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FINAL REPORT FOR CTIA

GLOBAL RACE TO 5G – UPDATE

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Contents

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1 Executive summary

Since Analysys Mason's first 'Global Race to 5G' report was published in April 2018, the pace of 5G developments has continued to be rapid. Several countries now have commercial 5G services in place (although limited to certain subscribers, or specific geographical areas initially). As we describe in this report, by 2020 we expect to see around 80 operators in more than 40 countries worldwide having made 5G services available to their subscribers. 5G device availability is expected to expand rapidly in the remainder of 2019. Operators are working with industrial partners to develop 5G services for specific industries, as well as offering 5G mobile broadband (offering faster speeds and quicker response times) to consumers.

Key findings

Our overall conclusion is that the countries ranked highest in our previous report are still positioned as 5G leaders in 2019. In the top tier of countries, the US has moved up to a tie with China as the leading nations in our '5G readiness' assessment, scoring higher than other nations on most of our metrics. South Korea and Japan follow closely behind China and the US. The US rise in the ranking reflects determined moves by the US operators to follow through 5G commercialization commitments with the launch of 5G services in 2018, aided by significant infrastructure reforms (e.g. in relation to small-cell siting) in the past year and initial 5G spectrum auctions. However, there is still more to be done to ensure that the US retains its leading position, and we have found that a key short-term goal for the US to maintain its leading position is improving the availability of mid-band spectrum.

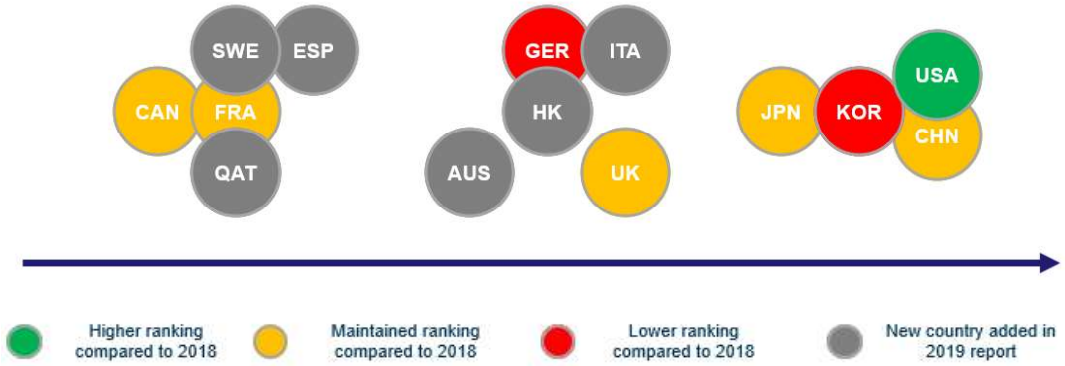
The second and third tiers of countries that we reported on last time have expanded to include a larger number of countries in our latest report. Several European nations are leading the second tier and could overtake some of the countries in the leading tier (e.g. Japan) during 2019.

The overall placing of countries is illustrated below.

Figure 1.1: Overall 5G readiness scores [Source: Analysys Mason, 2019]

Compared to the 2018 rankings, six countries have either maintained or improved their rankings, as shown below.

Figure 1.2: Overall 5G readiness scores 2019, color coded by change in ranking[1] since 2018 [Source: Analysys Mason, 2019]



A summary of other conclusions from the study is as follows:

Mid-band spectrum will be important for early 5G deployments and a critical building block for 5G services	Many of the planned 5G commercial launches referred to in our report will use mid-band spectrum, particularly in the 3GHz band. Many of the 5G devices becoming available in 2019 are expected to support this frequency range. The US has previously lagged behind other nations in terms of the amount of mid-band spectrum being released for 5G use. Whilst there has been significant progress in the US on other important aspects of 5G launch, such as reform of infrastructure planning procedures (e.g. in relation to small-cell siting), there is still more to be done to ensure that the US retains its leading position through better availability of mid-band spectrum, which is a key short-term goal.

Since the first edition of this report was published in 2018, the 5G market has continued to develop rapidly, with many operators preparing to launch services and several launches already announced	When our first report was published in 2018, we identified 5G pre-commercial trials being underway in the leading 5G markets. Since then, there has been rapid progress toward commercial deployment and service launch. The early commercial launches that we identified in last year's report have now occurred, and the 5G market is continuing to move rapidly from test/trials to large-scale pilots and commercial launches. Release 15-compatible RAN equipment is widely available and more 5G smartphones are expected to emerge during the second half of this year, which will allow consumers to use 5G networks from mobile devices.

[1] This is the change in ranking within the group of eight countries that have been assessed in both the 2018 and 2019 reports.

Actions being taken by national governments to encourage 5G deployment include reform of siting policies and license fees	Several case studies are identified in this report highlighting the importance of government policies to reduce or eliminate burdens on 5G deployment. In the US, federal and state policymakers have been instrumental in easing barriers to small-cell deployment. Examples of approaches in other markets include China waiving the standard per-MHz fee for spectrum for 5G licenses in the initial years, and a focus on reducing barriers to mobile deployment in the UK.

Enhanced mobile broadband (eMBB) and fixed wireless access have emerged as the initial 5G use cases	Early 5G services are predominantly eMBB and FWA; however, the service mix should increase as 5G evolves into the next phase of specifications anticipated in 3GPP Release 16. Several operators have announced collaborations with vendors and industry players to test the use of 5G in different industrial sectors, as described in this report, and hence vertical uses are expected to remain an important element of 5G services, as networks become more sophisticated beyond initial launch. In some markets, there have been proposals to reserve specific spectrum for 5G industrial use, however there is a need for regulators to consider such schemes carefully, including whether they are applicable or appropriate to specific bands.

Spectrum focus for 5G remains on the mid-band frequencies and on mm-wave bands	As identified in the first edition of this report, worldwide focus on 5G deployment has been on mid-band spectrum (mainly 3.4–4.2GHz), along with selected bands above 24GHz. Each of these bands has been included in 3GPP Release 15 specifications, and 5G handset availability is expected to improve in 2019 both for 3.4–3.8GHz and 28GHz (with 26GHz following thereafter). The US is leading other nations with the award of mm-wave spectrum for 5G use and it is expected that other countries will follow this lead, pending the outcome of WRC-19 (where worldwide discussion on mm-wave spectrum for 5G will take place).

2 Introduction and context for the study

This report is the latest in a series of reports prepared by Analysys Mason on behalf of CTIA comparing spectrum and infrastructure policies and deployments in markets worldwide for the latest generation of mobile services, referred to as Fifth Generation, or 5G.[2] The first 'Global Race to 5G' report that Analysys Mason prepared for CTIA was published in April 2018.[3] This report provides an update to the 2018 report, based on new analysis taking account of 5G developments since the previous report was produced.

Since the first edition of the 'Global Race to 5G' report was published in April 2018, there has been significant progress in 5G readiness – moving from 5G technology trials to deployment and commercial launch – with mobile operators in several world markets announcing 5G launches during the second half of 2018: South Korea, Qatar, Finland, Estonia, and the US. Many more operators are currently working on 5G deployment, ahead of further commercial launches being announced in 2019/2020. 5G launches have taken place so far in mid-band spectrum (e.g. 3.5GHz), and in high-band spectrum (e.g. 28GHz), with vendors having unveiled 5G equipment for these bands in 2018 ahead of equipment leveraging other bands becoming available during 2019.

As we describe in the remainder of this report, by 2020 we expect to see around 80 operators in more than 40 countries worldwide having made 5G services available to their subscribers.

At the time of producing this report, 5G services being launched are based on either home internet use or nomadic use via 5G routers, with some mobile 5G offerings. Most of the services being offered can be described as 'enhanced mobile broadband' (eMBB), offering higher speed mobile broadband services either for enterprise or consumer use.[4] Several vendors have already announced the launch of 5G smartphones during 2019, and further launches are expected in the remainder of this year.[5]

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2 CTIA is the leading trade association for the wireless industry in the US, representing companies reflecting all parts of the wireless ecosystem, including mobile network operators, equipment manufacturers, software providers, and other providers of products and services involved in the mobile wireless marketplace.

3 https://www.ctia.org/the-wireless-industry/the-race-to-5g

4 The ITU-R has defined three categories of 5G use cases:

(1) Enhanced mobile broadband (eMBB) – an evolution of existing 3G and 4G consumer MBB services, to provide significantly higher throughput, capacity and performance.

(2) 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.

(3) Ultra-reliable low-latency communications (uRLLC) – this refers to the capabilities of 5G enabling extremely low latency for applications and services (such as critical infrastructures and emergency services), with the possibility of 5G technology achieving a latency of no more than a few milliseconds for the connections between devices and applications servers.

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

5 In August 2018, Lenovo (Motorola) was the first major manufacturer to announce a 5G capable smartphone – the Moto Z3. The Moto Z3 is made 5G capable using a separate 5G modem module (the 5G Moto Mod) which is magnetically attached to the smartphone. The 5G Moto Mod is scheduled for shipment in "early 2019". More recently, in February 2019, Samsung, Huawei, LG, and Xiaomi have each launched 5G smartphones (the Samsung S10, Huawei Mate X,

Governments worldwide are continuing to take account of the race to 5G in their policy making, and there have been developments in several markets aimed at easing wireless infrastructure deployment by reforming siting policies to be suitable for the 5G era. 5G spectrum assignment has also progressed during 2018 with regulators in Italy, Spain, the UK, US, South Korea, and Australia having completed auctions of spectrum suitable for 5G deployment. As described in the first edition of the 'Global Race to 5G' report, worldwide focus on spectrum for 5G remains in mid-band spectrum (from around 3.3–4.2GHz) and in higher, millimeter-wave (mm-wave) bands (principally 24.25–29.5GHz). Low-band spectrum, such as the 600MHz and 700MHz bands, is also expected to play a key role globally in providing wider-area coverage for 5G services.

The industry equipment standards group, 3GPP, is now entering the second phase of 5G specifications ('3GPP Release 16'), the first stage of which is expected to be complete by March 2020, having largely completed the initial phase ('3GPP Release 15' specifications) in 2018. With 3GPP Release 16 expected to expand on 5G capabilities in both the radio and core components of mobile networks, further service opportunities will emerge as 5G networks become essential components of the connected digital opportunities that are widely foreseen over the next decade.

Given the rapid pace of 5G developments, CTIA commissioned Analysys Mason to update its first 'Global Race to 5G' report, to produce this second edition. As with the first report, the key objective has been to investigate 5G readiness in different world markets, and to contrast the different spectrum and infrastructure policies and approaches being proposed toward 5G launch and service evolution.

2.1 Summary of study objectives and approach

As with the previous report, the objectives of this study were twofold:

- To investigate actions taking place in markets worldwide, including the US, regarding the commercialization of 5G, including actions by operators, regulators and policy makers toward early 5G launch and service evolution.
- To compare what is happening on 5G in the US to other markets in terms of 'readiness' for 5G commercial launch, to produce an overall comparison of markets ranked according to a series of metrics defined for this study.

Compared to the first report, we have expanded the number of markets included in our analysis, with our research covering fourteen markets where significant 5G deployments are being planned or have taken place: Australia, Canada, China, France, Germany, Hong Kong, Italy, Japan, Qatar, South Korea, Spain, Sweden, the UK, and the US (referred to as the 'benchmark countries').

For each market, we have reviewed preparations for 5G spectrum awards compared to the previous report in 2018 (for markets included in the 2018 report) and identified key progress. We have also

LG V50 THINQ and Xiaomi Mi Mix 3 respectively). The smartphones are scheduled to be made commercially available later in 2019. Further details are provided in Section 3.2.

investigated specific policies being proposed in different markets to facilitate new mobile infrastructure deployment or to promote 5G technological development (including government funded and/or cross-industry trials aimed at validating new 5G use cases). We have also assessed what operators in different markets have announced with respect to 5G launch, to establish an overview of 5G launches expected in 2019, 2020, and beyond. Finally, considerations about spectrum, infrastructure, and 5G commercial launch have been combined to produce an overall assessment of '5G readiness'. We have updated the metrics used to assess 5G readiness in our first report to reflect progress on 5G developments during 2018 from trial to deployment/launch. The metrics we use to compare 5G readiness between different markets in the remainder of this report are as follows:

- **Industry commitment** (trials, pilots and commercial launches).
- **Amount and timeline of low-band spectrum** – this refers to the amount of mobile spectrum in the market below 3GHz, in bands identified for mobile ('International mobile telecommunications'[6]).
- **Amount and timeline of mid-band spectrum**, which refers to the amount of mobile spectrum assigned in bands allocated for primary mobile use, from 3–24GHz.
- **Amount and timeline of high-band spectrum**, which refers to the amount of mobile spectrum in mm-wave bands, above 24GHz.
- **Total mobile spectrum release** – this metric considers the total mobile spectrum available to mobile operators in each market, including spectrum assigned for previous mobile generations, and new spectrum already awarded for 5G.
- **Government support for 5G** (including pro-5G infrastructure policy).

As before, our analysis and conclusions reflect progress toward 5G launches taking place around the world at the time of producing this report and are based on comparison between countries in accordance with the metrics identified in the report. It is noted that other inherent factors within the wireless market – such as in relation to supply-side changes or changing priorities within planned network deployments – could influence the outcomes identified.

2.2 Structure of this report

The remainder of this document is laid out as follows:

- Section 3 discusses industry developments and 5G commercial launches
- Section 4 considers spectrum releases for 5G in low, mid and high bands
- Section 5 describes national strategies and government support for 5G, including revised mobile infrastructure policies and other pro-5G strategies

6 International mobile telecommunications or IMT is the ITU's term for public mobile services and the associated spectrum used

- Section 6 assesses the overall '5G readiness' of the benchmark countries, contrasting readiness against six key metrics that we have identified
- Section 7 provides our conclusions and recommendations.

The report includes two annexes containing supplementary material:

- Annex A summarizes the abbreviations used in the report
- Annex B provides 5G case studies for each of the benchmark countries.

3 Industry developments and 5G launches

Since the 2018 edition of this report, details of trials that mobile operators have been working on with vendors and industry (vertical) players have been publicized. Several early 5G commercial launches have occurred – notably in the US and in South Korea. Some early network launches are using proprietary 5G technology, whereas other network operators are opting to wait for 3GPP Release 15 equipment and devices to be available before launching commercial 5G services.

As we move forward through 2019, it is expected that more operators will progress from 5G technology trials to 3GPP Release 15-compliant commercial deployment, and 5G launch. In this section, we discuss industry progress toward 5G launch. This analysis covers the first metric in our 5G readiness assessment, 'Industry commitment (trials, pilots and commercial launch)'.

3.1 5G trials and commercial launches

5G trials and pre-commercial deployment are continuing to accelerate around the world as operators aim to reach full service launch with 5G networks. Several vendors are expected to launch 5G devices during 2019.[7] The availability of 3GPP-compliant devices is expected to boost the number of full commercial deployments of 5G over the remainder of 2019 and in 2020.

A report[8] published in February 2019 identified 201 operators in 83 countries that are actively investing in 5G (i.e. that have demonstrated, are testing or trialing,[9] or have been licensed to conduct field trials of 5G technologies, are deploying 5G new radio (NR) technology in their networks or have announced full service launches[10]). These countries are shown in Figure 3.1 below.

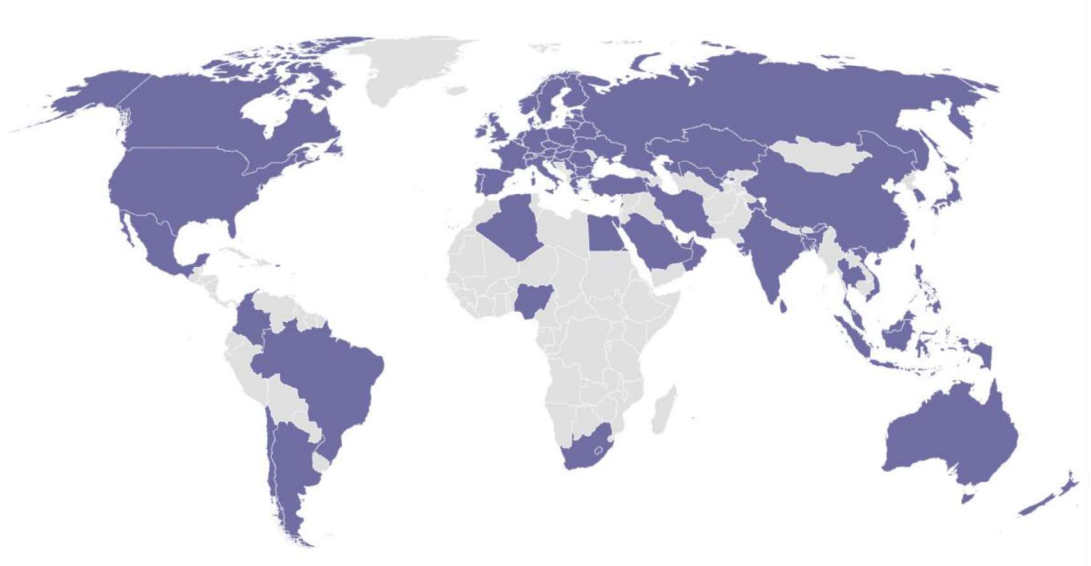
7 A number of vendors have now officially unveiled 5G smartphone models, which are scheduled to be made available later in 2019. A number of other vendors are also expected to launch 5G smartphones later in 2019. Further details are provided in Section 3.2.

8 "Global Progress to 5G - Trials, Deployments and Launches", published by the GSA in February 2018. See https://gsacom.com/

9 The GSA's definition of 5G trials excludes (where available data permits) trials of massive MIMO technologies that do not offer at least 64 transmit channels at the base station. The GSA states: "Such lower order MIMO trials with 8, 16 or 32 transmit channels (sometimes claimed by operators as pre-5G or 5G technologies), or where the MIMO order is not revealed, are now counted in GSA figures as LTE-Advanced or LTE-Advanced Pro trials as appropriate, unless the tests have other characteristics that would make them intrinsically 5G (such as use of new very high spectral frequencies or NR approaches)".

10 A commercial launch is defined as a service that is available to consumers (either using proprietary or 3GPP-compliant devices). Operators that have switched on 5G-NR at base station sites or are conducting 'live' trials with selected users (but without selling 5G subscriptions to consumers) are not classified as having achieved commercial launch.

Figure 3.1: Countries with operators investing in 5G [Source: GSA, February 2019. Powered by Bing © GeoNames, HERE, MSFT, Wikipedia]



The GSA has identified over 560 separate 5G demonstrations, technology tests, or live pre-commercial trials, across operators globally;[11] this excludes trials being run by vendors independently of MNOs. Almost all the nationwide MNOs in our group of benchmark countries have now announced extensive 5G trials, as a precursor to full service launch.[12] The report therefore focuses exclusively on these pre-commercial developments and commercial launch plans.

Several MNOs in the benchmark countries have now launched 5G services commercially. These are:

- **Verizon in the US**. On October 1, 2018, Verizon launched a commercial mm-wave (28GHz and 39GHz) 5G FWA service ('Verizon 5G Home') in parts of Sacramento, Houston, Indianapolis, and Los Angeles. The service is based on Verizon's own proprietary standard '5G TF' (Technical Forum), but will be upgraded to 3GPP standards once equipment becomes available.

- **AT&T in the US**. On December 21, 2018, AT&T commercially launched a 3GPP-compliant mobile 5G service, using 39GHz spectrum, in (parts of) 12 cities: Atlanta; Charlotte (NC), Dallas, Houston, Indianapolis, Jacksonville (FL), Louisville (KY), Oklahoma City, New Orleans, Raleigh (NC), San Antonio, and Waco (TX). The service is available with AT&T's NETGEAR Nighthawk mobile hotspot device.

- **SKT, KT, and LGU+ in South Korea**. On December 1, 2018, South Korea's three MNOs launched commercial 5G FWA services (based on 3GPP NR standards) using spectrum in the

11 As of February 2019.

12 These trials were detailed in our previous report, but many others have since been announced. Various resources are available which track 5G trials. For example, the European 5G Observatory tracks "trials, pilot tests, pre-commercial and commercial launches of 5G based services… around the globe". See https://5gobservatory.eu/5g-trial/

3420–3700MHz range. The MNOs launched services at the same time in specific locations across the country; services are limited to enterprise customers only.

Further information on these early 5G launches can be found in Annex A.

Several[13] other operators, not included in our group of benchmark countries, have also announced commercial 5G network launches. For example, MNO Etisalat (UAE) announced[14] in May 2018 that it had launched a commercial 5G FWA service, and Finnish/Estonian MNO Elisa announced[15] in June 2018 that it had launched a commercial 5G network (in Tampere in Finland and Tallinn in Estonia) and begun selling 5G subscriptions.[16]

In a number of other announced deployments, operators have stated that they have switched on 'commercial' 5G base stations, but are waiting for compatible devices to be available on the market to enable the offer of mobile services to consumers (device availability is discussed in Section 3.2 below). One of the earliest such announcements came from mobile operator Ooredoo, who announced in May 2018 that its first live 5G site had been switched on in Qatar ahead of mobile devices becoming available. In other cases, operators have used test licenses to deploy some form of limited service, but commercial services must wait until full licenses have been assigned. Finally, many other operators have announced pre-commercial 5G pilots. Most of the benchmark countries are in one of these categories.

The number of operators announcing schedules for the commercial introduction of 5G services is expected to rise substantially in the next year to 18 months or so as the first 5G-capable FWA devices and smartphones start to emerge (see Section 3.2). Launch dates and plans for commercial 5G services announced by operators in the benchmark countries are shown in Figure 3.2 below.

13 In addition to the examples of Elisa and Etisalat provided, the GSA also lists a number of other commercial 5G launches (for examples Vodacom in Lesotho).

14 On May 14, 2018, Etisalat announced that 5G FWA services "will be provided in select locations in UAE" with "commercial fixed devices and services… available for consumers starting from September this year [i.e. 2018]". See https://www.etisalat.ae/en/about-us/media_center/press_releases/etisalat_launches_first_commercial_5g_network_in_the_mena.jsp

15 Although the GSA classifies this as a commercial launch, at the time of the announcement only test spectrum licenses were available. FICORA, the regulator in Finland, has since auctioned spectrum in the 3.4–3.8GHz band. On October 1, 2018, Elisa stated that the spectrum it won at auction would "be in commercial use in Finland on 1 January 2019. The first commercial 5G devices are expected in the markets during 2019". See:

https://corporate.elisa.com/news-room/press-releases/elisa-press-release/?id=74816483692765&tag=corporate.elisa.com%3Apress and https://corporate.elisa.com/news-room/press-releases/elisa-press-release/?id=91355757317710&tag=corporate.elisa.com%3Apress

16 In all these cases, it should be noted that the services being provided are available in defined (mostly urban) locations only. In some cases, the 'commercial' 5G service is limited to certain users only, or to specific device types (e.g. restricted to a certain customer base or not using 3GPP-compliant equipment or devices). Nevertheless, in the services outlined above, we understand that the operators have both confirmed availability of devices and the provision of services to some commercial customers.

Figure 3.2: Commercial 5G launch plans of nationwide MNOs in benchmark countries [Source: GSA[17] and MNO announcements, see Annex A for further details and sources]

Country	MNO	5G commercial launch date	Overview of 5G launch plans
Australia	Telstra	H1 2019	Telstra has announced that its 5G roll-out will target major cities and regional centers and that its first 5G services will be launched in H1 2019
	Optus	H1 2019	5G FWA services to be launched in several locations in H1 2019
	VHA	N/d	5G commercial deployment date not yet publicly announced
Canada	Rogers	2020	Currently upgrading network with 5G-NR technology "to be ready for 5G commercial deployment in 2020"
	Bell	N/d	5G commercial deployment date not yet publicly announced
	Telus	2020	Telus has been testing 5G FWA services, and has stated it expects the technology to become commercially available from 2020
China	China Mobile	2020	China Mobile will "launch 5G smartphones in the first half of 2019, as part of the push for 5G pre-commercial trials in 2019 and commercialization by 2020"
	China Unicom	2020	China Unicom is aiming for "pre-commercial 5G network deployment in 2019 and large-scale deployment in 2020"
	China Telecom	2020	China Telecom is "commencing pre-commercialization of 5G technology in 2019", while commercial launch is targeted for 2020
France	Orange	2020	Orange Group has stated that "5G… will be installed in 17 European cities [including France and Spain] in 2019 and ready for commercial release in 2020, so long as enough 5G smartphones are available". We understand that customers in the 17 cities will be able to subscribe to 5G services in 2019
	SFR	2020	SFR has begun conducting live 5G trials in Nantes, and stated it expects commercial services to be available in 2021. Other recent reports have indicated that SFR is aiming to launch commercial services in 2020
	Bouygues	2020	Bouygues is currently preparing to deploy its 5G network, "which will be marketed in 2020"
	Free	N/d	5G commercial deployment plans not yet publicly announced
Germany	Telefonica	2020	5G commercial deployment date not yet publicly announced. However, reports have indicated that launch is likely to take place in 2020
	Vodafone	2020	Vodafone aims to make 5G services available to customers from 2020

17 There may be discrepancies with the details reported by the GSA, due to our own analysis of operator press releases and news reports.

Country	MNO	5G commercial launch date	Overview of 5G launch plans
	DT	2020	In October 2018, DT stated that it would launch commercial 5G operations in 2020, as long as enough commercial devices are available
Hong Kong	HKT	2020	These MNOs have not yet publicly announced 5G commercial deployment dates. However, a general timeframe of 2020 (at the earliest) has been referenced, in agreement with government announcements and spectrum availability
	SmarTone		
	Three		
	CMHK	2019	CMHK has stated that when 5G spectrum is released (2019–2020), it "will be ready to provide full services to users". CMHK notes that since 5G smartphones will not be available until H2 2019, the earliest services would be FWA
Italy	TIM	2020	TIM has installed a live 5G site in San Marino ahead of full commercial launch
	Vodafone	2019	A network in Milan has been deployed for testing, however since 5G devices are not yet commercially available, a full service has not been launched. Vodafone plans to add 5G networks in Turin, Bologna, Naples, and Rome during 2019
	Wind Tre	2019	Wind Tre expects the "first parts of the country" to see 5G deployment by end-2019, but 5G devices would not be available to the mass market until 2020 or 2021
	Iliad	N/d	5G commercial deployment date not yet publicly announced
Japan	NTT DOCOMO	2020	NTT DOCOMO plans to launch pre-commercial 5G services in September 2019 and aims to launch commercial 5G services across Japan by mid-2020
	KDDI	2020	KDDI "plans to offer a limited range of 5G-based services in 2019, before a full-fledged 5G launch in 2020"
	Softbank	2019	Softbank "plans to begin with a limited commercial deployment in 2019 and then deploy a full 5G service for smartphones in 2020"
	Rakuten	2020	Rakuten plans to launch commercial mobile services in October 2019. Services will initially be 4G only; it plans to launch 5G in early 2020
Qatar	Ooredoo	2019	Ooredoo has stated that a number of its sites are 5G ready, but it does not expect 5G mobile handsets to be available until mid-2019. Ooredoo is developing a 5G FWA device and has said that a number of locations will be connected with the device by "the end of the desert season in 2019"
	Vodafone	2019	Like Ooredoo, Vodafone has announced commercial 5G launch, but notes that 5G devices are not expected to be available until later in 2019. It announced its first 5G FWA "commercially connected" customer on December 31, 2018
S. Korea	SKT	Launched	Each of South Korea's three MNOs launched 5G FWA services (limited to enterprise customers only) on
	KT		

Country	MNO	5G commercial launch date	Overview of 5G launch plans
	LGU+		December 1, 2018. Full (mobile) commercial 5G launch for regular consumers is scheduled for March 2019, once 5G smartphones are available
Spain	Vodafone	N/d	5G commercial launch date not yet publicly announced. However, Vodafone has launched 5G trials in six Spanish cities
	Telefonica	N/d	Telefonica has launched 5G pilots in two Spanish cities, but reports indicate that the operator will not launch services before 2020
	Orange	2019	Orange Group has stated that "5G… will be installed in 17 European cities [including France and Spain] in 2019 and ready for commercial release in 2020, so long as enough 5G smartphones are available". We understand that customers in the 17 cities will be able to experience 5G services in 2019[18]
	Mas Movil	N/d	5G commercial deployment date not yet publicly announced
Sweden	Telia	2020	Telia is aiming for "a commercial launch of 5G in Sweden in 2020"
	Telenor	2020	Tele2 and Telenor have signed an agreement on deploying a joint nationwide 5G network. They aim to "give the first customers access to 5G by 2020"
	Tele2		
	Tre	N/d	5G commercial deployment date not yet publicly announced
UK	O2	N/d	O2 has confirmed that it will not roll out a commercial 5G deployment before 2020
	BT/EE	2019	BT/EE aims to upgrade 1500 sites to 5G in 2019, and to launch both mobile and FWA 5G services within a 2019–2020 timeframe
	Vodafone	2019	Vodafone aims to provide multiple cities in the UK with 5G coverage during 2019, and 1,000 5G sites by 2020
	Three UK	2019	Three has noted that the first commercial 5G devices are expected in H2 2019. It has not stated plans for launching 5G FWA services, but commissioned a report on the technology which was published in November 2018
US[19]	AT&T	Launched	In December 2018, AT&T launched a commercial 5G mobile service (using mm-wave spectrum) in parts of 12 cities using a mobile hotspot device. AT&T aims to offer nationwide mobile 5G services by early 2020. AT&T also aims to offer 5G FWA services
	Sprint	2019	Sprint has named a list of nine cities in which it aims to launch commercial 5G services in H1 2019

18 We have assigned Orange Spain an expected launch date of 2019, but Orange France a launch date of 2020. This reflects an emphasis on 5G in Spain in Orange's press releases.

19 US Cellular (the fifth largest MNO in the US market, currently operating in 23 states) announced in February 2018 that it aims to provide 5G services to its customers in the second half of 2019. See https://www.uscellular.com/about/press-room/2019/USCellular-selects-Ericsson-for-5G-deployments.html

Country	MNO	5G commercial launch date	Overview of 5G launch plans
	T-Mobile	2019	T-Mobile has named 30 cities which will be among the first to experience their 5G offering. T-Mobile is aiming to achieve nationwide 5G coverage by 2020
	Verizon	Launched	In October 2018, Verizon launched a commercial 5G FWA service in parts of certain cities, using proprietary standards. Verizon's 5G mobility service is scheduled to go live in certain cities in April 2019, and it aims to have launched in 30 cities by the end of 2019.

In summary, most MNOs in our benchmark countries are expected to launch commercial 5G services during 2019 and 2020. Many other MNOs globally are also expected to launch services over the coming years. Indeed, in February 2019 the GSA reported that 90 telecom operators in 48 countries have announced intentions of making 5G available to their customers before the end of 2021.[20]

Figure 3.3: Number of operators expected to launch commercial 5G services [Source: GSA,[21] March 2019]

Region	Already launched	Due to launch 2019	Due to launch 2020	Due to launch 2021	Testing/ trialing
Europe	2	18	20	5	21
Asia	6	10	13	2	29
North America	3	3	3	-	5
Rest of World	1	2	3	-	15
Total	**12**	**33**	**39**	**7**	**70**

Operators in our benchmark countries that are understood to be trialing or intending to launch 5G FWA services are shown in Figure 3.4 below.

Figure 3.4: Operators in benchmark countries planning or trialing 5G FWA services [Source: GSA and MNO announcements,[22] see Annex A for further details]

MNO	Country	5G FWA launch plans
Three	UK	Three has said that it will offer FWA when it launches 5G services in 2019. In November 2018, a report was published (commissioned by Three), entitled "5G Wireless Home Broadband: A Credible Alternative to Fixed Broadband", suggesting that 5G FWA could be a challenger to fixed line connections in the UK market
AT&T	US	AT&T has stated that its existing customers' FWA services would be upgradable to "take advantage of AT&T 5G when its available in their area"
CMHK	Hong Kong	CMHK has stated that when 5G spectrum is released [2019–2020], it "will be ready to provide full services to users". CMHK notes that since

20 "Global Progress to 5G - Trials, Deployments and Launches", published in February 2019. See https://gsacom.com/

21 For consistency, we have directly presented data here as reported by the GSA. Numbers are based on the GAMBoD database published in March 2019.

22 We note that the GSA lists DT (Germany) as planning an FWA service for 2019 and Vodafone (UK) as 'deploying or piloting' an FWA service. However, we have not been able to explicitly verify this based on MNO announcements.

MNO	Country	5G FWA launch plans
		5G smartphones will not be available until H2 2019, the earliest services would be FWA
BT/EE	UK	BT/EE aims to upgrade 1500 sites to 5G in 2019, and to launch both mobile and FWA 5G services in 2019. The MNO has selected sixteen UK cities where 5G sites will be deployed in 2019
KT	South Korea	FWA service launched (for enterprise customers only) in December 2018 (see above)
LGU+	South Korea	FWA service launched (for enterprise customers only) in December 2018 (see above)
Ooredoo	Qatar	Ooredoo has stated that "by end of the desert season in 2019, a host of the most popular desert locations will be connected with 5G Home Broadband [i.e. FWA] devices"
Optus	Australia	5G FWA services to be launched in a number of capital cities in H1 2019
SKT	South Korea	FWA service launched (for enterprise customers only) in December 2018 (see above)
Sprint	US	Sprint has announced that it is working with HTC to bring a "5G mobile smart hub" to the market in H1 2019. While this appears to be a mobile hotspot rather than an FWA device, Sprint has stated that it will serve "small households, apartment dwellers, [and] even small businesses" for primary internet access
Telefonica	Germany	In October 2018, Telefonica announced plans (with Samsung) to begin conducting 5G FWA trials. In February 2019, Telefonica confirmed that the trials (using spectrum in the 26GHz band) had been completed
Telstra	Australia	We are not aware of operator announcements regarding FWA, although Telstra has noted that "5G-capable smartphones are unlikely to hit the mainstream until late 2019 or early 2020, and in the meantime 5G will see use in other offerings such as fixed wireless". The GSA lists Telstra as planning an FWA service for 2020
Telus	Canada	Telus has been testing 5G FWA services, and has stated it expects the technology to become commercially available from 2020
T-Mobile	US	In April 2018, T-Mobile and Sprint announced that they had entered into an agreement to merge; the merger is currently being reviewed by regulators. T-Mobile has stated that the merged entity would offer "both in-home broadband services and mobile broadband". In particular, the merged entity would look to offer in-home broadband to 52% of zip codes across the US by 2024
Verizon	US	Service launched in October 2018 (see above)
Vodafone	Qatar	Vodafone announced its first 5G FWA "commercially connected" customer (Gulf Bridge International) on December 31, 2018

As discussed in our 2018 report, in addition to MNOs, several other participants in the value chain are conducting 5G trials and looking to launch 5G services using licensed spectrum. For example:

- In July 2017, UK telecom infrastructure company Arqiva announced[23] that it had launched Europe's first 5G FWA trial in central London with vendor Samsung, using existing fixed

23 See https://www.arqiva.com/news/press-releases/arqiva-and-samsung-kick-off-uks-first-5g-fixed-wireless-access-trial/. Plans for the trial were announced in February 2017: https://www.arqiva.com/news/press-releases/arqiva-and-

wireless licenses issued in the UK for the 28GHz band. In April 2018, Arqiva announced[24] a partnership with MNO O2 in to deploy 300 outdoor small cells across a central location in London. The deployment will use mm-wave spectrum; roll-out is scheduled to be completed in 2020.

- Dense Air, an operating company of the Airspan Group, acquired spectrum in the 3.4-3.8GHz band at auctions in both Ireland (2017) and Australia (2018). Dense Air aims to provide 'neutral host'[25] 4G and 5G services in densely populated areas, and it also holds spectrum for this purpose in Belgium, Portugal and New Zealand.

Trials and development of several industry-specific use cases are also underway. In October 2018, MNO Orange in Spain announced that it had selected seven cities for the testing of multiple 5G use cases, including connected cars, industrial automation, and virtual classrooms. MNO Telia in Finland is testing 5G technology in factory and vehicle automation, and remote-controlled machines. Competitive gaming (eSports) is also emerging as an early use case; Telia Finland is developing a 5G eSports service, and conducted a live trial at a public eSports event during 2018[26]. In South Korea, the three MNOs launched 5G FWA services to business customers in December 2018, with their first customers deliberately selected to showcase the applicability of 5G to various industry verticals:

- SKT's first customer was Myunghwa, an automotive-part company based in Banwol Industrial Complex, Ansan, Gyeonggi Province. Myunghwa used SKT's '5G-AI machine vision' solution to quality-check automotive parts from the production line.

- KT's first user was an AI-equipped robot called Lota.

- LGU+ has said that it expects to "adapt its 5G service for use in the remote controlling of heavy equipment and agricultural machines, drones, CCTV, smart factories and smart cities".[27] Its first 5G customer was tractor manufacturer LS Mtron.

3.2 Standardization progress and devices

As discussed in our previous report, 5G specifications are being defined by 3GPP. 3GPP unites various regional industry-based telecom standard development organizations from around the world

samsung-to-undertake-first-5g-fixed-wireless-access-trial-in-the-uk/. In July 2017, Arqiva announced the acquisition of a 2×112MHz license in the 28GHz band for Central and Greater London.

24 See https://www.arqiva.com/news/press-releases/arqiva-and-o2-to-improve-mobile-connectivity-in-london-boroughs/

25 'Neutral hosts' are third party (non-MNO) players, which then sell capacity on a wholesale basis to MNOs, allowing them to offload traffic from their macro networks in particular (congested) locations. For another example neutral-host 5G, see http://www.wirelessinfrastructure.co.uk/wig-raises-220m-to-accelerate-investment-into-new-neutral-host-wireless-infrastructure/

26 See https://www.teliacompany.com/en/news/news-articles/2018/telia-puts-5g-to-the-test-at-public-esports-event/

27 See Annex B.10.3 for link to source.

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).[28]

The first phase of the evolution to 5G in 3GPP's specifications was defined within the 3GPP Release 15 specifications (R15 in the diagram below). The first stage of the Release 15 specifications was finalized[29] by 3GPP in December 2017 and defined the 5G new radio (NR) 'non-standalone' (NSA) configuration[30] for enhanced mobile broadband (eMBB). The second stage of Release 15 specifications was finalized[31] by 3GPP in June 2018 and defined a 5G NR standalone (SA) configuration for 5G eMBB use. As well as defining the 5G-NR technology for the 5G air interface, the Release 15 specifications also define the first phase of a virtualized core network for mobile services. As such, the 3GPP specifications that are now in place allow for chipset makers and equipment vendors to produce the network equipment and devices needed for the commercialization of 5G mobile services.

A subsequent Release 16 of the 3GPP specifications (R16) will update the 5G specifications, expanding on the service-based architecture for the 5G core network and broadening the supported use cases beyond eMBB to cover the full range of envisaged 5G applications (including IoT and ultra-reliable, low latency applications).[32] The first stage of the Release 16 specifications is due to be completed by March 2020.[33]

Figure 3.5 below shows key ITU and 3GPP milestones (completed and planned) regarding the development of 5G.

28 See http://www.3gpp.org/about-3gpp

29 See http://www.3gpp.org/news-events/3gpp-news/1934-nr_verticals

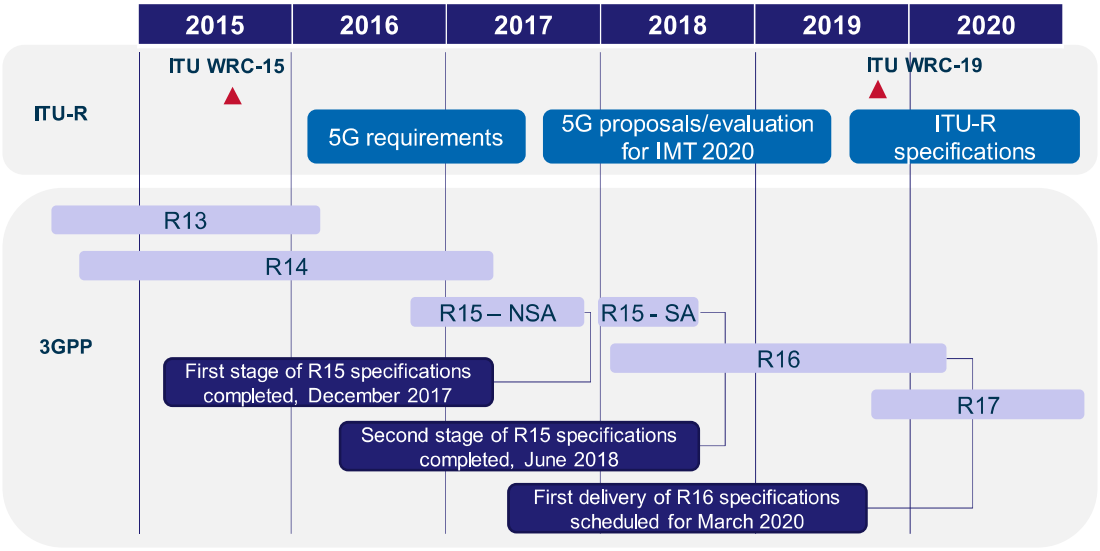
30 Non-standalone NR refers to deployment whereby NR carriers will be deployed in conjunction with existing 4G/LTE frequency carriers, with the network utilizing the 4G evolved packet core (EPC). Standalone NR refers to 5G frequency carriers being deployed independently of 4G, and with a 5G core network.

31 See http://www.3gpp.org/news-events/3gpp-news/1965-rel-15_news

32 For details, see http://www.3gpp.org/release-16

33 The first stage of the Release 16 specifications was previously due to be completed by December 2019. However, in December 2018, 3GPP announced a three-month delay to completion ('freeze') of the Release 15 'Late Drop' specifications, causing a corresponding delay for Release 16. See http://www.3gpp.org/news-events/3gpp-news/2005-ran_r16_schedule. See also http://www.3gpp.org/specifications/releases

Figure 3.5: Milestones in definition of 5G technology, and specifications release [Source: ITU, 3GPP, 2019]



With the acceleration of the 3GPP standards process by roughly two years since the 5G standards were originally envisioned to be completed, the industry is racing to develop and deploy network equipment and to develop and equip smartphones with 5G technology. 5G radio access network (RAN) equipment (compatible with several frequency bands) is now available from major vendors. In the US, 5G launches include network equipment from Ericsson, Nokia, and Samsung. Globally, the major network providers include Ericsson, Huawei, Nokia, Samsung, and ZTE. With 5G chipsets (modems) becoming commercially available from vendors in 2018, the availability of 5G smartphones should evolve rapidly in 2019 with multiple vendors expected to launch devices.

Figure 3.6 below outlines some of the 5G modems which are available from the major vendors and Figure 3.7 summarizes expected availability of 5G smartphones.

Figure 3.6: 5G modems of major vendors [Source: Analysys Mason, 2019]

Vendor	Status	5G chipset details
Qualcomm	Commercially available	In October 2016, Qualcomm became the first vendor to announce[34] plans for a 5G chipset with its Snapdragon X50 5G modem. The Snapdragon[35] X50 supports speeds of up to 5Gbps and is compatible with a range of 5G NR bands (both sub-6GHz and mm-wave). The X50 can be paired with (up to four) QTM052 mm-wave antenna modules (see below), to support features such as beam-forming/steering. When paired with a Snapdragon processor with an integrated gigabit class LTE modem, the complete Snapdragon X50 5G platform can provide multi-mode 4G/5G capability via dual connectivity (DC).

34 See https://www.qualcomm.com/news/onq/2016/10/17/meet-snapdragon-x50-qualcomms-first-5g-modem

35 See https://www.qualcomm.com/products/snapdragon-x50-5g-modem

Vendor	Status	5G chipset details
		We understand[36] that the X50 supports up to 800MHz of mm-wave bandwidth in the n257 (26.5–29.5GHz), n261 (27.5–28.35GHz) and n260 (37–40GHz) bands, and up to 100MHz in sub-6GHz bands.[37] The QTM052 mm-wave antenna module family and the Qualcomm QPM56xx sub-6GHz RF module family combine with the Snapdragon X50 5G modem to deliver modem-to-antenna capabilities across several spectrum bands. Most recently, on December 5, 2018, Qualcomm launched[38] its Snapdragon 855 5G platform.[39] The Snapdragon 855 chipset can be used in conjunction with the X50 modem to provide 5G functionality. In January 2019, Qualcomm announced[40] that over 30 devices (the majority of which are smartphones) would use the Snapdragon 855 platform and X50 modem which are scheduled to launch from early 2019.
Samsung	Commercially available	In August 2018, Samsung launched[41] its own 5G modem, Exynos 5100. Exynos 5100[42] supports speeds of up to 6Gbps, and (like Qualcomm's Snapdragon X50) is compatible with a range of 5G NR bands (both sub-6GHz and mm-wave). Unlike the Snapdragon X50, Exynos 5100 is a multi-mode modem (meaning that it will support 5G NR in both NSA and SA modes, as well as 4G, 3G, and 2G legacy radios in a single chipset).
Intel	Pre-commercial	In November 2017, Intel announced[43] the XMM 8000 series of 5G modems, the first of which is the XMM 8060. Like Samsung's Exynos 5100, the XMM 8060 is a multi-mode modem (supporting NSA/SA 5G NR as well as 2G/3G/4G in a single chipset). Intel stated that it expects to ship in commercial customer devices in mid-2019. In November 2018, Intel announced[44] the XMM 8160 5G modem, supporting speeds of up to 6Gbps. Intel stated that it expects to ship in H2 2019, with availability in commercial devices from H1 2020. It has been reported[45] that a subsequent model, the XMM 8161 (yet to be released), will be used in Apple iPhones from 2020.

36 See https://www.anandtech.com/show/13106/qualcomm-announces-their-first-5g-mmwave-antenna-module-qtm052-coming-this-year

37 We note reports that the first X50 modems will not support sub-6GHz bands. See for example: https://uk.pcmag.com/news/118720/qualcomm-expect-t-mobiles-600mhz-5g-network-later-in-2019

38 See https://www.qualcomm.com/news/onq/2018/12/05/snapdragon-855-premier-mobile-platform-new-decade-5g-ai-and-xr

39 See https://www.qualcomm.com/products/snapdragon-855-mobile-platform

40 In January 2018, Qualcomm announced that See https://www.qualcomm.com/news/releases/2019/01/07/qualcomm-chipsets-and-rf-front-end-power-more-30-commercial-5g-mobile

41 See https://www.samsung.com/semiconductor/minisite/exynos/newsroom/pressrelease/samsung-announces-exynos-modem-5100-industrys-first-5g-multi-mode-modem-fully-compliant-with-3gpp-standards/

42 See https://www.samsung.com/semiconductor/minisite/exynos/products/modemrf/exynos-modem-5100/

43 See https://newsroom.intel.com/news/intel-introduces-portfolio-new-commercial-5g-new-radio-modem-family/#gs.uzZorCjE

44 See https://newsroom.intel.com/news/intel-accelerates-timing-intel-xmm-8160-5g-multimode-modem-support-broad-global-5g-rollouts/#gs.ORcJfrsq

45 See https://www.fastcompany.com/90261969/source-apples-first-5g-iphone-will-arrive-in-2020

Vendor	Status	5G chipset details
Huawei	Commercially available	In February 2018, Huawei unveiled[46] its first 5G chipset (the Balong 5G0) at the 2018 Mobile World Congress. We understand that Huawei's Balong 5G01 supports download speeds of 2.3Gbps. At an analyst event in April 2018, Huawei announced[47] plans to commercially release a 5G smartphone in H2 2019. This will use the Kirin 980 chipset, according to reports. We understand that the Balong 5G01 is likely to be too large to be used in early 5G smartphones, and that it is mainly designed for mobile hotspots and connected cars.[48] However, the Balong 5G01 is expected to be used in future smartphone models. We understand[49] that Huawei has decided against licensing its modem to rival phone makers.

In August 2018, Lenovo (Motorola) was the first major manufacturer to announce[50] a 5G-capable smartphone – the Moto Z3.[51] The 5G Moto Mod is a separate 5G modem module which is magnetically attached to the Moto Z3 smartphone in order to provide 5G-capability. The 5G Moto Mod is expected to be commercially available in "early 2019" and will be for use exclusively with Verizon's 5G network in the US. Indeed, many of the first 5G smartphones have been developed by vendors in partnership with MNOs under certain exclusivity arrangements. Other US examples include smartphones being developed by Sprint and LG[52] and AT&T and Samsung.[53]

Several vendors launched 5G smartphones at Mobile World Congress (MWC), which was held at the end of February 2019: Huawei launched the Mate X, LG launched the V50 THINQ and Xiaomi the Mi Mix 3. A number of other vendors, including OnePlus and Oppo, showcased prototype devices. Samsung launched its Galaxy S10 5G model just before MWC, indicating an expected release date later in H1 2019.

In summary, the commercial availability of 5G consumer devices is expected to ramp up through 2019 and beyond. Most of the major device vendors have either announced or indicated plans for 5G devices. Figure 3.7 below outlines a selection of the 5G smartphones expected to be released by the major device manufacturers and their expected release date.

46 See https://www.samsung.com/semiconductor/minisite/exynos/newsroom/pressrelease/samsung-anno

47 See https://5g.co.uk/news/huawei-5g-enabled-smartphone/4348/

48 See https://5g.co.uk/news/huawei-5g-phone-foldable-screen/4508/

49 See https://www.netscribes.com/5g-modem-chipset-manufacturers-smartphones/

50 See https://www.neowin.net/news/motorola-announces-the-first-phone-that039s-upgradeable-to-5g-the-moto-z3

51 See https://www.motorola.com/us/products/moto-mods/moto-5g

52 See https://newsroom.sprint.com/sprint-and-lg-working-together-to-bring-first-5g-smartphone-to-us-in-first-half-2019.htm

53 See https://about.att.com/story/2018/5gdevice.html

Figure 3.7: Expected release date of 5G smartphones (selected manufacturers) [Source: Manufacturer announcements and news reports[54]]

Status	Manufacturer	Model	Expected commercial availability
Product has been officially launched	Lenovo (Motorola)	Moto Z3 with 5G Moto Mod	Early 2019
	Samsung	Galaxy S10 5G	H1 2019
	Huawei	Mate X	June 2019
	LG	V50 THINQ	April 2019
	Xiaomi	Mi Mix 3	May 2019
Product not yet officially launched	ZTE	AXON 10 PRO 5G	H1 2019
	Alcatel	Alcatel 7 (5G)	2019/2020
	Huawei	To be confirmed (P30 or Mate 30)	Mid-2019
	OnePlus	To be confirmed (OnePlus7 or OnePlus7T)	Early to mid-2019
	Oppo	To be confirmed	2019
	Honor	To be confirmed	2019
	Sony	Xperia 2	2019
	Vivo	To be confirmed	2019
	Apple	To be confirmed	2020

54 See https://www.t3.com/news/best-5g-phones and https://www.theverge.com/2019/2/27/18242957/5g-phones-announced-release-date-specs-price-samsung-zte-huawei-sony-oneplus-oppo-alcatel-mwc-2019

4 Spectrum releases for 5G

This section describes the latest status of 5G spectrum releases in different markets. We have assessed several aspects of 5G spectrum releases within the metrics defined for this study, to consider total 5G spectrum release, as well as amounts/timelines of spectrum release within the low, mid and high bands that are being standardized within 3GPP specifications for 5G.

We begin this section with an overview of mobile spectrum currently assigned in the different markets under study. We then provide a summary of the 5G spectrum to be released in different markets, across the low-, mid- and high-band ranges. A final section provides a discussion of spectrum pricing in recent 5G auctions.

4.1 Overview of mobile spectrum currently assigned in benchmark countries

The spectrum deployed in different countries today is typically in bands that have been identified internationally and harmonized regionally for mobile use. This means that network deployment benefits from economies of scale for equipment functioning in these harmonized bands, and there is wide availability of smartphones and other mobile devices. These existing bands are mostly now being deployed for 4G (with the majority of subscribers in many markets now using 4G rather than 2G/3G). Although there will be a progressive shift in the marketplace from 4G to 5G use, as networks evolve, operators will need to keep 4G networks running in existing spectrum for some time and are hence likely to deploy 5G initially in new spectrum bands, and will progressively re-purpose existing mobile bands for 5G use as the demand for new services evolves.

To date, the frequency bands used by mobile networks have historically been concentrated in bands from around 600MHz to 2.6GHz. Many initial 5G deployments will use spectrum around 3.5GHz and 5G services will additionally use higher bands, in the mm-wave range. Lower bands such as 600MHz and 700MHz are also likely to be used for 5G, enabling wider geographical coverage, subject to each operator's strategy. These lower bands could be useful for some 5G services requiring wide geographical coverage (massive machine-type connections, for example), but do not offer the large amount of bandwidth that will be available in the mid and high bands.

Use of larger bandwidths will be a key differentiator in the 5G era, given that one of the major changes in the 5G radio specifications compared to 4G lies in the use of larger contiguous bandwidths – 3GPP defines 100MHz bandwidths in 5G mid-band spectrum, and up to 400MHz in higher bands, as being optimal. Since sub-1GHz bands typically offer less than 100MHz bandwidth in total (and this is typically sub-divided amongst several operators), availability of mid-band spectrum and high-band spectrum is needed for 5G operators to achieve these larger bandwidths.

The following sub-sections describe the current amounts of total mobile spectrum licensed for use in the countries that we have studied for this report. Total mobile spectrum includes the spectrum currently licensed in each market for all generations of mobile technology in the market place (i.e.

