known as 'Oak' between Vodafone and the KKR–GIP consortium, with KKR and GIP owning 50% of Oak as of July 2024.	Vodafone
GD Towers	~40 000	9%		51% owned by Brookfield and DigitalBridge, whilst Deutsche Telekom retains a 49% stake	Deutsche Telekom
ATC	~30 000	7%		ATC Europe is 60% owned by American Tower, with minority stakes held by CDPQ and Allianz	Telefónica

Tower company	No. of EU sites	EU market share (% of total sites)	EU markets of operation	Ownership	Key anchor tenants
TOTEM	~27 000	6%		TOTEM is owned and operated by Orange	Orange

A number of MNOs operating in smaller EU markets, such as T-Mobile Romania, currently retain ownership of their passive infrastructure. However, these markets are expected to experience a further wave of tower asset sales.

Once structurally separated, the relationship between MNOs and tower companies is governed by long-term master service agreements (MSAs), which include commercial terms such as pricing and allowances for space on the towers as well as obligations and restrictions applying to both MNO and tower company. Although the terms included vary between agreements, common topics include:

- length of contract and renewal terms
- pricing, price indexation and space allowances (on the site), and terms for exceeding such allowances
- renewal options, which are typically on or close to an 'all or nothing' basis, limiting the ability of the MNO to churn selectively at renewal
- restrictions related to additional tenants such as 'golden sites', which are strategically important for the anchor tenant and cannot be offered for co-location
- churn for convenience allowances, which permit tenants to churn from a limited number of sites within a given timeframe, for example 0.5% of total sites per annum, with financial penalties for churn beyond these allowances
- service level agreements (SLAs) to be upheld by the tower company, including site access requirements and permittable site relocation
- discount/profit sharing clauses, such as a form of reduction of MSA fees if the tower company's lease-up rate (the average number of tenants per site) exceeds certain thresholds.

Most MSAs between anchor tenants (the lead tenant and often the MNO that originally constructed and sold the mobile site) and tower companies are similar in that they are long term in nature and have strict terms that prevent either party from deviating significantly from the operating model constructed at the time of the original sale-and-leaseback agreement.

Tower owners may also have contracts in place with other MNO or non-MNO tenants, other than the anchor tenant; however, these are typically shorter term in nature and provide more flexibility for both parties.

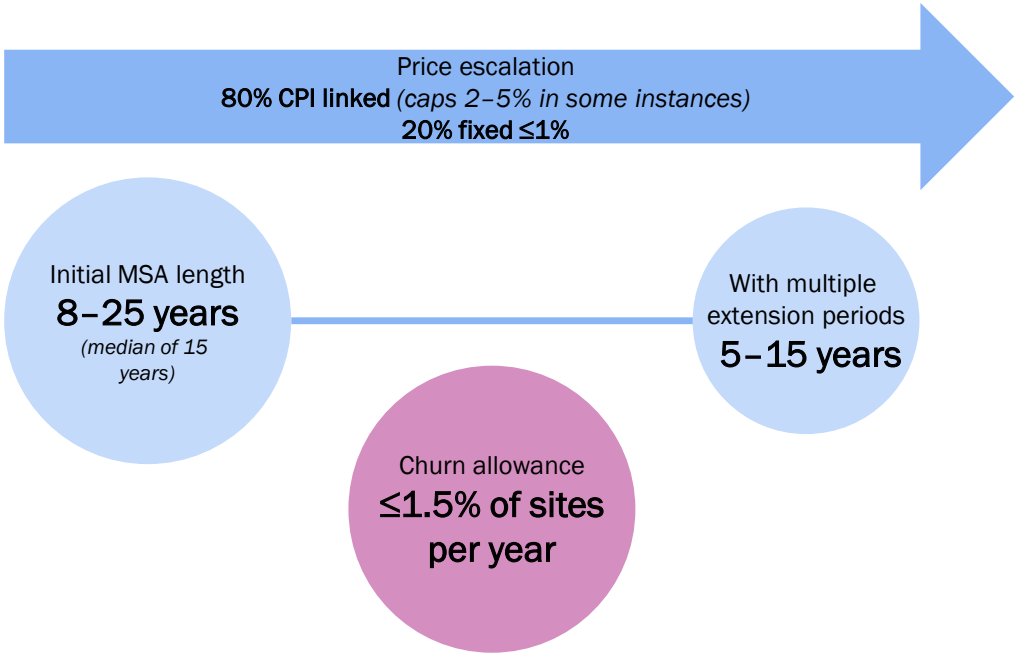
With tower companies' increasing role between landowners and MNOs, savings on land rents may not be passed on to MNOs, and therefore not to end users of electronic communications either, but instead captured by tower companies in the form of higher profits.

MSAs between tower companies and MNOs are long-term agreements that typically include annual price escalation terms (e.g. in line with inflation). As a result, cost savings (and cost increases) that

may arise during the validity period of an MSA are typically kept (or have to be borne) by tower companies, rather than passed on to MNOs. A limited number of tower company MSAs have contractual sharing mechanisms requiring a proportion of savings to be passed through to tenants. Cost savings on land would therefore primarily benefit only MNOs which still own (the majority of) their towers, although as shown in Figure 2.7, less than half of all sites are now fully owned by MNOs.

Over time, rental price changes can be passed on from tower companies to MNOs at the end of each MSA's term. However, this process will take many years, as the initial term typically ranges from 8 to 25 years, with extensions lasting 5 to 15 years, as shown in Figure 2.10.

Figure 2.10: Benchmarks of ten MSAs proposed or signed since 2016 [Source: Analysys Mason, 2023]



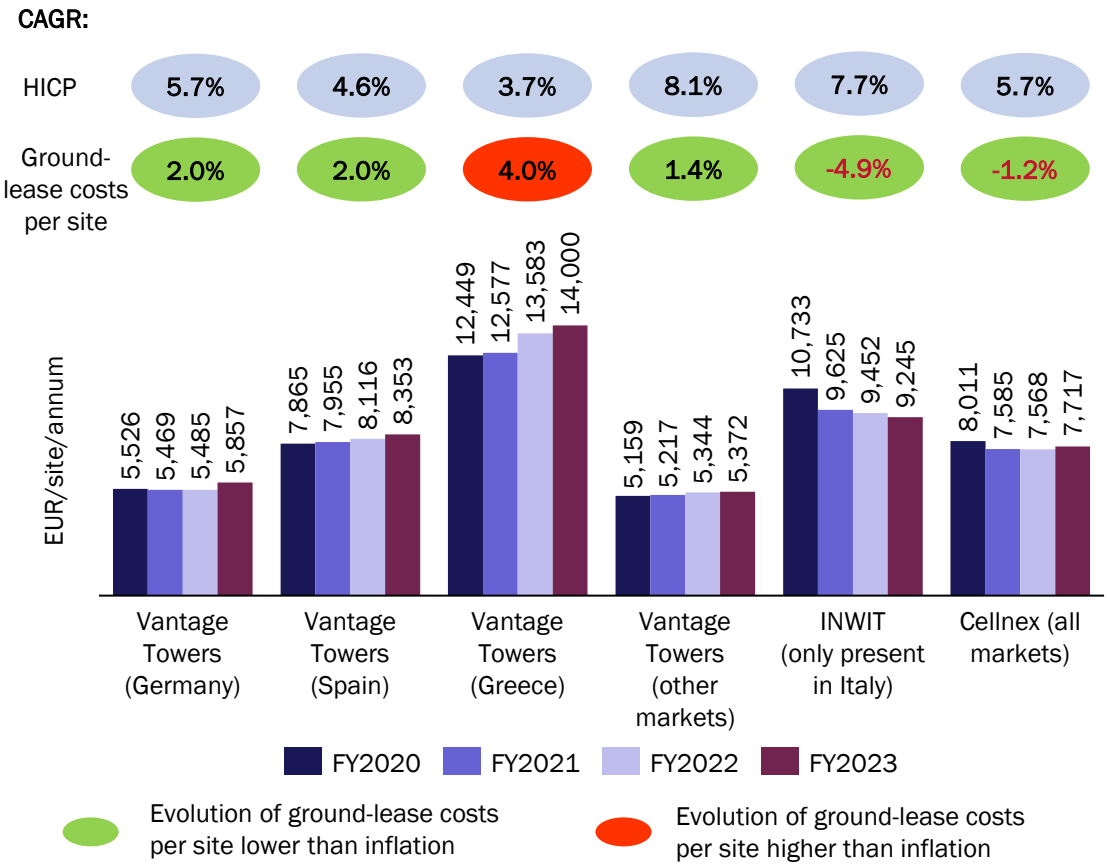
As a result of these dynamics, regulating land access pricing would have a limited financial impact on MNOs' overall network costs and their ability to deploy VHCNs. However, the potential disruption to network roll-out could be significant (as discussed in Section 6).

2.5 Prices for access to land have typically been flat or negative in real terms over the last few years

As found by Analysys Mason in its previous report,[29] ground-lease costs per site have either been decreasing or increasing below or broadly in line with inflation across the EU (see Figure 2.11).

29 Analysys Mason (27/09/2023), *Land providers in the context of the European Commission's planned Gigabit Infrastructure Act*.

Figure 2.11: Evolution of ground-lease costs per tower by tower company[30,31] [Source: Vantage Towers,[32] INWIT,[33] Eurostat,[34], Cellnex[35] 2023]



2.6 Tower companies have expressed concerns around access to land and support the GIA, however these issues do not appear to be significantly affecting mobile deployment

Potential issues related to accessing land owned by third parties could hinder the predictable deployment and operation of mobile networks. These include:

30 Ground-lease costs for Vantage Towers include depreciation of costs related to right-of-use assets, and interest on lease liabilities, while ground-lease costs for INWIT were estimated by Analysys Mason by dividing reported recurring lease payments by the estimated number of sites for which INWIT does not own the land, itself based on reported land ownership figures.

31 HICP: harmonised index of consumer prices. In the Euro area, HICP is used to measure consumer price inflation. The word "harmonised" means that all the countries in the EU follow the same methodology. See https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Harmonised_index_of_consumer_prices_(HICP)

32 See https://www.vantagetowers.com/en/investors/results-report-and-presentation

33 See https://www.inwit.it/en/investors/presentations-and-webcasts/

34 See https://ec.europa.eu/eurostat/databrowser/view/EI_CPHI_M__custom_7381723/default/table

35 See https://www.cellnex.com/investor-relations/financial-information/#shareholders-investors-financial-reports

- **'Ransom rent' demands upon renewal:** for a passive infrastructure operator, moving an existing tower to a new location can be very costly. The land owner may be aware of this and as such, when a lease agreement reaches the end of its term, the land owner could seek to leverage its position and significantly increase the rent upon renewal. This could force the infrastructure operator to accept the new ransom rent or move location, incurring the related site removal and reconstruction costs.

- **Non-renewal of existing leases:** when a lease agreement nears the end of its term, the land owner may choose not to renew it, thereby preventing the continuation of mobile services from that location.

- **Restriction or objections to site sharing or upgrading:** if additional space on the land is needed or access is required to complete works, land owners may object to the sharing or upgrading of sites, which could be detrimental to the financially viable deployment of new sites and technologies.

However, there appears to be limited evidence that such activities occur in practice, particularly in relation to demanding ransom rents.

As previously mentioned, in order to support wider EU objectives, the GIA aims to regulate access to land. This issue has been considered by a number of independent European industry bodies, including in the context of the consultation for the GIA[36] in 2023, with many organisations suggesting the current commercial model for obtaining access to land is effective. A support study[37] associated with a review of the BCRD, commissioned by the EC found that:

> Annex 3: "*there are sometime issues with private land owners, but in general the commercially negotiated terms are fair*".

In addition, BEREC's opinion on the Revision of the BCRD[38] concluded that:

> "*BEREC considers that – safe for possible, well defined and justified exceptions – the provision of access to non-network private facilities should normally be left to commercial agreements*."

Similarly, the Dutch competition authority (ACM) found the following:[39] "*In its research, the ACM does not see any direct indications that the risks mentioned by market parties [of concentration of supply of antenna sites such as by aggregators having an upward effect on prices] occur in practice*

36 European Commission (23/02/2023), *The future of the electronic communications sector and its infrastructure*.

37 European Union (2023), *Support study for the review of the Broadband Cost Reduction Directive*.

38 BEREC (11/03/2021), *BEREC Opinion on the Revision of the Broadband Cost Reduction Directive*.

39 Autoriteit Consument & Markt (14/07/2022): Marktverkenning Antenne-opstelpunten.

in a broad sense. The examples of significant market price increases provided by market parties appear to be more incidental in nature."

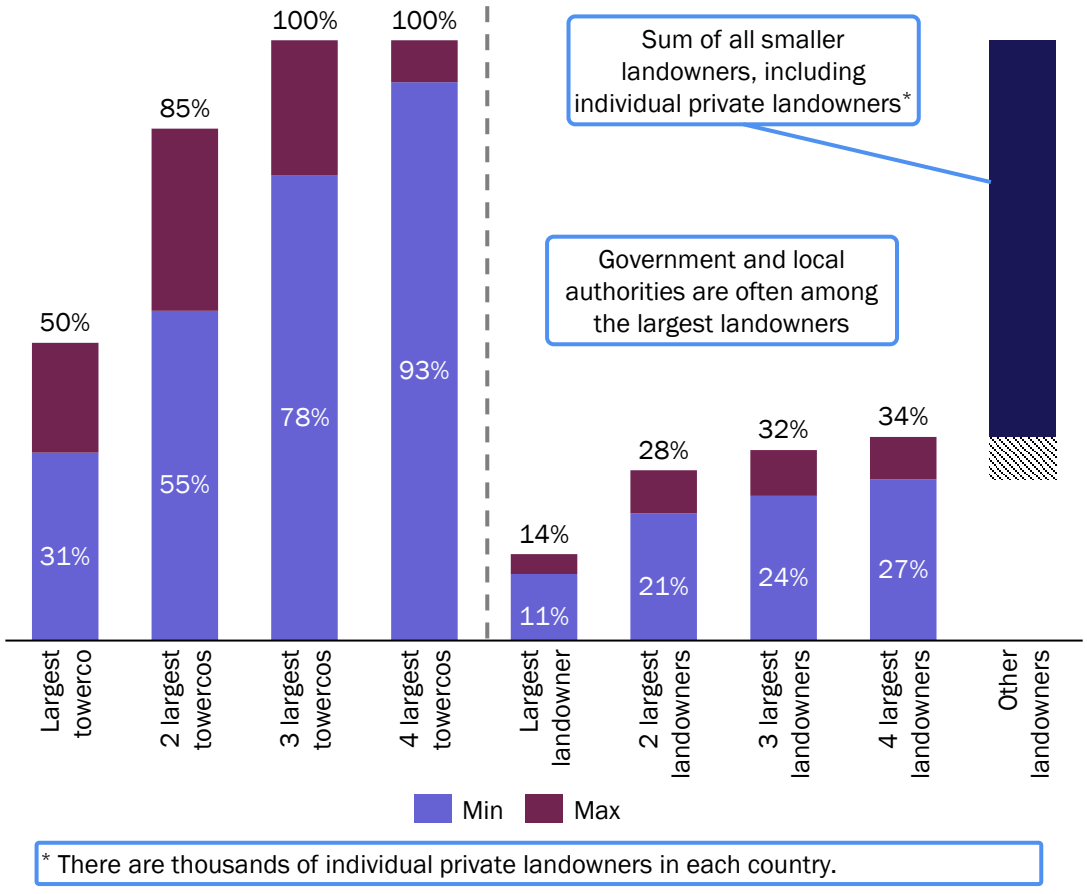
With regard to non-renewal of leases and restriction or objection to site sharing or upgrading, access providers are, under a model of commercially negotiated lease agreements, generally incentivised to support access seekers in these activities in order to ensure the continuation of the revenue stream derived from the lease agreement. In the case of site upgrades that require incremental land or associated space, there would typically be an increase in revenue for the access provider. It may be the case that engagement with access seekers is not the primary business of an access provider (for example the primary business of the owner of a field is likely to be farming, or the owner of a commercial building is likely to be renting its internal space or operating a business in another section) and this could lead to administrative delays related to renewals and permissions. However, this appears to be a function of disaggregated land ownership, rather than a specific disengagement from the telecoms industry by access providers.

