How spectrum will shape the outlook for 5G in Russia

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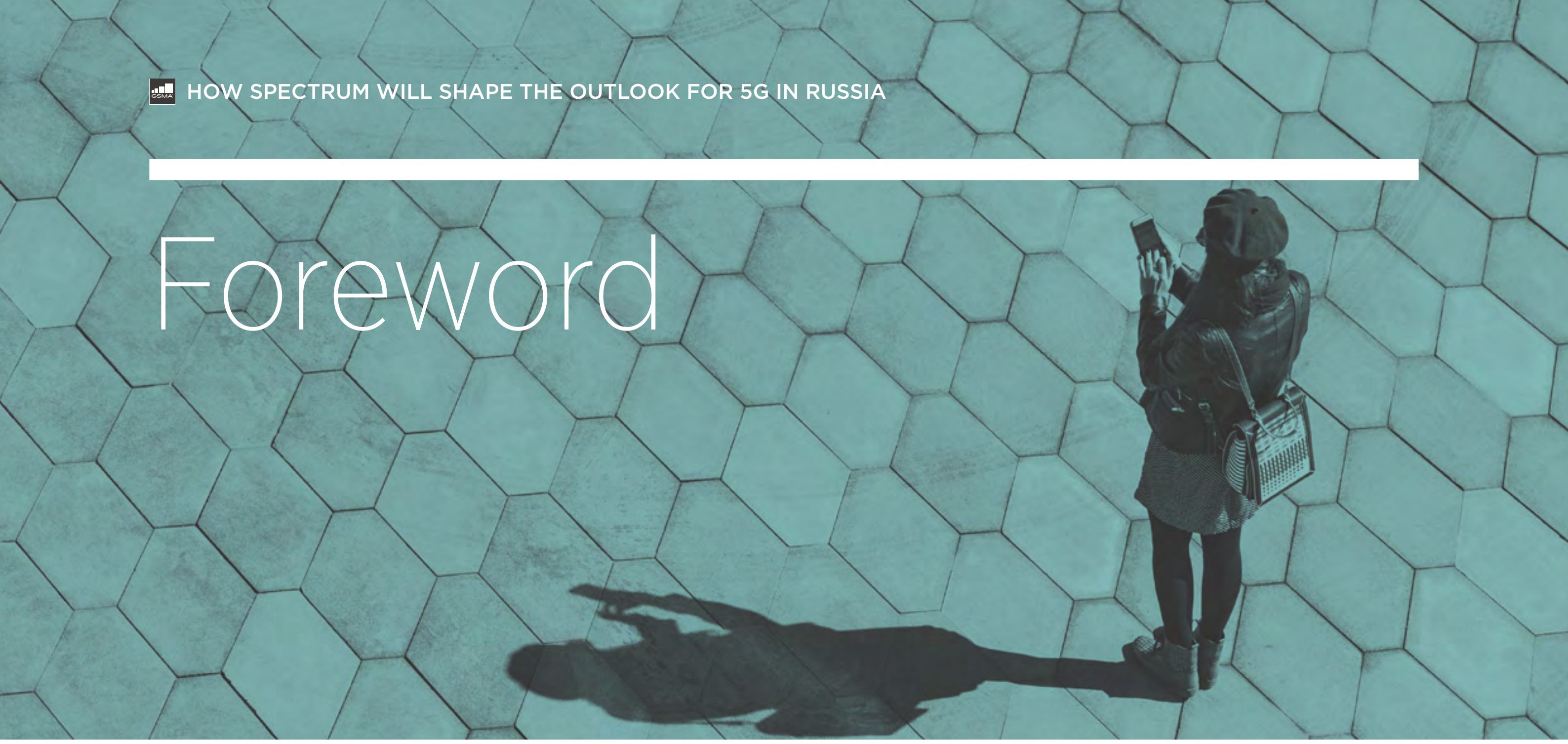


This report examines the outlook for 5G in Russia and sets it against the context of 5G adoption globally. It outlines forecasts for 5G uptake in Russia and the expected economic benefits that 5G will bring to the country.

The report looks in detail at which spectrum bands are most appropriate for the widest adoption of 5G, as well as how countries around the world are moving to clear and then allocate this spectrum for mobile operators to use. A current challenge in the Russian mobile market is how to allocate sufficient spectrum in the most appropriate bands to allow cost-effective 5G deployments – an issue also faced in other markets.

The GSMA has produced a number of reports highlighting the outlook for the mobile market in Russia, and the challenges and potential of 5G in particular. These include the following:

- The Mobile Economy Russia and CIS 2019[1]
- 5G in Russia: a global and local view on the way forward.[2]

A key theme underpinning these reports is the transformative potential of mobile networks and services. 5G will drive innovation and economic growth, delivering greater societal benefit than previous mobile technology generations and enabling new digital services and business models to thrive. However, this will require a supportive regulatory and policy environment, especially with regard to spectrum. In this report, the GSMA offers a number of insights and recommendations to ensure Russia can realise the full potential of 5G, within an appropriate timescale.

1 The Mobile Economy Russia & CIS 2019, GSMA Intelligence, 2019
2 5G in Russia: a local and global view on the way forward, GSMA, 2019

Executive summary

2020 marks the start of the global 5G era

The world has entered the 5G era, with most regions moving to live deployments and some markets experiencing accelerating adoption rates. 5G will support significantly faster mobile broadband speeds and lower latencies than previous mobile technology generations. It also promises a range of new services that will enhance the digital transformation of industries and provide new experiences for consumers.

As of the end of the second quarter of 2020, 5G was commercially available from 87 operators in 39 markets worldwide. While the global number of 5G connections stood at 57 million, this will rise to close to 145 million by year-end as more markets see launches and as adoption in the early-mover markets ramps up.

4G adoption accelerating in Russia; 5G yet to launch

By global standards, Russia is a mature and highly penetrated mobile market. Its unique mobile subscriber penetration rate was 89% at the end of 2019. After a delayed launch compared to many western markets, the proportion of 4G connections in the country is set to grow sharply, supported by significant investment in 4G networks over recent years.

Russia is not among the first wave of countries to launch 5G, but there have been a number of trials and tests in the country. With commercial launches expected in 2021, GSMA Intelligence forecasts that 5G will account for around 43 million connections by 2025, equivalent to just under a fifth of total connections.

These forecasts will place Russia broadly in line with the global average for 5G adoption by 2025. However, the country will lag behind the global leading markets where 5G commercial services have already been launched and adoption rates are accelerating.