2G/3G/4G plus 5G, in countries where 5G bands have already been licensed). Planned spectrum awards for 5G (i.e. bands that will be made available in 2019 and beyond in different countries, for 5G) are considered in the next section.

We consider low-band (<3GHz), mid-band (3–24GHz), and high-band (>24GHz) spectrum in successive sub-sections.

Low-band spectrum

Figure 4.1 below shows a summary of the current amount of low-band spectrum licensed[55] for mobile use in our benchmark countries. This includes spectrum that has been licensed for use in different markets in the following bands:

- Sub-1GHz: 450MHz (Sweden only), 600MHz (US only), 700MHz (US, Canada, some European countries, Australia, and Japan), 800/850MHz (all countries), and 900MHz (all countries excluding Canada and the US).
- Between 1 and 2GHz: 1400MHz (some European countries and Japan), 1700MHz[56] (US and Canada), 1800MHz (Europe, Asia–Pacific, and Qatar), and 1900MHz[57] (US, Canada, China, and Japan).
- Above 2GHz: 2100MHz (Europe, Asia–Pacific and Qatar), 2300MHz (US, Canada, the UK, and Asia–Pacific, excluding Japan), and 2600MHz[58] (all countries).

As can be seen, excluding Qatar, the majority of countries studied currently have comparable amounts of existing low-band mobile spectrum, with South Korea having the least spectrum of those countries overall (477MHz) and the US the most (716MHz).

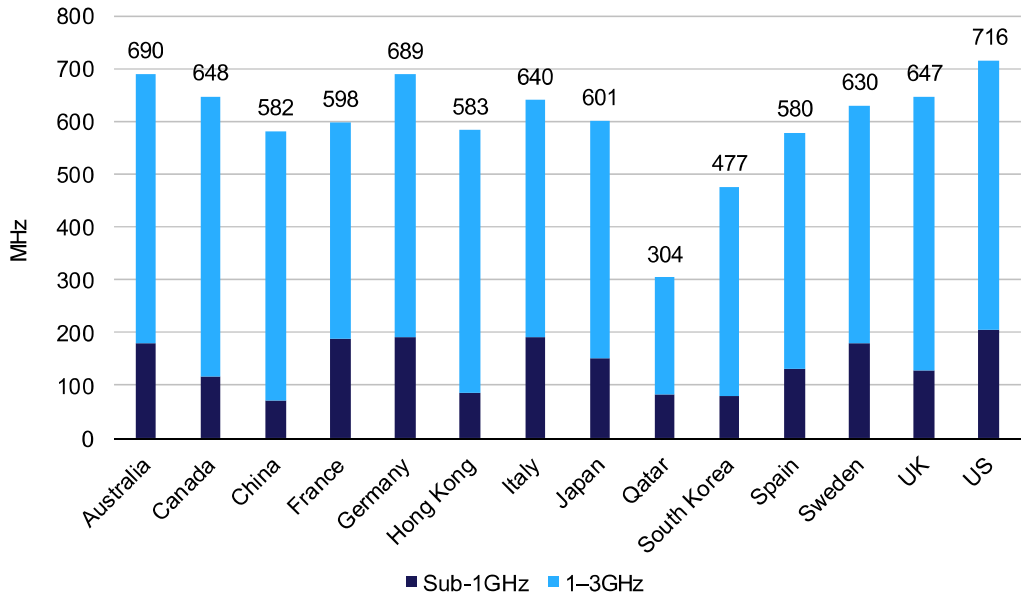
55 Spectrum licensed for mobile in 3GPP bands 33 (1900–1920MHz TDD) and 34 (2010–2025MHz TDD) is generally excluded, since it is generally not used.

56 I.e. AWS spectrum in the 1710–1780/2110–2180MHz and 2000–2020/2180–2200MHz ranges.

57 This includes broadband PCS spectrum licensed in Canada and the US in the 1850–1915/1930–1995MHz range.

58 This includes BRS/EBS spectrum in Canada and the US

Figure 4.1: Currently awarded low-band mobile spectrum[59,60] in benchmark countries [Source: Analysys Mason, 2019]



Further details of currently awarded spectrum are provided in the tables below.

Figure 4.2: Currently awarded mobile (uplink plus downlink MHz) spectrum (by band), benchmark countries in ITU regions 1 and 3 [Source: Analysys Mason, 2019]

Country	450	700	800/ 850	900	1400	1800	1900*	2100	2300	2600	Tot.
Australia	-	90	40	50	-	150	-	120	100	140	**690**
China	-	-	20	52	-	140	50	90	70	160	**582**
France	-	60	60	70	-	150	-	118	-	140	**598**
Germany	-	60	60	70	40	150	-	119	-	190	**689**
Hong Kong	-	-	25	60	-	150	-	118	90	140	**583**
Italy	-	60	60	70	40	140	-	120	-	150	**640**
Japan	-	60	60	30	70	150	31	120	-	80	**601**
Qatar	-	-	40	44	-	80	-	60	-	80	**304**
S. Korea	-	-	60	20	-	120	-	120	57	100	**477**
Spain	-	-	60	70	-	150	-	120	-	180	**580**
Sweden	10	40	60	70	-	140	-	120	-	190	**630**

59 Sub-1GHz bands include the 450, 600, 700, 800 and 900MHz bands (ITU regions 1 and 3), and the 600MHz, 700MHz, 800MHz SMR and Cellular bands in ITU region 2 (US and Canada). 1–3GHz bands include the 1400, 1800, 1900, 2100, 2300 and 2600MHz bands (ITU regions 1 and 3), and the PCS, H-block, AWS-1/2/3/4, WCS (2.3GHz) and EBS/BRS (2.6GHz) bands in ITU region 2 (US and Canada). It should be noted that where spectrum has been licensed to operators, it may not necessarily have been deployed, or be in current use for providing mobile services.

60 In the US and Canada (and for some bands in Australia), spectrum is auctioned and assigned on a regional basis. Values shown for the US represent national weighted average holdings summed across all licensed operators (including currently non-mobile players such as satellite broadcaster DISH; see Annex B for details).

Country	450	700	800/ 850	900	1400	1800	1900*	2100	2300	2600	Tot.
UK	-	-	60	70	40	143	-	119	40	175	**647**

* Spectrum assigned in 3GPP bands 33 (1900–1920MHz) and 34 (2010–2025MHz) is excluded where it is not used

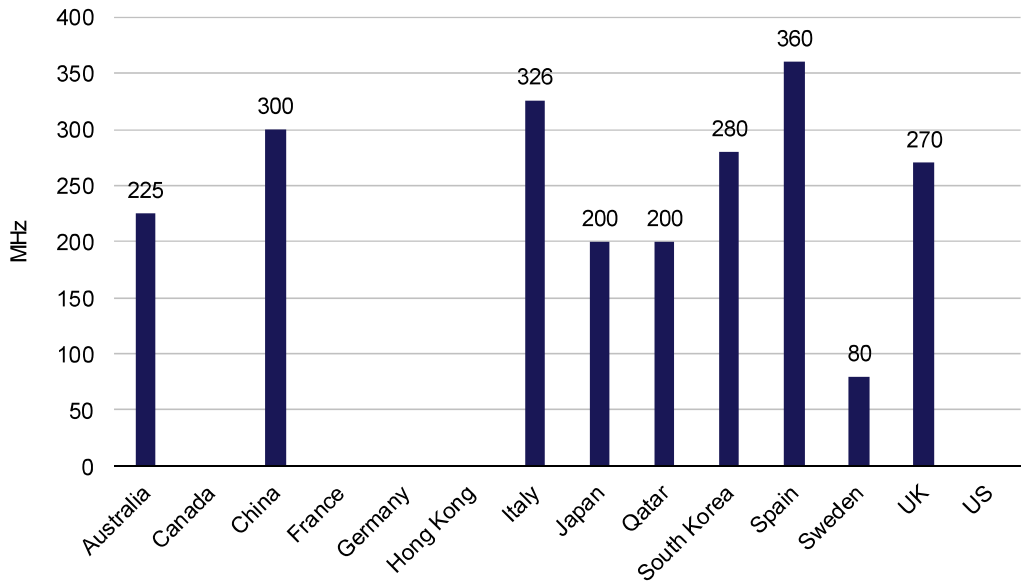
Figure 4.3: Currently awarded mobile (uplink plus downlink MHz) spectrum (by band), benchmark countries in ITU region 2 [Source: Analysys Mason, 2019]

Country	600	700	Cell.	SMR	PCS	H-block	AWS -1	AWS -3	AWS -4	WCS	BRS/ EBS	Tot.
Canada	-	68	50	-	130	-	90	50	40	30	190	**648**
US	70	70	50	14	130	10	90	65	40	20	157	**716**

Mid-band spectrum

Figure 4.4 below shows a summary of the current amount of mid-band spectrum licensed for mobile use in our benchmark countries. As can be seen, whilst many countries have now awarded over 100MHz of (exclusive nationwide) spectrum to mobile, several countries (China, Italy, and Spain) have awarded 300MHz or more. This higher availability of mid-band spectrum is especially suited to 5G, since equipment vendors have identified 100MHz or more per 5G network as being optimal in this range to deliver the best performing 5G services in terms of throughput and latency.

Figure 4.4: Currently awarded mid-band mobile spectrum (MHz) in benchmark countries [Source: Analysys Mason, 2019]



Although we have defined the mid band to be the 3–24GHz range, mobile assignments in this range are currently concentrated (in accordance with 3GPP specifications) around 3.5GHz. A breakdown

of currently awarded licensed mid-band spectrum into the 3.4–3.6GHz, 3.6-3.8GHz and >3.8GHz bands is shown in Figure 4.5 below.

Figure 4.5: Currently awarded mid-band mobile[61] spectrum (MHz) in benchmark countries [Source: Analysys Mason, 2019]

Country	3.4–3.6GHz	3.6–3.8GHz	Above 3.8GHz	Total
Australia	100*	125	-	**225**
Canada	-	-	-	**-**
China	200**	-	100**	**300**
France	-	-	-	**-**
Germany	-	-	-	**-**
Hong Kong	-	-	-	**-**
Italy	126	200	-	**326**
Japan	200	-	-	**200**
Qatar	200	-	-	**200**
S. Korea	180	100	-	**280**
Spain	160	200	-	**360**
Sweden	-	80*	-	**80**
UK	190	80	-	**270**
US	-	-	-	**-**

* Further spectrum has also been licensed in certain regions (see Annex A for details)

** Test licenses

Further details of these assignments are provided below.

Figure 4.6: Currently awarded mid-band mobile spectrum (MHz) in benchmark countries - details [Source: Analysys Mason, 2019]

Country	Details
Australia	• 3425–3492.5MHz and 3542.5–3575MHz ranges (a total of 100MHz) have been licensed in specific locations of Australia; the licenses are technology neutral and suitable for (5G) mobile use • In December 2018, Australia completed a regional auction of the 3575–3700MHz range, for mobile use
Canada	• No mid-band spectrum suitable for mobile use is currently assigned[62]
China	• In December 2018, nationwide test licenses were issued in the 3.4–3.6GHz and 4.8–4.9GHz ranges
France	• No mid-band spectrum suitable for mobile use is currently assigned[63]

61 Spectrum assigned explicitly for FWA is excluded. However, spectrum intended/used for FWA but licensed under service neutral terms is included.

62 Regional FWA licenses are assigned in the 3475–3625MHz range.

63 Regional FWA licenses are assigned (and currently available) in the 3410–3460MHz range.

Country	Details
Germany	• No mid-band spectrum suitable for mobile use is currently assigned[64]
Hong Kong	• No mid-band spectrum suitable for mobile use is currently assigned
Italy	• In October 2018, Italy auctioned 200MHz of spectrum in the 3.6–3.8GHz range on a national basis for 5G use, raising a total of ~USD5.02 billion from the award of four licenses (two licenses of 80MHz bandwidth and two licenses of 20MHz bandwidth)
Japan	• The 3.4–3.6GHz band is currently assigned to MNOs on a national basis; these licenses are suitable for mobile use
Qatar	• 100MHz has been assigned to each of the two MNOs in the 3.4–3.6GHz range
S. Korea	• In June 2018, South Korea auctioned 280MHz of spectrum in the 3420–3700MHz range on a national basis for 5G use, raising a total of ~USD2.89 billion from the sale of three licenses
Spain	• In June and July 2018, MNO Mas Movil privately acquired two 2×20MHz national licenses in the 3.4–3.6GHz band; two of Spain's other MNOs (Orange and Telefonica) already own 2×20MHz national licenses in this band • Later in July 2018, Spain auctioned 200MHz of spectrum in the 3.6–3.8GHz range
Sweden	• 80MHz of spectrum (3600–3640/3700–3740MHz) has been assigned to MNOs on a national basis; the licenses are technology and service neutral, and expire in December 2022 • Various regional licenses have also been assigned in the remainder of the 3.6–3.8GHz band[65]
UK	• UK MNO Three already holds national licenses in the 3480–3500MHz, 3580–3600MHz, and 3600–3680MHz ranges (suitable for mobile use[66]) • In April 2018, the UK auctioned 150MHz of spectrum from the 3.4–3.6GHz band, which was awarded to the UK's four MNOs in four licenses ranging in size from 20MHz up to 50MHz, raising a total of ~USD1.50 billion
US	• No mid-band spectrum suitable for mobile use is currently assigned

High-band spectrum

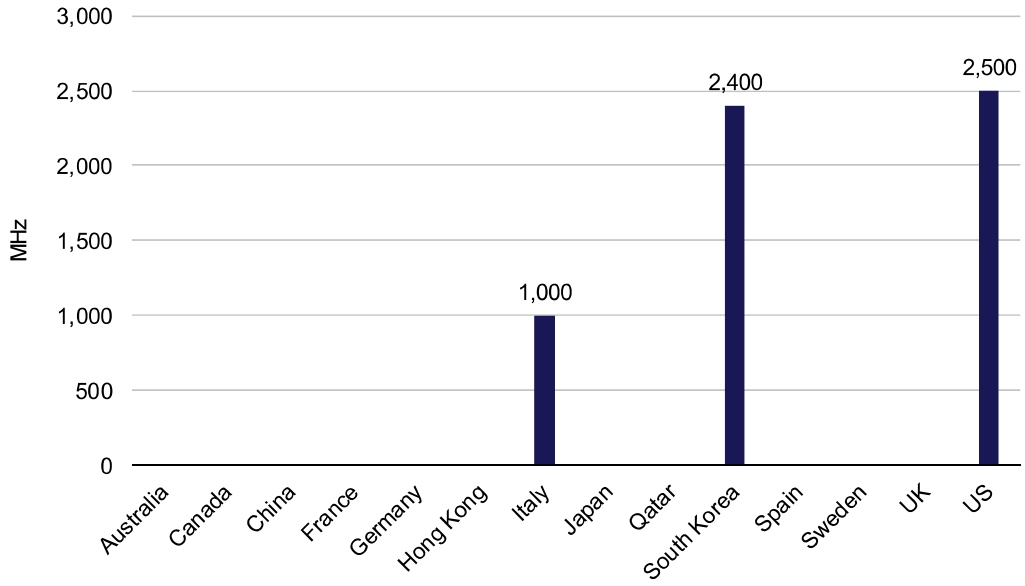
Figure 4.7 below shows a summary of the current amount of high-band spectrum licensed for mobile use in the benchmark countries. Although worldwide discussions on identification of mm-wave spectrum for 5G are taking place as part of the 2019 WRC, the inclusion of selected bandwidths from 24.25–29.5GHz in 3GPP Release 15 specifications has influenced regulators to award spectrum for mobile use in these bands over the past year or so.

64 Each of the three MNOs in Germany currently owns 2×21MHz of spectrum in the 3410–3473/3510–3573MHz range on a nationwide basis. Licenses are technology neutral but limited to FWA use (i.e. not suitable for mobile) and expire in December 2021. Various regional FWA licenses have also been assigned in the 3473–3494MHz and 3573–3594MHz ranges, expiring between 2020 and 2022.

65 Regional FWA licenses are assigned in the 3410–3438MHz and 3510–3538MHz ranges; licenses expire in March 2023.

66 Three also holds a spectrum license in the 3925–4009MHz range, but this is not suitable for mobile use.

Figure 4.7: Currently awarded high-band mobile spectrum[67] (MHz) in benchmark countries [Source: Analysys Mason, 2019]*



*The 2500MHz of spectrum currently assigned in the US includes 700MHz in the 24GHz band, which is currently being auctioned (see below for details).

As can be seen, only three countries have currently assigned mm-wave spectrum for 5G. These are Italy (26.5–27.5GHz), South Korea (26.5–28.9GHz), and the US (24.25–24.45GHz, 24.75–25.25GHz, 27.5–28.35GHz, and parts of the 38.6–40.0GHz band in certain areas):

- Italy completed an auction of the 26.5–27.5GHz band in October 2018. Each of Italy's four MNOs, as well as broadband provider Fastweb, won a 200MHz license; each paid close to the reserve price of ~USD37.1 million.

- South Korea completed an auction of the 26.5–28.9GHz band in June 2018. Each of South Korea's three MNOs won 800MHz, paying the reserve price of ~USD186 million each.

- In the US, around 68% of the 39GHz (38.6–40.0GHz) band (on a MHz-pop basis) is currently assigned (approximately 950MHz). The majority of the licenses (which are suitable for mobile use) are held by Verizon and AT&T, with T-Mobile also holding licenses in some markets. These licenses were acquired through private acquisitions.

  As of end-2018, around 76% of the 28GHz (27.5–28.35GHz) band (on a MHz-pop basis) was assigned. The majority of the licenses (which are suitable for mobile use) are held by Verizon, with T-Mobile also holding licenses in some markets. These licenses were acquired through private acquisitions. The remaining 24% of the 28GHz was auctioned in early 2019.

67 This excludes unlicensed spectrum, although it is noted that 5G-NR will potentially be useable in unlicensed spectrum in due course.

Around 1.8GHz of spectrum[68] has therefore already been assigned (on a MHz-pop basis) across the 28GHz and 39GHz bands. A further 700MHz is currently being auctioned in the 24GHz band (giving a total of 2.5GHz).

4.2 5G spectrum to be released in benchmark countries

Having considered the spectrum which has already been released for mobile in each of the benchmark countries (Section 4.1), we now consider further spectrum which is planned for release in the future. Low-, mid-, and high-band spectrum is covered in turn in the following sub-sections.

Low-band spectrum

Low-band (sub-3GHz) spectrum confirmed (or considered) for future allocation to mobile in each of the benchmark countries is shown in Figure 4.8 below.

Figure 4.8: Upcoming mobile spectrum allocations in the low band [Source: Analysys Mason, 2019]

Country	Details
Australia	• Australia has scheduled a decision to be made on the reconfiguration of the 803–960MHz band in Q3/4 2019. An additional 2×15MHz is expected to be made available for mobile broadband; an auction is scheduled for 2020 • Allocation of the L-band (1427–1518MHz) is scheduled for 2021
Canada	• An auction of 2×35MHz in the 617–652/663–698MHz range is scheduled for March 2019 • ISED will initiate a review of the 1500/1600MHz Ancillary Terrestrial Component (ATC) bands in late 2019
China	• A total of 687MHz of low-band IMT spectrum has currently been planned for mobile in China, of which 582MHz has already been awarded • The spectrum yet to be assigned consists of a further 10MHz in the 1800MHz band, 5MHz in the 1900MHz band, 30MHz in the 2100MHz band, 30MHz in the 2.3GHz band, and 30MHz in the 2.6GHz band. We are not aware of an official timeline for the release of this spectrum
France	• ARCEP has consulted assigning the 738–753MHz (unpaired) range; ARCEP has no plans to assign this spectrum before June 2019 (when the band is released by PMSE) • ARCEP has indicated that it may assign L-band spectrum at the same time as the 3.4–3.8GHz and 26GHz bands • ARCEP has stated that "work is well underway to… allow the introduction of the LTE in the 400MHz band"
Germany	• The 738–753MHz (unpaired) range may be considered for auction by BNetzA at a later date
Hong Kong	• CA intends to assign the vacated 'digital dividend' spectrum in the 700MHz (698–806MHz) band to mobile services as soon as possible after the analog switch-off (to be completed by 2020) • The 2010–2020MHz range went unsold at an auction in 2011; CA has said that it will "review demand for this band"

68 We have calculated this as 850MHz in the 28GHz bands, plus 68% of the 39GHz band (approximately 950MHz). See Annex B.14.1 for further details.

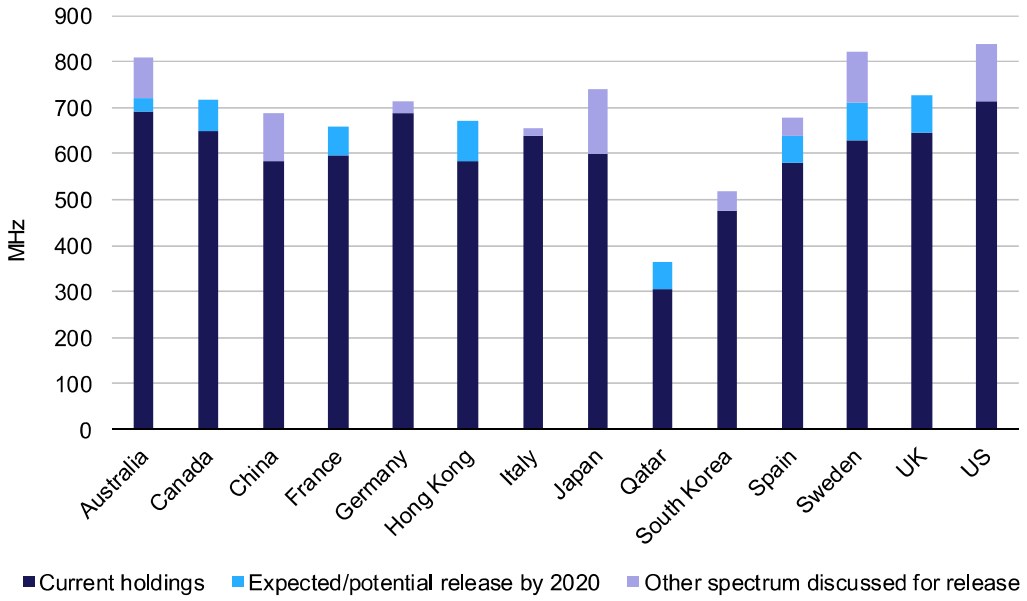
Country	Details
Italy	• The 733–748MHz (unpaired) range went unsold in the October 2018 multiband auction; it may be made available at a future date, although we are not aware of any official plans for a further auction
Japan	• MIC has stated that it will promote frequency sharing/allocation in the 2300–2330/2370–2400MHz ranges, and consider frequency sharing with mobile satellite in the 2500–2545/2645–2690MHz ranges
Qatar	• Qatar plans to assign 2×30MHz of spectrum (703–733/758–788MHz) in the 700MHz band for 5G
S. Korea	• We are not aware of any official upcoming assignment plans. However, we note that 2×20MHz of spectrum in the 700MHz band remained unsold at an auction in May 2016
Spain	• Spain expects to auction spectrum in the 700MHz band in early 2020 • Spain has also identified the L-band as a potential band for 5G use. The regulator has stated that "actions will be taken" to assign the 1452–1492MHz portion of the band (which is currently available), and that "actions should be taken" to free up the remainder of the band (which is currently in use); no timeframes have been specified • Demand for shared use of the 2.3–2.4GHz band for 5G "will be examined"
Sweden	• The 738–758MHz (unpaired) spectrum was offered to the market but not taken up in the December 2018 auction. PTS has said that it will "analyze the possible future use of the unsold SDL[69] licenses" • An award of spectrum in the 1400MHz band (1427–1518MHz) is planned for "2019 or later" • PTS are planning to award the 2300–2380MHz range to mobile (alongside the 3.4-3.7GHz range) in late 2019 or early 2020.
UK	• The UK plans to auction the 703–733/758–788MHz (paired) and 738–758MHz (unpaired) ranges by Spring 2020. Spectrum should be available for use by May/June 2020 • Ofcom is currently consulting on introducing spectrum-sharing arrangements in the 1781.7–1785/1876.7–1880MHz and 2390–2400MHz bands.
US	• The Spectrum Pipeline Act requires 30MHz of federal spectrum below 3GHz to be identified for allocation to commercial mobile services by 2022; the 1300–1350MHz and 1780-1830MHz bands are being evaluated for this purpose • The US is considering updating the framework for licensing Educational Broadband Service (EBS) spectrum in the 2.6GHz band. The FCC is proposing to "modernize and rationalize the EBS spectrum in the 2.6GHz band to allow more flexible use [including for 5G]".

As highlighted in the table above, the most common sub-3GHz band scheduled for assignment to mobile is the 700MHz band, though this band (or the paired portion of it) has already been awarded in a number of cases. Other sub-3GHz bands scheduled (or considered) for assignment to mobile are the L-band, 2300MHz band, and 2600MHz band, where these have not already been assigned.

Current and future sub-3GHz mobile spectrum holdings are summarized in Figure 4.9 below. Future spectrum holdings (as discussed in Figure 4.8 above) have been further divided into spectrum which is expected to be released by 2020, and spectrum which is expected to be released after this date (or has been discussed for release but no timeframe for assignment has been announced). Current spectrum holdings are shown in Figure 4.1 (see Section 4.1).

69 SDL = Supplementary Downlink i.e. spectrum specified by 3GPP to be used for mobile downlink transmissions.

Figure 4.9: Current and future low-band spectrum holdings [Source: Analysys Mason, 2019]



As can be seen, by 2020 a number of countries are expected to have awarded over 600MHz (in some cases over 700MHz) of low-band spectrum.

Mid-band spectrum

Mid-band spectrum confirmed (or considered) for future allocation to mobile in each of our benchmark countries is shown in Figure 4.10 below.

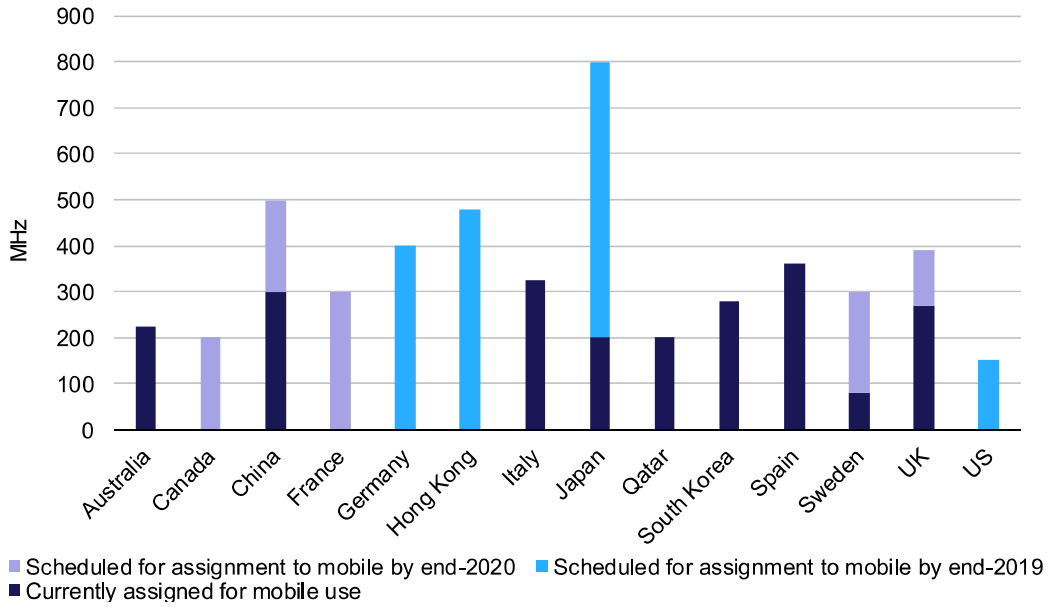
Figure 4.10: Upcoming mobile spectrum allocations in the mid band [Source: Analysys Mason, 2019]

Country	Details
Australia	• Australia plans to release discussion papers in 2019 on reconfiguration options in the 3400–3575MHz band and long-term arrangements in the 3.7–4.2GHz band
Canada	• In June 2018, Canada published 'Spectrum Outlook 2018-2022' as well as a specific consultation on the 3450–3650MHz band, with an auction for that band planned for late 2020 • The regulator is also seeking preliminary comments on the use of the 3400–3450MHz and 3650–4200MHz bands for 5G
China	• The June 2017, MIIT confirmed that 500MHz of spectrum (within 3.3–3.6GHz and 4.8–5.0GHz) would be released in China, with the 3.3–3.4GHz range available for indoor use • As noted in Section 4.1, MNOs were issued with nationwide test licenses in the 3.4–3.6GHz and 4.8–4.9GHz ranges in December 2018; we are not aware of further details regarding the approach and timing of the release of the 3.3–3.4GHz and 4.9–5.0GHz bands • Reports also indicate that China is likely to assign the 3.6–4.2GHz range to 5G use in the future, subject to co-ordination with existing satellite use
France	• 40MHz of spectrum in the 3420–3460MHz range is reserved for FWA use in currently underserved areas until 2026; there are also various other users in the lower part of the 3.4–3.8GHz band

Country	Details
	• An auction of spectrum in the 3.4–3.8GHz band for mobile use is planned, with the exact approach to be confirmed. ARCEP has indicated it expects 300MHz of contiguous spectrum to be available for 5G by 2020 • In October 2018, ARCEP published a consultation scheduling the assignment of 3.4–3.8GHz spectrum for late-2019. Subsequent reports have suggested that the auction is expected in early-2020
Germany	• Germany plans to award the entire 3.4–3.8GHz band for mobile use in early 2019. The 3.4–3.7GHz range (for nationwide use) will be auctioned; 3.7–3.8GHz will be for regional/local use
Hong Kong	• Hong Kong plans to auction three bands in July/August 2019 on a national basis: for 5G use 3.3–3.4GHz (for indoor use only), 3.4–3.6GHz and 4.84–4.92GHz. The regulator has said that spectrum will become available for use from end-2019/2020
Italy	• We are not aware of any plans for further release of mid-band spectrum
Japan	• In December 2018, the regulator stated plans to release six 100MHz blocks of spectrum (3.6–4.1GHz and 4.5–4.6GHz) by March 2019; the 4.6–4.8GHz range will be further considered for private 5G use
Qatar	• A document released by CRA in February 2018 indicates that the 3.6–3.8GHz range will be assigned for 5G use in the future
S. Korea	• We are not aware of any plans for further release of mid-band spectrum
Spain	• We are not aware of any plans for further release of mid-band spectrum
Sweden	• 80MHz of spectrum (3600–3640/3700–3740MHz) has been assigned to MNOs on a national basis; the licenses are technology and service neutral, and expire in December 2022. Various regional licenses have also been assigned in the remainder of the 3.6–3.8GHz band • Sweden plans to award the entire 3.4–3.8GHz band for mobile use. The 3.4–3.7GHz range (for nationwide use) is scheduled for auction in late 2019 or early 2020; the 3.7–3.8GHz range (for regional/local use) is scheduled to be assigned from 2023
UK	• The UK anticipates awarding 120MHz of spectrum in the 3680–3800MHz band by Spring 2020; the spectrum is expected to be available in most parts of the UK by mid-2020 • The regulator is currently consulting on introducing a sharing regime in the 3.8–4.2GHz range (licenses would be for a specific geographical area and co-ordinated by the regulator)
US	• The US is making 150MHz in the 3550–3700MHz (CBRS) band available, with 70MHz to be auctioned (potentially in 2019) and the 150MHz to be available on a shared basis (by mid-2019) • The FCC is exploring the 3.7–4.2GHz band, adopting an NPRM in July 2018, a move that could open up large additional blocks of mid-band spectrum • The US is also studying the 3.45–3.55GHz band (but there is no specific timing on the study or the availability of spectrum) and is considering options for use of the 5.925–7.125GHz range

A summary of the total amount of mid-band spectrum which has been confirmed for assignment to 5G by end-2019 and by end-2020 is shown in Figure 4.11 below. As can be seen, the US is expected to rank bottom by end-2020 (with all other benchmark countries in this report expected to have assigned 200MHz or more by that date). However, we note that the FCC is exploring possible mobile use of the 3.7–4.2GHz band, adopting an NPRM in July 2018, and is also considering allocations in the 3.45–3.55GHz and 5.925-7.125GHz ranges, steps that could create large additional blocks of mid-band spectrum, which would significantly improve the US situation compared to other markets.

Figure 4.11: Total amount of mid-band spectrum by end-2019 and end-2020 [Source: Analysys Mason, 2019[70]]



It should be emphasized that several other countries, not included in our benchmark list, have also assigned 5G mid-band spectrum (e.g. Austria,[71] Ireland,[72] Finland,[73] Oman,[74] Switzerland,[75] and the UAE[76]) or are committed to doing so later in 2019 (e.g. the Czech Republic[77]).

The charts below map the expected evolution of mid-band spectrum assignment in each of our benchmark countries from the current situation (Figure 4.12) to the situation expected by end-2019 (Figure 4.13) and by end-2020 (Figure 4.14).

70 Mid-band spectrum is shared among services (terrestrial and satellite), and hence the spectrum available to 5G in different markets will depend on protection requirements to satellite services.

71 In March 2019, RTR completed a regional auction of spectrum in the 3410–3800MHz range. Each of Austria's three MNOs won 100MHz or more in every region. See https://www.rtr.at/en/tk/5G-Auction-Outcome

72 Ireland conducted a regional auction of 350MHz in the 3410–3435MHz and 3475–3800MHz ranges in May 2017. In each of nine regions, there was one 25MHz 'A' lot available (3410–3435MHz) and sixty-five 5MHz 'B' lots available (3475–3800MHz). Five different operators won spectrum. See https://www.comreg.ie/industry/radio-spectrum/spectrum-awards/3-6ghz-band-spectrum-award/

73 In October 2018, Finland completed an auction of 390MHz in the 3.41–3.80GHz range. Finland's three MNOs each won 130MHz. See https://www.viestintavirasto.fi/en/ficora/news/2018/finland8217spathtobecomingaleading5gcountryspectrumauctionconcluded.html

74 In December 2018, TRA announced that it had assigned spectrum in the 3.4–3.6GHz range to MNOs Omantel and Ooredoo. See https://timesofoman.com/article/670109

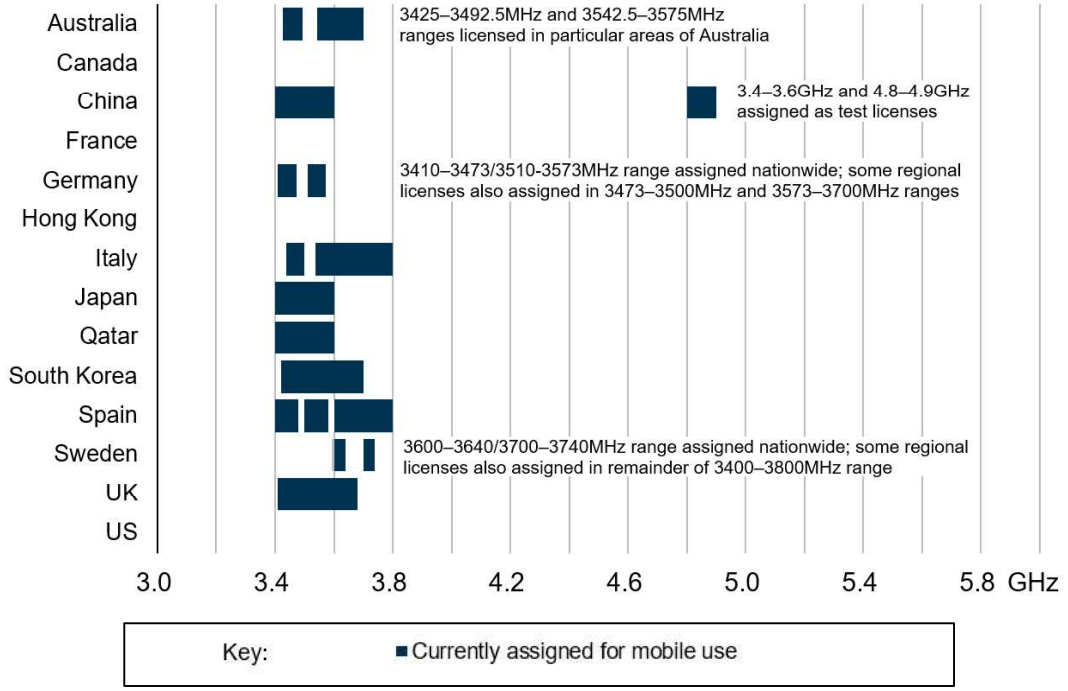
75 In February 2019, BAKOM completed an auction of spectrum in the 3.5-3.8GHz range. Each of Switzerland's three MNOs won spectrum. See https://www.bakom.admin.ch/bakom/en/homepage/frequencies-and-antennas/award-of-mobile-telephony-frequencies/starting-signal-for-new-award-of-mobile-radio-frequencies.html

76 In November 2018, TRA announced that it had assigned spectrum in the 3.3–3.8GHz band to MNOs Etisalat and Du. See https://www.thenational.ae/business/technology/tra-assigns-5g-frequencies-to-etisalat-and-du-1.792795

77 See https://uk.reuters.com/article/czech-telecoms/czech-telecoms-regulator-to-launch-5g-auction-bidding-in-november-idUKL5N20M5ES

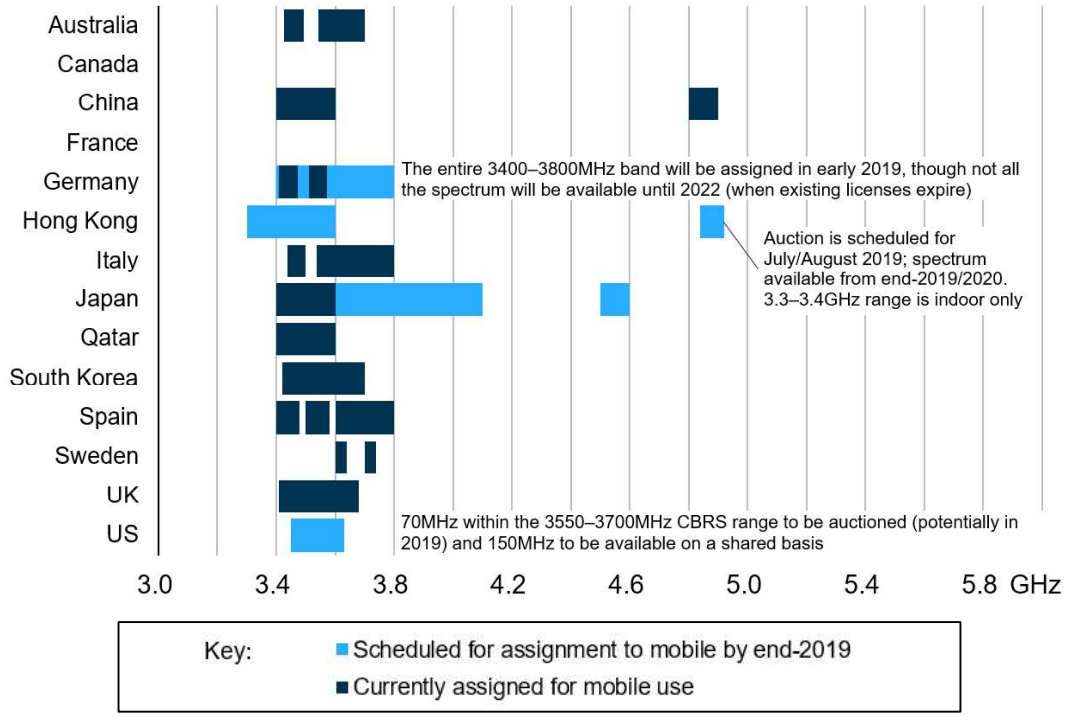
The first of these charts (i.e. current assignments of mid-band spectrum in each of the benchmark countries) is shown in Figure 4.12 below.

Figure 4.12: Mid-band spectrum for mobile use in benchmark countries (currently) [Source: Analysys Mason, 2019]



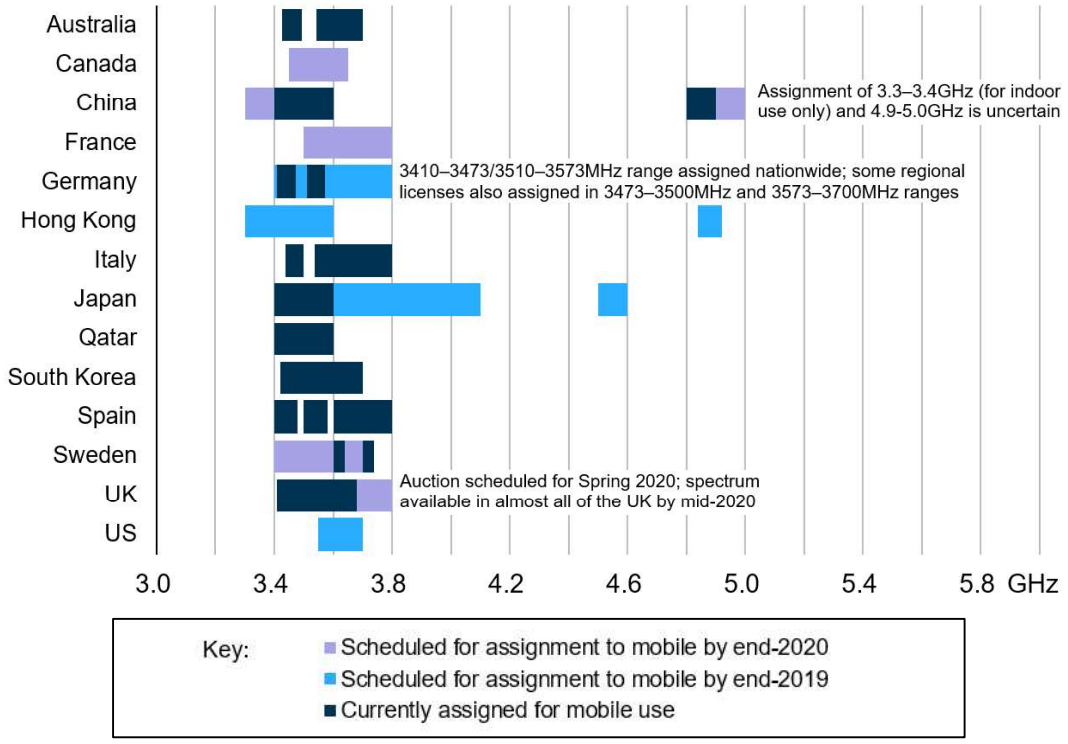
The expected change in mid-band spectrum ranges for each of the benchmark countries by end-2019 is shown in Figure 4.13 below.

Figure 4.13: Mid-band spectrum for mobile use in benchmark countries (by end-2019) [Source: Analysys Mason, 2019]



By end-2020, the expected mid-band spectrum ranges for each of our benchmark countries are shown in Figure 4.14 below.

Figure 4.14: Mid-band spectrum for mobile use in benchmark countries (by end-2020) [Source: Analysys Mason, 2019]



As can be seen, whilst a large number of countries have already assigned mid-band spectrum for 5G, there are several further significant awards expected through 2019 and 2020.

High-band spectrum

High-band spectrum confirmed (or considered) for future authorization for mobile use in each of the benchmark countries is shown in Figure 4.15 below.

Figure 4.15: Upcoming mobile spectrum allocations/awards in the high band [Source: Analysys Mason, 2019]

Country	Details
Australia	• Australia ran a consultation on the future use of the 26GHz (24.25–27.5GHz) band at the end of 2018. A reallocation decision on the band is scheduled for Q2 2019, with an auction scheduled for Q3/4 2020 • ACMA is also considering the future use of the 28GHz (27.5–29.5GHz) band
Canada	• ISED aim to release the 26GHz (26.5–27.5GHz) band for 5G by 2020. The 24.25–26.5GHz band has also been discussed, but this is lower priority • ISED expects to release the 28GHz (27.5–28.35GHz) and 37–40GHz bands for flexible fixed and mobile use in late 2021 • ISED expects to release the 64–71GHz for license-exempt use in late 2021 • ISED is also expecting to release the 31.8–33.4GHz band for backhaul use in late 2019, and the 71–76GHz and 81–86GHz bands for backhaul use with a potential release in mid-2020

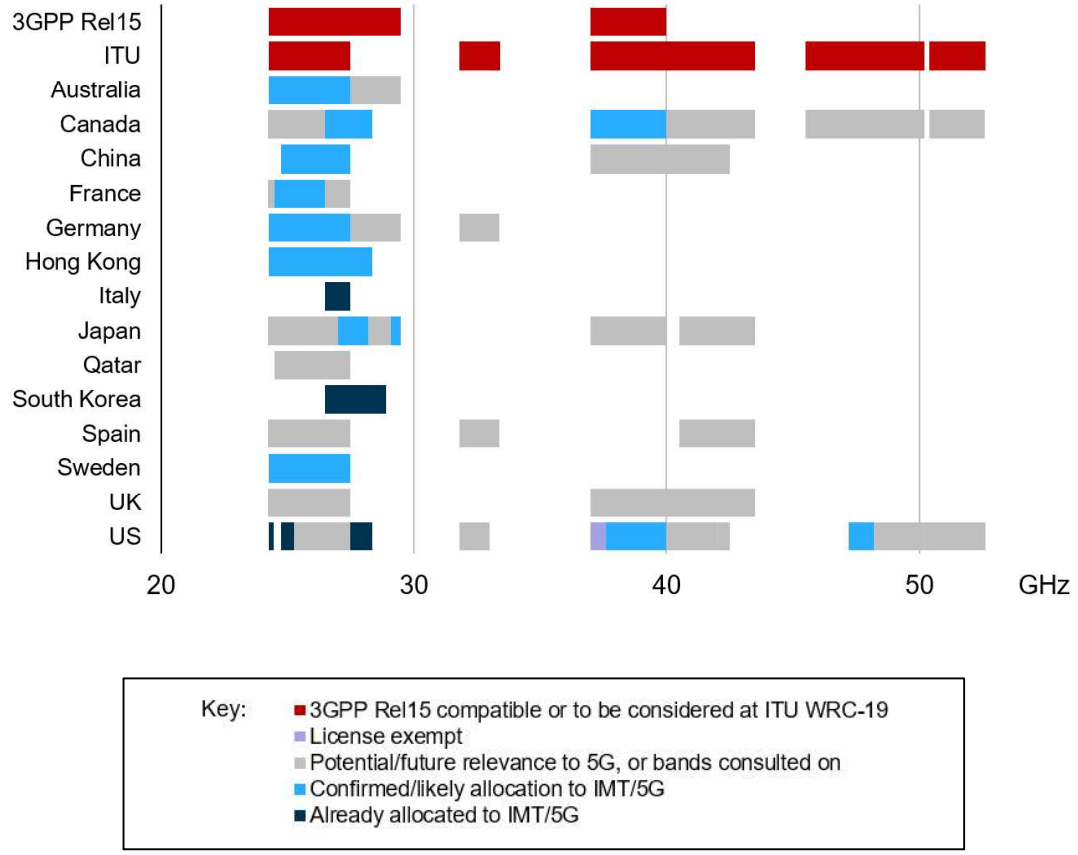
Country	Details
	• ISED is further considering mobile use in other bands (24.25–26.5GHz, 40–43.5GHz, 45.5–50.2GHz, 50.4–52.6GHz) which have the potential to be released by 2022
China	• MIIT has stated that it intends to make available 2GHz of spectrum per operator in the 24.25–43.5GHz range for 5G • In July 2017, MIIT approved two mm-wave bands (24.75–27.5GHz and 37–42.5GHz) for research and testing • MIIT has stated that it will continue to consider more bands (both low and high frequency) for 5G development
France	• ARCEP has confirmed it will not assign new point-to-point (PtP) links in the 26GHz (24.25–27.5GHz) band beyond December 31, 2023, with a view to making this spectrum available for 5G • The 26.5–27.5GHz band (currently used by French defense) will be assigned for commercial 5G use in 2020, while the 24.5–26.5GHz band is planned for release after the migration of the PtP radio links • The 24.25–24.5GHz range will also potentially be available for 5G in the future
Germany	• BNetzA's June 2017 framework document on 5G considers the 26GHz (24.25–27.5GHz), 28GHz (27.5–29.5GHz) and 32GHz (31.8–33.4GHz) ranges, with 26GHz being the most important one, having been designated as a European 'pioneer' band for 5G • BNetzA aims to develop an approach to releasing these bands for 5G (starting with spectrum in the 26GHz band) "as early as possible so that usage can start in 2020" • At the end of 2018, BNetzA completed a consultation on a co-ordinated FCFS licensing arrangement (for individual base stations) in the 26GHz band
Hong Kong	• A total of 4.1GHz will be made available, via administrative assignment across the 26GHz (24.25–27.5 GHz) and 28GHz bands (27.5–28.35GHz). 3.7GHz will be made available via exclusive nationwide licenses for "large scale public mobile services", and 400MHz will be made available on a geographically shared basis for "localized innovative wireless services" • Assignments are scheduled for H1 2019
Italy	• Italy completed a spectrum auction in the 26.5–27.5GHz range in October 2018 • We are not aware of any plans for further release of high-band spectrum
Japan	• MIC plans to allocate the 27.0–28.2GHz and 29.1–29.5GHz ranges to 5G use (as four 400MHz unpaired blocks) by the end of March 2019; the 28.2–29.1GHz range will be further considered for private 5G use • MIC's July 2017 consultation also considers all eleven mm-wave ITU bands to be studied internationally ahead of the ITU WRC-19 (in accordance with agenda item 1.13), with a particular focus on bands below 43.5GHz, to enable 5G launch in 2020
Qatar	• In February 2018, CRA announced that it would assign two 400MHz blocks to Vodafone and Ooredoo in the 26.5–27.5GHz range in 2018; we are not aware of confirmation of this assignment. CRA also said that the spectrum for assignment would expand to 25.5–27.5GHz by January 2019 and then to 24.5–27.5GHz by January 2021
S. Korea	• South Korea completed a spectrum auction in the 26.5–28.9GHz range in June 2018, resulting in award of three licenses • We are not aware of any plans for further release of high-band spectrum
Spain	• The 26GHz (24.25–27.5GHz) band has been identified as a potential band for 5G. Spain's '5G National Plan' notes that the lower 400MHz portion of the band is currently available for immediate use; however, we are not aware of any official decision relating to the timing of assignment • Spain has also stated that, in accordance with the RSPG recommendations, "actions will be taken" to facilitate the availability of the 31.8–33.4GHz and 40.5–43.5GHz bands for 5G in the future

Country	Details
Sweden	• Sweden has consulted on opening the 26.5–27.5GHz range for assignment (in small geographical areas on an administrative basis) from 2019, with the remainder of the spectrum in the 26GHz band (i.e. 24.25–26.5GHz) opened for assignment subsequently • However, we understand that, due to consultation responses, it now intends to assign the entire 26GHz band (i.e. 24.25–27.5GHz) together
UK	• Ofcom is undertaking work to make the 26GHz band (parts of 24.25–27.5GHz) available for 5G • Ofcom also considers 66–71GHz, and bands around 40GHz (37–43.5GHz), to have significant potential for 5G deployment, with the former band potentially available on a license-exempt basis
US	• As noted previously, an auction of the 24GHz (24.25–24.45GHz and 24.75–25.25GHz) band is currently ongoing • In December 2018, the FCC adopted rules for the auction of spectrum in the upper 37GHz (37.6–38.6GHz), 39GHz (38.6–40.0GHz) and 47GHz (47.2–48.2GHz) bands. The auction is scheduled for H2 2019 • The FCC is also seeking to make available the 26GHz (25.25–27.5GHz) and 42GHz (42–42.5GHz) bands, though no timeframe for assignment has yet been specified • The FCC continues to consider action on the 32GHz (31.8–33GHz) and 50GHz (50.4–52.6GHz) bands, and it previously sought comment on the 70/80GHz (71–76GHz and 81–86GHZ) bands for unlicensed/fixed or other innovative uses. • Furthermore, the FCC has made available the 57-71GHz bands for unlicensed use and recently adopted an R&O to permit unlicensed use of 21.2GHz of spectrum above 95GHz (the FCC is further considering licensed use of spectrum above 95GHz)

Figure 4.16 below shows the mm-wave bands (below 55GHz[78]) confirmed or being considered for 5G in each of the countries under study.

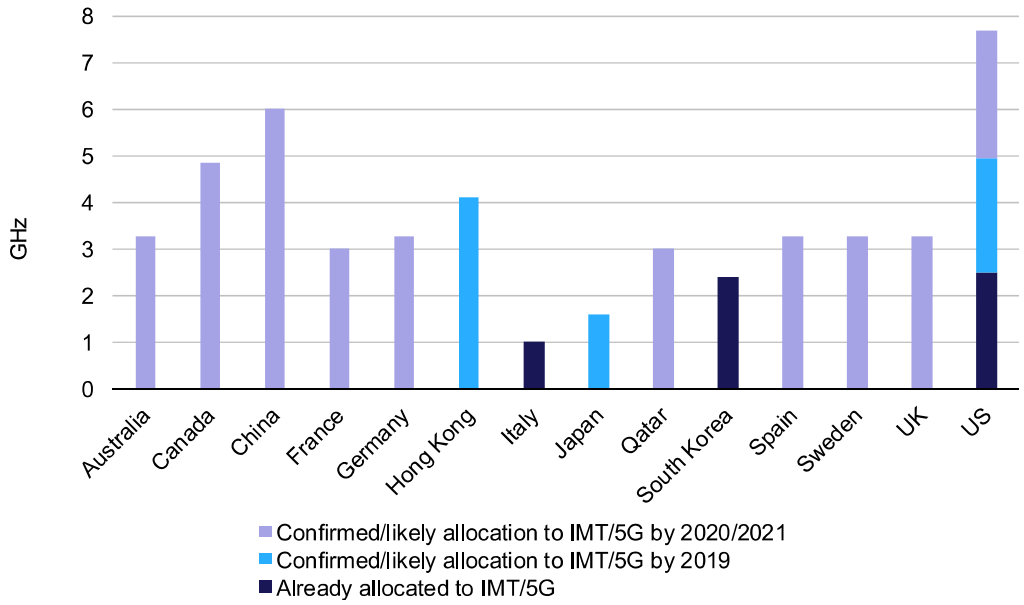
78 Higher bands are available in some markets, such as around 57–67GHz and 70–80GHz, that can be used to deploy 5G technology as well as for conventional fixed links.