Other concerns around land scarcity, the availability of required information such as ownership details, and the added complexity of having to negotiate with multiple property owners, may arise in some instances; however, they are unrelated to price and do not necessarily demonstrate unwillingness by property owners to engage in discussions.

3 Land aggregators bring benefits to the industry that support the achievement of the digital targets

As previously found by Analysys Mason in its report,[40] in contrast to the tower market, the market for access to land for telecoms infrastructure is highly fragmented. In each EU country, approximately 70% of the land used for telecoms sites is owned by companies and individuals other than the largest 2–4 access providers. The largest access providers are often government and local authorities (see Figure 3.1).

Figure 3.1: Benchmark of tower and land ownership in EU countries [Source: Analysys Mason, 2023]



Among the smaller access providers, many of which may provide access to land for a single site, there is a wide variety of individuals and entities. These may include private land owners such as farmers, owners of commercial real estate such as office buildings or factories, and even private home owners. A group of investors specialising in developing long-term access to real estate used for digital infrastructure and digital services work with these types of real-estate owners. In the

40 Analysys Mason (27/09/2023), *Land providers in the context of the European Commission's planned Gigabit Infrastructure Act*.

context of land used for mobile telecoms sites, these investors are often referred to as lease aggregators (or land aggregators).

3.1 Lease aggregators are infrastructure investors focusing on the passive layer of digital infrastructure across different asset classes, including land/rooftops for mobile sites

Lease aggregators invest in land and rooftop space leases supporting the wider digital infrastructure and service ecosystem. The primary model is to aggregate a variety of land access rights by reaching a purchase agreement with multiple individual land and building owners, and consolidating long-term rights into a larger portfolio of land to manage for the infrastructure tenants.

Some lease aggregators are also infrastructure investors focusing on other areas such as dark fibre, telecoms nodes, towers, data centres and other digital infrastructure, and are also readily accepted or even sought out by telecoms operators. Figure 3.2 below shows how operators divest assets to optimise financial and operational performance. This strategy allows them to focus their capital allocation and operations on their core activities, including greater and accelerated deployment of networks to serve end customers. With the decommissioning of copper fixed access networks, a new trend is emerging among incumbent operators to dispose of local exchanges on a sale-and-leaseback model, as for mobile towers, which could lead to the transformation of these buildings into the 10 000 edge nodes targeted by the EU's Digital Decade Policy Programme 2030 (see Section 1.1).

Figure 3.2: Examples of other telecoms investments by infrastructure investors [Source: Analysys Mason, 2025, MNO press releases (Vodafone, Telefónica, Bouygues Telecom, BT)]

Asset investment	Companies involved	Objectives
Fibre JV (Fibre Networks Ireland Limited)	Eir and InfraVia	"The establishment of Fibre Networks Ireland provides a vehicle for further investment in our already extensive network… we can improve our ability to connect customers faster than ever before and ensure that more homes in Ireland can access the high-speed internet" – *Stephen Tighe, CFO of eir, 2022*
Fibre JV (Bluevia)	Telefónica Spain, Crédit Agricole Assurances and Vauban Infrastructure Partners	"We aspire to expand the development outside the big cities. To this end, we will support Telefónica's fibre operations, **boosting and accelerating new deployments**" – *Luis Rivera, CEO of Bluevía, 2022*
Tower carve-out	Telefónica and American Tower	"After this great operation we will continue to focus on our most ambitious objectives: the integration of O2 with Virgin in the United Kingdom, the purchase of Oi mobile in Brazil and the reduction of debt" – *The President of Telefónica, José María Álvarez-Pallete, 2021*
Tower carve-out	Bouygues Telecom and Cellnex	"Bouygues Telecom will use the proceeds of this transaction to **continue developing its mobile and fixed activities**" – Press release, 2016

Asset investment	Companies involved	Objectives
Telecoms exchange real estate	Telecom Italia and various subsequent real-estate owners	Transfer of telephone exchange buildings on a sale-and-leaseback basis has been ongoing in Italy for over 20 years, highlighted by the statement of one recent real-estate owner: "The telephone exchange market continues to be of great interest both for Prelios and for national and **foreign investors looking for investments in infrastructures with good long-term profitability, with a coupon-type repayment profile**. We also believe that the ongoing technological infrastructural evolution **allows for a long-term positioning**, in which the skills of the manager and the selectivity of the investment are an element of increasing attention on the part of investors" – *Alessandro Busci, Prelios sgr.*
BT's carve-out of its property portfolio (Telereal Trillium)	BT, Land Securities Trillium and William Pears Group	"We are planning to grant long leases on much of our specialised properties to that company and to lease back these properties on a short-term basis. In the process, we expect to receive a significant cash sum which will **go towards reducing our borrowings**" – *BT 2001 annual report*

3.2 Lease aggregators typically adopt a long-term, low-risk approach, targeting stable and predictable cashflows

Figure 3.3 summarises some of the international lease aggregators that operate in Europe and their main shareholders and financial backers, which are generally large infrastructure investors. These investors are publicly identifying themselves as long-term investors seeking "stable, long-term value creation" and "low volatility".

Figure 3.3: Summary of key EU lease aggregators [Source: Analysys Mason, lease aggregators and financial investors' websites, 2025]

Lease aggregators	No. of assets under management, revenue (latest data)	HQ	Financial backers	Investment style
Radius Global Infrastructure (APWireless)	>10 000 (of which ~5000 are in Europe), USD3 billion in investments	USA	EQT Active Core Infrastructure / PSP	"EQT Active Core Infrastructure targets companies that provide essential services to society and offer a distinct and attractive risk-return proposition based on stable cash yield generation, inflation protection, low volatility, and pursuit of longer-term value creation opportunities"[41]

41 See also *Bridging the $3.3 Trillion Annual Infrastructure Gap Will Take Private Capital Investment*, EQT.

Lease aggregators	No. of assets under management, revenue (latest data)	HQ	Financial backers	Investment style
Everest Infrastructure Partners (Everest)	2500 (June 2023)	USA	Peppertree Capital Management	Peppertree Capital Management, Inc. is a private equity firm focused on making investments in growing communication infrastructure companies. Peppertree is primarily a "growth equity investor with a hands-on and patient style"
Landmark Dividend (Landmark)	1500, USD70 million AIPR (Dec 2021)	USA	Digital Bridge	Landmark Dividend "prioritizes long-term value creation through stability, strength, and collaborative partnerships"
Unison Infrastructure (Unison)	>6400 closed transactions	UK	Ardian	Ardian prioritises "long-term value creation through a disciplined industrial approach"
Telecom Infrastructure Partners (TIP)	Not available	UK	Digital Bridge and Swiss Life	TIP states: "TIP's investments in mobile site leases are comparable to bond investments: just like our tenants, we seek long-term, predictable, indeed "bond-like" cash flows"

3.3 The operational and financial benefits introduced by lease aggregators produce advantages for mobile operators and tower companies

The operational and financial benefits introduced by lease aggregators include a range of aspects:

- long-term partnership
- minimised re-location risk and associated site churn re-planning and environmental impacts
- long-term visibility
- predictability on costs
- cost management and cost efficiencies
- provision of optimised long-term capital
- simplifying property management
- facilitating access.

Long-term partnership

Lease aggregators' investment strategy focuses exclusively on the passive layer of critical digital infrastructure. These actors invest in sites hosting existing digital infrastructure to secure long-term returns from the lease payments made by the digital operator (the anchor tenant) occupying the site. To secure their returns, lease aggregators acquire real rights related to the land and/or rooftop where a mobile site is located. In this way, lease aggregators' interests align with those of tower companies in securing a long-term presence at the site. Consequently, it is in their best interest to maintain a

strong relationship with tower companies to retain them as tenants, thereby securing their up-front investment and a stable, long-term cashflow.

Minimised re-location risk and associated site churn re-planning and environmental impacts

An individual property owner deriving rental from a short- to medium-term lease, and whose primary business is not land rental but farming, office/commercial or residential property, may be uncertain or change its priorities or preferences over hosting a site, in consideration of the annual rent. On the other hand, if the land rights are acquired with an up-front payment in return for a long-term commitment, then these risks are largely removed. The core activity of lease aggregators is hosting tower infrastructure on their land assets, and as such they aim to reduce site churn as much as possible to secure the presence of the mobile site for as long as possible. The acquisition of the land rights underneath a mobile site by a lease aggregator therefore allows tower companies and MNOs to reduce virtually to zero the risk of a forced re-location and the associated capex risk, business risk, operational risk and financial risk.

Minimising site relocations also supports network planning efficiencies for MNOs and reduces the overall environmental impact associated with site churn (through reduction in duplicated concrete, steel and construction deployment activities, etc.).

Long-term visibility

Tower companies typically enter into long-term agreements with MNOs to provide tower infrastructure. However, contracts with individual land owners are often limited to short terms, such as five years. This discrepancy in agreement durations creates a gap between the tower company's commitment to the MNO and the duration of the ground lease, posing a risk that the tower company could be forced to vacate a site before fulfilling its contract with the MNO. Lease aggregators can help to mitigate this risk by offering longer-term contracts to tenants, thereby bridging the contractual duration gap between tower companies and MNOs, and between tower companies and land owners.

Predictability on costs

As a result of the long-term agreements that can be provided by lease aggregators, tower companies can enhance the visibility and predictability of their long-term costs. By avoiding frequent shorter-term renewals and aligning inflationary increases across contracts with both MNOs and land owners, tower companies can effectively safeguard themselves against inflation.

Cost management and cost efficiencies

A lease aggregator can also offer to enter into a joint ground-lease buy-out agreement with the tower company, in which the latter provides the lease aggregator with a list of its towers for the lease aggregator to acquire the land under them. In this arrangement, costs can be efficiently managed:

the lease aggregator can acquire the land at a lower cost due to the reduced costs of searching for the site, and these cost benefits can be shared in the joint agreement with the tower company.

Provision of optimised long-term capital

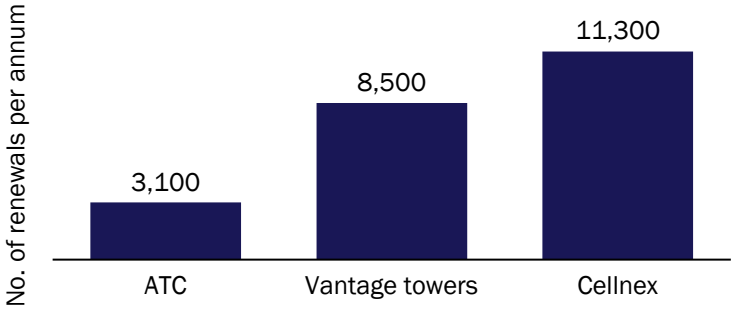
A lease aggregator's business model typically involves owning the long-term rights to the land or rooftop. This means that lease aggregation can be financed around 30+-year asset lives, with the expectation of stable and predictable demand for the towers and radio sites on the land. Tower companies are also active in the land market. They acquire land, following a similar approach to land aggregators, with the aim to secure the site, gain cashflow visibility and minimise relocation risk, as described earlier in Section 3.3. Several tower companies have already committed capital to acquire a growing share of the land underneath their sites, however, on average this share is still low, particularly in Europe, with the leading players such as Cellnex and Inwit targeting over 20% of land ownership by the end of their plans. Similar benefits can be achieved through long-term relationships with land aggregators, which would have the additional benefit to free up capital for tower companies and their investors to be deployed in further digital infrastructure. A long-term cost of capital based on a low-risk situation can be optimally obtained for the land segment of the mobile network. Separately, capital investments in towers, electronics, spectrum, environmental enhancements, etc. can have a capital financing structure optimised towards those assets, risks and technical lifetimes of other components of the mobile network (typically operated by tower companies and MNOs).

Simplifying property management

Lease aggregators build their portfolio of land and rooftop locations and act as a single landlord for all sites. This can reduce back-office work and management burden for the tower company and/or MNO. In particular, contract renewals become a strong efficiency point for a tower company or MNO if dealing with one lease aggregator party versus a large number of multiple individual owners, each with individual renewal or access priorities at various points in time.

Figure 3.4 estimates the number of renewals EU tower owners are likely to have to renegotiate per annum. This highlights the significant burden on major infrastructure providers in simply maintaining business operations with thousands of rental agreements. The resources associated with these activities, namely relationship management with access providers, could be more effectively used by identifying new land plots to deploy new sites and mobile PoPs.

Figure 3.4: Estimation of annual access-to-land contract renewals for major EU tower owners assuming a 10-year renewal cycle [Source: Analysys Mason, reports from tower companies (American Towers, Vantage Towers, Cellnex) 2023]



Facilitating access

By acting as a central point of contact, lease aggregators streamline the management of the property access aspect of the business (access, facilitation of maintenance and repairs, renewals, upgrades, etc.) for MNOs and tower companies. In this respect, lease aggregators manage all aspects of the request, from initial inquiry (some lease aggregators manage access portal tools with thousands of requests per year[42]) to execution. This streamlined approach eliminates the need for operators and tower companies to navigate varied and time-consuming interactions with property owners. This expertise ultimately ensures that access is given in a timely and efficient manner, reducing delays and allowing for faster deployment of network infrastructure.

It is also worth noting that lease aggregators generally acquire land with unrestricted operating rights for the aggregator and its tenant(s), meaning that additional equipment, such as new antennas, can be installed efficiently.

3.4 The efficiencies and optimisations introduced by lease aggregators can have a clear positive impact on the achievement of the Digital Decade targets

Lease aggregators are well positioned to help MNOs to address the operational challenges related to land access for the deployment of networks, in return for stable and long-term returns on investment in land lease aggregation. In providing the necessary up-front investment to overcome these challenges, lease aggregators contribute to the EC's EUR200 billion funding gap and increase the remaining funds available to infrastructure and network operators to focus on their core businesses. With all stakeholders in the value chain working together, this model can support the EU's Digital Decade target of ensuring all populated areas are covered by a wireless network at least equivalent to 5G, as outlined in Section 1.

42 APWireless offers such a portal in the UK and Ireland where, for a combined portfolio of around 2500 locations, more than 30 000 requests for access were processed in 2024.

In addition, we observe that lease aggregators invest in adjacent passive infrastructure, such as network nodes and data centres. They may collaborate with network operators to share infrastructure, thereby reducing the up-front costs and operational burdens for telecoms operators, ISPs and data-centre providers. This business model aligns with the broader goals of the Digital Decade initiative, extending beyond 5G, which aims to establish 10 000 edge nodes in the EU. This is facilitated through investments in local exchanges, often acquired under sale-and-leaseback models by lease aggregators, enabling their transformation into edge nodes with optimised long-term land footprints. This vertical/layered infrastructure-leasing ownership model can also support data centres, for example, in which lease aggregators own and lease space to host downstream players' equipment, reducing the need for them to invest in physical infrastructure.

4 The UK has already applied significant regulation to access to land for telecoms services with unintended consequences

In 2017, the UK government updated regulations to grant telecoms operators and tower companies greater rights to access land on more favourable (for code operators[43]) financial terms. This change was intended to generate savings that would enhance investment in network roll-out. Below, we discuss the regulation and challenges, disruption and disputes which have arisen subsequently.

4.1 2017 updated UK regulation

In 2017, the Digital Economy Act[44] reformed the Electronic Communications Code (ECC) with the objective of facilitating the roll-out and maintenance of infrastructure (such as telecoms masts, exchanges and cabinets) for network operators on public and private land. Specifically, in relation to access to land, the amendment aimed to make it easier for code operators to secure agreements with land owners, prevent land owners (acting as access providers) from demanding exorbitant rents and restrict land owners' ability to terminate existing agreements, ensuring greater stability for operators' infrastructure.