Ahead of commercial launches, there is positive news for the Russian mobile operators in terms of consumer awareness of the potential benefits of 5G networks. In the latest GSMA Intelligence Consumer Insights Survey, 81% of those questioned highlighted speed as a key differentiator for 5G networks, compared to 58% in the 2018 survey. With 4G networks in Russia typically offering only modest data speeds compared to those of Russia's European peers, there is clear appetite among consumers for the high speeds that 5G will bring.

5G promises a significant uplift in economic growth and productivity in Russia. Estimates from GSMA Intelligence indicate that 5G will benefit the Russian economy by more than $5.2 billion by 2025 in terms of GDP uplift, equivalent to an additional 0.3% of GDP. This will reach 0.9% by 2030. The impact is in addition to the economic growth delivered by existing mobile network generations (3G and 4G). Over the period 2022–2030, the total cumulative benefit to the Russian economy from 5G equates to $60 billion.

The importance of spectrum and the 3.5 GHz range for 5G

Spectrum is the fundamental building block of all mobile networks; the requirement for significant amounts of globally harmonised spectrum is even more pressing for 5G. If 5G new radio (NR) is to work optimally, it requires wide, contiguous spectrum blocks for operation. The ITU recommends that regulators get as close as possible to assigning 100 MHz per operator in the 5G mid bands.

Many countries have faced the challenge of incumbent users in the priority 5G bands. Several European regulators have succeeded in clearing and defragmenting the 3.4–3.8 GHz band, with the UK a good example. South Korea was the first country to auction spectrum in the 3.5 GHz range for 5G in 2018, while more recently the regulator has announced plans to assign a further 320 MHz in the 3.4–3.42 GHz and 3.7–4.0 GHz ranges by 2021.

At a global level, the 3.5 GHz range has emerged as a key band for 5G. Some 24 countries have assigned spectrum in this band. In 14 of these, operators have already launched 5G networks using the frequency. Spectrum in the 3.5 GHz range is widely viewed as offering an optimal balance of coverage and capacity. The spectrum can enable a broad range of potential use cases beyond eMBB to include supporting local networks in specific sectors such as healthcare, logistics, mining and agriculture.

While clearing the relevant spectrum bands should be the primary objective, spectrum sharing can be a solution where clearing a band is not possible or will take time. Licensed spectrum access (LSA) is a potential solution to manage interference between users.

Challenges allocating mid-band spectrum in Russia

In Russia, the 3.5 GHz range is not currently available for mobile networks, mainly due to its use for satellite services. An alternative under consideration is the 4.8–4.99 GHz range (the 4.8 GHz band). However, international regulation of this band for 5G is still in flux, with no certainty expected in the next three years at least. By the time of the next World Radiocommunication Conference (WRC) in 2023, it will be clearer as to whether sufficient scale has been realised to allow for affordable mass-market 5G deployments using this band.

A number of markets, including Taiwan, China, Hong Kong and Japan, have already licensed spectrum in the 4.8 GHz band. However, in these markets it has been allocated primarily as a supplementary band to other spectrum, or for specific localised use cases such as private networks.

Global harmonisation and ecosystem maturity

Mobile is a highly capital-intensive industry; 5G will require significant investment, particularly given the need for network densification, at a time when operators are still looking to fully monetise 4G. Having sufficient scale can provide huge benefits for all stakeholders (operators, consumers and enterprises) as the 5G ecosystem continues to evolve.

The benefits of scale highlight the importance of using globally harmonised spectrum bands and standards for 5G. The particular challenge for the 4.8 GHz band is the lack of maturity and scale in the supporting equipment and device ecosystems. Data from the GSA shows that there are currently far more handsets available that support the 3300–3800 MHz range than the 4400–5000 MHz range. The situation is further complicated by the fact that handsets available for the 4.8 GHz band do not support the main LTE bands in use in Russia today (where spectrum bands and devices have been harmonised with European standards). There are no signs of any meaningful moves to implement such design changes by Chinese OEMs. Vendors are unlikely to consider this until there is clarity on band assignments in Russia, together with a spectrum roadmap.

Few network equipment vendors today support 5G networks in the 4.8 GHz band. Nokia failed to secure any 5G network contracts in China so is unlikely to support this band, while Huawei at present does not have a public roadmap to support 5G in the 4.8 GHz band.

A further challenge concerns the proposed requirement for encryption in Russian 5G devices. As part of the current standards agreement process, the FSB (Federal Security Service) has introduced a new requirement (no.19 in the draft requirements for user devices) to support national encryption algorithm usage. As it currently stands, implementing requirement 19 will make it impossible for vendors to certify 5G terminal equipment in Russia, as vendors of chipsets, infrastructure and terminal equipment do not support non-standard encryption algorithms. Rather, they all adhere to the 3GPP standards, which is the foundation for telecommunications equipment compatibility in markets across the world.

Modelling the cost across the two focus spectrum bands

Modelling by GSMA Intelligence found that deploying and operating a non-standalone (NSA) 5G network between 2023 and 2030 using the 4.8 GHz band would cost Russian operators 84% more compared to using the 3.5 GHz range. This differential would be driven by three key factors: the higher densification requirement in the 4.8 GHz band requiring more greenfield cell sites; the relative immaturity of the vendor ecosystem in this band; and the higher energy consumption of the network in the 4.8 GHz band.

Recommendations for the Russian market

The GSMA offers a number of recommendations to ensure Russia can realise the full potential of 5G:

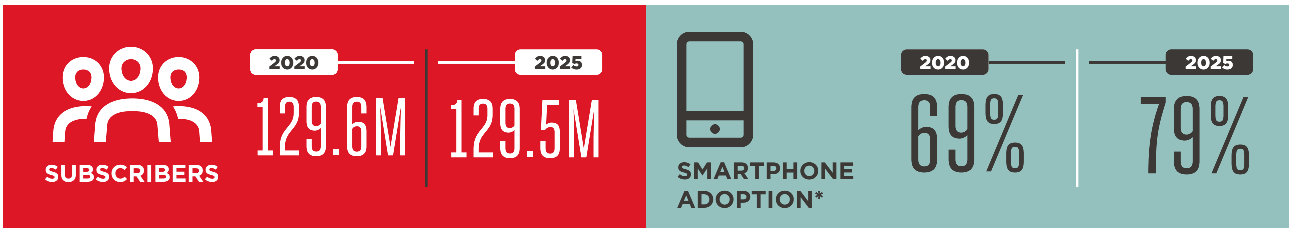
- Russian regulators should ideally clear the 3.5 GHz range for mobile use, and develop a clear roadmap for Russian mobile operators to provide 5G spectrum across the appropriate low-, mid- and high-band frequencies.
- Given that spectrum assignment is complicated by incumbents using part or all of the 3.5 GHz range, a long-term 5G roadmap should be developed so operators can understand how much spectrum will be made available by when. Considering the significant geographic scale of Russia, initial 5G deployments will focus on urban areas. One solution could be to clear the 3.5 GHz range for these urban areas while contemplating alternative bands for rural coverage over the longer term.
- If the 3.5 GHz range cannot be cleared over a realistic timescale, licensed shared access (LSA) offers a potential solution.
- The GSMA supports all governments that encourage national research and development efforts, particularly currently with 5G. However, it remains key that such efforts are aligned with international standards or gain subsequent recognition at an international level.