Figure 4.16: Mm-wave spectrum considered/confirmed for 5G [Source: Analysys Mason, 2019]



The total amount of high-band spectrum confirmed for assignment to 5G (on a licensed basis) in each of the benchmark countries is shown in the figure below.

Figure 4.17: Total amount of high-band spectrum confirmed for assignment to 5G on a licensed basis in benchmark countries [Source: Analysys Mason, 2019]*



*This excludes unlicensed spectrum

5 National strategies and plans

Alongside the assignment of spectrum for 5G use (discussed in the previous section), governments and national policy makers are proposing and/or adopting a number of other measures as part of their overall strategies to encourage 5G development and deployment. Government action to promote 5G technology includes (in some cases) direct financial investment in technology trials, pilots, and cross-industry collaborations. In several markets, mobile siting policies have been under review to ensure they are fit for purpose for the 5G era.

Section 5.1 discusses the key policy areas that governments have identified in their national 5G strategies and roadmaps, and provides examples of markets where government funding is being put forward for 5G projects. One key area of 5G policy is revising regulations to streamline mobile infrastructure deployment procedures; this issue is discussed further in Section 5.2.

5.1 National 5G strategies and government aid on 5G technology trials

National 5G strategies

Recognizing the importance of 5G technology and mobile networks to provide connectivity for new digital services over the next decade, governments of many leading 5G markets have now published a formal 5G strategy, and/or a program of policies to facilitate 5G development and deployment. Examples include:

- Australia: '5G—Enabling the future economy' strategy
- France: '5G Roadmap'
- Germany: '5G Strategy for Germany'
- Japan: 'Policy to realize 5G in 2020' (in time for 5G services to be available to the public during the Tokyo 2020 Olympics)
- Spain: '5G National Plan 2018–2020'
- The UK: 'Future Telecoms Infrastructure Review' and 'Next Generation Mobile Technologies: A 5G strategy for the UK'
- The US: '5G FAST Plan' and National Spectrum Strategy.

In other cases, while a specific formalized 5G plan has not been published, national governments have encouraged the development and commercial deployment of 5G technology as part of a broader national broadband plan, digital strategy, or similar. For example, in China, the 'Made in China 2025' plan and the 13th Five-Year Plan explicitly aim for commercial launch of 5G services by 2020.

The key aspects of the 5G strategies for Australia, Japan, Spain, and the US are highlighted below as examples.

Australia: '5G—Enabling the future economy' strategy

Australia's 5G strategy, published in October 2017, outlines four "immediate actions" that the government is undertaking to support the development of 5G:

- making spectrum available in a timely manner
- actively engaging in international spectrum harmonization activities
- streamlining arrangements to allow MNOs to deploy infrastructure more quickly
- reviewing existing regulatory arrangements to ensure they are fit-for-purpose.

Japan: '5G—Enabling the future economy' strategy

In 2016, MIC published its 'Policy to realize 5G in 2020' (in time for the Tokyo 2020 Olympics). This commits to a package of a "comprehensive promotion strategies for 5G" including:

- Promoting three activities to support 5G realization for 2020 and beyond:
  - activities of the 5G Mobile Forum (5GMF)
  - 5G R&D through 'Industry-Academic-Government Co-operation'
  - standardization activities at the ITU and 3GPP.

- The 5G 'System Trial'. The trial is being conducted in partnership with each of the country's MNOs as well as a number of equipment manufacturers (Panasonic, Sharp, and Fujitsu), and is expected to continue until 2020.

Spain: '5G National Plan 2018-2020'

In December 2017, MINTEAD published 'Spain's 5G National Plan 2018–2020', consisting of the following four 'pillars':

- radio spectrum management and planning
- driving 5G technology – Network and service pilot projects and R&D activities
- regulatory issues
- 5G Plan coordination and international co-operation.

US: '5G FAST plan' / National Spectrum Strategy

The FCC unveiled its '5G FAST' plan in September 2018. The plan categorizes the FCC's approach to 5G development under the following three primary headings:

- assignment of spectrum
- updating of infrastructure policy
- modernization of outdated regulation.

The White House also issued a "Presidential Memorandum on Developing a Sustainable Spectrum Strategy for America's Future" in October 2018, calling for the development of a National Spectrum Strategy by mid-2019, citing the "imperative that America be first in fifth-generation (5G) wireless technologies."

As illustrated by the examples above, governments' 5G strategies and policies cover a range of issues, typically including items such as: assignment of spectrum, revision of regulations to promote 5G more broadly, equipment certification, contribution to the development of international standards and international radio harmonization, establishing appropriate dialog with relevant industry verticals, and so on.

A key additional issue for governments is infrastructure policy, which we consider in Section 5.2 below. In addition to these issues, some governments have chosen to directly allocate funding for 5G R&D, pre-commercial trials, and so forth; this is discussed below.

Government funding for 5G

In a number of cases, funding for 5G has been made available through a larger digital connectivity fund or under a national broadband plan. For example, in March 2017, Germany adopted its 'Gigabit Germany Initiative for the Future'. The objective of the initiative is to invest EUR100 billion to create a high-performance broadband network in Germany by 2025 using the "most sophisticated technologies available" such as "fiber optics and […] 5G".

In other cases, specific 5G investment programs have been announced by government (sometimes in partnership with private industry stakeholders). For example, in March 2018, the Canadian government announced a CAD400 million (USD300 million) public-private partnership for pre-commercial 5G development.

Canada: a CAD400 million (USD300 million) public-private partnership for pre-commercial 5G development

In March 2018, the Canadian Minister of ISED announced a joint investment in 5G between the government and industry parties, known as the 'ENCQOR' project. ENCQOR is a CAD400 million project to "establish the first Canadian pre-commercial corridor of 5G digital infrastructure", with a particular focus on providing access to 5G networks to SMEs, researchers, and academia. The five-year project is funded by five private partners (Ericsson, Ciena, Thales, IBM Canada, and CGI), contributing a total of CAD200 million, and the governments of Canada, Ontario, and Quebec (contributing CAD66.7 million each).

South Korea provides another example of a 5G-specific government investment plan. In January 2014, the Ministry of Science and ICT announced a KRW1.6 trillion (USD1.5 billion) five-year investment program for 5G.

South Korea: KRW1.6 trillion (USD1.5 billion) by 2020 for building 5G networks

In January 2014, MSIT announced plans to invest KRW1.6 trillion by 2020 to enable local firms to build 5G networks. In January 2018, MSIT announced R&D funding for a range of science/ICT projects, covering mobile communications and broadcasting (KRW70 billion), 'SW computing' (KRW146.6 billion), broadcasting (KRW65.7 billion), next-generation security (KRW61.8 billion), and 'devices' (KRW43.5 billion). Details regarding to what extent funding would be directly allocated to 5G related projects were not provided.

The UK is one of the leading countries in terms of specific funding programs for 5G, and has funded a number of projects to date, as described below.

The UK: GBP200 million (USD260 million) allocated to the '5G testbeds and trials' (5GTT) program

The UK government has committed to investing over GBP1 billion by 2020–2021 in digital communications, including GBP740 million through the NPIF (National Productivity Investment Fund) targeted at supporting the roll-out of full fiber and 5G.

In particular, the Department for Culture Media and Sport (DCMS) is allocating GBP200 million from the NPIF to its '5G testbeds and trials' (5GTT) program:

- Initial projects benefitting from the investment have included: (1) GBP10 million to create facilities for 5G network security testing, and (2) GBP5 million for an initial trial, starting in 2018, to test 5G applications and deployment on roads, including testing benefits of self-driving cars.
- The first allocation of 5GTT funding was announced in July 2017. GBP16 million was allocated to 5GUK, a collaboration between three UK universities to develop a 5G test network and conduct end-to-end trials.
- In March 2018, recipients of the "first phase" of 5GTT funding (GBP25 million) were announced. The grants are for initial projects across the UK that will run from April 2018 until March 2019 (with possible extension beyond March 2019, which is expected to be discussed during early 2019).
- Also, in March 2018, DCMS announced plans to fund a "5G Urban Connected Communities project" across a "large-scale urban area" in the UK as part of the 5GTT program. In September 2018, DCMS announced that the West Midlands had been selected as the location for the project, with hubs to be deployed using 5G technology in Birmingham, Coventry, and Wolverhampton. DCMS states that GBP50 million is currently available for the project (GBP25 million of which is provided by DCMS from the NPIF, and the remaining GBP25 million is provided by regional partners); a further GBP25 million may be available at a later date.
- In September 2018, DCMS published an update regarding the 5GTT program which provides a number of details about the different government-supported 5G projects taking place in the UK. It also references the UK5G Innovation Network, which was launched in March 2018. UK5G

is a DCMS-funded "national innovation network dedicated to the promotion of research, collaboration and the commercial application of 5G".

The 2017 budget also announced (an additional) GBP35 million of funding for the Local Full Fibre Networks (LFFN) program, 5GTT and Network Rail (NR) to enable trials to improve mobile communications for rail passengers. A call for expressions of interest was published by DCMS in August 2018.

5.2 Infrastructure policy

As discussed in our 2018 report, there are several infrastructure-related challenges inherent in the evolution of mobile networks to 5G, both to deploy 5G technology at existing macro sites, and to densify networks using small cells.

Governments and market participants have discussed measures to overcome these barriers in many countries. This section provides several examples of infrastructure policies from around the world[79] that we have identified through our research for this study as being designed to facilitate the deployment of 5G technology. We have updated three of the examples provided in our previous report (the EU, the UK, and the US) and also provided a number of new examples. Most of the examples given highlight the key issues under consideration as being simplification of infrastructure regulations, and easing of barriers to small-cell deployment (including recommendations on fees that can reasonably be found to account for the costs to local authorities relating to review of applications for siting of small cells).

A key underlying rationale for policy changes on deploying mobile infrastructure is the recognition that in the 5G era, many more mobile sites will be deployed (both macro sites, and small cells). Current regulations in many cases do not align well with this scaling up of infrastructure (e.g. due to the time taken to process site applications, the fees applied, or the inapplicability of existing requirements to new types of technologies).

The emphasis from policy-makers on 'removing barriers' to infrastructure deployment might be motivated by several goals, including more rapid initial deployment and the desire to encourage greater investment (e.g. to extend coverage from new networks to a wider proportion of users).

Australia – updated infrastructure legislation to enable the efficient roll-out of 5G

Legislation[80] has been in place in Australia for some time to provide regulatory support for the deployment of telecom infrastructure. In particular, legislation helps telecom carriers provide better services more quickly and cost effectively, by assigning them "powers and immunities" under Schedule 3 to the Telecommunications Act 1997. These powers and immunities help carriers to deploy telecom infrastructure quickly in a nationally uniform way, rather than having to follow state,

79 We have considered both specific legislative reforms and more general policy statements.

80 See https://www.communications.gov.au/have-your-say/consultation-possible-amendments-telecommunications-carrier-powers-and-immunities

territory, and local government planning and environmental requirements that would otherwise apply.

However, most aspects of carrier powers and immunities have been in place since 1997. After requests from carriers, the Australian government ran a consultation[81] (between June and July 2017) on updating the legislation to reflect changes in communication technologies, and allow the fast and efficient roll-out of 5G networks. The Minister for Communications agreed to implement a number[82] of the proposed changes, which came into force in early 2018.

On October 12, 2017, the Australian government launched its '5G—Enabling the future economy' strategy (see Section 5.1). The strategy outlines four "immediate actions" that the government will undertake to support the development of 5G, one of which is "streamlining arrangements to allow MNOs to deploy infrastructure more quickly". Under this action, the strategy paper references the legislation changes described above. It notes that the government has recently consulted on proposed new arrangements to streamline the deployment processes for 5G technologies, and "will implement the first tranche of changes to carrier powers and immunities following the conclusion of the consultation process".

Main goals: recent amendments to legislation aim to streamline arrangements to allow MNOs to deploy infrastructure more quickly

Policy details: revisions to the Telecommunications (Low-impact Facilities) Determination 2018 (LIFD) and the Telecommunications Code of Practice 2018 (Code). Examples of revisions include:

- Requiring only the lead carrier's signature on relevant documentation, in a joint-venture arrangement where two carriers are installing or upgrading facilities
- Specifying omnidirectional antennas (of the type which might be used for 5G small cells) as "low-impact facilities" in residential and commercial areas, not just industrial and rural areas.

Implementation timing: the updated legislation came into force in early 2018.

We also note that, in December 2017, the Australian government established[83] a '5G working group' with the following objectives:

- identify enablers and barriers to the deployment and effective use of 5G in Australia, including at the sector and industry level
- examine how the Commonwealth regulatory settings in sectors, including but not limited to communications, can be optimized for 5G networks and technologies

81 See https://www.communications.gov.au/have-your-say/consultation-possible-amendments-telecommunications-carrier-powers-and-immunities

82 In particular, the Minister for Communications agreed to remake the Low Impact Facilities Determination and the Telecommunications Code of Practice with nine of the 24 proposed changes. The remade instruments are now available on the Federal Register of Legislation and are referred to as the Telecommunications (Low-impact Facilities) Determination 2018 (LIFD) and the Telecommunications Code of Practice 2018 (Code).

83 See https://www.communications.gov.au/documents/terms-reference-5g-working-group

- provide a platform for collaboration across government and industry on 5G matters
- engage, with the input of subject matter experts, in ongoing strategic dialog about 5G matters.

EU – stimulating infrastructure investment and simplifying small-cell procedures, through a new European Electronic Communications Code

As described in our previous report, on September 14, 2016, the European Commission published[84,85] a draft Directive to establish a new European Electronic Communications Code (the 'Code', or (E)ECC). A final form of the EECC was adopted by the European Council in November 2018[86] (Directive (EU) 2018/1972).

The intention is that the Code will "make it more attractive for all companies to invest in new top-quality infrastructures [including 5G infrastructure], everywhere in the EU, both locally and across national borders. The EC has stated that investments triggered by the new framework could boost [EU] GDP by an additional EUR910 billion and create 1.3 million new jobs over the next decade (by 2025)".[87]

Part II of the Code, dealing with networks, includes several important articles aimed at stimulating investment in and deployment of (5G) telecommunications infrastructure:

- Article 43 – Rights of way

  When considering applications for the installation of facilities to provide electronic communications networks (both public and private), authorities should act "on the basis of simple, efficient, transparent and publicly available procedures, applied without discrimination and without delay, and in any event makes its decision within six months of the application".

- Article 57 - Deployment and operation of small-area wireless access points

  EU Member States "shall ensure that operators have rights to access physical infrastructure controlled by national, regional, or local public authorities which is technically suitable to host small-area wireless access points…including street furniture such as light poles, street signs, traffic lights, billboards, bus and tramway stops and metro stations". Furthermore, small-area wireless access deployments shall not be subject to any fees beyond administrative charges.

- Article 72 - Access to civil engineering

  NRAs may impose obligations on players with SMP to "meet reasonable requests for access to, and use of, civil engineering including… buildings or entries to buildings, building cables,

84 See http://europa.eu/rapid/press-release_MEMO-16-3009_en.htm

85 See https://ec.europa.eu/digital-single-market/en/news/proposed-directive-establishing-european-electronic-communications-code

86 See http://www.europarl.europa.eu/RegData/etudes/BRIE/2016/593562/EPRS_BRI(2016)593562_EN.pdf

87 See http://europa.eu/rapid/press-release_IP-16-3008_en.htm

including wiring, antennae, towers and other supporting constructions, poles, masts, ducts, conduits, inspection chambers, manholes, and cabinets".

Main goals: the Code aims to harmonize regulation of electronic communications across the EU. The EC has stated that the Code will "stimulate competition which drives investments and strengthens the internal market and consumer rights".[88]

The new Code is part of a larger set of initiatives and legislative proposals designed to place the EU "at the forefront of internet connectivity", as part of its wider Digital Single Market strategy.

Policy details: the full text of the directive is publicly available.[89] Key articles relevant to 5G infrastructure include:

- Article 43, which limits the time taken for applications to install infrastructure to be granted
- Articles 57, which simplifies the conditions for the deployment and provisions of small cells to reduce costs of deploying very dense networks
- Article 72, which supports greater infrastructure competition by ensuring access to civil infrastructure, such as ducts, poles, etc., where these are held by operators with SMP.

Implementation timing: Member States have until December 21, 2020, to transpose the new directive into national legislation.[90]

Article 57 of the Code tasks the EC, by means of implementing acts, with specifying the physical and technical characteristics, such as the maximum size, weight and, where appropriate, emission power of small-area wireless access points, which will be exempt from any individual town planning permit or other prior individual permits, except for environmental or historical reasons, or public safety.

On January 16, 2019, the EC launched[91] a public consultation on relevant aspects of an implementing act; the deadline for responses to the consultation is April 10, 2019.

France – first steps in government support for 5G infrastructure roll-out

On July 16, 2018, ARCEP published a 5G roadmap (see Section 5.1), which listed four "priority projects to make 5G a success". One of these was to "provide support for 5G infrastructure roll-outs".

Under this heading, ARCEP's roadmap notes that infrastructure deployment streamlining measures have already been identified by the Housing, Planning and Digital Development bill (the ELAN bill)

88 See http://europa.eu/rapid/press-release_IP-16-3008_en.htm

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

90 See http://europa.eu/rapid/press-release_MEX-18-1503_en.htm

91 See https://ec.europa.eu/digital-single-market/en/news/public-consultation-light-deployment-regime-small-area-wireless-access-points

put forward by the Ministry of Territorial Cohesion, and the European Electronic Communications Code. The ELAN bill was definitively adopted[92] by France's Senate on October 16, 2018.

ARCEP and the government also plan on establishing a "best practices guide to facilitate and accelerate the deployment of future networks (e.g. regarding the terms governing operators' access to street furniture)".[93] ARCEP further states that it will also assess the feasibility and opportunity to share small-cell networks, notably according to roll-out restrictions.

Main goals: to provide support for 5G infrastructure roll-outs.

Policy details: ARCEP's roadmap identified providing support for 5G infrastructure roll-outs as one of its four key areas. Some infrastructure deployment streamlining measures relevant to 5G were adopted in October 2018 through new housing legislation. The French government is looking to implement further measures in future.

Implementation timing: ongoing.

South Korea – revised legislation to provide access to local government facilities

In April 2018, MSIT announced[94] a series of measures to achieve 5G commercialization at the earliest possible date. These measures include revisions to legislation to allow the operators greater access to local government-owned locations (such as streetlamps and traffic facilities) to enable the installation of mobile equipment for 5G services. The MNOs (as well as SK Broadband) have also committed to share existing assets, such as conduits, fiber cables and poles, for initial 5G roll-out.[95] Furthermore, operators have committed to jointly construct new facilities necessary for 5G services (both fixed-line facilities such as manholes and conduits, as well as wireless facilities such as base station sites and antennas).

MSIT has indicated that the network sharing measures are expected to save between USD360 million and USD900 million over the next 10 years, through "eliminating overlapping investment"[94] and increasing efficiency. We understand that MSIT has also announced[96] that it will provide tax benefits and security maintenance services to the MNOs.

Main goals: to enable 5G commercialization at the earliest possible date.

Policy details: the government has revised legislation to allow operators greater access to local government-owned locations to enable the installation of 5G equipment.

92 See https://www.gouvernement.fr/en/elan-a-law-to-reform-housing-planning-and-digital-technology

93 See 5G roadmap

94 See https://www.msit.go.kr/web/msipContents/contentsView.do?cateId=mssw311&artId=1379674

95 The government has commissioned the Korea Information Society Development Institute to develop pricing models for the network-sharing arrangement. See http://www.koreatimes.co.kr/www/tech/2018/04/133_247121.html. See also https://en.yna.co.kr/view/AEN20180410009600320

96 See https://www.rcrwireless.com/20180717/5g/south-korean-telcos-agree-launch-5g-services-same-time-tag23

The operators have also jointly committed to share existing network assets and to jointly construct new facilities necessary for 5G services.

Implementation timing: ongoing.

UK – reforming legislation to make it easier to deploy telecom infrastructure

The primary legislation in the UK relating to telecom infrastructure is the Electronic Communications Code (the 'Code' or ECC, not to be confused with the European level Code described above). The ECC regulates the relationship between electronic communications network operators and site providers (e.g. landowners). The UK amended the ECC in late 2017, aimed at making legislation more appropriate to future networks as they evolve, including making it easier to deploy new mobile sites and to modify existing sites, without incurring significant delays, or cost, through the need to re-plan sites (e.g. for addition of new antennas). A key goal of the amended legislation is to facilitate a consistent approach to calculating site and infrastructure rental costs, so that operators can continue to use existing sites, and roll out new sites, without uncertainties concerning the site rental costs that might be applied.

Main goals: reforms to the UK Code[97] are intended to make it easier for telecom operators to roll out infrastructure for mobile/fixed networks on public and private land.

The new Code gives additional flexibility to mobile operators to upgrade, share, access, and remain on their existing sites. This may be significant in facilitating 5G roll-outs, e.g. by enabling MNOs to avoid 'ransom rents' when upgrading infrastructure (i.e. changing or adding antennas for 5G).

Policy details: the key changes made include:

- increasing the scope of the code to legislate on access to infrastructure (e.g. masts) as well as land used to site wireless transmitters
- providing mobile operators with additional rights (e.g. rights of access, rights to remain)
- amending the rental regime for land and infrastructure on which wireless transmitters are installed (e.g. to implement a consistent approach to calculating site and infrastructure rental costs).

Implementation timing: the Code reforms became UK law in December 2017.[98]

UK – a government 'Taskforce' to remove barriers to 5G deployment

On November 28, 2017, DCMS launched its 'Future Telecoms Infrastructure Review' (the Review) of the UK telecom markets, in order to investigate "how it can support investment in the world-class

97 See https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/523788/Electronic_Communications_Code_160516_CLEAN_NO_WATERMARK.pdf

98 See https://www.out-law.com/en/articles/2017/december/uk-electronic-communications-code-to-become-law-on-28-december/

connectivity of the future [full fiber and 5G]". The findings of the Review were published on July 23, 2018, and set out a target for "the majority of the population to have 5G coverage by 2027".

The Review identified four priority areas to help foster a competitive mobile market and support investment in 5G. The first of these was to "make it easier and cheaper to deploy mobile infrastructure and support market expansion, including the implementation of the wide-ranging reforms to the ECC [see previous sub-section] on site access and consideration of further planning reforms".

DCMS notes that ECC measures to date have largely focused on macro cells, but that in the longer term, 5G is likely to require greater deployment of small cells. DCMS states that "additional measures will be required to make small cell deployment cost effective and practical" and that it has been asked by industry players to prioritize the following actions to reduce deployment barriers to 5G:

- ensuring the ECC reforms achieve their intended effect[99]
- considering further planning reforms to support macro-site expansion and small-cell deployment
- improving access to public sites and exploring ways to reduce costs
- facilitating access to power supplies
- identifying local solutions to address deployment barriers.

The UK government has created the "Barrier Busting Task Force" to work with both the fixed and mobile telecom industry to identify barriers to network deployment.

In May 2017, the Broadband Stakeholder Group (BSG[100]) (a government advisory group on broadband issues), published[101] a report entitled "Tackling Barriers to Telecoms Deployment". The report looked at the factors slowing down the roll-out of UK broadband, including local authority planning and the business rates regime for fiber.

In response to this report, the government said that its Barrier Busting Taskforce aims to "reduce the costs of street-works, liberalizing planning, to simplify wayleave agreements and tackle every and any barrier to roll-out" and that it would "examine every issue flagged in the report, and then working with local bodies to identify solutions or to implement best practice".[102]

99 The Review states that the government will consider undertaking a formal review of the ECC reforms to assess their impact in 2019

100 The Broadband Stakeholder Group (BSG) was established in 2001, and since 2006 has focused on next-generation broadband issues. See http://www.broadbanduk.org/about/

101 See http://www.broadbanduk.org/wp-content/uploads/2017/05/Lowering-barriers-to-telecoms-infrastructure-deployment-Final-report.pdf

102 See https://www.gov.uk/government/speeches/building-a-full-fibre-britain

A further report was published[103] by the BSG in July 2018, entitled "Lowering barriers to 5G deployment". The report identified a number of barriers and provided a series of recommendations aimed at UK government, devolved governments, local authorities, and industry stakeholders.

More recently, DCMS's Barrier Busting Taskforce launched[104] a 'Digital Connectivity Portal', an online resource for local authorities and communications network providers with guidance to support investment in broadband and mobile networks.

Main goals: beyond implementing the ECC, continuing to remove barriers to 5G deployment.

Policy details: DCMS has established a Barrier Busting Taskforce which aims to "reduce the costs of street-works, liberalizing planning, to simplify wayleave agreements and tackle every and any barrier to roll-out".

Implementation timing: the Barrier Busting Taskforce was set up in 2017. Implementation is ongoing.

US – reforming regulations to make it easier to deploy wireless infrastructure

In the US, deployment of wireless equipment generally requires approval from local/state authorities[105] and compliance with FCC rules.

Since our previous report, the FCC has adopted further reforms aimed at easing 5G infrastructure deployment:

- On March 22, 2018, the FCC adopted[106] a second R&O, reforming the rules applying to infrastructure deployment, streamlining the process of deploying next-generation wireless facilities, addressing the types of deployment subject to historic (NHPA) and environmental (NEPA) review, and establishing timeframes for the FCC to act upon Environmental Assessments.[107]

- On August 3, 2018, the FCC adopted[108] a declaratory ruling and third R&O. The Declaratory ruling concludes that state and local moratoria on wireless services and facilities deployment are barred by federal law.

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103 See http://www.broadbanduk.org/wp-content/uploads/2018/07/BSG-Report-Lowering-barriers-to-5G-deployment.pdf

104 See https://dcmsblog.uk/2018/12/introducing-the-digital-connectivity-portal/

105 To date, 21 US states have enacted legislation reforming rules governing wireless infrastructure deployment to prepare for 5G.

106 See https://www.fcc.gov/document/fcc-acts-speed-deployment-next-gen-wireless-infrastructure. The second R&O was released on March 30, 2018. See https://www.fcc.gov/document/fcc-acts-speed-deployment-next-gen-wireless-infrastructure-0

107 See https://transition.fcc.gov/Daily_Releases/Daily_Business/2018/db0301/DOC-349528A1.pdf

108 See https://docs.fcc.gov/public/attachments/FCC-18-111A1.pdf

- On September 26, 2018, the FCC adopted[109] another declaratory ruling and another third R&O. The Declaratory ruling provides guidance on whether state or local regulations serve to prohibit deployment, as well as on reasonable costs associated with state and local governments' reviews of the authorizations necessary to deploy small wireless facilities. The third R&O introduces two new 'shot clocks' for small wireless facilities. These specify the presumptively reasonable time period (60 days for co-location on pre-existing structures and 90 days for new builds) within which state and local governments must act on applications.

Main goals: recognizing the significant economic benefits that 5G will bring, the FCC's goal is to ensure that regulatory barriers are identified, and solutions are found to reduce or eliminate these barriers.

Policy details: a number of revisions to regulations in accordance with the above goal have been adopted, including eliminating barriers to deployment, streamlining the process of deploying next-generation wireless facilities, providing guidance on reasonable costs and timelines associated with siting reviews, and addressing the types of deployment subject to NHPA and NEPA review.

Implementation period: various reforms have been adopted between 2014 and 2018.

109 See https://www.fcc.gov/document/fcc-facilitates-wireless-infrastructure-deployment-5g

6 Comparison of 5G readiness across markets

This section provides an updated assessment of '5G readiness' in our new group of benchmark countries, based on our revised set of spectrum and infrastructure-related metrics.

Section 6.1 includes a description of the updated list of metrics we have used in our scoring, and presents the score assigned in each market for each metric. Section 6.2 provides an overall summary of our scores and findings.

6.1 Drivers of 5G readiness

Our 5G readiness analysis is based on an assessment of six different metrics described below. Two of these ('Industry commitment to commercial 5G launch', and 'National strategies/government support') are unchanged from our previous report. However, two of the other metrics used in our previous report – those related to 5G roadmaps and 5G trials – are no longer included. This is because almost all the major MNOs in our benchmark countries have now conducted (and are continuing to conduct) a comprehensive program of 5G trials. Similarly, the majority of governments under study have now issued 5G roadmaps (or equivalent strategy documents). To reflect the importance of low, mid, and high band spectrum, we have assigned separate metrics for low-, mid-, and high-band spectrum availability as well as overall (total spectrum), given that spectrum in each of these bands is needed to contribute to overall 5G capability (as described in Section 4.1). Thus, the set of metrics we use for our 2019 readiness analysis in this report is as follows:

- **Industry commitment to commercial 5G launch.** As in our previous report, this metric assesses the progress that is being made by network operators toward commercial 5G launch. This is measured to a large extent by public announcements made by MNOs which explicitly commit to commercial 5G launch dates, combined with an assessment of the maturity of pre-commercial activity such as widespread trials and pre-commercial service launches. A high score indicates that most or all MNOs have explicitly committed to an accelerated 5G commercial launch prior to 2020.

- **Amount and timeline of low-band 5G spectrum release.** This metric assesses the amount of low-band spectrum (defined as spectrum below 3GHz) which has already been assigned to mobile or is scheduled to be assigned in the future. A high score in this category is given where large amounts of 5G-suitable low-band spectrum have already been awarded (or are scheduled to be awarded imminently).

- **Amount and timeline of medium-band 5G spectrum release.** This metric is the same as above, but for mid-band spectrum (defined as spectrum in the 3–24GHz range).

- **Amount and timeline of high-band 5G spectrum release.** This metric is the same as above, but for high-band spectrum (defined as spectrum above 24GHz).

- **Total 5G spectrum release.** This metric brings together the previous three individual spectrum metrics, and is intended to capture the overall spectrum situation in a given country. Given that spectrum across each of the low, mid, and high bands is envisioned to be needed to provide the full range of services and levels of quality of experience achievable from 5G technology, it is important that governments ensure that spectrum is awarded in each of these bands. Countries that score highly here will have awarded (or plan to award imminently) sufficient amounts of spectrum in the low, mid, and high bands. Conversely, markets will be penalized where poor progress has been made in one (or more) band.

- **National strategies/government support.** As in our previous report, this metric aims to capture the extent to which national governments are proactively aiming for 5G deployment, and are putting policies in place aimed at encouraging further technological development and early commercial launch of 5G services. This metric includes policies aimed at easing 5G infrastructure deployment, as well as government backing for early 5G deployment (e.g. direct allocation of government funding or other relevant government initiatives aimed at accelerating 5G developments, technological advancement and encouragement of collaborative trials). Favorable policies toward 5G commercialization might include policies aimed at encouraging new infrastructure developments such as small cells, as well as broader policies aimed at streamlining planning processes for mobile operators relating to macro sites used within today's 4G networks, which will also be important to 5G. A high score for this metric reflects proactive government policy making (evidenced by public documentation) supportive of 5G, which might include specific infrastructure-based policies, funding being allocated to further the development of 5G technology in-country, or to facilitate large-scale, collaborative testing and development.

Our scoring between countries has been performed as follows:

- Each country is assigned a score between 0 and 4 for each of the six metrics. These scores (denoted S_1 to S_6) are depicted visually using Harvey balls, in accordance with the following scale:

Figure 6.1: Harvey ball scoring code [Source: Analysys Mason, 2019]

- A final *5G readiness score* is then calculated as a simple sum[110] of the individual scores:

$$5G\ readiness\ score,\ S_{Total} = S_1 + S_2 + S_3 + S_4 + S_5 + S_6$$

110 The relative importance of each metric to overall 5G readiness is likely to change over time. In order to provide a broadly comparable basis for various versions of this index over time, we have decided not to apply weightings to the individual metrics.

As noted in our previous report, it should be emphasized that market-readiness for 5G is an inherently qualitative concept, and quantitative scoring will not necessarily capture all the nuances of the real-life situation.

Below, we provide analysis and scoring for each of the six metrics being considered.

Industry commitment to commercial 5G launch

The following table summarizes our assessment of industry commitment and progress toward a 5G launch in each of the benchmark countries. As shown, top scores have been assigned to South Korea and the US; certain operators in both of these countries have already launched (limited) commercial 5G services in certain locations, and all operators are expected to have launched 5G services commercially by H1 2019.

Figure 6.2: Country scores for Metric 1 [Source: Analysys Mason, 2019]

Market	S_1	Details
Australia		• Telstra aims to have a 5G commercial deployment in certain locations from H1 2019 and in "all high-demand regional centers" in FY2020 • Optus plans to launch 5G FWA services in certain cities in H1 2019 • VHA and TPG have not yet announced 5G commercial deployment dates
Canada		• Rogers has said it expects commercial 5G deployment in 2020 • Telus has said it expects 5G FWA services to be available from 2020 • Bell has not yet announced 5G commercial deployment dates
China		• All Chinese operators have committed to large-scale 5G commercial launches from 2020
France		• Orange has indicated that customers in certain cities will be able to access 5G services in 2019, with commercialization in 2020 • Bouygues has said that 5G "will be marketed in 2020" • SFR and Free have not yet announced 5G commercial deployment dates
Germany		• Vodafone aims to make 5G services available to customers from 2020 • DT has said that it will launch commercial 5G operations in 2020, subject to device availability • Reports have indicated that Telefonica is likely to launch 5G services in 2020
Hong Kong		• CMHK has stated that it "will be ready to provide full [5G] services" when spectrum is released in 2019–2020 • HKY, SmarTone, and Three are expected to launch commercial services from 2020
Italy		• Vodafone has deployed pre-commercial 5G networks in various cities • Wind Tre expects initial 5G deployment in certain locations by end-2019 • TIM has switched on a 5G site in San Marino, ahead of full commercial launch • Iliad has not yet announced 5G commercial deployment dates
Japan		• All the major Japanese operators have committed to large-scale 5G commercial launches from 2020 • Rakuten aims to launch commercial 5G services in early 2020

Market	S_1	Details
Qatar		• Ooredoo and Vodafone are expected to launch commercial 5G services when devices become available in 2019
South Korea		• Each of South Korea's three MNOs launched 5G FWA services (limited to enterprise customers) in December 2018. Full (mobile) commercial 5G launch for regular consumers is scheduled for March 2019
Spain		• Orange has indicated that customers in certain cities will be able to access 5G services in 2019, with commercialization in 2020 • Telefonica has stated that its 5G services will not be available commercially prior to 2020 • Vodafone and Mas Movil have not yet announced 5G commercial deployment dates
Sweden		• Telia and Telenor/Tele2 are aiming for commercial launch of 5G in 2020 • Tre has not yet publicly announced 5G commercial launch dates
UK		• Vodafone and BT/EE have announced plans to provide commercial 5G services in 2019 • Three has indicated that it may provide 5G FWA services from 2019 • O2 has stated that its 5G services will not be available commercially prior to 2020
US[111]		• AT&T launched initial 5G commercial mobile services in December 2018 • Verizon launched initial 5G FWA services in October 2018 with 5G mobile services planned for 2019 • Sprint aims to launch commercial 5G services in certain cities in H1 2019 • T-Mobile plans to launch in early 2019, with nationwide 5G coverage by 2020

Low-band 5G spectrum: amount assigned/scheduled for release and corresponding timeline

The following table summarizes our assessment of the amount of low-band 5G spectrum released in each of the benchmark countries and corresponding timeline. As shown, top scores have been assigned to a number of countries (Australia, Canada, Germany, Sweden, the UK, and the US), each of which has already assigned over 600MHz of spectrum for mobile, and in a number of cases is expected to assign further spectrum by 2020. Qatar scores lowest in this category, with just over 300MHz low-band spectrum currently assigned to mobile.

Figure 6.3: Country scores for Metric 2 [Source: Analysys Mason, 2019]

Market	S_2	Details
Australia		Australia has already assigned a total of 690MHz of low-band spectrum for mobile, including spectrum in the 700MHz and 2300MHz bands. An additional 2×15MHz is expected to be assigned in the 850MHz band (3GPP bands 26/27) in 2020. Allocation of the L-band (1427–1518MHz) is scheduled for 2021.

111 Furthermore, sub-national operator US Cellular plans to launch 5G services in the second half of 2019

Market	S_2	Details
Canada		Canada has already assigned a total of 648MHz of low-band spectrum for mobile, the fourth highest of our benchmark countries. An auction of 2×35MHz in the 600MHz band is scheduled for early 2019 and ISED will initiate a review of the 1500/1600MHz bands in late 2019.
China		China has currently assigned a total of 582MHz of low-band spectrum for mobile, including spectrum in the 1900MHz and 2300MHz bands. This is the third lowest amongst our selected markets. Furthermore, only slightly more than 70MHz of sub-1GHz spectrum has been released, contributing to a low score on this metric. However, a total of 687MHz of low-band spectrum has been planned in China; various blocks of spectrum in the 1800MHz, 1900MHz, 2100MHz, 2300MHz, and 2600MHz bands have yet to be awarded, although we are not aware of an official timeline for doing so.
France		France has already assigned a total of 598MHz of low-band spectrum for mobile, including paired spectrum in the 700MHz band, placing it in the middle of our group of countries. ARCEP has consulted on assigning the 700MHz unpaired range, but has no plans to do so prior to June 2019. ARCEP has indicated that it may assign L-band spectrum at the same time as the 3.4–3.8GHz and 26GHz bands (2019/2020 respectively) and has also stated that work is "well underway" to introduce LTE in the 450MHz band.
Germany		Germany has already assigned a total of 689MHz of low-band spectrum for mobile, including paired spectrum in the 700MHz band as well as 40MHz in the L-band. In terms of current assignments, this ranks Germany in the top three of our benchmark, and top within European countries. BNetzA has said that the 700MHz unpaired range may be considered for auction at a later date.
Hong Kong		Hong Kong has currently assigned a total of 583MHz of low-band spectrum for mobile, including spectrum in the 2300MHz band, placing it toward the bottom of our benchmark. CA intends to assign 'digital dividend' spectrum in the 700MHz band to mobile as soon as possible after the analog switch-off (to be completed by 2020).
Italy		Italy has already assigned a total of 640MHz of low-band spectrum for mobile, including paired spectrum in the 700MHz band and 40MHz in the L-band. We are not aware of plans for further low-band spectrum assignment, though we note that the 700MHz unpaired range went unsold at the auction in 2018. Italy sits in the middle of our group of countries in terms of low-band spectrum.
Japan		Japan has currently assigned a total of 601MHz of low-band spectrum for mobile (including 70MHz in the 1500MHz band); this places Japan in the middle of our group of countries. MIC has stated that it will promote frequency sharing/allocation in the 2300–2330/2370–2400MHz range, and consider frequency sharing with mobile satellite in the 2500–2545/2645–2690MHz range.
Qatar		Qatar has currently assigned a total of 304MHz of low-band spectrum for mobile, more than 150MHz less than all the other benchmark countries. Qatar plans to assign 2×30MHz in the 700MHz band for 5G. However, only around half of the spectrum internationally harmonized for mobile in the 1800MHz, 2100MHz, and 2600MHz bands has been assigned, and we are not aware of plans for future awards in these bands.
South Korea		South Korea has currently assigned a total of 477MHz of low-band spectrum for mobile, including 57MHz in the 2300MHz band. Apart from Qatar, South Korea ranks lowest amongst the benchmark countries in terms of current low-band assignment. We are not aware of plans for further low-band spectrum assignment, though we note that 2×20MHz in the 700MHz band went unsold at an auction in 2016. South Korea has awarded the least sub-1GHz spectrum of any of the benchmark countries (60MHz in the 800MHz band and 20MHz in the 900MHz band).

Market	S_2	Details
Spain 		Spain has currently assigned a total of 580MHz of low-band spectrum for mobile. This is the lowest score among the European countries we have considered, and places Spain toward the bottom of our group of markets. However, Spain expects to auction spectrum in the 700MHz band in early 2020 and is taking measures to make spectrum available in the L-band. Spain has also said that demand for shared use of the 2.3–2.4GHz band for 5G "will be examined".
Sweden 		Sweden has already assigned a total of 630MHz of low-band spectrum for mobile, including 10MHz in the 450MHz band. An award of spectrum in the L-band is planned for "2019 or later", and the 2300–2380MHz range is scheduled to be assigned (together with the 3.4-3.7GHz range) in late 2019 or early 2020. PTS has also said that it will "analyze the possible future use" of unpaired 700MHz spectrum which went unsold in the 2018 auction. Given these future plans, Sweden is likely to be one of the top countries in terms of total low-band spectrum by 2020.
UK 		The UK has already assigned a total of 647MHz of low-band spectrum for mobile, including 40MHz in the L-band and 40MHz in the 2300MHz band. The UK plans to auction the 700MHz band (both paired and unpaired) by Spring 2020. This places the UK toward the top of our benchmark in terms of low-band spectrum. Furthermore, Ofcom is currently consulting on introducing spectrum-sharing arrangements in the DECT guard band (1781.7–1785/1876.7–1880MHz) and 2390–2400MHz band.
US 		The US has already assigned a total of 716MHz of low-band spectrum for mobile, including around 70MHz in the 600MHz band. EBS spectrum (part of the 2.6GHz band) is currently unused in large parts of the US, and the FCC is proposing to "modernize and rationalize" this spectrum.

Mid-band 5G spectrum: amount assigned/scheduled for release and corresponding timeline

The following table summarizes our assessment of the amount of mid-band 5G spectrum released in each of the benchmark countries and corresponding timeline. As shown, Canada and the US score lowest in this category, with no (or limited) mid-band spectrum currently assigned to mobile use, and limited further assignments confirmed by 2020. China and Japan are ranked highest for this metric.

Figure 6.4: Country scores for Metric 3 [Source: Analysys Mason, 2019]

Market	S_3	Details
Australia 		Australia has already assigned a total of 225MHz of mid-band spectrum suitable for mobile (100MHz within the 3400–3575MHz band in specific locations, and 125MHz in the 3575–3700MHz band). The regulator plans to release discussion papers in 2019 on reconfiguration options in the 3400–3575MHz band and long-term arrangements in the 3.7–4.2GHz band. Australia lies in the middle of our group of countries on this metric.
Canada 		No mid-band spectrum is currently assigned to mobile in Canada. An auction in the 3450–3650MHz band is planned for late 2020. The regulator is consulting on use of the 3400–3450MHz and 3650–4200MHz bands for 5G, but timeframes have not been decided. Canada is the only country in our group that will not make any mid-band spectrum available for 5G until 2020.

Market	S_3	Details
China		China has already assigned a total of 300MHz of mid-band spectrum (national test licenses in the 3.4–3.6GHz and 4.8–4.9GHz to each of the three MNOs). China ranks second highest among the benchmark countries. Furthermore, a total of 500MHz (3.3–3.6GHz and 4.8–5.0GHz) is scheduled to be released; this is expected to take place between H2 2019 and H1 2020. Reports also indicate that China is likely to assign the 3.6–4.2GHz range to 5G use in the future, subject to co-ordination with existing satellite use.
France		No mid-band spectrum is currently assigned to mobile in France. An auction of (parts of) the 3.4–3.8GHz range is scheduled for late-2019 or early-2020, although the exact approach is still be confirmed; ARCEP has previously said that it aims to make available 300MHz of contiguous mid-band spectrum for 5G by 2020.
Germany		No mid-band spectrum is currently assigned to mobile in Germany. The government plans to award the entire 3.4–3.8GHz band for mobile use in early 2019. The 3.4–3.7GHz range (for nationwide use) will be auctioned, while the 3.7–3.8GHz range will be for regional/local use.
Hong Kong		No mid-band spectrum is currently assigned to mobile in Hong Kong. The government plan to auction three bands in July/August 2019 on a national basis for 5G: 3.3–3.4GHz (for indoor use only), 3.4–3.6GHz and 4.84–4.92GHz. The regulator has said that spectrum will become available for use from end-2019/2020. Hong Kong sits in the middle of our benchmark for this metric; a large amount of spectrum has been confirmed for release (second only to Japan and China), but it will not be available until 2019/2020.
Italy		Italy has already assigned a total of 326MHz of mid-band spectrum suitable for mobile. This includes the 3.6–3.8GHz range, which was auctioned on a national basis in 2018, as well as regional assignments in the 3.4–3.6GHz band. Italy has currently assigned more mid-band spectrum than any of the countries in our benchmark apart from Spain, contributing to a high score on this metric.
Japan		Japan has already assigned a total of 200MHz (3.4–3.6GHz) of mid-band spectrum suitable for mobile use. The regulator plans to release six 100MHz blocks of spectrum (3.6–4.1GHz and 4.5–4.6GHz) by March 2019. This means that a total of 800MHz is expected to be available for mobile use, significantly more than any of the other benchmark countries. Furthermore, the 4.6–4.8GHz range will be considered for private 5G use.
Qatar		100MHz has been assigned to each of the two MNOs in the 3.4–3.6GHz range. A document released by CRA in February 2018 indicates that the 3.6–3.8GHz range will also be assigned for 5G use in the future.
South Korea		South Korea has already assigned a total of 280MHz (3.42–3.70GHz) of mid-band spectrum suitable for mobile use.
Spain		Spain has already assigned a total of 360MHz (3400–3480/3500–3580MHz and 3.6–3.8GHz) of mid-band spectrum suitable for mobile use. This is more than any of our other selected countries, contributing to a high score.
Sweden		80MHz of spectrum (3600–3640/3700–3740MHz) is currently assigned to MNOs on a national basis under service-neutral licenses expiring in 2022. Sweden plans to award the entire 3.4–3.8GHz band to mobile use; the 3.4–3.7GHz range (for nationwide use) is scheduled for auction in late 2019 or early 2020, while the 3.7–3.8GHz range (for regional/local use) is expected to be assigned from 2023.

Market	S_3	Details
UK		The UK has already assigned a total of 270MHz (3410–3680MHz) of mid-band spectrum suitable for mobile use. The UK also plans to award 120MHz (3680–3800MHz) by Spring 2020 and is currently consulting on introducing a sharing regime in the 3.8–4.2GHz range.
US		The US is making 150MHz in the 3550–3700MHz (CBRS) band available, with 70MHz to be auctioned (potentially in 2019) and the entire 150MHz to be available on a shared basis (in mid-2019). The FCC is exploring the 3.7–4.2GHz, adopting an NPRM in July 2018, a move that could open up large additional blocks of mid-band spectrum. The US is also studying the 3.45–3.55GHz band and considering options for use of the 5.925–7.125GHz range, but specific plans have not yet been confirmed.

High-band 5G spectrum: amount assigned/scheduled for release and corresponding timeline

The following table summarizes our assessment of the amount of high-band 5G spectrum released in each of the benchmark countries and corresponding timeline. As shown, the US scores the highest in this category, with China (and a selection of other countries) close behind. The US has recently completed its auction of the 28GHz band and is currently conducting an auction of the 24GHz band, while China has committed to assigning 2GHz of mm-wave spectrum to each MNO (although timing has not been confirmed).

Figure 6.5: Country scores for Metric 4 [Source: Analysys Mason, 2019]

Market	S_4	Details
Australia		No high-band spectrum is currently assigned for mobile use in Australia. An auction of the 26GHz (24.25–27.5GHz) band is scheduled for Q3/4 2020. ACMA is also considering the future use of the 28GHz (27.5–29.5GHz) band.
Canada		No high-band spectrum is currently assigned for mobile use in Canada. ISED aims to release the 26GHz (26.5–27.5GHz) band for 5G by 2020, the 28GHz (27.5–28.35GHz) and 37–40GHz bands for flexible fixed and mobile use by late 2021, and the 64–71GHz band for license-exempt use in late 2021. ISED is further considering mobile use in other bands (24.25–26.5GHz, 40–43.5GHz, 45.5–50.2GHz, 50.4–52.6GHz) which have the potential to be released by 2022. This means that the amount of confirmed/likely allocation of high-band spectrum for 5G in Canada is one of the highest among the benchmark countries.
China		No high-band spectrum is currently assigned for mobile use in China. However, MIIT has stated that it intends to make available 2GHz of spectrum per operator in the 24.25–42.5GHz range for 5G (significantly more than any other country). This commitment puts China near the top of our group of countries. MIIT has already approved the 24.75–27.5GHz and 37–42.5GHz bands for research and testing and has stated that it will consider further mm-wave bands for 5G development.
France		No high-band spectrum is currently assigned for mobile use in France. The 26.5–27.5GHz band will be assigned in 2020, while the 24.5–26.5GHz band is planned for release after the migration of PtP radio links. The 24.25–24.5GHz range will also potentially be available for 5G in the future.
Germany		No high-band spectrum is currently assigned for mobile use in Germany. BNetzA aims to develop an approach to releasing the 26GHz (24.25–27.5GHz), 28GHz (27.5–29.5GHz), and 32GHz (31.8–33.4GHz) bands for 5G (starting with the 26GHz band) "as early as possible so that usage can start in 2020". BNetzA has

Market	S_4	Details
		held a consultation on a co-ordinated licensing arrangement (for individual base stations) in the 26GHz band.
Hong Kong 		No high-band spectrum is currently assigned for mobile use in Hong Kong. A total of 4.1GHz will be made available, via administrative assignment across the 26GHz (24.25–27.5 GHz) and 28GHz (27.5–28.35GHz) bands. 3.7GHz will be made available via exclusive nationwide licenses and 400MHz will be made available on a geographically shared basis. Assignments are scheduled for H1 2019; this is early compared to many other countries, contributing to a high score in this metric.
Italy 		Italy has already assigned 1GHz (26.5–27.5GHz) of high-band spectrum for mobile, making it one of only three countries (the others being South Korea and the US) to have assigned high-band spectrum. However, we are not aware of any plans or consultations on further assignment, meaning that Italy may lag behind a number of the other benchmark countries by 2020.
Japan 		No high-band spectrum is currently assigned for mobile use in Japan. MIC plans to award licenses for the 27.0-28.2GHz and 29.1–29.5GHz ranges to 5G use (as four 400MHz unpaired blocks) by the end of March 2019. This early timeframe for award has contributed to a high score in this metric. We also note that other mm-wave bands are under consideration, and that the 28.2–29.1GHz range will be considered for private 5G use.
Qatar 		No high-band spectrum is currently assigned for mobile use in Qatar. CRA has said that it will assign two 400MHz blocks to Vodafone and Ooredoo in the 26.5–27.5GHz range in 2018; however, we are not aware of confirmation of this assignment. CRA also said that the spectrum for assignment would expand to 25.5–27.5GHz by January 2019 and then to 24.5–27.5GHz by January 2021.
South Korea 		South Korea has already assigned 2.4GHz (26.5–28.9GHz) of high-band spectrum for mobile use on a national basis. We are not aware of any plans for further release of high-band spectrum.
Spain 		No high-band spectrum is currently assigned for mobile use in Spain. The 24.25–27.5GHz band has been identified as a potential 5G band, and the lower 400MHz portion of this range is currently available. However, we are not aware of an official timeline for assignment. In accordance with RSPG recommendations, Spain will facilitate the availability of the 31.8–33.4GHz and 40.5–43.5GHz bands for 5G in the future.
Sweden 		No high-band spectrum is currently assigned for mobile use in Sweden. We understand that PTS intends to assign the entire 24.25–27.5GHz range, but no definite timeline has been set yet.
UK 		No high-band spectrum is currently assigned for mobile use in the UK. Ofcom has consulted on different approaches to make spectrum available for 5G in the 24.25–27.5GHz range. However, a decision on timing/approach has not yet been taken. Furthermore, Ofcom considers the 66–71GHz and 37–43.5GHz bands to have significant potential for 5G deployment, with the former potentially available on a license-exempt basis.
US 		The US has already assigned 850MHz of high-band spectrum in the 27.5–28.35GHz band. Around two-thirds of the 38.6–40.0GHz band (measured by MHz-pop) is also currently assigned (mostly to Verizon and AT&T). Furthermore, the 24.25–24.45GHz and 24.75–25.25GHz ranges are currently being auctioned. In December 2018, the FCC adopted rules for the auction of spectrum in the 37.6–38.6GHz, 38.6–40.0GHz (in regions where licenses have not already been assigned), and 47.2–48.2GHz bands. The auction is scheduled for H2 2019. The FCC has also sought comments on the 26GHz, 32GHz, 42GHz, 50GHz, and 70/80GHz bands, as well as bands above 95GHz.

Total 5G spectrum release

The following table summarizes our assessment of the total 5G spectrum release (across low, mid, and high bands) in each of the benchmark countries. As shown, China is the only country that has been assigned a maximum score (having scored strongly in each of the low-, mid-, and high-band spectrum metrics).