To achieve these targets, the reformed ECC made the following key amendments:

- **Made wholesale infrastructure providers (WIPs) 'code operators'**: WIPs, i.e. tower companies, could therefore benefit from the same rights as communications providers (CPs), i.e. operators, themselves.
- **Imposed easier access to land:** operators were given the right to request access to land for installation even if the land owner or occupier does not consent, provided certain conditions are met. This is subject to agreements being imposed by tribunals when negotiations fail.
- **Facilitated the sharing of infrastructure:** the reforms allowed operators to share infrastructure (e.g. mobile masts) with fewer restrictions, facilitating faster and more cost-effective network deployments.
- **Changed standard market value:** the reforms shifted the basis for determining the payment for land access from a commercial (negotiation driven) market value, tied to the use of the land (such as telecoms sites), to one based on its value for an alternative use, other than for the

43 'Code operators' refers to those operators designated by Ofcom as subject to the ECC, typically infrastructure and telecoms operators downstream from land owners.

44 Legislation.gov.uk (2017), *Digital Economy Act 2017*.

provision of an electronic communications network. This typically results in lower rents, e.g. in rural and remote areas where alternative use would traditionally be limited to farming.[45]

These key amendments, however, do not appear to have successfully facilitated network roll-out or improved 5G coverage as intended. As reported by the Social Market Foundation,[46] the UK ranks 30 out of 39 comparator countries for 5G availability and 37 out of 39 for quality of the 5G network. The issue was sufficiently significant to be included in the new UK government's manifesto,[47] which stated "[under the last government] investment in 5G is falling behind other countries".

4.2 Challenges facing the ECC

The ECC has faced many challenges, including resistance from site providers and adverse incentives for code operators (tower companies and telecoms operators), with evidence from multiple independent sources indicating it has not had the intended effect of promoting investment in network roll-out.

Changes to incentives for access providers and seekers appear to have led to reduced collaboration between actors

A key premise of the ECC in its target to support efficient and cost-effective network deployment was that agreements between code operators and access providers would be reached between the two parties based on terms that were mutually acceptable. Intervention or imposition of the ECC by a tribunal or another branch of the judicial system would only occur in cases where such a bilateral agreement could not be reached. A 2021 public consultation on the success of the ECC from 2017 onwards noted that these objectives can only be achieved if operators and potential site providers make reasonable efforts to reach agreement. For network deployment to occur quickly and cost effectively, cases should only be taken to court when no mutually agreeable position can be reached.[48]

However, the changes in incentives for both access providers and code operators introduced by the ECC seem to have made the use of the tribunal system more likely, suggesting the failure of the alternative dispute resolution mechanisms (arbitration/non-tribunal) that have been established.

For access providers, the changes to the ECC have reduced incentives to facilitate access to telecoms infrastructure providers in a timely and collaborative manner, as financial compensation can be significantly reduced. In some instances, the imposition of the ECC has resulted in an 85–90% reduction in access providers' financial benefit. This reduction applies as code operators invoke their right to a reduced payment as permitted by the ECC, which does not appear to be mandatory under bilateral agreements.

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45 We note that new alternative uses, such as solar panels and wind turbines, are increasingly a possibility for a roof or land owner.

46 Social Market Foundation (11/12/2024), *Network failure: How the UK can meet its 5G ambitions*.

47 https://labour.org.uk/wp-content/uploads/2024/06/Labour-Party-manifesto-2024.pdf

48 Service.gov.uk (27/01/2021), *Access to land: consultation on changes to the Electronic Communications Code*.

For code operators, the ECC offers a chance to reduce ground-lease costs and achieve financial benefits. However, resistance from land owners to accept lower payments often results in prolonged negotiations and potential litigation, which can negatively affect roll-out plans. There is also a risk that infrastructure providers will focus their resources on reducing lease payments for existing sites where coverage already exists, as highlighted by one European tower company's financial reporting.[49] Alternatively, these resources could be deployed to develop new sites that improve coverage and network quality.

Once access terms are agreed, or enforced, continued collaboration is required between access provider and seeker

The interaction between access provider and code operator does not end once an agreement for land access is reached. Depending on the location of the land, which may be located within a private property such as a farm or located on the rooftop of a building, the code operator continues to be reliant on the provider for regular access, initially for the deployment and installation of equipment and later for maintenance and upgrades. When receiving a more substantial compensation for access to land, access providers were typically incentivised to engage with access seekers in a collaborative manner to maintain a good relationship and ensure the renewal of the lease agreement. By contrast, with the reduction in financial compensation, access providers – whose primary business is often not the provision of land for telecoms services – may be less incentivised to engage as willingly and openly. This could lead to further litigation and delays in the deployment of mobile networks.

Increased disagreements also have a negative impact on the dispute resolution process, which in turn leads to greater delays

The number of disputes between access providers and seekers has increased significantly since the introduction of the ECC, with the England and Wales tribunal system reporting an almost sixfold increase in disputes handled annually between 2018 and 2023.[50] Despite the creation of a dedicated tribunal system to relieve pressure on dispute resolution systems under the ECC, this appears to have led to significant delays in the imposition of ECC agreements. The Social Market Foundation[51] reported that the average time to resolution for a tribunal process reached 11 months by 2024 and can be as long as 18 months. These delays in reaching agreements for access to land add further inefficiencies in network deployment and are detrimental to the achievement of policy targets related to 5G (or equivalent) coverage of populated areas, transport routes and remote communities.

49 Vantage Towers (08/03/2021), *Vantage Towers prospectus for the public offering in the Federal Republic of Germany*.

50 Based on an APWireless FOI request, there were 49 cases in 2018 vs. 289 cases in 2023. There were only 33 such cases in total from 1984 to 2017.

51 Social Market Foundation (11/12/2024), *Network failure: How the UK can meet its 5G ambitions*.

4.3 Disruption of access to land is an issue

Disruption to access to land for deployment in rural areas has been highlighted as an issue, such as in the roll-out of the UK's Shared Rural Network programme.

The Shared Rural Network (SRN) programme, signed in 2020, is a key component of the UK's ambition to achieve extensive mobile coverage and imposed specific coverage obligations on MNOs.[52] However, locating appropriate land for new coverage sites, many of which are required in highly rural areas, has proved a significant challenge for the delivery of the SRN, with the ECC not appearing to aide this process.

In the written evidence submitted by Three UK on its progress regarding the SRN targets,[53] the mobile operator voiced its concerns and identified various reasons for its inability to meet them on time. One of the three external challenges mentioned was "Site acquisitions", referring to the time delays related to the acquisition of land due to the ECC:

- "The average duration for heads of terms to be agreed with site providers and land owners has been far longer than we expected at the outset of the programme. Many negotiating processes remain unresolved after over a year".

- "In a small number of cases, we have had to use Code Notices against site providers to progress delivery. Such notices are also subject to delays, however, with a significant backlog of Lands Tribunal proceedings".

This evidence appears to suggest that access providers are not sufficiently incentivised to provide access on bilaterally agreed terms. Instead, access providers face having agreements imposed while, at the same time, the dispute resolution system and judicial system have become inundated by the volume of cases and are unable to resolve these disagreements in a timely manner. The overall outcome of this can be observed in network statistics (see Section 5) as a limitation on the expansion of rural coverage in the UK.

4.4 Significant disputes have negative effects on mobile deployment

A key objective of regulation was to reduce costs associated with mobile deployment, but significant disputes may have achieved the opposite effect, at least in the short term.

Given the reductions in lease costs payable by code operators, at least for those records publicly available from the Land Tribunal system of England and Wales, it appears likely that in the longer term the ECC may have the effect of reducing the operational cost of mobile network infrastructure owners. However, it is not clear that this aligns with the ECC's objective of facilitating cost-effective

52 Ofcom (12/09/2024), *Shared Rural Network Coverage Obligations: Assessing the mobile network operators' compliance with their geographic coverage obligations*.

53 Committees Parliament UK (04/2024), *Written evidence submitted by Three UK*.

network deployment, given the significant costs incurred by all parties involved to reach agreements for access to land.

According to a study published by the Social Market Foundation,[54] the cost of reaching an access agreement through the tribunal system can be upwards of GBP100 000, while mediation activities, a preliminary step to tribunal proceedings, can cost around GBP10 000. As such, it is unclear whether MNOs are rolling out their networks in a more cost-efficient way under the ECC, which is aimed to facilitate the achievement of the government policy targets for 5G services. It is also uncertain if any savings associated with enforced lower access fees will be realised in the future, once legal costs are taken into consideration. In addition, pass-through of savings over time to MNOs and end-user services will depend on the contractual arrangements and relative market power of players that are downstream from the access to land (i.e. tower companies, MNOs and service providers).

If the funds currently being spent on legal fees – which may not have been necessary without the ECC, given there were very few tribunal disputes prior to its introduction[55] – were instead allocated to the completion of new sites and the deployment of infrastructure and equipment in recent years, it is likely this would have had a positive impact on 5G availability in the UK. Based on a cost of GBP100 000 for a 5G site,[56] the number of court cases mentioned in Section 4.2, and the cost of a court case mentioned in the previous paragraph, the cost of litigation linked to access to land could have allowed the MNOs to roll out more than 100 additional 5G sites in 2023 alone if the same funds had instead been spent on network roll-out.

54 Social Market Foundation (11/12/2024), *Network failure: How the UK can meet its 5G ambitions*.

55 See footnote 50 in Section 4.2.

56 Cost of the active equipment for a 5G macro site, i.e. assuming the reuse of an existing tower, which is common for 5G rollout, based on Figure 5.6 of Analysys Mason's report for the National Infrastructure Commission, 5G wireless infrastructure deployment scenarios over the next decade.

Based on the numbers in that report, deploying active equipment for a 5G macro site in both the 700 MHz, 2100 MHz and 3.5 GHz band would cost a total of GBP 107 500.

5 Comparison of the UK to peers suggests that its mobile network performance has developed less well since 2017

5.1 Opensignal's mobile customer experience data indicates that the UK's mobile network performance and 5G roll-out lag behind those of its peers since 2017

We have used Opensignal data to compare mobile network performance and deployment metrics between the UK and peer countries (i.e. France, Germany, Spain, Italy and the USA).

Opensignal is an independent insights provider that uses crowd source data to assess customer experiences on telecoms networks worldwide. This includes a range of metrics related to actual experience of mobile services users, such as network availability and performance. It also includes infrastructure metrics that reflect network elements seen by its users that can indicate network deployment and upgrades. The Opensignal methodology is summarised in Annex A.

One of the metrics produced by Opensignal is *Reach*, which is the average proportion of locations where users were connected to a network out of all the unique locations visited by a user. This metric can be used as a proxy for coverage as traditionally used by regulators and will be referred to as such in this paper.

In addition to coverage, the Opensignal *Availability* metric shows the average proportion of time an Opensignal user, designated as a user for a given technology, is connected to that mobile technology (e.g. 5G). This can be used in combination with the reach metric to evaluate coverage in places where people spend most of their time, thus it is used to assess network coverage in a more customer-centric way.

Opensignal also produces network performance metrics, based on downloading and uploading mobile data, and on testing network latency by pinging internet servers (latency can be understood and experienced as the 'delay inherent in the exchange of data to and from the internet').

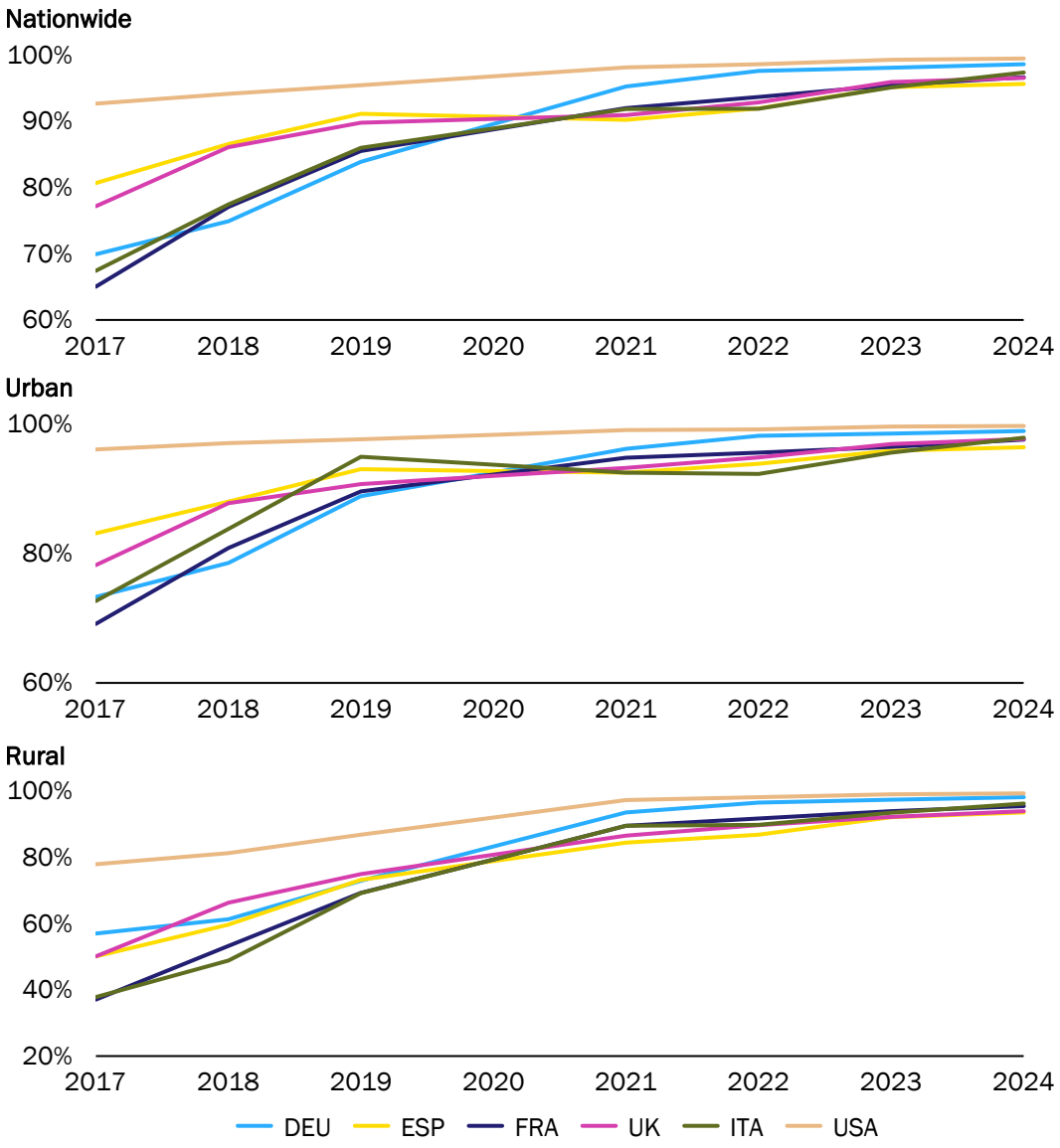
Overall, Opensignal's mobile experience metrics appear to demonstrate a lower level of investment in mobile networks in the UK compared to peer markets[57]. Certain areas, such as lower coverage, are intrinsically linked to access to land, although operators may also face other challenges in improving these network aspects. What does appear to be clear is that, even if the ECC has resulted in lower costs for network deployment as it intended (which as discussed in Section 4.4 remains uncertain), it has not resulted in greater network deployment (which was an overarching intention of the ECC). This is further reflected in the infrastructure data collected by Opensignal, as discussed in Section 5.3.

57 Peer markets are chosen as the large European markets and the USA, for which Opensignal has data.

4G users' coverage experience

Nationwide, UK 4G coverage is at the low end of our peer group range. Rural 4G coverage in the UK lags behind benchmark countries, with ~6% of rural areas which Opensignal users have visited not covered by 4G (see Figure 5.1). By comparison, average rural coverage within the peer group is ~96% (i.e. ~4% uncovered). This contrasts with 2017, when the UK was significantly ahead of three peers. Although 4G coverage is dependent on various network drivers, access to land plays a key role as operators require access to land to deploy new sites in rural areas. If operators are unable to secure access to land for these sites, it can negatively affect coverage expansion, as highlighted by Three UK (see Section 4.3).

