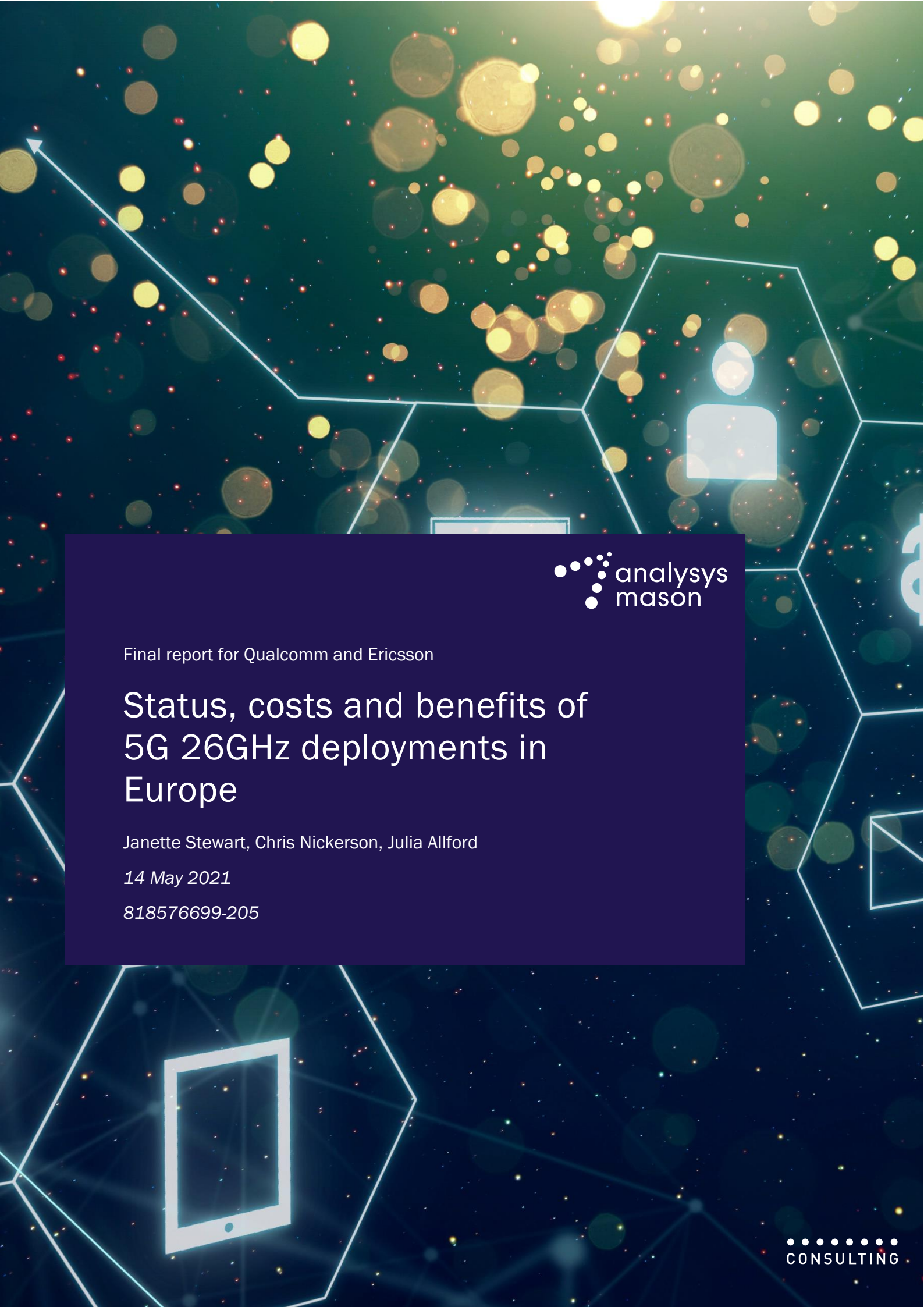


analysys mason

Final report for Qualcomm and Ericsson

Status, costs and benefits of 5G 26GHz deployments in Europe

Janette Stewart, Chris Nickerson, Julia Allford

14 May 2021

818576699-205

CONSULTING

Contents

Analysys Mason Limited
North West Wing, Bush House
Aldwych
London WC2B 4PJ
UK
Tel: +44 (0)20 7395 9000
london@analysysmason.com
www.analysysmason.com
Registered in England and Wales No. 5177472

1 Executive summary

Analysys Mason has conducted a study, on behalf of Qualcomm and Ericsson, on the status, costs and benefits of 5G 26GHz (also referred to as millimetre-wave or mmWave) deployment in Europe.

The study was focused across thirty European markets (EU27 plus Norway, Switzerland and the UK) and has involved three components of research and modelling:

- Primary research with selected mobile network operators (MNOs) to discuss plans for 5G mmWave deployment.
- Secondary research of mmWave reports and publications, as well as announcements made by industry players in the public domain.
- Economic modelling of the costs and benefits associated with the 5G functionality enabled by 26GHz deployment for selected use cases.

Higher bandwidth mmWave deployments are expected to play a key role in delivery of 5G use cases that produce significant volumes of data, which the bandwidth available in mmWave bands can help to accommodate.

In Europe, the 26GHz band is the primary band being used for 5G mmWave deployment. In 2016, the Radio Spectrum Policy Group (RSPG) – a high-level advisory group that assists the European Commission (EC) in the development of radio spectrum policy – identified the 24.25–27.5GHz range as one of the 'pioneer' bands for 5G.

The band was later harmonised worldwide for international mobile telecommunications (IMT) at the World Radiocommunication Conference 2019 (WRC-19), and the EC has passed legislation requiring Member States to make spectrum within the band available for 5G.

Deploying 5G mmWave spectrum will increase the amount of bandwidth available in mobile networks and help deliver consumer-based enhanced mobile broadband (eMBB) use cases. It will also support the use of 5G fixed-wireless access (FWA) to provide high-speed broadband into the home, and bandwidth for location-specific deployments where significant volumes of data are generated by mobile devices (such as at airports and train stations, venues, music halls and festivals and major event locations). The bandwidth available in mmWave bands can be used to support 5G applications that require high capacity and low latency.

The key conclusions from our study are summarised overleaf.

Figure 1.1: Key conclusions on the status, costs and benefits of 5G 26GHz deployment in Europe [Source: Analysys Mason, 2021]

Key conclusion 1

mmWave, complementing the use of mid-band spectrum, will be used to:

- **deliver 5G for eMBB use in high-capacity areas**
- **deliver 5G FWA services to homes and offices**
- **support industrial use cases.**

Regulators should prioritise the assignment of mmWave spectrum to enable this wide range of use cases to emerge.

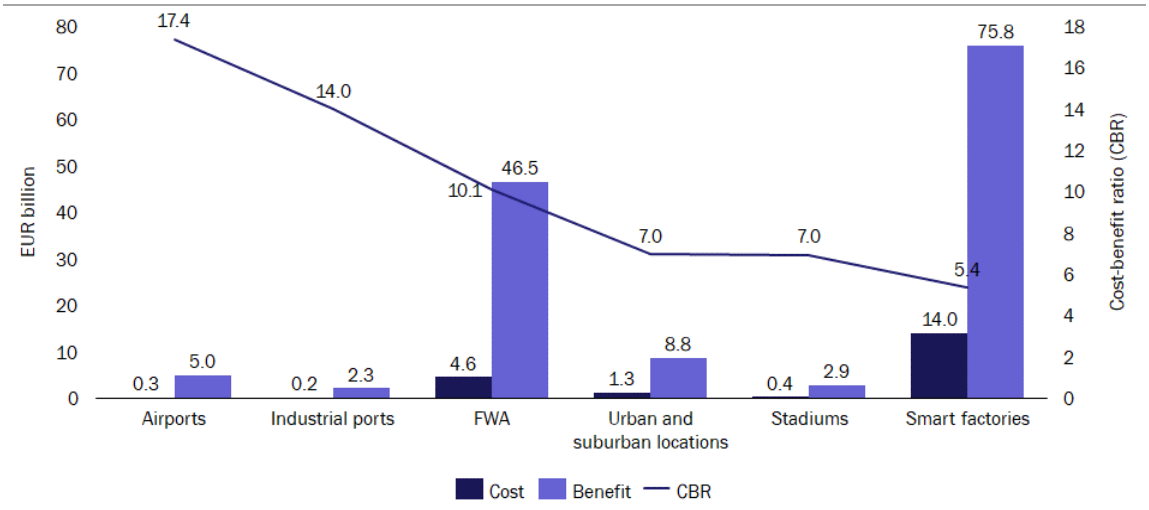
Our report describes a variety of eMBB uses of mmWave spectrum, together with use of 26GHz for 5G FWA services into homes and offices and a range of uses at specific locations where volumes of data traffic from mobile devices are especially high. What the 26GHz band might provide for MNOs over and above 3.5GHz deployment is the capability to accommodate eMBB traffic in high-use locations plus the potential to deliver, in specific locations, the multi-gigabit peak speeds, ultra-low latency and high-reliability connectivity needed by some of the 5G use cases that are widely discussed in published literature (e.g. gaming, industrial automation, augmented and virtual reality, immersive tourism experiences and next-generation transport applications). 26GHz might also be useful to enable operators to dimension capacity to meet the specific requirements for some use cases, such as those requiring high uplink capacity.

Key conclusion 2

Our modelling suggests significant economic benefit to deploying 5G mmWave across several use cases

Our modelling shows that there is a significant net economic benefit to deploying 5G mmWave primarily together with 3.5GHz but also as dedicated cells, across a wide range of scenarios, based on a 'base case' eMBB network deployment. For each of the use cases modelled, the estimated benefit is between 5 and 20 times greater than the estimated cost. Aggregating across all the use cases modelled, 5G mmWave deployment would generate an estimated GDP uplift (up to 2040) of more than EUR140 billion (cumulative) across thirty European markets, for around EUR21 billion of additional cost.[1] Figure 1.2 below shows the results of our economic modelling.

Figure 1.2: Present value of Europe-wide costs and benefits to 2040 of deploying 26GHz, by use case (EUR billion, 2020 terms) [Source: Analysys Mason, 2021]



[1] This cost is incremental to the cost of eMBB deployments in sub-6GHz bands and relates specifically to the deployment of 26GHz cells (plus some additional 3.5GHz deployment where required).

Key conclusion 3

MNOs we interviewed for the study indicated an expectation of using mmWave deployment to address a variety of use cases (including eMBB in high-capacity locations, 5G-based FWA, smart factory and other industrial applications, connected vehicles and venue-specific coverage)

Interviews with stakeholders demonstrated that MNOs intend to deploy mmWave spectrum in multiple specific locations (with variation in requirements based on local market demand). A large variety of use cases has been identified (including eMBB in high-capacity locations, 5G-based FWA, smart factory and other industrial applications, connected vehicles and venue-specific coverage). Stakeholders highlighted that mmWave spectrum can be used to maximise capacity within mobile networks (since frequencies can be re-used more intensively without co-channel interference occurring) as well as to allow for more flexibility to adapt time division duplex (TDD) frame structures to cater for local variations in traffic profile.

Interviews also highlighted that 5G mmWave technology has shown its capability to provide high capacity in trials and in commercial systems deployed to date. As the capabilities of mmWave technology continue to improve, MNOs expect that quality of service within deployments can be ensured even as traffic levels increase. Multiple mmWave networks have now been deployed globally on a commercial basis, with European markets in the process of catching up with these deployments. European MNOs commented that further European deployments (as well as non-European deployments in countries such as Australia and Brazil) will help to build the 26GHz equipment and device ecosystem.

2 Introduction

This report sets out the findings of a study prepared by Analysys Mason on the benefits of 5G 26GHz (also referred to as millimetre-wave or mmWave) deployment in Europe.

Higher bandwidth mmWave deployments are expected to play a key role in the delivery of 5G use cases both enhanced mobile broadband (eMBB) use and at specific locations where significant volumes of data are produced (e.g. transport hubs and event venues). The bandwidth available in mmWave bands can help to accommodate high capacity for eMBB applications for consumers whilst they are connected to mobile networks, whether they are on the move, in the office or at home. Use of mmWave bands can also help achieve very low latency, which will improve the 5G consumer user experience and support new real-time use cases (for example, for industrial or enterprise users). Several previously published studies, such as a study by the GSM Association on the socioeconomic benefits of 5G in mmWave spectrum, refer to use cases where 5G mmWave deployment might be used, such as urban connectivity, high-speed broadband in the home and office, rapid deployments/temporary connectivity, industrial automation, next-generation transport connectivity, education and others.[2,3]

In this study, our objective has been to consider the status, costs and benefits of 5G mmWave deployment, which, in Europe, is likely to use the 26GHz band initially.

The study was focused across thirty European markets (EU27 plus Norway, Switzerland and the UK) and has involved three components of research and modelling:

- Primary research with selected mobile network operators (MNOs) to discuss plans for 5G mmWave deployment. The primary research involved two elements: questionnaires sent to MNOs and interviews conducted by video call.
- Secondary research of mmWave reports and publications, as well as announcements made by industry players (MNOs, vendors, industry verticals, etc.), in the public domain.
- Economic modelling of the costs and benefits associated with the 5G functionality enabled by 26GHz deployment for selected use cases. The modelling builds on previous modelling exercises conducted by Analysys Mason for recent studies commissioned by Ericsson and Qualcomm on the costs and benefits of 5G deployment in Europe.[4]

2 See https://www.gsma.com/spectrum/wp-content/uploads/2019/10/mmWave-5G-benefits.pdf

3 See https://www.gsma.com/spectrum/wp-content/uploads/2019/07/mmWave-5G-Regional-Spotlights.pdf

4 See https://www.analysysmason.com/consulting-redirect/reports/filling-europes-5g-coverage-gaps/ and https://www.ericsson.com/4ab850/assets/local/about-ericsson/company-facts/europe/5g-action-plan-review-for-europe-executive-summary.pdf

Specifically, the study assesses:

- what 5G services (use cases) might be provided using 26GHz spectrum in Europe
- the deployment options for these services, and the timelines for European deployment
- how much spectrum is needed
- what benefits 5G mmWave offers
- the costs and benefits of 5G mmWave deployment in Europe, for selected key use cases.

The remainder of this document is laid out as follows:

- Section 3 provides an overview on the 26GHz band and the status of 26GHz assignment for 5G in Europe. The progress of 5G mmWave deployment in a selection of markets (both inside and outside Europe) where spectrum has already been assigned is also discussed, highlighting the range of use cases being explored by operators
- Section 4 describes results from the primary research conducted for this study into 26GHz use cases and deployment in Europe
- Section 5 presents the results of the economic modelling exercise we undertook and provides an estimate of the net economic benefit (benefit vs. cost of deployment) for selected mmWave use cases in Europe
- Section 6 summarises the conclusions from the study.

The report includes two annexes containing supplementary material:

- Annex A provides a detailed summary of the status of 26GHz award in European countries
- Annex B provides a bibliography of recent mmWave reports and publications reviewed as part of the study.

3 Overview and status of the 26GHz band for 5G

This section provides an overview on the 26GHz band and the status of 26GHz assignment for 5G in Europe. The progress of 5G mmWave deployment in a selection of markets (both inside and outside Europe) where spectrum has already been assigned is also discussed, highlighting the range of use cases being explored by operators. We also summarise several mmWave trials that have been conducted by MNOs and other players.

3.1 Overview of 5G spectrum in Europe, and the role of mmWave

In 2016, the European Commission (EC) published its 5G Action Plan for Europe (5GAP) aimed at ensuring that initial 5G deployment across Europe would occur by 2020. The 5GAP set out a roadmap for 5G introduction, including the spectrum bands that would underpin 5G deployment.

The 5GAP refers to a mix of bands being used in 5G deployment. The 5GAP notes that, whilst low-frequency bands such as 700MHz provide the most cost effective of ensuring wide-area coverage in less densely populated areas with fewer cell sites, enablement of the full range of 5G capabilities, including high-capacity and low-latency connectivity, will require a combination of bands. Following publication of the 5GAP, the EC defined harmonised use of the 3.5GHz and 26GHz bands as 5G 'pioneer' bands. These 5G bands are expected to be used together with existing mobile bands available to mobile operators for previous generations of mobile technology (such as 800MHz, 900MHz, 1800MHz, 2100MHz and 2600MHz).

The 26GHz band will provide additional capacity in 5G networks for eMBB consumers in localised areas where there is high concentration of eMBB use either outdoors or indoors, and will be used for 5G fixed-wireless access (FWA) to deliver high-speed broadband into the home. Additionally, location-specific use cases for the 26GHz band include those where there is a benefit from digitalisation of use, such as in airport terminals, train stations, shopping centres, offices, event locations and tourist sites. Industrial-based applications are envisaged too, using the available bandwidth in the mmWave bands to provide very low latency connectivity such as for robotics, industrial machinery automation and industrial augmented reality/virtual reality.

Operators in most European markets have now launched 5G services using a combination of the available bands. In markets where 3.5GHz spectrum has been made available, initial 5G launches have taken place using this spectrum. In some markets, operators have used existing mobile bands, such as 1800MHz or 2100MHz for 5G. To date, there has been more limited deployment of mmWave spectrum for 5G, although, as discussed in the remainder of this report, this situation is set to alter as 26GHz 5G licences become available in more European markets. MNOs are expected to use 26GHz spectrum alongside 3.5GHz and other frequency bands in their mobile networks to provide additional capacity for 5G eMBB traffic and for other specific use cases, once licences are available. 26GHz spectrum could also be deployed standalone (e.g. to provide a dedicated 5G fixed wireless network).

To enhance 5G deployment using lower bands, 26GHz bandwidth might provide the capability to deliver, in specific locations, gigabit peak speeds, ultra-low latency and high-reliability connectivity. The 26GHz band can also be deployed to provide capacity needed by some of the 5G use cases that are widely discussed in published literature, such as gaming, industrial automation, virtual reality and next-generation transport applications. As the 5GAP indicates, where the 700MHz, 3.5GHz and 26GHz bands are used in 5G networks will depend on where the use case is being deployed and the volumes of connections to be supported.

5G mmWave frequency ranges defined by 3GPP

As indicated above, pre-5G mobile networks have generally used spectrum bands from around 600MHz to 3.5GHz. However, 5G can additionally make use of higher bands, in the mmWave range (i.e. above 24GHz).

To date, five mmWave bands have been included in 3GPP[5] specifications for 5G new radio (5G-NR). These are shown in Figure 3.1 below.

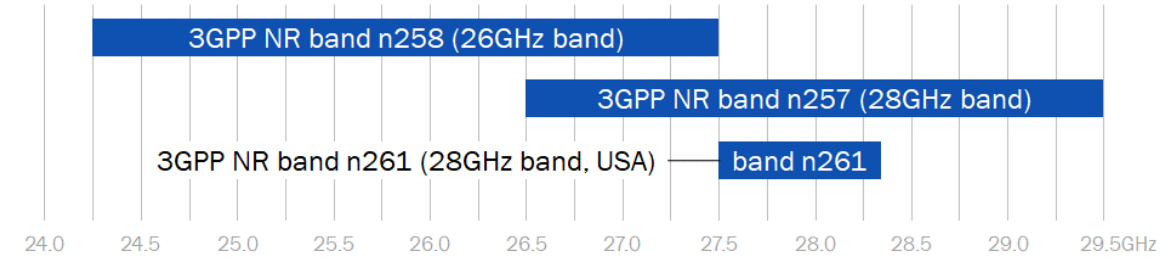
Figure 3.1: mmWave bands included in 3GPP specifications [Source: 3GPP, 2021]

Band	Common name	Range	Geographical area
n257	28GHz	26.50–29.50GHz	Global
n258	26GHz	24.25–27.50GHz	Global
n259	41GHz	39.50–43.50GHz	Global
n260	39GHz	37.00–40.00GHz	Global
n261	28GHz	27.50–28.35GHz	North America

Additional mmWave bands are expected to be included in further 3GPP releases.