Figure 6.6: Country scores for Metric 5 [Source: Analysys Mason, 2019]

Market	S_5	Details
Australia		Australia has now released 225MHz of mid-band spectrum for mobile, with a large amount of sub-3GHz spectrum also available. However, no further mid-band spectrum has been confirmed for award, and mm-wave spectrum is not scheduled for release until end-2020.
Canada		Canada's overall spectrum score is the lowest among the benchmark countries. Although it has already assigned nearly 650MHz of low-band spectrum (with an auction in the 600MHz band expected shortly), no mid-band spectrum is currently available for mobile (and only 200MHz is scheduled for assignment by 2020).
China		China has been assigned a maximum score for this metric. While high-band spectrum is yet to be released, China has committed to assigning 2GHz of mm-wave spectrum per MNO for 5G. Furthermore, 100MHz of mid-band spectrum per MNO has been assigned (under test licenses).
France		France has already assigned the 700MHz band for mobile use, and is expected to assign large amounts of the 3.4–3.8GHz band in 2019/20, as well as 1GHz of mm-wave spectrum in 2020.
Germany		Germany has assigned a large amount of low-band spectrum for mobile (including the paired 700MHz band). No mid- or high-band spectrum has currently been assigned. However, the 3.4–3.7GHz range is scheduled to be released in early 2019, and a consultation has been completed on releasing the entire 24.25–27.5GHz range (on a shared basis) to enable use by 2020.
Hong Kong		Hong Kong has assigned nearly 600MHz of low-band spectrum for mobile use (including the 700MHz band). No mid- or high-band spectrum has yet been assigned, however a large amount of spectrum is scheduled to be released (2019/20 in the mid band and 2019 in the high band).
Italy		Italy scores highly on this metric. A multi-band 5G auction in 2018 assigned spectrum in the 700MHz, 3.6–3.8GHz, and 26.5–27.5GHz bands, making it one of the few countries to have already released mobile spectrum for 5G in the low, mid, and high bands.
Japan		Japan also scores highly on this metric. 200MHz of mid-band spectrum is already available for mobile, and a further 600MHz (along with 1.6GHz in the high band) is scheduled to be assigned in March 2019.
Qatar		A limited amount of sub-3GHz spectrum has been assigned to mobile in Qatar compared to the other benchmark countries. However, the 3.4–3.6GHz range was assigned to MNOs in 2018, and Qatar has outlined plans for the further assignment of the 700MHz, 3.6–3.8GHz, and 26GHz bands.
South Korea		South Korea has been assigned a high score on this metric. Although the amount of low-band spectrum assigned for mobile is less than in many of the other benchmark countries, South Korea was the first country to assign spectrum in the mid and high bands.

Market	S_5	Details
Spain 		Spain has assigned more mid-band spectrum for mobile (380MHz) than any of the other benchmark countries. It has also assigned nearly 600MHz of low-band spectrum, with the 700MHz band to be auctioned in early 2020. However, no definitive plans have been confirmed regarding high-band spectrum.
Sweden 		Sweden has already assigned the 700MHz band, and plans to assign the entire 3.4–3.7GHz band for mobile use in 2019/20. Sweden plans to release the entire 24.25–27.5GHz band, but no timeline for the assignment has been confirmed.
UK 		The UK has now released 270MHz of mid-band spectrum for mobile use and over 600MHz of low-band spectrum. It plans to auction spectrum in the 700MHz and 3680–3800MHz bands in early 2020. A consultation has been issued on the 26GHz band, but no definitive plans have been announced.
US 		The US scores well on this metric. The US has already made over 700MHz of low-band spectrum available for mobile (including the 600MHz band). Furthermore, 1800MHz of mm-wave spectrum has already been assigned, with an auction of a further 700MHz currently ongoing (and further auctions scheduled for 2019). However, its lack of mid-band spectrum prevents a maximum score.

National strategies/government support

The following table summarizes our assessment of government commitments to promote 5G leadership, including favorable policies toward 5G testing and development, funding for 5G trials, and policies aimed at facilitating 5G infrastructure deployment (including streamlining of planning processes for existing mobile sites, and consideration of policies to encourage small-cell roll-out).

The table indicates that significant infrastructure policies aimed at accelerating 5G deployment have been made in several of the markets under study, especially in China, Japan, South Korea, and the US.

Figure 6.7: Country scores for Metric 6 [Source: Analysys Mason, 2019]

Market	S_6	Details
Australia 		The Australian government's "5G—Enabling the future economy" strategy aims at "streamlining arrangements to allow MNOs to deploy infrastructure more quickly". Revised legislation was adopted in early 2018 to this effect, and in December 2017 the government established a '5G working group' to "identify enablers and barriers to the deployment and effective use of 5G".
Canada 		The government's Communications Research Centre (CRC) has been working on 5G technological development since 2014. In March 2018, plans were announced for a public-private partnership in which the government and industry parties will invest CAD400 million to develop 5G.
China 		Details regarding direct funding initiatives for 5G technological development and/or trials are not known, however the Chinese government is explicitly backing 5G technology development, industry collaboration, and commercial deployment through a range of policies and initiatives, such as the 'Made in China 2025' plan and the 13th Five-Year plan. MIIT has conducted several of its own 5G compatibility trials, and scheduled 5G research and development into a number of specific phases prior to commercial launch in 2020.

Market	S_6	Details
France 		The French government has invested in improving fiber coverage which it hopes will stimulate 5G and infrastructure deployment in the longer term. ARCEP's 5G roadmap, published in July 2018, prioritizes providing support for 5G infrastructure roll-outs. Some infrastructure deployment streamlining measures relevant to 5G were adopted in October 2018 through new housing legislation; the French government is looking to implement further measures.
Germany 		The "5G Strategy for Germany" includes five action points specifically targeting 5G development. Under the "promote co-operation between telecommunications and user industries" action point, the government set up the '5G Dialog Forum' in 2016. Under the "targeted and co-ordinated research" action point, the government is making up to EUR80 million available for 5G research and development. In 2017, the government launched a program to invest EUR100billion in high-performance broadband (5G and fiber) by 2025.
Hong Kong 		Hong Kong has been looking to support 5G infrastructure deployment. In Hong Kong's 2018 policy address, a government official stated that "the government [would] proactively open up suitable government premises and roof-tops for the installation of base stations" to support 5G roll-out.
Italy 		In March 2017, the Italian government launched a 5G trial in five Italian cities. The Italian Competition Authority has recommended that the government simplify the regulations applying to the deployment of small cells, and consider whether transmission power limits should be increased.
Japan 		MIC's 5G roadmap commits to a package of "comprehensive promotion strategies for 5G". These include conducting a '5G system trial' and promoting 5G research and development (through 'Industry-Academic-Government Cooperation' and the 5G Mobile Forum (5GMF)).
Qatar 		Limited data available for Qatar; we are not aware of government actions to support 5G (through funding or lowering deployment barriers). Both MNOs have confirmed plans to launch 5G commercially once devices are available, and have already been assigned mid-band spectrum.
South Korea 		The South Korean government is encouraging research and trials to enable accelerated 5G commercial launch. In 2014, MSIT announced plans to invest KRW1.6 trillion (USD1.5 billion) by 2020 to enable local firms to build 5G networks. In April 2018, MSIT announced a series of infrastructure-based measures (including network-sharing obligations and revised legislation to enable operator access to street furniture) aimed at accelerating 5G deployment. MSIT has also said that it will provide tax benefits and security maintenance services to the MNOs.
Spain 		In December 2017, the Spanish government published "Spain's 5G National Plan 2018–2020". Within the framework of the National Plan, EUR20 million will be provided to two private-sector 5G pilot projects.
Sweden 		Sweden adopted a national broadband plan in 2016, which specifies a target of reaching "ubiquitous access to 'high-quality' mobile services by 2023". In May 2018, Sweden signed a declaration on 5G with the Nordic governments, agreeing "a common action plan for early adoption of 5G technology".
UK 		Recent revisions to the UK's Electronic Communications Code aim to simplify the deployment of telecom infrastructure. DCMS has completed its "Future Telecoms Infrastructure Review" which prioritizes implementing policies to streamline 5G infrastructure deployment, and a taskforce has been established to identify and reduce barriers facing operators. DCMS is also allocating USD260 million to its '5G testbeds and trials' (5GTT) program; specific industrial developments are also being promoted such as connected cars and connected healthcare.

Market	S_6	Details
US 		The FCC has adopted several reforms to rules applying to infrastructure deployment, including eliminating barriers to deployment, streamlining the process of deploying next-generation wireless facilities, providing guidance on reasonable costs and timelines associated with siting reviews, and addressing the types of deployment subject to NHPA and NEPA review. As of early 2019, 21 states had enacted legislation aimed at accelerating small-cell deployment. Furthermore, the US government has taken steps to ensure that 5G R&D investments are encouraged through tax reform and other actions.

6.2 5G readiness comparison

Our overall readiness comparison combines the individual scores per country for the six metrics that we have assessed.

The following table provides an overall summary of our 5G readiness assessment of each benchmark country, and total score. As can be seen, China, the US, South Korea, and Japan remain the top ranked countries as compared to our previous report, although their relative rankings have changed.

Figure 6.8: Overall 5G readiness scores [Source: Analysys Mason, 2019]

Market	S_{Total}	Details
Australia 	13	Australia is one of the mid-scoring countries from our analysis. An auction in the 3.6GHz band was completed in 2018, and a large amount of sub-3GHz spectrum has already been assigned to mobile (including the 700MHz band). In early 2018, revised legislation was introduced to streamline the deployment of small cells, and a government working group has been established to continue to lower barriers to 5G infrastructure deployment. Both Telstra and Optus are expected to launch initial commercial 5G services in H1 2019.
Canada 	9	Canada is the lowest scoring of the countries considered, based on the research we have undertaken for this study. While a large amount of sub-3GHz spectrum is currently assigned to mobile use (and an auction of the 600MHz band is scheduled for early 2019), plans for spectrum assignment in the mid and high bands are lagging behind those of several other countries. CRC has been conducting 5G trials, and the government (in collaboration with private partners) has committed to a USD300 million project to fund 5G development (the ENCQOR project). Two MNOs have indicated that commercial 5G launch is expected in 2020.
China 	19	China is the highest-scoring country (joint with the US) from our analysis in terms of 5G readiness. There is strong government backing for 5G research and development, combined with strong industry backing, with the government's '13th Five-Year Plan' aiming for commercial 5G launch by 2020. All MNOs have announced extensive trials and have committed to launching services in 2020. The government has committed to large amounts of mid- and high-band spectrum for 5G; nationwide mid-band test licenses of 100MHz were awarded to each MNO in December 2018.
France 	11	The French regulator has already awarded licenses for use of the 700MHz band for mobile services, and intends to award spectrum licenses in the 3.4–3.8GHz band during 2019/20 and in the 26.5–27.5GHz band during 2020. A 5G roadmap has been published prioritizing support for 5G infrastructure roll-outs, and the government has implemented some initial measures to that end. Orange and Bouygues have both made explicit commitments to provide 5G services in 2020.

Market	S_{Total}	Details
Germany 	14	Germany is one of the mid-scoring countries from our analysis. The German government has published a detailed 5G strategy which aims for roll-out in 2020, and has developed plans for spectrum award in a number of bands. Germany has a large amount of low-band spectrum currently assigned for mobile use (including the 700MHz band). Spectrum in the 3.4–3.7GHz band is expected to be auctioned in early 2019; the assignment timeline for mm-wave spectrum is still to be confirmed.
Hong Kong 	14	Hong Kong is also one of the mid-scoring countries from our analysis. No mid- and high-band spectrum has yet been assigned, but plans have now been announced to do so, and a large of amount of spectrum (more than in most of the benchmark countries) is scheduled to be released during 2019 and 2020. Most operators are expected to launch commercial 5G services in 2020.
Italy 	15	Italy ranks in the upper-middle section of our benchmark. It is one of only three countries to have assigned low-, mid-, and high-band spectrum. Two MNOs have indicated that initial 5G commercial services will be available in 2019.
Japan 	17	Japan scored well across each of the metrics that we have considered. The hosting of the 2020 Olympic and Paralympic Games in Tokyo is providing a strong focus for early 5G service availability, which is galvanizing 5G progress. Japan's MNOs are leaders in 5G testing and the regulator has committed to releasing mid- and high-band spectrum for 5G by March 2019.
Qatar 	10	Limited data is available for Qatar. However, both MNOs have been awarded mid-band spectrum and are expected to launch commercial 5G services when devices become available in 2019.
South Korea 	18	South Korea has scored strongly on most metrics, similar to the 2018 report. Spectrum in both the 3.5GHz and 28GHz bands was auctioned in mid-2018, and all three MNOs obtained large contiguous blocks of spectrum in both bands. The three South Korean MNOs launched commercial 5G services in December 2018 (offering FWA initially), and plan to launch mobile services in early 2019. The government has committed to a large 5G investment program. Where South Korea lags slightly compared to the leading countries in our analysis is in total mobile spectrum holdings, and in mm-wave spectrum (e.g. compared to the US).
Spain 	11	Spain has assigned more mid-band spectrum for 5G than any of the other benchmark countries, and is expected to auction the 700MHz band in early 2020. However, no timeline has been confirmed for the assignment of mm-wave spectrum. Most of the Spanish MNOs have not yet announced 5G commercial deployment dates.
Sweden 	10	Sweden ranks toward the bottom of the benchmark countries. While the 700MHz band was awarded in 2018, spectrum in the 3.4–3.8GHz band is not scheduled for assignment until late 2019/early 2020, and no timeline has yet been confirmed for mm-wave spectrum. Telia and Telenor/Tele2 are aiming for commercial launch of 5G in 2020.
UK 	15	The UK government has announced a significant amount of funding for 5G trials and R&D, as well as regulatory backing to ease infrastructure deployment for mobile networks. The 2.3GHz and 3.4GHz bands were auctioned in 2018, and the 700MHz and 3.6GHz bands are scheduled for auction in early 2020. However, details have not yet been confirmed regarding mm-wave spectrum, leading to a low score in the high-band spectrum metric. Most operators have committed to launching 5G in 2019.
US 	19	The US scores highly on most metrics, and has been assigned the highest score (joint with China) of the countries analyzed. This high score reflects the strong industry commitment to early 5G launch, with all major MNOs having committed to launches in 2019, and Verizon and AT&T both having launched early 5G

Market	S_{Total}	Details
		services in 2018. To support the operators with these early 5G launches, the FCC has introduced several regulatory reforms to eliminate barriers to the deployment of 5G infrastructure, and many states have enacted small-cell legislation. Regarding spectrum, the FCC was one of the first regulators globally to confirm a strategy for releasing mm-wave spectrum. The 28GHz band and parts of the 39GHz band have been assigned, and the 24GHz band is currently being auctioned. The remainder of the 39GHz band as well as the 37GHz and 47GHz bands are scheduled to be auctioned later in the year. The US also scores highly on sub-3GHz spectrum, a large amount of which has already been released for mobile use (including the 600MHz band), with further spectrum (1.3GHz and 1.7GHz) under investigation for release. However, the US has scored poorly in terms of mid-band spectrum: only a limited amount (via the CBRS band) is expected to become available during 2019, and future assignment plans have not yet been confirmed.

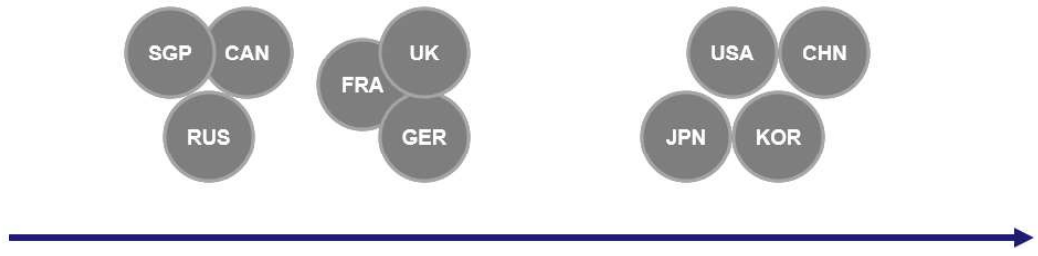
These scores are plotted on a scale in Figure 6.9 below.

Figure 6.9: Overall 5G readiness scores, 2019 [Source: Analysys Mason, 2019]

As can be seen from the above, there is a leading tier of countries consisting of China, the US, South Korea, and Japan, followed by second and third tiers of countries which include the other Asia–Pacific countries under consideration, European countries, and Canada.

For comparison, the scores of the countries assessed in our 2018 report are shown in Figure 6.10 below.

Figure 6.10: Overall 5G readiness scores,[112] 2018 [Source: Analysys Mason, 2018]



112 The scales in Figure 6.9 are Figure 6.10 are different (since a different scoring system was used in the 2018 report).

As can be seen, the top cluster of countries (those most ready for 5G) has remained unchanged since our previous report. China and the US are joint leaders of this group, closely followed by South Korea and Japan.

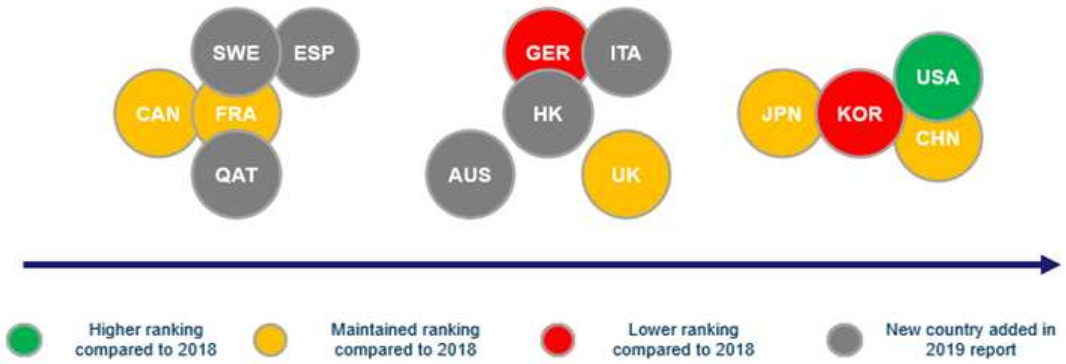
China was the top-scoring country (ahead of the US) in our 2018 report. It has maintained a leading position due to a strong commitment from the government to achieve 5G success, and large amounts of spectrum released (or confirmed for release) in the low, mid, and high bands. A particularly significant development was the announcement from MIIT in December 2018 that nationwide (test) licenses of 100MHz of contiguous mid-band spectrum had been awarded to each MNO. While the Chinese operators have not announced early commercial launches (as in South Korea and the US), large-scale commercialization is expected in 2020.

The US scored in third position (slightly behind both China and South Korea) in our 2018 report and is now joint leader with China. Operators are strongly committed to 5G in the US, with early commercial launches announced by both Verizon and AT&T at the end of 2018, and significant deployments planned for 2019 by Sprint and T-Mobile, as well as US Cellular. Furthermore, the US has been assigned top scores in terms of low- and high-band spectrum; a large amount of sub-3GHz spectrum has already been assigned to mobile in the US, and the first mm-wave 5G spectrum auctions were completed at the start of 2019 (with further awards planned). In our previous report, the US scored lower in terms of government support for infrastructure deployment, and lower still in terms of mid-band spectrum. Progress has been made on both fronts, and this has been reflected in the updated scores. However, challenges to the infrastructure decisions made by the FCC last year will require continued monitoring in 2019. Likewise, further attention on mid-band spectrum assignment will be needed in the future.

The second and third tiers of countries that we reported on last time now include a larger number of countries (split into two groups of five countries). Countries toward the top of the second tier include Italy (which held a 5G auction for low-, mid-, and high-band spectrum in 2018), the UK (which is planning to hold a 700MHz and 3.6GHz auction in early 2020 and is implementing a number of policies to reduce barriers to 5G infrastructure deployment) and Hong Kong (which plans to auction large amounts of mid- and high-band spectrum in 2019/2020). Whilst China, the US, South Korea, and Japan are still leading the race to 5G, several countries (particularly in Europe) are close behind and could overtake some of the leading countries (e.g. Japan) during 2019.

The chart below illustrates the country rankings we have identified for 2019, compared to the previous ranking for that country (where relevant) in our 2018 report.

Figure 6.11: Overall 5G readiness scores 2019, color coded by change in ranking[113] since 2018 [Source: Analysys Mason, 2019]



As noted in our previous report, this analysis represents a view of 5G readiness at this point in time, and other inherent factors – such as supply-side developments, changes to commercial launch plans, and other market or policy developments – could affect the eventual outcome of the 5G market globally. The shifts in 5G readiness which occurred in 2017 and 2018 have already advanced timetables in some countries, affirming that the situation is fluid, and the current leadership rankings are not fixed.

113 This is the change in ranking within the group of eight countries that have been assessed in both the 2018 and 2019 reports.

7 Conclusions

From our analysis of 5G readiness, we have identified that the countries that are currently the furthest advanced with launching 5G services (at the time of producing this report) are China, South Korea, the US, and Japan. Within this group, China and the US are joint leaders, followed closely by South Korea and Japan.

This leading group of four countries remains unchanged from our 2018 report. However, the rankings within the group have changed: the US has moved from third position to joint first, reflecting industry commitment for early 5G launch being carried through, alongside progress on the government side in the assignment of high-band spectrum as well as the implementation of policies to reduce barriers to 5G infrastructure deployment.

This shift in rankings also emphasizes the fluid nature of the race to 5G. The change in rankings in 2019 compared to our first report in 2018 indicates that the 5G leadership rankings are not fixed and can be influenced by a range of factors including industry efforts to bring 5G to market alongside regulatory and government moves to facilitate 5G through availability of spectrum and infrastructure policies. The early launch of 5G services in some countries is also encouraging operators in other markets to accelerate their 5G launch plans and hence a further update to this report in 2020 could well show further changes to rankings and 5G leadership.

Notwithstanding this, and as noted in the analysis, several other inherent factors – including supply-side developments, shifts in commercial strategy, and other market developments – also influence how the 5G market will develop globally.

Our conclusions from the study are as follows:

China and the US are the leading nations in our '5G readiness' assessment, scoring higher than other nations on most of the metrics we have assessed	Our overall conclusion is that the countries ranked highest in our previous report are still positioned as 5G leaders in 2019. The order of scoring amongst the leading nations has shifted, with China and the US now tied in top place, reflecting determined moves by the US operators to follow through 5G commercialization commitments with the launch of 5G services in 2018. Whilst China, the US, South Korea, and Japan are still leading the race to 5G, several European nations are close behind and could overtake some of the leading countries (e.g. Japan) during 2019.

Mid-band spectrum will be important for early 5G deployments and a	Many of the planned 5G commercial launches referred to in our report will use mid-band spectrum, particularly in the 3GHz band. Many of the 5G devices becoming available in 2019 are expected to support this

critical building block for 5G services	frequency range. The US has previously lagged behind other nations in terms of the amount of mid-band spectrum being released for 5G use. Whilst there has been significant progress in the US on other important aspects of 5G launch, such as reform of infrastructure planning procedures (e.g. in relation to small-cell siting), there is still more to be done to ensure that the US retains its leading position through better availability of mid-band spectrum, which is a key short-term goal.

Since the first edition of this report was published in 2018, the 5G market has continued to develop rapidly, with many operators preparing to launch services and several launches already announced	When our first report was published in 2018, we identified 5G pre-commercial trials being underway in the leading 5G markets. Since then, there has been rapid progress toward commercial deployment and service launch. The early commercial launches that we identified in last year's report have now occurred, and the 5G market is continuing to move rapidly from test/trials to large-scale pilots and commercial launches. Release 15-compatible RAN equipment is widely available and more 5G smartphones are expected to emerge during the second half of this year, which will allow consumers to use 5G networks from mobile devices.

Actions being taken by national governments to encourage 5G deployment include reform of siting policies and license fees	Several case studies are identified in this report highlighting the importance of government policies to reduce or eliminate burdens on 5G deployment. In the US, federal and state policymakers have been instrumental in easing barriers to small-cell deployment. Examples of approaches in other markets include China waiving the standard per-MHz fee for spectrum for 5G licenses in the initial years, and a focus on reducing barriers to mobile deployment in the UK.

Enhanced mobile broadband (eMBB) and fixed wireless access have emerged as the initial 5G use cases	Early 5G services are predominantly eMBB and FWA; however, the service mix should increase as 5G evolves into the next phase of specifications anticipated in 3GPP Release 16. Several operators have announced collaborations with vendors and industry players to test the use of 5G in different industrial sectors, as described in this report, and hence vertical uses are expected to remain an important element of 5G services, as networks become more sophisticated beyond initial launch. In some markets, there have been proposals to reserve specific spectrum for 5G industrial use, however there is a need for regulators to consider such schemes carefully, including whether they are applicable or appropriate to specific bands.

Spectrum focus for 5G remains on the mid-band frequencies and on mm-wave bands	As identified in the first edition of this report, worldwide focus on 5G deployment has been on mid-band spectrum (mainly 3.4–4.2GHz), along with selected bands above 24GHz. Each of these bands has been included in 3GPP Release 15 specifications, and 5G handset availability is expected to improve in 2019 both for 3.4–3.8GHz and 28GHz (with 26GHz following thereafter). The US is leading other nations with the award of mm-wave spectrum for 5G use and it is expected that other countries will follow this lead, pending the outcome of WRC-19 (where worldwide discussion on mm-wave spectrum for 5G will take place).

Annex A Abbreviations used in this report

ACMA	Australian Communications and Media Authority (Australian NRA)
AGCOM	Autorità per le Garanzie nelle Comunicazioni (Italian NRA)
AI	Artificial Intelligence
ARCEP	Autorité de Régulation des Communications Électroniques et des Postes (French NRA)
AWS	Advanced Wireless Services
BNetzA	Bundesnetzagentur (German NRA)
BRS	Broadband Radio Service
CA	Carrier Aggregation
CA	Communications Authority (Hong Kong NRA)
CBRS	Citizens Broadband Radio Service
CNMC	Comisión Nacional de los Mercados y la Competencia (Spanish NRA)
CRA	Communications Regulatory Authority (Qatari NRA)
DL/UL	Downlink/Uplink
EBS	Educational Broadband Services
eMBB	Enhanced Mobile Broadband
EC	European Commission
EPC	Evolved Packet Core
EU	European Union
FCC	Federal Communications Commission (US NRA)
FDD	Frequency Division Duplex
FNPRM	Further Notice of Proposed Rulemaking
FSS	Fixed-Satellite Service
FWA	Fixed Wireless Access
GAA	General Authorized Access
GSA	Global Supplier Association
GSM	Global System for Mobile Communications
GSMA	GSM Association
HD	High Definition
IMT	International Mobile Telecommunication system
IoT	Internet of Things
ISED	Department for Innovation, Science and Economic Development (Canadian NRA)
ISP	Internet Service Provider

ITU	International Telecommunications Union
LTE	Long Term Evolution
MBB	Mobile Broadband
MBS	Mobile Broadband Services
MIC	Ministry of Internal Affairs and Communications (Japanese NRA)
MIIT	Ministry of Industry and Information Technology (Chinese NRA)
MIMO	Multiple Input, Multiple Output
MSIT	Ministry of Science and ICT (South Korean NRA)
mm-wave	Millimeter-wave
MNO	Mobile Network Operator
MoU	Memorandum of Understanding
NOI	Notice of Inquiry
NPRM	Notice of Proposed Rulemaking
NRA	National Regulatory Authority
NR	New Radio
NSA	Non-Standalone
NTIA	National Telecommunications and Information Administration
Ofcom	Office of Communications (UK NRA)
PAL	Priority Access License
PCS	Personal Communications Service
PHS	Personal Handy-phone System
PPDR	Public Protection and Disaster Relief
PPP	Public Private Partnership
PTS	Post- och telestyrelsen (Swedish NRA)
QAM	Quadrature Amplitude Modulation
R&O	Report and Order
R&D	Research and development
RAN	Radio Access Network
RSPG	Radio Spectrum Policy Group
SA	Standalone
SDL	Supplemental Downlink
SMRA	Simultaneous Multi-Round Ascending
TDD	Time Division Duplex
UHD	Ultra-High Definition
UMTS	Universal Mobile Telecommunications System
URLLC	Ultra-Reliable Low Latency Communications
V2X	Vehicle-to-everything

VR	Virtual Reality
WCS	Wireless Communications Service
WiMAX	Worldwide Interoperability for Microwave Access
WRC	World Radio Council
2G/3G/4G/5G	Second/Third/Fourth/Fifth Generation of mobile technology
3GPP	Third Generation Partnership Project

Annex B Country case studies

The following sections provide an overview of 5G developments (with a focus on spectrum and deployment plans) in each of the benchmark countries (Australia, Canada, China, France, Germany, Hong Kong, Italy, Japan, Qatar, South Korea, Spain, Sweden, and the UK), as well as the US.

B.1 Australia

The Department for Communications and the Arts is the government department responsible for communications policy in Australia and the Australian Communications and Media Authority (ACMA) is the regulator for the communications sector, including spectrum policy and assignment. Telstra, Optus, Vodafone Hutchison Australian (VHA), and TPG are the currently licensed mobile operators. TPG was awarded mobile spectrum in the 700MHz and 2.6GHz bands in 2017, having previously operated as a mobile virtual network operator (MVNO). TPG and VHA have formed a joint venture which, along with Telstra and Optus, won 5G spectrum in ACMA's 3.6GHz auction in December 2018. The Australian government and ACMA have been proactive in encouraging 5G roll-out, with a government 5G strategy published in 2017, streamlining of mobile siting policies announced and a 5G auction (3.6GHz) in December 2018. Both Telstra and Optus have plans to launch commercial 5G services in Australia in 2019 and have been preparing for launch in 2018 by installing 5G equipment within their existing 4G networks.

B.1.1 Current spectrum holdings

Low-band spectrum

As shown in Figure B.1 below, 670MHz of low-band spectrum is currently assigned to commercial mobile services in Australia.

Figure B.1: Current low-band spectrum holdings of MNOs in Australia, MHz [Source: ACMA,[114] APT[115]]

MNO	450	700	850	900	1400	1800	1900*	2100	2300	2600	Total
Telstra	–	40	20	16.8	–		–			80	N/a**
Optus	–	20	–	16.8	–	150**	–	120**	100**	40	N/a**
VHA	–	10	20	16.4	–		–			–	N/a**
TPG[116]	–	20	–	–	–		–			20	N/a**

[114] See https://web.acma.gov.au/rrl and https://www.acma.gov.au/Industry/Spectrum/Radiocomms-licensing/Spectrum-licences/spectrum-auctions-list-spectrum-planning-acma

[115] Data from APT report APT/AWG/REP-15(Rev.5). See http://www.apt.int/AWG-RECS-REPS

[116] TPG currently operates as an MVNO in Australia. In April 2017, it announced plans to launch its own mobile network (based principally on a small-cell architecture) and began roll-out, using Huawei as its principal vendor. TPG stated that a "key reason" for this selection of vendor was "that that there was a simple upgrade path to 5G". However, on January 29, 2019, TPG announced that it "has decided to cease the rollout of its mobile network in Australia" citing the government's ban on using Huawei for 5G equipment.

See https://www.asx.com.au/asxpdf/20190129/pdf/44247b6xdpq097.pdf

MNO	450	700	850	900	1400	1800	1900*	2100	2300	2600	Total
Total	–	90	40	50	–	150	–	120	100	140	670

* Spectrum assigned in 3GPP bands 33 and 34 is excluded, since it is not used.

** Spectrum in 1800MHz, 2100MHz,[117] and 2300MHz has been made available on a regional basis. The amount shown may not have been made available across all regions.

Note: the 850MHz assignments shown apply in metro areas only; in regional areas, Telstra has 2×15MHz and VHA has 2×5MHz.

Mid-band spectrum

MNOs Optus and Telstra own the majority of spectrum (licensed on a regional basis) in the 3425–3492.5MHz and 3542.5–3575MHz ranges; a small number of regional blocks in this range are held by other players.[118] The licenses are technology neutral.

In December 2018, ACMA completed a regional auction[119] of the 3575–3700MHz range. 125MHz was made available in twenty-five 5MHz lots in each of 14 regions (6 'metropolitan' areas and 8 'regional' areas). Licenses have an 11-year duration, are technology neutral and without coverage obligations.

All of the spectrum was sold,[120] raising a total of USD616 million, corresponding to ~USD0.20/MHz/pop (after adjusting[121] to a 20-year license). Each of Australia's MNOs won

117 Two nationwide licences were made available at the 2.1GHz auction in 2001. See https://www.acma.gov.au/Industry/Spectrum/Radiocomms-licensing/Spectrum-licences/auction-summary-2-ghz-third-generation-mobiles-2001-1

118 In April 2000, the relevant government minister made the Radiocommunications (Spectrum Reallocation) Declaration 2000 (the 3.4GHz reallocation declaration) that allowed the introduction of spectrum licensing in the 3425–3492.5MHz and 3542.5–3575MHz ranges (the 3.4GHz band) in particular areas of Australia.

The auction was held in October 2000; the majority of lots were won by AKAL (owned by Optus). Of the available 482 lots, 22 went unsold. These 22 lots were re-offered in 2002; however, they again remained unsold. These lots were offered for assignment on a quarterly basis from 2004 to 2008.

The original spectrum licenses expired in December 2015. The majority of spectrum licenses were re-issued to the same licensees, with a new expiry date of 13 December 2030.

In December 2017, ACMA's 'residual auction' made available 3.4GHz spectrum, consisting of a combination of the spectrum that was not reissued in 2015 and unsold lots from the preceding 3.4GHz assignments.

See http://auction.acma.gov.au/auction_results/3.4ghz_results_page/34_pdf/lot_prices.pdf

See https://www.acma.gov.au/-/media/Spectrum-Licensing-Policy/Information/Mulitband-auction/Multiband-residual-lots_Auction-guide-pdf.pdf

See https://www.acma.gov.au/theACMA/possible-changes-to-2831-ghz-spectrum-licences

See https://www.commsalliance.com.au/__data/assets/pdf_file/0004/45328/CA-response-on-ACMA-3.5-GHz-band-transition-opportunities.pdf

See Table 3 of ACMA's December 2016 consultation: https://www.acma.gov.au/theACMA/spectrum-licensing-2ghz-and-3_4ghz

Current holdings in the 3.4GHz band are shown in Table 9 of the August 2018 auction guide (see below).

119 For details, see https://www.acma.gov.au/theACMA/applicant-information-package-3-6-ghz-band-auction

120 For full auction results, see https://www.acma.gov.au/theACMA/3-6-ghz-band-spectrum-auction-results

121 Using a WACC of 6.0%.

spectrum, with VHA and TPG bidding as a joint venture. Wholesale service provider Dense Air also won spectrum, and announced[122] its intention to start providing 5G neutral host services in Australia.

High-band spectrum

No high-band spectrum is currently available for commercial mobile services in Australia.

B.1.2 Main 5G spectrum proposals

In September 2018, ACMA published[123] its final "five-year spectrum outlook [FYSO] 2018–2022", which provides details of a number of spectrum plans relevant to 5G. These are outlined in the following sub-sections, along with other relevant documentation.

Low-band spectrum

ACMA first commenced[124] a review of arrangements in the 803–960MHz band in May 2011. In December 2016, a consultation on reconfiguring the 900MHz (890–915/935–960MHz) band was published.[125] Subject to finalizing plans for an LTE PPDR network (referred to as the PSMB network), ACMA decided to implement its proposed '850MHz expansion plan', making a further 2×15MHz in 3GPP bands 26/27 (809–824/854–869MHz) available for mobile broadband.[126] The September 2018 FYSO schedules a planning decision on the 850/900MHz bands for Q4 2018; the 'potential timing' of allocation is listed as Q3/4 2020.

In October 2016, ACMA released a discussion paper[127] on the 1500MHz band. The September 2018 FYSO states that further consideration of the L-band (1427–1518MHz) is deferred to Q1/2 2020; the 'potential timing' of allocation is listed as Q1/2 2021.

Mid-band spectrum

In December 2017, ACMA completed a multi-band auction of 'residual' spectrum lots (i.e. lots left unsold in previous auctions). A total of 40 lots were made available across four bands: 1800MHz, 2.1GHz, 2.3GHz, and 3.4GHz. A single lot in the 3.4GHz went unsold; the September 2018 FYSO states that this lot will be re-offered to the market in Q1 2019.

122 See http://denseair.net/dense-air-to-offer-neutral-host-5g-densification-services-in-australia/

123 See https://acma.gov.au/Industry/Spectrum/Spectrum-projects/5-Year-Spectrum-Outlook/five-year-spectrum-outlook?utm_medium=email

124 See http://www.acma.gov.au/Industry/Spectrum/Spectrum-projects/800-and-900-MHz-bands

125 See http://www.acma.gov.au/Industry/Spectrum/Spectrum-projects/800-and-900-MHz-bands/latest-developments-in-803-960-mhz

126 See https://www.acma.gov.au/Industry/Spectrum/Spectrum-projects/800-and-900-MHz-bands/review-of-the-803-960-mhz-band

127 See https://www.acma.gov.au/theACMA/future-use-of-the-1_5-ghz-and-3_6-ghz-bands-2

The September 2018 FYSO also states that ACMA intends to issue a discussion paper on reconfiguration options in the 3400–3575MHz band in Q1 2019, following the conclusion of the 3575–3700MHz auction.

Finally, the September 2018 FYSO states that ACMA is considering releasing a discussion paper in Q2 2019 on the long-term arrangements in the 3.7–4.2GHz band.

High-band spectrum

ACMA ran a consultation[128] on the 26GHz (24.25–27.5GHz) band between September 22, 2018, and November 2, 2018. ACMA ran a separate consultation[129] on the 28GHz (27.5–29.5GHz) band between September 28, 2018, and November 23, 2018.

The press release accompanying the 26GHz consultation stated: "To assist the Authority and industry in taking a 'holistic' view of all issues affecting 26 and 28GHz use, ACMA is keen to align its consultation process on the 28GHz band with the present (26GHz) paper. The 28GHz spectrum is more heavily used than 26GHz in Australia, and there is potential interest in the band from several different sectors and use cases. Consideration of the 28GHz band is currently at the initial investigation phase and a forthcoming discussion paper, expected in the weeks following release of the 26GHz paper [see above], will float some early ACMA thinking on broad planning scenarios. Responses to that paper will help crystallize these scenarios into more discrete formal planning options, which will be the subject of a future consultation process."

The September 2018 FYSO scheduled a planning decision[130] on the 26GHz band for Q4 2018 and a reallocation decision for Q2 2019; the 'potential timing' of allocation is listed as Q3/4 2020.

B.1.3 MNOs' 5G commercial deployment plans

Figure B.5 outlines 5G commercial deployment plans announced by the major MNOs in Australia.

Figure B.2: Announcements of 5G deployment plans by major MNOs in Australia [Source: MNO press releases]

MNO	Details of 5G commercial deployment plans
Telstra	• In June 20, 2018, Telstra's CEO stated[131] that "we will have a network that is 5G ready in the first half of FY2019" and that "5G commercial launch will be in FY2020… we will have a national commercial deployment of 5G in major cities and all high-demand regional centers in FY2020". It was also noted that "5G-capable smartphones are unlikely to hit the mainstream until late 2019 or early 2020, and in the meantime 5G will see use in other offerings such as fixed wireless"

128 See https://www.acma.gov.au/theACMA/options-for-wireless-broadband-in-the-26-ghz-band

129 See https://www.acma.gov.au/theACMA/spectrum-planning-for-the-28-ghz-band

130 Based on Scenario 1 in the forward allocation work plan

131 See https://www.computerworld.com.au/article/642708/telstra-predicts-5g-boost-wireless-only-households/

MNO	Details of 5G commercial deployment plans
	• In August 2018, Telstra announced[132] switching on its first 5G-capable site in parts of the Gold Coast. Later that month, it announced that Toowoomba had become the first 5G-capable regional location. Telstra stated that more than 200 5G-capable sites are planned to be live around the country by the end of 2018 • On October 19, 2018, Telstra announced[133] the launch of 5G sites in Canberra, Adelaide, and Perth, as well as having switched on its 50th 5G-capable site • On December 10, 2018, after winning spectrum in the 3.6GHz auction, Telstra stated[134] "while these licenses will not come into effect until March 2020, we are working with ACMA to enable early access where it is suitable to do so, to ramp up our roll-out plan for 5G in the first half of next year" • On December 18, 2018, Telstra announced[135] that it had been granted early access to the 3.6GHz spectrum it won at auction, enabling it to switch on 5G at sites in Melbourne and Sydney. With these additions, Telstra stated that it had now switched on 187 5G-capable sites • In December 2018, Telstra published[136] a '5G update' providing further details.
Optus	• On January 31, 2019, following a number of earlier announcements, Optus provided details of its 5G deployment and launch plans. Optus noted that 5G sites are now live in two suburbs of Canberra, with an additional site live in Sydney. 47 additional sites are planned to be online by March 2019 with further sites scheduled to go live across Adelaide, Brisbane, Canberra, Perth, and Sydney "over the coming months". Furthermore, Optus is aiming for a total of 1200 live sites by March 2020 across the ACT, Victoria, New South Wales, Queensland, South Australia, and Western Australia. The 1200 sites will include "residential locations and other key customer hotspots surrounding airports, train stations, sports stadiums and CBD locations". Optus's press release states that its 5G network roll-out strategy includes upgrading and adding new mobile sites as well as densifying the network with small cells in highly populated locations • Optus plans to release a 'Home Broadband' (i.e. FWA) service, which will be priced at AUD70 per month for unlimited data and speeds of 50Mbps. Optus states that "off-the-shelf [FWA] products will be available… in the coming months" and that "initial services are expected to be delivered in Q2 2019" • Optus also stated that 5G mobile services will be possible once compatible handsets are available. Optus is "working with a range of smartphone manufacturers and will announce details about 5G smartphone handset availability and plans in the future" • On February 11, 2019, Optus confirmed[137] that a second 5G site was now operational in Sydney.
VHA	• No explicit 5G commercial launch dates have been publicly announced • On May 21, 2018, VHA announced[138] the launch of massive-MIMO technology in the 1800MHz band in Western Sydney; VHA terms the technology '4.9G'. In the press release, VHA stated that it is "focused on continuing to evolve and enhance our 4G

132 See https://www.telstra.com.au/aboutus/media/media-releases/Telstra-rolls-out-regional-5G-first-in-Toowoomba

133 See https://www.telstra.com.au/aboutus/media/media-releases/Telstra-confirms-5G-partnership-with-Ericsson-as-it-launches-sites-in-Canberra-Adelaide-and-Perth

134 See https://exchange.telstra.com.au/telstra-invests-386m-to-secure-30-80-mhz-nationwide-in-5g-spectrum-auction/

135 See https://www.telstra.com.au/aboutus/media/media-releases/Telstra_launches_first_5G_Melbourne_and_Sydney_sites

136 See https://www.telstra.com.au/content/dam/tcom/about-us/investors/pdf%20F/2018-Telstra-5G-Update.pdf

137 See https://www.optus.com.au/about/media-centre/media-releases/2019/02/Optus-switches-on-new-5G-site-in-Kellyville-NSW

138 See https://www.vodafone.com.au/media/vodafone-launches-4-9g-in-sydneys-west

MNO	Details of 5G commercial deployment plans
	network to deliver real benefits to our customers now, while Australians wait for the introduction of 5G to consumers in coming years" • On December 10, 2018, after the mid-band 5G spectrum auction, VHA stated[139] that "consumers won't be able to start using 5G on mobile until enabled smartphones are launched over the next few years, and we are working to launch 5G services in major cities before handsets are widely available". • An article published by consumer comparison website WhistleOut on November 5, 2018, states that: "by and large, Australian 5G networks will be switched on from 2019. Telstra and Optus have both committed to selling commercial 5G services next year [i.e. 2019], and Vodafone will follow in 2020".

B.1.4 National strategies/government support

On October 12, 2017, the Australian government launched[140] its '5G—Enabling the future economy' strategy, which outlined four "immediate actions" that the government will undertake to support the development of 5G:

- making spectrum available in a timely manner
- actively engaging in international spectrum harmonization activities
- streamlining arrangements to allow MNOs to deploy infrastructure more quickly
- reviewing existing regulatory arrangements to ensure they are fit-for-purpose.

Under the infrastructure action, the strategy paper notes that the government has recently consulted on proposed new arrangements to streamline the deployment processes for 5G technologies. The government will "will implement the first tranche of changes to carrier powers and immunities following the conclusion of the consultation process".

Under the regulatory-review action, the strategy paper states that "the government will continue to work with industry to modernize current telecommunications regulatory arrangements to ensure they encourage competition and innovation in the sector".

B.1.5 Outlook

Our 5G outlook/assessment for Australia is summarized in Figure B.6 below.

Figure B.3: 5G outlook for Australia [Source: Analysys Mason, 2019]

Metric	Description	Score
1. Industry commitment to 5G launch	• Two MNOs to launch 5G in 2019; one MNO has not confirmed a launch date	2/4
2. Low-band spectrum	• 690MHz of spectrum currently released • Further 30MHz in the 850MHz band scheduled for release by 2020; L-band spectrum for potential assignment beyond 2020	4/4

139 See https://www.vodafone.com.au/media/5g-another-step-closer-with-national-spectrum-acquisition

140 See https://www.communications.gov.au/departmental-news/5g-enabling-future-economy

Metric	Description	Score
3. Mid-band spectrum	• 225MHz of spectrum currently released • Reconfiguration of 3400–3575MHz band and long-term arrangements in 3.7–4.2GHz band to be discussed	2/4
4. High-band spectrum	• No high-band spectrum currently released • 26GHz to be awarded in 2020; 28GHz band also under consideration	1/4
5. Total spectrum	• Weakest in high band, with no spectrum to be assigned until late 2020	2/4
6. National strategies/government support	• Revised legislation passed to ease infrastructure deployments • Taskforce established to identify enablers and barriers to deployment	2/4

B.2 Canada

The federal government is responsible for spectrum policy in Canada. Innovation, Science, and Economic Development Canada (ISED) is the department that manages the use of spectrum. The Communications Research Centre (CRC), which is part of ISED, provides the department with scientific and technological evidence to support spectrum-management decisions. ISED launched a 5G consultation in June 2017 (focusing on three mm-wave bands: 28GHz, 37–40GHz, and 64–71GHz), and announced that it aims to make spectrum available for 5G by 2020. Subsequent consultations in 2018 have confirmed that ISED will auction spectrum in the 600MHz band in March 2019 and in the 3.5GHz band in 2020. Licensing conditions will enable mobile use in the 26GHz and 28GHz bands, and in 64–71GHz (which will be released on an unlicensed basis). Two of Canada's MNOs (Bell and Telus) have announced 5G trials, with Telus explicitly aiming for commercial 5G deployment in 2020. In 2018, the Canadian government announced the 'ENCQOR' project, a CAD400 million public-private partnership focused on research and innovation in 5G. As part of this project, two 5G innovation hubs have subsequently been launched in Quebec.

B.2.1 Current spectrum holdings

Low-band spectrum

As shown in Figure B.4 below, 648MHz of low-band spectrum is currently allocated to commercial mobile services in Canada.

Figure B.4: Current low-band spectrum holdings[141] of MNOs in Canada, MHz [Source: ISED[142]]

Spectrum*	600	MBS	Cell.	PCS	AWS1	AWS3	AWS4	WCS	BRS	Total
TDD	-	12	-	-	-	-	-	-	50	**62**
FDD	-	2×28	2×25	2×65	2×45	2×25	2×20	2×15	2×70	**2×293**
Total	**-**	**68**	**50**	**130**	**90**	**50**	**40**	**30**	**190**	**648**

* Amount made available per region

Mid-band spectrum

No mid-band spectrum is currently available for commercial mobile services in Canada.

141 Abbreviations for spectrum bands: MBS (Mobile Broadband Service), Cell. (Cellular), PCS (Personal Communications Service), AWS (Advanced Wireless Service), WCS (Wireless Communications Service), and BRS (Broadband Radio Service.

142 See http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf11333.html#s6.1, Table 1 and http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf08748.html

High-band spectrum

No high-band spectrum is currently available for commercial mobile services in Canada.[143]

B.2.2 Main 5G spectrum proposals

On June 6, 2018, ISED published[144] its spectrum outlook 2018–2022. This document categorizes each band under discussion into one of three priority groups:

- Bands identified as "Priority 1".[145] These are planned for release between 2018 and 2022.[146]
- Bands identified as "Priority 2".[147] These bands could potentially be released between 2018 and 2022, subject to international developments such as WRC-19 and equipment availability.
- Bands identified as "Priority 3". These will be regularly monitored by ISED during the period 2018 to 2022. Based on currently available information, there is uncertainty regarding the international developments or potential equipment available for these bands.

The following subsections focus on Priority 1 bands.

Low-band spectrum

ISED has published multiple consultations[148] on releasing spectrum in the 600MHz band. On March 28, 2018, a final licensing framework for the auction was published.[149] The June 2018 spectrum outlook confirmed that 2×35MHz in the 617–652/663–698MHz range will be auctioned in March 2019, with 2×15MHz set aside for regional players and new entrants. On December 6, 2018, ISED published[150] a list of applicants for the auction.

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143 Mid-band spectrum was auctioned for FWA between 2004 and 2009; it is currently not licensed for mobile applications and is largely held by Inukshuk (a joint venture owned by Bell and Rogers) in most urban markets. See https://assets.ctfassets.net/rz9m1rynx8pv/30cPueYwwUSuysoSSeE6oe/4bc06c10c67a516f4ff77e2ef72bb0d7/TELUS_2017_annual_report-for_online.pdf

144 See http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf11403.html

145 These are generally bands that have established international standards, and for which equipment is available or is expected to be available. In some cases, work to make these bands available in Canada is already underway.

146 For bands identified as Priority 2, ISED expects to begin work (e.g. policy or technical standard development, review of existing and potential uses and/or international coordination) between 2018 and 2022. These bands could potentially be released between 2018 and 2022, subject to international developments such as WRC-19 and equipment availability. Bands identified as Priority 3 will be regularly monitored by ISED during the period 2018 to 2022. Based on currently available information, there is uncertainty regarding the international developments or potential equipment available for these bands.

147 For bands identified as Priority 2, ISED expects to begin work (e.g. policy or technical standard development, review of existing and potential uses and/or international coordination) between 2018 and 2022.

148 Most recently, a consultation was run between August 2017 and October 2017. See http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf11316.html

149 See http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf11374.html

150 See http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf11454.html

In addition to the 600MHz band, the 1500/1600MHz[151] Ancillary Terrestrial Component (ATC) bands are also classified as Priority 1. ISED will initiate a review in late 2019, with a view to enabling further use of these bands where possible.

Mid-band spectrum

The 3450–3650MHz range is considered to be Priority 1 and is scheduled to be auctioned in late 2020. The 3650–4200MHz range is also discussed by ISED, but this is considered to be Priority 2. A specific consultation[152] on these two bands was released in June 2018.

High-band spectrum

A number of mm-wave bands[153] are considered to be Priority 1 for mobile use:[154]

- 26GHz (26.5–27.5GHz[155]): ISED aims to release this band for 5G by 2020. A specific consultation[156] on this band was released in June 2017.
- 28GHz (27.5–28.35GHz) and 37–40GHz bands: ISED expects to release these bands for flexible fixed and mobile use in late 2021.
- 64–71GHz: ISED expects to release this band for license-exempt use in late 2021.

High-frequency Priority 2 bands for mobile use[157] are 24.25–26.5GHz, 40–43.5GHz, 45.5–50.2GHz, and 50.4–52.6GHz.

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151 I.e. 1525–1559/1626.5–1660.5MHz (1550MHz) and 1610.5–1626.5/2483.5–2500MHz (1600MHz). These bands are currently used for MSS in Canada.

152 See https://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf11401.html

153 Prior to the spectrum outlook 2018–2020, ISED published its "Consultation on Releasing Millimetre Wave Spectrum to Support 5G" in June 2017. See https://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf11298.html

154 ISED expects to release the 32GHz (31.8–33.4GHz) band for backhaul use in late 2019 (Priority 1). 70GHz (71–76GHz) and 80GHz (81–86GHz) are also considered as Priority 1 bands for backhaul, with potential release in mid-2020, following a consultation on the conditions of the license.

155 The 24GHz band (24.25–26.5GHz) is discussed separately and considered to be Priority 2.

156 'Addendum to the Consultation on Releasing Millimetre Wave Spectrum to Support 5G'. See https://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf11399.html

157 ISED lists the following mm-wave bands as Priority 2:

(1) Extended 23GHz (21.2–21.8GHz and 22.4–23GHz) for potential backhaul use.

(2) 24GHz (24.25–26.5GHz). ISED will "continue to monitor... developments to determine when, and for which services, these bands should be made available".

(3) 40–43.5GHz, 45.5–50.2GHz, and 50.4–52.6GHz. ISED will "continue to monitor... developments to determine when, and for which services, these bands should be made available".

Non-backhaul use of the 32GHz, 70GHz, and 80GHz bands is considered to be Priority 3 along with bands >95GHz.

B.2.3 MNOs' 5G commercial deployment plans

Figure B.5 outlines 5G commercial deployment plans announced by the major MNOs in Canada:

Figure B.5: Announcements of 5G deployment plans by major MNOs in Canada [Source: MNO press releases]

MNO	Details of 5G commercial deployment plans
Rogers	• On April 16, 2018, Rogers announced[158] a 'multi-year network' 5G network deployment plan in partnership with Ericsson, however specific details were not provided • On September 20, 2018, Rogers and the University of British Columbia (UBC) announced[159] a three-year partnership to build a 5G testbed on the UBC campus; 5G-ready network equipment and infrastructure will be deployed from early 2019. Rogers also stated that it is continuing to upgrade its 4.5G network with "the latest 5G-ready technology to be ready for 5G commercial deployment in 2020".
Bell	• No explicit 5G commercial launch dates publicly announced
Telus	• On June 23, 2017, Telus announced[160] a successful 'Wireless-to-the-Premise (WTTx)' (i.e. FWA) 5G pilot in partnership with Huawei, using spectrum at 28GHz. The pilot was part of Telus's and Huawei's 5G 'Living Lab' in Vancouver. Telus stated: "5G wireless technology is expected to become commercially available beginning in 2020, however, TELUS customers living in the Vancouver area will have early access to some of the most cutting-edge wireless technologies in the world thanks to advancements made at the 5G Living Lab".