Figure 5.1: 4G users' coverage experience[58] [Source: Opensignal, 2024]

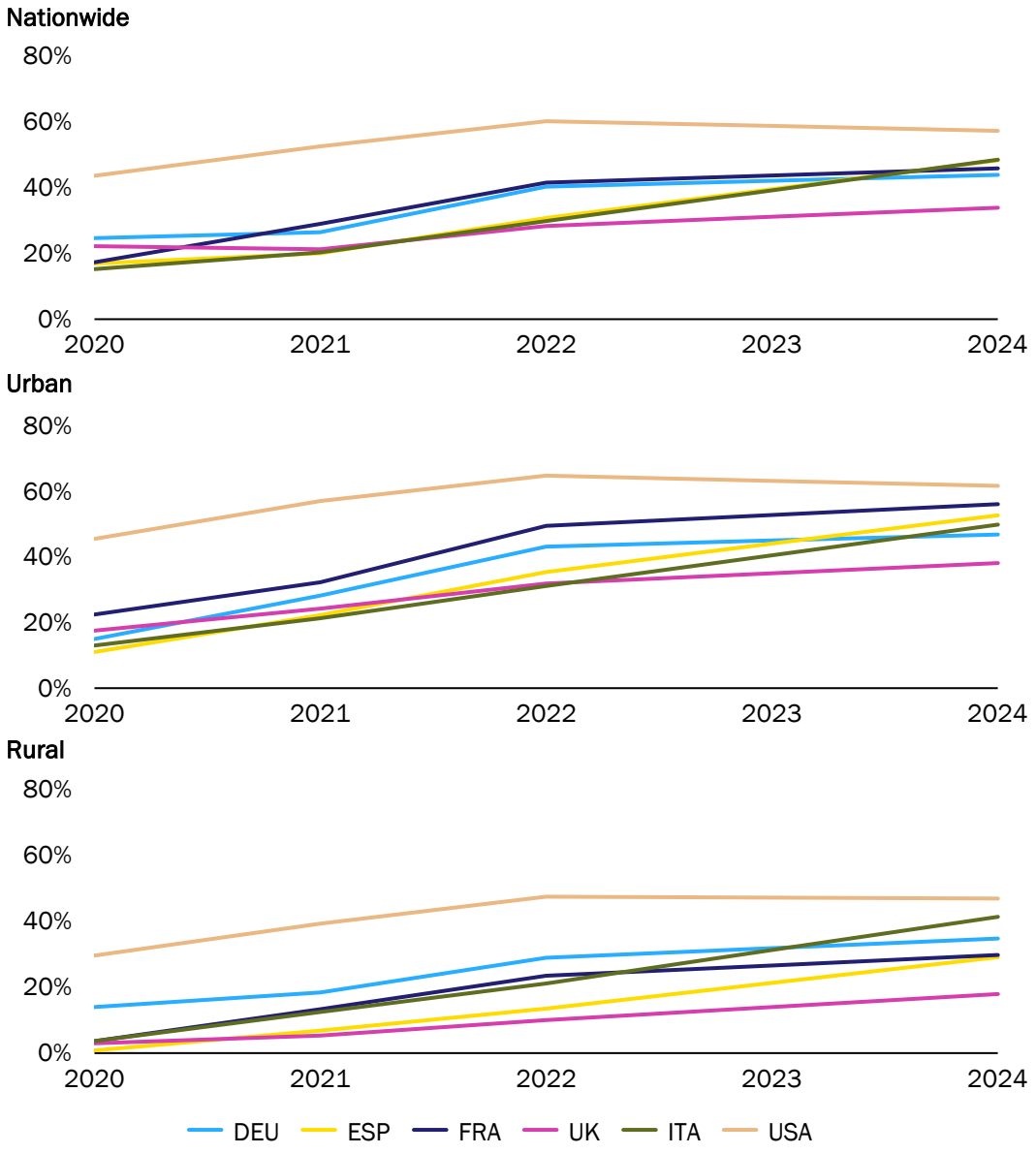


58 Data for 2020 has been replaced with a trendline from 2019 to 2021 due to an inconsistent set of readings reported by Opensignal.

5G users' coverage experience

5G coverage (see Figure 5.2) in the UK also lags behind benchmark countries, being a third below the average of peers in 2024, from a roughly similar level in 2020. This is expected to be driven primarily by lower levels of upgrades for existing sites as 5G is typically deployed in 'overlay' with the existing 4G network, using the same physical locations. In this respect, there are a number influencing factors, with access to land also playing a role here as operators require access to existing sites, including potentially access to additional land to host additional equipment, in order to complete 5G upgrades.

Figure 5.2: 5G users' coverage experience[59] [Source: Opensignal, 2024]



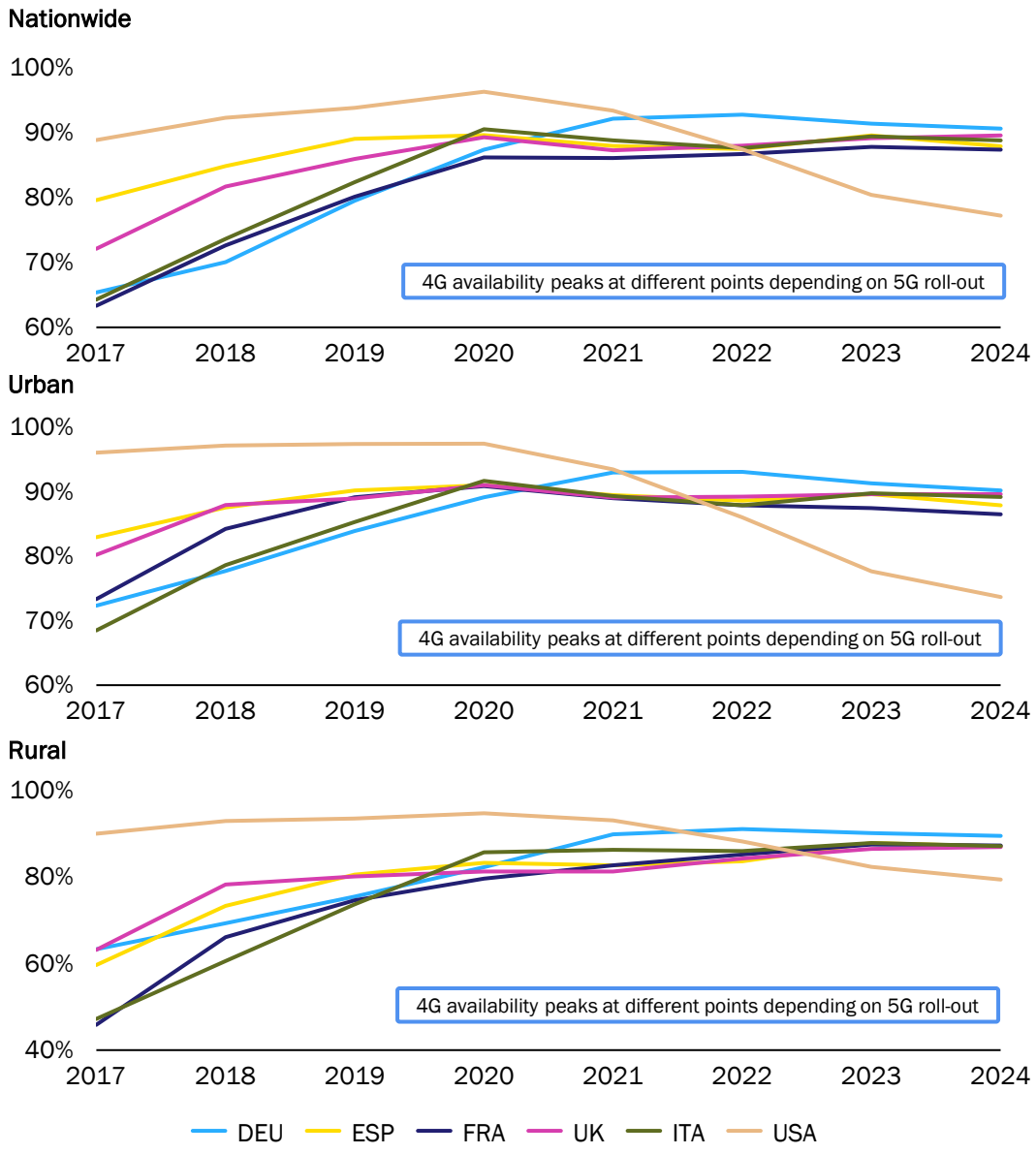
59 Data for 2023 has been replaced with a trendline from 2022 to 2024 due to an inconsistent set of readings reported by Opensignal.

4G availability

Growth in 4G availability (see Figure 5.3) as seen by Opensignal users in the UK has been lower and slower than benchmark countries across both urban and rural areas. For each country, 4G availability peaks at a certain point in time before starting to decrease because as 5G is rolled out, 4G availability will start decreasing when user devices connect more often to the newer technology.

A lower and later 4G availability peak demonstrates the UK performs less well both in places where users spend most of their time (and there should be commercial incentives to deploy) and in places where people may go frequently.

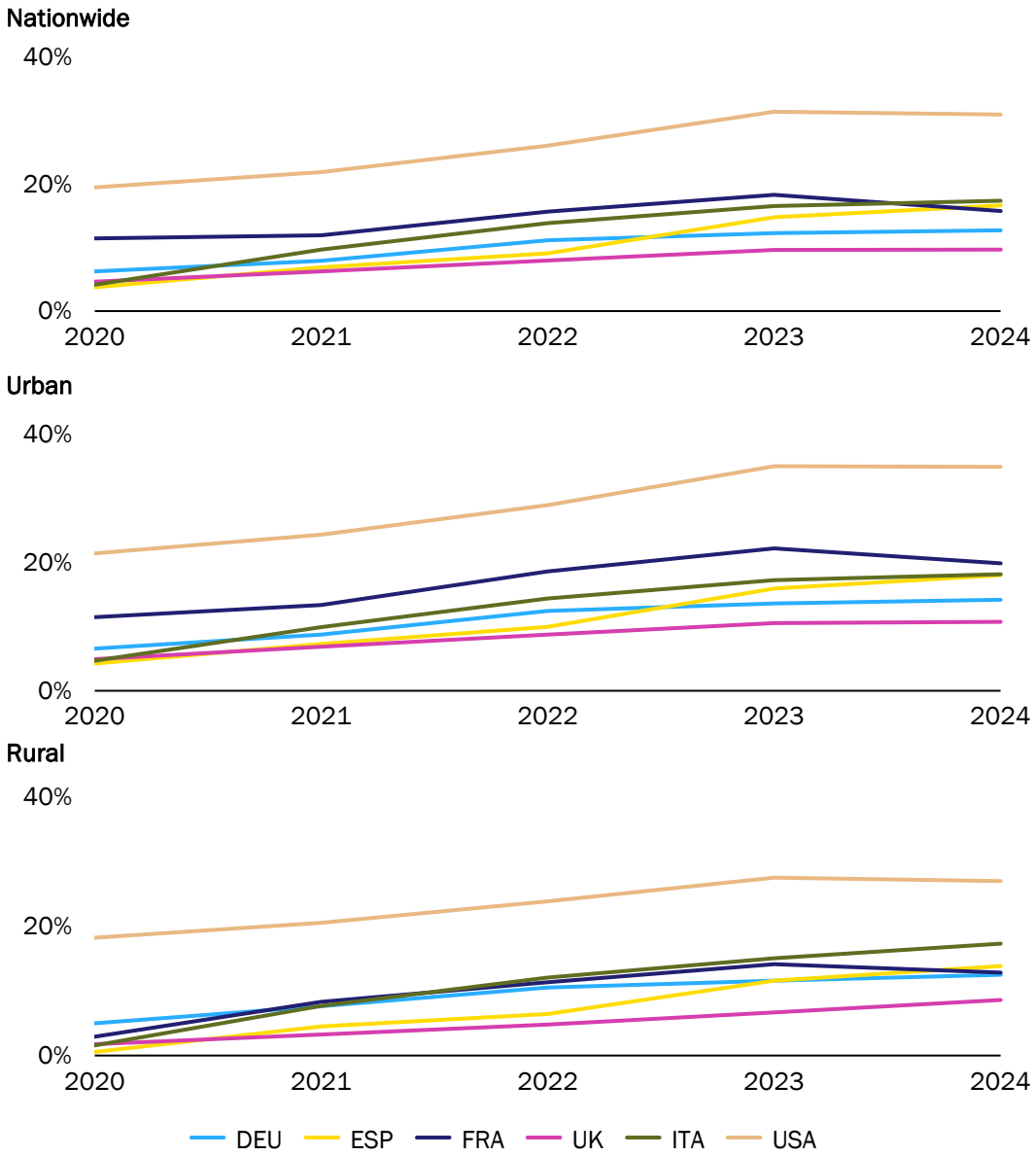
Figure 5.3: 4G availability [Source: Opensignal, 2024]



5G availability

5G availability for Opensignal users in the UK has also been consistently lower than benchmark countries across both urban and rural areas (see Figure 5.4), and is about 50% lower than for peers in 2024. Lower 5G availability is expected to be highly correlated with lower levels of upgrades of the existing 4G network, with lower coverage in general also resulting in lower availability as experienced by users. In the UK, users have more limited 5G, even in areas where they spend a significant proportion of their time.

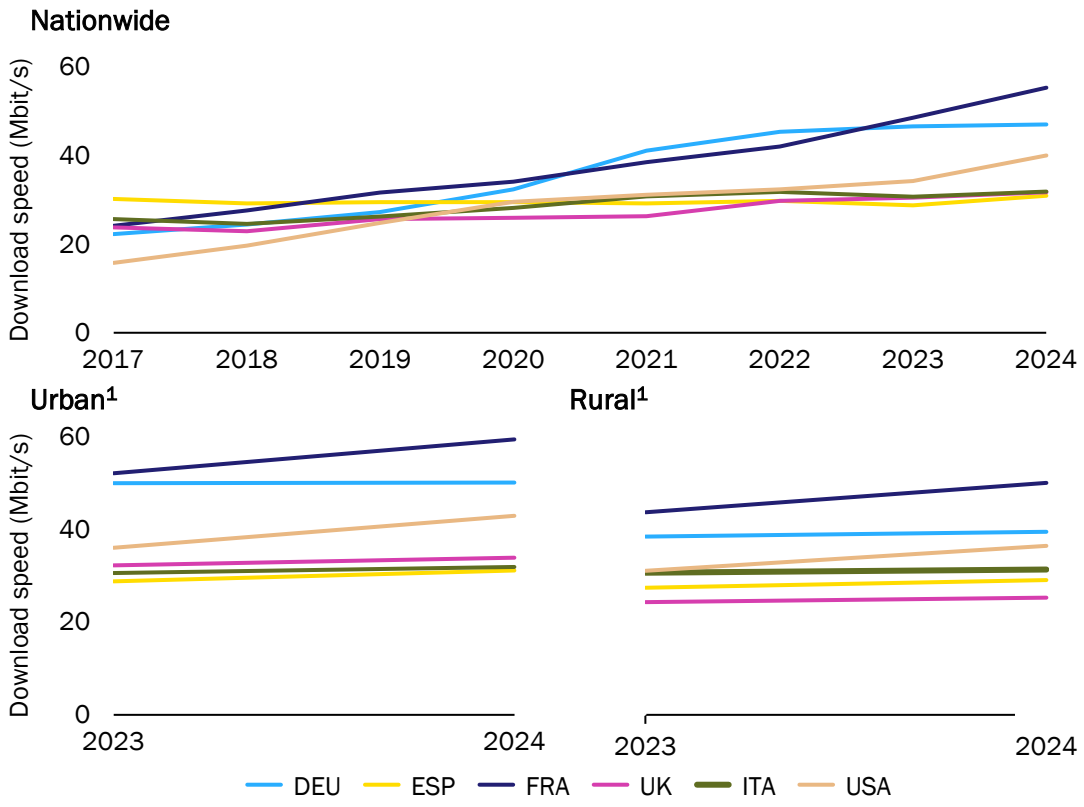
Figure 5.4: 5G availability [Source: Opensignal, 2024]



4G and 5G network performance: download and upload speed experience

Measured in Mbit/s, Opensignal's download and upload speed experience represents the rate at which users are able to receive and send information via their mobile network. These metrics are a strong indicator of end-user experience for mobile data services. Opensignal data indicates that the performance of 4G networks (see Figure 5.5 and Figure 5.6) in the UK is at the lower end of benchmarks, with download speeds not having increased significantly since 2017. Average upload speeds in the UK (see Figure 5.6) have declined between 2017 and 2024, suggesting network investment has not kept up with user demand. Opensignal data paints a similar picture for 5G networks, with the UK lagging behind its peers in both 5G data download and upload speeds in 2024, as shown in Figure 5.7 and Figure 5.8. For both technologies (4G and 5G) and directions of traffic (downlink and uplink), the performance of the UK is 20% to 30% lower than the average of peers in 2024.