The most significant mmWave bands, in terms of initial 5G mmWave deployments worldwide, are band n258 ('26GHz band') and bands n257/n261 ('28GHz band'). These are shown in Figure 3.2 below.

Figure 3.2: 3GPP bands n257, n258 and n261 [Source: 3GPP, 2021]



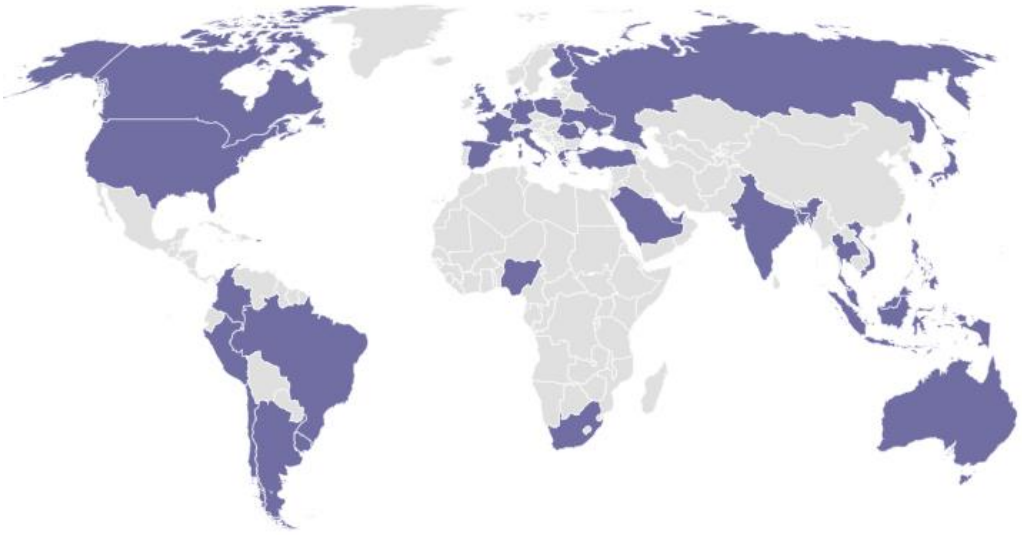
5 The Third Generation Partnership Project (3GPP) unites various regional industry-based telecoms standard development organisations from around the world and, based on members' contributions, produces the reports and specifications that define the 3GPP family of mobile network technologies (which now includes GSM, UMTS, LTE, and 5G). See http://www.3gpp.org/about-3gpp

In Europe, the 26GHz band is the primary band being used for 5G mmWave deployment. In 2016, the Radio Spectrum Policy Group (RSPG) – a high-level advisory group that assists the EC in the development of radio spectrum policy – identified the 24.25–27.5GHz range as one of the 'pioneer' bands for 5G. The band was later harmonised worldwide for international mobile telecommunications (IMT) at the World Radiocommunication Conference 2019 (WRC-19), and the EC has passed legislation requiring Member States to make spectrum within the band available for 5G.

Commercial deployment of to date

According to GSA,[6] as of March 2021, 150 operators in 45 different countries worldwide were investing in 5G deployment in the 26GHz or 28GHz bands (in the form of trials, licences, deployments or operational networks).[7] These countries are shown in Figure 3.3 below.

Figure 3.3: Countries with operators investing in 5G deployment in the 26/28GHz bands (i.e. n257, n258 or n261 bands) [Source: GSA, April 2021. Powered by Bing © Australian Bureau of Statistics, GeoNames, Microsoft, Navinfo, TomTom, Wikipedia]



A considerable number of countries are in the early stages of investing in 5G 26GHz/28GHz (e.g. planning/trialling technologies) and a growing number of commercial networks have been launched or are planned to be launched to date.

The first commercial 5G mmWave networks were launched in the 28GHz band in the USA in 2018 and 2019; MNOs in other countries (such as Japan and South Korea) have now also launched commercial 5G mmWave services in the 28GHz band. However, as discussed in later sections,

6 The Global mobile Suppliers Association.

7 GSA's GAMBoD (GSA Analyser for Mobile Broadband Data) Mobile Broadband Networks, Technologies and Spectrum (NTS) tool.

whilst many European regulators have completed 5G awards for 700MHz and 3.5GHz spectrum, fewer licensing processes have been concluded for 5G use in the 26GHz band, with seven European countries[8] to date having made spectrum available.

Further European countries are expected to award 26GHz spectrum in the short term. It is expected that 40% of European countries[9] will make available part or all of the 26GHz band by the end of 2021 (see Section 3.2 for details).

In addition to releasing spectrum, several governments are putting policies in place to encourage 5G deployment, such as streamlining of infrastructure deployment regulations and tax incentives.[10] Direct funding is also being made available. For example, in Singapore, the national regulatory authority (NRA) recently announced a programme of grants for solution providers and technology developers commercialising 5G solutions.[11]

Device ecosystem

The number of commercial and pre-commercial 5G devices compatible with at least one mmWave band is shown in Figure 3.4 below.[12] The figure also splits out the number of devices compatible with NR band n258 (26GHz) and with NR bands n257/n261 (28GHz).

8 European countries are defined here as the EU27, Norway, Switzerland and the UK.

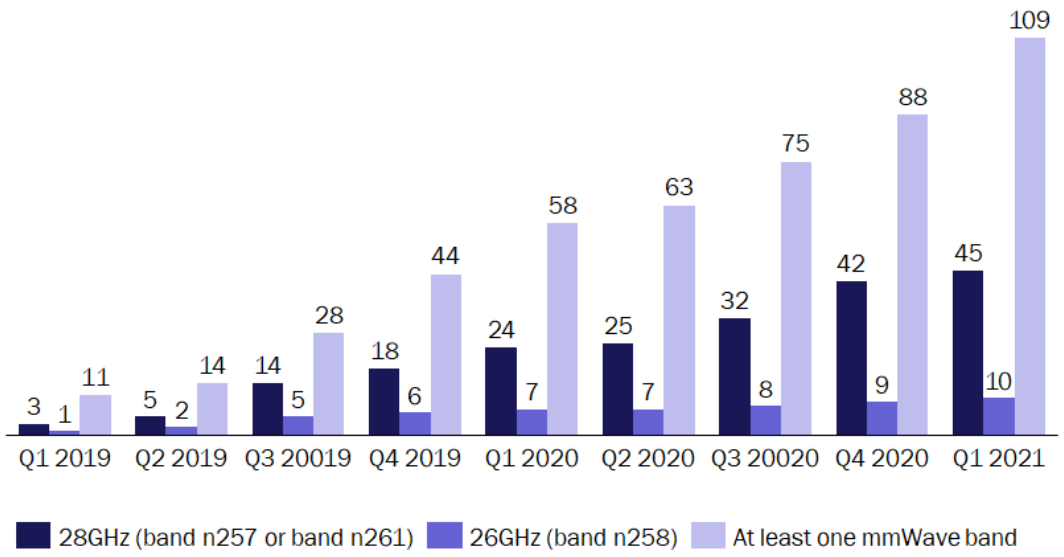
9 European countries are defined here as the EU27, Norway, Switzerland and the UK.

10 For example, mobile network operators in Japan can qualify for 5G tax breaks. See Section 3.3.2.

11 See https://www.imda.gov.sg/programme-listing/5G-Innovation/5G-Grant

12 As of the March 2021 update, the GAMBoD database includes mmWave devices compatible with bands n257, n258, n260 and n261, as well as a single device which is compatible (only) with the 66–71GHz band.

Figure 3.4: Number of 5G-compatible devices in the 26GHz and 28GHz bands [Source: GSA GAMBoD[13] database, March 2021]



As can be seen, the device ecosystem for the 26/28GHz bands is at a relatively early stage of development, but is growing quickly. With the earliest commercial 5G mmWave networks having been launched in the last few years and with further launches anticipated, it is expected that device availability will continue to accelerate rapidly.

Figure 3.4 also shows that the 28GHz device ecosystem is currently more mature than the 26GHz device ecosystem, with over four times as many compatible devices; this reflects the earlier assignment of mmWave spectrum and deployment of networks in the 28GHz band outside Europe (as described above). However, this may change as further European markets proceed with 26GHz licensing during 2021. The upper 1GHz of the 26GHz band (i.e. 26.5–27.5GHz) already has a well-developed ecosystem, since this range overlaps with the bottom 1GHz of the 28GHz band (see Figure 3.2 above).

As an increasing number of spectrum assignments are made, networks are deployed and demand increases, the device ecosystem is expected to grow accordingly. We understand that the ecosystem of network equipment and device chipset providers is ready to support 26GHz solutions as and when demand emerges.

Characteristics of 26GHz spectrum and potential use cases

Larger contiguous bandwidths (relative to the bandwidths available in traditional mobile bands) are available in mmWave spectrum, allowing ultra-high speeds to be achieved. This additional bandwidth can be beneficial to deliver truly differentiated 5G services where use cases rely on very high uplink and downlink capacity. The larger bandwidth available in mmWave spectrum

13 GAMBoD (GSA Analyser for Mobile Broadband Data).

potentially enables larger contiguous blocks to be used by MNOs.[14] As described later in this section, MNO 5G trials in the 26GHz band have used large contiguous blocks of spectrum such as 400MHz to achieve speeds of several Gbit/s. Indeed, we understand that a number of networks are now operating commercially using contiguous blocks of 800MHz.

However, the higher frequency of mmWave spectrum means that the signal propagates over shorter distances, and does not penetrate obstacles or building walls as well as lower-frequency bands. The achievable cell radius is therefore limited (e.g. typically to as little as a few hundred metres in some scenarios/architectures). However, various technologies (such as beamforming and beam management systems) have been developed and are already commercialised to improve the range of mmWave. Indeed, a recent 26GHz trial conducted by Ericsson and Qualcomm achieved speeds of 1Gbit/s over a distance of 6.5km (see Section 3).

The short propagation distances can also be exploited to maximise capacity within mobile networks (since frequencies can be re-used more intensively without co-channel interference occurring) as well as to allow for more flexibility to adapt the time division duplex (TDD) frame structure. The limited penetration of mmWave signals into buildings from sites deployed outdoors also potentially enables more intensive re-use of spectrum, with possibilities of the same spectrum as used in an outdoor site to be re-deployed using an indoor base station, without interference.

While higher-frequency spectrum limits cell radius, the wavelength is shorter meaning that higher capacity cells can be provisioned. The physical size of the antenna (or antenna array) can be optimised so that 26GHz radio equipment can provide high performance and can be installed at existing mobile sites, for operators to scale their deployment to match market demand.

The very high capacity achievable with 26GHz equipment is most efficiently deployed using sufficiently large blocks of 26GHz spectrum, which, combined with the very low latency that can be achieved (e.g. a few milliseconds), allows very high capacity to be delivered where needed.

The ITU-R[15] has defined three broad categories of 5G use case:[16]

- Enhanced mobile broadband (eMBB) – an evolution of existing 3G and 4G consumer MBB services, to provide significantly higher throughput, capacity and performance.
- Massive machine type communication (mMTC) – embraces the Internet of Things to deliver services in a world where a vast number of devices, things and objects are connected by 5G networks.
- Ultra-reliable low-latency communications (uRLLC) – this refers to the capabilities of 5G enabling extremely low latency for applications and services (such as critical infrastructure and

14 3GPP NR bands n257/n261 and n258 define channel bandwidths of up to 400MHz. Larger channel bandwidths per network are achievable by means of carrier aggregation (CA).

15 International Telecommunication Union Radiocommunication Sector (ITU-R)

16 See, for example, https://www.itu.int/en/ITU-D/Documents/ITU_5G_REPORT-2018.pdf

emergency services), with the possibility of 5G technology achieving latency of no more than a few milliseconds for the connections between devices and application servers.

The characteristics of 26GHz spectrum as described above make it suitable for a large number of specific use cases across these three broad categories. These include eMBB, FWA, connected vehicles, venue-specific coverage (e.g. stadiums, concert halls, transportation hubs and event premises) and industrial applications.

3.2 Status of award of 26GHz band for 5G in Europe

Harmonisation of 26GHz for 5G

Historically, the 26GHz band in Europe has been used for fixed-wireless links.[17] The level of use of the 26GHz band for fixed-wireless links varies by country – some countries have very few links, other countries only have fixed links in areas that may be complementary to potential areas for 5G mmWave deployment, while others have a larger proportion of fixed links located in areas that might also be attractive for deployment of 5G mmWave services. As such, the challenge of making the band available for 5G services varies by country, and the European Conference of Postal and Telecommunications Administrations (CEPT) has also developed guidelines for the coexistence of 26GHz fixed links and 5G services.[18]

In 2016, the RSPG identified the 24.25–27.5GHz range as one of the 'pioneer' bands for 5G. The band has since been harmonised worldwide for IMT, and the EC has passed legislation requiring Member States to make spectrum within the band available for 5G. A timeline of the key decisions, publications and legislation related to making the 26GHz band available for 5G in Europe is summarised below:

- In September 2016, the EC launched[19] its '5GAP' to boost EU efforts for the deployment of 5G infrastructure and services across the Digital Single Market by 2020.
- In accordance with the action plan, in November 2016 the RSPG issued[20] its first 'Opinion on 5G', which identified the following three main 'pioneer' 5G bands: 700MHz, 3400–3800MHz and 24.25–27.5GHz (26GHz).

17 The 26GHz band has been allocated by the ITU to fixed services (FS) in Europe. Fixed wireless links are a specific subset of FS applications, namely fixed links – both point-to-point (P2P) and point-to-multipoint (PMP) – and FWA networks.

18 See https://docdb.cept.org/download/09bce05a-999a/ECC%20Report%20303.pdf

19 See https://ec.europa.eu/digital-single-market/en/5g-europe-action-plan

20 RSPG16-032 FINAL. See http://rspg-spectrum.eu/wp-content/uploads/2013/05/RPSG16-032-Opinion_5G.pdf

- In January 2018, the RSPG published its second Opinion on 5G[21] and recommended that an individual licence regime should be the focus for the 24.25–27.5GHz band (while not excluding the possibility of a general authorisation regime under sharing conditions). The RSPG further recommended that Member States should make a "sufficiently large portion (e.g. 1GHz)" of the band available in response to market demand by 2020.

- In January 2019, the RSPG published its third Opinion on 5G, however the recommendations made were not specific to 26GHz.[22]

- In December 2018, the EC adopted a new European Electronic Communications Code (the 'Code', or EECC),[23] to be transposed into the national law of each Member State by the end of 2020. In accordance with the RSPG's recommendation, Article 54 of the EECC states that:

> *1. By 31 December 2020, for terrestrial systems capable of providing wireless broadband services, Member States shall, where necessary in order to facilitate the roll-out of 5G, take all appropriate measures to:*
>
> *(a) reorganise and allow the use of sufficiently large blocks of the 3.4–3.8 GHz band;*
> *(b) allow the use of at least 1 GHz of the 24.25–27.5 GHz band, provided that there is clear evidence of market demand and of the absence of significant constraints for migration of existing users or band clearance.*
>
> *2. Member States may, however, extend the deadline laid down in paragraph 1 of this Article, where justified, in accordance with Article 45(3) or Article 53(2), (3) or (4).*

- In May 2019, the EC adopted Implementing Decision (EU) 2019/784 to harmonise the 24.25–27.5GHz band.[24] Following the Decision, the EC commented that Member states could now "set common technical conditions and subsequently allow the use of the 26GHz band for 5G systems by 31 December 2020 in line with the EECC".[25]

- In November 2019, WRC-19 identified the 24.25–27.5GHz band for IMT on a global basis.[26]

21 See https://circabc.europa.eu/sd/a/fe1a3338-b751-43e3-9ed8-a5632f051d1f/RSPG18-005final-2nd_opinion_on_5G.pdf

22 See https://rspg-spectrum.eu/wp-content/uploads/2013/05/RSPG19-007final-3rd_opinion_on_5G.pdf

23 See https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1547633333762&uri=CELEX:32018L1972

24 See https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32019D0784

25 See https://ec.europa.eu/digital-single-market/en/news/european-commission-harmonise-last-pioneer-frequency-band-needed-5g-deployment

26 See https://www.itu.int/en/ITU-R/conferences/wrc/2019/Pages/default.aspx

- In April 2020, Implementing Decision (EU) 2019/784 was amended by Implementing Decision (EU) 2020/590.[27]
- In September 2020, the EC published a recommendation "calling Member States to boost investment in very high-capacity broadband connectivity infrastructure, including 5G, which is the most fundamental block of the digital transformation and an essential pillar of the recovery".[28]

Current status of 26GHz award for 5G in European countries

While EC legislation required Member States to make at least 1GHz in the 26GHz band available for 5G by the end of 2020, only a small number of Member States met this deadline. However, several European countries are expected to award 26GHz spectrum for 5G later in 2021, including Spain, Sweden, Croatia, Estonia and Malta.

A summary of the status of 26GHz award in thirty European countries (EU27, Norway, Switzerland and the UK), as of March 2021, is given in Figure 3.5 and Figure 3.6 below. Further details for each country are provided in Annex A.

Figure 3.5: Map showing status of 26GHz award for 5G deployment in Europe [Source: NRAs, 2021]

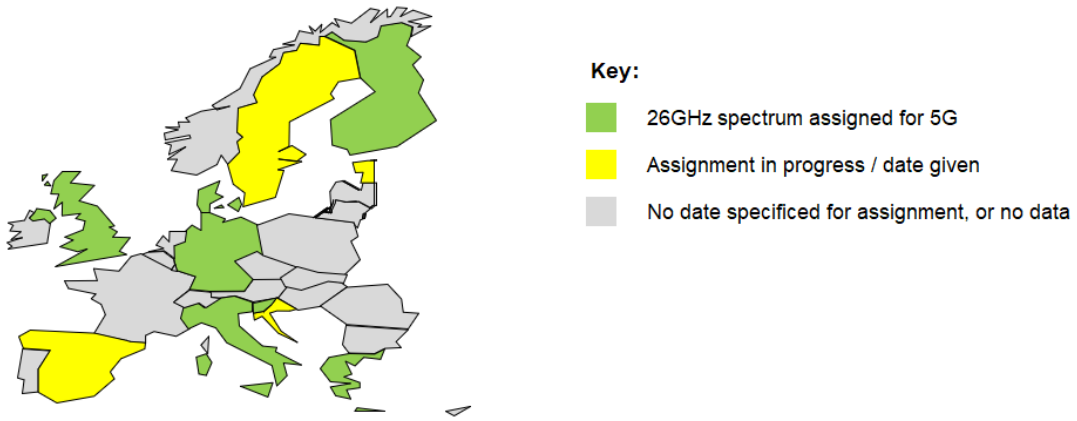


Figure 3.6: Status of 26GHz award for 5G deployment in Europe [Source: NRAs, RSPG, 2021 – see Annex A for further details]

Country	Status of 26GHz award for 5G
Austria	Consultation completed in August 2019: regulator RTR intends to assign the 24.25–27.5GHz band for 5G with award likely in 2022.