B.2.4 National strategies/government support

As described in our previous report, CRC (in collaboration with the National Research Council of Canada and GGI Solutions) has been working on 5G technology since 2014[161] and began demonstrations in 2017.

In March 2018, the Canadian Minister of ISED announced[162] a joint investment between the government and industry on 5G, known as the 'ENCQOR' project. ENCQOR[163] is a CAD400 million (USD300 million) project to "establish the first Canadian pre-commercial corridor of 5G digital infrastructure", with a particular focus on providing access to 5G networks to SMEs, researchers, and academia. The five-year project is funded by five private partners (Ericsson, Ciena, Thales, IBM Canada, and CGI), contributing a total of CAD200 million, and the governments of Canada, Ontario, and Quebec (contributing CAD66.7 million each).

158 See https://about.rogers.com/2018/04/16/rogers-ericsson-partner-bring-5g-canadians/

159 See https://about.rogers.com/2018/09/20/rogers-ubc-ink-multi-year-agreement-build-5g-hub-vancouver/

160 See https://www.telus.com/en/about/news-and-events/media-releases/successful-5g-pilot-places-canada-at-the-forefront-of-global-wireless

161 See http://www.ic.gc.ca/eic/site/069.nsf/eng/00083.html

162 See https://www.canada.ca/en/innovation-science-economic-development/news/2018/03/strategic-innovation-fundencqor-investment.html

163 Evolution of Networked Services through a Corridor in Quebec and Ontario for Research and Innovation (ENCQOR). See http://www.encqor.ca/faq/

On June 22, 2018, as part of the ENCQOR initiative, Quebec announced[164] plans to launch two "5G innovation hubs" in Fall 2018 in Quebec City's Metro High Tech Park.

B.2.5 Outlook

Our 5G outlook/assessment for Canada is summarized in Figure B.6 below.

Figure B.6: 5G outlook for Canada [Source: Analysys Mason, 2019]

Metric	Description	Score
1. Industry commitment to 5G launch	• Two MNOs to launch 5G in 2020; one MNO has not confirmed a launch date	1/4
2. Low-band spectrum	• 648MHz of spectrum currently released • Auction of 2×35MHz in 600MHz band scheduled for 2019	4/4
3. Mid-band spectrum	• No mid-band spectrum currently released • 3450–3650MHz band to be released in 2020; further ranges being consulted on	0/4
4. High-band spectrum	• No high-band spectrum currently released • 26.5–27.5GHz to be awarded in 2020; 27.5–28.35GHz and 37–40GHz to be awarded in 2021. Other bands are also under consideration	1/4
5. Total spectrum	• Strong in low-band (with 600MHz auction expected soon), but behind in mid and high bands	1/4
6. National strategies/government support	• Public-private partnership established in which government and industry will invest USD300 million into 5G trials	2/4

164 See https://quebec.encqor.ca/en/new-5g-innovation-hubs-will-be-launched-in-montreal-and-quebec-city/

B.3 China

The Ministry of Industry and Information Technology (MIIT) is responsible for radiocommunication regulation in China. The State Radio Regulation of China (SRRC) is a specialized technical agency of MIIT responsible for radio monitoring and spectrum management. Government policy is to support both the development of 5G technological specifications and the commercial deployment of 5G networks through a range of policies and initiatives, including government support for technology research and network development. These include the 'Made in China 2025' plan and the 13th Five Year Plan, which aims for a commercial launch of 5G services by 2020.[165] MIIT has confirmed the use of the 3.3–3.6GHz and 4.8–5.0GHz ranges for 5G, and is conducting tests in a number of mm-wave bands. Each of China's three MNOs have announced plans for commercial 5G launch in 2020. 5G test licenses in the 3.4–3.6GHz and 4.5–4.9GHz bands have been issued. China Mobile was assigned licenses in the 2515–2675MHz and 4.8–4.9GHz bands, while China Telecom and China Unicom received licenses in the 3.4–3.5GHz and 3.5–3.6GHz bands respectively. The National Development and Reform Commission (NDRC) in China has also announced the standard per MHz fee has been reduced for 5G licenses, and will be waived completely for the first three years of issue (and not reach the full rate until seven years after licenses have been issued).

B.3.1 Current spectrum holdings

Low-band spectrum

As shown in Figure B.7 below, 582MHz of low-band spectrum is currently allocated to commercial mobile services in China.

Figure B.7: Current low-band spectrum holdings of MNOs in China, MHz [Source: MIIT,[166] APT[167]]

MNO	450	700	850	900	1400	1800	1900	2100	2300	2600	Total
China Unicom	–	–	–	12	–	60	–	50	20	–	**142**
China Mobile	–	–	–	40	–	50	50	–	50	160*	**350**
China Telecom	–	–	20	–	–	30	–	40	**	–	**90**
Total	**–**	**–**	**20**	**52**	**–**	**140**	**50**	**90**	**70**	**100**	**582**

* 160MHz (2515–2675MHz) in the 2.6GHz band has been assigned as a 5G test license to China Mobile; this replaces all previous MNO assignments in the 2.6GHz band. See below for further details

**Some reports indicate that China Telecom also holds 20MHz of 2.3GHz spectrum (2370–2390MHz)[168]

Note: the 1900MHz band includes 3GPP band 39 as well as 3GPP bands 33 and 34.

165 See https://5g-ppp.eu/wp-content/uploads/2016/11/Opening-1_Qian-Hang.pdf. Wording taken from GSMA and CAICT's report: '5G in China: Outlook and regional comparisons' published in 2017. The 13th Five-year plan (2016–2020) can be found at http://www.miit.gov.cn/n1146295/n1652858/n1652930/n3757016/c5465203/content.html. The 'Made in China 2025' plan can be downloaded from http://www.cbbc.org/mic2025/

166 See https://5g-ppp.eu/wp-content/uploads/2016/11/03_9-Nov_Session-2_Chang-Ruoting-1.pdf

167 Data from APT report APT/AWG/REP-15(Rev.5). See http://www.apt.int/AWG-RECS-REPS

168 E.g. see http://www.gtigroup.org/Special/4G/Latest/2013-12-26/1922.html/. However, this is not included in MIIT's September 2017 report (see below).

Mid-band spectrum

On December 10, 2018, MIIT announced[169] that it had issued 5G test licenses to each of the incumbent MNOs. China Mobile was assigned licenses in the 2515–2675MHz and 4.8–4.9GHz bands,[170] while China Telecom and China Unicom received licenses in the 3.4–3.5GHz and 3.5–3.6GHz bands respectively.[171]

High-band spectrum

No high-band spectrum is currently available for commercial mobile services in China.

B.3.2 Main 5G spectrum proposals

Low-band spectrum

A total of 687MHz of low-band IMT spectrum has currently been planned for mobile in China, of which 522MHz has already been awarded for use (as shown in Figure B.7 above). The spectrum yet to be assigned consists of a further 10MHz in the 1800MHz band, 5MHz in the 1900MHz band, 30MHz in the 2100MHz band, 30MHz in the 2.3GHz band, and 30MHz in the 2.6GHz band.[172] We are not aware of an official timeline for the release of this spectrum, however we note that on December 10, 2018, MIIT issued[173] a 5G test license in the 2.6GHz band to China Mobile.

There has also been some discussion over the award of 700MHz spectrum in China;[174] we are not aware of official details regarding the release of spectrum in the 700MHz band.

169 See http://www.miit.gov.cn/n1146285/n1146352/n3054355/n3057735/n3057743/c6534379/content.html

170 China Mobile already has a license in the 2575–2635MHz range. The nationwide 5G test license lasts until June 30, 2020. We understand that China Telecom and China Unicom will stop using the 2555–2575MHz and 2635–2655MHz bands by March 31, 2019, and the range will be refarmed by MIIT. See:

https://www.chinamobileltd.com/en/file/view.php?id=204725

https://www.telecompaper.com/news/china-awards-5g-trial-spectrum-for-35-ghz-26-ghz-48-ghz-bands--1272639

171 See https://www.4gltemall.com/blog/tag/china-telecom-5g-frequency-band/

172 See 'Radio Spectrum Management in China', Bureau of Radio Regulation, MIIT, September 11, 2017

173 See http://www.miit.gov.cn/n1146285/n1146352/n3054355/n3057735/n3057743/c6534379/content.html

174 For a discussion of 700MHz spectrum in China, see https://www.fiercewireless.com/wireless/china-issues-plan-to-use-3300-3600-mhz-4800-5000-mhz-for-5g https://www.fiercewireless.com/wireless/china-reserves-spectrum-for-5g-says-more-low-band-frequencies-coming-report

Mid-band spectrum

A presentation released[175] in November 2016 states that "to enable business success of 5G eMBB deployment" MIIT intends to make available more than 100MHz of additional spectrum per operator in the 'medium' frequency range.

In June 2017, MIIT released[176] a consultation on using spectrum in the 3.3–3.6GHz and 4.8–5.0GHz ranges for 5G technologies, with the 3.3–3.4GHz range limited to indoor use. These ranges were confirmed in a subsequent announcement[177] in November 2017, with MIIT adding that it would not approve any further fixed or satellite licenses in these bands. Reports further stated[178] that China is likely to assign the 3.6–4.2GHz range to 5G in the future.

As noted above, the 3.4–3.6GHz and 4.8–4.9GHz ranges were assigned as test licenses in December 2019. We are not aware of further details regarding the approach and timing of the release of the 3.3–3.4GHz and 4.9–5.0GHz bands, however reports have suggested that license awards are expected to take place in 2019/20.[179]

High-band spectrum

The November 2016 presentation referred to above also states MIIT's intention to make available 2GHz of spectrum per operator in the 24.25–43.5GHz range.

MIIT approved[180] two mm-wave bands (24.75–27.5GHz and 37–42.5GHz) for research and testing in July 2017 and has stated[181] that it will continue to consider more bands (both low and high frequency) for 5G development. We are not aware of an official timeline for the spectrum release.

B.3.3 MNOs' 5G commercial deployment plans

Figure B.8 outlines 5G commercial deployment plans announced by the major MNOs in China:

175 *Ibid*. The presentation also references the 4.4–4.5GHz range for 5G. See also 'Radio Spectrum Management in China', Bureau of Radio Regulation, MIIT, September 11, 2017

176 See https://www.fiercewireless.com/wireless/china-reserves-spectrum-for-5g-says-more-low-band-frequencies-coming-report. We understand that MIIT also sought comment on non-exclusive use of the 24.75-27.5GHz and 37-42.5GHz bands in June 2017; see https://www.qualcomm.com/media/documents/spectrum-4g-and-5g

177 See http://www.miit.gov.cn/n1146295/n1652858/n1652930/n3757020/c5907905/content.html http://www.miit.gov.cn/n1146290/n4388791/c5906943/content.html, http://www.caict.ac.cn/xwdt/hyxw/201711/t20171115_2214806.htm and http://www.srrc.org.cn/en/news3434.aspx

178 See http://www.atimes.com/article/china-reserves-spectrum-5g-services/

179 See http://www.scmp.com/tech/china-tech/article/2075179/china-mobile-targets-steady-build-out-5g-infrastructure-2018. Note that this source also references spectrum allocation in the 4.5GHz band.

180 See http://www.miit.gov.cn/n1146295/n1652858/n1653100/n3767755/c5677054/content.html and http://www.miit.gov.cn/n1146290/n1146402/n1146440/c5730538/content.html

181 See http://www.miit.gov.cn/n1146290/n4388791/c5906943/content.html

Figure B.8: Announcements of 5G deployment plans by major MNOs in China [Source: MNO press releases]

MNO	Details of 5G commercial deployment plans
China Mobile	• At the Global Mobile Broadband Forum in November 2017, China Mobile stated[182] that it aimed to have 10,000 5G base stations in commercial deployment in 2020 • On February 12, 2018, news reports stated[183] that China Mobile, in partnership with vendor VIAVI, was aiming to accelerate 5G launch and introduce 5G services by the end of 2019 • On July 10, 2018, after completing a 5G trial with Huawei and Intel, China Mobile announced[184] that it "will release the first version of its 5G commercial product requirements this year and launch the first pre-commercial terminals in 2019" • In November 2018, China Mobile launched its '5G terminal pioneer' program under which[185] the operator will "launch 5G smartphones in the first half of 2019, as part of the push for 5G pre-commercial trials in 2019 and commercialization by 2020".
China Unicom	• In August 2018, China Unicom launched[186] its 'NEXT 5G' initiative, under which the MNO will build 300 5G base stations in Beijing in 2018 (for pilot commercialization and testing). China Unicom also announced plans to pilot 5G technology in Tianjin, Qingdao, Hangzhou, Nanjing, Wuhan, Guiyang, Chengdu, Shenzhen, Fuzhou, Zhengzhou, and Shenyang.
China Telecom	• On December 11, 2017, reports[187] stated that China Telecom had deployed a new 5G base station in Lanzhou, expanding its pilot project for 5G networks to six cities • China Telecom previously announced plans to 'run laboratory and networks tests' until the end of 2018, before commencing pre-commercialization of 5G technology in 2019. Commercial launch is targeted for 2020.[188] We understand that China Telecom has tested 5G technology in large urban areas including Shenzhen, Shanghai, Suzhou, and Chengdu.

B.3.4 National strategies/government support

In February 2013, three Chinese government ministries[189] established the IMT-2020 Promotion Group to promote 5G research in China.

As described in our previous report, in addition to MNO trials, MIIT has conducting several of its own 5G tests. On January 7, 2016, the Ministry launched[190] a trial to assess the compatibility

182 See https://www.lightreading.com/mobile/5g/china-mobile-to-deploy-10000-5g-basestations-by-2020/d/d-id/738307

183 See http://markets.businessinsider.com/news/stocks/china-mobile-research-institute-enlists-viavi-to-support-introduction-of-5g-service-1002078175

In January 2018, VIAVI stated that: "in order to realize China Mobile's vision of introducing 5G service by the end of 2019, principal technologies including Slicing Packet Network (SPN) for transport must be standardized by the ITU-T. We have advanced our test technology to meet this objective, and our solutions are ready to support the China Mobile ecosystem of partners to deliver interoperable network infrastructure".

184 See https://www.techradar.com/uk/news/china-mobile-intel-and-huawei-complete-5g-interoperability-testing

185 See http://www.chinadaily.com.cn/a/201811/24/WS5bf8ab2da310eff30328acbe.html

186 See https://seekingalpha.com/news/3384962-china-unicom-promises-300-beijing-5g-bases-year

187 See https://www.rcrwireless.com/20171211/5g/china-telecom-adds-5g-testing-sites-tag23

188 See https://www.rcrwireless.com/20180821/5g/china-unicom-build-300-5g-base-stations-beijing-year

189 The Ministry of Industry and Information Technology (MIIT), the National Development and Reform Commission (NDRC) and the Ministry of Science and Technology (MOST). See http://www.imt-2020.org.cn/en

190 See https://5g-ppp.eu/wp-content/uploads/2016/11/03_9-Nov_Session-2_Chang-Ruoting-1.pdf

between 5G IMT in the 3.4–3.6GHz band and FSS in the 3.6–4.2GHz bands. MIIT is also conducting[191] compatibility studies in other WRC-19 AI 1.13 bands, such as 25.25–27.5GHz (between IMT and ISS) and 37–42.5GHz.[192] MIIT policy schedules MNO 5G research and development into 'phases' prior to commercial launch in 2020.[193]

Government policy is to support both the development of 5G technological specifications and the commercial deployment of 5G networks through a range of policies and initiatives, including government support for technology research and network development. These include the 'Made in China 2025' plan and the 13th Five-Year Plan (2016–2020), which aim for a commercial launch of 5G services by 2020.[194,195]

As described in Annex B.3.2, in December 2018, MIIT announced that it had issued mid-band 5G test licenses to each of the incumbent MNOs. The National Development and Reform Commission (NDRC) has announced[196] significant reductions in spectrum fees (for 5G mobile licensees) in this band. The standard per-MHz fee has been reduced, and will be waived completely for the first three years of issue (and not reach the full rate until seven years after licenses have been issued).

B.3.5 Outlook

Our 5G outlook/assessment for China is summarized in Figure B.9 below.

Figure B.9: 5G outlook for China [Source: Analysys Mason, 2019]

Metric	Description	Score
1. Industry commitment to 5G launch	• All MNOs to launch to launch large-scale services in 2020	2/4
2. Low-band spectrum	• 522MHz of spectrum currently released • A total of 687MHz has been planned for award	2/4
3. Mid-band spectrum	• 300MHz of spectrum currently released • A total of 500MHz is expected to be released by 2020	4/4
4. High-band spectrum	• No high-band spectrum currently released • 2GHz per MNO to be awarded in 24.75–27.5GHz and 37–42.5GHz bands	3/4

191 *Ibid*. MIIT is also conducting LTE-V2X trials in the 5.9GHz band in Shanghai, Chongqing and other locations.

192 See http://www.miit.gov.cn/n1146295/n1652858/n1653100/n3767755/c5677054/content.html and http://www.miit.gov.cn/n1146290/n1146402/n1146440/c5730538/content.html

193 See https://5g-ppp.eu/wp-content/uploads/2016/11/Opening-1_Qian-Hang.pdf. See also news releases from the CAICT.

194 See https://5g-ppp.eu/wp-content/uploads/2016/11/Opening-1_Qian-Hang.pdf. Wording taken from GSMA and CAICT's report: '5G in China: Outlook and regional comparisons' published in 2017. The 13th five-year plan (2016–2020) can be found at http://www.miit.gov.cn/n1146295/n1652858/n1652930/n3757016/c5465203/content.html. The 'Made in China 2025' plan can be downloaded from http://www.cbbc.org/mic2025/

195 For a recent report providing further details of government policy to support 5G in China, see https://www.ey.com/Publication/vwLUAssets/ey-china-is-poised-to-win-the-5g-race-en/$FILE/ey-china-is-poised-to-win-the-5g-race-en.pdf

196 See http://www.ndrc.gov.cn/gzdt/201804/t20180424_883233.html

Metric	Description	Score
5. Total spectrum	• Strong in mid-band (100MHz assigned to each MNO); large amount of high-band spectrum planned, but timing not confirmed	4/4
6. National strategies/government support	• '13th Five-Year Plan' aims for commercial 5G launch by 2020 • MIIT has also published a '5G promotion plan' for 2013–2020	4/4

B.4 France

ARCEP is the telecommunications regulator in France, with responsibility for spectrum policy and management. The Agence Nationale des Fréquences (ANFR) is responsible for spectrum assignment and licensing. ARCEP has announced plans to release 300MHz of contiguous C-band spectrum for 5G in 2019, useable from 2020 onwards, and 340MHz (3460–3800MHz) by 2026. Having already awarded 2×30MHz of paired spectrum in the European 700MHz band, which can be used for 5G, the regulator has also consulted on allocating a further 700MHz unpaired block, as well as spectrum in the 2.3GHz and 26GHz bands. A progressive release of mm-wave spectrum is planned: the 26.5–27.5GHz portion of the 26GHz band will be assigned in 2020, while the 24.5–26.5GHz band is planned for release after the migration of fixed radio links. Bouygues Telecom and SFR have conducted a number of 5G trials, with Bouygues explicitly stating that it expects to roll out commercial services in 2020 and SFR in 2021. The Orange Group also announced in December 2018 that it will roll out 5G technology in seventeen European cities across Belgium, Spain, France, Luxembourg, Poland, and Romania as it prepares for 5G commercial services to be available in 2020.

B.4.1 Current spectrum holdings

Low-band spectrum

As shown in Figure B.10 below, 598MHz of low-band spectrum is currently allocated to commercial mobile services in France.

Figure B.10: Current low-band spectrum holdings of MNOs in France, MHz [Source: ARCEP[197]]

MNO	450	700	800	900	1400	1800	1900*	2100	2300	2600	Total
Orange	–	10	20	20	–	40	–	39.2	–	40	179.2
SFR	–	10	20	20	–	40	–	39.6	–	30	159.6
Bouygues	–	10	20	19.6	–	40	–	29.6	–	30	149.2
Free	–	20	–	10	–	30	–	10	–	40	110
Total	**–**	**60**	**60**	**69.6**	**–**	**150**	**–**	**118.4**	**–**	**140**	**598**

* Spectrum assigned in 3GPP bands 33 and 34 is excluded, since it is not used.

Note: the proportion of the 900MHz and 2100MHz bands which is held by the different MNOs will change from March 2021 and August 2021 respectively.[198]

197 See https://www.arcep.fr/uploads/tx_gspublication/consult-frequences-terr-entreprises-5G-innov_01.pdf

198 In early 2018, the French government announced plans for renewing MNOs' licenses in the 900MHz, 1800MHz, and 2100MHz bands. On October 23, 2018, ARCEP issued a decision stating how the spectrum holdings of the MNOs would be rebalanced over time, to accompany the license renewals. Eventually both the 900MHz and 2100MHz bands will be split equally between the four MNOs. See https://www.arcep.fr/actualites/le-fil-dinfos/detail/n/new-deal-mobile-3.html

Mid-band spectrum

No mid-band spectrum is currently available for commercial mobile services in France, although a number of test licenses have been issued in the 3.4–3.8GHz band (further details are provided in the sub-section on government strategy).

40MHz at 3420–3460MHz[199] is currently available for FWA in specific geographical areas[200,201] (with an additional 10MHz at 3410–3420MHz in certain areas, depending on coexistence constraints). This spectrum is technology neutral, though it is expected to be used for LTE. On May 25, 2018, ARCEP announced[202] that Covage subsidiary Sem@for77 became the first operator to be allocated spectrum in the 3410–3460MHz band for regional FWA (in the Seine-et-Marne region).

High-band spectrum

No high-band spectrum is currently available for commercial mobile services in France.

B.4.2 Main 5G spectrum proposals

Low-band spectrum

ARCEP plans[203] to assign the 2.6GHz TDD band (2570–2620MHz) to private mobile radio (PMR). ARCEP's public consultation on 5G, published[204] on October 26, 2018, states that "ARCEP is currently analyzing and drafting the final document specifying the assignment approach [for the 2.6GHz TDD band]".

ARCEP previously ran a public consultation[205] on new spectrum for 5G from January to March 2017. This focused on the 2.6GHz TDD and 3.4–3.8GHz bands, but also discussed the following bands:

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199 The entire 3420–3460MHz range is not available in all departments. See https://www.arcep.fr/index.php?id=13756

200 I.e. areas not covered by FTTH deployments (the purpose of assigning the spectrum for FWA is to boost high-speed connectivity in France). Operators can apply for a license within a particular department, but coverage is only permitted in areas not covered by FTTH. For example, in the Seine-et-Marne department, operator Sem@for77 is licensed to cover 142 communes representing 33% of the total area of the department.

See https://www.arcep.fr/fileadmin/reprise/dossiers/thd-radio/FichesSynthese/Fiche_77__Semafor77.pdf

201 A consultation on FWA spectrum was published on July 13, 2017, and a document outlining the assignment approach on December 11, 2017. As of March 2018, players are able to request regional FWA licenses from the regulator. See:
https://www.arcep.fr/uploads/tx_gspublication/consult-attribution-THD_radio-juil2017.pdf
https://www.arcep.fr/uploads/tx_gspublication/modalites_attribution_THD_radio-dec2017.pdf
https://www.arcep.fr/?id=7108

202 See https://www.arcep.fr/index.php?id=13756

203 See https://www.arcep.fr/uploads/tx_gspublication/consult-attrib-freqc-2-6GHz-thd-mobile-pro-mars2018.pdf

204 See https://www.arcep.fr/uploads/tx_gspublication/consultation-attribution_frequences_5G-2610178.pdf

205 See https://www.arcep.fr/uploads/tx_gspublication/consult-frequences-terr-entreprises-5G-innov.pdf

- **700MHz SDL band**. 700MHz FDD spectrum (703–733MHz and 758–788MHz) was auctioned by ARCEP in December 2015. The consultation asks whether there is demand for the unallocated spectrum in the 700MHz band, in particular four 5MHz blocks at 738–753MHz. The consultation states that ARCEP has no plans to assign this spectrum before June 1, 2019 (which is when PMSE should have released the band).

- **400MHz band** (380–399.9MHz, 406.1–430MHz, and 440–470MHz). The consultation notes that, in accordance with CEPT discussions "work is well underway to assess the possibility of assigning authorizations for use of wider frequency bands, which [would] allow the introduction of the LTE in the 400MHz band."

- **L-band**.[206] ARCEP notes that the central 40MHz portion of the L-band (1452–1492MHz) is more readily accessible than the remaining 51MHz (1427–1452MHz and 1492–1518MHz), which is currently used by the MoD and infrastructure links. Most recently, the October 2018 public consultation[207] on 5G envisaged assigning L-band spectrum at the same time as the 3.4-3.8GHz and 26GHz bands (see below).[208]

- **2.3GHz band**. ARCEP notes that the "assignment in this band depends on the needs of the MoD, and to date appears unlikely".[209]

Mid-band spectrum

In the 2017 public consultation on new spectrum for 5G (referred to above), ARCEP confirmed its intention to allocate 300MHz of contiguous C-band spectrum for 5G by 2020, and 340MHz[210] (3460–3800MHz) by 2026.

On June 9, 2018, ARCEP published[211] an official notice regarding the release schedule for the 3.4–3.6GHz band. The notice states that the band will be progressively vacated (by department) of incumbent wireless backhaul links (used by the Ministry of Internal Affair's PPDR network) by March 1, 2020, at the latest.

206 ARCEP ran a specific consultation on the L-band between July and September 2018. See: https://www.arcep.fr/uploads/tx_gspublication/consult-5g-bande-L-juil2018.pdf

207 The consultation states that, to date, the 1452–1492MHz range will be free by 2020, and that work is underway to define a radio-relay migration schedule in the bands 1427–1452MHz and 1492–1517MHz (currently allocated to the MoD), with potential availability from 2023.

208 This therefore raises the possibility of a progressive release of the L-band (i.e. the central 40MHz range is assigned first, followed by the 1427–1452MHz and 1492–1517MHz ranges).

209 Between 2014 and 2016, ARCEP granted the Telecom Platform Association and the Red company permission to use the 2.3GHz band experimentally.

210 390MHz in certain locations.

211 See https://www.arcep.fr/uploads/tx_gsavis/18-0538.pdf

The October 2018 public consultation on 5G states that ARCEP has begun working with incumbent licensees in the 3.4–3.8GHz band, with a view to making spectrum available for 5G.[212] The consultation states that an assignment of 3.4–3.8GHz spectrum is envisaged for mid-2019. Two possible assignment approaches are consulted on: (1) assigning the entire 3.4–3.8GHz band in 2019, with certain parts only being available from 2026; (2) only assigning spectrum which will be available from 2020 at an auction in 2019, and assigning the remaining spectrum at a later date.

Most recently, on January 30, 2019, a government minister reportedly[213] stated that the auction was expected to take place at the start of 2020.

High-band spectrum

ARCEP ran a public consultation[214] on the release of the 26GHz (24.25–27.5GHz) band from May to June 2018.[215]

The October 2018 public consultation on 5G states that, following the 26GHz consultation, ARCEP will not assign new PtP links in the 26GHz band beyond December 31, 2023. The consultation further states that a progressive release of the band is planned: the 26.5–27.5GHz band (currently used by the MoD) will be assigned in 2020, while the 24.5–26.5GHz band is planned for release after the migration of radio links. The 24.25–24.5GHz range will also potentially be available for 5G in the future, provided that interference with satellites can be managed.

B.4.3 MNOs' 5G commercial deployment plans

Figure B.11 outlines 5G commercial deployment plans announced by the major MNOs in France:

212 Before 2026, without any redevelopment (i.e. as of end-2018) 220MHz would be available for 5G in the 3.4–3.8GHz band. However, in the case of redevelopment, 280–340MHz could be assigned to 5G. The 3.4–3.8GHz band is currently used by various operators: (i) Regional FWA [THD] operators in the 3410–3460MHz band. ARCEP is issuing licenses in this band until the end of 2019, (ii) Regional WiMAX operators [BLR] in the 3410–3580MHz band, (iii) Other (regional) spectrum holders: Bollore Telecom and SHD, (iv) satellite users in the 3.7–3.8GHz band, with licenses up to 2023.

Incumbent licences expire by 2026 at the latest. After 2026, there will be a need for a 10–20MHz guard band to avoid interference from radars below 3.4GHz.

213 See http://www.lefigaro.fr/secteur/high-tech/2019/01/30/32001-20190130ARTFIG00316-le-gouvernement-donne-le-coup-d-envoi-a-la-5g.php. The Minister is reported as saying "the government will fix the political framework in spring [2019]. ARCEP will then establish the specific requirements, which will be certified in autumn [2019]…The auction will then be launched with attributions at the start of 2020".

214 See https://www.arcep.fr/uploads/tx_gspublication/consultation-publique-bande-26GHz_5G-mai2018.pdf. ARCEP also discussed the 26GHz band in the 2017 consultation on 5G.

215 On July 30, 2018, ARCEP announced that it had received 13 responses to the 26GHz consultation. ARCEP stated that "some players consider that the first 5G deployments should be limited to the last gigahertz of the band (26.5–27.5GHz) due to the availability of equipment". ARCEP said it would consult with the military (user of the 26.5–27.5GHz range) for this band to be transferred to ARCEP. "To prepare for the arrival of 5G in the rest of the band, ARCEP will study with the actors the conditions for migration of radio links and plans to limit the duration of new authorizations to a maximum until December 31, 2023".

Figure B.11: Announcements of 5G deployment plans by major MNOs in France [Source: MNO press releases]

MNO	Details of 5G commercial deployment plans
Orange	• Orange has stated[216] that it "expects capital expenditure to peak in 2018 or 2019, as [it] prepares for the introduction of 5G". The company produced[217] a 5G position paper in May 2017 which anticipates that European MNOs will launch 5G commercial networks "from 2020" • Orange's website currently states[218] that it will "pilot 5G tests in areas already authorized by ARCEP… From 2018, in the cities of Lille, Douai, Marseille, Châtillon on the Orange Gardens site and on the Linas-Monthléry circuit. In 2019, in the Paris Opera district" • On December 12, 2018, Orange Group stated[219] that "5G is gradually being deployed on existing 4G sites. It will be installed in 17 European cities [Belgium, France, Luxembourg, Poland, Romania and Spain[220]] in 2019 and ready for commercial release in 2020, so long as enough 5G smartphones are available". We understand[221] that customers in the 17 cities will be able to experience 5G services in 2019, and that the initial services will be mainly targeted at enterprise customers.
SFR	• On January 23, 2018, reports[222] stated that SFR had begun conducting live 5G trials in Nantes, with commercial services expected to be available for consumers in 2021 • Other recent reports[223] (published in 2019) have indicated that SFR is aiming to launch commercial services in 2020.
Bouygues	• On January 7, 2018, Bouygues issued[224] a press release announcing the completion of a 5G trial in Lyon. The announcement notes that this is the second city where Bouygues has piloted 5G (following Bordeaux in July 2018), and that 11 5G sites have now been deployed. Reports[225] stated that Bouygues is aiming to deploy commercial services in 2020 • Bouygues's website currently states[226] that it is in the process of preparing to deploy its 5G network, "which will be marketed in 2020".
Free Mobile	• No explicit 5G commercial launch dates publicly announced

216 See https://www.lightreading.com/mobile/5g/orange-sees-peak-capex-in-2018-19-ups-2017-guidance/d/d-id/733295

217 See https://www.orange.com/en/news/2017/Juillet/5G-a-mobile-revolution-of-the-future

218 See https://reseaux.orange.fr/5g-deploiement

219 See https://www.orange-business.com/en/press/orange-presents-major-innovations-focused-digital-inclusion-show-hello

220 See https://www.lightreading.com/mobile/5g/eurobites-orange-preps-5g-launch-in-17-european-cities/d/d-id/748227

221 See https://www.rcrwireless.com/20181214/5g/orange-launch-5g-17-european-cities-next-year

222 See https://www.francebleu.fr/infos/societe/alain-weill-patron-de-sfr-les-nantais-seront-parmi-les-premiers-servis-en-france-pour-l-internet-5g-1548164881

223 See https://www.sdxcentral.com/articles/news/bouygues-telecom-signals-5g-progress-as-france-gets-its-ducks-in-line/2019/01/

224 See http://www.bouygues.com/wp-content/uploads/2019/01/20190107_cp_bouygues-telecom-passe-un-appel-5g-en-conditions-reelles-dans-les-rues-de-lyon-avec-un-des-premiers-terminaux-5g-disponibles.pdf

225 See https://www.sdxcentral.com/articles/news/bouygues-telecom-signals-5g-progress-as-france-gets-its-ducks-in-line/2019/01/

226 See https://www.corporate.bouyguestelecom.fr/nos-activites/reseau-5g/

B.4.4 National strategies/government support

As described in our previous report, ARCEP has actively encouraged industry players to conduct 5G (and LTE) testing. After awarding licenses for use of the 700MHz band in 2015, the regulator has invited[227] stakeholders to request spectrum for experimentation in the 2.6GHz and 3.4–3.6GHz bands. In ARCEP's June 2017 announcement (see above), the regulator encouraged industry players to conduct 5G pilots. It nominated 80MHz (3600–3680MHz) of spectrum for that purpose, and identified six cities where pilot projects could be carried out (Lyon, Nantes, Lille, Le Havre, Saint-Etienne, and Grenoble).

On January 16, 2018, ARCEP formally opened a '5G pilot window',[228] inviting industry players to apply for trial licenses with the objectives of:

- engaging all players across the 5G value chain in co-operation (new verticals as well as MNOs)
- assigning spectrum for 5G pilots, particularly in the 3.4–3.8GHz and 26GHz bands. (The announcement notes that 3.4–3.8GHz spectrum is already available for 5G pilots in the six cities mentioned above, but that those cities are 'not exhaustive and may change'.[229] Players interested in deploying networks in other frequency ranges/areas are invited to contact ARCEP.)
- receiving initial feedback on the deployment of 5G networks. This feedback will help ARCEP to prepare the procedure for awarding future 5G licenses.

We understand[230] that the pilot licenses will last 18–24 months, and that pilot sites will consist of "a few tens of towers representing a modest investment of a few million euros". The first pilot licenses were issued by ARCEP (in the 3.4–3.8GHz band) to Orange and Bouygues in February 2018.[231]

On July 16, 2018, ARCEP published[232] a 5G roadmap, which lists the following four "priority projects to make 5G a success":

- free up and allocate radio frequencies
- foster the development of new uses
- support for 5G infrastructure roll-outs
- ensure transparency and dialog on roll-outs and the public's exposure.

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227 See https://www.arcep.fr/index.php?id=8571&no_cache=1&tx_gsactualite_pi1%5buid%5d=1843&tx_gsactualite_pi1%5bbackID%5d=26&cHash=4b0291e929f616fc99ac087b8f3e18c6

228 See https://www.arcep.fr/index.php?id=8571&no_cache=0&tx_gsactualite_pi1[uid]=2119&tx_gsactualite_pi1[annee]=&tx_gsactualite_pi1[theme]=&tx_gsactualite_pi1[motscle]=&tx_gsactualite_pi1[backID]=26&cHash=7a322a2c0239bb9c53b8f95be9d7e7e2

229 The interview with ARCEP's president (link below) states that there are nine pilot cities, with Bordeaux, Douai, and Montpellier in addition to the six cities mentioned above.

230 See interview with ARCEP's president at: https://www.usinenouvelle.com/article/neuf-sites-pilotes-pour-la-5g-en-2018-2019-annonce-sebastien-soriano-president-de-l-arcep.N638013

231 See https://www.telegeography.com/products/commsupdate/articles/2018/03/02/arcep-issues-two-5g-trial-licences-assigns-3-5ghz-spectrum-in-saint-martin

232 See https://www.arcep.fr/fileadmin/reprise/dossiers/programme-5G/Roadmap_5G_-_VA.pdf

Under the infrastructure roll-out category, ARCEP notes that infrastructure deployment streamlining measures have already been identified by the Housing, Planning and Digital Development bill ("loi ELAN") put forward by the Ministry of Territorial Cohesion, and the European Electronic Communications Code. ARCEP and the government also plan on establishing a "best practices guide to facilitate and accelerate the deployment of… future networks (e.g. regarding the terms governing operators' access to street furniture)". ARCEP further states that it will also assess the feasibility and opportunity to share small-cell networks, notably according to roll-out restrictions.

B.4.5 Outlook

Our 5G outlook/assessment for France is summarized in Figure B.12 below.

Figure B.12: 5G outlook for France [Source: Analysys Mason, 2019]

Metric	Description	Score
1. Industry commitment to 5G launch	• Two MNOs to launch 5G in 2019/2020; two MNOs have not confirmed launch dates	2/4
2. Low-band spectrum	• 598MHz of spectrum currently released • 700MHz unpaired and L-band spectrum for future potential assignment	2/4
3. Mid-band spectrum	• No mid-band spectrum currently released • 300MHz in the 3.4–3.8GHz band to be available by 2020	2/4
4. High-band spectrum	• No high-band spectrum currently released • 1GHz in the 26GHz band to be awarded in 2020; remainder of 26GHz may also be assigned subsequently	1/4
5. Total spectrum	• Strong in low-band (with 700MHz already assigned); mid- and high-band assignments scheduled by 2020	2/4
6. National strategies/government support	• ARCEP's 5G roadmap prioritizes providing support for 5G infrastructure roll-outs; some initial measures have already been adopted	2/4

B.5 Germany

The Federal Network Agency (Bundesnetzagentur or BNetzA) is the regulatory authority for a number of markets in Germany including telecommunications, and oversees the management and licensing of radio spectrum. The market has a large amount of spectrum currently assigned for mobile use, including the European 700MHz band, and L-band, as well as national and regional FWA spectrum licenses in the 3.4–3.6GHz range, all suited for 5G use. The regulator has announced plans to allocate the entire 3.4–3.8GHz range to 5G in 2018, and an auction is being prepared. The regulator is also considering action in the 700MHz unpaired block not awarded along with the paired blocks, as well as 26GHz, 28GHz, and possibly other mm-wave bands. An auction of 300MHz of spectrum from 3400–3700MHz is scheduled for Spring 2019, alongside award of 5G spectrum for regional/local use from 3700–3800MHz. Germany MNOs are advanced in their 5G trials and deployment plans, with commercial services expected in 2020. As well as MNO trials, a number of initiatives are stimulating the development of 5G technology, including Germany's '5G Lab' and the '5G Berlin' initiative.

B.5.1 Current spectrum holdings

Low-band spectrum

As shown in Figure B.13 below, 689MHz of low-band spectrum is currently allocated to commercial mobile services in Germany.

Figure B.13: Current low-band spectrum holdings of MNOs in Germany, MHz [Source: BNetzA[233]]

MNO	450	700**	800	900	1400	1800	1900*	2100	2300	2600	Total
Telefonica	–	20	20	20	–	40	–	69.3	–	80	**249.3**
Vodafone	–	20	20	20	20	50	–	29.7	–	65	**224.7**
Deutsche Telekom (DT)	–	20	20	30	20	60	–	19.8	–	45	**214.8**
Total	**–**	**60**	**60**	**70**	**40**	**150**	**–**	**118.8**	**–**	**190**	**688.8**

*Spectrum assigned in 3GPP bands 33 and 34 is excluded, since it is not used.

**The 700MHz band was auctioned for mobile in 2015, however we understand that it will not be available for use until 2019.

233 See https://www.bundesnetzagentur.de/SharedDocs/Downloads/DE/Sachgebiete/Telekommunikation/Unternehmen_Institutionen/Frequenzen/OffentlicheNetze/Mobilfunk/DrahtloserNetzzugang/Projekt2016/Frequenzen700bis1800_pdf.pdf?__blob=publicationFile&v=3

Mid-band spectrum

Each of the three MNOs in Germany currently owns 2×21MHz of spectrum in the 3410–3473/3510–3573MHz range on a nationwide basis;[234,235] licenses are technology neutral but limited to FWA use (i.e. not suitable for mobile) and expire in December 2021. Various regional FWA licenses have also been assigned in the 3473–3594MHz and 3573–3594MHz ranges, expiring between 2020 and 2022.[236]

High-band spectrum

No high-band spectrum is currently available for commercial mobile services in Germany.

B.5.2 Main 5G spectrum proposals

Low-band spectrum

BNetzA issued[237,238] a 5G 'Key Elements' document on June 27, 2017, which identified the 738–753MHz range for 5G. This range was not part of the 700MHz FDD auction in 2016 and is currently used for PMSE services. The range is unpaired and could be used for TDD or SDL technology; BNetzA states that it will be considered for auction at a later date.

234 Four 2×21MHz lots (3410–3494/3510–3594MHz) were made available for FWA in each of 28 regions at an auction in 2006. The first lot was won by Clearwire (subsequently WiMee-Connect) in all regions. The second lot was won by Inquam (subsequently WiMee Plus) in all regions. Telefónica subsequently acquired both operators. The third lot was won by DBD in all regions. We understand that T-Mobile subsequently acquired DBD. See https://www.bundesnetzagentur.de/EN/Areas/Telecommunications/Companies/FrequencyManagement/BroadbandWirelessAccess/broadbandwirelessaccess_node.html

We note that BNetzA's recent consultation states that one assignment holder holds licenses in the third lot in 27 out of the 28 regions (as well as the fourth lot in the remaining region).

235 See https://www.bundesnetzagentur.de/SharedDocs/Downloads/DE/Sachgebiete/Telekommunikation/Unternehmen_Institutionen/Frequenzen/OffentlicheNetze/Mobilfunk/DrahtloserNetzzugang/Projekt2016/Frequenzen700bis1800_pdf.pdf?__blob=publicationFile&v=3

On February 21, 2018, Telefónica announced that it had sold half of its spectrum in the 3410–3452/3510–3552MHz range (i.e. 2×21MHz) to Vodafone. See https://www.telefonica.de/fixed/news/6094/more-high-speed-for-germany-vodafone-and-telefonica-deutschland-to-cooperate-over-fast-fibre-optic-connections-for-mobile-networks.html

236 These licenses were assigned on an individual basis. There are currently around 80 regional FWA assignments; licensees are generally SMEs. The latest expiry date of these licenses is December 2022.

237 See https://www.bundesnetzagentur.de/SharedDocs/Downloads/DE/Sachgebiete/Telekommunikation/Unternehmen_Institutionen/Frequenzen/OffentlicheNetze/Mobilfunk/EckpunkteBedarfsermittlung.pdf?__blob=publicationFile&v=2

238 This follows the 'Frequency Compass' and 'Points of Orientation' documents published in 2016.

Mid-band spectrum

BNetzA's 'Key Elements' document also identified 400MHz in the 3.4–3.8GHz range for 5G.[239] On January 31, 2018, BNetzA published a draft decision,[240] confirming its intention to auction 300MHz in the 3400–3700MHz range for nationwide use, and to assign 100MHz in the 3700–3800MHz range on a regional/local basis.

- **3.4–3.7GHz (nationwide use[241])**

  On September 17, 2018, BNetzA published[242] initial draft rules for the 3.4–3.7GHz auction, followed by final draft rules[243] on November 19, 2018. After approval from the Advisory Council on November 26, 2018, the final rules were published,[244] and BNetzA opened the qualification procedure. The auction is scheduled to take place in Spring 2019, however we note that all three German MNOs have registered opposition to the auction rules. In January 2019, DT became the third MNO (following Vodafone and Telefonica) to sue[245] BNetzA over the auction rules, objecting to the proposed coverage obligations and competition conditions. Despite this, on February 25, 2019, BNetzA stated[246] that the auction was scheduled to begin on March 19, 2019, and that the three MNOs (as well as MVNO Drillisch) had been approved to participate.

239 Both the 2.1GHz and C-band spectrum will be technology neutral; licenses will expire on December 31, 2040.

240 See https://www.bundesnetzagentur.de/DE/Sachgebiete/Telekommunikation/Unternehmen_Institutionen/Frequenzen/OeffentlicheNetze/Mobilfunknetze/mobilfunknetze-node.html

241 For an index of relevant documentation, see: https://www.bundesnetzagentur.de/DE/Sachgebiete/Telekommunikation/Unternehmen_Institutionen/Frequenzen/OeffentlicheNetze/Mobilfunknetze/mobilfunknetze-node.html

242 See https://www.bundesnetzagentur.de/DE/Allgemeines/Presse/Reden/5GVergabebedinungen.pdf?__blob=publicationFile&v=2

243 The draft auction rules impose the following coverage obligations on licensees: a requirement to provide: (i) 98% of households in each state with a minimum speed of 100Mbps, by end-2022; (ii) speeds of 100Mbps on main roads and railway routes, by end-2022; (iii) speeds of 100Mbps to all other main roads, and speeds of 50Mbps to smaller roads, railways, seaports, and the main waterways, by end-2024; (iv) 1000 5G base stations with a further 500 in unserved rural areas ('white spots'), by end-2022. See https://www.bundesnetzagentur.de/SharedDocs/Pressemitteilungen/DE/2018/Entscheidungsentwurf.pdf?__blob=publicationFile&v=2

244 See https://www.bundesnetzagentur.de/SharedDocs/Pressemitteilungen/EN/2018/20181126_5G.html;jsessionid=B13E5FA0598833285B53671E3DB1D42E

245 See, for example, https://www.reuters.com/article/us-deutsche-telekom-auction/deutsche-telekom-sues-german-government-over-5g-auction-welt-idUSKCN1OV1ND

246 See https://www.bundesnetzagentur.de/SharedDocs/Pressemitteilungen/DE/2019/2019025_Frequenzauktion.html?nn=265778

- **3.7–3.8GHz (regional/local use[247])**

  In September 2018, BNetzA published[248] a separate consultation on the assignment of the 3700–3800MHz range. BNetzA is proposing to make licenses available on an individual basis. To be eligible, an applicant cannot hold nationwide licenses in the 700MHz or 3.4–3.7GHz bands. For outdoor use, up to 80MHz (3700–3780MHz) will be available for regional use, and 20MHz (3780–3800MHz) for local use. For (local) indoor use, up to 100MHz is to be made available using a simplified assignment procedure. Local indoor use is to co-exist with regional outdoor use.

High-band spectrum

BNetzA's 'Key Elements' document considered frequencies in the 26GHz (24.25–27.5GHz), 28GHz (27.5–29.5GHz) and 32GHz (31.8–33.4GHz) ranges.[249]

In October 2018, BNetzA ran a public consultation on the assignment approach of the 26GHz band. The consultation proposes an individual licensing arrangement: applicants can apply to install 5G base stations in specific locations on a first-come, first-served (FCFS) basis. BNetzA will only approve an application if it will not cause interference with incumbent licensees (PtP/PMP links and FSS).[250] Responses to the consultation were published[251] on November 21, 2018.

B.5.3 MNOs' 5G commercial deployment plans

Figure B.14 outlines 5G commercial deployment plans announced by the major MNOs in Germany:

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247 For an index of relevant documentation, see https://www.bundesnetzagentur.de/DE/Sachgebiete/Telekommunikation/Unternehmen_Institutionen/Frequenzen/OeffentlicheNetze/RegionaleNetze/regionalenetze-node.html;jsessionid=BF25AE9F175144A066383647398BD0F5

248 See https://www.bundesnetzagentur.de/SharedDocs/Downloads/DE/Sachgebiete/Telekommunikation/Unternehmen_Institutionen/Frequenzen/OffentlicheNetze/RegionaleNetze/Entwurf%20Antragsverfahren%203,7%20-%203,8%20GHz.pdf?__blob=publicationFile&v=2

249 In the 'Key Elements' document, BNetzA states that it plans to develop an application procedure for 5G use in these bands, starting with the 26GHz band.

250 Furthermore:

>>Licenses will be technology and service neutral.

>>BNetzA does not propose the migration of existing PtP/PMP links in the 26GHz band, however it states that new links should primarily use alternative bands (e.g. the 28GHz band). Current licenses in the 28GHz band expire on December 31, 2020, and BNetzA is working on new assignment rules for the band. BNetzA is also investigating whether the current frequency usage of links in the 26GHz can be optimized (e.g. due to concentration of links in certain frequency sub-ranges).

>>5G licenses will be in multiples of 200MHz TDD blocks (up to 800MHz). In certain cases, 50MHz TDD blocks or multiples thereof may be assigned.

>>Licenses will have a use-it-or-lose-it clause; spectrum must be in use within one year of assignment.

>>BNetzA is considering a "simplified approach" for indoor use.

251 See https://www.bundesnetzagentur.de/DE/Sachgebiete/Telekommunikation/Unternehmen_Institutionen/Frequenzen/OeffentlicheNetze/RegionaleNetze/regionalenetze-node.html;jsessionid=BF25AE9F175144A066383647398BD0F5

Figure B.14: Announcements of 5G deployment plans by major MNOs in Germany [Source: MNO press releases]

MNO	Details of 5G commercial deployment plans
Telefonica	• On October 18, 2018, Telefonica and Samsung announced[252] plans to conduct 5G FWA trials. On February 15, 2019, Telefonica confirmed[253] that the trials (using spectrum in the 26GHz band) has been completed • On December 19, 2018, Telefonica and Nokia announced[254] completion of the construction of their '5G innovation cluster' in Berlin involving several base stations to be used to test 5G services in an urban environment. Reports[255] indicated that the MNO is targeting 2020 for commercial launch.
Vodafone	• On November 2, 2018, Vodafone announced[256] that it had activated its first 5G mast in Germany (in the city of Aldenhoven). Several automobile companies (e.GO, Audi, and Continental) and Railway company Deutsche Bahn were named as Vodafone's first 5G partners • Vodafone's website currently states that it aims to launch 5G services for customers from 2020 • Vodafone Group has also announced a collaboration with IBM to progress its cloud business and digital transformation, aided by 5G, artificial intelligence, edge and software-defined networking.[257]
Deutsche Telekom (DT)	• On October 10, 2018, reports stated[258] that DT would launch commercial 5G operations in Germany in 2020, as long as enough commercial devices are available • On October 11, 2018, DT announced an eight-point program for the development and launch of 5G. DT stated: "by 2025, we will cover 99 percent of the population and 90 percent of the country with 5G" • DT Is also working with Nokia and the Hamburg Port Authority to test industrial applications of 5G using network slicing[259] • It was also announced in October 2018 that DT and SK Telecom (Korea) were strengthening an existing collaboration deal between the two operators on 5G, edge computing, and IoT[260] • On January 22, 2019, DT stated[261] that over 50 5G antennas are already transmitting in Berlin, and that it will set up additional 5G test areas in other German cities in 2019

252 See https://www.telefonica.de/fixed/news/6148/cooperation-on-alternative-broadband-technology-telefonica-deutschland-and-samsung-test-5-g-fixed-wireless-access-in-germany.html

253 See https://www.telefonica.de/fixed/news/6191/conclusion-of-three-month-pilot-in-hamburg-5-g-fixed-wireless-access-from-telefonica-deutschland-and-samsung-proves-successful.html

254 See https://www.nokia.com/about-us/news/releases/2018/12/19/nokia-and-telefonica-deutschland-built-up-joint-early-5g-innovation-cluster-in-berlin/

255 See https://www.sdxcentral.com/articles/news/telefonica-germany-and-nokia-enter-5g-testing-stage-in-berlin/2018/12/

256 See https://www.vodafone.de/medien/digitales-leben/5g-mobility-lab-vodafone-startet-ersten-5g-mast-in-deutschland/

257 https://newsroom.ibm.com/2019-01-17-IBM-Vodafone-Business-Join-Forces-to-Drive-Innovation-in-Rapidly-Changing-World

258 See https://www.reuters.com/article/us-deutsche-telekom-strategy/deutsche-telekom-to-launch-commercial-5g-operations-in-2020-idUSKCN1MK129

259 See https://www.telekom.com/en/media/media-information/archive/port-of-hamburg-5g-applications-pass-field-test-551178

260 See https://www.sdxcentral.com/articles/news/dt-sk-telecom-invest-in-each-others-5g-focused-pet-projects/2018/10/

261 See https://www.telekom.com/en/media/media-information/archive/network-2019-558784

MNO	Details of 5G commercial deployment plans
	(starting in Q1 with Darmstadt). On February 6, 2019, DT confirmed[262] that the Darmstadt 5G test was now operational.

B.5.4 National strategies/government support

As described in our previous report, the federal government outlined five action points as part of its '5G Strategy for Germany' published[263] in September 2017:

- step up network roll-out
- make available frequencies based on demand
- promote co-operation between telecommunications and user industries
- targeted and co-ordinated research
- initiate 5G for towns and cities.

Under the 'targeted and co-ordinated research' action point, the federal government is funding research and development for 5G in its 'Industrial Communications of the Future' initiative. The focus is on three research priorities: 'reliable wireless communications in the industry', '5G: industrial internet', and '5G: tactile internet', for which up to EUR80 million will be made available.[264] Examples of projects funded include the A9 Digital Motorway Test Bed, 'TACNET 4.0' and the 'PMSE-xG' initiative.

Under the 'promote co-operation between telecommunications and user industries' action point, the government describes the '5G Dialog Forum', which was set up in September 2016 to support 'the active exchange and networking between the telecommunications sector and vertical industries'. The first sector-specific dialog forum on 5G prospects for the automotive industry was held in February 2017, followed by an exchange on health issues in March.