Figure 5.5: Download speed 4G [Source: Opensignal, 2024]



[1] The Opensignal data split by geotype for these metrics is not available prior to 2023

Figure 5.6: Upload speed 4G [Source: Opensignal, 2024]

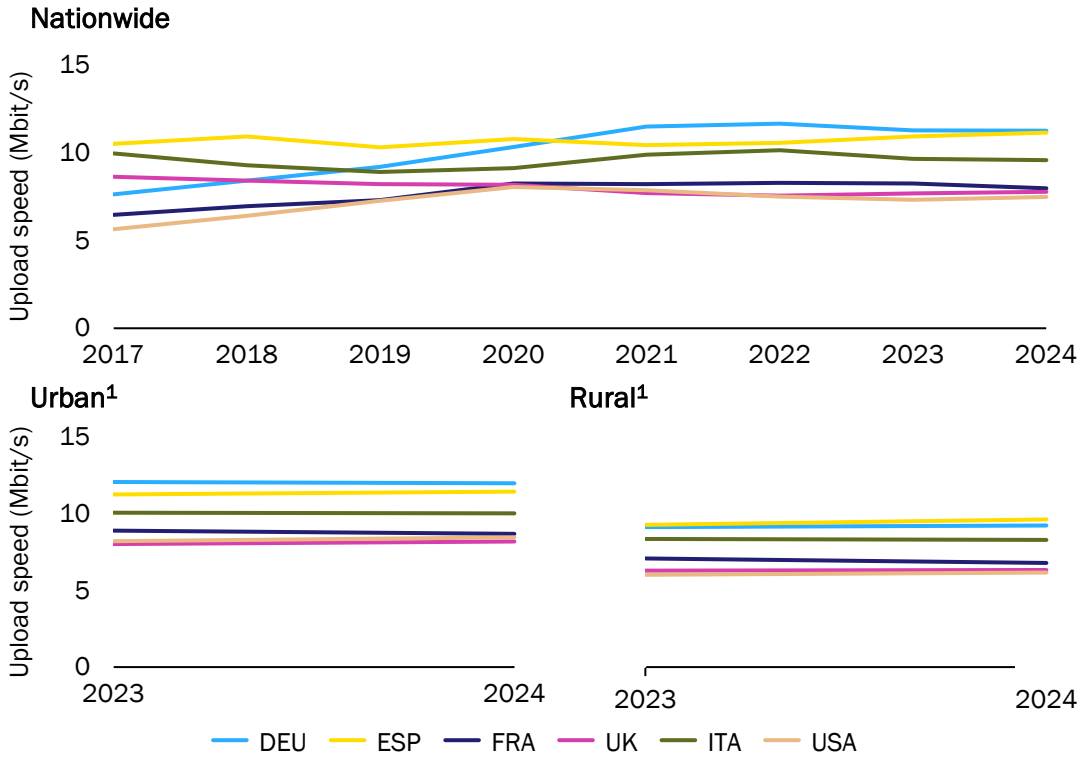
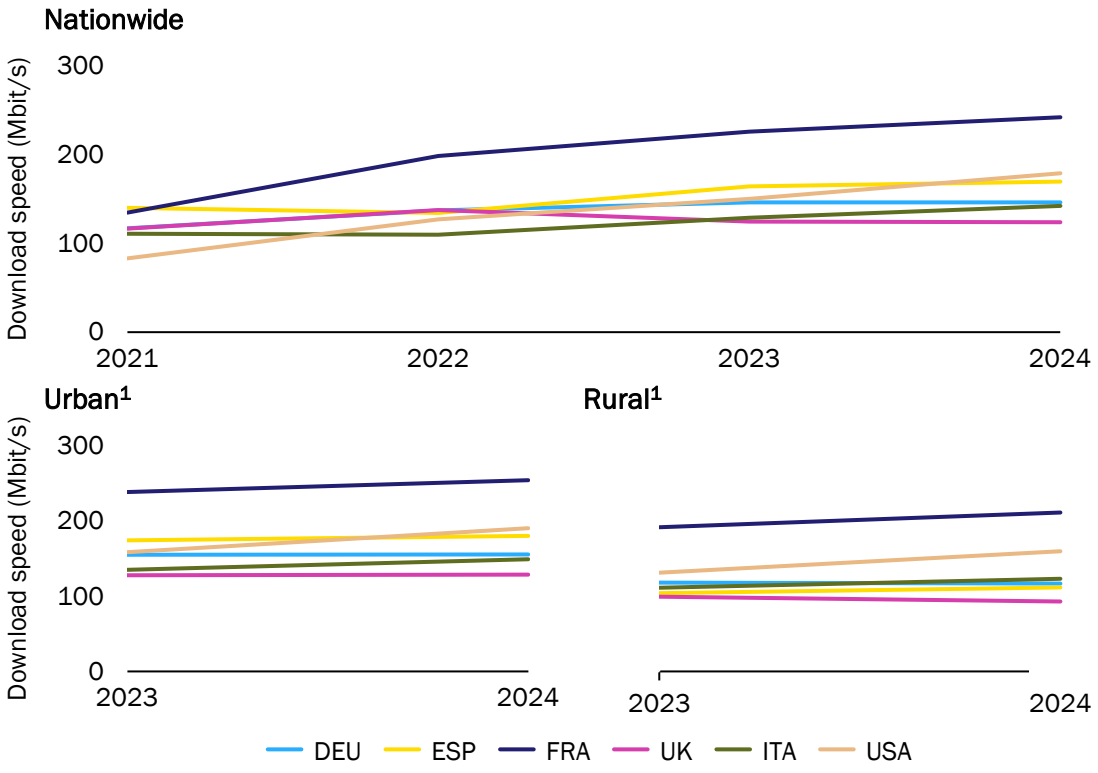
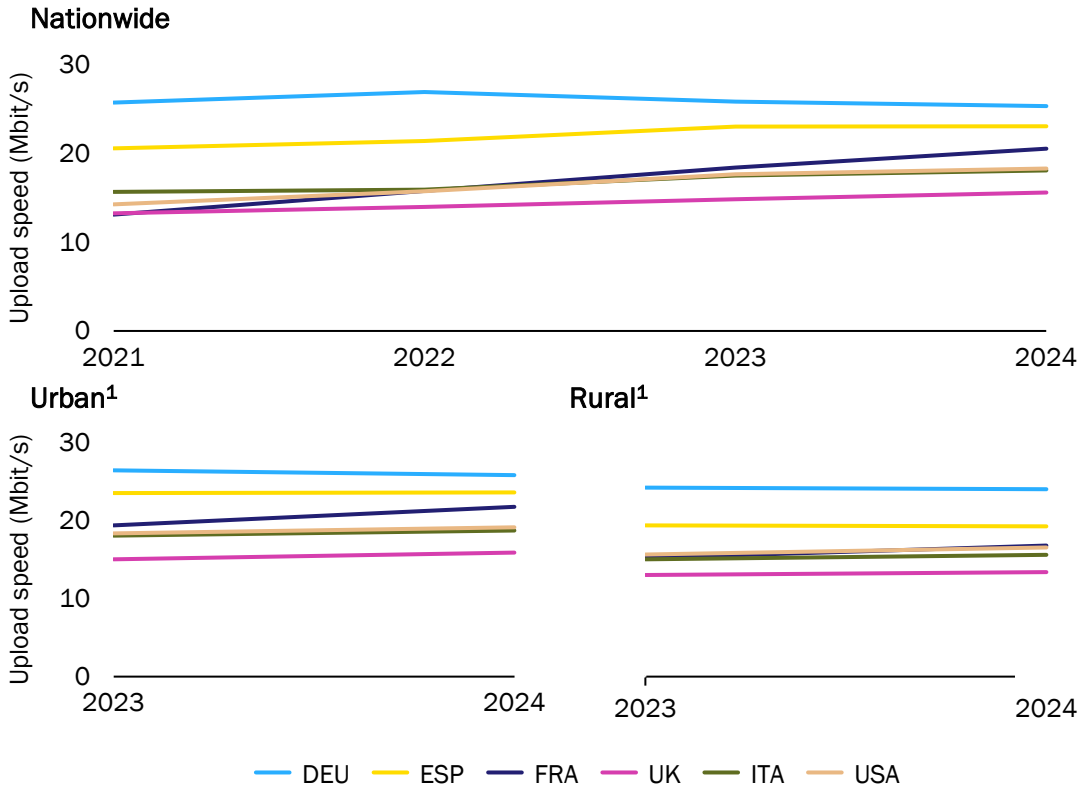


Figure 5.7: Download speed 5G [Source: Opensignal, 2024]



[1] The Opensignal data split by geotype for these metrics is not available prior to 2023

Figure 5.8: Upload speed 5G [Source: Opensignal, 2024]



[1] The Opensignal data split by geotype for these metrics is not available prior to 2023

4G and 5G network latency

The UK does not underperform on all customer metrics tracked by Opensignal and is in the middle of benchmarks for latency on both 4G and 5G networks. Latency is a measure of the time it takes for a command signal to be sent and a response received by a device, enabling data transfer to begin. Lower latency corresponds to better customer experience.

However, the core of the network, i.e. the network between the internet traffic handover point in a data centre and the mobile PoP is a key factor for the overall measured latency. Therefore, better performance by the UK in this metric may be less related to the radio access network (RAN), which is the focus of this report.

Furthermore, the relatively small difference between latencies of 30, 40, 50 or 60 milliseconds is usually only experienced in the most time sensitive of mobile data applications, typically online mobile gaming. The variations in latency would generally not be experienced any differently for users of email, internet access, file sharing, viewing mobile video on demand, etc.

Figure 5.9: Latency per market [Source: Opensignal, 2024]

Country	4G latency (ms)			5G latency (ms)		
	Nationwide	Urban	Rural	Nationwide	Urban	Rural
DEU	45	43	47	35	35	36
ESP	47	46	48	40	39	42
FRA	47	45	50	35	33	37
UK	50	48	53	39	39	42
ITA	51	49	52	47	47	49
USA	56	52	61	43	41	45

5.2 Key indicators such as market structure and smartphone penetration show broad alignment between the UK and peer countries

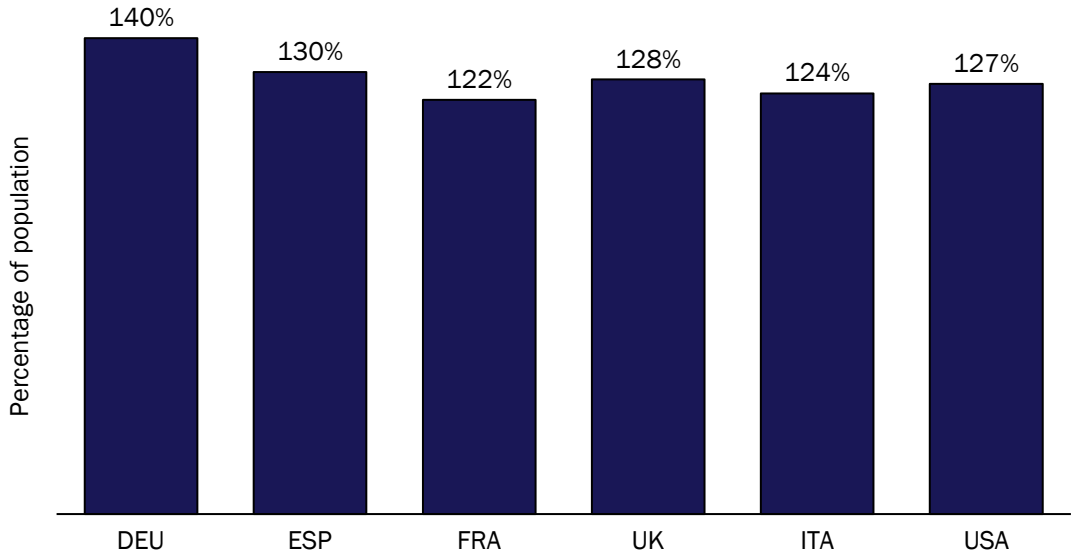
A number of key market indicators, including market structure, user demand for services, smartphone penetration, data volumes and spectrum policy, could be expected to lead to differences in network investments, network capacity and subsequent network performance. For example, markets with significantly older handsets in use, and therefore fewer users on 4G and 5G technologies, would not be expected to have deployed as extensive 4G and 5G network upgrades. Alternatively, if there are few users and significant installed capacity, user experience such as download speeds could be anticipated to be higher, as traffic would not be subject to heavy network congestion. Similarly, spectrum allocations play a significant role in the network capacity available to an operator, which can affect user experience.

However, these key indicators show limited differences between the UK and its peers. This suggests that variations in network quality are more likely due to different levels of network investment, such as the deployment of coverage and capacity PoPs and upgrades to the latest technologies like 5G.

Mobile penetration[60] in 2023, as shown in Figure 5.10, was broadly comparable between benchmark countries. The UK had a penetration rate of 128%, which is close to the peer average of 129%.

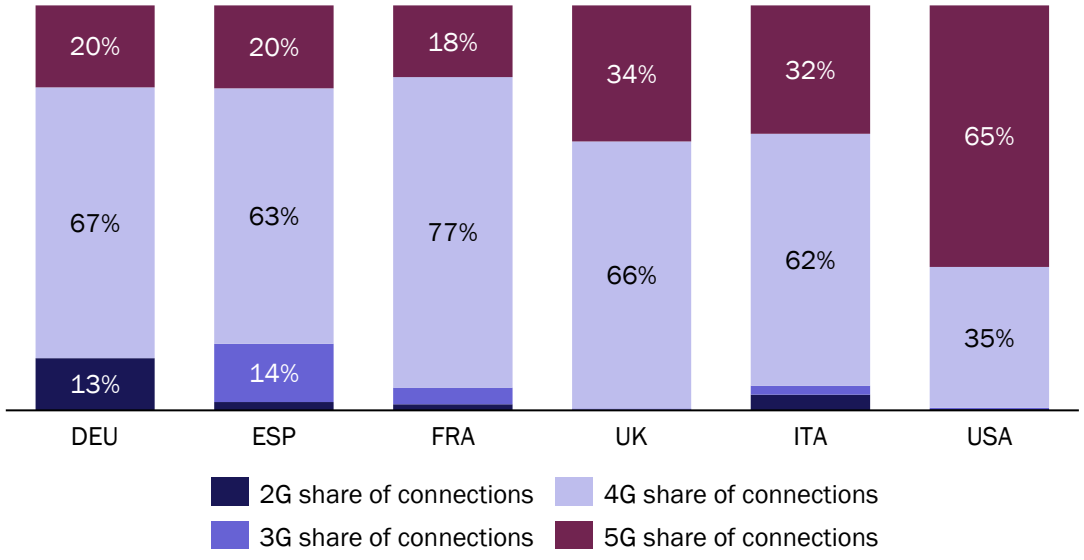
60 Excluding IoT SIMs, which have significantly different data demands and can also be operated on distinct, dedicated networks such as LoRaWAN as well as primary MNO networks.