The final point is relevant to two areas. Firstly, efforts to utilise the 4.8 GHz band for 5G risk suffering from insufficient scale due to a lack of maturity in the device and network equipment ecosystems over the short to medium term. This will increase costs for operators and end users, potentially reducing uptake and the anticipated economic benefits of 5G.

Secondly, current proposals for the development of a national encryption algorithm will make it impossible for vendors to certify 5G terminal equipment in Russia, as they would not adhere to 3GPP standards. The best course of action would be for the Russian authorities to work alongside the 3GPP organisation and its relevant channels and specifications groups in order to strengthen the encryption algorithms.

Figure 1

Russian mobile market in numbers



Source: GSMA Intelligence *Percentage of total connections

1 5G: a global and Russian perspective

1.1 Entering the 5G era

Despite the impact of the Covid-19 pandemic, the world has now clearly entered the 5G era. Global lockdowns have only served to emphasise the criticality of reliable, high-speed connectivity. Shifts in patterns of work and entertainment will likely accelerate the need for higher network speeds, greater capacity and, crucially, the innovative new services that 5G promises.

5G networks will sit at the heart of new smarter ecosystems that benefit everyone: society will use technology to tackle the world's biggest challenges; consumers will enjoy immersive, contextual experiences; and enterprises will be able to embrace the Fourth Industrial Revolution.

5G networks will deliver a clear step-change in the capability and functionality of networks compared to 4G. 5G could offer 10–100× faster data rates and latencies up to 10 times smaller than with 4G networks.

These capabilities will in turn enable a range of other technologies (such as AI, big data and cloud services) to be deployed in new scenarios, realising new use cases. The improved performance of 5G will come from a more advanced core network, using more efficient radio technologies (such as massive MIMO), access to more spectrum bandwidth, and network densification.

As of the end of the second quarter of 2020, 5G was commercially available from 87 operators in 39 markets worldwide. Although the global number of 5G connections stood at 57 million, this figure will rise to close to 145 million by year-end as more markets see launches and adoption levels in the early-adopter markets ramp up.

While a number of countries are leading the way on 5G and seeing 5G adoption rates accelerate, others have been more willing to be followers and allow the technology to mature. Indeed, a number of major markets have yet to see full commercial launches.

Figure 2

5G at a glance: global outlook

	Spectrum assignments	Trials	Commercial launches**	Adoption
In Q2 2020	NZL, SGP, FIN	7 trials in 6 markets	22 operators in 14 markets	
To end of Q2 2020	108 operators* in 32 markets	212 operators in 98 markets	87 operators in 39 markets	57 million connections
Q3 2020	USA, GRC, CZE, 5 others		TWN, CZE, SYC, MAC	90 million connections
2020	45 countries completed assignments		153 operators in 54 markets	145 million connections (1.8% adoption)
2025			413 operators in 123 markets	1.7 billion connections (20% adoption)

Source: GSMA Intelligence *Excludes regional US and Canadian operators. **Launches of commercial mobile and FWA 5G services.

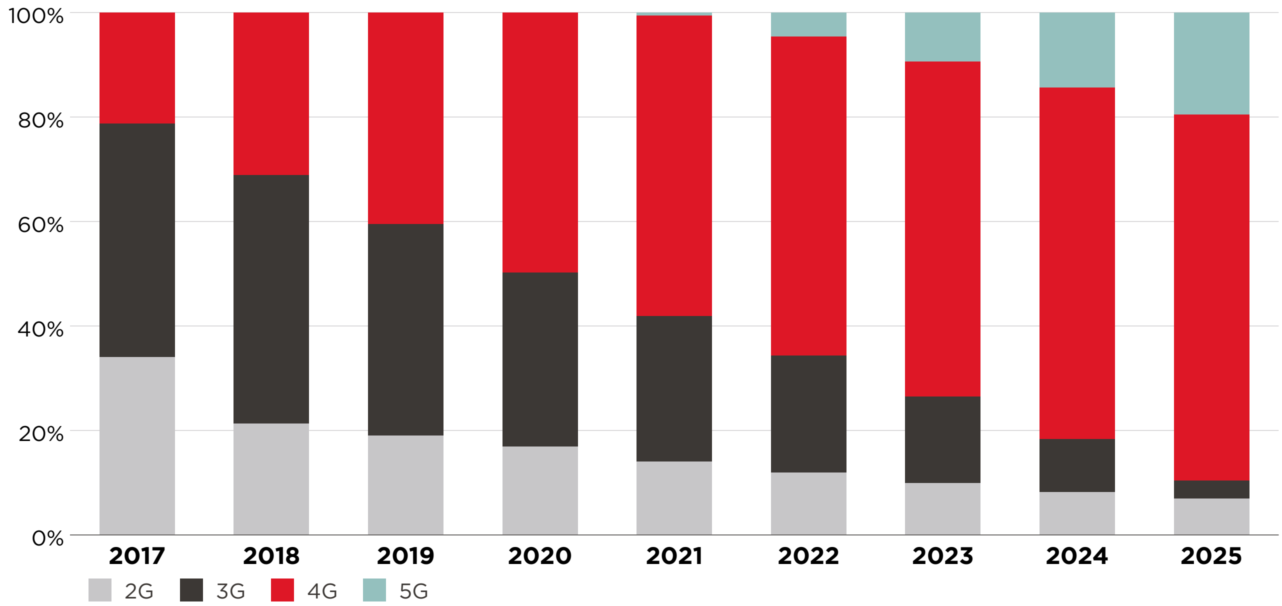
1.2 Russia: a mature mobile market moving to 4G

By global standards, Russia is a mature and highly penetrated mobile market. Its unique mobile subscriber penetration rate[3] of 89% at the end of 2019 is slightly ahead of both the developed and European market averages. With limited population growth, subscriber penetration will remain broadly unchanged over the period to 2025.

After a somewhat delayed start to 4G deployments, Russian operators have invested heavily in recent years to improve network coverage and speeds. These investments have supported the rapid migration to 4G that the mobile market is now seeing. 4G as a proportion of total connections is set to grow sharply over the next couple of years, from 40% at the end of 2019 to 61% by 2022.