Regarding financial investment, on March 7, 2017, the Federal Minister of Transport and Digital Infrastructure and the members of the Network Alliance for a Digital Germany adopted[265] the 'Gigabit Germany Initiative for the Future'. The objective of the joint strategy is to invest EUR100 billion to create a high-performance broadband network in Germany by 2025. In a statement,[266] the Minister said that using the 'most sophisticated technologies available' such as 'fiber optics and […] 5G'. We are not aware of details regarding the specific amount to be allocated to 5G.

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262 See https://www.telekom.com/en/media/media-information/archive/5g-test-field-in-darmstadt-561588

263 See https://www.bmvi.de/SharedDocs/EN/publications/5g-strategy-for-germany.html

264 Moreover, the Federal government is funding 'further R&D activities within the framework of different programs with regard to applications where 5G is an important driver in the realization process'. For example, the combination of a driving simulator, test vehicles and the 'CERMcity' urban test field in Aldenhoven that has been developed by the RWTH Aachen; see '5G Strategy for Germany' (p.19).

265 See https://www.bmvi.de/SharedDocs/EN/PressRelease/2017/029-network-alliance.html

266 *Ibid*.

BNetzA has also launched[267] an 'exchange platform' to 'support user companies and industries in their standardization activities for 5G'.

B.5.5 Outlook

Our 5G outlook/assessment for Germany is summarized in Figure B.15 below.

Figure B.15: 5G outlook for Germany [Source: Analysys Mason, 2019]

Metric	Description	Score
1. Industry commitment to 5G launch	• All MNOs confirmed or expected to launch 5G in 2020	2/4
2. Low-band spectrum	• 689MHz of spectrum currently released • 700MHz unpaired and L-band spectrum for potential future assignment	4/4
3. Mid-band spectrum	• No mid-band spectrum currently released • 3.4–3.7GHz scheduled for auction in 2019; the 3.7–3.8GHz range will be for regional/local use	2/4
4. High-band spectrum	• No high-band spectrum currently released • 26GHz, 28GHz, and 32GHz bands under consideration; priority is 26GHz band to enable use from 2020	1/4
5. Total spectrum	• Strong in low-band (with 700MHz already assigned). Mid-band auction expected soon; further behind in high-band	2/4
6. National strategies/government support	• EUR80 million available for 5G R&D • Broader 'Gigabit Germany Initiative for the Future' (which encompasses 5G technology) aims to invest EUR100 billion by 2025	3/4

267 See https://www.bundesnetzagentur.de/SharedDocs/Pressemitteilungen/DE/2017/24102017_5G.html

B.6 Hong Kong

The Communications Authority (CA) in Hong Kong is responsible for communications market policy, and the Office of the Communications Authority (OFCA) is the regulator that administers CA policy. CA has been proactive along with the Secretary for Commerce and Economic Development (SCED) have been responsible for pro-5G policies aimed at ensuring sufficient spectrum in the market for 5G launch in 2020. The intention is for several portions of spectrum in mid-band and high-band to be licensed for 5G use as well as release of spectrum in the 700MHz band. A statement in December 2018 confirmed CA's intention that 380MHz of spectrum in the 3.3–3.4GHz, 3.4–3.6GHz and 4.84–4.92GHz bands is to be assigned for mobile use, along with 4.1GHz spectrum in the 26GHz and 28GHz bands. Operators are understood to be targeting 2020 for commercial launch, once spectrum licenses are confirmed. In a 2018 policy address, a government official stated that "the government [would] proactively open up suitable government premises and roof-tops for the installation of base stations" to support 5G roll-out.

B.6.1 Current spectrum holdings

Low-band spectrum

As shown in Figure B.16 below, 583MHz of low-band spectrum is currently allocated to commercial mobile services in Hong Kong.

Figure B.16: Current low-band spectrum holdings of MNOs in Hong Kong, MHz [Source: OFCA,[268] APT[269]]

MNO	450	700	850	900	1400	1800	1900	2100	2300	2600	Total
HKT	–	–	15	20	–	40	–	29.6	–	40	**144.6**
SmarTone	–	–	10	10	–	40	–	39.6	–	20	**119.6**
Three	–	–	–	20	–	30	–	29.6	30	–	**109.6**
CMHK	–	–	–	10	–	40	–	19.6	30	40	**139.6**
21 Vianet**	–	–	–	–	–	–	–	–	30	–	**30**
Genius Brand***	–	–	–	–	–	–	–	–	–	40	**40**
Total	**–**	**–**	**25**	**60**	**–**	**150**	**–**	**118.4**	**90**	**140**	**583.4**

* Spectrum assigned in 3GPP bands 33 and 34 is excluded, since it is not used.

** 21 Vianet holds a 2.3GHz license, though this is used to provide FWA LTE services (not mobile).

*** HKT and Three won 2600MHz licenses in January 2009 and March 2013 via joint venture Genius Brand.

Note: Holdings in the 900MHz and 1800MHz bands will apply from 2021[270]

268 See Annex 1 of https://www.coms-auth.hk/filemanager/statement/en/upload/429/ca_statements20171219_en.pdf. We have classified the 885-890/930-935MHz block won by Three at an auction in 2011 as 900MHz not 850MHz (as in the CA document). See also https://www.ofca.gov.hk/en/industry_focus/radio_spectrum/auctions/index.html

269 Data from APT report APT/AWG/REP-15(Rev.5). See http://www.apt.int/AWG-RECS-REPS

270 See https://www.ofca.gov.hk/mobile/en/industry_focus/radio_spectrum/auctions/900_mhz_and_1800_mhz_bands_auction/index.html

Mid-band spectrum

No mid-band spectrum is currently available for commercial mobile services in Hong Kong.

High-band spectrum

No high-band spectrum is currently available for commercial mobile services in Hong Kong.

B.6.2 Main 5G spectrum proposals

Low-band spectrum

On March 21, 2017, the Communications Authority (CA) announced[271] plans for making available additional spectrum for public mobile services "toward 2020 and beyond". CA noted that the government would review its working target of switching off the analog terrestrial television service by 2020. CA intends to assign the vacated 'digital dividend' spectrum in the 700MHz (698–806MHz) band to mobile services as soon as possible after the analog switch-off (ASO). The 'Spectrum Release Plan for 2019–2021', published[272] by CA in February 2019, lists the earliest release date for spectrum[273] in the 617–803MHz range as 2020. The document also remarks that assignment of spectrum in the 617–803MHz range for the provision of indoor[274] mobile services will be possible from July 2021 at the earliest.

The 2010–2020MHz range was made available at an auction in 2011, but was not acquired by any bidder. The 'Spectrum Release Plan for 2019–2021'[275] states that CA will "review the demand for this band".

Mid-band spectrum

On December 13, 2018, the Secretary for Commerce and Economic Development (SCED) and CA issued[276] a final decision on the assignment of mid-band spectrum for the provision of public mobile services. As shown in Figure B.17 below, a total of 380MHz is scheduled to be auctioned by mid-2019 across three bands:

271 See http://www.coms-auth.hk/en/media_focus/press_releases/index_id_1423.html

272 See https://www.ofca.gov.hk/filemanager/ofca/common/Industry/broadcasting/spectrum_plan2019_en.pdf. This document also states that the 1466–1480MHz band "has been reserved subject to further development of the worldwide market".

273 CA state that, based on 3GPP band plans, a maximum of 160MHz in the 617–803MHz range is planes to be released.

274 CA state that "20MHz of spectrum in the 703–803MHz band can be used for outdoor deployment as well".

275 The Spectrum Release Plan for 2019–2021 also states that the 1466–1480MHz band "has been reserved subject to further development of the worldwide market".

276 See https://www.coms-auth.hk/en/media_focus/press_releases/index_id_1824.html

Figure B.17: Details of mid-band spectrum to be auctioned in Hong Kong [Source: CA,[277] 2018]

License details	3.3–3.4GHz band	3.4–3.6GHz band	4.84–4.92GHz band*
Allowed usage	Provision of public mobile services		
Amount of spectrum	100MHz	200MHz	80MHz*
Geographical use	Indoor use only	Nationwide (subject to restriction zones)	Nationwide
Assignment approach	Clock auction	Two-stage auction (primary and assignment)	SMRA
Number of lots	Ten 10MHz lots	Twenty 10MHz lots	Two 40MHz lots
Spectrum cap per licensee	40MHz	70MHz	40MHz
Coverage obligations	400 base stations within 5 years	45% population coverage within 5 years	50% population coverage within 5 years
Target assignment date	July/August 2019		
License start date	October 2019	April 2020	October 2019
License duration	15 years	15 years	15 years
Other conditions	Licenses are technology neutral. Frequency swapping is not permitted within the first 5 years of assignment.		

* The full 4.83–4.93GHz band has been allocated to mobile on a co-primary basis. Two 10MHz blocks (4.83–4.84GHz and 4.92–4.93GHz) will be reserved for potential future assignment at a later date.

High-band spectrum

On December 13, 2018, SCED and CA also issued[278] a final decision on the assignment of high-band spectrum. As shown in Figure B.18 below, a total of 4.1GHz will be made available, via administrative assignment across the 26GHz (24.25–27.5 GHz) and 28GHz bands (27.5–28.35GHz). 3.7GHz will be made available via exclusive nationwide licenses for "large scale public mobile services", and 400MHz will be made available on a geographically shared basis for "localized innovative wireless services".

Figure B.18: Details of high-band spectrum to be auctioned in Hong Kong [Source: CA,[279] 2018]

License details	24.25–28.5GHz band	
Allowed usage	Large-scale public mobile services	Localized wireless services including fixed services
Amount of spectrum	3700MHz	400MHz

277 See https://www.coms-auth.hk/filemanager/en/content_713/annex.pdf. Full details:

https://www.coms-auth.hk/filemanager/statement/en/upload/482/joint_statement_st_072018.pdf
https://www.coms-auth.hk/filemanager/statement/en/upload/481/joint_statement_st_062018.pdf

278 See https://www.coms-auth.hk/filemanager/statement/en/upload/480/joint_statement_st_052018.pdf

279 See https://www.coms-auth.hk/filemanager/en/content_713/annex.pdf. Full details:

https://www.coms-auth.hk/filemanager/statement/en/upload/482/joint_statement_st_072018.pdf
https://www.coms-auth.hk/filemanager/statement/en/upload/481/joint_statement_st_062018.pdf

License details	24.25–28.5GHz band	
Geographical use	Nationwide	Spectrum geographically shared; license valid for specific geographical area
Assignment approach	Administrative assignment* (all interested parties to submit requests for spectrum**)	Administrative assignment (licenses issued using a first-come, first-served approach)
Number of blocks	Forty-one 100MHz blocks	Operators may apply for block sizes up to 400MHz
Spectrum cap per licensee	800MHz	Maximum aggregate network coverage of a licensee is 50 sq. km
Coverage obligations[280]	5,000 radio units[281] within five years** for 800MHz of spectrum assigned[282]	None
Target assignment date	March 2019	Q2 2019
License start date	April 2019	July 2019
License duration	15 years (expiring March 31, 2034)	Licenses can be applied for at any time; licenses will expire on March 31, 2034
Spectrum utilization fee (SUF)	SUFs apply only if >75% of spectrum is occupied. SUF = HKD21,600/MHz/year (same value as for fixed links)	SUFs apply only if >75% of spectrum is occupied. SUF = HKD1,080/MHz/year/50 sq. km of network footprint

* The procedure for the case where demand exceeds supply is specified in the decision document.

** See decision document for details.

Note: Licensees of spectrum for the provision of large-scale public mobile services will not be eligible for localized licenses.

On December 21, 2018, CA invited[283] applications for the assignment of high-band spectrum. On March 20, 2019, CA announced[284] a list of provisional successful applicants for spectrum to be used for large-scale public mobile services (each of CMHK, HKT and SmarTone have been provisionally offered 400MHz). Final approval is pending.

B.6.3 MNOs' 5G commercial deployment plans

Figure B.19 outlines 5G commercial deployment plans announced by the major MNOs in Hong Kong:

280 Revisions to the coverage obligations were announced by the CA in January 2019, stating that assignees will be required to install 20% of the minimum number of radio units within three years, 50% within four years, and 100% within five years. See https://www.coms-auth.hk/en/media_focus/press_releases/index_id_1858.html

281 I.e. active antenna unit, antenna integrated radio, or remote radio head/unit.

282 The number of radio units is reduced proportionally for spectrum assignments below 800MHz.

283 See https://www.ofca.gov.hk/en/media_focus/press_releases/index_id_1840.html

284 See https://www.ofca.gov.hk/filemanager/ofca/en/content_1127/26_28_GHz_Provisional_Successful_Applicant_Notice.pdf

Figure B.19: Announcements of 5G deployment plans by major MNOs in Hong Kong [Source: MNO press releases]

MNO	Details of 5G commercial deployment plans
HKT[285] SmarTone Three	• No explicit 5G launch dates have publicly been announced by these MNOs. However, a general timeframe of 2020 has been referenced, in agreement with government announcements: – On December 01, 2017, CA was cited[286] as saying that Hong Kong would be one of the world's earliest adopters of 5G mobile technology in 2020. CA said that once 5G standards are formalized by the ITU in 2019, commercial services are expected to be rolled out the following year – In its 2017/18 annual report, CA confirmed that its "goal is to make available sufficient spectrum for the industry to enable the commercial launch of 5G services in the timeframe of 2020" – In November 22, 2018, the Hong Kong Economic Journal published[287] an article stating that "the government plans to host a 5G spectrum auction next year [i.e. 2019] with the service expected to be rolled out in 2020 at the earliest".
CMHK	• On August 13, 2018, CMHK announced[288] the successful completion of end-to-end 5G FWA network testing. CMHK stated that when 5G spectrum is released, it "will be ready to provide full services to users". CMHK noted that since 5G smartphones will not be available until H2 2019, the earliest services would be FWA.

B.6.4 National strategies/government support

In Hong Kong, CA gives operators the right of access to any private building for the purposes of installing and maintaining telecommunications equipment so that they are able to provide their services to occupiers of the building.[289] CA also mandates that building owners assist operators with their efforts to install and maintain telecommunications equipment. Furthermore, property owners in Hong Kong are not allowed to "impose any fees, deposit, access charge, administrative fees or rental charge on the operators for the access to the building" or the "use of any in-building telecommunications system".

In Hong Kong's 2018 policy address, a government official stated that "the government [would] proactively open up suitable government premises and roof-tops for the installation of base stations" to support 5G roll-out.[290]

285 In November 2018, reports stated that HKT and Huawei are constructing a 5G network on a new Mass Transit Railway (MTR) line; the network will be shared by all operators to offer 5G services. See https://www.mobileworldlive.com/featured-content/asia-home-banner/hkt-huawei-prepare-hk-train-line-for-5g/

286 See https://www.scmp.com/news/hong-kong/economy/article/2122511/hong-kong-be-one-worlds-earliest-adopters-5g-technology

287 See http://www.ejinsight.com/20181122-let-s-prepare-ourselves-for-the-coming-of-5g/

288 See https://www.hk.chinamobile.com/en/about_us/media_centre/NewsPDF/20180813pr.html

289 See https://www.ofca.gov.hk/filemanager/ofca/common/Industry/telecom/inote0004_12e.pdf

290 See https://www.policyaddress.gov.hk/2018/eng/policy_ch04.html. In June-2018, HKT published a paper urging the government to do more to encourage the development of 5G in Hong Kong, including a request to enable easier access to buildings in order to install and maintain mobile equipment. See https://www.hkcsl.com/r/cms/pccw/2018/201806040/20180611e-Telecom-Policy-Paper-en.pdf

B.6.5 Outlook

Our 5G outlook/assessment for Hong Kong is summarized in Figure B.20 below.

Figure B.20: 5G outlook for Hong Kong [Source: Analysys Mason, 2019]

Metric	Description	Score
1. Industry commitment to 5G launch	• Most MNOs expected to launch 5G in 2020	3/4
2. Low-band spectrum	• 583MHz of spectrum currently released • 700MHz band scheduled for release from 2020	2/4
3. Mid-band spectrum	• No mid-band spectrum currently released • 3.3–3.4GHz, 3.4–3.6GHz, and 4.84–4.92GHz bands to be auctioned in 2019	1/4
4. High-band spectrum	• No high-band spectrum currently released • 4.1GHz across 26GHz and 28GHz to be made available through administrative assignment in 2019	3/4
5. Total spectrum	• Large amount of mid- and high-band spectrum to be released in 2019/2020	2/4
6. National strategies/government support	• Government premises to be offered for installation of base stations	3/4

B.7 Italy

AGCOM is the regulator and competition authority for the communications sector in Italy and is responsible for spectrum management. In October 2018, AGCOM held a multi-band 5G auction, which resulted in the sale of spectrum in the low, mid, and high bands: 2×30MHz in the 700MHz band, 200MHz in the 3.6GHz band, and 1GHz in the 26.5–27.5GHz band. In March 2017, the Italian government launched a 5G trial in five Italian cities: the metropolitan area of Milan, Prato, L'Aquila, Bari, and Matera. Multiple MNOs are expected to launch commercial 5G services in 2019.

B.7.1 Current spectrum holdings

Low-band spectrum

As shown in Figure B.21 below, 640MHz of low-band spectrum is currently allocated to commercial mobile services in Italy.

Figure B.21: Current low-band spectrum holdings of MNOs in Italy, MHz [Source: spectrummonitoring.com, Analysys Mason Spectrum Auction Tracker]

MNO	450	700	800	900	1400	1800	1900*	2100	2300	2600	Total
TIM	–	20	20	20	20	40	–	30	–	30	**180**
Vodafone	–	20	20	20	20	40	–	30	–	30	**180**
Wind Tre	–	–	20	20	–	40	–	40	–	70	**190**
Iliad	–	20	–	10	–	20	–	20	–	20	**90**
Total	**–**	**60**	**60**	**70**	**40**	**140**	**–**	**120**	**–**	**150**	**640**

* Spectrum assigned in 3GPP bands 33 and 34 is excluded, since it is not used.

The 60MHz (2×30MHz) of 700MHz spectrum shown in Figure B.21 was assigned at a multiband auction completed in October 2018. Licenses[291] have a 15.5-year duration (from July 1, 2022) and are nationwide; certain coverage obligations are attached to the licenses (see Section 5.2 for details). As shown in Figure B.22 below, three of the four MNOs won spectrum: TIM, Vodafone, and Iliad.

Figure B.22: Outcome of Italy's 700MHz auction in July 2018 [Source: AGCOM,[292] 2018]

Operator	Spectrum won	Spectrum range (MHz)[293]	Price paid (USD)	Adjusted* USD/MHz/pop
TIM	2×10MHz	N/d	786,000,000	0.7523
Vodafone	2×10MHz	N/d	790,000,000	0.7557
Iliad	2×10MHz	N/d	782,000,000	0.7482
Total	**2×30MHz**	**-**	**2,040,000,000**	**0.7520**

* Adjusted to a 20-year license using a WACC of 6.0%

291 See https://www.sviluppoeconomico.gov.it/images/stories/normativa/Disciplinare_Gara_multibanda2018.pdf

292 See http://www.sviluppoeconomico.gov.it/index.php/it/198-notizie-stampa/2038666-gara-5g

293 The spectrum was awarded as generic blocks; we understand that exact assignments are yet to be confirmed.

Spectrum sold close to the reserve price; the total price paid was ~USD0.75/MHz/pop (after adjusting to a 20-year license duration).

Spectrum was also made available in the 700MHz SDL, 3.6–3.8GHz, and 26.5–27.5GHz bands; assignment of this spectrum is discussed in the following sub-sections.

Mid-band spectrum

The October 2018 multiband auction made available two 80MHz blocks and two 20MHz blocks in the 3600–3800MHz band. Licenses[294] have a 19-year duration (from January 1, 2019) and are nationwide; certain coverage obligations are attached to the 80MHz lots. As shown in Figure B.23 below, each of the four MNOs won spectrum: TIM, Vodafone, Wind, and Iliad.

Figure B.23: Outcome of Italy's 3.6–3.8GHz auction in July 2018 [Source: AGCOM,[295] 2018]

Operator	Spectrum won	Spectrum range (MHz) [296]	Price paid (USD)	Adjusted* USD/MHz/pop
TIM	80MHz	3720–3800	1,958,000,000	0.4048
Vodafone	80MHz	N/d	1,948,000,000	0.4026
Wind Tre	20MHz	N/d	559,000,000	0.4625
Iliad	20MHz	N/d	559,000,000	0.4625
Total	**200MHz**	**-**	**5,025,000,000**	**0.4271**

* Adjusted to a 20-year license using a WACC of 6.0%.

Spectrum sold significantly above the reserve price of EUR39.7 million (USD45.1 million) per 20MHz lot and EUR158.7 million (USD180.5 million) per 80MHz lot. The total price paid was ~USD0.43/MHz/pop (after adjusting to a 20-year license duration).

Spectrum in the 3.4–3.6GHz band was auctioned in February 2008 (originally used for the provision of WiMAX services). Three 2×21MHz lots (3437–3500/3537–3600MHz) were made available on a regional basis.[297] After subsequent license trading, there are currently[298] four main[299] license holders:

- Aria (Tiscali) holds a single license in every region

294 See https://www.sviluppoeconomico.gov.it/images/stories/normativa/Disciplinare_Gara_multibanda2018.pdf

295 See http://www.sviluppoeconomico.gov.it/index.php/it/198-notizie-stampa/2038666-gara-5g

296 Apart from the 80MHz block won by TIM, the spectrum was awarded as generic blocks; we understand that exact assignments are yet to be confirmed.

297 The lower two blocks (A and B) were auctioned in seven macro-regions, while the upper block (C) was auctioned in 21 sub-regions, meaning that a total of 35 licenses were offered. For details of the different regions, see: https://www.agcom.it/documents/10179/3265296/Allegato+22-1-2018+1516643247616/4be118b1-80af-40ee-9c32-900f739bb21d?version=1.0

298 As of November 2017 (see source above).

299 Three further players also hold a single license each. Brennercom and eolo hold (block C) 2×21MHz licenses in Provincia autonoma di Bolzano and Valle d'Aosta respectively. Mandarin holds a 21MHz TDD license in Sicily.

- Linkem holds a single license in every region (and two licenses in Sicily[300] and seven northern regions)
- TIM holds a single license in Sardinia and in eight regions across central and southern Italy
- GO Internet holds a single license in the regions of Emilia-Romagna and Marche.

In June 2009 (i.e. shortly after the original WiMAX auction), Aria (Tiscali) and TIM announced[301] a spectrum-share deal in the regions licensed to TIM. In March 2018, Linkem and GO Internet announced[302] a spectrum-share deal in the Emilia-Romagna and Marche regions. In November 2018, broadband provider Fastweb acquired[303] Tiscali's FWA business (including its mid-band spectrum) for EUR198 million (USD225 million).

Licenses were originally auctioned with a duration of 15 years, expiring in December 2023. In November 2017, AGCOM launched a consultation[304] on extending the licenses (for a fee) by six years to December 2029. Under the terms of the extension, AGCOM is proposing:

- a maximum of 40MHz (2×20MHz) to be renewed for each of the assigned blocks
- a cap of 100MHz in any region (including spectrum held in the 3.6–3.8GHz band)
- a reconfiguration of the entire 3.4–3.6GHz band into a TDD arrangement suitable for 5G. Spectrum freed up as a result of this reconfiguration (which is currently occupied by the Ministry of Defense) may be offered to the market.

We understand[305] that license extensions were granted in Summer 2018 (shortly before the 3.6–3.8GHz auction). However, there has been considerable opposition[306] from MNOs to the license extension arrangements; the prices paid by MNOs in the 3.6–3.8GHz auction were significantly higher than the 3.4–3.6GHz license extension fees. We understand that TIM, Vodafone, and Iliad have each appealed against the license extensions; AGCOM has not yet announced a final decision.

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300 Linkem (along with Mandarin) holds a 21MHz TDD license in Sicily.

301 See https://www.telegeography.com/products/commsupdate/articles/2009/06/09/telecom-italia-and-aria-announce-wimax-partnership/

302 See http://www.gtigroup.org/news/ind/2018-03-28/12055.html

303 In addition to the spectrum, the assets acquired include 835 towers and 34 FTEs. "At the same time, Tiscali will enter into a wholesale agreement with Fastweb gaining full access to Fastweb fiber-based network infrastructure… Fastweb will finance the transaction from its own available cash resources. The value of the deal will be approximately EUR198m, of which EUR130m in cash (thereof EUR50m in 2018 and EUR80m in 2019), a 4 to 5 year's wholesale agreement of a total value of EUR55m and EUR13m of debts toward suppliers." The original agreement (announced in July 2018) was for a transaction value of EUR150m, but this was increased to EUR198m to "reflect recent market dynamics". See https://www.swisscom.ch/en/about/medien/press-releases/2018/07/20180730-mm-fastweb-5g-frequenzen-tiscali.html

https://www.swisscom.ch/en/about/medien/press-releases/2018/11/20181112-mm-tiscali.html

304 See https://www.agcom.it/documents/10179/3265296/Allegato+22-1-2018+1516643247616/4be118b1-80af-40ee-9c32-900f739bb21d?version=1.0

305 See https://www.edisoninvestmentresearch.com/?ACT=18&ID=22991&LANG=

306 See, for example, https://www.telecompaper.com/news/tim-latest-to-appeal-against-5g-spectrum-extension-report--1268978

High-band spectrum

The October 2018 multiband auction also made available five 200MHz blocks in the 26.5–27.5GHz band. Licenses[307] have a 19-year duration (from January 1, 2019), are nationwide and without coverage obligations. Each of Italy's four MNOs, as well as broadband provider Fastweb, won a license; each paid close to the reserve price of EUR32.6 million (USD37.1 million) per 200MHz block.

B.7.2 Main 5G spectrum proposals

Low-band spectrum

The October 2018 multiband auction made available three 5MHz lots in the 700MHz TDD band (733–748MHz). These lots went unsold; they may be made available at a future date, although we are not aware of any official plans for a further auction.

Mid-band spectrum

As described in Annex B.7.1, a total of 80MHz in the 3.4–3.6GHz (which is currently held by the Ministry of Defense) may be allocated to mobile. However, confirmation has not yet been provided by the regulator.

High-band spectrum

We are not aware of any plans for further release of high-band spectrum.

B.7.3 MNOs' 5G commercial deployment plans

Figure B.24 outlines 5G commercial deployment plans announced by the major MNOs in Italy:

Figure B.24: Announcements of 5G deployment plans by major MNOs in Italy [Source: MNO press releases]

MNO	Details of 5G commercial deployment plans
TIM	• On September 4, 2018 TIM announced[308] that it had switched on its first 5G mast in San Marino, and that it aimed to provide "complete 5G coverage" in the country by the end of the year • On November 12, 2018, reports[309] stated that TIM and Vodafone were considering a 5G infrastructure sharing deal, with the aim of reaching an agreement by Q1 2019

307 See https://www.sviluppoeconomico.gov.it/images/stories/normativa/Disciplinare_Gara_multibanda2018.pdf

308 See https://www.telecomitalia.com/tit/en/archivio/media/note-stampa/market/2018/NS-TIM-Nokia-SanMarino-40918.html

309 See https://www.bloomberg.com/news/articles/2018-11-12/vodafone-telecom-italia-are-said-to-discuss-5g-network-deal

MNO	Details of 5G commercial deployment plans
	• On November 28, 2018, TIM, Ericsson, and Qualcomm announced[310] that they had conducted a successful test of a prototype 3GPP-compliant 5G smartphone which used the Snapdragon X50 chipset. TIM noted that the X50 would "be in some of the first 5G smartphones available on the market in 2019" • On February 4, 2019, TIM announced[311] that it "is deploying some antennas" for the new 5G network in Sanremo.
Vodafone	• On October 2, 2018, after acquiring spectrum in the 5G multiband auction, Vodafone stated[312] that the 3.6–3.8GHz spectrum could be used immediately "for the rapid development of 5G services". Vodafone noted that it is conducting 5G trials in Milan and expects to achieve 80% coverage of the metropolitan area by December 2018 • In December 2018, reports stated[313] that the Milan network had been turned on, and the 80% coverage target had been achieved using 120 sites. However, the network is currently being used for testing only, with 5G devices not yet commercially available. Vodafone plans to add 5G networks in Turin, Bologna, Naples, and Rome during 2019.
Wind Tre	• On November 16, 2018, reports[314] stated that Wind Tre expects the "first parts of the country" to see 5G deployment by end-2019, but that 5G devices would not be available to the mass market until 2020 or 2021.
Iliad	• We are not aware of specific 5G commercial deployment plans announced by Iliad.

B.7.4 National strategies/government support

In March 2017, the Italian government launched[315] a 5G trial in five Italian cities: the metropolitan area of Milan, Prato, L'Aquila, Bari, and Matera.

On December 31, 2018, the Italian Competition Authority (AGCM) published[316,317] a document discussing the legislation associated with the deployment of mobile infrastructure, raising concerns over the amount of local (regional and municipal) regulations applying to the installation of small cells. The document also expresses concerns that the transmission power limits may be too strict (i.e. unsuitable for future 5G deployments).

The AGCM recommend that the government simplify regulations relating to small cell deployments and establish whether the transmission power limits should be increased.

310 See https://www.telecomitalia.com/tit/en/archivio/media/note-stampa/market/2018/PR-First-prototype-5G-smartphone-TIM.html

311 See https://www.telecomitalia.com/tit/en/archivio/media/note-stampa/market/2019/NS-TIM-5G-a-Sanremo-4-febbraio.html

312 See https://www.vodafone.com/content/index/media/vodafone-group-releases/2018/vodafone-italy-acquires-spectrum-for-5g-services.html

313 See https://www.telegeography.com/products/commsupdate/articles/2018/12/13/vodafone-and-tim-claim-5g-firsts-in-italy/

314 See https://www.lightreading.com/mobile/5g/italys-struggling-wind-tre-eyes-5g-rollout-in-late-2019/d/d-id/747661

315 See http://bandaultralarga.italia.it/en/5g-5-italian-cities/

316 See http://www.agcm.it/dotcmsdoc/bollettini/2018/49-18.pdf

317 See https://www.corrierecomunicazioni.it/digital-economy/5g-lallarme-antitrust-troppi-vincoli-a-rischio-lo-sviluppo/

B.7.5 Outlook

Our 5G outlook/assessment for Italy is summarized in Figure B.25 below.

Figure B.25: 5G outlook for Italy [Source: Analysys Mason, 2019]

Metric	Description	Score
1. Industry commitment to 5G launch	• Some MNOs have confirmed 5G launch in 2019/2020; others have not yet confirmed launch dates	2/4
2. Low-band spectrum	• 640MHz of spectrum currently released • No plans for future spectrum assignment	3/4
3. Mid-band spectrum	• 326MHz of spectrum currently released • 3.4–3.6GHz band may be reconfigured allowing further release of spectrum	3/4
4. High-band spectrum	• 1GHz of spectrum currently released • No plans for future assignment	2/4
5. Total spectrum	• Spectrum assigned in low, mid, and high bands	3/4
6. National strategies/government support	• The Italian government has sponsored a 5G trial across a number of cities	2/4

B.8 Japan

The Ministry of Internal Affairs and Communications (MIC) regulates the Japanese telecom market. In 2016, MIC published its 'Policy to realize 5G in 2020' (in time for the Tokyo 2020 Olympics). Policy includes promoting the work of the 5G Mobile Forum (5GMF), 5G R&D and standardization activities. The regulator has outlined plans to release/share spectrum in several bands (both below and above 6GHz) and plans release spectrum in the 3.6–4.2GHz, 4.4–4.9GHz and 27.5–29.5GHz ranges during 2019. Japan's MNOs have all conducted extensive 5G trials and plan to launch commercial services in 2019/20.

B.8.1 Current spectrum holdings

Low-band spectrum

As shown in Figure B.26 below, 601MHz of low-band spectrum is currently allocated to commercial mobile services in Japan.

Figure B.26: Current low-band spectrum holdings of MNOs in Japan, MHz [Source: MIC,[318] APT[319]]

MNO	450	700	850	900	1400	1800	1900	2100	2300	2600*	Total
NTT DOCOMO	–	20	30	–	30	40	–	40	–	–	160
KDDI	–	20	30	–	20	40	–	40	–	50	200
Softbank	–	20	–	30	20	30	31.2**	40	–	30	201.2
Rakuten	–	–	–	–	–	40	–	–	–	–	40
Total	**–**	**60**	**60**	**30**	**70**	**150**	**31.2**	**120**	**–**	**80**	**601.2**

* Excludes regional WiMAX (20MHz TDD)

** PHS TDD spectrum

Note: the 850MHz band refers to 3GPP bands 18 and 19, the 1400MHz band refers to 3GPP bands 11 and 21, and the 1800MHz band refers to 3GPP band 9.

On April 6, 2018, MIC approved[320,321] a bid from internet retailer Rakuten to become Japan's fourth MNO, assigning the company 2×20MHz of spectrum[322] in the 1730–1750/1825–1845MHz range. On May 10, 2018, Rakuten published[323] its Q1 financial results for FY2018, indicating its intention

318 See https://www.gsma.com/spectrum/wp-content/uploads/2016/08/MIC_Spectrum-for-5G-MIC-Kuniko-OGAWA.pdf See also http://www.tele.soumu.go.jp/e/adm/freq/search/myuse/0002/index.htm

319 Data from APT report APT/AWG/REP-15(Rev.5). See http://www.apt.int/AWG-RECS-REPS

320 See https://www.telegeography.com/products/commsupdate/articles/2018/04/09/mic-advisory-panel-gives-green-light-to-rakutens-mobile-bid/

321 See http://www.soumu.go.jp/menu_news/s-news/01kiban14_02000333.html

322 A consultation released by MIC in December 2017 proposed draft rules for releasing this band. See http://www.soumu.go.jp/main_content/000517622.pdf

323 See https://global.rakuten.com/corp/investors/assets/doc/documents/18Q1PPT_E.pdf

to launch services in October 2019 using its 1.8GHz spectrum. MIC also assigned the 1710–1730/1805–1825MHz (2×20MHz) range to KDDI.[324]

Mid-band spectrum

Each of the three incumbent MNOs in Japan (i.e. NTT DOCOMO, KDDI, and Softbank) were licensed to use 40MHz of spectrum in the 3480–3600MHz range in 2014 on a national basis.[325] The licenses are suitable for mobile use.

Furthermore, in April 2018, the 3440–3480MHz range was assigned to NTT DOCOMO and the 3400–3440MHz range was assigned to Softbank.[326]

High-band spectrum

No high-band spectrum is currently available for commercial mobile services in Japan.

B.8.2 Main 5G spectrum proposals

MIC published a 5G roadmap[327] on June 28, 2016, which outlines its aim 'to realize 5G in 2020' in time for the Tokyo Olympics. The roadmap states that frequency sharing with other services should ensure a total bandwidth of 2700MHz (including bandwidth for wireless LAN) below 6GHz by 2020. Above 6GHz, MIC is targeting a total bandwidth[328] of around 23GHz "looking ahead to the 2020s".

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324 We also understand that NTT DOCOMO's license in the 1765–1785/1860–1880MHz (2×20MHz) range was extended to include the regions of Tokyo, Nagoya, and Osaka.

325 See http://www.gtigroup.org/news/ind/2014-12-25/5208.html

326 We understand that Rakuten had previously submitted an application to MIC for 4G suitable spectrum in both the 1.8GHz and 3.4GHz bands (3400–3480MHz), however the 3.4GHz spectrum was awarded to Softbank and NTT DOCOMO.

See https://www.telegeography.com/products/commsupdate/articles/2018/02/27/japanese-e-tailer-rakuten-submits-application-for-mobile-frequencies/

See http://www.soumu.go.jp/menu_news/s-news/01kiban14_02000333.html

327 See https://www.gsma.com/spectrum/wp-content/uploads/2016/08/MIC_Spectrum-for-5G-MIC-Kuniko-OGAWA.pdf. MIC has since published a number of similar iterations of the presentation; see https://5g-ppp.eu/wp-content/uploads/2016/11/Opening-1_Yuji-Nakamura.pdf (November 9, 2016), https://5g-ppp.eu/wp-content/uploads/2016/11/04_9-Nov_Session-2_Yuji-Nakamura.pdf (November 9, 2016) and http://5gmf.jp/wp/wp-content/uploads/2017/06/02-Opening-Session-1_Isao-Sugino.pdf (May 24, 2017).

328 MIC states that it is targeting the following frequency bands: 8.4/14/28/40/48/70/80GHz.

A 5G consultation[329] was subsequently published by MIC in July 2017, providing further details on the expected bands and timeline for assignments. An updated roadmap was published[330] by MIC on June 28, 2018. MIC completed its most recent consultation[331] on 5G spectrum in December 2018.

Low-band spectrum

The July 2017 consultation states that, in order to address the current mobile spectrum shortage, MIC will promote frequency sharing/allocation in the 2300–2330/2370–2400MHz range, and consider frequency sharing with mobile satellite in the 2500–2545/2645–2690MHz range.

Mid-band spectrum

MIC's December 2018 consultation states that it intends to allocate the 3.6–4.1GHz and 4.5–4.6GHz ranges[332] to 5G (as six 100MHz TDD blocks) by the end of March 2019. The 4.6–4.8GHz range will be further considered for private 5G use.[333, 334]

High-band spectrum

MIC is proposing to license a number of mm-wave bands for 5G, with an initial focus on the 28GHz band. The December 2018 consultation outlines MIC's plans to allocate the 27.0–28.2GHz and 29.1–29.5GHz ranges to 5G (as four 400MHz TDD blocks) by the end of March 2019.[335] The 28.2–29.1GHz range will be further considered for private 5G use.

MIC also acknowledges the potential of all 11 ITU mm-wave candidate bands (24.25–86GHz). Allocation in this range (with priority given to bands below 43.5GHz) is expected in the first half of the 2020s.

329 'Draft report from New generation mobile communication system committee', July 28, 2017 (in Japanese); see http://www.soumu.go.jp/main_content/000499652.pdf. See also section 9 of the 5GMF white paper version 1.1.

330 See https://www.gsma.com/spectrum/wp-content/uploads/2018/07/Kohei-Satoh-MWC-Shanghai_MIC-Japan-1.pdf

331 See http://www.soumu.go.jp/menu_news/s-news/01kiban14_02000358.html

332 See http://www.soumu.go.jp/main_content/000582765.pdf/ The June 2016 roadmap indicated that MIC also aimed to share the 5.15–5.35GHz band with 5G; however, this band is not mentioned in subsequent documentation.

333 Ibid.

334 We note that, on February 26, 2019, the Japan Times reports that the three incumbent MNOs and Rakuten had all applied to MIC for 5G licenses, and that MIC will review the applications "before seeking final approval by an advisory panel to the minister on April 10". See https://www.japantimes.co.jp/news/2019/02/26/business/corporate-business/japans-top-three-mobile-carriers-rakuten-apply-5g-band-allocation/#.XHkGrYj7RPY and http://www.soumu.go.jp/menu_news/s-news/01kiban14_02000375.html

335 Regarding timelines for assignment, see also the previous footnote.

B.8.3 MNOs' 5G commercial deployment plans

Figure B.27 outlines 5G commercial deployment plans announced by the major MNOs in Japan. The three major MNOs are all expected to commercialize 5G services by the 2020 Olympics in Tokyo.[336]

Figure B.27: Announcements of 5G deployment plans by major MNOs in Japan [Source: MNO press releases]

MNO	Details of 5G commercial deployment plans
NTT DOCOMO	• NTT DOCOMO has stated[337] that it aims to launch a commercial 5G service in 2020 in time for the Tokyo Olympics • On January 19, 2018, Nokia confirmed[338] that it had signed an agreement with NTT DOCOMO to supply "5G baseband products for aiming to deploy in a 5G mobile network planned to be in commercial service by 2020" • A presentation[339] delivered by NTT DOCOMO at the MWC in 2017 provided further details. Launch will take place in selected 'high performance' areas in 2020 (using the existing LTE EPC), before expanding nationwide by '202X' (eventually using separate 5G core equipment). NTT DOCOMO has identified three bands for initial 5G launch: 3.4–3.8GHz, 4.4–5GHz and 27.5–29.5GHz • In June 2018, NTT DOCOMO announced[340] at the MWC that it intended to launch standalone 5G "within 800 days" • On November 2, 2018, NTT DOCOMO stated[341] that it had plans to launch pre-commercial 5G services in September 2019 and aimed to launch commercial 5G services across Japan by mid-2020. NTT DOCOMO also said that customers would be able to "experience 5G services" at the 2019 Rugby World Cup.
KDDI	• In November 2018, KDDI announced[342] "plans to offer a limited range of 5G-based services in 2019, before a full-fledged 5G launch in 2020". KDDI's President said: "in limited areas, we are aiming at distributing high-resolution images and drone security. In 2020, in a full-fledged launch manner, we are planning to provide 5G in areas of Tokyo for the Olympic and Paralympic Games and in areas in accordance with the request of municipalities and our partner companies".
Softbank	• In October 2018, reports stated[343] that representatives of Softbank (as well as NTT DOCOMO and KDDI) said during a government hearing that they "plan to begin with a limited commercial deployment in 2019 and then deploy a full 5G service for smartphones in 2020".
Rakuten	• Rakuten has yet to launch commercial mobile services (as an MNO) in Japan. In October 2018, Rakuten stated[344] that it plans to launch services (initially 4G only) in October 2019

336 See https://asia.nikkei.com/Business/Companies/Japan-s-4-carriers-to-shun-Chinese-5G-tech

337 See https://www.nttdocomo.co.jp/english/corporate/technology/rd/tech/5g/

338 See https://www.nokia.com/en_int/news/releases/2018/01/19/nokia-to-supply-5g-equipment-to-ntt-docomo-in-support-of-launch-of-commercial-5g-service

339 See https://www.youtube.com/watch?v=yJdBYSWXmMs

340 See https://www.mobileworldlive.com/featured-content/top-three/docomo-starts-countdown-to-5g/

341 See https://www.rcrwireless.com/20181102/5g/ntt-docomo-launch-pre-commercial-5g-services-september-2019

342 See http://techblog.comsoc.org/2018/11/13/kddi-to-launch-limited-5g-based-services-in-2019-full-5g-in-2020/

343 See https://www.rcrwireless.com/20181011/5g/japan-mobile-carriers-launch-limited-commercial-5g-services-next-year

344 See https://global.rakuten.com/corp/news/press/2018/1002_01.html

MNO	Details of 5G commercial deployment plans
	• Rakuten has been conducting 5G trials,[345] and has stated that it is "committed to support the smooth network evolution from 4G to 5G" • In February 2019, Rakuten stated[346] that it plans to launch 5G services in early 2020.

B.8.4 National strategies/government support

As described in our previous report, in 2016 MIC published its 'Policy to realize 5G in 2020' (in time for the Tokyo 2020 Olympics). This commits to a package of "comprehensive promotion strategies for 5G" including:

- promoting three activities to support 5G realization for 2020 and beyond:
  - activities of the 5G Mobile Forum (5GMF)
  - 5G R&D through 'Industry-Academic-Government Co-operation'
  - standardization activities at the ITU and 3GPP
- the 5G 'System Trial'.

In May 2017, MIC began[347] its 5G 'System Trial' in Tokyo and rural areas of Japan. The trial is being conducted in partnership with each of the country's MNOs as well as a number of equipment manufacturers (Panasonic, Sharp, and Fujitsu), and is expected to continue until 2020. For example, on March 8, 2018, NTT DOCOMO, Huawei, and Tobu Railway announced[348] 5G testing in a dense urban area (Tokyo Skytree Town, the commercial center of the Sumida District of Tokyo) in the 28GHz band, as part of MIC's 5G System Trial.

Extensive trialing is also being conducted by the 5GMF group. The 5GMF[349] was founded on September 30, 2014, with the objective of developing 5G technology through conducting research and development relevant to global 5G standardization, liaising/co-ordinating with related organizations, and promoting 5G awareness. Members includes a large number of industry players, institutions, and universities. A detailed white paper published[350] in September 2017 addresses the results of studies carried out by the 5GMF. More recently, in April 2018 the 5GMF published[351] a report on the 5G System (Integration Verification) Trial.

345 For example, see https://global.rakuten.com/corp/news/press/2019/0220_02.html and https://global.rakuten.com/corp/innovation/rakuten_today/2019/0222-2734/

346 See https://global.rakuten.com/corp/news/press/2019/0212_06.html

347 See https://www.telecomstechnews.com/news/2017/may/31/japan-prepares-2020-olympic-games-5g-trial-system/

348 See https://www.huawei.com/en/press-events/news/2018/3/NTT-DOCOMO-TOBU-RAILWAY-5G-Field-Trial-Japan

349 See http://5gmf.jp/en for further details.
See also http://5gmf.jp/wp/wp-content/uploads/2015/11/CEATEC2015_5GWS_5GMF.pdf and the 5GMF White Papers. An overview of 5GMF and its IMT-2020 Evaluation Group published in October 2017 is available here: https://www.itu.int/en/ITU-R/study-groups/rsg5/rwp5d/imt-2020/Documents/S03–7_5GMF%20Japan.pdf

350 See http://5gmf.jp/wp/wp-content/uploads/2017/10/5GMF-White-Paper-v1_1-All.pdf

351 See https://5gmf.jp/en/whitepaper/

B.8.5 Outlook

Our 5G outlook/assessment for Japan is summarized in Figure B.28 below.

Figure B.28: 5G outlook for Japan [Source: Analysys Mason, 2019]

Metric	Description	Score
1. Industry commitment to 5G launch	• All three major MNOs have committed to large-scale launch in 2020	3/4
2. Low-band spectrum	• 601MHz of spectrum currently released • Potential further assignment in 2300MHz and 2600MHz bands	2/4
3. Mid-band spectrum	• 200MHz of spectrum currently released • A further six 100MHz blocks to be released in 2019	4/4
4. High-band spectrum	• 1GHz of spectrum currently released • No plans for further assignment	2/4
5. Total spectrum	• Significant amount of low- and mid-band spectrum already assigned; large amounts of mid- and high-band spectrum to be assigned in early 2019	3/4
6. National strategies/ government support	• MIC's 5G roadmap commits to a package of 'comprehensive promotion strategies for 5G', including R&D and the 5GMF	3/4

B.9 Qatar

The Ministry of Transport and Communications oversees the development of the information and communications technology sector in Qatar. The Communications Regulatory Authority (CRA) in the State of Qatar is responsible for spectrum licensing. In February 2018, CRA stated that both mobile operators in Qatar, Vodafone and Ooredoo, would be assigned 100MHz in the 3.4–3.6GHz range. Ooredoo and Vodafone subsequently confirmed that they had received test licenses in the 3.4–3.6GHz band; these were upgraded to full 5G licenses at the end of 2018. Ooredoo claimed to be the first mobile operator in the world to launch a 5G network during 2018, although the service is not currently being marketed to consumers.

B.9.1 Current spectrum holdings

Low-band spectrum

As shown in Figure B.29 below, 304MHz of low-band spectrum is currently allocated to commercial mobile services in Qatar.

Figure B.29: Current low-band spectrum holdings of MNOs in Qatar, MHz [Source: https://www.spectrummonitoring.com, https://halberdbastion.com/intelligence/mobile-networks]

MNO	450	700	800	900	1400	1800	1900	2100	2300	2600	Total
Ooredoo	–	–	20	22	–	40	–	30	–	40	**152**
Vodafone	–	–	20	22	–	40	–	30	–	40	**152**
Total	**–**	**–**	**40**	**44**	**–**	**80**	**–**	**60**	**–**	**80**	**304**

Mid-band spectrum

On February 22, 2018, CRA stated[352] that both Vodafone and Ooredoo would be assigned 100MHz in the 3.4–3.6GHz range. Ooredoo and Vodafone subsequently confirmed[353] that they had received test licenses in the 3.4–3.6GHz band; these were upgraded[354] to full 5G licenses at the end of 2018.

High-band spectrum

No high-band spectrum is currently available for commercial mobile services in Qatar.

B.9.2 Main 5G spectrum proposals

Low-band spectrum

In February 2018, CRA published[355] a document outlining preliminary band plans for 5G mobile services. The regulator has reserved 2×30MHz (703–733/758–788MHz) in the 700MHz band for 5G.

Mid-band spectrum

The document referred to above indicates that CRA will assign the 3.6–3.8GHz range to 5G in the future (in addition to the 3.4–3.6GHz range already assigned – see above).

High-band spectrum

The document referred to above states that CRA will assign two 400MHz blocks to Vodafone and Ooredoo in the 26.5–27.5GHz range in 2018. The spectrum for assignment will expand to 25.5–27.5GHz by January 2019 and then to 24.5–27.5GHz by January 2021. We are not aware of confirmation that these timelines have been achieved.

352 See http://cra.gov.qa/en/document/preliminary-frequency-bands-plans-5g-mobile-services

https://ooredoo.com/en/media/news_view/ooredoo-group-acquires-5g-network-spectrum-and-announces-the-worlds-first-5g-deployments-in-qatar/

https://www.vodafone.qa/pressrelease/the-start-of-a-gigabit-qatar-with-5g

353 See https://ooredoo.com/en/media/news_view/ooredoo-group-acquires-5g-network-spectrum-and-announces-the-worlds-first-5g-deployments-in-qatar/ and https://www.vodafone.qa/pressrelease/the-start-of-a-gigabit-qatar-with-5g

354 See https://www.vodafone.qa/pressrelease/vodafone-first-to-be-live-with-5g-commercially

355 See http://cra.gov.qa/en/document/preliminary-frequency-bands-plans-5g-mobile-services
See also http://cra.gov.qa/en/news/cra-preliminary-frequency-plans-5g-technology-are-ready

B.9.3 MNOs' 5G commercial deployment plans

Under the terms of Vodafone's and Ooredoo's mid-band 5G licenses, each MNO must "roll out 5G networks before the end of 2020 in all densely populated areas, all primary roads and highways as well as all venues associated with [FIFA] 2022 World Cup including stadiums and fan zones".[356]

Figure B.30 outlines the major MNOs' progress regarding 5G commercial deployments in Qatar.

Figure B.30: Announcements regarding 5G deployment progress by major MNOs in Qatar [Source: MNO press releases]

MNO	Details of 5G commercial deployment plans
Ooredoo	• On May 14, 2018, Ooredoo announced[357] that it had launched its 5G mobile network commercially in Doha, but that 5G mobile devices were not yet available. Ooredoo plans to upgrade 1,200 sites to be 5G-ready for when devices become available • On June 10, 2018, Ooredoo announced[358] that it had begun testing 5G home broadband (i.e. FWA) devices on its network • On July 22, 2018, Ooredoo announced[359] that its 5G commercial network had reached 50 sites and stated that it was testing 5G home broadband (i.e. FWA) devices. Reports[360] stated that Ooredoo plans to extend 5G coverage to 100 sites by August 2018, but it does not expect 5G mobile handsets to be available until mid-2019 • On August 4, 2018, Ooredoo stated[361] that it was "pushing forward with testing… live 5G home broadband devices". It also noted that 75 5G-ready towers had now been installed around Doha • On December 4, 2018, Ooredoo noted[362] that 85 sites were now 5G ready. Ooredoo states that "by end of the desert season in 2019, a host of the most popular desert locations will be connected with 5G Home Broadband devices" • On February 26, 2019, Ooredoo noted[363] that 100 sites were now 5G ready. Ooredoo stated that it is "now covering more than a third of the population, and nearly all large enterprises, with 5G" and that "this will grow to more than 50% population coverage [later] in 2019".
Vodafone	• On August 27, 2018, Vodafone announced[364] having switched on its first live 5G network at an event in Doha. Vodafone outlined its vision for providing 5G services at the 2022 Qatar FIFA World Cup

356 See http://www.qatarisbooming.com/article/cra-grants-radio-spectrum-licenses-5g-commercial-networks-telecommunications-companies

357 See https://www.ooredoo.qa/portal/OoredooQatar/supernet-5g
See also https://ooredoo.com/en/media/news_view/ooredoo-first-in-the-world-to-launch-5g-commercial-network/

358 See https://ooredoo.com/en/media/news_view/ooredoo-first-in-the-world-to-have-live-5g-home-broadband-device/

359 See https://ooredoo.com/en/media/news_view/50-ooredoo-5g-network-towers-now-live/

360 See https://www.telegeography.com/products/commsupdate/articles/2018/07/24/ooredoo-reaches-50-active-5g-base-stations-thats-two-per-active-device/

361 See https://ooredoo.com/en/media/news_view/ooredoos-5g-home-broadband-test-results-show-mega-speeds-available/

362 See https://ooredoo.com/en/media/news_view/ooredoos-5g-network-tests-are-in-full-swing-in-the-desert/

363 See https://ooredoo.com/en/media/news_view/ooredoo-drives-qatar-to-5g-global-top-five-country-status/

364 See https://www.vodafone.qa/pressrelease/vodafone-qatar-switches-on-its-5g-network

MNO	Details of 5G commercial deployment plans
	• On August 28, 2018, Vodafone announced[365] the connection of its first enterprise (FWA) customer to its 5G network • On October 15, 2018, Vodafone stated[366] that it is accelerating its 5G deployment in key locations across the country[367] • On November 28, 2018, Vodafone announced[368] that it had deployed 5G sites in the Al Waab area • On December 13, 2018, Vodafone announced[369] that it had deployed its 5G network in Katara Cultural Village in time for Qatar's National Day celebrations • On December 17, 2018, Vodafone announced[370] that it had deployed its 5G network in Souq Waqif (Doha) • On December 31, 2018, Vodafone announced[371] that its test mid-band license had been upgraded to a full license, allowing the company to go live commercially. Vodafone stated that Gulf Bridge International (GBI) would be the first entity to be commercially connected to its 5G network and that several customers in Doha would be commercially connected to its 5G network from January 1, 2019. However, it also noted that 5G-enabled handsets would not be available until later in 2019.