27 See https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32020D0590. The original Decision had required Member States to designate and make available (on a non-exclusive basis) the 24.25–27.5GHz band by the end of March 2020, and to report to the EC on the implementation of the Decision by the end of June 2020. In the amended Decision, these dates were pushed back to the end of June 2020 and the end of September 2020 respectively.

28 See https://ec.europa.eu/digital-single-market/en/news/commission-recommendation-common-union-toolbox-reducing-cost-deploying-very-high-capacity

Country	Status of 26GHz award for 5G
Belgium	Consultation completed 2019: 1.2GHz is available for potential 5G use, but no timeframe has been announced.
Bulgaria	Regulator CRC plans to issue a consultation on demand for the 26GHz band by the end of 2022.
Croatia	Regulator HAKOM plans to auction the 26.5–27.5GHz range on a nationwide basis. A consultation on the auction rules was launched in April 2021; the auction is scheduled to take place in July 2021.
Cyprus	No plans for auction as consultation revealed "no clear market demand".
Czech Republic	Consultation completed in September 2020: regulator CTU proposes to make 1GHz available, but no timeframe has been announced.
Denmark	Auction completed in April 2021. The 24.65–27.5GHz range was auctioned on a nationwide basis, with licences valid until the end of 2041. The 24.25–24.65GHz range will be allocated for private networks. See Section 3.3.1 for further details.
Estonia	Consultation on planning the use of 24.25–27.5GHz completed in December 2019. Award expected by the end of 2021.
Finland	Auction completed in June 2020. The 25.1–27.5GHz range was auctioned on a nationwide basis, with licences valid until the end of 2033. The lower part of the band (24.25–25.1GHz) has been reserved for local use, and has yet to be awarded. See Section 3.3.1 for further details.
France	Three-year local trial licences awarded in October 2019 in the 26.5–27.5GHz band. Assignment timeline for commercial licences yet to be announced.
Germany	Regulator BNetzA made the entire 24.25–27.5GHz band available for local licences from 1 January 2021. See Section 3.3.1 for further details.
Greece	The 26.5–27.5GHz range was auctioned on a nationwide basis in December 2020, with licences valid for 15 years. See Section 3.3.1 for further details.
Hungary	Consultation in July 2019 revealed limited current market demand. In December 2019, regulator NMHH published a document seeking input on a variety of award options, but no further announcements have been made.
Ireland	In January 2021, regulator ComReg published a study on the 26GHz band, and opened a consultation on the study's recommendations. The recommendations include: (1) 26.5–27.5GHz should be awarded on a local-licensing basis, either on a frequency/area basis or using an individual small-cell approach. Timing for award could be from 2023 to 2027, depending on type of award used. (2) 24.25–24.5GHz should be made available using a light-licensing approach; award could be from 2022 to 2023, subject to demand.
Italy	Italy auctioned 1GHz of 26GHz spectrum (26.5–27.5GHz) in October 2018. Spectrum is available under a "club use" model. See Section 3.3.1 for further details.
Latvia	We are not aware of any announcements recent concerning the 26GHz band from the NRA. A document published by the RSPG in February 2021 states that an assignment is expected before 2024, subject to results of consultation.
Lithuania	Consultation completed in January 2020. In November 2020, regulator RRT stated that 26GHz spectrum would be awarded when there is clear market demand.
Luxembourg	Consultation completed in December 2020 (and results announced in March 2021). Operators stated that they do not have immediate need for the spectrum. As a consequence, licences will not be assigned until 'a later date'.
Malta	In April 2021, regulator MCA issued a decision on award of the 26GHz band. Six 200MHz lots within the 24.25–27.5GHz range will be made available (with a cap of

Country	Status of 26GHz award for 5G
	400MHz of contiguous spectrum per licensee); the remaining spectrum within the band will be reserved for future use. An award is expected before the end of 2021.
Netherlands	Consultation completed in March 2020: the Ministry intends to release the 26GHz band for mobile "in the coming years".
Norway	As of December 2020, regulator Nkom's website states that demand for the 26GHz band in Norway "has so far been low and Nkom has therefore chosen to wait to allocate the band".
Poland	Consultation completed in September 2020: MNOs stated at the time that they did not see a need for 26GHz spectrum before 2022/23 (further consultation has not yet been announced).
Portugal	Consultation concluded in July 2018 and showed MNOs were interested; however, 26GHz was not on offer in the following auction. Despite speculation about another consultation or auction, the NRA has not yet made any announcements.
Romania	In 2018, regulator ANCOM stated that it planned to release at least the upper 1GHz portion of the 26GHz band by 2021; however, to date no award has been scheduled. ANCOM's 2021 action plan states that it will publish a consultation to help decide on timings for award of spectrum above 24GHz.
Slovakia	In June 2017, regulator RU stated that it is likely that the upper 1GHz of the 26GHz band will be made available for 5G services but no details have since been provided.
Slovenia	The 26.5–27.5GHz range was auctioned on a nationwide basis in April 2021, with licences valid for 15 years. See Section 3.3.1 for further details.
Spain	In December 2020, the Spanish government detailed a plan to allocate 26GHz frequency by the end of 2021.
Sweden	In May 2021, regulator PTS opened a consultation on awarding local 5G licences in the 24.25–25.1GHz range; PTS plans to begin awarding licences later in 2021.
Switzerland	Switzerland has not announced any plans regarding 26GHz.
UK	In July 2019, Ofcom announced that the 24.25–26.5GHz range would be made available (by the end of the year) for 5G through local licences for indoor-only use. See Section 3.3.1 for further details. Ofcom also stated that it would "continue to work with the Ministry of Defence in the 26.5–27.5GHz [range]… so that this band can also be made available in the future". Ofcom's plan of work for 2021/22 (published in March 2021) states that it intends to issue a consultation about the award of spectrum in the 26GHz band in Q3 2021/22.

Current status of 26/28GHz award for 5G in non-European countries

We also note that several non-European countries have now awarded spectrum in the 26/28GHz bands for 5G. A selection of these are summarised in the table below.

Figure 3.7: Status of 26GHz award for 5G deployment in non-European countries [Source: NRAs, 2021 – see Annex A for further details]

Country	Status of 26GHz award for 5G
Australia	Regulator ACMA completed a regional auction of spectrum licences in the 25.1–27.5GHz range in April 2021. Licences are valid for 15 years.[29] Separately, the ACMA has developed 'area-wide apparatus licences' (AWLs) for the 24.7–25.1GHz and 27.5–29.5GHz bands. These are a new type of licence (suitable for 5G), issued on an administrative basis that can cover a wide area and are available upon request to meet the specific requirements of users.[30]
Chile	In February 2021, Chile assigned three MNOs 400MHz each in the 25.9–27.5GHz band for nationwide 5G use. Since demand did not exceed supply in the band, the spectrum was assigned without an auction at zero cost.[31]
Japan	The 27.0–28.2GHz and 29.1–29.5GHz ranges have been assigned for exclusive nationwide 5G use. The 28.2–29.1GHz range has been made available for local 5G licences. See Section 3.3.2 for further details.
Hong Kong	The CA has set aside 4.1GHz of spectrum across the 26/28GHz bands for the provision of wireless broadband services: 3.7GHz (24.25–27.95GHz) for exclusive nationwide licences and 400MHz (27.95–28.35GHz) for local licences. In March 2019, 1.2GHz (26.55–27.75GHz) of the available 3.7GHz spectrum was (administratively) assigned.[32] In July 2019, the CA opened applications for local licences (to be assigned on a first-come, first-served basis).[33]
Russia	In March 2020, regulator SCRF made the 24.25–24.65GHz range available for 5G use. In July 2020, MNO MTS received the country's first licence for commercial 5G operations (in the full 24.25–24.65GHz range and covering 83 regions of Russia). See Section 3.3.2 for further details.
Singapore	Each of the country's four MNOs was assigned 800MHz of mmWave spectrum in the 26.3–29.5GHz range in a beauty contest. See Section 3.3.2 for further details.
South Korea	An auction of the 26.5–28.9GHz range (a total of 2.4GHz) was completed in June 2018. Each of the three South Korean MNOs (SKT, KT and LGU+) won 800MHz of spectrum. Licences last five years and are nationwide. Regulator MSIT also has plans to release further mmWave spectrum. See Section 3.3.2 for further details.
Taiwan	In January 2020, 2.5GHz in the 28GHz band was made available at auction in Taiwan. A total of 1GHz (28.5–29.5GHz) was sold; licences are nationwide and last 20 years.[34]
Thailand	In February 2021, an auction of the 24.3–27.0GHz range was concluded in Thailand. Twenty-seven blocks of 100MHz each were made available, and 26 were sold. Licences are nationwide and last 15 years.[35]

29 See https://www.acma.gov.au/auction-summary-26-ghz-band-2021

30 See https://www.acma.gov.au/area-wide-apparatus-licensing-26-and-28-ghz-bands

31 See https://www.subtel.gob.cl/concursos5g/

32 See https://www.ofca.gov.hk/en/media_focus/press_releases/index_id_1891.html. Note: the CA are planning to make the 2.5GHz of spectrum that remained unassigned in March 2019 available in a second round of administrative assignment (to take place in the first half of 2021 at the earliest). See https://en.arcep.fr/news/press-releases/p/n/5g-6.html

33 See https://www.ofca.gov.hk/en/media_focus/press_releases/index_id_1953.html

34 See https://www.ncc.gov.tw/english/news_detail.aspx?site_content_sn=360&sn_f=5056

35 See https://spectrumauction.nbtc.go.th/News/%E0%B8%87%E0%B8%B2%E0%B8%99%E0%B8%9B%E0%B8%

Country	Status of 26GHz award for 5G
UAE	In September 2020, regulator TRA awarded UAE's two MNOs 500MHz each in the 26.5–27.5GHz range. A further 500MHz will be awarded to each operator from Q3 2021, extending the assigned range to 25.5–27.5GHz.[36]
USA	Regulator FCC has made several mmWave bands available on a licensed basis: 28GHz (27.5–28.35GHz), 24GHz (24.25–24.45GHz, 24.75–25.25GHz), upper 37GHz (37.6–38.6GHz), 39GHz (38.6–40.0GHz), and 47GHz (47.2–48.2GHz) bands. See Section 3.3.2 for further details.

Several other non-European markets have made spectrum in the 26/28GHz bands available for test licences, are consulting on assignment, or are expected to assign spectrum shortly (e.g. an auction is expected to take place in Brazil later in 2021).

3.3 Progress of mmWave deployment in specific markets

This section provides further details of markets where 26GHz spectrum (or 28GHz spectrum in some countries outside of Europe) has already been made available for 5G. We provide additional details of the award process itself, as well as the level of deployment of the spectrum to date and/or plans and trials announced by operators. Section 3.3.1 provides European examples, while Section 3.3.2 provides a selection of non-European examples.

3.3.1 European MNOs

As described in Section 3.2, there are currently seven countries within Europe (i.e. EU27, Norway, Switzerland and the UK) that have made spectrum in the 26GHz band available for 5G: Denmark, Germany, Greece, Finland, Italy, Slovenia and the UK. These countries are discussed in turn below.

Denmark

The Danish Energy Agency (DEA) auctioned the 24.65–27.5GHz range (a total of 2.85GHz) in April 2020 alongside spectrum in several other bands. Lots of 200/250MHz were made available (with a cap of 1650MHz per bidder) at a reserve price of EUR5 million per lot using a combinatorial multi-round auction (CMRA). Licences are for exclusive nationwide use and expire on 31 January 2042. Each of Denmark's main MNOs won spectrum: Hi3G won 1000MHz, TDC won 1250MHz and TT-N (the joint venture between Telia and Telenor) won 600MHz. The 24.25–24.65GHz range will be allocated for private networks.

Finland

The Finnish Transport and Communications Agency (Traficom) auctioned the 25.1–27.5GHz range (a total of 2.4GHz) in June 2020. Three 800MHz lots were made available (with a cap of one lot per

A3%E0%B8%B0%E0%B8%8A%E0%B8%B2%E0%B8%AA%E0%B8%B1%E0%B8%A1%E0%B8%9E%E0%B8%B1%E0%B8%99%E0%B8%98%E0%B9%8C/129.aspx

36 See https://www.tra.gov.ae/ar/media-hub/press-releases/2020/9/15/tra-allocates-new-frequencies-for-5g-networks.aspx

bidder) at a reserve price of EUR7 million per lot using a simultaneous multi-round auction (SMRA). Licences are for exclusive nationwide use (excluding the Aland islands) and expire at the end of 2033. Finland's three MNOs (Elisa, Telia and DNA) each won 800MHz, paying the reserve price.

The lower part of the 26GHz band (i.e. 24.25–25.1GHz) has been reserved for local use and has yet to be awarded. The Ministry of Communications issued a consultation on making the 24.25–25.1GHz band available for local use in February 2021.

Trials – Finland

- In April 2021, it was reported that Telia had achieved downlink speeds of 4.1Gbit/s and uplink speeds of 200Mbit/s (with a latency of below 10ms) using a 5G base station in Helsinki operating in the 26GHz band.[37]
- In November 2020, Elisa, Qualcomm and Nokia announced that they had achieved speeds of 8Gbit/s over Elisa's commercial 5G network in Finland using 26GHz spectrum.[38,39] The announcement stated that the 26GHz technology would "support a range of new low-latency, high-bandwidth services, such as high-speed video downloads, mission-critical or virtual reality (VR) and augmented reality (AR) applications" for mobile broadband, as well as enable enhanced capacity for FWA.[40] The announcement further stated that "services are expected to be implemented in 2021".
- In December 2019, Nokia and Telia reported achieving 5G speeds of 2Gbit/s on Telia's live network in Helsinki using mmWave spectrum.[41] The trial (which took place before the 26GHz auction) used test spectrum.

Germany

BNetzA made the entire 24.25–27.5GHz band available for local licences from 1 January 2021. Licences are technology and service neutral and expire on 31 December 2040; block sizes of 50MHz, 100MHz, 150MHz, 200MHz and multiples of 200MHz (with no limit on the number of

37 See https://www.telecompaper.com/news/telia-finland-exceeds-4-gbps-download-speed-on-5g-in-eastern-helsinki-using-26-ghz-band--1379602

38 See https://www.qualcomm.com/news/releases/2020/11/17/nokia-elisa-and-qualcomm-achieve-5g-speed-record-finland

39 "The base station utilized two Nokia AirScale radios, each using 800 MHz of commercial millimeter wave 5G spectrum at 26 GHz. These provided connectivity to two 5G smartphone form factor test devices powered by a Qualcomm® Snapdragon™ X55 5G Modem-RF System featuring second-generation Qualcomm® QTM525 mmWave antenna modules, with each device reaching 4 Gbps peak speeds from the base station".

40 We note that Elisa has conducted several 5G trials covering a range of other use cases, for example: Covid-19 robot, remote-controlled tractor, smart multi-vendor track and trace system and drones for environmental management work. See Elisa press releases. However, we are not aware of the spectrum used for these 5G trials.

41 See https://www.nokia.com/about-us/news/releases/2019/12/05/nokia-and-telia-finland-fire-up-new-innovation-hub-offering-blistering-5g-speeds-to-spark-creativity/

multiples) are available.[42] A "use it or lose it" clause allows BNetzA to revoke licences where they are not used within one year of assignment. Licences are assigned on an administrative first-come-first-served basis, with applications being subject to co-ordination and approval by BNetzA. There is no limit to the geographical area which can be applied for. Licence fees are determined according to the following formula:

Licence fee = EUR1000 + B * t * 0.63 * ($6a_1 + a_2$)

where:

- B = bandwidth (in MHz) ;
- t = licence duration (in years) ;
- a_1 is the urban area (in km^2) covered by the licence, and a_2 is the rural area (in km^2) covered by the licence.[43]

Licences assigned by BNetzA are confidential, unless the licensee gives its consent to be publicly listed. In May 2021, BNetzA reported that five licences had been assigned; a single licensee (TU Dortmund University) had consented to being publicly listed.[44]

Trials – Germany

- Between December 2018 and February 2019, Telefónica and Samsung conducted 5G FWA trials in Hamburg using the 26GHz band, achieving speeds of up to 1Gbit/s.[45, 46]

Greece

In December 2020, Greece auctioned the 26.5–27.5GHz range (a total of 1GHz). Five 200MHz lots were made available (with a cap of two lots per bidder) at a reserve price of EUR3.2 million per lot using an SMRA. Licences are for exclusive nationwide use and have a duration of 15 years. Each

42 Justification must be provided for the bandwidth request. We understand that, given current device capability, BNetzA will not grant applications for more than 800MHz.

43 For details, see https://www.bundesnetzagentur.de/DE/Sachgebiete/Telekommunikation/Unternehmen_Institutionen/Frequenzen/OeffentlicheNetze/LokaleNetze/lokalenetze-node.html

44 See https://www.bundesnetzagentur.de/SharedDocs/Downloads/DE/Sachgebiete/Telekommunikation/Unternehmen_Institutionen/Frequenzen/OffentlicheNetze/LokaleNetze/Zuteilungsinhaber26GHz.pdf;jsessionid=41E45A68268729DC9AE114FFDA89C1F2?__blob=publicationFile&v=2

45 See https://news.samsung.com/global/telefonica-deutschland-and-samsung-test-5g-fixed-wireless-access-in-germany

46 See https://www.telefonica.de/news/press-releases-telefonica-germany/2019/02/conclusion-of-three-month-pilot-in-hamburg-5g-fixed-wireless-access-from-telefonica-deutschland-and-samsung-proves-successful.html

of the country's MNOs won spectrum at the reserve price (Cosmote and Vodafone each won 400MHz, while Wind won 200MHz), raising a total of EUR16.2 million.[47]

Italy

Italy auctioned 1GHz of 26GHz spectrum (26.5–27.5GHz) in October 2018. Five 200MHz lots were made available (with a cap of two lots per bidder) at a reserve price of EUR32.6 million per lot using an SMRA. Five operators (Fastweb, Telecom Italia (TIM), Iliad, Wind and Vodafone) won 200MHz, paying roughly the reserve price (totalling EUR163 million). Licences are nationwide and last from 1 January 2019 to 31 December 2037 (i.e. 19 years). Licensees must use the awarded spectrum within four years of the start date in all Italian provinces.[48]

A 'club use' model applies to the spectrum.[49] Under this arrangement:

- if spectrum is unused in a particular area, another licensee has the right to use it (but right of first refusal must be offered to the original licensee)
- licensees will decide upon their own rules of coexistence and management; they may elect to use a neutral third party for management purposes
- there is no spectrum cap on "club use" (i.e. licensees can access up to 1GHz in a particular area).

Furthermore, licensees have an obligation to offer wholesale access to other players for the development of 5G services. On private property (such as ports, airports and stadiums), licensee(s) deploying coverage must offer access to other licensee(s).