Figure 5.10: Mobile penetration in 2023 (excl. IoT SIMs) [Source: Analysys Mason, 2025]



In addition, the share of mobile connections by technology in 2023 (see Figure 5.11) was also broadly similar, with the UK performing well with 4G and 5G technologies. The share of mobile connections on 4G and 5G (the dominant and most modern technologies) among peers was 93%, compared to ~100% in the UK. Demand for 5G services is also outperforming peers, with the UK having the highest share of 5G connections among European peers.

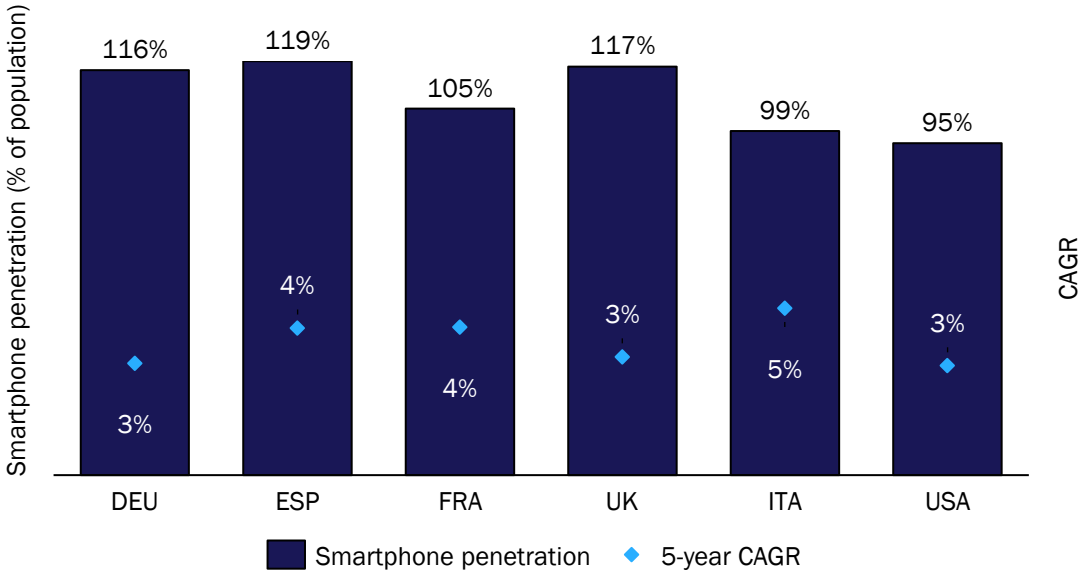
Figure 5.11: Share of mobile connections by technology in 2023 [Source: Analysys Mason, 2025]



Smartphone penetration in 2023 was high in all peer countries, meaning that users in those markets are in a good position to benefit from 4G and 5G data services as they are rolled out to additional areas of the country, providing greater speeds and capacity. Smartphone penetration in the UK is

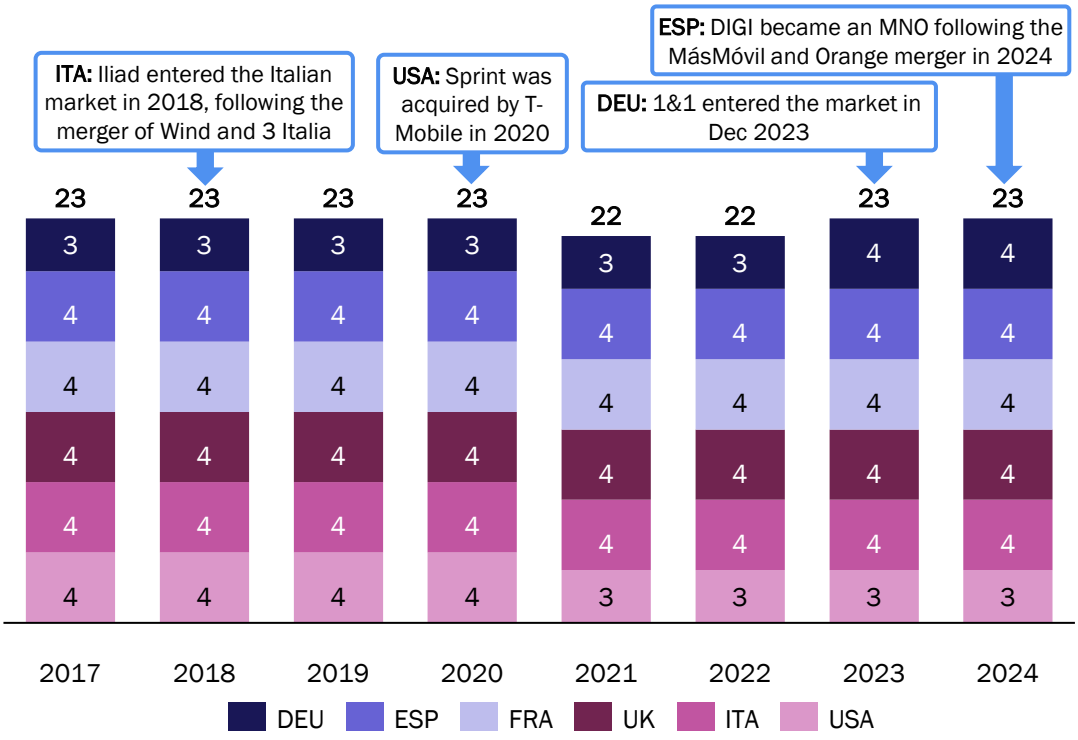
among the highest compared to benchmarks, emphasising the previous point that UK users are not lagging behind in their adoption of mobile technologies.

Figure 5.12: Smartphone penetration in 2023 [Source: Analysys Mason, 2025]



Between 2017 and 2024, few new mobile operators have entered the markets. This, coupled with operator consolidation across peer countries, has resulted in largely stable markets with three to four MNOs in each country.

Figure 5.13: Number of mobile operators per benchmark market [Source: TeleGeography, 2025]



Coverage requirements, typically set by the regulator or other policy makers, can also contribute to network performance and, in particular, to widespread network coverage. In recent years, these have typically been used by regulators to encourage or mandate MNOs to deploy networks to areas where it would not otherwise be economically viable to do so in order to serve limited numbers of users in these areas. The level and nature of coverage requirements can vary between markets based on the ambitions of the regulator and policy makers.

Figure 5.14 shows all 5G spectrum auctions in European peer markets were tied to technology-specific coverage obligations, including a proportion of the population and specific areas such as roads and rail. In the UK, obligations for the SRN were implemented not directly as part of a spectrum auction, but through separate discussions with government. In contrast to other European peers however, the SRN focuses on 4G geographical coverage and does not include specific obligations for 5G coverage, which may have resulted in lower focus on 5G deployment from the MNOs.

Figure 5.14: Coverage obligations in benchmark countries [Source: Analysys Mason, 2025]

Country	Spectrum band	Date of auction	Coverage obligations	Target
DEU	700MHz	2015	• 98% household coverage with >50Mbit/s • Coverage of main traffic routes	2019
	3.3–3.8GHz[61]	2019	• >100Mbit/s speed to at least 98% of households in all states • Road and rail coverage • 1000 new 5G base stations and 500 base stations in uncovered areas	2022
ESP	700MHz	2015	• 100% of urban areas with a population greater than 50 000, in addition to covering: – all capitals of provinces and autonomous communities – transport infrastructure including motorways, multi-lane roads and train stations	2025
FRA	700MHz	2015	• 99.6% metropolitan population coverage • 97.7% coverage of population in priority deployment areas • Priority road coverage and regional rail coverage	2030
	3.3–3.8GHz	2020	• 5G coverage of 50% in two cities with a population above 150 000 • Deployment of 10 500 5G sites • Full coverage of motorways and main roads (71 555km)	2020 2025 2027

61 Applied only to the three incumbent mobile operators.

Country	Spectrum band	Date of auction	Coverage obligations	Target
UK	700MHz 3.3–3.8GHz	2021 2018	• No 5G coverage obligations as these were replaced by the SRN • The SRN coverage obligations on operators include: – each reach 90% geographical coverage of the UK including specific regional targets • collectively provide additional coverage to 280 000 premises and 16 000km of roads	2026
ITA	700MHz	2018	• Provide 80% 5G population coverage at >30Mbit/s and including all municipalities with more than 30 000 inhabitants • 99.4% of population coverage • Road and rail coverage	2021 2022 2021
	3.3–3.8GHz	2018	• Coverage of at least 10% of municipalities with fewer than 5000 inhabitants • 5G coverage to any customer within 6 months of request	2018
USA	600MHz	2017	• 40% population coverage	2023
	3.5GHz	2022	• 80% population coverage	2030
	3.7GHz	2021	• 80% population coverage	2033

5.3 The key drivers defining network performance include spectrum efficiency, spectrum allocation and network densification

Spectrum efficiency

Spectrum efficiency is mainly driven by technological progress, as such this remains relatively constant across the benchmark markets which are all currently leveraging widespread 4G technology and migrating to 5G to achieve the highest spectrum efficiency.

Spectrum allocation

Based on our research, 5G spectrum availability in the benchmark countries is considered reasonably comparable, with 700MHz spectrum allocations ranging from 60MHz to 80MHz (see Figure 5.15 below), with the UK having the most spectrum in this band amongst peers. This spectrum was not auctioned in the UK until 2021 (up to 6 years later than peers), when the SRN negotiations were finalised, however, regardless of the auction date in other countries, the 700 MHz spectrum was freed up by free-to-air (FTA) / broadcast TV and made available to MNOs between 2019 and 2022 in the European peer countries, and was freed up in the UK in 2020, in line with peers. Moreover, 5G was not generally activated in European markets until 2019 or 2020 and as such, the delay in the auction is unlikely to have significantly affected 5G deployment as the technology was rolled out using other bands, such as the 3.3–3.8MHz band in 2018. For the 3.3–3.8GHz band, the range of spectrum allocations in the benchmark countries is between 200MHz and 390MHz, with the UK

having the most. For the total overall spectrum allocation, the UK leads European benchmarks, with 1150MHz (excluding millimetre wave), while Italy has auctioned the least amount of spectrum, with 865MHz. Overall, this suggests MNOs in the UK have gained access to a similar or greater volume of spectrum in aggregate and with similar timing compared to peers with which to deliver 5G services. Hence, it does not appear that spectrum availability would significantly affect relative network quality. In addition, MNOs in European benchmark countries have invested comparable amounts in their 5G spectrum assets when normalised for total spectrum amount and population coverage, with the UK towards the lower end of benchmarks.

In the USA, due to the vast majority of spectrum being auctioned at a regional level and creating variations between geographical areas, Chicago has been considered as an example for benchmarking purposes. Our research shows that a similar amount of spectrum has been auctioned in Chicago in the low and mid bands[62] and a large amount of spectrum in the millimetre wave bands, which are not yet widely deployed in Europe. The more widespread deployment of millimetre-wave spectrum for capacity purposes may contribute to higher network capacity and hence improved customer experience metrics in the USA.

Figure 5.15: 5G spectrum allocation [Source: Analysys Mason, TeleGeography, 2025]

Country	Spectrum band	Spectrum amount	Date	Price paid for 5G spectrum (EUR/ MHz/inhabitant)[63]	Total spectrum allocated[64]
DEU	700MHz	60MHz	2015	0.17	1010MHz
	3.3–3.8GHz	300MHz	2019		
ESP	700MHz	60MHz	2021	0.07	980MHz
	3.3–3.8GHz	380MHz	2018		
FRA	700MHz	60MHz	2015	0.22	920MHz
	3.3–3.8GHz	310MHz	2020		
UK	700MHz	80MHz	2021	0.12	1150MHz
	3.3–3.8GHz	390MHz	2018		
ITA	700MHz	60MHz	2018	0.41	865MHz
	3.3–3.8GHz	200MHz	2018		
Chicago (USA)	600MHz	70MHz	2017	1.35	862MHz low and mid-band 7562MHz incl. mmWave
	3.3–3.8GHz	380MHz	2021/2022		
	5G mmWave (24, 37, 39, 47GHz)	4100MHz	2019/2020		

62 'Low band' includes spectrum bands under 1GHz, while 'mid band' includes spectrum between 1 and 4GHz.

63 Payments made at auctions for 5G spectrum normalised by amount of spectrum and population.

64 Excludes 26GHz spectrum for European markets as this is not allocated in all markets and is not currently widely used for mobile services.

Spectrum refarming has occurred in the benchmark countries for some 2G and 3G spectrum bands, such as 1800MHz and 2100MHz to deploy for 5G alongside its optimal 5G spectrum (see Figure 5.16), but no networks were launched exclusively on these bands. 700MHz spectrum was used for free-to-air (FTA) TV before being freed up to be used for 5G deployment between 2020 and 2022 in European benchmark countries.

Figure 5.16: 5G spectrum refarming [Source: TeleGeography, 2025]

Country	Spectrum band (MHz)	Date spectrum was deployed/refarmed for 5G deployment	Date 700MHz spectrum was freed up by FTA TV
DEU	700	2020	2019
	1800	2021	
	2100	2020	
ESP	700	2020	2020
FRA	700	2020	2020
	2100	2020	
UK	700	2020	2020
	2100	2019	
ITA	700	2022	2022
	1800	2020	
	2100	2020	
USA	600	2019	2017
	850	2019	
	1900	2022	
	2500	2022	

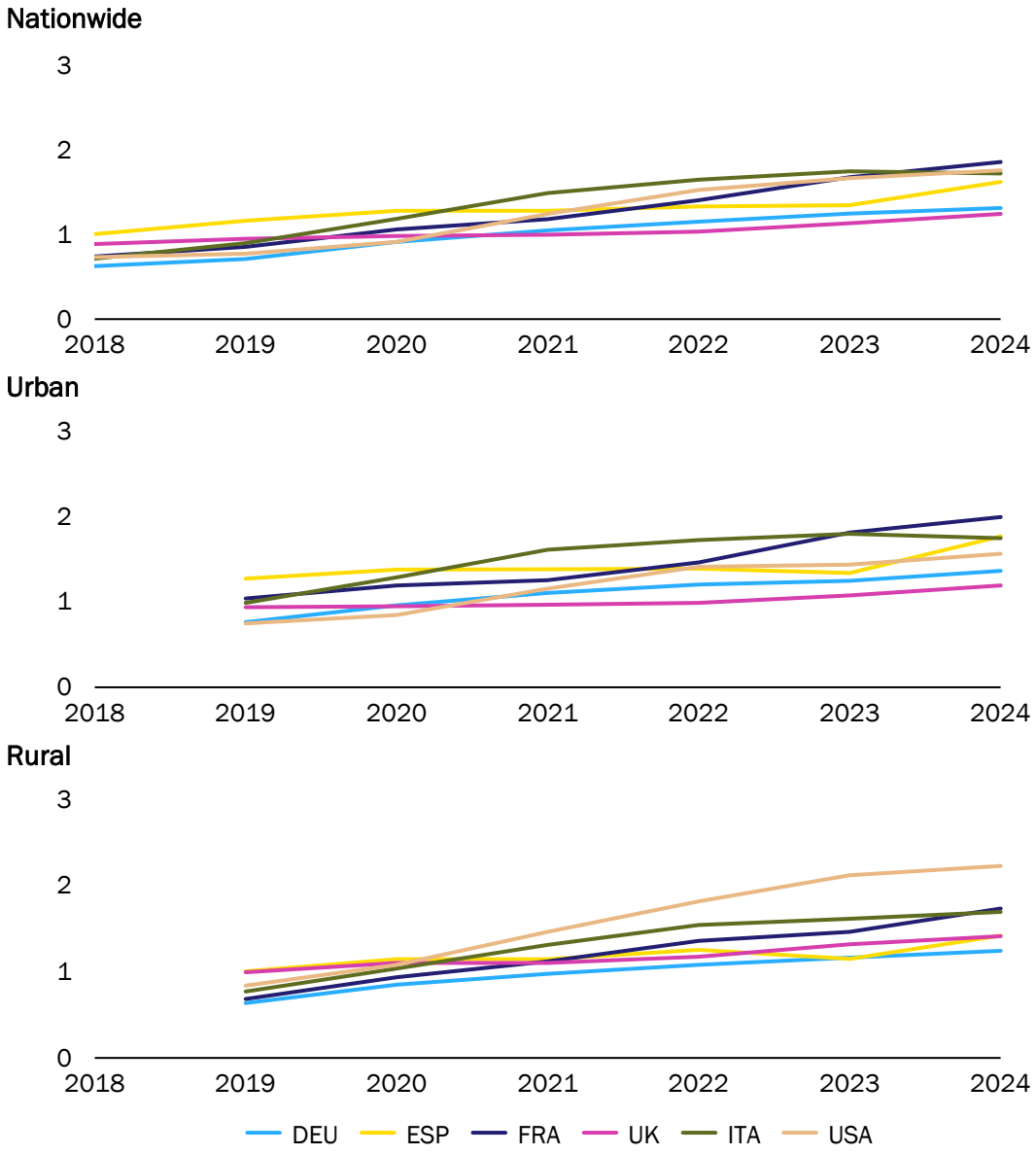
In summary, we find that the UK has auctioned comparable amounts of 5G spectrum to other benchmark European markets, and spectrum refarming has occurred across the board to complement 5G deployment in the 700MHz and 3.5GHz bands. This has led to comparable 5G deployment opportunities and activations, available at similar times in the UK and across European benchmarks.