B.9.4 National strategies/government support

Limited data available.

B.9.5 Outlook

Our 5G outlook/assessment for Qatar is summarized in Figure B.31 below.

Figure B.31: 5G outlook for Qatar [Source: Analysys Mason, 2019]

Metric	Description	Score
1. Industry commitment to 5G launch	• Both MNOs to launch 5G in 2019 having deployed 5G RAN technology on existing mobile sites during 2018	3/4
2. Low-band spectrum	• 304MHz of spectrum currently released • 700MHz band scheduled for assignment to 5G	0/4
3. Mid-band spectrum	• 200MHz of spectrum currently released • 3.4–3.6GHz band also scheduled to be released	2/4
4. High-band spectrum	• No high-band spectrum currently released • 25.5–27.5GHz range to be awarded by 2019, expanding to the entire 26GHz band by early 2021	2/4

365 See https://www.vodafone.qa/pressrelease/vodafone-qatar-connects-the-first-customer-in-the-country-to-5g

366 See https://www.vodafone.qa/pressrelease/vodafone-qatar-accelerates-its-5g-network-deployment-in-key-locations-across-the-country

367 To include Abu Hamour, Al Azizya, Al Mamoura, Al Rayyan, Salwa Road, and Umm Salal Muhammed.

368 See https://www.vodafone.qa/pressrelease/vodafone-deploys-its-5g-network-in-al-waab

369 See https://www.vodafone.qa/pressrelease/vodafone-deploys-5g-network-at-katara-in-celebration-of-qatar-national-day

370 See https://www.vodafone.qa/pressrelease/vodafone-qatar-deploys-5g-at-souq-waqif-marking-latest-progress-for-qatar-national-day

371 See https://www.vodafone.qa/pressrelease/vodafone-first-to-be-live-with-5g-commercially

Metric	Description	Score
5. Total spectrum	• Small amounts of sub-3GHz spectrum released compared to other countries	2/4
6. National strategies/government support	• Limited data available	1/4

B.10 South Korea

The Ministry of Science and ICT (MSIT, formerly MSIP), is the government ministry of South Korea with responsibility for radio policy and spectrum allocation. South Korea used the 2018 Winter Olympics (held in PyeongChang in February 2018) as an opportunity to showcase 5G technologies, and the government has supported 5G research and trials, as well as making a commitment to invest USD1.5 billion in 5G by 2020. MSIT's 'K-ICT' plan committed to making 1300MHz to 5G by 2018 across the 3.5GHz and 28GHz bands, with a potential further 2GHz to be released in the 28GHz band. South Korea's MNOs all conducted extensive 5G testing, with the aim to be among the first operators in the world to commercialize 5G. MSIT auctioned spectrum in the 3420–3700MHz range in 2018, alongside 2.4GHz of spectrum in the 28GHz band. Following award of spectrum, the three operators confirmed 5G services were commercially available toward the end of 2018, initially for enterprise use.

B.10.1 Current spectrum holdings

Low-band spectrum

As shown in Figure B.32 below, 477MHz of low-band spectrum is currently allocated to commercial mobile services in South Korea.

Figure B.32: Current low-band spectrum holdings of MNOs in South Korea, MHz [Source: APT[372]]

MNO	450	700	850	900	1400	1800	1900	2100	2300	2600	Total
SKT	–	–	30	–	–	40	–	40	27	60	**197**
KT	–	–	10	20	–	60	–	40	30	–	**160**
LGU+	–	–	20	–	–	20	–	40	–	40	**120**
Total	**–**	**–**	**60**	**20**	**–**	**120**	**–**	**120**	**57**	**100**	**477**

Mid-band spectrum

The 3420–3700MHz range was auctioned in June 2018.[373] As shown in Figure B.33 below, each of the three South Korean MNOs won spectrum. Licenses start on December 1, 2018, and last 10 years. Licenses are national and include a coverage obligation to build a certain number of base stations within a given timeframe.[374]

372 Data from APT report APT/AWG/REP-15(Rev.5) and 2016 auction results; see http://www.apt.int/AWG-RECS-REPS

373 MSIT announced results on June 18, 2018.
See http://www.msit.go.kr/web/msipContents/contentsView.do?cateId=mssw311&artId=1386500

374 See MSIT announcement for details.

Figure B.33: Outcome of South Korea's 3420–3700MHz auction [Source: Analysys Mason, MSIT,[375] 2018]

Operator	Spectrum won	Spectrum range (MHz)	Price paid* (USD)	Adjusted** USD/MHz/pop
SKT	100MHz	3600–3700MHz	1,100,000,000	0.3317
KT	100MHz	3500–3600MHz	872,000,000	0.2629
LGU+	80MHz	3420–3500MHz	729,000,000	0.2748
Total	**280MHz**	**3420–3700MHz**	**2,701,000,000**	**0.2898**

*Sum of prices from principal and assignment stages.

**Adjusted to a 20-year license using a WACC of 6.0%.

The auction consisted of a principal stage and an assignment stage (clock auction and single-round sealed bid respectively). Spectrum sold at the reserve price in the principal stage; the total price paid was ~USD0.29/MHz/pop (after adjusting to a 20-year license duration).

High-band spectrum

2.4GHz of spectrum in the 28GHz band was auctioned alongside the 3420–3700MHz spectrum. As shown in Figure B.33 below, each of the three South Korean MNOs won spectrum. Licenses start on December 1, 2018, and last five years. Licenses are national and include a coverage obligation to build a certain number of base stations within a given timeframe.[376]

Figure B.34: Outcome of South Korea's 28GHz auction [Source: Analysys Mason, MSIT,[377] 2018]

Operator	Spectrum won	Spectrum range (MHz)	Price paid* (USD)	Adjusted** USD/MHz/pop
SKT	800MHz	28100–28900MHz	186,700,000	0.0123
KT	800MHz	26500–27300MHz	187,200,000	0.0123
LGU+	800MHz	27300–28100MHz	186,600,000	0.0123
Total	**2400MHz**	**26500–28900MHz**	**560,500,000**	**0.0123**

*Sum of prices from principal and assignment stages

**Adjusted to a 20-year license using a WACC of 6.0%

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 was ~USD0.012/MHz/pop (after adjusting to a 20-year license duration).

375 Ibid.

376 See MSIT announcement for details.

377 Ibid.

B.10.2 Main 5G spectrum proposals

Low-band spectrum

We are not aware of any official upcoming assignment plans. However, we note that in South Korea's most recent auction (May 2016), 2×20MHz of spectrum in the 700MHz band remained unsold. MSIT may choose to re-auction this block in the future.

Mid-band spectrum

We are not aware of any plans for further release of mid-band spectrum.

High-band spectrum

We are not aware of any plans for further release of high-band spectrum.

B.10.3 MNOs' 5G commercial deployment plans

Each of South Korea's three MNOs launched FWA 5G services (based on 3GPP NR standards) on December 1, 2018,[378] using spectrum in the 3420–3700MHz range. However, the service is limited to enterprise customers only; details reported at the network launch are provided in Figure B.35 below. Full (mobile) commercial 5G launch for regular consumers is scheduled for March 2019 (the MNOs have again agreed to launch at the same time[379, 380]). Figure B.35 also outlines further details of the 5G commercial deployment plans announced by the three MNOs in South Korea.

Figure B.35: Announcements of 5G deployment progress by major MNOs in South Korea [Source: http://www.koreaherald.com/view.php?ud=20181202000143 unless otherwise specified]

MNO	Details of 5G commercial deployment plans
SKT	• As of December 1, 2018, SKT has deployed 5G infrastructure in "13 cities and counties" including Busan, Daejeon, and Gwangju • Myunghwa – an automotive-part company based in Banwol Industrial Complex, Ansan, Gyeonggi Province – became SKT's first 5G customer. Myunghwa used SKT's telecom "5G-AI machine vision" solution to quality-check automotive parts from the production line.
KT	• As of December 1, 2018, KT has deployed 5G infrastructure in Seoul and six other metropolitan cities across the country. KT plans to expand coverage to 24 major cities, including subway and bullet train KTX stations • KT's first user was an AI-equipped robot called Lota.
LGU+	• As of December 1, 2018, LGU+ has built around 4,100 5G base stations in eleven cities including Seoul, Incheon, Daejeon, Bucheon, Goyang, Gwangmyeong, Hanam,

378 See http://www.koreaherald.com/view.php?ud=20181202000143

379 See https://venturebeat.com/2018/11/29/south-korean-carriers-set-surprise-commercial-5g-launch-for-december-1/

380 We note that reports emerged in March 2019 stating that commercial 5G launch may be delayed to April 2019. See http://www.koreaherald.com/view.php?ud=20190307000772

MNO	Details of 5G commercial deployment plans
	and other cities in Gyeonggi Province.[381] LGU+ planned to reach 7,000 5G base stations by the end of December 2018 • We understand that LGU+ expects to "adapt its 5G service for use in the remote controlling of heavy equipment and agricultural machines, drones, CCTV, smart factories and smart cities".[382] Its first 5G customer was tractor manufacturer LS Mtron • On January 22, 2019, LGU+ reportedly[383] stated that it would complete building its 5G infrastructure in major cities by the end of 2019. It also confirmed that it had built 5,500 5G base stations as of end 2018; the report noted that KT and SKT were estimated to each have around 3,000 5G base stations "on air" as of end 2018.

B.10.4 National strategies/government support

As described in our previous report, there was a strong focus on the Winter Olympics (held in PyeongChang in February 2018) as an opportunity to showcase 5G technologies, and the government also supported research and trials.[384] The Olympics were used to demonstrate a variety of next-generation use cases, which the South Korean government/MSIT extensively marketed,[385] classified into five categories: 5G, IoT, VR, AI, and UHD.

In January 2014, MSIT announced[386] plans to invest KRW1.6 trillion (USD1.5 billion) by 2020 to enable local firms to build 5G networks. In January 2018, MSIT announced[387] R&D funding for a range of science/ICT projects, covering mobile communications and broadcasting (KRW70 billion), 'SW computing' (KRW146.6 billion), broadcasting (KRW65.7 billion), next-generation security (KRW61.8 billion), and 'devices' (KRW43.5 billion). Details regarding to what extent funding would be directly allocated to 5G-related projects were not provided. We understand that MSIT has explicitly said[388] that it hopes to co-operate with the major telecom providers in order to build 5G infrastructure.

Indeed, in April 2018, MSIT announced[389] a series of infrastructure-based measures (including network-sharing obligations and revised legislation to enable operator access to street furniture) aimed at accelerating 5G deployment. Further details are provided in Section 5.2. MSIT has also announced[390] that it will provide tax benefits and security maintenance services to the MNOs.

381 See https://www.telegeography.com/products/commsupdate/articles/2018/12/03/south-korean-5g-networks-live-for-enterprise-customers/

382 Ibid.

383 See https://en.yna.co.kr/view/AEN20190122007852320

384 See for example the 5GCHAMPION project (which received financial support from the European Union H2020 Programme and MSIT).

385 See https://blog.naver.com/with_msip/220979864407

386 See http://english.yonhapnews.co.kr/business/2014/01/22/0504000000AEN20140122001200320.html

387 See http://www.msit.go.kr/web/msipContents/contentsView.do?cateId=mssw311&artId=1371962

388 See http://koreabizwire.com/5g-infrastructure-at-the-forefront-of-technology-investment-in-south-korea/106298

389 See https://www.msit.go.kr/web/msipContents/contentsView.do?cateId=mssw311&artId=1379674

390 See https://www.rcrwireless.com/20180717/5g/south-korean-telcos-agree-launch-5g-services-same-time-tag23

B.10.5 Outlook

Our 5G outlook/assessment for South Korea is summarized in Figure B.36 below.

Figure B.36: 5G outlook for South Korea [Source: Analysys Mason, 2019]

Metric	Description	Score
1. Industry commitment to 5G launch	• All three MNOs launched limited FWA services in 2018	4/4
2. Low-band spectrum	• 47MHz of spectrum currently released • No plans for further spectrum assignment; 700MHz band unsold at previous auction	1/4
3. Mid-band spectrum	• 280MHz of spectrum currently released • No plans for further spectrum assignment	3/4
4. High-band spectrum	• 2.4GHz of spectrum currently released • No plans for further spectrum assignment	3/4
5. Total spectrum	• Spectrum released across low, mid, and high bands	3/4
6. National strategies/government support	• MSIT announced plans to invest USD1.5 billion by 2020 for the construction of 5G networks • Tax benefits and security maintenance services for the MNOs • A series of infrastructure-based measures have also been announced	4/4

B.11 Spain

The Ministry of Economy and Enterprise (MINECO in Spanish) and the Ministry of Energy, Tourism and Digital Agenda (MINTEAD) in Spain are the government departments responsible for communications industries and spectrum policy. The National Commission on Markets and Competition (CNMC) is an entity that promotes efficient functioning of all markets in the interests of consumers and businesses. The Spanish government has published a 5G plan, and CNMC has announced 5G technology trials. Spectrum in the 3.6–3.8GHz band was auctioned in July 2018. Operators are understood to be targeting commercial launch in 2020.

B.11.1 Current spectrum holdings

Low-band spectrum

As shown in Figure B.37 below, 580MHz of low-band spectrum is currently allocated to commercial mobile services in Spain.

Figure B.37: Current low-band spectrum holdings of MNOs in Spain, MHz [Source: MINECO[391]]

MNO	450	700	800	900	1400	1800	1900*	2100	2300	2600	Total
Orange	–	–	20	20	–	40	–	30	–	50	**160**
Vodafone	–	–	20	20	–	40	–	30	–	60	**170**
Telefonica	–	–	20	30	–	40	–	30	–	40	**160**
Mas Movil	–	–	–	–	–	30	–	30	–	–	**60**
Total	**–**	**–**	**60**	**70**	**–**	**150**	**–**	**120**	**–**	**180****	**580**

* Spectrum assigned in 3GPP bands 33 and 34 is excluded, since it is not used.

** 30MHz in the 2.6GHz band is assigned on a regional basis.[392]

Mid-band spectrum

Three of Spain's MNOs own national licenses in the 3.4–3.6GHz band:[393] Orange (2×20MHz), Telefonica (2×20MHz), and Mas Movil (2×40MHz). These licenses are suitable for delivering 5G.

391 See https://sedeaplicaciones.minetur.gob.es/setsi_regconcesiones/default.aspx

392 I.e. the 2560–2570/2680–2690MHz FDD range and the 2595–2605MHz TDD range.

393 The exact assignments are as follows: Mas Movil (3400–3440/3500–3540MHz), Telefónica (3440–3460/3540–3560MHz), Orange (3460–3480/3560–3580MHz). See https://sedeaplicaciones.minetur.gob.es/setsi_regconcesiones/default.aspx

Orange acquired its spectrum at an auction in September 2016 for EUR20 million. See https://www.xatakamovil.com/conectividad/la-subasta-de-nuevo-espectro-para-telefonia-movil-en-los-2-6-ghz-y-3-5-ghz-se-aplaza-a-enero

Mas Movil acquired Neutra Network Services (for EUR15.5 million) in 2018 to gain 2×20MHz (3420–3440/3520–3540MHz) of spectrum. It also acquired 2×20MHz (3400–3420/3500–3520MHz) from Eurona Wireless Telecom (for EUR30 million) in 2018. See https://www.eurona.com/en/eurona-culmina-acuerdo-masmovil-licencia-5g-30-millones/ and https://www.mobileworldlive.com/featured-content/top-three/masmovil-secures-5g-boost-with-neutra-network-deal/

The remaining 2×20MHz of the 3.4–3.6GHz band is used by the military for radiolocation services; a consultation issued by MINTEAD in July 2017 indicates that this block is not expected to be reallocated.[394]

MINTEAD completed an auction of the 3.6–3.8GHz range in July 2018. Forty 5MHz blocks were available in the 3600–3800MHz band; licenses have a 20-year duration, are nationwide, technology neutral and without coverage obligations. As shown in Figure B.38 below, three MNOs won spectrum: Vodafone, Telefónica, and Orange.

Figure B.38: Outcome of Spain's 3.6–3.8GHz auction in July 2018 [Source: MINTEAD, 2018]

Operator	Spectrum won	Spectrum range (MHz) [395]	Price paid* (USD)	Adjusted** USD/MHz/pop
Vodafone	90MHz	N/d	493,000,000	0.1174
Telefonica	50MHz	N/d	271,000,000	0.1161
Orange	60MHz	N/d	329,000,000	0.1174
Mas Movil	-	-	-	-
Total	**200MHz**	**-**	**1,092,000,000**	**0.1171**

* Price includes NPV of annual license fees incurred over the duration of the license (discounted using WACC of 6.0%).

**Adjusted to a 20-year license using a WACC of 6.0%.

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 was ~USD0.012/MHz/pop (after adjusting to a 20-year license duration).

High-band spectrum

No high-band spectrum is currently available for commercial mobile services in Spain.

B.11.2 Main 5G spectrum proposals

Low-band spectrum

On November 28, 2017, Spain's MINTEAD launched[396] a public consultation on allocating the 700MHz band (currently used for DTT) to mobile. Later in 2018, MINECO published[397] a roadmap for the licensing of the 700MHz band, stating that the government aims to release the band by June 30, 2020 (in accordance with EU requirements). Migration of incumbent DTT services will

394 See http://www.mincotur.gob.es/telecomunicaciones/es-ES/Participacion/Documents/Plan-Nacional-5G.pdf

395 The spectrum was awarded as generic blocks; we understand that exact assignments are yet to be confirmed.

396 See http://www.minetad.gob.es/telecomunicaciones/es-ES/Participacion/Paginas/consulta-publica-banda-700-MHz.aspx

397 See http://www.mineco.gob.es/stfls/mineco/comun/pdf/Hoja_de_Ruta_Segundo_Dividendo_Digital.pdf

happen between January 2019 and March 2020. Reports[398] in November 2018 suggest that MINECO expects to auction the band in early 2020.

At the beginning of July 2017, MINTEAD launched[399] a consultation on the future introduction of 5G technology. The document identified the L-band (1427–1518MHz) as a potential band for 5G. In December 2018, MINTEAD published[400] "Spain's 5G National Plan 2018–2020", which states that "actions will be taken" to assign the 1452–1492MHz portion of the band (which is currently available), and that "actions should be taken" to free up the remainder of the band (which is currently in use). No timeframes have been specified. The document also states[401] that demand for shared use of the 2.3–2.4GHz band for 5G "will be examined".

Mid-band spectrum

We are not aware of any plans for further release of mid-band spectrum.

High-band spectrum

The 5G consultation launched by MINTEAD in July 2017 (see above) also identified mm-wave bands (particularly the 24.25–27.5GHz band) as having further potential for 5G.

The document notes that the lower 400MHz portion of the 24.25–27.5GHz band is currently available for immediate 5G use, as well as "another 500MHz plus 500MHz with limitations" in the upper portion of the band; we are not aware of any official decision relating to the timing of assignment. Finally, the document also states that, in accordance with the RSPG recommendations, "actions will be taken" to facilitate the availability of the 31.8–33.4GHz and 40.5–43.5GHz bands for 5G in the future.

B.11.3 MNOs' 5G commercial deployment plans

Figure B.39 outlines 5G commercial deployment plans announced by the major MNOs in Spain:

Figure B.39: Announcements of 5G deployment plans by major MNOs in Spain [Source: MNO press releases]

MNO	Details of 5G commercial deployment plans
Vodafone	• No explicit 5G commercial launch dates publicly announced

398 Previous reports had suggested that the auction was scheduled for Q1 2019. See for example:

https://www.rcrwireless.com/20181105/5g/spain-award-700-spectrum-5g-services-q1-2019
https://www.telegeography.com/products/commsupdate/articles/2018/11/22/spain-postpones-700mhz-sale-until-2020

399 See http://www.minetad.gob.es/telecomunicaciones/es-ES/Participacion/Paginas/plan-nacional-5G.aspx

400 See https://avancedigital.gob.es/5G/Documents/plan_nacional_5G_en.pdf

401 The band is currently being used for telemetry and television mobile radio links (ENG) services in Spain, meaning that "in the short term it could only be used through Licensed Shared Access (LSA)". Demand for 5G mobile usage of the band under an LSA arrangement will be examined.

MNO	Details of 5G commercial deployment plans
	• On July 27, 2018, reports[402] stated that Vodafone had deployed over thirty antennas for pre-commercial NSA 5G trials across six cities: Madrid, Barcelona, Seville, Malaga, Bilbao, and Valencia.
Telefonica	• On January 22, 2018, Telefonica unveiled[403] its '5G Technological Cities' project, which will convert the cities of Segovia and Talavera de la Reina into 5G 'living laboratories' between 2018 and 2020 • On May 20, 2018, reports[404] stated that Telefonica does not plan to launch commercial 5G services prior to 2020.
Orange	• In February 2018, Orange stated[405] that it was in the process of selecting four cities in which to launch commercial 5G services in 2019 • In October 2018, Orange announced[406] the first seven cities in which it will carry out 5G pilot tests until the end of 2019. Barcelona, Seville, Santiago de Compostela, Vigo, Malaga, Valencia, and Bilbao will be used for the testing of 35 5G use cases, including connected cars, industrial automation, and virtual classrooms • On December 12, 2018, Orange Group stated[407] that "5G is gradually being deployed on existing 4G sites. It will be installed in 17 European cities [Belgium, France, Luxembourg, Poland, Romania and Spain[408]] in 2019 and ready for commercial release in 2020, so long as enough 5G smartphones are available". We understand[409] that customers in the 17 cities will be able to experience 5G services in 2019, and that the initial services will be mainly targeted at enterprise customers. In the case of Spain, Orange stated that it aims to achieve pre-commercial deployments of 5G in "three or four" cities in 2019.
Mas Movil	• No explicit 5G commercial launch dates publicly announced

B.11.4 National strategies/government support

In December 2017, MINTEAD published[410] "Spain's 5G National Plan 2018–2020", consisting of the following four 'pillars':

- radio spectrum management and planning
- driving 5G technology – Network and service pilot projects and R&D activities
- regulatory issues

402 See https://www.panoramaaudiovisual.com/en/2018/07/27/%EF%BB%BF%EF%BB%BFvodafone-despliegue-5g-precomercial-madrid-barcelona-sevilla-malaga-bilbao-valencia/

403 See https://www.telefonica.com/en/web/press-office/-/telefonica-leads-the-way-towards-5g-with-deployments-in-two-spanish-cities

404 See https://www.efe.com/efe/espana/economia/telefonica-ve-arriesgado-comenzar-el-despliegue-de-5g-antes-2020/10003-3621482

405 See https://www.telegeography.com/products/commsupdate/articles/2018/03/01/orange-espana-earmarks-3-5ghz-band-for-5g-eyes-four-city-launch-in-2019/

406 See https://www.telegeography.com/products/commsupdate/articles/2018/10/26/orange-unveils-seven-spanish-5g-test-cities/

407 See https://www.orange-business.com/en/press/orange-presents-major-innovations-focused-digital-inclusion-show-hello

408 See https://www.lightreading.com/mobile/5g/eurobites-orange-preps-5g-launch-in-17-european-cities/d/d-id/748227

409 See https://www.rcrwireless.com/20181214/5g/orange-launch-5g-17-european-cities-next-year

410 See https://avancedigital.gob.es/5G/Documents/plan_nacional_5G_en.pdf

- 5G Plan co-ordination and international co-operation.

Under the 'Driving 5G technology' pillar, measures include:

- calling for one or more pilot projects for the experimental deployment of 5G networks
- using such infrastructure to test other third-party innovative applications in the area of intelligent territories, farming, tourism, connected vehicle, etc.
- monitoring and disseminating the different pilot projects and their outcomes through the National Plan Technical Office
- adopting R&D measures on 5G technologies within the Strategic Action Economy and Digital Society.

Within the framework of the National Plan, in February 2018 MINTEAD announced[411] that EUR20 million would be provided to two private-sector 5G pilot projects; a call for applications was published[412] in October 2018.

B.11.5 Outlook

Our 5G outlook/assessment for Spain is summarized in Figure B.40 below.

Figure B.40: 5G outlook for Spain [Source: Analysys Mason, 2019]

Metric	Description	Score
1. Industry commitment to 5G launch	• Two MNOs to launch in 2019; two MNOs have not confirmed launch dates	2/4
2. Low-band spectrum	• 580MHz of spectrum currently released • 700MHz to be assigned in 2020; L-band and 2.3GHz for potential future assignment	3/4
3. Mid-band spectrum	• 360MHz of spectrum currently released • No plans for further spectrum assignment	3/4
4. High-band spectrum	• No high-band spectrum currently released • Spectrum in 26GHz to be made available; no timeline confirmed	0/4
5. Total spectrum	• Strong performance in mid-band spectrum. Further behind in low and high bands	2/4
6. National strategies/government support	• Spain's 5G National Plan 2018–2020 • EUR20 million will be provided to two private-sector 5G pilot projects	2/4

411 See https://techcraftblog.blogspot.com/2018/02/the-spain-government-will-invest-20-million-euros-to-boost-the-5G-networks.html

412 See http://www.lamoncloa.gob.es/lang/en/gobierno/news/Paginas/2018/20181035gtechnology.aspx

B.12 Sweden

The Ministry of Enterprise and Innovation is the government department in Sweden responsible for information technology, enterprise and industrial policy, and the Swedish Post and Telecom Authority (PTS) is the telecommunications regulatory authority in Sweden, responsible for spectrum assignment and licensing. In February 2018, PTS issued a consultation document on plans to award 5G spectrum licenses in the 3.4–3.8GHz band and in 26.5–27.5GHz. The intention is for spectrum within both bands to be assigned for 5G use during 2019, with the spectrum available for use after 2020. In the 3.4–3.8GHz band, 300MHz of spectrum will be made available initially from 3400–3700MHz. PTS also conducted an auction of 700MHz spectrum in December 2018. Swedish mobile operator Telia announced in December 2018 that in partnership with Ericsson and KTH (Royal Institute of Technology in Stockholm), it was launching an innovation arena where 5G applications can be tested, using 3GPP-standardized 5G radio access network technology. It is understood that Telia and other Swedish operators are targeting 2020 for commercial 5G launch, once spectrum has been assigned.

B.12.1 Current spectrum holdings

Low-band spectrum

As shown in Figure B.41 below, 590MHz of low-band spectrum is currently allocated to commercial mobile services in Sweden.

Figure B.41: Current low-band spectrum holdings of MNOs in Sweden, MHz [Source: PTS]

MNO	450	700	800	900	1400	1800	1900*	2100	2300	2600	Total
Telia	–	20	20	20	–	70	–	–	–	40	**170**
Telenor	–	–		10	–	–	–	40	–	–	**50**
Tele2	–	–		18	–	–	–		–	–	**18**
Tre	–	–	20	10	–	–	–	40	–	70	**140**
Net4 Mobility**	–	20	20	12	–	70	–	–	–	80	**202**
SUNAB***	–	–	–	–	–	–	–	40	–	–	**40**
Net 1	10	–	–	–	–	–	–	–	–	–	**10**
Total	**10**	**40**	**60**	**70**	**–**	**140**	**–**	**120**	**–**	**190**	**630**

* Spectrum assigned in 3GPP bands 33 and 34 is excluded, since it is not used.

** Net4Mobility is a joint venture between Tele2 and Telenor.

*** SUNAB is a joint venture between Tele2 and Telia.

We also note that 3GIS is a joint venture between Telenor and Tre, which was set up following the assignment of 3G spectrum in the 2100MHz band.[413]

The 40MHz of spectrum in the 700MHz band was won at an auction held in December 2018.[414] Three FDD lots were made available: one 2×10MHz lot (713–723/768–778MHz) with specific

413 Telenor's and Three's licenses required each MNO to deploy individual networks in Stockholm, Gothenburg, Malmo, and Karlskrona (with population coverage of 30%) by end-2003, while 3GIS took responsibility to provide 3G services to 70% of the Swedish population in all other areas by that date. See http://www.3gis.net/English

414 See https://pts.se/en/english-b/radio/auctions/700/

coverage obligations attached and two 2×5MHz lots (723–733/778–788MHz) with no coverage obligations. As shown in Figure B.42 below, the former was won by Telia for ~USD152 million, while the latter was won by Net4 Mobility for ~USD158 million. Tre participated in the auction but did not win any spectrum. The average price paid was ~USD0.76/MHz/pop (after adjusting to a 20-year license duration).

Figure B.42: Outcome of Sweden's 3.6–3.8GHz auction in July 2018 [Source: PTS, 2018]

Operator	Spectrum won	Spectrum range (MHz)	Price paid (USD)	Adjusted** USD/MHz/pop
Telia	20MHz	713–723/768–778*	152,313,000	0.7456
Net4 Mobility	20MHz	723–733/778–788	158,843,000	0.7775
Total	**40MHz**	**713–733/768–788**	**311,156,000**	**0.7616**

*Spectrum license includes coverage obligations.

**Adjusted to a 20-year license using a WACC of 6.0%.

The 2×10MHz block at the bottom of the 700MHz band (703–713/758–768MHz) has been reserved for PPDR.

Mid-band spectrum

Two MNOs in Sweden own national[415] 2×20MHz licenses in the 3.6–3.8GHz band: TDC Sverige (owned by Tele2) (3600–3620MHz, 3700–3720MHz) and B2 Bredband (owned by Telenor) (3620–3640MHz, 3720–3740MHz). These licenses are technology and service neutral and expire in December 2022. The remaining spectrum in the 3.6–3.8GHz range was auctioned on a regional basis, though most of the licenses have not been assigned.

Until recently, two MNOs in Sweden also owned national licenses in the 3.4–3.6GHz band: Telia-Sonera (3438–3466MHz, 3538–3566MHz) and Tele2 (3466–3494MHz, 3566–3594MHz). However, these licenses expired in December 2017. The 3410–3438MHz and 3510–3538MHz ranges are currently allocated to several local operators with regional[416] based technology-neutral licenses which expire (at the latest) in March 2023.

415 In 2007, PTS auctioned four 40MHz blocks (two FDD and two TDD) in the 3.6–3.8GHz band in each of Sweden's 290 municipalities. B2 Bredband won one FDD block in every municipality, meaning that it effectively holds a national license of 2×20MHz. Of the remaining 870 licenses, the majority (758) remained unsold and were re-auctioned in 2009. 265 of these licenses are now assigned; these licenses are spread out geographically across the country (most assigned licenses are in the more northerly municipalities). The 2009 auction also made available a national 2×20MHz block, which was won by TDC Sverige. All licenses expire in December 2022. See February 2018 consultation.

416 The licenses in the 3.4–3.6GHz band were originally assigned on a county basis, but the charging base for the annual fees comprises population by municipality. There are licenses assigned in 98 out of 290 municipalities; most of these are concentrated in the North of Sweden. The February 2018 consultation states that the majority of license holders are not using their licenses. On October 16, 2018, PTS announced that it had asked all licensees that were not using (or lightly using) their licenses to return them to the regulator. See https://www.pts.se/sv/nyheter/radio/2018/pts-vill-att-kommunala-frekvenstillstand-i-35-ghz-bandet-lamnas-tillbaka/

High-band spectrum

No high-band spectrum is currently available for commercial mobile services in Sweden.

B.12.2 Main 5G spectrum proposals

Low-band spectrum

The 700MHz auction held in December 2018 made available four 5MHz blocks of SDL spectrum (738–758MHz) in addition to the FDD spectrum described above. However, the SDL spectrum was not sold. PTS stated[417] that it would "analyze the possible future use of the unsold SDL licenses".

PTS has plans to release spectrum in both the 1400MHz[418] and 2300MHz[419] bands for mobile broadband:

- On March 29, 2018, PTS published[420] its '[2018] orientation plan' for future spectrum awards. PTS states that an award of spectrum in the 1400MHz band (1427–1518MHz) is planned for "2019 or later".
- On May 2, 2018, PTS proposed[421] that the 2300–2380MHz range[422] be assigned to mobile "by selection procedure in 2019 or later, possibly along with the 3.4–3.8GHz frequency band". On September 25, 2018, a further consultation was issued.[423]. Most recently, on February 6, 2018, the PTS proposed[424] that the 2300–2380MHz range is assigned in eight 10MHz blocks in a clock-auction format alongside the 3.4-3.8GHz band; licenses would expire in 2044.

Mid-band spectrum

PTS issued[425] a consultation on August 30, 2016, analyzing the need for the award of spectrum in the 3438–3510MHz and 3538–3600MHz ranges. The consultation proposed that the two bands be handled together, and therefore that PTS would hold off on a new assignment "until the [entire] 3.4–

417 See https://pts.se/en/news/press-releases/2018/700-mhz-auction-is-closed--auction-proceeds-were-28-billion-sek/

418 For an index of documentation and news relating to the 1500MHz band (including previous consultations, etc.), see https://pts.se/sv/bransch/radio/auktioner/15-ghz/

419 For an index of documentation and news relating to the 2.3GHz band (including previous consultations, etc.), see https://pts.se/sv/bransch/radio/auktioner/23-ghz-bandet/

420 See http://pts.se/en/news/radio/2018/pts-orientation-plan-for-spectrum-management/

421 See https://pts.se/sv/dokument/remisser/radio/2018/remiss-av-uppdaterad-forstudie-infor-tilldelning-i-23-ghz-bandet/

422 The 2380–2400MHz range will continue to be used by wireless cameras and mobile video links. PTS also proposes a protection for Onsala Space Observatory operations through state conditions where licensees are required to collectively ensure that any mobile broadband interference in the Gothenburg area does not exceed certain levels.

423 See https://pts.se/sv/dokument/remisser/radio/2018/konsultation-avseende-tilldelning-i-23-och-35-ghz-banden/

424 See https://pts.se/sv/nyheter/radio/2019/pts-tar-emot-synpunkter-pa-forslag-om-tilldelning-av-23--och-35-ghz-banden/

425 See http://www.pts.se/upload/Remisser/2016/Spektrum/3-5-GHZ-forstudie-2016-25.pdf

3.8GHz band can be reassigned". This approach was confirmed in a statement[426, 427] released by PTS on October 14, 2016.

On February 15, 2018, PTS published[428] a consultation on the release of the 3.4–3.8GHz band for 5G. On May 3, 2018, PTS published[429] responses to the consultation and its revised proposals for assigning the spectrum. PTS has since confirmed[430] its intention to assign the 3.4–3.7GHz range on a nationwide basis in late 2019 or early 2020,[431] and the 3.7–3.8GHz range on a regional basis from 2023.

Most recently, further consultations have proposed details of the assignment approach:

- On February 6, 2018, the PTS proposed[432] that the 3.4-3.7GHz range is assigned in fifteen 20MHz blocks in a clock-auction format alongside the 2.3GHz band; a cap of 120MHz would apply and licenses would expire in 2044.
- In October 2018, PTS published a consultation outlining different options[433] for the 3.7–3.8GHz band. Spectrum in this range will be assigned administratively, whereas spectrum in the 3.4–3.7GHz range will be assigned via some form of competitive market mechanism (e.g. an auction).

High-band spectrum

The consultation (referred to above) published by PTS on February 15, 2018, also sought comment on the release of the 26GHz (24.25–27.5GHz) band for 5G. PTS proposed that the 26.5–27.5GHz range should be opened for assignment (in small geographical areas on an administrative basis) from 2019, with the remainder of the band opened for assignment subsequently (once technical conditions, etc. have been clarified).

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426 See http://www.pts.se/sv/Dokument/Rapporter/Radio/2016/Analys-av-behov-och-efterfragan-for-en-ny-tilldelning-genom-urvalsforfarande-i-frekvensomradena-34383510-och-35383600-MHz/

427 PTS also re-released the consultation document, with an additional section on stakeholder responses, claiming that all stakeholders that responded to the consultation (Hi3G, Huawei, Tele2, Telenor, TeliaSonera) endorsed its recommendations.

428 See https://www.pts.se/contentassets/9057a944959742878f4b3ce0e7ade9f7/remiss-av-rapport-infor-framtida-tilldelning-av-frekvenser-for-5g/forstudie-frekvenser-5g-remissrapport.pdf (English version also available)

429 See https://www.pts.se/contentassets/9057a944959742878f4b3ce0e7ade9f7/inriktning-frekvenser-for-5g-bemotande-remissvar.pdf (English version also available)

430 See https://pts.se/globalassets/startpage/dokument/listningar-pa-textsidor/35-ghz/infomote-21-sep.pdf

431 The potential date of access differs depending on when existing licenses expire.

432 See https://pts.se/sv/nyheter/radio/2019/pts-tar-emot-synpunkter-pa-forslag-om-tilldelning-av-23--och-35-ghz-banden/

433 The consultation considers an option where spectrum is licensed exclusively on a site-by-site basis, as well as an option where spectrum is shared between local coverage providers and site-by-site licensees. Details of the region size for local coverage licenses have not been provided. We note that in the previous 3.4–3.8GHz auctions lots have been made available in each of Sweden's 290 municipalities. At the time of the 3.6–3.8GHz auction in 2007, the average municipality population was ~33,000. See https://pts.se/globalassets/startpage/dokument/listningar-pa-textsidor/35-ghz/infomote-21-sep.pdf

However, due to consultation responses, on May 3, 2018, PTS announced its decision[434] that the best option was to "begin work on assigning frequencies at a point when the conditions for assignment of the entire band can be determined".

B.12.3 MNOs' 5G commercial deployment plans

Figure B.43 outlines 5G commercial deployment plans announced by the major MNOs in Sweden:

Figure B.43: Announcements of 5G deployment plans by major MNOs in Sweden [Source: MNO press releases]

MNO	Details of 5G commercial deployment plans
Telia	• On December 5, 2018, Telia and Ericsson announced[435] the launch of a 5G network at KTH (the Royal Institute of Technology in Stockholm). Telia described this as "a key step toward commercial launch of 5G in Sweden in 2020".
Telenor	• On November 9, 2018, Telenor announced[436] that it had launched a 5G pilot in Kongsberg which will run until Summer 2019. The MNO stated that "the plan is, together with Tele2, to start rolling out a new nationwide network that is 5G-compatible during the second half of 2019, with the ambition of giving the first customers access to 5G with full functionality in 2020"
Tele2	• On December 10, 2018, Tele2 and Telenor announced[437] that they had "signed a new supplementary agreement on the expansion of a joint and nationwide 5G network in Sweden. The parties have agreed on the details of the implementation planned for the second half of 2019." They aim to "give the first customers access to 5G by 2020"
Tre	• No explicit 5G commercial launch dates publicly announced.

B.12.4 National strategies/government support

Sweden adopted[438] a national broadband plan in 2016, which included the following targets:

- 95% coverage of households and companies with 100Mbps broadband by 2020
- 98% coverage of households and companies with 1Gbps broadband by 2025; of the remaining 2%, 1.9% must have speeds of 100Mbps, and 0.1% must have speeds of 30Mbps
- ubiquitous[439] access to 'high-quality' mobile services by 2023.

434 See https://pts.se/globalassets/startpage/dokument/icke-legala-dokument/rapporter/2018/radio/preliminary-study-consultation-pts-responses.pdf

435 See https://www.teliacompany.com/en/news/news-articles/2018/swedens-first-5g-network-goes-live/

436 See http://press.telenor.se/pressreleases/telenor-inleder-skandinaviens-foersta-5g-pilot-ger-familjer-tillgaang-till-framtidens-mobilnaet-2793357

437 See https://www.tele2.com/sv/Media/pressmeddelanden/2018/tele2-och-telenor-sakrar-nya-frekvenser-och-befaster-gemensam-plan-for-5g-nat-i-sverige

438 See https://www.government.se/496173/contentassets/afe9f1cfeaac4e39abcdd3b82d9bee5d/sweden-completely-connected-by-2025-eng.pdf

439 See document for details.

Sweden is part of the Nordic-Baltic co-operation on 5G, undertaken within the framework of the Nordic Council of Ministers.[440] In May 2018, the Nordic governments signed[441] a declaration on 5G, with the common vision of being the "first and foremost-integrated region in the world". To achieve this goal, the Nordic-Baltic countries have set up "a common action plan for early adoption of 5G technology".

B.12.5 Outlook

Our 5G outlook/assessment for Sweden is summarized in Figure B.44 below.

Figure B.44: 5G outlook for Sweden [Source: Analysys Mason, 2019]

Metric	Description	Score
1. Industry commitment to 5G launch	• Two MNOs to launch 5G in 2020; one MNO has not confirmed a launch date	2/4
2. Low-band spectrum	• 630MHz of spectrum currently released • L-band spectrum to be awarded in 2019 or later	4/4
3. Mid-band spectrum	• 80MHz of spectrum currently released • Entire 3.4–3.8GHz to be awarded for mobile use (3.4–3.7GHz on a nationwide basis in 2019/20)	1/4
4. High-band spectrum	• No high-band spectrum currently released • Entire 26GHz band to be assigned together; timeline not yet confirmed	0/4
5. Total spectrum	• Strong performance in low-band spectrum, with 700MHz band already auctioned. Further behind with mid- and high-band spectrum	2/4
6. National strategies/government support	• National broadband plan has set coverage targets for mobile services	1/4

440 See https://ec.europa.eu/digital-single-market/en/country-information-sweden

441 See https://www.government.se/49b8be/globalassets/government/dokument/statsradsberedningen/letter-of-intent--development-of-5g-in-the-nordic-region-.pdf

B.13 UK

The Department for Culture, Media and Sport (DCMS) is the government department responsible for telecom strategy and policy in the UK, and Ofcom is the communications regulator with responsibility for spectrum management. The UK government has stated that it is aiming for the UK market to be a global leader in 5G and has committed to investing GBP740 million in full fiber and 5G technology by 2020–21. Ofcom has put in place specific plans to release each of the bands identified by the European Commission for 5G use in Europe (700MHz, 3.4–3.8GHz, and 24.25–27.5GHz). An auction of spectrum in the 3.4–3.6GHz band was completed in 2018 and Ofcom has subsequently confirmed plans to auction a further 120MHz of spectrum in the 3.6–3.8GHz band along with 2×30MHz of paired spectrum, and 20MHz of unpaired 'center gap' spectrum in the 700MHz band. Ofcom's 700MHz auction will include coverage obligations designed to improve outdoor mobile coverage in the UK, and coverage to premises. Two major UK operators – BT/EE and Vodafone – have announced 5G trials, with three operators (BT/EE, Vodafone, and Three) indicating that they will have commercial 5G services available in 2019.

B.13.1 Current spectrum holdings

Low-band spectrum

As shown in Figure B.45 below, 647MHz of low-band spectrum is currently allocated to commercial mobile services in the UK.

Figure B.45: Current low-band spectrum holdings of MNOs in the UK, MHz [Source: Ofcom[442]]

MNO	450	700	800	900	1400	1800	1900*	2100	2300	2600	Total
O2	–	–	20	34.8	–	11.6	–	20	40	–	126.4
BT/EE	–	–	10	–	–	90	–	40	–	115	255
Vodafone	–	–	20	34.8	20	11.6	–	29.6	–	60	176
Three UK	–	–	10	–	20	30	–	29.5	–	–	89.5
Total	**–**	**–**	**60**	**69.6**	**40**	**143.2**	**–**	**119.1**	**40**	**175**	**646.9**

* Spectrum assigned in 3GPP bands 33 and 34 is excluded, since it is not used

The 40MHz of 2.3GHz band spectrum licensed to O2 was assigned alongside 3.4GHz spectrum at an auction held in April 2018 (see below).

442 See Figure 5.2 in the following consultation: https://www.ofcom.org.uk/__data/assets/pdf_file/0019/130726/Award-of-the-700-MHz-and-3.6-3.8-GHz-spectrum-bands.pdf

Mid-band spectrum

FWA operator UK Broadband (owned by MNO Three) owns national licenses in the 3480–3500MHz, 3580–3600MHz,[443] 3600–3680MHz,[444] and 3925–4009MHz[445] mid-band ranges.

In April 2018, Ofcom completed an auction of 150MHz in the 3.4–3.6GHz band. Thirty 5MHz blocks were auctioned in the 3410–3480MHz and 3500–3580MHz ranges[446] at a reserve price of GBP1 million (USD1.3 million) per block. Licenses are national, technology neutral and without coverage obligations. Licenses were awarded in perpetuity (with further payment required after 20 years[447]). As shown in Figure B.46 below, all four MNOs won spectrum.

Figure B.46: Outcome of the UK's 3.4–3.6GHz auction in April 2018 [Source: Ofcom,[448] 2018]

Operator	Spectrum won	Spectrum range (MHz) [449]	Price paid* (USD)	Adjusted** USD/MHz/pop
O2	40MHz	3500–3540	445,000,000	0.1675
BT/EE	40MHz	3540–3580	425,000,000	0.1601
Vodafone	50MHz	3410–3460	530,000,000	0.1595
Three	20MHz	3460–3480	230,000,000	0.1734
Total	**150MHz**	**-**	**1,631,000,000**	**0.1637**

*Sum of prices from principal and assignment stages

**Adjusted to a 20-year license using a WACC of 6.0%

443 In June 2003 the Radiocommunications Agency (RA) held a regional 3.4–3.6GHz FWA auction. Two 20MHz TDD blocks (3480–3500MHz and 3580–3600MHz) were made available under a single license in each of 15 regions; the 15 regions collectively covered the entirety of the UK. Poundradio (which changed its name to UK Broadband shortly after the auction) won licenses in 13 out of the 15 regions. It subsequently acquired the remaining two licenses, by buying the companies (Red Spectrum and Public Hub) that won them in the auction. In March 2007, Ofcom agreed to combine UK Broadband's licenses into a single nationwide license. Later in 2007, UK Broadband successfully requested a variation to its license conditions to allow technology and application neutrality (thereby allowing mobile as well as FWA use). In June 2014, Ofcom extended the duration of the license to be indefinite (the original licenses expired after 15 years). See:

https://www.ofcom.org.uk/research-and-data/telecoms-research/broadband-research/oftel_internet_broadband_brief
https://www.ofcom.org.uk/consultations-and-statements/category-2/uk-broadband-licence

444 This license was previously for 3605–3689MHz. On June 27, 2018, Ofcom published a consultation on varying UK Broadband's license in this range. UK Broadband requested to shift its license to 3600–3680MHz and change the applicable technical conditions. The request was granted by Ofcom on December 14, 2018. See:

https://www.ofcom.org.uk/__data/assets/pdf_file/0028/96913/UK-Broadband.pdf
https://www.ofcom.org.uk/consultations-and-statements/category-2/variation-uk-broadbands-spectrum-access-licence-3.6-ghz
https://www.ofcom.org.uk/__data/assets/pdf_file/0014/130253/Statement-UK-Broadbands-spectrum-access-licence-3.6-GHz.pdf

445 Unlike UK Broadband's other mid-band spectrum licenses, this license is for FWA only, and allows individual deployments on a first-come, first-served basis, subject to co-ordination by Ofcom (with incumbent satellite earth stations and fixed links).

446 I.e. the full 3.4–3.6GHz band was auctioned, excluding the two 20MHz TDD portions already licensed to UK Broadband, and a guard band at 3400–3410MHz.

447 See auction documentation for details: https://www.ofcom.org.uk/spectrum/spectrum-management/spectrum-awards/awards-archive/2-3-and-3-4-ghz-auction

448 See https://www.ofcom.org.uk/spectrum/spectrum-management/spectrum-awards/awards-in-progress/2-3-and-3-4-ghz-auction

449 The spectrum was awarded as generic blocks; we understand that exact assignments are yet to be confirmed.

The auction consisted of a principal stage and an assignment stage (SMRA auction and single-round sealed bid respectively). The average price paid was ~USD0.16/MHz/pop (after adjusting to a 20-year license duration).

High-band spectrum

No high-band spectrum is currently available for commercial mobile services in the UK.

B.13.2 Main 5G spectrum proposals

Low-band spectrum

Ofcom plans to release 2×30MHz in the 700MHz FDD band (703–733/758–788MHz) and 20MHz in the 700MHz TDD band (738–758MHz) for mobile. Incumbent DTT users are in the process of vacating the band. On December 10, 2018, Ofcom published its most recent update of the 700MHz clearance program, stating that the expected completion date is Q2 2020.

On December 18, 2018, Ofcom published[450] a consultation on its proposal to conduct a combined auction of the 700MHz and 3.6–3.8GHz ranges in CCA format; responses are due by March 12, 2019. The consultation proposes to award six 2×5MHz lots (with a reserve price in the range GBP100 million–240 million per lot) and four 5MHz lots (with a reserve price of GBP1 million per lot). Further details (e.g. coverage obligations[451]) can be found in the consultation. The award is expected to have concluded by Spring 2020, with 700MHz spectrum available for mobile use by May/June 2020.

Also on December 18, 2018, Ofcom published[452] a consultation on enabling shared access to spectrum. Two types of sharing are proposed:

- **Three 'shared access bands'**: 1781.7–1785/1876.7–1880MHz, 2390–2400MHz, and 3.8–4.2GHz.[453] Under the proposals, companies would be able to apply to Ofcom for a license in these spectrum ranges in a specific location. Subject to co-ordination by Ofcom, licenses would

450 See https://www.ofcom.org.uk/__data/assets/pdf_file/0019/130726/Award-of-the-700-MHz-and-3.6-3.8-GHz-spectrum-bands.pdf

451 Up to two winning bidders would each have to, within four years of the award: (1) Extend good, outdoor data coverage to at least 90% of the UK's entire land area; (2) Improve coverage for at least 140,000 homes and offices which they do not already cover. This means new coverage will be targeted at areas that are harder to reach; and (3) Provide coverage from at least 500 new mobile mast stations in rural areas. This will ensure operators transform coverage in areas where it is lacking, rather than meeting the rules by just boosting existing signals.

Ofcom is proposing to offer the two coverage obligations as two "coverage lots" in the auction (in addition to the spectrum lots). The winner of a coverage lot would receive a discount on its spectrum lots, up to a maximum set by Ofcom.

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

453 The 1800MHz shared spectrum is currently authorised to 12 Concurrent Spectrum Access (CSA) licensees on a shared basis. The MoD has some deployments in the 2300MHz shared spectrum. The 3.8–4.2GHz band is currently used by satellite Earth stations, point-to-point fixed links and wireless access applications (fixed) by UK Broadband. Deployments in the band are technically co-ordinated by Ofcom on a first-come, first-served basis.

be issued on a first-come, first-served basis; a cost-based annual fee would apply. Ofcom states that it will "explore the potential for introducing DSA in the three shared access bands".

- **Access to previously awarded mobile spectrum**: currently the 800MHz, 900MHz, 1400MHz, 1800MHz, 1900MHz, 2100MHz, 2.3GHz, 2.6GHz, and 3.4GHz bands. Under the proposals, companies would be able to apply to Ofcom for a license in these spectrum ranges in a specific location. Ofcom would then contact the relevant MNO(s), and if no reasonable objection is raised, a local license would be issued for a default term of three years.

The consultation closes on March 12, 2019. Ofcom intends to publish a statement in Q2 2019 to confirm its proposals, and it plans to make new licenses available in the second half of 2019.

Mid-band spectrum

As referred to above, on December 18, 2018, Ofcom published a consultation[454] on its proposal to conduct a combined auction of the 700MHz and 3.6–3.8GHz ranges (excluding the 80MHz already licensed to UK Broadband[455]) in CCA format; responses are due by March 12, 2019. The consultation proposes to award twenty-four 5MHz lots (with a reserve price in the range GBP15 million–25 million per lot). Further details (e.g. spectrum caps[456]) can be found in the consultation. The award is expected to have concluded by Spring 2020, with 3.6–3.8GHz spectrum available for mobile use in some parts of the UK by mid-2020, and possibly as early as 2019, subject to interim co-ordination requirements.[457]

As also referred to above, on December 18, 2018, Ofcom published[458] a consultation on proposed sharing arrangements in the 3.8–4.2GHz band (see above for details).

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454 Three further consultations were published on January 31, 2019, relating to the 700MHz and 3.6–3.8GHz auction:

(1) Ofcom's approach to verifying compliance [with the coverage obligations]
(2) Proposals to make a limitation order and amend the mobile trading and the register regulations
(3) Proposals to make the auction regulations

See:

https://www.ofcom.org.uk/consultations-and-statements/category-2/coverage-obligations-in-the-700-mhz-and-3.6-3.8-ghz-spectrum-award
https://www.ofcom.org.uk/consultations-and-statements/category-2/regulations-award-700-mhz-3.6-3.8-ghz
https://www.ofcom.org.uk/consultations-and-statements/category-2/proposal-auction-regulations-700mhz-3.6-3.8-ghz

455 I.e. 3600–3680MHz.

456 An overall spectrum cap (on currently held spectrum and spectrum won in the 3.6–3.8GHz band) of 416MHz will apply to each operator. This limits the amount which certain operators can bid for.

457 Most of the users will have left the band by mid-2020, thereby making the band useable nationwide by this date with only some relatively minor deployment restrictions. (Beyond mid-2020 the only incumbent user that could potentially affect deployment to any significant degree is a fixed link operating between the Isle of Wight and Portsmouth which is due to be cleared by the end of 2022.)

458 This follows a 'Call for Input' on the 3.8–4.2GHz range published in 2016. See https://www.ofcom.org.uk/__data/assets/pdf_file/0031/79564/3.8-GHz-to-4.2-GHz-band-Opportunities-for-Innovation.pdf

High-band spectrum

Several regional licenses have been assigned in the 28GHz band in the UK, but these are not suitable for mobile use.