Trials – Italy

A number of 5G mmWave trials have been conducted by Italian operators, for example:

- In December 2020, TIM, Qualcomm and Ericsson announced that they had conducted a 5G FWA trial using 26GHz, achieving speeds of 1Gbit/s over a distance of 6.5km.[50]
- In September 2020, TIM, Qualcomm and Ericsson announced that they had conducted a 5G trial using 26GHz, achieving speeds of 4Gbit/s on a live 5G network.[51]

47 See https://www.eett.gr/opencms/opencms/admin/News_new/news_1353.html

48 'Use of the awarded spectrum' means: (1) "the activation of the physical carriers of BS/fixed links, connected to an end-to-end transport network", and (2) "the commercial launch of the wireless broadband service (retail or wholesale), also in the form of roaming, MORAN, MOCN, or supply of network slices (normally with prohibition of frequency pooling)". See https://www.itu.int/en/ITU-D/Regional-Presence/Europe/Documents/Events/2018/5G%20Greece/Session%202%20Mauro%20Martino%20New.pdf

49 See https://www.itu.int/en/ITU-D/Regional-Presence/Europe/Documents/Events/2018/5G%20Greece/Session%202%20Mauro%20Martino%20New.pdf

50 See https://www.qualcomm.com/news/releases/2020/12/04/tim-ericsson-and-qualcomm-set-world-record-long-distance-speed-5g-mmwave

51 See https://www.gruppotim.it/en/press-archive/market/2020/CS-TIM-record-5G-4-09-2020.html

- In July 2020, Fastweb, Ericsson and Atac (the public transport company of Rome) announced that they had conducted a connected bus trial using 5G 26GHz spectrum as part of the 'Roma5G' initiative (founded by Fastweb and Ericsson in 2017).[52]

- In January 2020, TIM, Qualcomm and Ericsson announced that they had achieved speeds of over 2Gbit/s on a live 5G commercial network, using 400MHz of spectrum in the 26GHz band (200MHz licensed to TIM, and a further 200MHz via club use).[53] TIM indicated that 26GHz spectrum would be used for a range of 5G use cases, stating that the band was suitable for developing FWA services as well as new Industry 4.0 applications.

► *Commercial services*

Fastweb, originally a fixed ISP and MVNO, plans to deploy 5G FWA coverage using 26GHz spectrum to 12 million homes by 2025. In July 2018, Fastweb acquired 40MHz of 3.5GHz spectrum in a private transaction, and in October 2018 it won 200MHz of 26GHz spectrum in Italy's multi-band auction (see above). In June 2019, it signed a 10-year 5G network sharing agreement with MNO WindTre (which aims to cover 90% of the population by 2025), and in July 2019 it was designated as Italy's fifth MNO. Details of Fastweb's 26GHz deployment are shown in Figure 3.8 below.

Figure 3.8: Details of Fastweb's 26GHz deployment [Source: Fastweb website,[54] 2021]

Category	Details
In use or planned?	Fastweb (in partnership with Linkem) launched commercial 5G FWA services (using 26GHz and 3.5GHz spectrum) in December 2020. Initial commercial launch took place in 50 towns/cities.[55] Roll-out continues – in April 2021, Fastweb announced that 5G FWA services were available in parts of Tuscany.[56]
Use cases	5G FWA (also 5G mobile services and trialling of other use cases – see above).
Service details	Customer premises equipment (CPE) is based on Qualcomm's Snapdragon X55 Modem-RF System. CPE is free and installed by an engineer. Speeds of up to 1Gbit/s downlink and 200Mbit/s uplink, no traffic limits or maximum number of connected devices. Similar price to entry-level high-speed broadband offers.

52 See https://www.sportsgaming.win/2020/07/atac-fastweb-ericsson-here-is-first-5g.html

53 See https://www.gruppotim.it/en/press-archive/corporate/2020/PR-TIM-5G-overcame-the-2-Gbps-speed-a-new-European-record-080120.html

54 See https://www.fastweb.it/corporate/5g/ and press releases. See also https://fsr.eui.eu/wp-content/uploads/2019/12/Tiziana-TALEVI_Fastweb.pdf and Linkem's website.

55 See https://www.fastweb.it/corporate/media/comunicati-stampa/fastweb-sceglie-qualcomm-per-il-lancio-commerciale-del-5g-fixed-wireless-access-in-italia/ and https://www.fastweb.it/corporate/media/comunicati-stampa/fastweb-al-via-il-nexxt-generation-2025/

56 See https://www.fastweb.it/corporate/media/comunicati-stampa/fastweb-in-toscana-arrivano-le-connessioni-a-banda-larga-con-lultra-fixed-wireless-access/

Category	Details
Current coverage/level of deployment	We understand that initial 5G FWA launch took place in 50 municipalities in Italy, with deployment planned for 500 municipalities by the end of 2021 and 2000 by the end of 2024.
Coverage targets	Fastweb plans to deploy 5G FWA (1Gbit/s speeds using 26GHz spectrum) to 12 million homes (c.45% of population) by 2024.[57]

Slovenia

In April 2021, Slovenia auctioned the 26.5–27.5GHz range (a total of 1GHz). Five 200MHz lots were made available (with a cap of four lots per bidder) at a reserve price of EUR250 000 per lot. Licences are for exclusive nationwide use and have a duration of 15 years. Three of the country's four MNOs won spectrum: A1 Slovenia and Telecom Slovenije each won 400MHz, and Telemach won 200MHz.[58]

UK

In July 2019, Ofcom announced that it would make the lower 26GHz band (24.25–26.5GHz) available (by the end of the year) for 5G via low-power local 'Shared Access' licences for indoor-only use.[59] Licences are assigned on an administrative first-come-first-served basis, with applications being subject to co-ordination and approval by Ofcom. Licensees can deploy multiple base stations within a 50m radius under a single licence; terminal stations are also covered by the same licence. An annual licence fee of GBP320 (EUR370) applies, independent of channel size (with channel sizes of 50MHz, 100MHz and 200MHz available). Licences must be used within six months of being assigned, and continue to be operational thereafter. If spectrum is not used within this timeframe or is subsequently no longer used, Ofcom reserves the right to revoke the licence with one month's notice.

As of March 2021, Ofcom's publicly available frequency register does not include any low-power 26GHz licences.

57 In May 2019, Fastweb announced plans to double its high-speed broadband footprint over the next five years from 8 million homes (4 million FTTP and 4 million FTTC) to 16 million. 5G FWA (using the 26GHz band) will be used to cover the additional 8 million homes by 2024, requiring EUR3 billion of investment.

In December 2019, Fastweb announced a partnership with Linkem (an independent FWA player) to accelerate their respective FWA roll-outs. The partnership covered 8 million homes (c.30% of population) in "grey areas" in small and medium cities. In August 2020, Fastweb and Linkem announced an extension to their agreement to cover an additional 4 million homes (not currently covered by high-speed broadband) by 2024. Network deployment will begin in 2021 and be completed within three years.

58 See https://www.akos-rs.si/medijsko-sredisce/sporocila-za-javnost/novica/uspesno-zakljucena-javna-drazba-frekvenc-za-zagotavljanje-javnih-mobilnih-komunikacijskih-storitev. For auction documentation, see https://www.akos-rs.si/medijsko-sredisce/sporocila-za-javnost/novica/javni-razpis-z-javno-drazbo-za-dodelitev-radijskih-frekvenc-za-zagotavljanje-javnih-komunikacijskih-storitev-koncnim-uporabnikom-v-radiofrekvencnih-pasovih-700-mhz-1500-mhz-2100-mhz-2300-mhz-3600-mhz-in-26-ghz and https://www.akos-rs.si/fileadmin/user_upload/Razpisna_dokumentacija_za_vecfrekvencno_drazbo_17122020_koncna.pdf

59 See https://www.ofcom.org.uk/consultations-and-statements/category-1/enabling-opportunities-for-innovation

Trials – UK

- In March 2021, the UK's Minister for Digital Infrastructure announced a new partnership between Qualcomm and the 5G RuralDorset project.[60] The project is partly funded by the Department for Culture, Media and Sport (DCMS) via its 5G Rural Testbed & Trials programme (which provides funding for a range of 5G research projects and trials). The partnership will "explore innovative uses for 5G mmWave spectrum to revolutionise the agricultural sector", with Qualcomm supplying 5G mmWave modules to the project in order to test their efficacy in 5G connected robotic farming.

3.3.2 International examples

The following sections focus on five advanced non-European markets where spectrum in the 26/28GHz bands has already been assigned, and is being deployed by operators: the USA, Japan, Singapore, South Korea and Russia.

USA

In January 2019, the FCC completed an auction of spectrum in the 28GHz band (27.5–28.35GHz) in each county where blocks of spectrum were available for assignment.[61, 62] This was followed by an auction of the 24GHz band (24.25–24.45GHz, 24.75–25.25GHz); spectrum was divided for auction into 'partial economic area' (PEA) licences, and the auction completed in May 2019.[63]

Several other mmWave bands have also been made available in the USA on a licensed basis: the upper 37GHz (37.6–38.6GHz), 39GHz (38.6–40.0GHz), and 47GHz (47.2–48.2GHz) bands.[64] The FCC is also working to make spectrum available for 5G in the 26GHz band (25.25–27.5GHz) and 42GHz band (42.0–42.5GHz).[65]

► *Commercial services*

All three of the large MNOs in the USA hold licences for mmWave spectrum, and have launched commercial 5G services:

60 See https://5gruraldorset.org/2021/03/23/new-qualcomm-and-5g-ruraldorset-relationship/

61 The 28GHz band was not already assigned in 1536 counties (corresponding to roughly 24% of spectrum in the band, on a MHz-per-pop basis). Two 425MHz blocks were auctioned in each of these counties; 2965 of the 3072 licences were sold.

62 Auction 101. See https://www.fcc.gov/auction/101

63 Seven 100MHz blocks were auctioned in each PEA (in the upper 24GHz segment (24.75–25.25GHz), four 100MHz blocks and one 75MHz block were available in one PEA and only four blocks in three other PEAs). 2904 of the 2909 licences were sold. See https://www.fcc.gov/auction/102

64 See https://api.ctia.org/wp-content/uploads/2020/06/Comparison-of-Total-Mobile-Spectrum-in-Different-Markets-Final-Report-290620.pdf

65 See https://www.fcc.gov/5G

- Verizon launched a commercial mmWave 5G FWA service in October 2018,[66] and a commercial mmWave 5G mobile service in April 2019.[67] Services use the 28GHz and 39GHz bands.[68, 69]

  – Verizon's 5G mobile strategy had an initial focus on mmWave, with sub-6GHz spectrum (providing wider coverage) being introduced later (via DSS technology) in October 2020. Verizon refers to its 5G mmWave mobile service as '5G Ultra Wideband' (5G UW). As of March 2021, Verizon's website states that 5G UW coverage is available in 'parts of dozens of major cities' across the USA; we understand that Verizon achieved its target of deploying 5G UW in 60 cities by the end of 2020.70 The website includes a coverage map identifying locations where mmWave 5G UW has been deployed. In January 2021, Verizon published its Q4 2020 earnings report, indicating that it plans to add more than 14 000 5G UW "sites" in 2021 (taking the total number to over 30 000), as well as expand 5G UW coverage to an additional 20 cities.
  – As of March 2021, Verizon's website indicates that its 5G FWA service ("Verizon 5G Home Internet") is available in parts of over 20 cities (no coverage map is available). The January 2021 earnings report referred to above states that Verizon plans to extend coverage to more than 20 additional cities in 2021. The maximum download speed of the service is 1Gbit/s (with 300Mbit/s typical); unlimited data is offered. We understand that CPE is free and can be self-installed in new cities.

- AT&T launched a commercial mobile 5G service using 39GHz spectrum in (parts of) 12 cities across the USA in December 2018.[71] The 5G mmWave service (referred to by AT&T as '5G+') was initially only available to business customers, but was expanded to non-business customers in March 2020 (alongside the launch of compatible Samsung S20 smartphones).[72] AT&T's '2021 5G Strategy' (announced in March 2021) states that 5G+ nodes have been deployed in parts of 38 cities across the USA to date.[73, 74] The strategy also notes that:

  – AT&T plan to deploy 5G+ in 17 venues across the USA by the end of 2021, including stadiums, arenas and practice venues
  – Following 5G+ deployment at the Dallas Discovery District, AT&T is aiming to deploy 5G+ at more than 30 company-owned retail locations by the end of 2021

66 See https://www.verizon.com/about/news/verizon-turns-worlds-first-5g-network

67 See https://www.verizon.com/about/news/verizon-5g-mobility-service-and-motorola-5g-smartphone-are-here

68 See https://www.verizon.com/about/our-company/5g/what-frequency-5g

69 See https://www.fiercewireless.com/operators/verizon-debuts-all-one-5g-home-cpe

70 See https://www.verizon.com/coverage-map/

71 See http://about.att.com/story/2018/att_brings_5g_service_to_us.html

72 See https://about.att.com/newsroom/2020/5g_announcements.html

73 See https://about.att.com/story/2021/5g_strategy.html

74 See also https://www.att.com/5g/consumer/

  - Having launched 5G+ at Tampa International Airport, AT&T is aiming to deploy 5G+ at an additional seven airports by the end of the year. This will give "customers more seamless experiences when accessing mobile applications and streaming or downloading entertainment with a 5G+ capable device"
  - The strategy also highlights how the lower latency of 5G+ can be used in real-time video gaming.

- T-Mobile used mmWave spectrum (28GHz and 39GHz) for its initial commercial 5G launch in June 2019; services were launched in parts of six cities, and were accessible via the Samsung

Galaxy S10 smartphone.[75] However, T-Mobile has subsequently focused primarily on 5G deployment using low- and mid-frequency spectrum. Nevertheless, T-Mobile states that it "will

75 See https://www.t-mobile.com/news/press/samsung-galaxy-s10-5g

continue building out 5G in mmWave, where it makes sense [to do so], like dense urban areas".[76] We note that T-Mobile has begun to use 5G for its FWA service, though our understanding is that mmWave spectrum is not currently being used.[77]

Japan

The 27.0–28.2GHz and 29.1–29.5GHz ranges were assigned (for nationwide use) in April 2019; each of Japan's four MNOs (NTT Docomo, KDDI, SoftBank and Rakuten) was assigned a 400MHz block. The spectrum was assigned administratively to the MNOs at zero cost in exchange for certain levels of roll-out and investment commitments. Under the terms of the assignment, we understand that NTT Docomo/KDDI/SoftBank/Rakuten have committed to deploying c.5000/12 000/4000/8000 28GHz base stations respectively by 2024.

The 28.2–29.1GHz range has been made available for local 5G licence applications.[78, 79]

Notably, new tax policies implemented in 2020 have played a significant role in accelerating roll-outs and investments in supporting infrastructure and equipment.[80] We understand that the tax policies resulted in each of the MNOs bringing forward their planned investments in sub-6GHz and mmWave infrastructure years ahead of schedule (in order to take advantage of the tax incentive window).

Trials – Japan

Japanese MNOs have conducted a large number 5G 28GHz trials. A selection of recent examples is provided below:

- In December 2020, Rakuten announced that it had used its 5G mmWave network to trial "a new [soccer] match viewing experience".[81]
- In September 2019, NTT Docomo announced that it had conducted a 5G trial using the 28GHz band to communicate between a base station and a high-speed bullet train, achieving speeds of over 1Gbit/s.[82]
- In May 2019, NTT Docomo, AGC and Ericsson announced that they had used an antenna embedded in synthetic fused silica glass to transmit and receive 28GHz 5G mobile signals in buildings, vehicles and trains. Downlink speeds averaging 1.3Gbit/s within a 100m range were achieved (with maximum speeds of 3.8Gbit/s using 400MHz of spectrum).[83]
- In March 2018, KDDI and Samsung announced the successful completion of a 28GHz 5G trial at a baseball stadium in Okinawa. The trial used a virtualised core and RAN to demonstrate live simultaneous streaming of 4K video content downloaded to multiple 5G tablets.[84, 85]

76 See https://www.t-mobile.com/news/_admin/uploads/2020/06/5G-Fact-Sheet-Original-File.pdf. See also T-Mobile's mm-wave deployment at the Super Bowl - https://www.t-mobile.com/news/network/big-game-changing-5g

77 See https://tmo.report/2021/01/5g-modems-begin-shipping-to-new-home-internet-customers/

81 See https://corp.mobile.rakuten.co.jp/english/news/press/2020/1203_01/

82 See https://www.nttdocomo.co.jp/english/info/media_center/pr/2019/0930_00.html

► *Commercial services*

According to the Ministry of Internal Affairs and Communications (MIC)'s public database, as of April 2021, each of Japan's four MNOs had deployed between 1500 and 2600 mmWave base stations.[86]

We understand that all four MNOs in Japan have now launched commercial 5G services using the 28GHz band:

- In September 2020, NTT Docomo launched commercial eMBB 5G services using 28GHz spectrum (see table below for further details).
- In March 2021, SoftBank announced that it had launched commercial 5G services in the 28GHz band, using devices based on Qualcomm technology.[87] Along with the launch, SoftBank is making the "Pocket WiFi 5G A004ZT" 5G mmWave mobile hotspot available for sale.
- KDDI launched commercial 5G services in March 2020. We note that KDDI's first device (a mobile Wi-Fi router) compatible with 5G mmWave was made available in July 2020,[88] and that several 5G mmWave-compatible smartphones are now also available.[89]
- In September 2020, Rakuten launched commercial 5G services.[90] We note that Rakuten has released a number of 5G mmWave-compatible smartphones.[91] Rakuten is using Airspan equipment for its mmWave deployment.[92]

80 See https://www.japantimes.co.jp/news/2020/02/18/business/tech/5g-drone/

81 See https://corp.mobile.rakuten.co.jp/english/news/press/2020/1203_01/

82 See https://www.nttdocomo.co.jp/english/info/media_center/pr/2019/0930_00.html

83 See https://www.nttdocomo.co.jp/english/info/media_center/pr/2019/0529_00.html

84 See https://news.samsung.com/global/kddi-and-samsung-successfully-complete-5g-multi-device-trial-at-a-professional-baseball-stadium-in-okinawa-japan

85 For further 28GHz trials conducted by KDDI and Samsung, see https://news.samsung.com/global/samsung-selected-as-a-5g-network-solution-provider-for-kddi-in-japan

86 See https://www.tele.soumu.go.jp/musen/SearchServlet?pageID=1. As of 27 April 2021, the database records 1920/2369/2570/1577 mm-wave base stations for NTT Docomo/KDDI/Softbank/Rakuten.

87 See https://www.qualcomm.com/news/releases/2021/03/18/softbank-corp-launches-multi-gigabit-5g-mmwave-japan-qualcomm-technologies

88 See https://www.au.com/mobile/product/data/x001/

89 See https://www.au.com/mobile/area/other_speed/?bid=mb-mb-area-0116

90 See https://global.rakuten.com/corp/news/press/2020/0930_02.html

91 See https://network.mobile.rakuten.co.jp/product/smartphone/rakuten-big/ and https://corp.mobile.rakuten.co.jp/english/news/press/2021/0419_02/

92 See https://the-mobile-network.com/2020/10/getting-the-latest-on-rakutens-5g-rollout/

Further details of the status of NTT Docomo's 28GHz[93] 5G service are provided in Figure 3.9 below.