Network densification

While on spectrum efficiency and spectrum allocation the UK appears aligned to the peer countries, the UK lags behind on the third element defining the network performance, i.e. network densification. Opensignal is able to record the number of eNodeBs that are 'seen' by its users, meaning end -users' mobile devices have connected to the eNodeB. An eNodeB is the hardware responsible for the management of signals from the antennas located on a site for a given technology and is a key part of 4G mobile networks. The equivalent equipment in a 5G network is called a gNodeB. The number of eNodeBs deployed can vary based on a number of factors, including the number of physical locations in which equipment is deployed, the share of those locations that are upgraded to 4G, as well as vendor and network strategies each affecting the number of eNodeBs per location. ENodeBs and gNodeBs are also known as 4G and 5G base stations, respectively.

Data from Opensignal indicates that in 2018, as shown in Figure 5.17, the UK had among the highest number of 4G base stations per 1000 inhabitants (normalised by population to account for the size of each market). It is noted, however, that this does not appear to have resulted in significantly higher 4G performance at this time, as shown by the customer performance metrics in Section 5.1. By 2024, the number of 4G base stations per 1000 inhabitants in the UK has experienced limited growth compared to benchmarks, placing the UK at the bottom among its peers. This suggests lower investment in 4G networks during this period in the UK when compared to benchmarks. It must be noted that it is not possible to determine the extent to which these differences are related to variations in network and vendor strategies, which may not affect network performance. In contrast, the number of 4G PoPs is more reflective of investment and network performance.

Figure 5.17: 4G base stations per 1000 inhabitants [Source: Opensignal, 2024][65]



65 The 2023 datapoint for the UK refers to Q3 due to a measurement error in Q4 2023.

5G network upgrade

The progress of network upgrades to 5G can be understood through the deployment of 5G base stations, which can be broadly categorised into two types:[66]

- Low-band 5G base stations: these are the 5G base stations that are responsible for broadcast of low-band frequencies, such as 700MHz, which provide a wide area of coverage but offer limited capacity due to the relatively small bandwidth of the spectrum. Sites upgraded to deploy low-band 5G stations would only require access to conduct an upgrade, which would typically involve an antenna swap on a reasonably like-for-like basis in terms of space and visual impact.

- Mid-band 5G base stations: these are the 5G base stations responsible for broadcast of frequencies in the 'mid band' such as 3.5GHz. These frequency bands offer significantly increased capacity but over smaller geographical areas compared to frequencies in the low band. As a result, these bands have a greater impact on end-user experience metrics. Mid-band spectrum for 5G is typically deployed through a new antenna type known as MIMO, which further increases the capacity that can be achieved with the spectrum. This requires a more complex upgrade including a larger new antenna, which may require additional passive structures and can in some instances require access to additional land, particularly in the case of rooftop sites.

As such, the number of low-band 5G base stations deployed within a market offers a view on the number of 5G upgrades undertaken that provide the most extensive coverage improvement and would require access to land to install the upgraded antennas. Opensignal data, as shown in Figure 5.18 and Figure 5.19, demonstrates that the UK appears to have developed less well as regards the upgrade of 5G base stations and low-band 5G base stations specifically.

66 High-band 5G base stations (mmWave) are currently uncommon in Europe, so they have been excluded from this analysis.

Figure 5.18: 5G base stations per 1000 inhabitants [Source: Opensignal, 2024]

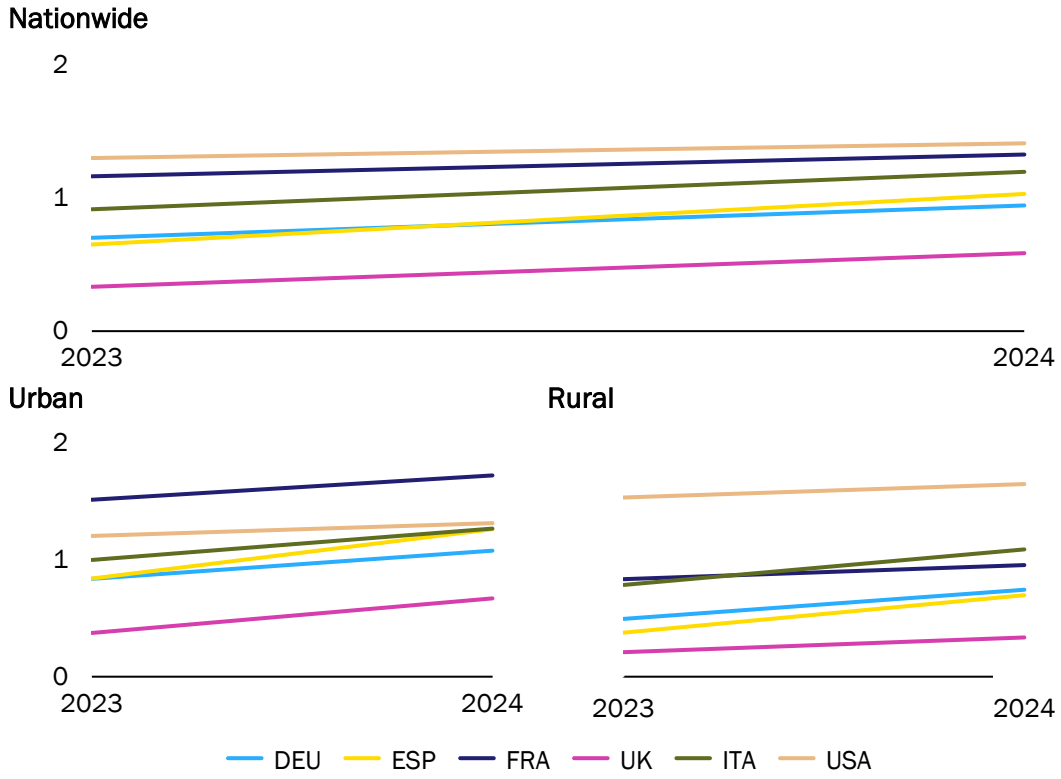
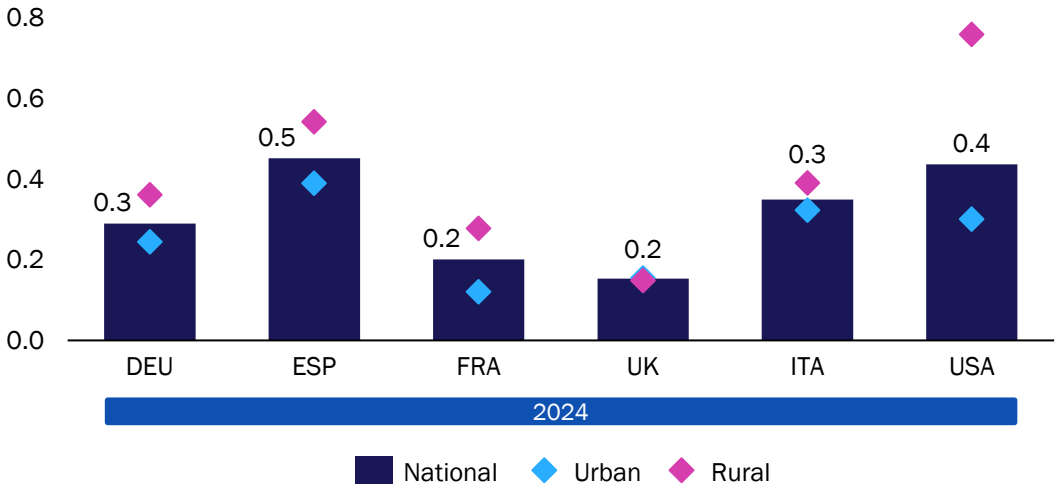


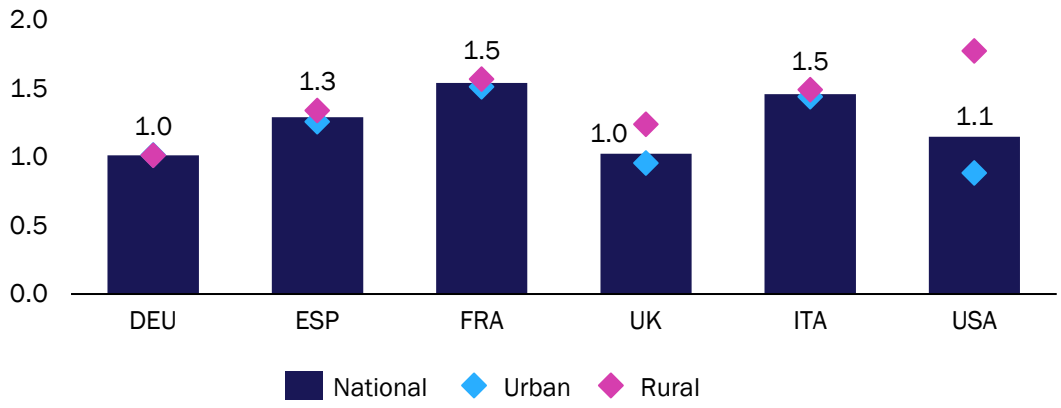
Figure 5.19: 5G low-band base stations per 1000 inhabitants [Source: Opensignal, 2024]



Network PoPs and sites

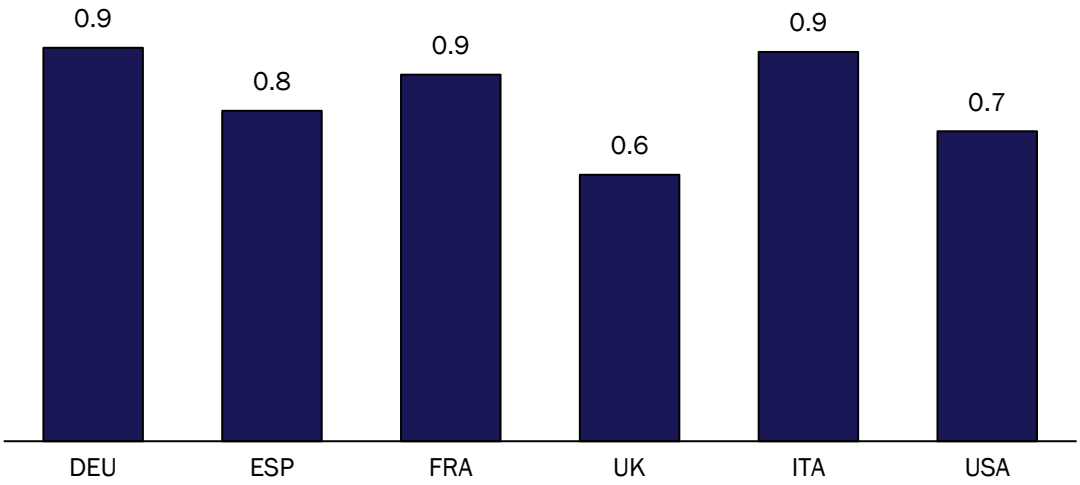
The number of network PoPs (4G and 5G) per inhabitant in the UK is lagging behind most peers in our comparison (see Figure 5.20). The UK's regulation on access to land, and increased litigation around land access renewals, as a consequence of the ECC will in our view have affected the UK's PoP deployment and expansion to 2024, amongst other factors.

Figure 5.20: PoPs[67] (4G and 5G) per 1000 inhabitants [Source: Opensignal, 2024]



The number of macro sites per inhabitant in the UK is also at the bottom of benchmarks (see Figure 5.21), which can partly be attributed to the access-to-land regulation and increased litigation as a consequence of the ECC. Evidence suggests this has hindered 4G and 5G deployment and as a result has negatively affected customer experience.

Figure 5.21: Estimated number of mobile macro sites per 1000 inhabitants [Source: Analysys Mason based on operator websites, analyst reports and tower company publications, 2023-24]



As with the customer experience metrics discussed in Section 5.1, the infrastructure data collected by Opensignal appears to suggest a lower level of investment by operators in the UK, in contradiction with the targets of the ECC.

67 The number of PoPs was estimated using the number of base stations and excluding the duplicates from the same operator using multiple technologies.

5.4 Many complex factors affect network deployment and performance, however access to land is a critical enabler for network roll-out and network upgrade

As outlined within the paper, network deployment and upgrades are affected by a series of factors which include access to land but also other demand- and supply-side drivers:

- **Consumer demand for mobile services:** as outlined in Section 5.2, demand for mobile services will affect the ability and willingness of MNOs to deploy networks, although these factors are broadly aligned amongst the markets considered by this paper.
- **Market structure:** operators in less competitive environments may face lower pressure from competitors to improve the services they offer in order to retain or build market share. In Europe, most markets are characterised by 3–4 nationwide MNOs, although the exact competitive dynamics vary between markets.
- **Coverage and performance obligations:** these obligations, related to operational and spectrum licences such as those reflected in Figure 5.14, will dictate which areas an operator is expected to prioritise as part of its network deployment.
- **Geographical topology of an area:** mountainous terrains or areas with very dense vegetation can significantly obstruct radio signals and require additional mobile sites or repeaters to maintain connectivity, which would incur additional costs and deployment efforts.
- **Population distribution:** more populous areas are more attractive for deployment due to a larger target market and thus potential customer base.
- **Timing and amount of spectrum availability:** a lower amount of spectrum available requires the deployment of more sites to provide a similar total network capacity.
- **Access to land:** the ability of operators to access land for the deployment of new sites and the upgrade of existing ones is critical for the expansion of coverage, capacity and improvement of consumer experience.

All of these factors play a key role in the ongoing deployment of mobile networks, but good access to land is a foundational necessity without which mobile networks cannot be deployed and upgraded. The ECC's impact on the market for access to land in the UK has disrupted a system that had functioned well since the initial deployment of mobile networks, over the 30 years that have preceded the reform of the ECC. The GIA could cause a similar disruption potentially having detrimental effects on MNOs' deployments and hindering the achievement of Europe's Digital Decade targets.

This is illustrated by the Opensignal data presented in Sections 5.1 and 5.3, which shows that the UK, being the only market in Europe to impose significant access-to-land regulations to date, has performed less well than its peers. Whilst access to land is expected to be only a part of the challenges faced by the market, these findings suggest that intentional regulations into price and terms of land access have not resulted in the improvement of mobile network performance.