Figure 3

Migration to 4G accelerating in Russia



Source: GSMA Intelligence

Examples of operator investments include the following:

- MegaFon's 4G population coverage increased from 50% in 2014 to 82% by the end of 2019. Its LTE-Advanced (LTE-A) networks are now available in 49 regions across Russia and can offer speeds in excess of 150 Mbps.
- MTS has extended coverage of its 4G network to 75% of the population, while at the same time investing to prepare its network for 5G. The company has deployed the latest LTE technologies in 21 regions, including massive MIMO and the use of licensed assisted access (LAA). LAA uses unlicensed 5 GHz spectrum in combination with licensed spectrum to deliver a performance boost for mobile users.
- Beeline (VEON) is also investing heavily in 4G, deploying an additional 11,000 LTE base stations in 2018. The number of 4G base stations across the country increased by a further 36% year-on-year in Q4 2019 and population coverage reached 86%. This helped data usage per connection increase by more than 50% year-on-year in Q4 2019.
- Tele2 saw strong growth in its LTE base stations in 2019. As a result, LTE devices as a proportion of smartphones increased by 14 percentage points in a number of regions. LTE devices accounted for 83% of smartphones across the Tele2 network. Smartphones as a share of all devices (phones, tablets, routers) grew to 71%.

3 A unique subscriber is defined as a unique user who is subscribed to mobile services at the end of the period, excluding cellular IoT. Subscribers differ from connections such that a unique user can have multiple connections.

1.3 Outlook for 5G in Russia

The main Russian operators continue to focus on investing in their 4G networks and deploying the latest 5G-ready technology. The focus is on improving 4G network coverage and improving speeds and capacity on LTE networks. There are, however, some limited trial deployments of 5G underway.

Table 1

5G status and trials

Operator	Current status
MTS	Testing industrial, smart city and AR/VR use cases in a number of pilot zones in cities including Moscow and St. Petersburg.
MegaFon	Trials taking place in different domains such as cloud gaming and autonomous driving.
Rostelecom (Tele2)	Trials taking place, including a test zone in central Moscow to demonstrate consumer use cases.
Beeline	Trials and test deployments underway, including smart cities and use cases in AR/VR and telemedicine.

Source: company data

MegaFon and Rostelecom have formed a joint venture (JV) – called New Digital Solutions – to look at 5G development. The new entity has been allocated spectrum in the 24.65–27.5 GHz band for 5G testing purposes until early 2021. MTS and Beeline are working on entering into a JV in the near future.

Russia is clearly not among the first wave of countries to launch 5G. However, there has for some time been a clear understanding within the industry and among relevant policy-makers of the importance of 5G to the mobile sector and broader economy. With a number of near-term constraints, including those related to releasing appropriate amounts of spectrum in the crucial 3.5 GHz range, the question is how much Russia will lag other developing markets in 5G, and whether it can still realistically attain the status of a 'fast-follower' market.

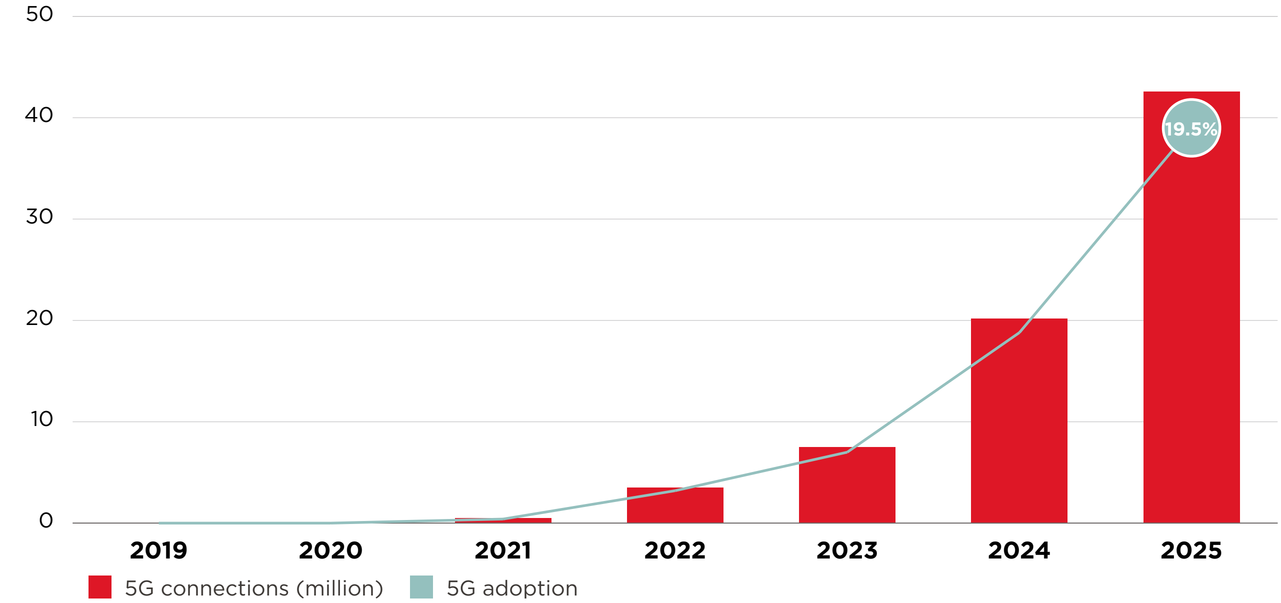
Countries such as the US, Japan and South Korea have been vying for global leadership in 5G, and there may be advantages from being a first-mover. Fast followers can see benefits in moving later, though this does not reduce the need to focus efforts on accelerating deployments from the current position. Advantages for fast followers include allowing the technology to stabilise and benefiting from hardware price reductions as vendors realise economies of scale. Device availability will also improve as chipsets fall in price and devices are able to support a broader range of spectrum bands.

LTE has proved an effective technology in the Russian market as consumers have readily adopted apps and smartphones, with the latest iterations allowing LTE to support rapidly growing data volumes that are among the highest in the world on a per-capita basis. However, with mobile data pricing low in Russia compared to many markets, 5G offers the promise of a lower cost per gigabyte compared to 4G. Ericsson has suggested this could be by up to a factor of 10. This will be important in allowing operators to justify their 5G investments.

The latest GSMA Intelligence forecasts indicate that, after a slow start, 5G will account for around 43 million connections by 2025, equivalent to just under a fifth of the total connections base in the country by that date. The forecasts for Russia and globally for the period to 2025 have been updated to reflect the likely impact of the Covid-19 pandemic, with the greatest impact in the nearer term while medium-term outcomes remain largely unchanged.