Figure 3.9: NTT Docomo's 28GHz deployment [Source: NTT Docomo, 2021]

Category	Details
In use or planned?	NTT Docomo launched commercial eMBB 5G services using 28GHz spectrum in September 2020.[94]
Use cases	eMBB in dense urban locations. NTT Docomo's website provides a map of locations where mmWave is currently available. Locations are classified into the following categories: (1) stadiums/Olympic facilities, (2) transportation facilities, (3) tourist/commercial facilities, (4) Docomo shops, (5) other indoor locations, and (6) other outdoor locations.
Service details	NTT Docomo's website states that the maximum downlink and uplink speeds using 28GHz spectrum (via compatible devices) is 4.1Gbit/s and 480Mbit/s respectively. The service is available at no additional cost to the normal 5G service.
Current coverage/level of deployment	In its September 2020 announcement, NTT Docomo stated that 5G mmWave was currently available in 66 locations, and that it planned to cover 164 locations by the end of the month. (See NTT Docomo's website for map of locations where mmWave is currently available.)
Coverage targets	NTT Docomo's website also maps further locations where 5G mmWave is planned for deployment within the next five months. We note that NTT Docomo committed to investing c.JPY134billion (c.EUR1.0billion) over the period 2019–2024 when it was assigned its 400MHz mmWave licence (and, as mentioned above, it is committed to deploying c.5000 5G 28GHz base stations).

93 NTT Docomo has also trialled 5G in the 39GHz band – see https://www.nttdocomo.co.jp/english/info/media_center/pr/2018/0522_00.html. However, we are not aware to what extent 39GHz has been used in commercial deployments to date.

94 See https://www.nttdocomo.co.jp/info/news_release/2020/09/18_00.html

Singapore

In June 2020, the Infocomm Media Development Authority (IMDA) awarded each of the country's four MNOs (SingTel, StarHub, M1 and TPG) 800MHz of mmWave spectrum in the 26.3–29.5GHz range[95] via a beauty contest.[96] Licences have a duration of 16 years.[97]

► *Commercial services*

In December 2020, Singtel announced that it had launched services using its 28GHz spectrum.[98] The announcement stated that mmWave spectrum "is an ideal frequency to deliver mobile coverage in manufacturing and industrial plants, maritime ports and airports, as well as dense environments such as concert venues and live sporting events". Initial deployment of mmWave is taking place in several locations across the island, including Orchard Road, the Padang area and Marina Bay Sands Expo.

The announcement further states that:

- Customers with 5G plans can expect speeds of up to 3Gbit/s when mmWave-enabled handsets arrive in Singapore in 2021
- Singtel will be launching '5G Experience Zones' across Singapore, which will allow customers with any smartphone to experience Singtel's 5G mmWave speeds for free[99]
- Singtel has achieved 5G speeds of 3.2Gbit/s at its flagship pop-up store 'UNBOXED': "As Singtel's first 5G use case, UNBOXED is an example of how mmWave 5G can enable innovative business solutions and enhance consumer experiences by offering reliable high bandwidth connectivity that supports real-time machine communications, artificial intelligence and smart analytics".

We also note that, in December 2020, Ericsson and Singtel announced that they were "accelerating their 5G partnership in Singapore through the deployment of high-end 5G technology enabled by

95 See https://www.imda.gov.sg/regulations-and-licensing-listing/spectrum-management-and-coordination/spectrum-right-issued

96 3.5GHz was also awarded. StarHub and M1 bid under a joint-venture consortium (JVCo). There was no charge for the mmWave spectrum lots under the Call for Proposal (CFP) process; however, winners had to bid for the final assignment of their respective two 400MHz lots. M1, Singtel and StarHub submitted the winning assignment bids of SGD250 001, SGD750 128 and SGD1 respectively. TPG (which failed to secure any 3.5GHz spectrum) applied for, and was assigned, the remaining two mmWave 400MHz lots at zero cost. mmWave licensees must pay an annual fee of SGD1 232 000 per 800MHz. See https://www.imda.gov.sg/regulations-and-licensing-listing/spectrum-management-and-coordination/spectrum-rights-auctions-and-assignment/5G-CFP-2020 and https://www.imda.gov.sg/regulations-and-licensing-listing/spectrum-management-and-coordination/spectrum-right-issued

97 See https://www.imda.gov.sg/-/media/Imda/Files/Regulation-Licensing-and-Consultations/Consultations/Consultation-Papers/Second-Public-Consultation-on-5G-Mobile-Services-and-Networks/5G-Second-Consultation-Executive-Summary.pdf?la=en

98 See https://www.singtel.com/about-us/media-centre/news-releases/singtel-delivers-its-fastest-5g-speds-with-28-ghz-mwave-deployment

99 See also https://www.singtel.com/about-us/media-centre/news-releases/singtel-launches-unboxed-lite-5g-experience-zones-on-orchard-road0

5G NR Standalone and dual-mode 5G core network products and solutions, including real-time rating and policy control". The network will operate on Singtel's 3.5GHz and 28GHz spectrum and provide both outdoor and indoor coverage; mmWave connectivity will also be deployed in hotspots across Singapore.[100]

We are not aware of details regarding the commercial launch plans for the other MNOs in Singapore.

South Korea

An auction of the 26.5–28.9GHz range (a total of 2.4GHz) was completed in June 2018. Each of the three South Korean MNOs (SKT, KT and LGU+) won 800MHz of spectrum.[101] Licences started on 1 December 2018 and last five years. Licences are national and include a coverage obligation to build a certain number of base stations within a given timeframe. The auction consisted of a principal stage and an assignment stage (clock auction and sealed bid respectively). Spectrum sold at the reserve price in the principal stage; the total price paid across all MNOs was USD560 million (EUR470 million).

In December 2019, the Ministry of Science and ICT (MSIT) confirmed its "5G+ spectrum plan" which aims to "secure the world's largest 5G spectrum supply" by releasing an additional 2640MHz of 5G spectrum by 2026. This includes assigning 2000MHz in mmWave bands (1400MHz by 2021 in bands adjacent to the currently assigned 26.5–28.9GHz range, and a further 600MHz by 2026 in the 24GHz and 37GHz bands).[102]

Trials – South Korea

- In August 2019, SKT and Samsung announced the completion of a 28GHz 5G trial at the 'Korea International Circuit' racetrack. The trial demonstrated a stable 5G connection (and smooth cell-handover) between a device in the race cars and trackside 5G sites, achieving download speeds of up to 1Gbit/s using 200MHz of spectrum.[103]

100 See https://www.ericsson.com/en/press-releases/2020/12/ericsson-and-singtel-drive-high-end-5g-connectivity-to-benefit-singapore

101 See http://www.msit.go.kr/web/msipContents/contentsView.do?cateId=mssw311&artId=1386500

102 See https://www.msit.go.kr/bbs/view.do?sCode=user&mId=113&mPid=112&pageIndex=4&bbsSeqNo=94&nttSeqNo=2360371&searchOpt=ALL&searchTxt=5g

103 See https://news.samsung.com/global/samsung-and-sk-telecom-showcase-real-world-5g-use-case-in-high-speed-motor-racing

► *Commercial services*

In April 2020, news reports stated that MNOs in South Korea were expecting to launch 5G mmWave for business-to-business services (most likely in smart factories) later in 2020.[104] We understand that consumer 5G services using mmWave are not expected to be available until 2021/2022.

- In December 2020, Qualcomm and LG UPlus announced that they had deployed South Korea's first 5G mmWave (28GHz) network compatible with a commercial 5G smartphone.[105] The deployment was on a university campus (the Kumoh National Institute of Technology). The 'smart campus' services are accessible through a commercial LG smartphone (powered by a Qualcomm modem). The announcement states that mmWave deployment in South Korea is expected to ramp up in 2021, and that mmWave technology enables "smart campuses, indoor enterprises, indoor/outdoor venues, transportation hubs, fixed wireless access devices, and the industrial Internet of Things".

- In September 2020, SKT stated that it aimed to commercialise mmWave 5G for business-to-business services by the end of the year.[106] In October 2020, it was reported that SKT had begun testing 28GHz 5G commercial networks, using equipment from several vendors.[107]

Russia

In March 2020, Russia's State Commission on Radio Frequencies (SCRF) made the 24.25–24.65GHz range (a total of 400MHz) available to an indefinite number of users (both telecoms operators and industrial companies) for 5G use.[108]

A large number of players have conducted trials using 26/28GHz spectrum in Russia using trial licences. For example, in March 2020, SCRF awarded a test licence in the 24.65–27.5GHz band to New Digital Solutions (a joint venture between MegaFon and Rostelecom) for trialling 5G capabilities in partnership with state corporation Roscosmos.[109] We understand the test licence lasted for one year and has now expired.[110] A selection of recent 5G mmWave trials conducted in Russia is provided in the box below.

Trials – Russia

- In March 2021, MTS, Ericsson, Motorola and Qualcomm announced that they had achieved 5G download speeds exceeding 4Gbit/s in an indoor trial using 800MHz of spectrum (aggregating eight 100MHz carriers) in the 24.25–27.5GHz band. The trial used a Motorola smartphone with Qualcomm modem.[111]

- In August 2020, Beeline, Nokia and Qualcomm launched a 5G pilot network at a port in St Petersburg using a trial licence in the 26/28GHz band. The network will enable VR/online gaming via the Beeline Gaming cloud service.[112]

- In August 2019, Tele2 and Ericsson launched a 5G pilot zone in central Moscow on Tele2's commercial network. The 5G pilot zone uses the 28GHz band in a non-standalone (NSA) configuration (using the 2600MHz as an LTE anchor). 5G pocket routers are used as end-user devices for mobile broadband services with ultra-high speeds.[113]

► *Commercial services*

In July 2020, MTS announced that it had received the country's first licence for commercial 5G operations in the range made available by the SCRF's decision. The licence is for the full 24.25–24.65GHz range, covers 83 Russian regions and expires in July 2025.[114] In its announcement, MTS stated that it planned to launch a range of 5G-based solutions for corporate customers in the near future, including:

- Manufacturing — machine vision, predictive analytics, and digital twins for remote equipment monitoring and control.
- Agriculture, pulp and paper, and oil and gas — drone-based infrastructure inspection and monitoring.
- Healthcare — remote surgery and patient monitoring.
- Retail — digitised smart stores and biometric payment systems.
- Logistics — automated warehouse operations and autonomous vehicles.

104 See http://www.koreaherald.com/view.php?ud=20200420000849

105 See https://www.qualcomm.com/news/releases/2020/12/07/qualcomm-lg-uplus-and-lg-electronics-bring-5g-mmwave-south-korea

106 See https://en.yna.co.kr/view/AEN20200923010900320

107 See http://www.thelec.net/news/articleView.html?idxno=1775

108 See https://www.comnews.ru/content/205070/2020-03-18/2020-w12/promyshlennye-predpriyatiya-poluchat-chastoty-dlya-5g-bez-aukcionov. The SCRF's announcement confirmed that a previous proposal for an auction of the 25.25–25.9GHz range had been cancelled. Under the proposed auction, two regional lots in each region of Russia (170 lots in total), would have been auctioned.

109 See https://www.comnews.ru/content/205070/2020-03-18/2020-w12/promyshlennye-predpriyatiya-poluchat-chastoty-dlya-5g-bez-aukcionov

110 See https://www.gsma.com/spectrum/wp-content/uploads/2020/12/5G-spectrum-in-Russia.pdf

111 See http://ir.mts.ru/ir-blog/mts-blog-details/2021/MTS-Ericsson-Qualcomm-Set-European-5G-Speed-Record-for-Commercially-Available-Smartphones/default.aspx

112 See https://www.broadbandtvnews.com/2020/08/18/beeline-launches-5g-network/

113 See https://www.ericsson.com/en/news/2019/8/russias-first-5g-zone-deployed-in-moscow

114 See http://ir.mts.ru/news-and-events/news/news-details/2020/MTS-Receives-Russias-First-5G-License/default.aspx

In August 2020, MTS launched trial 5G mmWave networks at two locations in the Tomsk region: the Tomsk State University of Control Systems & Radioelectronics (TUSUR) and a Micran factory (a telecoms equipment manufacturer).[115]

3.4 Other notable trials

Several other notable 26GHz/28GHz 5G trials have taken place in countries beyond those discussed above, which highlight the advances being made in 5G mmWave technology and the full-5G functionality which the spectrum can enable. A further selection of recent trials conducted by MNOs is presented in the box below.

Trials (MNOs) – selected countries

- In March 2021, Nokia and Türk Telekom announced that they had achieved speeds of over 4.5Gbit/s on live commercial 5G equipment in a 26GHz trial conducted in Ankara.[116] The trial used Nokia's AirScale 5G RAN solution, 800MHz of 26GHz spectrum and a single user device. The announcement stated that "the high speeds achieved during the trial will enable more high-bandwidth and latency-sensitive enterprise services, such as remotely controlled devices for industrial needs or mission-critical applications. 5G-powered networks will also allow customers to enjoy VR/AR experiences, download 4K video content or games in a matter of seconds, as well as enable enhanced capacity fixed wireless access connectivity".

- In February 2021, Nokia and Telefónica announced their first deployment of 26GHz for an ongoing project in the city of Segovia (Spain).[117] The mmWave spectrum will be used to provide an immersive music/video VR therapy service for people with neurodegenerative diseases. The project, which is publicly funded by the Centre for Industrial Technological Development (CDTI), began in July 2020 and is scheduled to conclude in July 2022.

- In December 2020, ASE (a semiconductor company), Chunghwa Telecom and Qualcomm claimed to unveil "the world's first smart factory powered by a private 5G mmWave network" at an ASE facility in Taiwan.[118] Three use cases were identified for the deployment at the facility: AI + AGV (artificial intelligence + automated guided vehicles), smart transportation, remote augmented reality assistance and "the AR experience" at a Technology Education Centre. The companies' announcement states that "these use cases demonstrate the extensive scope and sophistication of 5G technology application that will accelerate the transformation of smart manufacturing and automation".

115 See https://www.riatomsk.ru/article/20200820/the-first-5g-test-zones-in-tomsk-open-on-the-basis-of-micran-and-tusur/

116 See https://www.nokia.com/about-us/news/releases/2021/03/22/nokia-achieves-5g-speed-world-record-with-turk-telekom/

117 See https://www.telefonica.com/es/web/sala-de-prensa/-/telefonica-y-nokia-implantan-la-primera-iniciativa-en-espana-con-el-5g-de-mayor-capacidad-con-un-proyecto-de-musicoterapia-inmersiva-para-la-estimulac

118 See https://ase.aseglobal.com/en/press_room/content/5g_smart_factory_en

The trials described above involve MNOs. However, 26GHz trials are also being conducted by other players (e.g. vendors and academic institutions). A selection of these is provided in the box below.

Trials (MNOs and other players) – selected countries

- In April 2021, Qualcomm announced that it had successfully completed 5G data calls that combined mmWave and frequency division duplex (FDD) or time division duplex (TDD) sub-6GHz spectrum using 5G standalone (SA) Dual Connectivity technology. Qualcomm reported successfully aggregating 28GHz mmWave spectrum with sub-6GHz FDD spectrum, as well as 39GHz mmWave spectrum with sub-6GHz TDD spectrum. A smartphone device was used for the data call, equipped with the Snapdragon X65 modem.[119]

- In March 2021, Samsung announced that it had achieved 5G speeds of 5.23Gbit/s (to a single device) using E-UTRAN NR Dual Connectivity (EN-DC) technology (i.e. non-standalone (NSA) technology in which aggregates 4G and 5G spectrum).[120] The trial was carried out in Samsung's lab in Korea, and combined 40MHz of 4G spectrum in the 800MHz band with 5G mmWave. This follows several other 5G mmWave trials conducted by Samsung.[121]

- In August 2020, Qualcomm, Ericsson and Casa systems, announced that they had successfully completed "the world's first extended-range 5G NR data call over mmWave" at a location in Regional Victoria (Australia).[122] The trial achieved a connection distance of 3.8km The announcement stated that the trial would "enable enhanced fixed broadband services and additional opportunities to utilize 5G network infrastructure for broad coverage in urban, suburban and rural environments". Qualcomm and Ericsson have since conducted further trials extending the range of mmWave further (see for example the trial with Telecom Italia (TIM) referenced in Section 3.3.1).[123]

- In February 2020, Ericsson announced that it had achieved 5G mmWave speeds of 4.3Gbit/s at a trial in its Stockholm lab. The trial used eight component carriers (8CC) aggregating 800MHz of spectrum, and "was achieved during interoperability testing using commercial solutions". A 5G smartphone form factor test device was used (powered by a Qualcomm modem). The announcement stated that the trial was "good news for enhanced mobile broadband use cases such as multi-player gaming, AR gaming and rich video streaming. Higher downlink speeds will also expand opportunities for communications service providers

119 See https://www.qualcomm.com/news/releases/2021/04/13/qualcomm-announces-successful-data-calls-using-5g-mmwave-and-sub-6-ghz

120 See https://news.samsung.com/global/samsung-breaks-5g-speed-record-reaching-5-23gbps

121 See above link for further details.

122 See https://www.qualcomm.com/news/releases/2020/08/31/qualcomm-casa-systems-and-ericsson-achieve-worlds-first-extended-range-5g

123 See also https://www.qualcomm.com/news/onq/2020/09/17/fwa-breakthroughs-show-promise-5g-mmwave-extended-ranges

to bring fixed wireless access to consumers, with cellular mmWave connectivity of up to four times faster than fiber".

- In January 2019, the French government and regulator ARCEP issued a joint call for the creation of 5G trial platforms that would be open to third parties and use the 26GHz band.[124] To date, ARCEP has selected 14 projects and awarded them a licence to use 26GHz spectrum for a period of up to three years.[125] The projects are as follows:
  - Universcience, at the Cité des Sciences et de l'Industrie, in collaboration with Nokia (education and innovation)
  - Saint-Quentin-en-Yvelines, at the Vélodrome National, in collaboration with Nokia, Qualcomm and France TV (sports arena)
  - Bordeaux Métropole, with Bouygues Telecom (hotspots and smart cities)
  - Le Grand Port Maritime du Havre, in collaboration with Siemens, EDF and Nokia (sea port)
  - Paris la Défense, in Puteaux (neutral host, urban area, business centre)
  - Bouygues Telecom, for the Lyon Part-Dieu train station, in collaboration with SNCF (train station)
  - Bouygues Telecom, for an industrial zone in the city of Saint-Priest (industrial area)
  - Bouygues Telecom, for the cities of Vélizy and Meudon (smart cities)
  - Orange, for the Rennes railway station, in collaboration with SNCF and Nokia (train station)
  - Orange, for the 5G Lab co-innovation space, in Châtillon (business campus, innovation, multimedia and video production)
  - Franconville, with Syrtem, Orange (urban hotspots and FWA)
  - Puteaux, Icade with Orange and Cisco (indoor connectivity in connected buildings)
  - Nozay, Paris-Saclay Nokia Campus, with Alcatel-Lucent (innovation).

124 See https://en.arcep.fr/news/press-releases/p/n/5g-6.html

125 See https://www.arcep.fr/cartes-et-donnees/nos-publications-chiffrees/experimentations-5g-en-france/tableau-de-bord-des-experimentations-5g-en-france.html

4 Deployments and use cases

This section provides a discussion of the responses from mobile and wireless broadband network operators on 5G mmWave deployment, including the potential services to be offered, the deployment options, timeframes and benefits of using mmWave spectrum for selected 5G services. We have combined the written responses to questionnaires with the responses given during interviews conducted by video call.

4.1 Proposed services

What services are proposed or envisaged?