6 Policy makers must carefully consider intervention in access to land to ensure outcomes are supportive of digital targets

6.1 One objective of the GIA is to speed up, simplify and lower the costs of telecoms networks through regulation of parts of the value chain, including access to land

As outlined in Section 1.3, the GIA is a newly introduced EU regulation that aims to ensure faster, cheaper and simpler roll-out of gigabit networks, including wireless networks. The regulation will apply to a wide range of stakeholders, including providers of networks not only within the telecoms sector but also other utilities such as water and gas to the extent the infrastructure or works of these networks can be shared and co-ordinated with telecoms network operators to improve efficiencies. It will also apply to a range of stakeholders that are not directly network operators but that own or control physical assets, such as towers or buildings, which can be used for the deployment of VHCNs.

In the context of access to land, the GIA considers access providers for existing and new land plots to fall into this second category of stakeholder, in that they control physical assets that may be used for VHCN deployment.

The key challenges related to cost and efficiency of deployment, as identified by the GIA,[68] are as follows:

- **Civil engineering work** represents a significant proportion of deployment costs. Policy makers suggest that these costs can be at least somewhat mitigated through greater sharing of infrastructure, which would reduce the need for further civil works to create duplicate infrastructure.

- **Roll-out inefficiencies** lead to high financial barriers, especially in rural areas, such as:
  - the [lack of] use of existing infrastructure such as […] poles, masts, antenna installations [and] towers
  - bottlenecks related to the coordination of civils works
  - burdensome administrative procedures to grant permits
  - bottlenecks in in-building deployment of networks.

The key challenges outlined within the GIA, which the regulation seeks to address, have limited relevance to access to land, as there is no requirement to build new land, but rather to reach contractual agreements with land owners to install telecoms infrastructure.

The regulation also includes providers of passive infrastructure, such as tower companies, under its definition of network operators in order to offer them the same benefits as an MNO. In principle, this appears to be a reasonable approach as such tower companies are typically often acting to

68 European Union (29/04/2024), REGULATION (EU) 2024/1309 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL, paragraphs 5 and 6.

provide the underlying infrastructure on which operators of networks rely. However, the extension of GIA protections to tower companies (and similar providers of 'associated facilities'), brings tower companies' access to land also into its remit.

Access to land, for the purposes of providing access for facilities that have or are planned to be installed for the provision of VHCNs, is therefore brought under the GIA in order to "ensure continuity of service and predictability for the planned deployments". However, as mentioned in Section 2.6 no significant issues have been identified in relation to access to land for this purpose.

Under the GIA, access providers are required to negotiate with operators in good faith and inform national regulatory authorities about their agreements, including negotiated price, which should reflect market conditions. Member States are also encouraged to provide guidance, in particular on price for access to land.

6.2 Potential interventions in the market for land, including price, must be carefully considered to ensure unintended or counter-productive outcomes do not arise

As outlined in Section 2.2, the market for access to land for the purposes of deploying mobile networks has been largely well functioning since the launch of the first mobile networks over 35 years ago. Any interventions should be proportional to market issues that do arise and should ensure they do not disrupt currently functioning areas of the market due to the risk of unintended consequences.

The access-to-land market is complex, with many varied stakeholders and implications that stretch far beyond the deployment of VHCNs. There is also evidence to suggest that regulation of access to land may not always achieve its objectives.

6.2.1 The implementation of the ECC in the UK appears to have had unintended consequences that may have contributed to the UK developing less well than peers

As discussed in Sections 4 and 5, the mobile network performance in the UK appears to have developed less well than peers, despite the implementation of the ECC which was designed to create a more efficient environment for network deployment. Evidence from Opensignal shows that customers' mobile service experiences are low in the UK across numerous measures, including available PoPs per inhabitant. We have calculated that the number of mobile macro sites per 1000 inhabitants is markedly low in the UK compared to its peers. These macro sites specifically require access to land, either on the ground or on rooftops.

Regulation of site rental prices under a principle other than one of commercial negotiations appears to have been a significant driver of changing incentives for both access providers and code operators, leading to difficulties for access to land, and consequently less infrastructure development and fewer mobile sites. As discussed previously, access providers appear less motivated to engage collaboratively to provide land due to a reduction in financial compensation. On the other hand, code operators may be motivated to take a dispute to mediation or tribunal in order to secure lower access costs than can be achieved through commercial negotiation.

The result is significant costs spent on legal fees that could have otherwise been invested in VCHNs, as well as lengthy delays to site renewal and deployment. These costs and delays are exacerbated as a result of land access disputes requiring mediation and potentially deferral to statutory tribunals. In contrast, a bilateral commercial agreement between parties would typically be expected to result in an agreement on access to land in a mutually beneficial short period of time.

These unintended consequences have been described as a 'chilling' effect on the supply of land.[69]

6.2.2 The draft Simplification Bill in France risks unintended effects such as increased complexity, litigation, barriers to entry, while also reducing rights and incentives for access providers

The Simplification Bill[70] currently being considered by the French government aims to reduce barriers to a significant range of business activities. Article 17 makes reference to access to land for telecoms operators. The proposed bill effectively restricts the transfer of property rights for land on which telecoms infrastructure is currently, or planned to be, deployed. In order for the land or a building hosting such infrastructure to be transferred, the seller would require confirmation from an MNO that it intends to use the infrastructure deployed on this land. In practice, this appears to give any MNO using or planning to use the land a veto right over land transfer, as no transfer can occur without the MNO's confirmation. This could lead MNOs to engage in discriminatory behaviour that supports their vested interests (including their relationship with the tower company that owns this infrastructure), with no consideration of the preferences or priorities of property and land owners.

It is understood this regulation is designed to avoid speculative business models that may seek to benefit from the high barriers to churn of MNO infrastructure already in situ and provide certainty to network operators, including infrastructure operators. Under its current drafting, the requirement for an MNO's explicit approval of a sale appears to restrict access providers, most of which will not be actively involved in the telecoms industry beyond hosting infrastructure.

In order to effect the transfer of the rights to land, any existing owner of property (for example a farm or commercial building) would require formal confirmation from an MNO that it intends to use the site. The MNO's use of the site may be limited to a very small area of a single field or the rooftop of a building that otherwise serves an entirely different function. As outlined in the GIA, tower companies now act as intermediaries in many relationships between access providers and MNOs in Europe which could mean the party looking to dispose of the property has no direct access to the MNO from which they require permission. Even if they are able to contact the relevant MNO tenant, the MNO (which may receive thousands of such requests) has limited incentives to act swiftly and affirmatively to support the access provider. The overall impact of such regulation appears to restrict the transfer of property, which could negatively affect the property owners (sellers) and disincentivise access providers from allowing access to any of their property for telecoms networks. It may also disrupt the efficient use of the other business activities unrelated to telecoms infrastructure, for example preventing a company from acquiring new offices for their staff due to

69 Social Market Foundation (11/12/2024), *Network failure: How the UK can meet its 5G ambitions*.

70 French National Assembly (23/10/2024), *Bill No. 481 rectified*.

delays in land transfers associated with seeking MNO approvals. Finally, it is likely to create a significant administrative burden on all parties, including whichever public organisation is required to ensure compliance.

While Article 17 of the Simplification Bill may seek to address one perceived market risk, it may inadvertently create other market issues. This demonstrates the risks of implementing broad regulatory measures in the market for access to land, where commercial negotiations based on mutual benefits have historically worked well without regulatory intervention.

6.3 Policy makers should rely on the approach set by the GIA to solve specific challenges if they arise within the market for access to land

In relation to Articles 3a and 3b of the GIA, guidance from the EC and implementation into Member States should be carefully considered by national policy makers. The approach should be light touch where possible and targeted proportionally to any negative effects identified.

The wording of the GIA, including "negotiate in good faith", "terms and conditions that are fair and reasonable" and "reflect market conditions", introduces a level of ambiguity to the implementation of national regulation. ETNO[71] highlighted that the suggested flexible wording does not clearly define the conditions under which Member States should ensure agreement on access to land is reached.

As such, policy makers of Member States should carefully consider the principle of purposive construction to ensure the implementation of the GIA achieves the ambitions outlined for faster, cheaper and easier roll-out of VHCNs. This may require particular interpretations of the GIA's wording, whilst avoiding alternative or overly intrusive interpretations that could lead to unintended and undesirable outcomes.

Given the broad functioning of the access-to-land market at present and the risks that disruption to this market can pose, the most appropriate regulatory interpretation appears to be one which deviates little from the current model of bilateral commercial negotiation for mutual benefit. That interpretation, however, should still protect against specific and demonstrated harms arising from unfair and unreasonable behaviour by either party to negotiation.

Such a model could include general rights to automatic renewal, except in pre-defined circumstances such as redevelopment of the site; this would offer certainty and stability to network operators whilst still allowing land owners certain rights over their land. It could also offer protections against above market rate rent increases, safeguarding against 'ransom rents' whilst ensuring access providers are appropriately compensated.

We do not believe such 'ransom' abuses occur in a material way across the sector, hence such safeguarding regulation should have limited impact on the overall fair, commercially negotiated

71 ETNO (05/2023), *European Commission's proposal "Gigabit Infrastructure Act"*.

functioning of the market for access, while increasing protections for telecoms as a critical national infrastructure and key service for citizens.

A lighter approach to regulation also presents the additional positive impact of limiting the number of disputes likely to be sent for referral to the dispute body. This would improve the ability of the dispute body to effectively deal with true instances of abuse in a very timely manner to the benefit of network deployment.

7 Conclusions

The ability of network operators to access land for deploying new sites to expand coverage and densify networks, as well as accessing existing sites to upgrade networks to next-generation technology, is crucial for achieving the Digital Decade targets. Therefore, policy makers should carefully consider the matter of access to land, bearing in mind that, as has been outlined in this paper, regulation which disrupts commercial incentives may not be the best approach to ensuring sufficient access to land to achieve broader digital inclusion targets.

7.1 The regulation of the market for access to land could have detrimental effects on its functioning and reduce benefits brought about by investment in this segment

The access-to-land market has been functioning well for over 35 years as tens of mobile networks have been deployed, including hundreds of individual technology layers, across hundreds of thousands of mobile sites located on the ground and on rooftops. Until now, access to land for telecoms operators has been primary left to commercial negotiation between operators (access seekers) and land owners (access providers) in Europe, without clear evidence this has negatively affected network deployment.

By comparison, policy makers in the UK have taken a different stance with significant regulation of access to land in favour of network operators in a number of areas including price. Introduced in 2017, this regulation has caused significant disruption to the commercially incentivised access-to-land market, with increases in disputes between access seekers and providers resulting in high dispute-related costs and delays to land access agreements.

As such, it is clear that regulation of an existing commercially led market such as access to land, in particular in relation to price, can have wide-ranging impacts that are unintended and could have a harmful effect on broader targets for the deployment of VHCNs and digital infrastructure investment. Incentives will change for access providers – both existing and new providers – if they lack sufficient financial motivation to engage in collaborative discussions. Meanwhile, access seekers (including non-operators such as tower companies) may be more incentivised to focus on cost savings through renegotiating existing sites rather than deploying new ones.

The impact of these changes can lead to a greater number of disputes arising, lengthier negotiation periods for access-to-land agreements and less collaboration between parties. As a result, the network deployment essential for deploying 5G, enhancing coverage and otherwise improving mobile services will be slower.

Regulation or deviations from the current commercial market structure will also negatively affect the incentives of lease aggregators. These aggregators primarily invest in creating land portfolios to realise operational and financial efficiency benefits, which they share with downstream tower companies and MNOs. The lease aggregation investment activity and the long-term predictability

and stability it brings therefore actively supports the value chain to achieve the Digital Decade targets. As previously discussed, lease aggregators are investors seeking long-term and stable returns, and a significant policy change in this area is likely to create market disruption and uncertainty potentially deterring private capital investments. The outcome could therefore be a reduction in lease aggregation and optimisation activities. This in turn could have long-term negative impacts (in particular operational efficiencies, which cannot be regulated) on the mobile market, including for the upgrade to 5G technologies and future mobile technologies.

7.2 Regulation could also have detrimental impacts on the broader sector, negatively affecting consumer outcomes, network roll-out and achievement of digital targets

Given its importance for the telecoms sector, disruption to the market for access to land could also have wide-ranging negative consequences for the industry as a whole. As previously discussed, the mobile telecoms industry currently faces profitability challenges, with reducing ARPUs and sustained capex requirements for network upgrades.

Regulation that creates uncertainty or concerns for investors, including lease aggregators, could be perceived by the wider investor community as a signal of policy makers' views on the importance of digital investors across the telecoms space. It could also suggest future risks of similar regulation being applied to other telecoms elements, such as towers, fibre, data centres and more. At a time when telecoms operators struggle to fund investment, this could be detrimental to the achievement of the Digital Decade targets by 2030 and future targets beyond that.

7.3 Alternative approaches to regulating access to land, such as light-touch intervention or forbearance, are preferable as they allow for greater market flexibility

Regulation of access to land, through the application of the GIA and any future policies, should therefore aim to address only specific market failures as and when they arise, such as specific instances of landowners or speculators demanding ransom rents. These can be targeted using specific and limited applications of the GIA.

In all other instances, the most effective approach to ensure the spirit of the GIA is met and the EC's Digital Decade targets are achieved on time appears to be to continue to allow the market to function in its current form as it has done so successfully for more than 30 years, through flexible and mutually beneficial commercial negotiations between fairly behaved land access providers and access seekers.

Annex A Opensignal methodology

Analysys Mason has used a rich dataset from Opensignal in this report. We provide below a summary of the Opensignal data collection methodology.

Figure A.1: Opensignal methodology [Source: Opensignal, 2024]

Opensignal terminology	Opensignal methodology	Analysys Mason comment
Reach (4G/5G)	• Opensignal's 'Reach' metric measures how its mobile users experience the geographical extent of an operator's network • Reach analyses the average proportion of locations where users were connected to a network out of all the unique locations visited by users • This data is collected multiple times a day	• This is used as a proxy for coverage, representing the proportion of geographical places that are visited by real users where a specific technology is available • Reach is different to geographical or population coverage as may be reported by MNOs, but represents all the locations where users are present
Availability (4G/5G)	• The 'Availability' metric shows the average proportion of time an Opensignal user, designated as user for a given technology, is connected to that mobile technology (e.g. 5G) • This data is collected multiple times a day	• This is used in combination with reach to evaluate the coverage in places where people spend most of their time – as such, it is used to assess network coverage in a more customer-centric way
Download speed (4G/5G)	• Measured in Mbit/s, Opensignal's 'Download Speed Experience' represents the typical download speeds an average user experience • This test is performed weekly	• This is used to evaluate network performance and the quality of networks as experienced by Opensignal users
Upload speed (4G/5G)	• Measured in Mbit/s, Opensignal's 'Upload Speed Experience' represents the typical upload speeds an average user experiences • This test is performed weekly	• This is used to evaluate network performance and the quality of networks as experienced by Opensignal users

Opensignal data is summarised on a 'one device – one vote' system, meaning results are the average of individual user experiences, rather than average of all measurements taken. For the purposes of this report, measurements are considered as MNO neutral and so weighting of performance between MNOs is implicitly by number of Opensignal users per MNO, which should be broadly representative of market shares.

All the quality-of-experience metric datapoints, unless otherwise stated, refer to the average of the four quarter datapoints for each year, with the exception of 2024 values, for which only the first three quarters of the year were available. The number of network elements identified in each country

may also depend on the sample size and the data collection methodology available at each point in time. We note that Opensignal has been expanding its methodology and its user bases over the past five years, alongside the introduction of 5G technology.

In the Opensignal dataset, base stations constitute the fixed infrastructure within a mobile network responsible for managing wireless communication with devices, including smartphones. They serve as the connection point between user equipment and the core network, overseeing radio signal management and facilitating the transmission of both data and voice. Specifically, eNodeBs are the base stations that enable 4G LTE networks, while gNodeBs serve the same function for 5G networks.