Figure 4

Russia 5G adoption forecasts

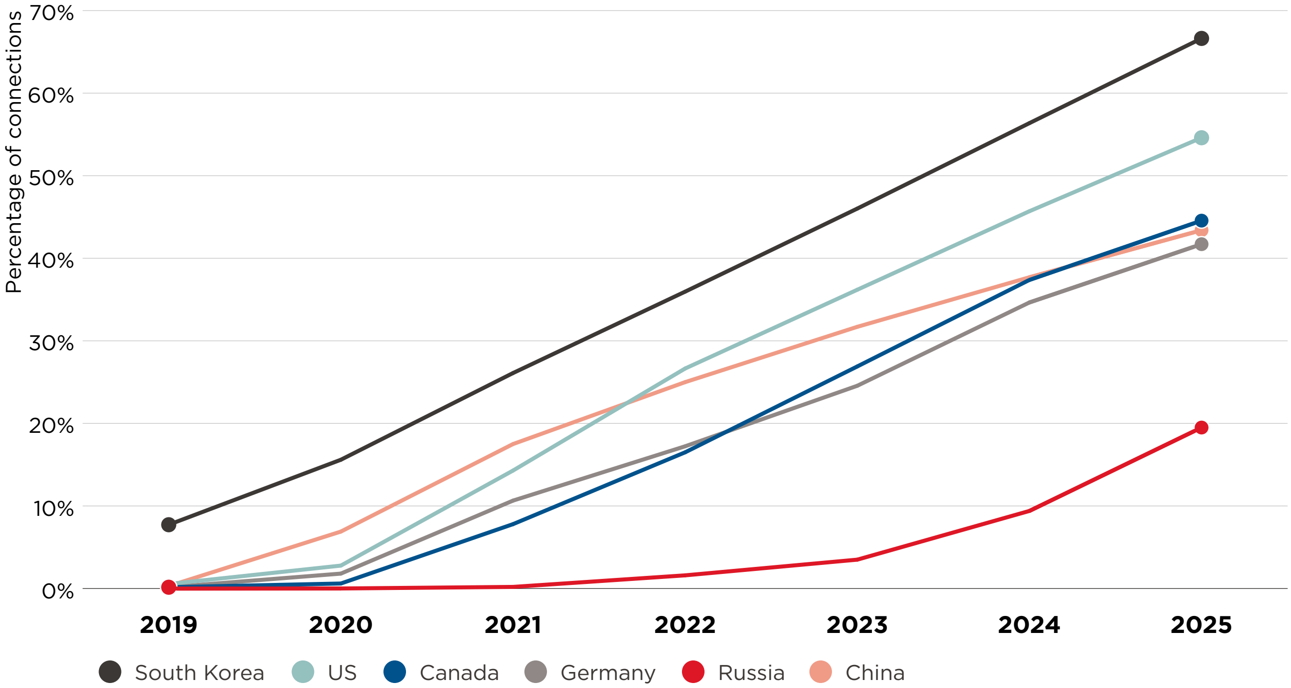


Source: GSMA Intelligence

The forecasts place Russia broadly in line with the global average for 5G adoption by 2025 but still trailing those markets that have already launched 5G commercial services and are seeing adoption rates accelerate. South Korea will retain its global leadership, with almost 70% of total connections running over 5G by 2025. Noteworthy, however, are other markets that have still to see 5G commercial launches but will experience strong adoption going forward. In Canada, for example, 5G will account for nearly half the total connections base by 2025.

Figure 5

5G adoption forecast for different markets



Source: GSMA Intelligence

1.4 5G deployment models

Nearly all global 5G deployments to date have been non-standalone (NSA), whereby operators deploy a new radio access network (RAN) but are able to reuse the existing LTE core network to manage both the 5G and 4G access networks. Devices are then able to connect to either network, or indeed both simultaneously.

This approach will contain overall investment levels by avoiding the need for a new set of base stations. It should therefore improve the rate of return from incremental revenues from the early 5G use cases (such as eMBB). LTE data traffic offload onto new 5G networks is a further benefit to operators given high monthly data volumes.

Under an NSA deployment model, operators are able to use existing macro sites and LTE spectrum as an anchor connection, with a densified network of small cells and use of mid-band (1–6 GHz) and upper-band (above 6 GHz) spectrum to facilitate high-speed data.

In contrast, standalone (SA) requires operators to deploy a completely new core network. This new core was only finalised in the 5G standards in June 2018; there is a typical lag of at least 18 months between standard completion and the commercial introduction of a new technology. This implies that the new 5G core will be used in widespread commercial deployments from 2021.

The SA approach allows operators to realise all the potential new capabilities of 5G NR, as well as the new core network architecture. These include advanced features such as network slicing (multiple logical networks on a single physical network) and ultra-reliable, low-latency transmission. This set of features makes an SA deployment more appropriate to addressing the enterprise market, which could be a key segment for 5G use cases in Russia.

While it is generally accepted that NSA will prove less costly to deploy in the short term, SA may offer longer-term capital efficiencies and avoid the need (with NSA) to go through a second round of hardware and software upgrades as part of the inevitable migration to SA. In this regard, Russian operators, given their later starting date, may favour the SA deployment model over the NSA approach. However, deployment models may also reflect use cases, with NSA used in urban areas to provide improved capacity and speeds, and SA deployed selectively such as in campus areas for manufacturing and specific verticals such as ports and mining.

Table 2

Comparison of main features of standalone versus non-standalone 5G

	Standalone	Non-standalone
Deployment period	2021 onwards	2019 onwards
Network core	New 5G core (5GC) controlling 5G RAN (NR)	4G core (EPC) controlling 4G RAN (LTE) and 5G RAN (NR)
Use cases	All use cases including IoT and URLLC*	eMBB
Ultra-low-latency capable?	Yes – around 1 ms	No – around 5 ms
Spectrum	Coverage for NR in high bands is very limited, because of the absence of 5G-LTE anchor	Existing LTE network provides coverage. NR deployed on new 5G spectrum

Source: GSMA Intelligence *Ultra-reliable, low-latency communication; massive IoT supported in future 3GPP releases. Also available in some NSA scenarios

1.5 The consumer perspective of 5G in Russia

The latest update of the GSMA Intelligence Consumer Insights Survey shows expectations among consumers for 5G in Russia. In common with most developed markets, consumers see higher speeds as the key differentiator for 5G. Particularly noteworthy is the increase in the proportion of respondents who see this as a key differentiator, with 81% of those questioned highlighting speed compared to 58% in the 2018 survey.