Use cases	MNOs commented 26GHz spectrum will be used to deliver consumer-based 5G eMBB services in targeted areas where the highest capacity is needed. 5G FWA is also a specific use case of interest to several European operators. MNOs also commented that the 26GHz band can provide capacity for additional use cases beyond consumer-based eMBB, including industrial and enterprise deployments, where the volume of traffic is high in the uplink direction.
Types of traffic supported	MNOs commented that for typical eMBB services, downlink traffic dominates and hence for eMBB use, the 26GHz band capacity might be deployed symmetrically (i.e. similar capacity in uplink and downlink directions). However, industrial/enterprise customer use cases will need additional uplink capacity (and this uplink capacity requirement might vary between different industrial uses). There was a general view that mmWave spectrum can provide the flexibility to tailor uplink/downlink capacity at a localised level.

What are the proposed or envisaged timescales for the launch of services?

Timing of launch	Some wireless operators that we spoke to as part of the study and already hold 26GHz spectrum licences commented that 5G FWA deployment in Europe using 26GHz will be launched shortly. Other MNOs in markets where 26GHz has been licensed commented that late 2021 would be a best estimate to start commercial utilisation of mmWave technologies. In markets where 26GHz is yet to be licensed in Europe, operators commented it might be a few years before 26GHz deployment commences, allowing for timescales for licensing, equipment procurement and network planning.

4.2 Types of deployments

Will coverage be national, regional or locally delivered using 26GHz?

Coverage using 26GHz

Due to coverage limitations of 26GHz/mmWave spectrum when compared with 5G deployment using the 3.5GHz band, and/or use of legacy mobile bands below 3GHz, MNOs commented that mmWave deployment is likely to be used for sub-regional or local coverage. This sub-regional or local coverage might be deployed in multiple targeted locations within a wider network footprint (which might include targeted urban, suburban or rural areas with a requirement for localised high-capacity coverage, and/or to cover specific industrial locations and corporate campuses). In locations within European markets where 5G FWA is used to deliver high-speed broadband services (e.g. using 5G FWA to deliver high-speed broadband to homes and businesses that are not expected to be reached by fibre to the premises (FTTP) networks in the short/medium term), the 26GHz band might be used in suburban and in specific cases in rural towns requiring very high capacity (alongside 3.5GHz). For 5G FWA deployment, 26GHz provides potential to offer gigabit-capable wireless broadband connections. One stakeholder that we interviewed as part of this study referred to results of technology trials (conducted together with Qualcomm and Ericsson) where capability to deliver 2Gbit/s speeds to 5G FWA-connected premises using an aggregate of 600MHz of 26GHz spectrum was demonstrated. With suitable external CPE for 5G FWA deployment, the coverage range achievable can be around 6km (at 1Gbit/s).

Other MNOs commented that trials have shown that mmWave is useful to enhance 5G network performance and throughput, including in the uplink direction.

Types of deployments

With the focus currently in Europe on deploying 5G radio using 3.5GHz spectrum added to existing macro sites, it is appealing to be able to deploy 26GHz onto existing 3.5GHz macro sites, as a capacity offload solution.

Although initial deployments will be via macro sites, it is likely that, based on market demand, small-cell/street-level coverage will also be deployed, and indoor solutions are also envisaged, based on demand.

Although 26GHz is most likely to be used to provide localised coverage and/or to cater for specific customer needs (e.g. for industrial sites), some MNOs commented that the ability to offer the 26Hz service in locations nationwide via the same spectrum blocks is important, to avoid additional cost and complexity within network deployment.

Standalone or non-standalone architecture for 5G mmWave	MNOs commented that 5G non-standalone (NSA) deployments are most widespread currently in Europe, and will start to be complemented with 5G SA starting from 2021. The role of mmWave is as a 5G capacity layer, and hence it is envisaged to mainly be deployed in combination with 3.5GHz. Other MNOs commented that once equipment is available, mmWave will both be deployed with, and without, 3.5GHz.

Will coverage be outdoors, indoors or both using 26GHz?

Coverage environments	MNOs commented that mmWave spectrum might be used for outdoor, or indoor coverage, depending on the use case. The initial focus was generally agreed to be deployment of high capacity outdoors, and 5G FWA using external antennas at customer premises. However, as the mmWave ecosystem evolves, it is expected that 26GHz deployments might serve indoor locations such as industrial sites and offices for the provision of corporate customer applications. Some MNOs commented the size and weight of mmWave antennas currently makes them suited to outdoor deployment only using macro sites. However, tailored coverage to industrial users and indoor coverage can be achieved using small-cell form factors.

4.3 Spectrum requirements for the proposed services

What spectrum is needed in the 26GHz band to deploy the services you envisage, and how should this spectrum be available (nationally, regionally, locally, per site)?

Local or national spectrum	Whilst spectrum might be deployed in specific locations only, some MNOs commented that the ability to offer a mmWave service in selected locations nationwide via the same spectrum blocks is important, since this not only benefits network procurement but also ensures that industrial or enterprise users operating across multiple campuses in a country can be connected using the same network equipment and devices. Some MNOs commented that, although aggregation of non-contiguous spectrum blocks is possible in mmWave spectrum, there can be additional costs of doing this, and there is a possible impact (e.g. additional power consumption).
Bandwidth required	MNOs commented that between 800MHz and 1GHz of contiguous spectrum is required per operator for 26GHz deployment. Contiguity is preferred since mmWave radios have a limited bandwidth, so having non-contiguous blocks would mean multiple radios needing to be deployed, which increases deployment costs. Using more than 400MHz is beneficial to boost uplink/downlink capacity and to achieve the highest peak speeds – for

example, one operator referred to trials using 800MHz of spectrum in which peak speeds of 4Gbit/s were achieved.

4.4 Benefits of using mmWave spectrum for the proposed services

What characteristics of 26GHz spectrum make the band suitable for the use cases envisaged?

Properties of mmWave that are most beneficial for 5G deployment

All the following properties of mmWave spectrum are important drivers for 26GHz deployment: ability to deploy very low latency connections, to provide capacity for offloading 5G traffic from the 3.5GHz band and for provisioning higher 5G throughput (e.g. in the uplink, needed in particular for some industrial use cases). Examples provided by some stakeholders of use cases needing additional uplink capacity are robotics, and real-time video surveillance cameras for example in a stadium, factory campus, at street level or in a building. MNOs also commented that 5G mmWave has shown its capability in trials to provide high capacity for use cases such as those involving real-time video.

Some MNOs also commented that they see 26 GHz (and higher frequencies in general) paving the way towards advanced 5G, and 6G, deployments.

Potential for local optimisation of uplink and downlink capacity

Several MNOs commented that one especially interesting prospect from mmWave deployment is that the TDD frame structure can be adapted to fit local needs – for example, if a factory or other location needs additional uplink capacity, this might be provisioned using a different TDD frame structure for that location compared to that used in other locations. The limited coverage of mmWave means that flexibility to adapt the frame structure exists without the risk of interference.

5 Economic modelling – costs and benefits of 26GHz

This section provides a summary of our economic modelling to quantify the costs and benefits (at a Europe-wide level) associated with the deployment of 26GHz spectrum for a selection of 5G use cases. Our modelling builds on earlier modelling conducted by Analysys Mason as part of two previous studies also commissioned by Ericsson and Qualcomm:

- **"5G action plan review for Europe" (September 2020)**. The aim of this study was to provide a cost–benefit analysis to inform development of updated European 5G goals (including releasing 5G's full potential to aid 5G recovery post-2020), and taking account of experience from 5G trials, technology development and deployments since the 5GAP was developed back in 2016.[126]

- **"Analysis of the costs and benefits of 5G geographical roll-out in Europe" (March 2021)**. The purpose of this study was to model 5G investment in Europe, and the associated costs and benefits, for three deployment scenarios, and for 13 different use cases.[127]

The new modelling makes use of several of the results calculated in these studies, and adapts/refines the approach where required to focus specifically on the costs and benefits of 26GHz deployment. The remainder of this section is structured as follows:

- Section 5.1 provides a summary of the modelling approach
- Section 5.2 presents the results of the modelling.

5.1 Approach

Use cases

The economic modelling has focused on a selection of 26GHz use cases, grouped into three clusters: industrial, FWA and urban/sub-urban locations.

Figure 5.1: 26GHz use cases modelled [Source: Analysys Mason, 2021]

Use-case cluster	Use case	Features of use case
Industrial	Industrial ports	• Real-time inventory and asset tracking • Ultra-high definition (UHD) surveillance; reliable robotic control of machinery; AR guided repairs
	Airports	• Autonomous airside vehicles and collision avoidance • AR guided repairs and maintenance • Edge computing and AI for passenger ID and security

126 See https://www.ericsson.com/4ab850/assets/local/about-ericsson/company-facts/europe/5g-action-plan-review-for-europe-executive-summary.pdf

127 See https://www.analysysmason.com/consulting-redirect/reports/filling-europes-5g-coverage-gaps/

Use-case cluster	Use case	Features of use case
		• Augmented shopping experience
	Smart factories	• Machinery monitoring for predictive maintenance and remote-control,-reduced downtime • Real-time supply chain visibility • X-reality guided procedures and repairs • UHD surveillance
FWA	FWA	• High-speed broadband connectivity for consumers and businesses in areas not reached by full-fibre networks (which could include urban, suburban and rural areas) • Could also support implementation of other 5G use cases, such as remote monitoring/remote healthcare
Urban/sub-urban locations	High-density urban and suburban locations	• eMBB for high footfall locations (e.g. shopping centres, city centres, transport hubs, etc.) • Immersive content is likely to generate significant consumer interest in the future and having mobile, fast and stable 5G MBB coverage in town centres and other locations will allow for a rich variety of 5G-enabled mixed-reality applications to emerge. Examples might include: – mixed-reality fashion shows[128] – virtual production studios for media content creation[129] – live streaming of e-sports events in town centres – smart tourism applications – live streaming of festivals and music events
	Stadiums/large venues	• New immersive experiences (e.g. multi-view AR/VR) • Social video sharing • UHD video surveillance • Real-time smart parking

Network architecture

As shown in Figure 5.2 below, three different 26GHz deployment architectures are modelled: small cells, macro-site upgrades and new dedicated sites.

Figure 5.2: 26GHz network architectures modelled [Source: Analysys Mason, 2021]

26GH network architecture	Description
Small cell	26GHz-only small cells could be attached to street furniture (e.g. lamp post or side of building) or deployed indoors. Fibre backhaul is also required. Small cells are low cost and have a limited cell radius due to lower power
Macro-site upgrade	Macro sites which already have 3.5GHz 5G are upgraded with 26GHz radio equipment (including integrated antenna). The macro site already includes fibre backhaul, 5G BBU and 3.5GHz radio. Larger cell radius than small cell (though still smaller than

128 See https://rewind.co/portfolio/three-mobile-5g-mixed-reality-fashion-show/

129 See https://www.ibc.org/trends/verizon-unveils-london-5g-lab-and-studio/5451.article

26GH network architecture	Description
	cell radius of 3.5GHz), due to more advanced beamforming than in small cell. Traffic with stringent quality of service requirements can be served via network slicing
New dedicated site	New 5G RAN deployment of 26GHz which is dedicated to the use case in question (i.e. not shared with eMBB). The deployment can share 3.5GHz from a nearby macro site. The 26GHz antennas would be mounted on suitable poles/towers in the vicinity of the use case. 26GHz equipment (and cell radius) is the same as for a macro-site upgrade

Different architectures are suitable for different use cases. To determine what architecture options might be deployed, we have considered what network architectures might be used depending on where the use case is being deployed (e.g. urban or outside of urban areas, outdoors or indoors, close to population centres where 5G population-led MBB roll-outs might occur, or not). It is noted that in some locations, there will be different architectures deployed in the same location – for example at an airport where multiple MNOs might provide eMBB connectivity as well as other dedicated connectivity being deployed.

Figure 5.3 below shows which of the three network architectures described above we have assumed for the different use cases modelled.

Figure 5.3: 26GHz network architecture assumptions by use case [Source: Analysys Mason, 2021]

Use case cluster	Use case	Network architecture assumptions
Industrial	Industrial ports	12 dedicated sites per port
	Airports	We model a mixture of architectures: • Macro-site upgrades (1 macro upgrade per airport) • Dedicated sites (12 dedicated sites per airport)
	Smart factories	We model a mixture of architectures: • Some smart factories within the coverage footprint of public mobile networks will be served by a macro upgrade (1 macro upgrade per factory) • Some smart factories are served by additional dedicated small cells (6 small cells per factory) • Some smaller factories are served by dedicated sites (1 dedicated site per factory)
FWA	FWA	Macro-site upgrades
Urban/sub-urban locations	High-density urban and suburban locations	We model a mixture of architectures: • Macro-site upgrades to add capacity into public mobile networks • Small cells to add localised eMBB capacity in the public networks (5 small cells per macro-site upgrade)
	Stadiums/large venues	We model a mixture of architectures:

Use case cluster	Use case	Network architecture assumptions
		• Macro-site upgrade (1 macro upgrade per stadium) to add eMBB capacity into public mobile networks • An additional 12 small cells per stadium to address the immersive experience use cases indicated in Figure 5.1.

Number of installations

The number of 26GHz 'installations' (i.e. the total number of cells, comprising macro upgrades, small cells and dedicated sites) builds on data collected, per European market, in previous studies. A summary of the sources and approaches used to estimate the number of 26GHz installations is shown in Figure 5.4 below.

Figure 5.4: Sources/approach for number of 26GHz installations [Source: Analysys Mason, 2021]

Use case cluster	Use case	Source/approach for number of installations
Industrial	Industrial ports	• Ports where gross weight of good transported to/from port exceeds 2 million tonnes per annum • Source: Eurostat[130]
	Airports	• Commercial airports with more than 15 000 passengers per annum • Source: Eurostat[131]
	Smart factories	• Estimate based on number of manufacturing enterprises by number of employees. We have assumed a mapping between enterprise size and the number of 5G factories • Source: Eurostat[132]
FWA	FWA	• Number of mobile macro sites per market is based on NRA site databases and Analysys Mason project work[133]) • Population distribution calculations are based on data provided by Facebook, WorldPop and Eurostat • A forecast of FTTH coverage over time is based on Analysys Mason Research data ('FTTx coverage and capex: worldwide trends and forecasts 2019–2026'[134]) • We assume FWA is deployed outside of FTTH coverage areas, and also that a certain portion of mobile macro sites within areas covered by FTTH (at the date of

130 https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=mar_go_am_be&lang=en

131 https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=avia_if_arp&lang=en

132 https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=sbs_sc_sca_r2&lang=en

133 Sites per population of known countries calculated and used where data is not available.

134 See https://www.analysysmason.com/research/. Note that this forecast has been updated since the previous studies.

Use case cluster	Use case	Source/approach for number of installations
		26GHz assignment) are upgraded with 26GHz for FWA as an alternative broadband option for consumers within FTTH areas • Outside of areas covered by FTTH, we assume that all sites are upgraded with 26GHz for FWA, provided that the population density exceeds 300 people per km^2
Urban and suburban locations	High-density urban and suburban locations	• We assume one macro-site upgrade per 20 000 population in all cities with a population above 200 000 • Source (for cities by population): worldpopulationreview.com[135]
	Stadiums/large venues	• All stadiums with capacity over 10 000 • Source: worldstadiums.com

For the industrial use cases, we have modelled a single service provider per location. For example, we model a single 26GHz network at a port provided by a single service provider on behalf of the port operator (as opposed to modelling the costs of multiple competing service providers each installing separate networks at the same port, for public mobile use). We consider this approach to be appropriate, given that duplication by multiple networks is unlikely for specific industrial use cases. It is more likely that, for example, a port would issue an invitation to tender for the provision of 5G services, and this would be won by a single provider. In some locations, there will be 5G implementations installed/used by multiple providers (e.g. multiple MNO networks covering an airport terminal, along with 5G infrastructure that might be dedicated for use by the airport authority, either via network slicing from a public network or via cells deployed separately by the MNO).

However, for the FWA and urban/sub-urban locations use cases, we assume that multiple competing players (specifically MNOs) provide services. We therefore multiply costs by the number of mobile networks in the market.[136]

Unit costs

Unit costs for the different network architectures are shown in Figure 5.5 below. Our modelling does not calculate capacity requirements to meet traffic loads in different locations and hence the total spectrum needed in different areas in the network is not quantified. Unit costs refer to typical spectrum assumptions for the bands in question e.g. a 100MHz deployment for 3.5GHz and a 800MHz to 1GHz deployment for 26GHz.

135 https://worldpopulationreview.com/continents/cities-in-europe/

136 Commensurate with previous studies, we multiply costs by the number of mobile *networks* (i.e. number of MNOs, adjusted to reflect active network-sharing arrangements). Number of MNOs and number of active network-sharing arrangements is based on MNO announcements, BEREC, NRAs, TeleGeography and Analysys Mason project work.

Figure 5.5: Unit costs for different network architectures modelled [Source: Analysys Mason, 2021] [137]

Network architecture	Cost item	Capex (EUR, 2020)	Opex (EUR, 2020)	Asset lifetime (years)
Small cell	26GHz radio	5000	-	15
	Fibre backhaul	500	-	30
	Power and maintenance	-	420	-
Macro-site upgrade	26GHz radio	37 500	-	15
	Power and maintenance	-	625	-
New dedicated site	Site civils and acquisition	5000	-	50
	Fibre backhaul	2000	-	30
	5G BBU	7500	-	15
	26GHz radio	37 500	-	15
	Power and maintenance	-	1625	-

Price trends are applied to reflect changes in unit costs over time (e.g. the unit cost of radio equipment is expected to fall significantly as the equipment ecosystem develops and we model a price erosion of 3–7% in this case). For all architectures, we apply a 10% uplift to account for core network costs. Spectrum costs are excluded.

Deployment profile

For the eMBB (high-density urban and suburban locations) and FWA use cases, the total number of installations estimated (see above) is assumed to be deployed over a period of five years, beginning in the year that 26GHz is expected to be assigned (see Section 3.2). For the remaining use cases, we assume that deployment begins one year later (and also takes place over a period of five years).

In the countries where 26GHz has already been assigned for outdoor 5G mobile use (i.e. Denmark, Finland, Germany, Greece, Italy and Slovenia), we model deployment beginning in 2021/2022. Where a market has not specified timings for 26GHz assignment, or no data is available, we assume that deployment will begin in 2022/2023 (noting the stipulations of the EECC, and that by the end of 2022/2023 the ecosystem for 26GHz devices and network equipment is expected to be somewhat more mature than currently and hence operators might be planning for 26GHz deployment ahead of licences being awarded).

We assume a linear build profile over the five-year period.