On September 22, 2017, Ofcom concluded[459] its 'Call for Inputs on the 26GHz spectrum band'. The document states that Ofcom is undertaking work to make the 26GHz band (24.25–27.5GHz) available for 5G, and also provides a 5G roadmap for further mm-wave bands. In particular, Ofcom believes that "the bands with significant potential are 66–71GHz, and bands around 40GHz (37–43.5GHz)".[460] Although the 32GHz band was initially considered to be "a promising band for 5G in Europe", because of the potential for global equipment harmonization around 40GHz, Ofcom "considers 40GHz is a higher priority".

Test licences in the lower part of the 26GHz band are available through Ofcom's "Innovation and trial licensing" program, under which trial licenses can be requested in the 5.9–26.1GHz band. In March 2018, Ofcom opened[461] its 'Innovation and Trial' portal to help applicants access spectrum for innovative uses (in particular 5G applications).

B.13.3 MNOs' 5G commercial deployment plans

Figure B.47 outlines 5G commercial deployment plans announced by the major MNOs in the UK:

Figure B.47: Announcements of 5G deployment plans by major MNOs in the UK [Source: MNO press releases]

MNO	Details of 5G commercial deployment plans
O2	• O2 has confirmed[462] that it will not roll out a commercial 5G deployment before 2020 and described pre-2020 Release 15 (i.e. non-standalone) deployments as a 'lite version' of 5G • On January 23, 2019, Vodafone and O2 announced[463] that they had "entered into non-binding heads of terms intended to strengthen their existing network sharing partnership". The two MNOs plan to extend the existing network-sharing partnership term and include 5G at joint radio network sites.
BT/EE	• On May 15, 2018, BT/EE stated[464] that it could have a "commercial [5G] product launched in the next 18 months"

459 See https://www.ofcom.org.uk/__data/assets/pdf_file/0014/104702/5G-spectrum-access-at-26-GHz.pdf

460 We note that only the 26GHz and 66–71GHz bands are referenced in Ofcom's March 2018 'Enabling 5G in the UK' paper.

461 See https://www.ofcom.org.uk/manage-your-licence/radiocommunication-licences/non-operational-licences

462 See https://5g.co.uk/o2/

463 See https://www.telefonica.com/es/web/press-office/-/telefonica-and-vodafone-to-strengthen-their-network-partnership-in-the-uk-with-5g-sharing

464 See https://www.ispreview.co.uk/index.php/2018/05/bt-and-ee-aiming-to-uk-launch-commercial-5g-mobile-in-2019.html

MNO	Details of 5G commercial deployment plans
	• On September 11, 2018, BT/EE announced[465] that its commercial 5G network would launch in 2019 • On November 13, 2018, BT/EE announced[466] that it is switching on 5G sites in 16 UK cities in 2019, with the first launch cities being the UK's four capital cities, Manchester and Birmingham. BT/EE states that it "will launch with multiple smartphone partners, as well as an EE 5G Home router with external antenna [for FWA services]". The announcement notes that "the first 1,500 sites that EE is upgrading to 5G in 2019 carry 25% of all data across the whole network, but only cover 15% of the UK population… EE is upgrading transmission to 10Gbps links at each 5G site" • On December 5, 2018, BT/EE announced a partnership with OnePlus to deliver a 5G smartphone in 2019.
Vodafone	• On June 20, 2018, Vodafone announced[467] seven cities[468] that will become 5G trial areas, with roll-outs starting between October and December 2018. Vodafone stated that "discussions with a number of enterprise customers are also underway, with a view to testing new 5G applications such as augmented and virtual reality in offices, factories and hospitals" • On September 20, 2018, Vodafone announced[469] that two areas in the UK (Cornwall and the Lake District) would receive 5G during 2019, and that it would have installed 1000 5G sites by 2020 • On October 25, 2018, Vodafone claimed[470] to have switched on the UK's first full 5G site (in Salford, Greater Manchester), using massive MIMO technology at 3.4GHz • On January 23, 2019, Vodafone and O2 announced the extension of their existing network-sharing partnership to 5G (see above) • On March 7, 2019, Vodafone announced[471] a list of twelve additional cities[472] in which 5G would be launched during 2019.
Three	• On July 9, 2018, Three stated[473] that initial deployments of 5G services "are expected to begin in H2 2019 when the first 5G capable handsets and home broadband devices are released by manufacturers" • On November 7, 2018, Three announced[474] that it had "completed a number of key steps" in preparing its network for 5G, as part of a wider GBP2+billion infrastructure investment program. These include deploying a 5G-ready "fully integrated cloud native core network" and rolling out CA technology to 2,500 sites. Three described itself as "well positioned to bring… 5G to customers in 2019" and noted that the first commercial 5G smartphone and home broadband devices are expected in H2 2019

465 See https://newsroom.ee.co.uk/ee-turns-3g-into-4g-to-boost-smartphone-speeds-and-lay-foundation-for-5g-launch-in-2019/

466 See https://newsroom.ee.co.uk/ee-announces-5g-launch-locations-for-2019/

467 See https://mediacentre.vodafone.co.uk/news/5g-trial-seven-cities/

468 Birmingham, Bristol, Cardiff, Glasgow, Liverpool, London, and Manchester.

469 See https://mediacentre.vodafone.co.uk/news/vodafone-makes-uks-first-holographic-call-using-5g/

470 See https://mediacentre.vodafone.co.uk/news/vodafone-first-full-5g-in-the-uk/

471 See https://mediacentre.vodafone.co.uk/news/5g-in-19-cities-during-2019/

472 Birkenhead, Blackpool, Bournemouth, Guildford, Newbury, Portsmouth, Plymouth, Reading, Southampton, Stoke-on-Trent, Warrington and Wolverhampton.

473 See http://www.threemediacentre.co.uk/news/2018/sse-unbundling-announcement.aspx

474 See http://www.threemediacentre.co.uk/news/2018/three-UK-committed-to-invest-into-5g.aspx

MNO	Details of 5G commercial deployment plans
	• On November 20, 2018, a report on 5G FWA (commissioned by Three) was published[475] entitled '5G Wireless Home Broadband: A Credible Alternative to Fixed Broadband'.

B.13.4 National strategies/government support

As described in our previous report, on March 8, 2017, DCMS published[476] a strategy paper for 5G in the UK. The strategy outlined a number of "key themes that will determine our progress toward 5G".[477]

On November 28, 2017, DCMS launched[478] its 'Future Telecoms Infrastructure Review' (the Review) of the UK telecom markets, in order to investigate "how it can support investment in the world-class connectivity of the future [full fiber and 5G]". The findings of the Review were published[479] on July 23, 2018, and set out targets "to see 15 million premises connected to full fibre by 2025, with coverage across all parts of the country by 2033" and for "the majority of the population to have 5G coverage by 2027". The Review identified four priority areas[480] to help foster a competitive mobile market and support investment in 5G:

- Make it easier and cheaper to deploy mobile infrastructure and support market expansion, including the implementation of the wide-ranging reforms to the Electronic Communications Code (ECC) on site access and consideration of further planning reforms.
- Support the growth of infrastructure models that promote competition and investment in network densification and extension.
- Fund beneficial 5G-enabled use cases through the government's 5G Testbeds and Trials (5GTT) program (see below), to help de-risk business models for 5G.
- Promote new, innovative 5G services from existing and new players, through the release and authorization of additional spectrum.

475 See http://www.threemediacentre.co.uk/~/media/Files/T/Three-Media-Centre/documents/5g-wireless-home-broadband-predicted-to-double-internet-speeds-for-uk-households.pdf

476 'Next Generation Mobile Technologies: A 5G strategy for the UK '. This was informed by two major reports commissioned by the government: (1) in December 2016, the National Infrastructure Commission (NIC) set out its recommendations on steps that the UK should take to become a world leader in the deployment of 5G telecommunications networks, and (2) in January 2017, the Future Communications Challenge Group (FCCG), established by DCMS, provided advice on how the UK could become a world leader in the development of 5G telecommunications networks. See https://www.gov.uk/government/publications/next-generation-mobile-technologies-a-5g-strategy-for-the-uk

477 In particular, 'building the economic case', fit-for-purpose regulations, local areas – governance and capability, coverage and capacity – convergence and the road to 5G, ensuring a safe and secure deployment of 5G, spectrum and technology and standards.

478 See https://www.gov.uk/government/news/government-launches-review-into-future-telecoms-infrastructure-investment

479 See https://www.gov.uk/government/publications/future-telecoms-infrastructure-review

480 See also the five 'actions' being taken by Ofcom to enable 5G roll-out, as listed in its 'Enabling 5G in the UK' document, published on March 9, 2018. See https://www.ofcom.org.uk/spectrum/information/innovation-licensing/enabling-5g-uk

To contribute to the implementation of the Review's measures, in December 2018 DCMS launched[481] a "digital connectivity portal". The portal provides "guidance for local authorities and network providers on improving connectivity in local areas". The UK government has also created the "Barrier Busting Task Force" to identify barriers to network deployment and is implementing recommendations of the Broadband Stakeholder Group (BSG). Further details are provided in Section 5.1.

Most recently, in February 2019, DCMS published[482] its 'Statement of Strategic Priorities for telecommunications, the management of radio spectrum and postal services'. The document "reiterates the importance of ensuring that market conditions are conducive to 5G investment, and considering flexible spectrum models to support innovation and coverage".

The UK government has made a number of commitments to invest in 5G technology:

- The 2016 Autumn Statement announced[483] that the government would invest over GBP1 billion by 2020–2021 in digital communications, including GBP740 million through the NPIF (National Productivity Investment Fund) targeted at supporting the roll-out of full fiber and 5G.
- The 2017 Budget confirmed the GBP740 million commitment,[484] and announced[485] specific plans to allocate GBP160 million from the NPIF to a '5G testbeds and trials' (5GTT) program.
  - Subsequent government announcements[486] have clarified that the total 5GTT funding is GBP200 million.
  - The budget states that initial projects to benefit from the investment include: (1) GBP10 million to create facilities for 5G network security testing, and (2) GBP5 million for an initial trial, starting in 2018, to test 5G applications and deployment on roads, including testing benefits of self-driving cars.[487]

481 See https://www.gov.uk/guidance/digital-connectivity-portal

482 See https://www.gov.uk/government/consultations/public-consultation-on-the-statement-of-strategic-priorities

483 See https://www.gov.uk/government/publications/autumn-statement-2016-documents/autumn-statement-2016

484 The 2017 Budget also states that it "commits GBP385 million to projects to develop next generation 5G mobile and full-fiber broadband networks, both funded from the NPIF". See also the "Industrial Strategy: building a Britain fit for the future" policy paper published on November 27, 2017.

485 See https://www.gov.uk/government/publications/autumn-budget-2017-documents/autumn-budget-2017

486 For example, see https://www.gov.uk/government/publications/5g-testbeds-trials-programme-update

487 As part of the GBP5 million for the development of 5G applications on roads, we understand that a feasibility study was completed in December 2018, with a review of the pilot proposal to be completed by March 31, 2019. See September 2018 update of 5GTT program.

- The first allocation of 5GTT funding was announced[488] on July 6, 2017. GBP16 million was allocated to 5GUK,[489] a collaboration across three UK universities (King's College London and the Universities of Surrey and Bristol) to develop a 5G test network and conduct end-to-end trials. The trials were completed[490] in March 2018

- From October 23, 2017, to December 6, 2017, DCMS ran a competition[491] to allocate its "first phase" of 5GTT funding (GBP25 million from the NPIF). The grants are for initial projects across the UK that will run from April 1, 2018, until March 31, 2019. Recipients of the grants were announced[492] by the government in March 2018.

- On March 30, 2018, DCMS announced[493] plans to fund a "5G Urban Connected Communities project" across a "large-scale urban area" in the UK as part of the 5GTT program. On September 4, 2018, DCMS announced that the West Midlands had been selected as the location for the project, with hubs to be deployed in Birmingham, Coventry and Wolverhampton. DCMS states that GBP50 million is currently available for the project (GBP25 million of which is provided by DCMS from the NPIF, and the remaining GBP25 million is provided by regional partners); a further GBP25 million may be available at a later date.

- On September 10, 2018, DCMS published[494] an update of the 5GTT program. This update provides a number of details on the different government-supported 5G projects taking place in the UK. It also references the UK5G Innovation Network,[495] which was launched in March 2018. UK5G is a DCMS-funded "national innovation network dedicated to the promotion of research, collaboration and the commercial application of 5G".

- The 2017 budget also announced (an additional) GBP35 million of funding for the Local Full Fibre Networks (LFFN) program, 5GTT and Network Rail (NR) to enable trials to improve mobile communications for rail passengers.[496] A call for expressions of interest was published[497] by DCMS on August 17, 2018.

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488 See https://www.gov.uk/government/news/three-universities-to-develop-16m-5g-test-network

489 See http://www.bristol.ac.uk/engineering/research/smart/projects/uk-5g/

490 DCMS's 5GTT update, published in September 2018, notes that "the 5GUK test network is now open for business and is being used to trial further 5G applications and technologies. This includes our Phase 1 projects, and over 25 further projects".

491 See https://apply-for-innovation-funding.service.gov.uk/competition/46/overview

492 See https://www.gov.uk/government/news/25m-for-5g-projects-on-the-anniversary-of-the-uks-digital-strategy, and https://www.totaltele.com/499595/UK-government-awards-25m-in-funding-to-six-5G-projects

493 See https://www.gov.uk/government/publications/5g-urban-connected-communities-project#history

494 See https://www.gov.uk/government/publications/5g-testbeds-trials-programme-update

495 See https://uk5g.org/

496 Specifically, the funding will be used to: upgrade a portion of the Network Rail test track, install trackside infrastructure along a portion of the Trans-Pennine route, and support the roll-out of full fiber and 5G networks.

497 See https://www.gov.uk/government/news/trans-pennine-railway-5g-trial

B.13.5 Outlook

Our 5G outlook/assessment for the UK is summarized in Figure B.48 below.

Figure B.48: 5G outlook for the UK [Source: Analysys Mason, 2019]

Metric	Description	Score
1. Industry commitment to 5G launch	• Most MNOs have confirmed plans to launch in 2019	3/4
2. Low-band spectrum	• 647MHz of spectrum currently released • 700MHz band to be awarded in 2020	4/4
3. Mid-band spectrum	• 270MHz of spectrum currently released • Further 120MHz to be awarded in 2020	3/4
4. High-band spectrum	• No high-band spectrum currently released • Spectrum within the 26GHz to be released; approach/timeline not yet confirmed	0/4
5. Total spectrum	• Strong performance in low- and mid-band spectrum. High-band spectrum yet to be confirmed	2/4
6. National strategies/government support	• GBP200 million of government funding for testbeds and trials • Revisions to legislation to simplify infrastructure deployment; government has also established a taskforce to identify and reduce further barriers	3/4

B.14 US

The Federal Communications Commission (FCC) regulates interstate and international communications in the US and has responsibility for spectrum assignment and management. An independent US government agency overseen by Congress, the FCC is the federal agency responsible for implementing and enforcing US communications law and regulations. In July 2016, the FCC adopted new rules that authorize around 11GHz of high-range spectrum for flexible, mobile and fixed use: 27.5–28.3, 37–38.6, 38.6–40GHz (licensed), and 64–71GHz (unlicensed). An auction of spectrum in the 37, 39, and 47GHz bands is widely expected to take place during 2019. The FCC is in the process of releasing the CBRS band (3550–3700MHz) for shared/licensed wireless broadband use and is exploring other mid-range bands (e.g., 3.7-4.2GHz). All the major MNOs have conducted 5G trials and two operators (Verizon and AT&T) announced that they had launched commercial 5G services in 2018. All four nationwide operators are planning significant 5G deployments in 2019, as well as sub-national operator US Cellular.

B.14.1 Current spectrum holdings

Low-band spectrum

As shown in Figure B.50 below, 716MHz of low-band spectrum is currently allocated to commercial mobile services in the US.

Figure B.49: Current low-band spectrum[498] allocated to commercial mobile services in the US, MHz [Source: FCC's First Communications Marketplace Report[499], December 2018]

MNO	600	700	Cell.	SMR	PCS	H-blk.	AWS1	AWS3	AWS4	WCS	BRS	EBS	Tot.
Total	70	70	50	14	130	10	90	65	40	20	67.5	89	715.5

Note: spectrum is allocated in the US on a regional basis. Holdings shown are population weighted averages.

Figure B.50 below shows the population-weighted average low-band spectrum holdings of the major operators in the US.[500]

498 Abbreviations for spectrum bands: Cell. (Cellular), SMR (Specialized Mobile Radio Service), PCS (Personal Communications Service), AWS (Advanced Wireless Service) WCS (Wireless Communications Service), BRS (Broadband Radio Service), and EBS (Educational Broadband Service).

499 See https://docs.fcc.gov/public/attachments/FCC-18-181A1.pdf. Values shown are from Fig. A-23 of this document (*Spectrum Included in the Spectrum Screen*). As described in the footnote to Fig. A-23, a total of 122.5MHz is nominally available in the EBS band, however this is discounted to 89MHz for the FCC Spectrum Screen.

500 We note that spectrum holdings summed across all operators (Figure B.50) is more than the total amount allocated to mobile (Figure B.49) in certain bands. This is the case in the *FCC's First Communications Marketplace Report*. We have used the numbers from Figure B.49 (i.e. total spectrum allocated to mobile) for our analysis in Section 4.

Figure B.50: Current low-band spectrum holdings of the major US operators, MHz [Source: FCC's First Communications Marketplace Report[501], December 2018[502]]

MNO	600	700	Cell.	SMR	PCS	H-blk.	AWS1	AWS3	AWS4	WCS	BRS	EBS	Tot.
AT&T	2.6	29.4	23.6	-	37.9	-	14.6	20.3	-	20	-	-	**148.4**
Sprint	-	0.3	-	13.8	37.7	-	-	-	-	-	62.9	85.2	**199.9**
T-Mobile	30.8	10	-	-	29	-	37	3.3	-	-	-	-	**110.1**
Verizon	-	21.7	25.2	-	21.6	-	35.7	11.5	-	-	-	-	**115.7**
US Cell.[503]	1.8	2.5	2.1	-	1.4	-	0.7	1.6	-	-	-	-	**10.1**
DISH[504]	17.8	4.6	-	-	-	10	-	21.1	40	-	-	-	**93.5**
Other[505]	14.9	1.6	2	0.5	2.6	-	2	3	-	-	4.6	3.8	**35**
Total	**67.9**	**70.1**	**52.9**	**14.3**	**130.2**	**10**	**90**	**60.8**	**40**	**20**	**67.5**	**89**	**712.7**

Note: spectrum is allocated in the US on a regional basis. Holdings shown are population weighted averages.

Mid-band spectrum

No mid-band spectrum is currently available for commercial mobile services in the US. As discussed in the following section, unlicensed access to mid-band spectrum in the CBRS band is expected in H1 2019, with a licensed spectrum auction likely in H2 2019.

High-band spectrum

Several of the major MNOs have acquired companies holding high-frequency spectrum suitable for the provision of mobile services:

501 See https://docs.fcc.gov/public/attachments/FCC-18-181A1.pdf. Values shown are from Fig. A-25 of this document (*Population-Weighted Average Megahertz Holdings by Licensee, by Frequency Band*) and are estimates as of August 2018.

502 The source may not be adjusted for recent spectrum transactions (e.g. https://www.fiercewireless.com/wireless/at-t-looks-to-sell-600-mhz-spectrum-to-lb-license-co-for-nearly-1b and https://www.lightreading.com/mobile/5g/atandt-is-collecting-lots-of-700mhz-spectrum-licenses-possibly-for-5g/d/d-id/749991). Note: slight discrepancy with other sources, e.g. Macquarie Research report 'A Global View of Spectrum' (June 8, 2017) (see https://www.scribd.com/document/358684577/2017-Jun-Macquiare-Bank-Global-View-on-Spectrum), Sprint (see http://newsroom.sprint.com/in-land-wireless-spectrum-is-king.htm), and Allnet Insights & Analytics (see https://www.fiercewireless.com/wireless/25-charts-spectrum-ownership-united-states)

503 US Cellular is the fifth largest MNO in the US market, currently operating in 23 states (see https://www.uscellular.com/uscellular/support/faq/faqDetails.jsp?topic=press-room.html)

504 DISH Network, a satellite broadcaster, owns a significant amount of mobile spectrum, however it does not currently offer mobile services.

505 Smaller MNOs include C Spire Wireless, Shentel, and others. Cable player Comcast and a number of other non-mobile players also own mobile spectrum.

- Verizon acquired XO Communications in February 2017,[506] and then in May 2017 acquired Straight Path Communications in an all-stock deal worth USD3.1 billion.[507] Both XO and Straight Path hold licenses in the 28GHz (27.5–28.35GHz) and 39GHz (38.6–40GHz) bands.

- AT&T acquired FiberTower in February 2017.[508] FiberTower held spectrum licenses (across a number of regions) in the 24GHz (24.25–24.45GHz and 24.75–25.25GHz) and 39GHz bands, but in January 2018 the FCC took back[509] all its 24GHz licenses and some of its 39GHz licenses.

- T-Mobile acquired MetroPCS in October 2012. MetroPCS held licenses in the 28GHz and 39GHz bands.[510] More recently, in February 2018, news reports[511] stated that T-Mobile was applying for permission to buy around 1150MHz of LMDS spectrum (28–31GHz) in Ohio, which the MNO said it plans to use for 5G. We understand that the application was approved by the FCC in September 2018.

As a consequence of such transactions, 76% of the 28GHz band (on a MHz-pop basis[512]) and 68% of the 39GHz band (on a MHz-pop basis[513]) have been assigned to licensees.

On January 24, 2019, the FCC completed[514] an auction of the remaining 24% of the 28GHz band, raising a total of USD702 million; and SMRA format was used. Two 425MHz licenses (with a duration of 10 years) were offered in each county where the spectrum was not already assigned (a total of 1536 counties). The winning bidders will be announced upon completion of the 24GHz auction, which is currently ongoing (see Annex B.14.2).

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506 Permission from the FCC for the acquisition appears to have been granted in November 2016, and an article published on February 1, 2017, by PR Newswire confirmed the acquisition had taken place; see http://www.prnewswire.com/news-releases/verizon-completes-purchase-of-xo-communications-fiber-business-300400440.html. For details of XO's spectrum licenses, see https://www.fiercewireless.com/wireless/verizon-to-gain-180-billion-mhz-pops-millimeter-wave-spectrum-through-xo-transaction

507 Straight Path holds an average of 620MHz in the top 30 US markets and covers the entire nation with 39GHz spectrum. It has retained all its 28GHz spectrum licenses. See http://www.fiercewireless.com/wireless/verizon-to-acquire-straight-path-for-3-1b-ending-bidding-war-at-t

508 FiberTower, which had filed for bankruptcy, had spectrum in the 24GHz and 39GHz bands covering 30 billion MHz POPs, according to Wells Fargo Securities and AllNet Insights. FiberTower (First Avenue Networks, Inc.) acquired 24GHz spectrum in the FCC's auction 56 in 2004. See http://www.fiercewireless.com/wireless/at-t-quietly-acquires-fibertower-for-24-39-ghz-spectrum. On January 26, 2018, the FCC announced FiberTower must return hundreds of mm-wave spectrum licenses (in both the 24GHz and 39GHz bands) to the NRA. AT&T will acquire ~500 licenses in the 39GHz band, but none in the 24GHz band; see https://www.fcc.gov/document/fibertower-spectrum-holdings-llc

509 See https://www.fiercewireless.com/wireless/at-t-to-lose-hundreds-5g-millimeter-wave-spectrum-licenses-as-part-fcc-fibertower and https://www.fcc.gov/document/fibertower-spectrum-holdings-llc

510 See https://www.fiercewireless.com/tech/analyst-t-mobile-s-28-39-ghz-spectrum-could-give-it-advantage-5g-trials

511 See https://www.fiercewireless.com/wireless/t-mobile-buys-1150-mhz-millimeter-wave-spectrum-covering-ohio-for-5g

512 See https://www.fcc.gov/auction/101

513 Around 40% of the 39GHz band is licensed to Verizon, and around 27% to AT&T. A small number of licenses are also held by T-Mobile and other players. See https://docs.fcc.gov/public/attachments/FCC-18-110A1.pdf (paragraphs 3 to 6). See also https://ecfsapi.fcc.gov/file/10214044930219/T-Mobile%20Ex%20Parte%2002142018.pdf

514 See https://www.fcc.gov/auction/101

As discussed in Annex B.14.2, the remaining 32% of the 39GHz band, as well as the 37GHz and 47GHz bands, is scheduled to be auctioned by the FCC in H2 2019.

B.14.2 Main 5G spectrum proposals

Low-band spectrum[515]

In August 2017, the US Congress introduced legislation identifying the 1300–1350MHz and 1780–1830MHz bands as candidates for reallocation to non-federal use, and directing the National Telecommunications and Information Administration (NTIA) to submit a report to Congress on relocating incumbent federal users from those bands.[516]

On May 10, 2018, the FCC adopted[517] an NPRM to consider updating the framework for licensing Educational Broadband Service (EBS[518]) spectrum in the 2.6GHz band (2496–2690MHz). The FCC stated that "EBS spectrum… currently lies fallow across approximately one-half of the US, primarily in rural areas. Moreover, access to this spectrum has been strictly limited since 1995, and current licensees are subject to outdated regulations. The NPRM proposes to modernize and rationalize the EBS spectrum in the 2.6GHz band to allow more flexible use [including for 5G]".

Furthermore, the Spectrum Pipeline Act[519] requires NTIA to identify for auction 30MHz of federal spectrum below 3GHz by 2022, and to identify an additional 100MHz beyond that. As part of this effort, NTIA, along with the Office of Management and Budget (OMB) and the FCC, has begun evaluating proposed "pipeline plans" submitted by federal agencies. Two have been approved and funded: the 1300–1350MHz and 1675–1680MHz bands. NTIA states that "additional pipeline plans are under review or are being prepared". [520]

Most recently, on February 22, 2019, the FCC published[521] an NPRM which proposes to reconfigure the 900MHz (896–901/935–940MHz) band, which is currently designated for narrowband private land mobile radio (PLMR) communications, for wireless broadband use.

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515 In addition to the potential further spectrum assignments discussed, the FCC is also acting to implement changes in the 800MHz and 900MHz bands to improve efficiency for 5G use. See https://docs.fcc.gov/public/attachments/DOC-354326A1.pdf and https://www.fcc.gov/document/900-mhz-notice-inquiry

516 See http://docs.house.gov/meetings/IF/IF16/20171116/106636/HHRG-115-IF16-20171116-SD005-U5.pdf

517 See https://www.fcc.gov/document/fcc-seeks-transform-25-ghz-band-nextgen-5g-connectivity

518 The 2.6GHz band is divided into two radio services, Educational Broadband Services (EBS) and Broadband Radio Service (BRS). The 2.6GHz band consists of thirty-three 5.5MHz or 6.0MHz channels, of which twenty are for EBS and thirteen are for BRS. See https://selectspectrum.com/EBS_BRS.html

519 See https://www.congress.gov/bill/114th-congress/house-bill/1314

520 See https://www.ntia.doc.gov/speechtestimony/2018/remarks-assistant-secretary-redl-ctias-race-5g-summit

521 See https://docs.fcc.gov/public/attachments/DOC-356298A1.pdf

Mid-band spectrum

The FCC is in the process of releasing the citizens broadband radio service (CBRS) band (3550–3700MHz) for shared wireless broadband use.[522] The band is governed by a three-tier authorization framework that allows commercial users to share spectrum with existing federal and non-federal users:

- Tier 1 consists of incumbent users[523] (primarily the US military), which have top priority.
- Tier 2 consists of priority access licenses (PALs), which will be granted for a fee (via an auction). A maximum of seven PALs, each 10MHz in size, will be licensed in any given geographical area in the bottom 3550–3650MHz range. Use of these bands can be pre-empted by Tier 1 users.
- Tier 3 users have general authorized access (GAA) – opportunistic use of any available block in the 3550–3700MHz band without a defined license term.

On October 23, 2018, the FCC adopted[524] revised rules governing the PALs, including[525] larger license areas (counties) and longer license terms (10 years). The changes are intended to "help ensure the rapid deployment of advanced wireless technologies – including 5G – in the US". PALs are expected to be auctioned at the end of 2019.

On December 12, 2018, NTIA announced[526] that it had completed certification testing of certain CBRS equipment.[527] We understand that use of GAA spectrum can begin as soon as all the necessary equipment and spectrum management databases have been certified,[528] which is expected in H1 2019.

Beyond the CBRS band, the FCC is considering assignment of mid-band spectrum for mobile use in several other bands. On August 3, 2017, the FCC issued[529] an NOI entitled "Exploring Flexible Use in Mid-Band Spectrum Between 3.7 GHz and 24 GHz". The NOI consults on three specific

522 See https://www.fcc.gov/rulemaking/12-354#block-menu-block-4 for an index of FCC CBRS documentation.

523 Tier 1 incumbent users mainly use these bands for naval radar applications in coastal areas, so this capacity remains largely unused in inland areas.

524 See https://www.fcc.gov/document/fcc-acts-increase-investment-and-deployment-35-ghz-band-0

525 The revised rules also included changes to renewability and performance requirements, as well as changes to the bidding rules for the PAL auction and to the ability to partition and disaggregate areas within PALs.

526 See https://www.ntia.doc.gov/blog/2018/its-marks-next-milestone-toward-spectrum-sharing-35-ghz

527 In particular, the Environmental Sensing Capability (ESC) equipment – the sensors that will help enable dynamic sharing between US Navy radars and CBRS devices.

528 See https://www.ntia.doc.gov/blog/2018/moving-closer-making-spectrum-sharing-35-ghz-reality

529 See http://transition.fcc.gov/Daily_Releases/Daily_Business/2017/db0713/DOC-345789A1.pdf and https://commlawmonitor2.lexblogplatformthree.com/wp-content/uploads/sites/512/2017/08/Mid-Band-Spectum-NOI.pdf

mid-range bands (3.7–4.2GHz, 5.925–6.425GHz, and 6.425–7.125GHz) for 'expanded flexible use' and seeks comment on further bands between 3.7GHz and 24GHz which might also be suitable.

- On July 13, 2018, the FCC issued[530] an NPRM seeking comment on repurposing the 3.7–4.2GHz band for flexible use, including mobile broadband. The NPRM seeks comment on various proposals for transitioning part or all of the band for flexible use, including market-based, auction, and alternative mechanisms.[531]

- On October 23, 2018, the FCC issued[532] an NPRM proposing rules to allow unlicensed use (e.g. for Wi-Fi and other unlicensed standards) to make use of up to 1200MHz in the 6GHz band (5.925–7.125GHz).

Finally, on February 26, 2018, NTIA, in co-ordination with the Department of Defense (DOD) and other federal agencies, announced[533] that it had identified 100MHz (3450–3550MHz) for "potential repurposing to… commercial wireless". The "DOD plans to submit a proposal under the Spectrum Pipeline Act to carry out a comprehensive radio-frequency engineering study to determine the potential for introducing advanced wireless services in this band (which is currently used for military radar) without harming critical government operations".[534]

High-band spectrum

In July 2016, the FCC published[535] an R&O[536] adopting new rules to authorize 10.85GHz of high-band spectrum. Upper Microwave Flexible Use Service (UMFUS) rules were adopted for three licensed bands (28GHz, upper 37GHz, and 39GHz[537]) and operations were authorized in 7GHz of

530 See https://www.fcc.gov/document/fcc-expands-flexible-use-mid-band-spectrum

Alongside the NPRM, the FCC also issued an Order which required Fixed Satellite Service earth stations operating in the 3.7–4.2GHz band to certify the accuracy of existing registration and license information. The Order will also collect additional information from space station licensees on their operations in the band to assist the Commission in developing a clearer understanding of how the band is currently being used.

531 We note that, in February 2019, the FCC granted AT&T test licenses (from May 2019 to May 2021) for the 3.4–3.6GHz and 3.7–4.2GHz bands (as well as other bands). The licenses are for AT&T's lab in Texas; conditions stipulate that AT&T "must coordinate with all earth station operating in the 3650-4200MHz band". See https://apps.fcc.gov/els/GetAtt.html?id=222920&x=.

532 See https://transition.fcc.gov/oet/ea/presentations/files/oct18/3.1-Rulemakings-JSP.PDF

533 See https://www.ntia.doc.gov/blog/2018/ntia-identifies-3450-3550-mhz-study-potential-band-wireless-broadband-use. The "DOD plans to submit a proposal under the Spectrum Pipeline Act to carry out a comprehensive radio-frequency engineering study to determine the potential for introducing advanced wireless services in this band [which is currently used for military radar] without harming critical government operations".

534 We note that on December 20, 2018, NTIA published a 'Request for Comments on Developing a Sustainable Spectrum Strategy for America's Future'. The comments received were published on January 29, 2019. See https://www.ntia.doc.gov/federal-register-notice/2019/comments-developing-sustainable-spectrum-strategy-america-s-future

535 See https://www.fcc.gov/document/spectrum-frontiers-ro-and-fnprm

536 (F)NPRM = (Further) Notice of proposed rulemaking, R&O = Report and order. See https://www.fcc.gov/general/rulemaking-fcc for full explanation.

537 I.e. 27.5–28.35GHz (28GHz), 37–38.6GHz (37GHz), and 38.6–40GHz (39GHz). Note the 37GHz band is sub-divided into the lower 37GHz band (37–37.6GHz) and the upper 37 band (37.6–38.6GHz).

unlicensed spectrum (64–71GHz).[538] The FCC also issued an FNPRM, seeking comment on applying the flexible use service and technical rules adopted in the R&O to another 18GHz of spectrum encompassing eight additional high-frequency bands.[539]

On November 16, 2017, the FCC voted[540] through a second R&O and second FNPRM, expanding the UMFUS rules to cover an additional 1.7GHz of high-band spectrum (700MHz in the 24GHz band and 1GHz in the 47GHz band).[541]

As discussed in Annex B.14.1, the auction of the 28GHz band was completed on January 24, 2019; the auction of the 24GHz band is currently ongoing.[542]

On May 17, 2018, the FCC published[543] a third R&O and third FNPRM, further developing preparations for 5G in high-frequency spectrum bands. The FNPRM sought comment on co-ordination mechanisms for sharing the lower 37GHz band between federal and non-federal users.[544] The FNPRM also sought comment on making the 26GHz band (25.25–27.5GHz) available for flexible fixed and mobile use, and on how the 42GHz band (42.0–42.5GHz) could be used for commercial wireless broadband services.

On August 2, 2018, the FCC published[545] a fourth FNPRM, seeking comment on proposals for the upper 37GHz, 39GHz, and 47GHz bands (a total bandwidth of 3.4GHz). On December 12, 2018, the FCC published[546] its fourth R&O, adopting rules for the auction of these bands; the auction is scheduled to take place in the second half of 2019. Spectrum in the 37GHz and 47GHz bands will be auctioned (on a regional basis) across the entire US. However, only approximately one-third of the 39GHz band (measured in MHz-pop) will be available for auction; around 40% of the 39GHz

538 The unlicensed 64–71GHz band is adjacent to the 57–64GHz band, which is already unlicensed, resulting in a continuous unlicensed band of 14GHz.

539 Namely: 24.25–24.45GHz together with 24.75–25.25GHz (24GHz band), 31.8–33GHz (32GHz band), 42–42.5GHz (42GHz band), 47.2–50.2GHz (47GHz band), 50.4–52.6GHz (50GHz band), 71–76GHz band together with the 81–86GHz bands (70/80GHz bands), and bands above 95GHz. As described above, the 24GHz band and a 1GHz portion of the 47GHz band have been identified for mobile. On February 22, 2018, the FCC issued an NPRM on spectrum above 95GHz for new services and technologies. See https://www.fcc.gov/document/fcc-proposes-open-spectrum-horizons-new-services-technologies

540 See https://www.fcc.gov/document/fcc-takes-next-steps-facilitate-spectrum-frontiers

541 I.e. the 24.25–24.45 and 24.75–25.25GHz bands (24GHz band) and the 47.2–48.2GHz (47GHz) band.

542 A clock auction format will be used; seven 100MHz licenses will be available in each Partial Economic Area (PEA). On January 31, 2019, the FCC announced that the 24GHz auction would begin on March 14, 2019. See https://www.fcc.gov/document/auction-102-upfront-payment-deadline-and-bidding-start-date-announced

543 See https://docs.fcc.gov/public/attachments/DOC-350768A1.pdf

544 The FCC has stated that it is committed to working with NTIA and other federal agencies to develop a sharing approach in 2019.

545 See https://www.fcc.gov/document/fcc-proposes-steps-towards-auction-37-ghz-39-ghz-and-47-ghz-bands-0

546 See https://www.fcc.gov/document/fcc-adopts-rules-major-2019-5g-incentive-auction

band is already licensed to Verizon, and around 27% to AT&T (with a small number of 39GHz licenses also held by T-Mobile and other players[547]).

On March 15, 2019, the FCC adopted[548] an R&O to expand access to spectrum above 95GHz in its 'Spectrum Horizons' program for new services and technologies. The R&O makes a total of 21.2GHz of spectrum available for use by unlicensed devices, and creates a new category of experimental licenses for use of frequencies between 95GHz and 3THz.

B.14.3 MNOs' 5G commercial deployment plans

Figure B.51 outlines 5G commercial deployment plans announced by the major MNOs in the US:

Figure B.51: Announcements of 5G deployment plans by major MNOs in the US [Source: MNO press releases]

MNO	Details of 5G commercial deployment plans
AT&T	• On October 26, 2018, AT&T unveiled[549] a standards-based mm-wave mobile 5G smartphone device, the NETGEAR Nighthawk 5G Mobile Hotspot, which uses the Qualcomm Snapdragon X50 5G modem. The device is to be made available exclusively for use on AT&T's mobile 5G network • On December 4, 2018, AT&T announced[550] plans for a second 3GPP-compliant mobile 5G device, to be developed with Samsung, which is scheduled to be made available in H1 2019 • On December 5, 2018, AT&T announced[551] plans for a third 3GPP-compliant mobile 5G device, to be developed with Samsung. The smartphone will be able to access both mm-wave and sub-6GHz spectrum, and is expected to be available in H2 2019 • On December 21, 2018, AT&T commercially launched a standards-based mobile 5G service, using mm-wave spectrum, in (parts of) 12 cities across the US: Atlanta, Charlotte (NC), Dallas, Houston, Indianapolis, Jacksonville (FL), Louisville (KY), Oklahoma City, New Orleans, Raleigh (NC), San Antonio, and Waco (TX) • AT&T's press release states:[552] "Through an initial offer, we'll deliver select businesses and consumers our first mobile 5G device [i.e. the Nighthawk] plus 5G data usage at no cost for at least 90 days. Next spring, customers will be able to get the Nighthawk for USD499 upfront and 15GB of data for USD70 a month on a compatible plan and no annual commitment" • AT&T said that: "In the first half of 2019 we plan to deploy mobile 5G in parts of these 7 additional cities: Las Vegas, Los Angeles, Nashville, Orlando, San Diego, San Francisco and San Jose, Calif". AT&T will announce additional markets individually as its 5G mobile network goes live in further locations[553] • In conjunction, AT&T is rolling out "5G Evolution" technology (256 QAM functionality, 4×4 MIMO, and tri-band CA) to prepare the way for 5G in other locations. An

547 See https://docs.fcc.gov/public/attachments/FCC-18-110A1.pdf (paragraphs 3 to 6) for further details. See also https://ecfsapi.fcc.gov/file/10214044930219/T-Mobile%20Ex%20Parte%2002142018.pdf

548 See https://www.fcc.gov/document/fcc-opens-spectrum-horizons-new-services-technologies

549 See https://about.att.com/newsroom/2018/first_5G_connection.html

550 See https://about.att.com/story/2018/5gdevice.html

551 See https://about.att.com/story/2018/5g_second_samsung_smartphone.html

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

553 See https://about.att.com/newsroom/2018/first_5G_connection.html

MNO	Details of 5G commercial deployment plans
	announcement[554] on December 20, 2018, states that 385 markets currently have the technology available, with plans to reach 400 by the year-end. On January 9, 2019, AT&T said[555] that it is aiming for nationwide coverage by Spring 2019 • On January 22, 2019 AT&T stated[556,557] that it aims to have a standards-based mobile 5G network nationwide in early 2020 (using sub-6GHz spectrum[558]). Regarding FWA, AT&T states that its existing FWA service would be upgradable to "take advantage of AT&T 5G when its available in their area".
Sprint	• On May 10, 2017, Sprint, Softbank (its Japanese parent), and Qualcomm announced[559] that they would develop 5G NR technology in Band 41 (2.5GHz). The company reaffirmed[560] this in a statement on December 21, 2017, after 3GPP announced the ratification of its NSA 5G NR specification (which includes the 2.6GHz band) • On February 2, 2018, Sprint held its fiscal Q3 2017 results call.[561] The MNO stated that it is working with Qualcomm and vendors to deliver 5G by H1 2019. The accompanying press release[562] provides further details of its 5G plans • On February 27, 2018, Sprint announced[563] plans to install Massive MIMO technology in six cities (Chicago, Dallas, and Los Angeles in April 2018, followed by Atlanta, Houston, and Washington, D.C. later in 2018). Sprint called the plans a "critical bridge" to its 5G network. • On April 29, 2018, T-Mobile and Sprint announced[564] that they had entered into an agreement to merge; the merger is awaiting regulatory approval. On June 18, 2018, T-Mobile filed[565] a Public Interest Statement with the FCC, which outlines the 5G plans of the proposed merged entity (see below for details) • On May 15, 2018, Sprint reaffirmed[566] its plan to launch commercial 5G services in H1 2019, and added three additional cities (New York City, Phoenix, and Kansas City) to its list of initial 5G locations

554 See https://about.att.com/innovationblog/2018/12/evolution_in_400_markets.html

555 See https://about.att.com/story/2019/2019_and_beyond.html

556 See https://about.att.com/story/2019/5g_business.html. For earlier statements on 5G FWA, see http://about.att.com/innovationblog/standardized_5g

557 See also a press release issued on January 9, 2018: https://about.att.com/story/2019/2019_and_beyond.html

558 Reports state that AT&T plans to use its 850MHz and 1900MHz spectrum to provide wide-area 5G coverage. See https://uk.pcmag.com/news/118720/qualcomm-expect-t-mobiles-600mhz-5g-network-later-in-2019

559 See http://newsroom.sprint.com/qualcomm-softbank-and-sprint-announce-collaboration-on-25-ghz-5g.htm

560 See http://investors.sprint.com/news-and-events/press-releases/press-release-details/2017/Sprints-25-GHz-Spectrum-Included-in-Non-Standalone-3GPP-5G-NR-Specification/default.aspx

561 See http://www.lightreading.com/mobile/5g/sprint-promises-mobile-5g-in-h1-2019-signals-more-job-cuts/d/d-id/740273

562 See http://s21.q4cdn.com/487940486/files/doc_financials/quarterly/2017/q3/01_Fiscal-3Q17-Earnings-Release-FINAL.pdf

563 See http://newsroom.sprint.com/sprint-unveils-5g-ready-massive-mimo-markets.htm

564 See https://www.youtube.com/watch?v=1nsbmtwMrgY&feature=youtu.be

565 See https://ecfsapi.fcc.gov/file/10618281006240/Public%20Interest%20Statement%20and%20Appendices%20A-J%20(Public%20Redacted)%20.pdf

566 See http://investors.sprint.com/news-and-events/press-releases/press-release-details/2018/Sprint-Announces-New-York-City-Phoenix-and-Kansas-City-Among-First-to-Experience-Sprint-5G/default.aspx

MNO	Details of 5G commercial deployment plans
	• On August 14, 2018, Sprint announced[567] plans to introduce a mobile 5G smartphone in the US, in partnership with LG, in H1 2019 • On November 27, 2018, Sprint announced[568] that it is working with HTC to bring a "5G mobile smart hub" to the market in H1 2019. While this appears to be a mobile hotspot rather than an FWA device, Sprint has stated[569] that it will be suitable for "home internet access" and good enough to serve "small households, apartment dwellers, [and] even small businesses" for primary access • On February 24, 2019, Sprint announced[570] its first 5G smartphone, the LG V50 ThinQ 5G • On February 25, 2019, Sprint announced[571] that standards-based 5G is now "on-air" in parts of Chicago, with commercial mobile service expected to be launched in May.[572]
T-Mobile	• T-Mobile has stated[573] that it is targeting a nationwide 600MHz 5G network by 2020 • On February 27, 2018, at the MWC in Spain, T-Mobile announced[574] that it plans to build its 5G network (using 600MHz spectrum) in 30 cities in 2018. Customers in New York, Los Angeles, Dallas, and Las Vegas will be the first to experience the service, "when the first 5G smartphones launch early next year [i.e. 2019]". T-Mobile also plans to begin deploying 5G on mm-wave spectrum in 2018 • On April 29, 2018, T-Mobile and Sprint announced[575] that they had entered into an agreement to merge; the merger is awaiting regulatory approval • On June 18, 2018, T-Mobile filed[576] a Public Interest Statement with the FCC, which outlines the 5G plans of the proposed merged entity. T-Mobile's CEO stated:[577] "The combined company's 5G network will deliver mobile broadband speeds in excess of 100Mbps to roughly two-thirds of the population in just a few years and 90% of the country by 2024" and that "both in-home broadband services and mobile broadband" would be offered. In September 2018, T-Mobile stated[578] that the merged entity would look to offer in-home broadband to 52% of zip codes across the US by 2024

567 See https://newsroom.sprint.com/sprint-and-lg-working-together-to-bring-first-5g-smartphone-to-us-in-first-half-2019.htm

568 See https://newsroom.sprint.com/sprint-and-htc-announce-innovative-5g-mobile-smart-hub-coming-in-first-half-2019.htm?linkId=60241732

569 See https://uk.pcmag.com/news/118668/sprint-well-have-5g-home-internet-and-samsung-devices-too

570 See https://newsroom.sprint.com/sprints-first-5g-smartphone-lg-v50-thinq-5g-launches-this-spring.htm

571 See https://newsroom.sprint.com/sprint-announces-commercial-5g-service-to-launch-in-may-starting-in-chicago-atlanta-dallas-and-kansas-city.htm

572 Sprint's press release states: "Chicago, Atlanta, Dallas and Kansas City are expected to be among the first cities to offer commercial 5G service; with Houston, Los Angeles, New York City, Phoenix and Washington D.C. also slated to launch in the first half of 2019". At launch there will be "a total initial 5G coverage footprint of more than 1,000 square miles across all nine cities".

573 See https://newsroom.t-mobile.com/news-and-blogs/nationwide-5g-blog.htm. See also https://newsroom.t-mobile.com/news-and-blogs/nationwide-5g.htm

574 See https://newsroom.t-mobile.com/news-and-blogs/mwc-2018-5g.htm

575 See https://www.youtube.com/watch?v=1nsbmtwMrgY&feature=youtu.be

576 See https://ecfsapi.fcc.gov/file/10618281006240/Public%20Interest%20Statement%20and%20Appendices%20A-J%20(Public%20Redacted)%20.pdf

577 See https://www.t-mobile.com/content/t-mobile/corporate/news/articles/2018/06/taking-the-next-step-in-supercharging-the-un-carrier.html

578 See https://www.fiercewireless.com/5g/new-t-mobile-s-plans-for-home-fixed-wireless-internet-services-begin-to-take-shape

MNO	Details of 5G commercial deployment plans
	• On November 10, 2018, T-Mobile announced[579] that it had deployed 600MHz spectrum (for LTE) to 1,500 cities and towns in 37 states (and Puerto Rico). The announcement confirmed T-Mobile's ambition to achieve nationwide 5G coverage by 2020 using the 600MHz spectrum; "5G-ready" equipment is being deployed as the 600MHz LTE spectrum is rolled out.
Verizon	• On August 2, 2018, Verizon and Lenovo (Motorola) launched[580] a 5G-upgradable smartphone, the Moto Z3. The Moto Z3 can be made 5G-capable by magnetically attaching a separate modem module (the Moto Mod). The device is available for use exclusively with Verizon's 5G network in the US • On October 1, 2018, Verizon launched a commercial mm-wave 5G FWA service (called "Verizon 5G Home") in parts of Sacramento, Houston, Indianapolis, and Los Angeles • The press release[581] states that "Verizon Wireless customers with a qualifying smartphone plan will pay USD50 per month for the service, while non-Verizon. Wireless customers will pay USD70 per month… 5G Home customers will also get YouTube TV free for the first three months and a free Apple TV 4K or Google Chromecast Ultra device at installation." Certain perks are made available to early adopters ("First on 5G" members) • The service is based on Verizon's own proprietary standard 5G TF (Technical Forum). Verizon states that it did not want to wait for the "formal 3GPP 5G NR standard to be incorporated into network equipment, devices, chipsets and software". However, "when new network equipment is available and introduced, we'll expand our 5G broadband internet coverage area quickly and bring 5G to additional cities" • On December 3, 2018, Verizon announced[582] plans for a 5G smartphone, to be developed with Samsung, which is scheduled to be made available in H1 2019. The device (known as the Samsung Galaxy S10 5G[583]) will be powered by the Qualcomm Snapdragon X50 5G modem. The press release states: "Verizon 5G mobility service will go live in early 2019 and expand rapidly" • On February 21, 2019, Verizon announced[584] that it plans to launch a standards-based mobile 5G service (using mm-wave spectrum) in 30 cities by the end of 2019 • On February 24, 2019, Verizon announced[585] plans for a third 5G smartphone (the LG V50 ThinQ 5G) which it plans to make available in Summer 2019 • On March 13, 2019, Verizon announced[586] that 5G mobile services would be launched in two cities (Chicago and Minneapolis) on April 11, 2019, and began accepting (pre-) orders for the Moto Z3 and Moto Mod (see above).

579 See https://www.t-mobile.com/news/first-600mhz-5g-test. See also https://www.t-mobile.com/news/600-mhz-update-puerto-rico

580 See https://www.verizon.com/about/news/verizon-and-motorola-unveil-worlds-first-5g-upgradable-smartphone--moto-z3

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

582 See https://www.verizon.com/about/news/verizon-and-samsung-release-5g-smartphone-us-first-half-2019

583 See https://www.verizon.com/about/news/verizon-adds-third-5g-smartphone-2019

584 See https://www.theverge.com/2019/2/21/18234755/verizon-5g-30-cities-2019-launch

585 See https://www.verizon.com/about/news/verizon-adds-third-5g-smartphone-2019

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

B.14.4 National strategies/government support

As described in our last report, on July 15, 2016, the US government announced[587] the launch of the USD400 million Advanced Wireless Research Initiative (AWRI) led by the National Science Foundation (NSF). The AWRI includes:

- USD85 million investment in 'advanced wireless testing platforms' via a public-private partnership, including NSF and over 20 technology companies and associations.[588]
- Plans by NSF to invest an additional USD350 million over the next seven years in academic research that can use these testing platforms.
- A number of complementary efforts by other federal agencies were also announced.

Further details can be found in our previous report. However, we note that the AWRI is not a 5G-specific initiative. Rather, it is a longer-range NSF initiative with government sponsoring advanced wireless test beds for cutting-edge wireless technologies and use cases.

In September 2018, the FCC unveiled[589] its '5G FAST' plan, which includes the following three primary components:

- assignment of spectrum
- updating of infrastructure policy
- modernization of outdated regulation.

Measures adopted by the FCC to update infrastructure policy are discussed in Section 5.2. A list of areas in which the FCC is "modernizing outdated regulations" can be found on its website.[590] In addition, 21 states have enacted legislation aimed at accelerating small-cell deployment to date.[591]

Finally, we note that, on October 25, 2018, a "Presidential Memorandum on Developing a Sustainable Spectrum Strategy for America's Future" was issued.[592] The Memorandum states that the US government shall "continue to encourage investment and adoption by federal agencies of commercial, dual-use, or other advanced technologies that meet mission requirements, including 5G technologies".

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587 See https://obamawhitehouse.archives.gov/the-press-office/2016/07/15/fact-sheet-administration-announces-advanced-wireless-research

588 These include all the main MNOs, key vendors, and a number of other key industry players, as well as associations such as CTIA. See announcement for full details.

589 See https://www.fcc.gov/document/fccs-5g-fast-plan

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

591 See http://www.ncsl.org/research/telecommunications-and-information-technology/mobile-5g-and-small-cell-legislation.aspx

592 See https://www.whitehouse.gov/presidential-actions/presidential-memorandum-developing-sustainable-spectrum-strategy-americas-future/

B.14.5 Outlook

Our 5G outlook/assessment for the US is summarized in Figure B.52 below.

Figure B.52: 5G outlook for the US [Source: Analysys Mason, 2019]

Metric	Description	Score
1. Industry commitment to 5G launch	• Two MNOs have already launched 5G services; others are expected to do so in 2019	4/4
2. Low-band spectrum	• 716MHz of spectrum currently released • FCC consulting on allowing greater use of 2.6GHz spectrum and policymakers are exploring use of 1.3GHz and 1.7GHz bands	4/4
3. Mid-band spectrum	• No mid-band spectrum currently released • 150MHz in CBRS to become available (70MHz on a licensed basis) in 2020; further mid-band spectrum in the 3.7–4.2GHz band and elsewhere under consultation	1/4
4. High-band spectrum	• 2.5GHz currently released • 37.6–38.6GHz, 38.6–40.0GHz (where available), and 47.2–50.2GHz bands to be auctioned in 2019; other bands also under consideration	4/4
5. Total spectrum	• Strong performance on low- and high-band spectrum. No mid-band spectrum currently available	3/4
6. National strategies/government support	• A number of reforms to regulations aimed at streamlining infrastructure deployment have been passed	3/4