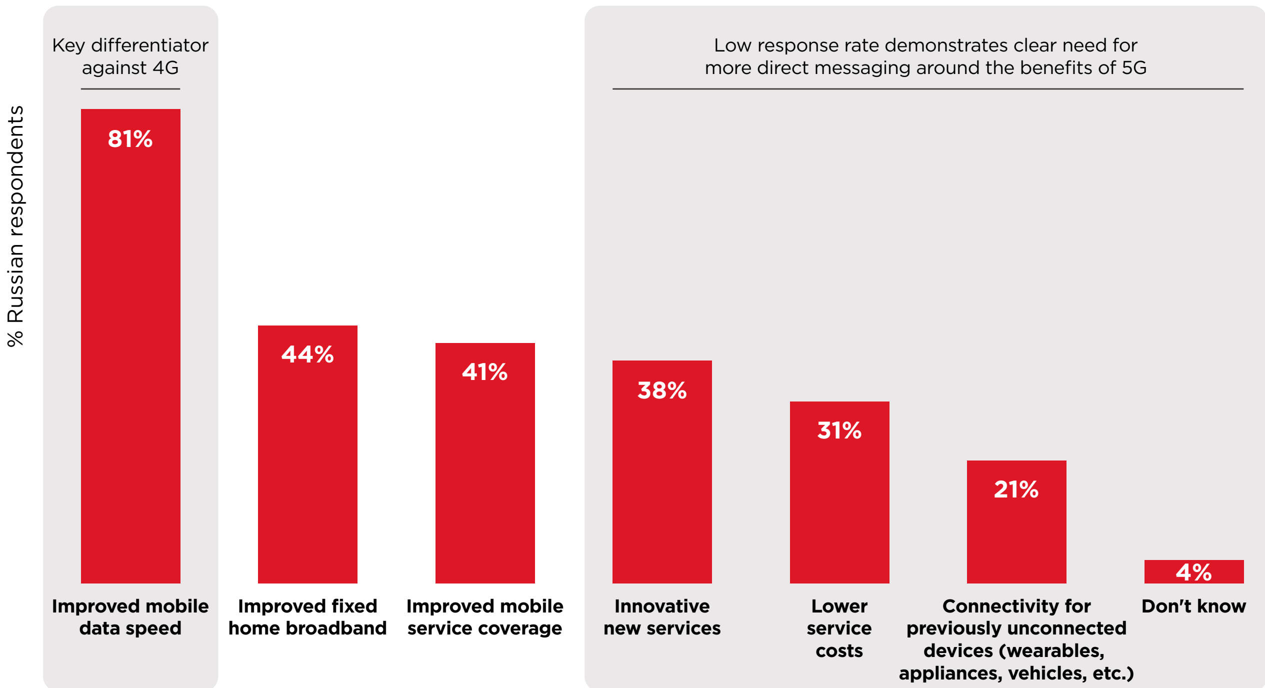
Across the markets surveyed globally, the expectation for higher speeds stood at an average of 71%. With LTE speeds in Russia well below a number of leading markets, there is a clear opportunity for operators to differentiate 5G services and position their commercial offers accordingly.

5G networks will likely bring a range of new and enhanced consumer experiences, drawing on key features of the technology including higher data throughput and lower latency. In common with consumers in other markets, less than 40% of Russian consumers see this as a key opportunity for 5G. The lower levels of awareness of new use cases and the scope to connect new ranges of devices highlight the need for targeted messaging from operators on the benefits of 5G. They also underscore the need for operators to work with other ecosystem players to bring the new capabilities to life.

Figure 6

Despite opportunities for new services and experiences, consumer expectations for 5G in Russia centre on faster speeds

Question: "From what you know of 5G, what do you expect it will deliver?"



Source: GSMA Intelligence Consumer Insights Survey 2019

1.6 Economic contribution of 5G in Russia

Investment in technology is paramount to boost productivity and economic growth in Russia. 5G technology, with its range of use cases applied to Industry 4.0, advanced services and ICT, can be a major driver of change.

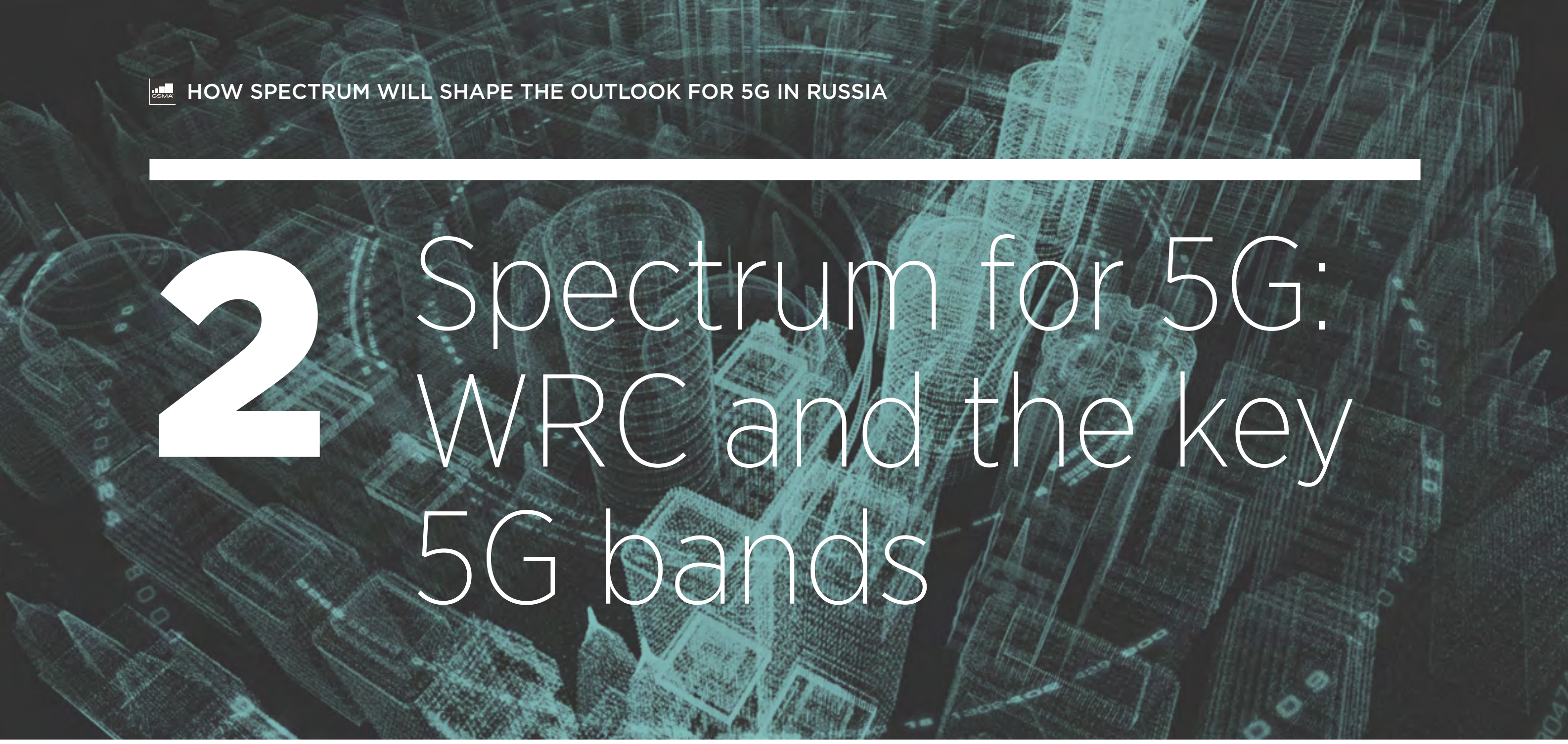
Estimates from GSMA Intelligence foresee that 5G will benefit the Russian economy by more than $5.2 billion by 2025 in terms of GDP uplift, equivalent to an additional 0.3% of GDP. This impact is in addition to the productivity boost that will be delivered by existing mobile network generations, which we expect to continue going forward. By 2030, further 5G adoption and the broader benefits of this are expected to grow the uplift to $16 billion per year, equating to 0.85% of GDP. Over the period 2020–2030, the total cumulative benefit to the Russian economy equates to $60 billion.