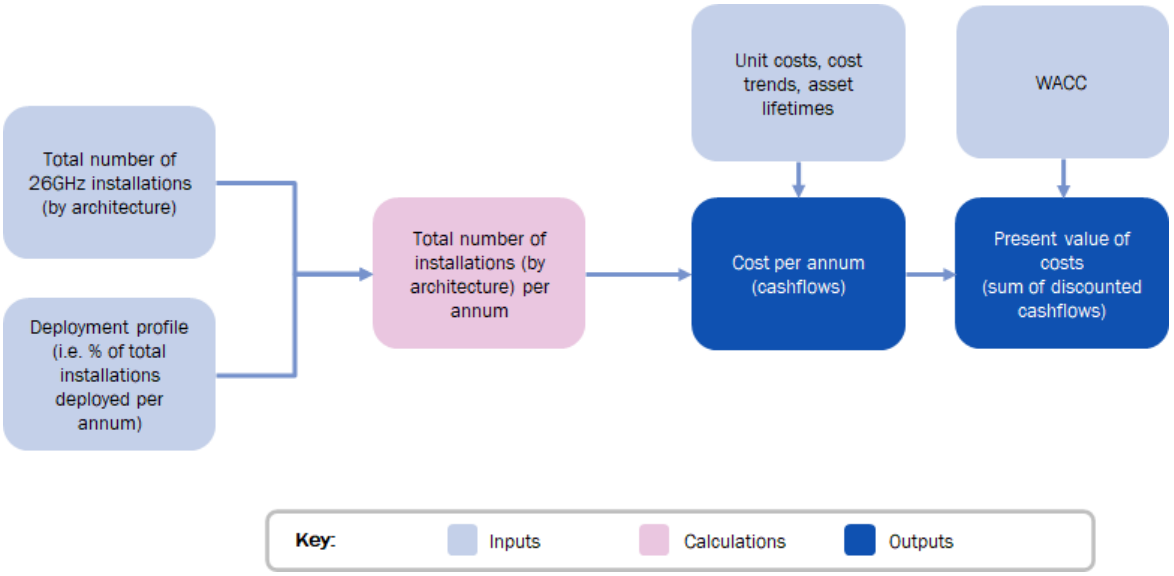
137 Note: radio equipment unit costs shown in Figure 5.5 are for a single 400MHz carrier. For the FWA and stadiums use cases, we assume that 800MHz carriers would be needed, and we model increased unit costs accordingly.

Cost calculation

Overall cost per use case and per European market is calculated using a simple discounted cashflow calculation from 2021/2022 to 2040 (capturing capex, opex and replacement capex), using a weighted average cost of capital (WACC) of 6.0%.

A summary of the cost calculation approach we have used is shown in Figure 5.6 below.

Figure 5.6: Summary of cost calculation approach [Source: Analysys Mason, 2021]



Benefit calculation

An approach to calculating the incremental economic benefits associated with deploying 5G for specific industrial and enterprise use cases (built on top of a 'base case' eMBB network deployment) was developed in the previous two studies, and is re-used in the current study.[138] For several use cases, we use a two-step process to estimate how the deployment of 26GHz spectrum will benefit economic growth (i.e. GDP):

1. Calculate the GDP of the sector which is attributable to the use case in question[139]
2. Uplift the relevant sectoral GDP to reflect the impact of 5G 26GHz.

Short-term GDP forecasts are taken from the IMF's World Economic Outlook Database. This data takes account of the impact of the Covid-19 pandemic on an individual country level. In the long term, we have applied a growth rate equal to the compound annual growth rate (CAGR) that was forecast pre-pandemic for the period 2019–2024.

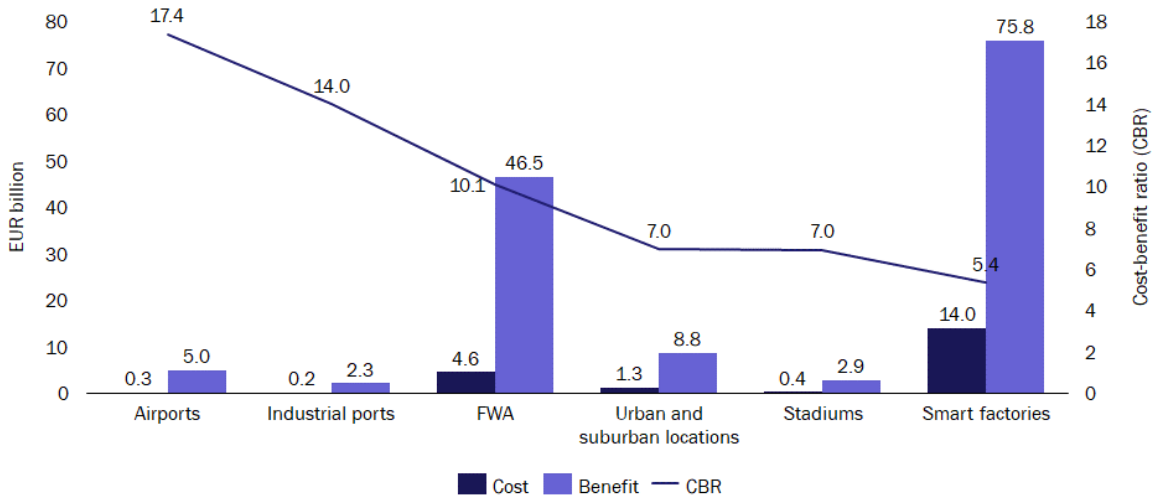
138 Adjustments have been made where required to account for changes in deployment profile assumptions.

139 Where data is available, country-specific values are used for GDP sector splits. Further detail on the benefit calculation approach is available in the previous studies.

5.2 Results

Figure 5.7 shows the results of the economic modelling 2021/2022 to 2040, by use case, aggregated across European countries (i.e. EU27 plus Norway, Switzerland and the UK).

Figure 5.7: Present value of Europe-wide costs and benefits to 2040 of deploying 26GHz, by use case (EUR billion, 2020 terms) [Source: Analysys Mason, 2021]



As can be seen, the smart factories use case has the largest absolute cost (and benefit) associated with 5G deployment using 26GHz: EUR76 billion of benefit for EUR14 billion of cost – a cost–benefit ratio (CBR) of around 5. The CBR for smart factories reflects our modelling estimates on the number of potential smart factories which could be equipped with 26GHz 5G capability, and the wide-ranging benefits of smart factories in terms of increased productivity across Europe's manufacturing sector. While the absolute costs and benefits from the other use cases modelled are lower than for smart factories, the CBR is higher (e.g. around 7 for urban and suburban locations, and around 10 for FWA), demonstrating the possibility of an even more significant return on investment for these use cases.

A full breakdown of costs, benefits and CBR by use case is provided in Figure 5.8 below.

Figure 5.8: Present value of Europe-wide costs and benefits to 2040 of deploying 26GHz, by use case [Source: Analysys Mason, 2021]

Use-case cluster	Use case	Cost (EUR billion, 2020 terms)	Benefit (EUR billion, 2020 terms)	CBR
Industrial	Industrial ports	0.2	2.3	14.0
	Airports	0.3	5.0	17.4
	Smart factories	14.0	75.8	5.4
	Total	**14.5**	**83.1**	**5.7**
FWA	**Total**	**4.6**	**46.5**	**10.1**

Use-case cluster	Use case	Cost (EUR billion, 2020 terms)	Benefit (EUR billion, 2020 terms)	CBR
Urban and sub-urban locations	High-density urban locations	1.3	8.8	7.0
	Stadiums/large venues	0.4	2.9	7.0
	Total	**1.7**	**11.7**	**7.0**
Total	**Total**	**20.8**	**141.3**	**6.8**

6 Conclusions

Three key conclusions from our study are summarised below:

1. **mmWave spectrum, complementing the use of mid-band spectrum, will be used to:**
   - **deliver 5G for eMBB use in high-capacity areas**
   - **deliver 5G FWA services to homes and offices**
   - **support industrial use cases.**

   Regulators should prioritise the assignment of mmWave spectrum to enable this wide range of use cases to emerge.

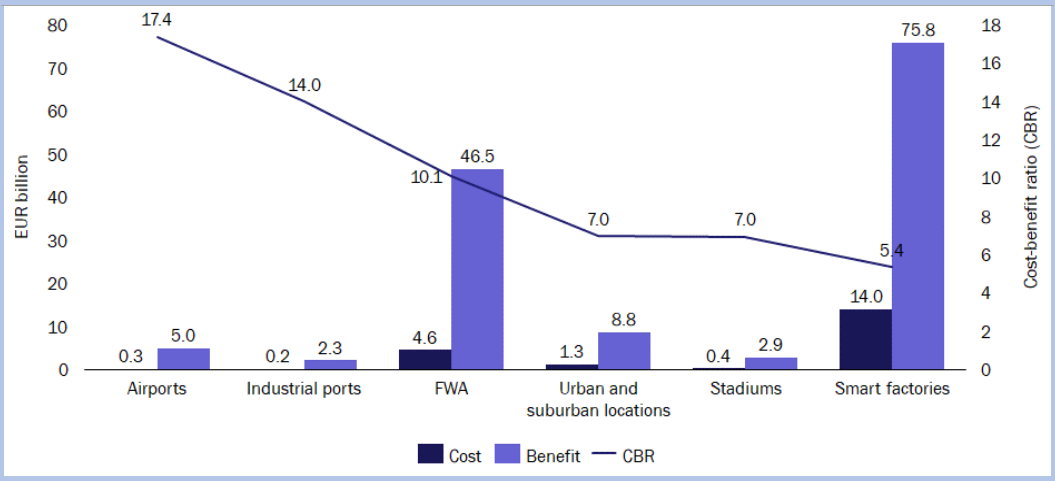
   Our report describes a variety of eMBB uses of mmWave spectrum, together with use of 26GHz for 5G FWA services into homes and offices and a range of uses at specific locations where volumes of data traffic from mobile devices are especially high. What the 26GHz band might provide for MNOs over and above 3.5GHz deployment is the capability to accommodate eMBB traffic in high-use locations plus the potential to deliver, in specific locations, the multi-gigabit peak speeds, ultra-low latency and high-reliability connectivity needed by some of the 5G use cases that are widely discussed in published literature (e.g. gaming, industrial automation, augmented and virtual reality, immersive tourism experiences and next-generation transport applications). 26GHz might also be useful to enable operators to dimension capacity to meet the specific requirements for some use cases, such as those requiring high uplink capacity.

2. **Our modelling suggests significant economic benefit to deploying 5G mmWave across several use cases.**

   Our modelling shows that there is a significant net economic benefit to deploying 5G mmWave primarily together with 3.5GHz but also as dedicated cells, across a wide range of scenarios, based on a 'base case' eMBB network deployment. For each of the use cases modelled, the estimated benefit is between 5 and 20 times greater than the estimated cost. Aggregating across all the use cases modelled, 5G mmWave deployment would generate an estimated GDP uplift (up to 2040) of more than EUR140 billion (cumulative) across thirty European markets, for around EUR21 billion of additional cost.[140] Figure 6.1 below shows the results of our economic modelling.

[140] This cost is incremental to the cost of eMBB deployments in sub-6GHz bands and relates specifically to the deployment of 26GHz cells (plus some additional 3.5GHz deployment where required).

Figure 6.1: Present value of Europe-wide costs and benefits to 2040 of deploying 26GHz, by use case (EUR billion, 2020 terms) [Source: Analysys Mason, 2021]



3. **MNOs we interviewed for the study indicated an expectation of using mmWave deployment to address a variety of use cases (including eMBB in high-capacity locations, 5G-based FWA, smart factory and other industrial applications, connected vehicles and venue-specific coverage).**

   Interviews with stakeholders demonstrated that MNOs intend to deploy mmWave spectrum in multiple specific locations (with variation in requirements based on local market demand). A large variety of use cases has been identified (including eMBB in high-capacity locations, 5G-based FWA, smart factory and other industrial applications, connected vehicles and venue-specific coverage). Stakeholders highlighted that mmWave spectrum can be used to maximise capacity within mobile networks (since frequencies can be re-used more intensively without co-channel interference occurring) as well as to allow for more flexibility to adapt time division duplex (TDD) frame structures to cater for local variations in traffic profile.

   Interviews also highlighted that 5G mmWave technology has shown its capability to provide high capacity in trials and in commercial systems deployed to date. As the capabilities of mmWave technology continue to improve, MNOs expect that quality of service within deployments can be ensured even as traffic levels increase. Multiple mmWave networks have now been deployed globally on a commercial basis, with European markets in the process of catching up with these deployments. European MNOs commented that further European deployments (as well as non-European deployments in countries such as Australia and Brazil) will help to build the 26GHz equipment and device ecosystem.

Annex A Detailed summary of status of 26GHz award for 5G in European countries

Figure A.1 below provides a detailed summary of the status of 26GHz award for 5G in European countries (EU27, Norway, Switzerland and the UK). Footnotes include links to relevant NRA announcements/documents.

Figure A.1: Status of 26GHz award for 5G in European countries [Source: NRAs, RSPG.[141] 2021]

Country	Status of 26GHz award for 5G
Austria	• A consultation on the 26GHz was completed in August 2019[142] • RTR states that the 24.25–27.5GHz band is intended for 5G, but no timelines for assignment have been proposed[143]
Belgium	BIPT held a consultation on the 26GHz band in 2019, indicating that: • 1.2GHz is available for potential 5G use in two contiguous blocks: 200MHz in the 26.3–26.5GHz range and 1GHz in the 26.5–27.5GHz range • the remaining 26GHz spectrum (10 blocks of 200MHz each) cannot currently be allocated for 5G without limitations, due to current users. BIPT will consider potential redesign and organisation of a second allocation procedure for this spectrum at a later stage
Bulgaria	• In December 2020, CRC launched a consultation on the use of the 26GHz band.[144] In accordance with responses to the consultation, in March 2021 CRC announced that it plans to issue a new consultation on demand for the 26GHz band by the end of 2022[145]
Croatia	• In April 2021, HAKOM launched a consultation on its plans for auctioning the 700MHz, 3.6GHz and 26GHz bands • HAKOM is proposing that five 200MHz blocks are made available in the 26.5–27.5GHz range using an SMRA. HAKOM is consulting on a reserve price of HRK7.5 million (EUR1 million) per lot, with a cap of two lots per bidder. Licences are proposed to be nationwide, with a duration of 15 years • The consultation closes in May 2021, and the auction is planned to take place in July 2021[146]

141 See https://rspg-spectrum.eu/wp-content/uploads/2021/02/RSPG21-003final_state_of_play_5G.pdf. The document contains information provided by RSPG Members.

142 See https://www.rtr.at/TKP/aktuelles/veroeffentlichungen/veroeffentlichungen/konsultationen/konsult26-ghz-2300-mhz.en.html

143 See https://www.rtr.at/TKP/was_wir_tun/telekommunikation/spectrum/bands/26GHz/26GHz-band.en.html

144 See https://crc.bg/bg/novini/1362/krs-provezhda-obshtestveni-konsultacii-za-izpolzvane-na-radiochestoten-obhvat-26-g-hz

145 See https://crc.bg/bg/novini/1371/krs-prie-rezultatite-ot-obshtestvenite-konsultacii-za-polzvane-na-svobodniq-resurs-v-radiochestoten-obhvat-26-g-hz

146 See https://www.hakom.hr/hr/pokrenuta-javna-rasprava-o-prijedlozima-planova-dodjele-za-frekvencijske-pojaseve-700-mhz-3600-mhz-i-26-ghz/6418

Country	Status of 26GHz award for 5G
Cyprus	• Cyprus held a consultation on auctioning the 700MHz, 3.6GHz and 26GHz bands in 2019, and completed an auction of the 700MHz and 3.6GHz bands in December 2020[147] • A document published in October 2020 by the Deputy Ministry of Research, Innovation and Digital policy states that "there is no clear market demand for 26GHz"[148]
Czech Republic	• In September 2020, CTU completed a consultation on the 26GHz band[149] • CTU proposes to make 1GHz available for the provision of ultra-high-speed services
Denmark	• In April 2021, DEA completed an auction of the 26GHz band (24.65–27.5GHz), alongside spectrum in the 1500MHz, 2.1GHz, 2.3GHz and 3.5GHz bands. All 2850MHz of spectrum in the 26GHz band was assigned; licences are nationwide and expire on 31 January 2042[150] • The 24.25–24.65GHz range will be allocated for private networks [See section 3 for details]
Estonia	• A public consultation on the 26GHz band was completed in December 2019[151] • The consultation states that Estonia has started planning the use of the 24.25–27.5GHz range. No proposed timelines or licensing arrangements were provided, however we note that an RSPG document published in February 2021 states that an award is expected by the end of 2021[152]
Finland	• In June 2020, the 25.1–27.5GHz range was auctioned on a nationwide basis, with licences valid until the end of 2033[153] • The lower part of the band (24.25–25.1GHz) has been reserved for local use, and has yet to be awarded.[154] The Ministry of Communications issued a consultation on this band available for local use in February 2021[155] [See section 3 for details]
France	• Following a consultation in 2018, in October 2019 ARCEP issued local licences for 5G trials in the 26.5–27.5GHz band. Licences have a duration of three years[156, 157]

147 See https://tekdeeps.com/cyta-epic-cablenet-and-primetel-announced-temporary-winners-of-5g-licenses-auction/

148 See https://www.itu.int/en/ITU-D/Regional-Presence/Europe/Documents/Events/2020/5G_EUR_CIS/Session%202_Stelios%20Himonas%20-%20ITU_5G_Forum_CYP_Dr_Stelios_Himonas.pdf

149 See https://www.ctu.eu/press-release-26-ghz-band-will-be-made-acessible

150 See https://ens.dk/ansvarsomraader/frekvenser/auktioner-og-udbud-frekvenser

151 See https://www.ttja.ee/ariklient/ametist/avalikud-konkursid/raadioteenuse-osutamine#algasid-ettevalmistu

152 See https://rspg-spectrum.eu/wp-content/uploads/2021/02/RSPG21-003final_state_of_play_5G.pdf

153 See https://www.traficom.fi/en/communications/communications-networks/spectrum-auction-26-ghz-frequency-band

154 See https://www.lvm.fi/en/-/government-decides-on-the-terms-of-the-5g-auction-1164498

155 See https://www.lvm.fi/en/-/taajuusasetuksen-muutos-lausuntokierrokselle-1255118 and https://www.lausuntopalvelu.fi/FI/Proposal/Participation?proposalId=3e971eba-ed71-49a7-ab65-3446fd3e85ae

156 See https://en.arcep.fr/news/press-releases/p/n/5g-6.html

157 See also https://www.commsupdate.com/articles/2020/10/09/orange-france-planning-to-launch-5g-services-in-december/

Country	Status of 26GHz award for 5G
Germany	• BNetzA made the entire 24.25–27.5GHz band available for local licences from 1 January 2021[158] [See section 3 for details]
Greece	• In December 2020, the 26.5–27.5GHz range was auctioned on a nationwide basis, with licences valid for 15 years[159] [See section 3 for details] • We understand that EETT has also set aside 200MHz of spectrum in the 26GHz band to be used free of charge for 12 months for research purposes (e.g. by universities and start-ups)[160]
Hungary	• In June 2019, the Hungarian Minister of Innovation and Technology made an announcement regarding 5G spectrum. News reports state that "according to the Minister, the first pilot 5G services should launch in Q3 2019, whilst 'high capacity services' using the 26GHz band are expected to be available from 2020 (including commercial 5G launches in industrial facilities – with dedicated frequencies reserved for industrial companies and institutions including universities, potentially in the 26GHz and 2300MHz bands)"[161] • However, in July 2019 a consultation revealed limited current market demand, meaning that award plans for the 26GHz band were put on hold[162] • In December 2019, NMHH published a document seeking input on a variety of award options[163]
Ireland	• Nineteen 2×28MHz blocks in the 26GHz band (24.745–25.277/25.753–26.285GHz) were auctioned (and sixteen sold) in June 2018.[164] The licences have a duration of 10 years, and are suitable only for point-to-point fixed-link use • Given other spectrum within the 24.25–27.5GHz range allocated for point-to-point fixed links and FWA, three blocks remain which could potentially be made available for 5G: Block A (26.453–27.5GHz, i.e. 1047MHz), Block B (25.445–25.613GHz, i.e. 168MHz) and Block C (24.25–24.605GHz, i.e. 355MHz) • In January 2021, ComReg published a study on the 26GHz band, and opened a consultation on the study's recommendations.[165] The recommendations include: (1) 26.5–27.5GHz (i.e. within Block A) should be awarded on a local-licensing basis, either on a frequency/area basis or using an individual small-cell approach. Timing for award could be from 2023 to 2027, depending on type of award used; (2) 24.25–24.5GHz (i.e. within Block C) should be made available using a light-licensing approach; award could be from 2022 to 2023, subject to demand

158 See https://www.bundesnetzagentur.de/DE/Sachgebiete/Telekommunikation/Unternehmen_Institutionen/Frequenzen/OeffentlicheNetze/LokaleNetze/lokalenetze-node.html

159 See https://www.eett.gr/opencms/opencms/admin/News_new/news_1353.html

160 See https://enterpriseiotinsights.com/20200930/channels/news/greece-reserves-5g-spectrum-and-auction-revenues-for-industrial-5g-research

161 See https://www.commsupdate.com/articles/2019/06/20/nmhh-issues-autumn-5g-auction-plan-minister-stresses-state-role-in-5g-rollouts/

162 Source: 'mmWave bands: global licensing and usage for 5G' (GSA, November 2020)

163 See https://nmhh.hu/dokumentum/208403/konzultacios_anyag_vezeteknelkuli_szelessav_12_03.pdf

164 See https://www.comreg.ie/industry/radio-spectrum/spectrum-awards/26-ghz-spectrum-award/

165 See https://www.comreg.ie/?dlm_download=information-notice-26-ghz-band-5g-study

Country	Status of 26GHz award for 5G
Italy	• In October 2018, the 26.5–27.5GHz range was auctioned on a nationwide basis, with licences valid until the end of 2037. A "club use" licensing approach applies: if spectrum is unused in a particular area, another licensee has the right to use it[166] [See section 3 for details]
Latvia	• We are not aware of any recent announcements from the Latvian NRA regarding the assignment of 26GHz • In February 2021, the RSPG published a document stating that there is currently no clear market demand for 26GHz spectrum, but that 1GHz of the band is available for testing. The document also states that a public consultation is planned for 2021, and that an award is expected prior to 2024 (subject to the results of the consultation)[167]
Lithuania	• A consultation on the 26GHz was completed in January 2020. RRT proposed to make 1200MHz available for 5G in the 26.3–27.5GHz band (in 200MHz blocks)[168] • In November 2020, RRT said that an award of spectrum in the 26GHz band would take place when it is clear that there is market demand[169]
Luxembourg	• A consultation on the 26GHz band was completed in December 2020 to ascertain the level of demand and potential use cases[170] • In March 2021, the results of the consultation were announced. Feedback from nine stakeholders indicated that there is interest (in principle) in using the 26GHz band in the medium term, but that there is no immediate need for the spectrum. As a consequence, Luxembourg will not assign 26GHz licences until 'a later date'[171]
Malta	• In February 2021, MCA issued a consultation on the 700MHz, 3.6GHz and 26GHz bands, proposing an award structure and licence conditions. The consultation closed at the end of February 2021[172] • In April 2021, MCA issued a decision on the spectrum award. Six 200MHz lots within the 24.25–27.5GHz range will be made available (with a cap of 400MHz of contiguous spectrum per licensee); the remaining spectrum within the band will be reserved for future use[173] • We understand that the assignment process will begin if MCA receives an expression of interest for the spectrum. MCA will then issue a call for applications, and conduct an auction if demand exceeds supply. Pricing for the 26GHz band is yet to be determined. We understand that an award is expected before the end of 2021[174]

166 See https://www.itu.int/en/ITU-D/Regional-Presence/Europe/Documents/Events/2018/5G%20Greece/Session%202%20Mauro%20Martino%20New.pdf

167 See https://rspg-spectrum.eu/wp-content/uploads/2021/02/RSPG21-003final_state_of_play_5G.pdf

168 See https://www.rrt.lt/rrt-skelbia-viesaja-apklausa-del-5g-pletros-26-ghz-radijo-dazniu-juostoje/

169 See https://www.rrt.lt/en/rrt-shares-the-5g-development-plans-in-lithuania/

170 See https://assets.ilr.lu/frequences/Consultation/20201028_Bande-26GHz/20201028_Band-26GHz-Consultation.pdf

171 See https://smc.gouvernement.lu/fr/actualites/articles/2021/ResultatConsultation26GHZ.html

172 See https://www.mca.org.mt/articles/additional-spectrum-wireless-broadband-electronic-communications-services. See also https://www.mca.org.mt/initiatives/towards-5g

173 See https://www.mca.org.mt/spectrum?q=node/6634

174 See https://rspg-spectrum.eu/wp-content/uploads/2021/02/RSPG21-003final_state_of_play_5G.pdf

Country	Status of 26GHz award for 5G
Netherlands	• In March 2020, the Dutch Ministry of Economic Affairs and Climate ("the Ministry") completed a consultation on demand for the 26GHz band[175] • The consultation states that the Ministry intends to release the 26GHz band for mobile "in the coming years". The initial focus will be on the top 1GHz – given the uncertainty of demand and of compatible equipment, the Ministry notes that setting the right timeline for releasing spectrum is "challenging" – it is considering making the spectrum available for shared use, such as via local licences – it is unclear whether the best assignment mechanism for shared-use licences is via an auction or an administrative process • The Dutch government's website currently states that "the 3.5GHz and 26GHz bands will be allocated over the next few years".[176] The RSPG document states that the 26GHz band is expected to be awarded in 2021/2022[177]
Norway	• In its June 2019 consultation, Nkom states that, on the basis of low demand and a poorly developed ecosystem, etc., it considers it too early to award the 700MHz SDL, 1500MHz SDL or 26GHz bands in 2021. Indeed, the consultation states that "there is no basis for assigning these frequency bands in the next few years"[178] • As of December 2020, Nkom's website states that it expects to award the 26GHz band "at a later date" for regional/local/private 5G networks. Nkom invites input from stakeholders. Demand for the 26GHz band in Norway "has so far been low and Nkom has therefore chosen to wait to allocate the band"[179] • Nkom is currently issuing test licences in the 26GHz band where possible (e.g. Telenor in Kongsberg[180])
Poland	• In its 2018 consultation, UKE stated that the 24.3–26.6GHz range would be assigned to 5G services in the long term, but in the medium term the lower 26GHz band would be reconfigured allowing 1.4GHz in this range to be refarmed for 5G[181] • A further consultation on the 26GHz band was completed in September 2020. In response to the consultation, MNOs stated that they did not see a need for 26GHz spectrum before 2022/23[182]
Portugal	• In March 2020, news reports stated that the NRA had plans to run a consultation on the 26GHz band after the multi-band auction[183]

175 See https://www.internetconsultatie.nl/marktconsultatie26ghzband

176 See https://www.government.nl/topics/ict/plans-for-5g-and-testing-antennas

177 See https://rspg-spectrum.eu/wp-content/uploads/2021/02/RSPG21-003final_state_of_play_5G.pdf

178 See https://www.nkom.no/frekvenser-og-elektronisk-utstyr/frekvensauksjoner/tildeling-av-frekvenser-til-mobilkommunikasjon-og-5g#relatedDocs

179 See https://www.nkom.no/frekvenser-og-elektronisk-utstyr/frekvenser-til-mobilkommunikasjon-og-5g/frekvensressurser-til-regionale-lokale-private-nett

180 See https://halberdbastion.com/intelligence/mobile-networks/telenor-norge

181 See https://uke.gov.pl/en/newsroom/frequencies-for-5g-consultations-concerning-radio-spectrum-management,76.html

182 See https://bip.uke.gov.pl/konsultacje-i-wyniki-konsultacji/wyniki-konsultacji-w-sprawie-wykorzystania-pasma-26-ghz-oraz-innych-pasm-milimetrowych,1367.html

183 See https://eco.sapo.pt/2020/03/11/anacom-devera-fazer-novo-leilao-para-5g-ultrarrapido-em-2023/. See also https://rspg-spectrum.eu/wp-content/uploads/2021/02/RSPG21-003final_state_of_play_5G.pdf

Country	Status of 26GHz award for 5G
	• There has been speculation that a 26GHz auction would take place in 2023[184]
Romania	• In its 2018 "Strategy for 5G" paper, ANCOM stated that it plans to release, at a minimum, the upper 1GHz portion of the 26GHz band by 2021[185] • At the end of 2019, ANCOM published its 2020 action plan, including an action to issue a consultation to assess the level of demand for the 26GHz band.[186] Based on the consultation results, ANCOM said it would consider an assignment procedure for 26GHz spectrum in 2020 • However, to date no award has been scheduled. The 2021 action plan states that ANCOM plans to issue a consultation to decide on a timeline for award of spectrum above 24GHz[187]
Slovakia	• In June 2017, RU stated that it is likely that the upper 1GHz of the 26GHz band will be made available for 5G services but no details have since been provided • The RSPG document published in February 2021 states that there is currently no market demand, and an award is not expected to take place before 2023 (subject to negotiation with the military)[188]
Slovenia	• In April 2021, the 26.5–27.5GHz range was auctioned on a nationwide basis, with licences valid for 15 years[189] [See section 3 for details]
Spain	• In December 2020, the Spanish government approved a 5G Technology Boost Strategy which details a plan to allocate 26GHz spectrum by the end of 2021, starting with another public consultation.[190] In May 2021, reports confirmed plans for a forthcoming consultation with award by the end of 2021[191] • Pilot projects are currently authorised to use up to 1GHz at the top of the 26GHz band (e.g. pilots in Andalusia and Galicia)[192]
Sweden	In April 2020, PTS announced details of its plans for the 26GHz band[193] • 850MHz in the 24.25–25.1GHz range will be made available for 5G via local licences – assignment (via an administrative process) will take place no later than 2021. Until 2025, licences will be limited to indoor use only • 2400MHz in the 25.1–27.5GHz range will be made available for 5G via two types of licences:

184 See https://eco.sapo.pt/2020/03/11/anacom-devera-fazer-novo-leilao-para-5g-ultrarrapido-em-2023/

185 See http://www.ancom.org.ro/uploads/forms_files/Strategia_5G_pentru_Romania1542734913.pdf

186 See https://www.ancom.ro/en/action-plan_119

187 See https://www.ancom.ro/en/ancom-adopted-its-action-plan-for-2021-_6329

188 See https://rspg-spectrum.eu/wp-content/uploads/2021/02/RSPG21-003final_state_of_play_5G.pdf

189 See https://www.akos-rs.si/medijsko-sredisce/sporocila-za-javnost/novica/uspesno-zakljucena-javna-drazba-frekvenc-za-zagotavljanje-javnih-mobilnih-komunikacijskih-storitev

190 See https://portal.mineco.gob.es/RecursosArticulo/mineco/ministerio/ficheros/201202_Impulso_de_la_tecnolog%C3%ADa_5G.pdf

191 See https://pledgetimes.com/the-government-will-complete-the-5g-map-before-the-end-of-the-year/

192 See Resolucion SEAD (Bandas de Frecuencia).pdf available at https://www.red.es/redes/es/que-hacemos/pilotos-5g

193 See https://www.pts.se/sv/nyheter/radio/2020/pts-presenterar-inriktning-for-26-ghz-bandet/

Country	Status of 26GHz award for 5G
	– "block" licences for the country's major urban areas. These could be granted from 1 January 2025 in Stockholm, Gothenburg and Malmö and from 1 January 2026 in other major urban areas – "local" licences for area coverage outside major urban areas. These could be granted from 1 January 2026 • PTS expects to conduct further analysis of both the 26GHz and 28GHz bands in 2022 • PTS also intends to consider the timing of a potential auction (for block licences) or administrative assignment (for local licences), as well as licence conditions, etc. in 2022 In May 2021, PTS opened a consultation on awarding local 5G licences in the 24.25–25.1GHz range. The licences are intended for a variety of applications such as hospitals, warehousing, mines and ports. PTS plans to begin awarding licences later in 2021; the consultation closes in June 2021[194]
Switzerland	• Switzerland has not announced any plans regarding 26GHz
UK	• In July 2019, Ofcom announced that the lower 26GHz (24.25–26.5GHz) band would be made available (by the end of the year) for 5G through local "Shared Access" licences for indoor-only use[195] – licences are assigned via an administrative process on a per-location basis – licence holders can deploy multiple base stations within a radius of 50m without needing additional licences – an annual licence fee of GBP320 will apply for channels of 50MHz, 100MHz or 200MHz width • In its July 2019 announcement, Ofcom stated that it would "continue to work with the Ministry of Defence in the 26.5–27.5GHz [band]… so that this band can also be made available in the future. We will also consider how best to authorise other 5G uses across the full 26GHz band (such as for outdoor high-power mobile)" • Ofcom's plan of work for 2021/22 (published in March 2021) states that it intends to issue a consultation about the award of spectrum in the 26GHz band in Q3 2021/22[196]

194 See https://www.pts.se/sv/nyheter/radio/2021/pts-har-tagit-fram-forslag-till-villkor-for-lokala-5g-tillstand/

195 See https://www.ofcom.org.uk/consultations-and-statements/category-1/enabling-opportunities-for-innovation

196 See https://www.ofcom.org.uk/consultations-and-statements/category-2/plan-of-work-2021-22

Annex B Bibliography

Figure B.1 below provides a non-exhaustive selection of key mmWave reports and publications relevant to 5G 26GHz deployment in Europe, which have been reviewed as part of the study.

Figure B.1: mmWave report and materials reviewed as part of the study [Source: Analysys Mason, 2021]

Organisation	Report(s)
Analysys Mason	• 'Costs and benefits of 5G geographical coverage in Europe' (March 2021)[197] • '5G action plan review for Europe' (September 2020)[198] • Large range of reports and resources available on Analysys Mason's website
UK SPF	• 'A 7 point response to a DCMS request for industry advice on the high-level principles to be applied to the release of 5G pioneer band at 26 GHz' (August 2019)[199] • 'A report on the principles for the release of the 3rd 5G pioneer band at 26 GHz and shared access within the band.' (August 2019)[200]
Real Wireless	• '26 GHz -the opportunity for a fresh approach to licensing in higher frequencies' (January 2021)[201]
GSMA	• 'Is the use of mmWave in 5G cost effective?' (February 2021)[202] • 'The economics of mmWave 5G An assessment of total cost of ownership in the period to 2025' (January 2021)[203] • 'GSMA Europe 26 GHz Spectrum Policy Paper' (October 2020)[204] • 'Mobile Networks for Industry Verticals: Spectrum Best Practice – GSMA Public Policy Position' (May 2020)[205] • 'Regional Spotlights: Impact of mmWave 5G' (July 2019)[206] • 'Study on Socio-Economic Benefits of 5G Services Provided in mmWave Bands' (December 2018)[207]
GSA	• 'National Spectrum Positions 26–28 GHz Snapshot' (February 2021) and earlier snapshots/spectrum updates

197 See https://www.analysysmason.com/consulting-redirect/reports/filling-europes-5g-coverage-gaps/

198 See https://www.ericsson.com/4ab850/assets/local/about-ericsson/company-facts/europe/5g-action-plan-review-for-europe-executive-summary.pdf

199 See https://www.techuk.org/resource/uk-spf-publish-principles-for-the-release-of-26-ghz-5g-pioneer-band.html

200 See https://www.techuk.org/resource/uk-spf-publish-principles-for-the-release-of-26-ghz-5g-pioneer-band.html

201 See https://www.techuk.org/resource/a-new-approach-to-spectrum-licensing-the-26-ghz-band.html

202 See https://data.gsmaintelligence.com/api-web/v2/research-file-download?id=60620820&file=160221-mmWave-infographic.pdf

203 See https://data.gsmaintelligence.com/api-web/v2/research-file-download?id=59768858&file=210121-Economics-of-mmWave.pdf

204 See https://www.gsma.com/gsmaeurope/wp-content/uploads/2020/10/GSMA-Europe-26-GHz-Spectrum-Policy-Paper.pdf

205 See https://www.gsma.com/spectrum/resources/mobile-networks-for-verticals/

206 See https://www.gsma.com/spectrum/resources/mmwave-5g-benefits/

207 See https://www.gsma.com/spectrum/wp-content/uploads/2019/10/mmWave-5G-benefits.pdf

Organisation	Report(s)
	• 'mmWave bands: global licensing and usage for 5G' (November 2020) • GSA insight webinar: 'mmWave 5G in Europe' (February 2021)[208]
Qualcomm	• 'What's in the future of 5G millimeter wave?' (January 2021)[209] • 'Deploying mmWave to unleash 5G's full potential' (November 2020)[210] • Several other resources available at https://www.qualcomm.com/research/5g/5g-nr/mmwave
Ericsson	• 'Leveraging the potential of 5G millimeter wave' (2021)[211]
IDATE/Plum Consulting	• '26 GHz Band 5G Study - A study by Plum Consulting and IDATE regarding the future use of the 26 GHz Band' (January 2021)[212] • 'Study on using millimetre waves bands for the deployment of the 5G ecosystem in the Union' (October 2019)[213]
European 5G Observatory	• Quarterly reports and various tools and information (see https://5gobservatory.eu/)
EC	• 'Commission Recommendation on a common Union toolbox for reducing the cost of deploying very high capacity networks and ensuring timely and investment-friendly access to 5G radio spectrum' (September 2020)[214]
The European Round Table for Industry (ERT) and Global Counsel	• 'Assessment of 5G Deployment Status in Europe' (September 2020)[215]
SiGNALS Research Group	• 'All things 5G NR mmWave - An update on 5G NR millimeter wave (mmWave) network performance and new use cases' (January 2021)[216]
5G Americas	• 'Understanding Millimeter Wave Spectrum for 5G Networks' (December 2020)[217]
China Mobile	• 'The Next Journey for 5G--The Standardization and Application of mmWave' (September 2020)[218]

208 See https://gsacom.com/webinar/mmwave-5g-in-europe/

209 See https://www.qualcomm.com/media/documents/files/what-s-in-the-future-of-5g-millimeter-wave.pdf

210 See https://www.qualcomm.com/media/documents/files/deploying-mmwave-to-unleash-5g-s-full-potential.pdf

211 See https://www.ericsson.com/en/reports-and-papers/further-insights/leveraging-the-potential-of-5g-millimeter-wave

212 See https://www.comreg.ie/publication/26-ghz-band-5g-study

213 See https://www.bruegel.org/wp-content/uploads/2019/10/KK0319410ENN.en_.pdf

214 See https://ec.europa.eu/digital-single-market/en/news/commission-recommendation-common-union-toolbox-reducing-cost-deploying-very-high-capacity

215 See https://ert.eu/documents/5g-assessment/

216 See https://gsacom.com/paper/all-things-5g-nr-mmwave-signals-research-group-whitepaper/

217 See https://www.5gamericas.org/understanding-millimeter-wave-spectrum-for-5g-networks/

218 See https://www.gsma.com/greater-china/wp-content/uploads/2020/09/%E6%AF%AB%E7%B1%B3%E6%B3%A2%E6%A0%87%E5%87%86%E5%8C%96%E5%92%8C%E8%AF%95%E9%AA%8C%E8%BF%9B%E5%B1%95_%E4%B8%AD%E5%9B%BD%E7%A7%BB%E5%8A%A8_%E6%9D%8E%E7%94%B7-1.pdf