For context, GSMA Intelligence previously estimated that in 2018 mobile technology contributed $101 billion to the broader Commonwealth of Independent States (CIS) region, equivalent to 4.7% of the region's GDP.[4]

These estimates rely on a model that is built on two main pillars: the first assesses how different use cases – applications and new/upgraded industrial process supported by 5G technology – can boost growth and benefit the economy; the second looks at the likely impact on economic growth of 5G-based technologies and their impact on productivity. Together, the two pillars allow the model to forecast the impact on each sector of the economy.

4 The Mobile Economy Russia & CIS 2019, GSMA Intelligence, 2019

2 Spectrum for 5G: WRC and the key 5G bands



Spectrum in the appropriate bands and in sufficient quantity is a prerequisite for any commercial mobile network launch. Allocation of new spectrum has become a fundamental requirement for the mobile industry in order to improve capacity and enhance mobile broadband, particularly as demand for mobile data surges in markets across the world. The need for new spectrum has gained even greater focus as countries around the world begin to allocate spectrum for 5G.

2.1 Suitable spectrum bands for 5G

5G networks need spectrum across low, mid and high bands in order to deliver widespread coverage and enough capacity to support all use cases. All three band ranges have important roles to play:

- **Low band** (sub-1 GHz): supports widespread coverage across urban, suburban and rural areas and helps support IoT services. 5G services will struggle to reach beyond urban centres and deep inside buildings without this spectrum.
- **Mid band** (1–6 GHz): typically offers a good mix of coverage and capacity benefits. The majority of commercial 5G networks are relying on spectrum within the 3.3–3.8 GHz range. Other bands that may be assigned to, or refarmed by, operators for 5G include 1800 MHz, 2.3 GHz and 2.6 GHz. In the long term, more spectrum is needed in bands between 3 and 24 GHz to maintain 5G quality of service and meet growing demand.
- **High band** (24 GHz and above): needed to meet the ultra-high broadband speeds envisioned for 5G. High-band or millimetre wave (mmWave) spectrum has the advantage of offering very high speeds but suffers from challenges in terms of propagation and penetration; mmWave signals travel relatively short distances and can be susceptible to interference from objects such as trees and buildings. Currently 26, 28 and 40 GHz have the most international support and momentum.

The mobile industry aims to achieve harmonised spectrum allocations across all markets and regions. The advantage of spectrum harmonisation is that it typically leads to a much broader ecosystem in terms of technology, equipment and general engineering expertise. This in turn benefits operators (and indeed end users) through the realisation of significant economies of scale, lower costs of deployment and more rapid rollout of new services.

2.2 How much spectrum does 5G need?

A central component in the evolution of all mobile technology generations has been the use of increasingly wide frequency bands to support higher speeds and larger amounts of traffic.

By design, if 5G new radio (NR) is to work optimally, it requires wide, contiguous spectrum blocks for operation. To meet the performance requirements associated with 5G usage scenarios, the aim should be to make available 80–100 MHz of spectrum per operator. Currently, the ITU recommends that regulators should get as close as possible to assigning 100 MHz per operator in 5G mid bands.

Assigning sufficient spectrum in low, medium and high frequency bands per operator has the following advantages:

- increased data rates to support eMBB usage, with a typical user experience of 100 Mbps
- reduced terminal front-end complexity and power consumption (compared to carrier aggregation using non-contiguous channels)
- cost-effective rollout, with the ability to support new services such as URLLC and capabilities such as simultaneous wireless backhauling and fronthauling to 5G NR base stations.

Making less spectrum available reduces the peak data rates that the network can deliver, while significantly increasing the number of cell sites required in a typical network deployment. Alongside the need for adequate mid-band spectrum, an additional 1 GHz in mmWave bands will best support the fastest 5G services.

2.3 Which bands are being considered for 5G?

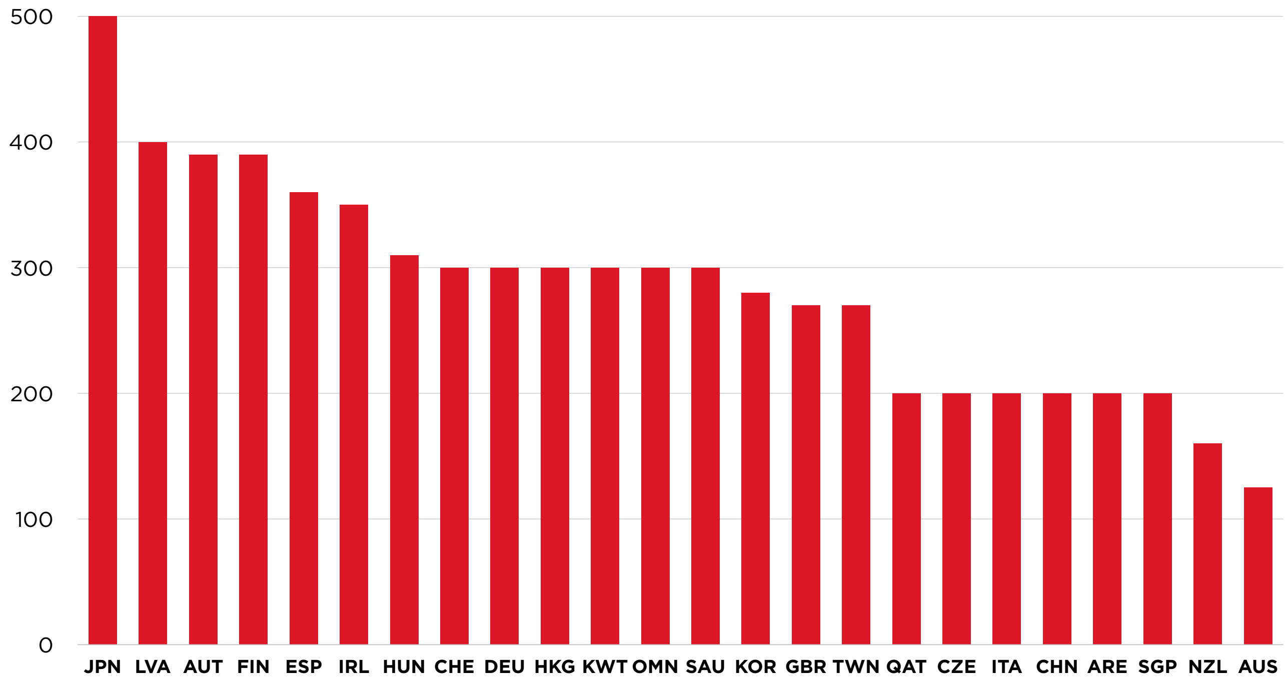
Regulators around the world are developing their 5G spectrum plans; indeed, a growing number have completed the first assignments. A number of different bands are being considered for 5G in specific markets, with most in the mid or high bands:

- **Low bands:** The European Commission supports the use of the 700 MHz band for 5G service. Seven markets have already assigned this band. In the US, T-Mobile is already using 600 MHz spectrum for 5G across the country.
- **Mid bands:** 3.5 GHz is being adopted across several countries and regions. In addition to this:
  - Some countries, such as China and Japan, plan to use spectrum in the 4.5–5 GHz range to complement 3.5 GHz and 2.6 GHz for 5G
  - A growing number of countries are considering the 3.8–4.2 GHz range
  - There is also interest in assigning the 2.3 GHz and 2.5/2.6 GHz bands for 5G.[5]
- **High bands:** spectrum in the upper bands has been assigned to date in only a limited number of countries. Italy is the first European market to assign spectrum in the 26 GHz band, though a number of other European countries are set to follow with assignments later in 2020. Leading 5G markets such as the US, South Korea and Japan have seen mmWave assignments; operators (especially those in the US) have moved quickly to utilise these bands.

At a global level, the 3.5 GHz band has emerged as a key band for 5G. Some 24 countries have already assigned spectrum in this band. In 14 of these, operators have already launched 5G networks using this frequency.

Figure 7

5G spectrum assigned in the 3.5 GHz band by country



Source: GSMA Intelligence, regulatory data

5 "FCC pushing to open up the 2.5 GHz band for 5G", RCR Wireless, June 2019

2.4 The importance of the 3.5 GHz range

To realise the full potential of 5G, high-speed eMBB services should be capable of delivering peak download speeds of at least 20 Gbps, a reliable 100 Mbps user experience data rate in urban areas, and 4 millisecond latency.[6]

The 3.5 GHz range is widely viewed today as offering an optimal balance of coverage and capacity. As a result, it can support a range of potential use cases beyond eMBB to include supporting local networks in specific sectors.

Current use of the wider 3.5 GHz range (3.3–4.2 GHz) varies across the world. The band offers the largest contiguous bandwidth available for 5G in the sub-6 GHz range. The main users of this spectrum (other than for mobile services) are fixed satellite services. Parts of the band are also used for radiolocation and fixed service (mainly point to multipoint or wireless broadband services).

- In Europe, 3400–3800 MHz is accepted as the primary band for 5G. Some administrations in Europe are eyeing the opportunity to utilise additional mid-band spectrum in the 3800-4200 MHz range for 5G. The UK has started the assignment procedures for this range.
- Regulators across the Middle East and North Africa have decided that the 3300–3800 MHz range is key for the introduction of 5G. Five commercial networks were launched in the 3300–3800 MHz range, while some administrations are also looking at opportunities in the 3800–4200 MHz range.
- The 3400–3600 MHz range is already identified for 5G in African countries, though it is predominantly used today for FWA services. Countries are in the process of transitioning regulations to allow mobile use.
- In the US, the 3550–3700 MHz range (CBRS band) has been made available for 5G on a shared basis, while plans for the release of 3700–3980 MHz for 5G were announced by the FCC in February 2020.
- South Korea auctioned the 3.4–3.7 GHz range for 5G use in 2018. The regulator has announced plans to assign a further 320 MHz in the 3.40–3.42 GHz and 3.7–4.0 GHz ranges by 2021. As a result, 600 MHz of contiguous spectrum would then be available for operators in the mid band.
- Most Latin American markets are planning to assign all or a portion of the 3300–3800 MHz band to 5G.

Progress with the assignment of the 3.5 GHz band is most advanced in Europe, where it has been identified as a pioneer 5G band. Nearly 140 operators are currently investing in 5G networks in 3300–4200 MHz globally; 43 operators have launched or announced plans to launch 5G networks using this spectrum.

6 ITU. Minimum requirements related to technical performance for IMT-2020 radio interface(s), ITU, 2017

2.5 Clearing spectrum bands for 5G

In many countries, there are incumbent users in the priority 5G bands, so meeting the aforementioned targets in terms of spectrum per operator can be challenging. It is essential that regulators make every effort to make this spectrum available for 5G use – especially in the 3.5 GHz (3.3–3.8 GHz) range. This can include a number of approaches:

- providing incentives for incumbents to migrate ahead of awarding the spectrum
- moving incumbents to alternative bands or within a single portion of the range
- allowing incumbents to trade their licences with mobile operators.

The GSMA recommends that where spectrum assignment is complicated by incumbents using part or all of the band, long-term 5G roadmaps should be developed in consultation with stakeholders so operators can understand how much spectrum will be made available and by when. As well as providing clarity on what will happen to incumbent users of the band, this will help to inform spectrum-trading decisions.

Several European countries have succeeded in clearing and defragmenting the 3400–3800 MHz band. A previous review of usage in the C-band by the European Conference of Postal and Telecommunications Administrations confirmed its large fragmentation in a number of countries and the need for timely decisions enabling availability of wider bandwidth for 5G by 2020 on a national basis.[7]

In addition, the Radio Spectrum Policy Group (RSPG) of the European Commission suggested that European administrations consider coexistence with FSS earth stations, using the technical toolkit developed by the EC, where clearing the band was challenging. It recommended that administrations consider the relocation of incumbent users to a different geographical location or to a different band above 3800 MHz, with the goal of making the band substantially available by 2020.

Clearing the 3.4–3.8 GHz band in the UK

The UK initially made 3410–3600 MHz available for mobile networks, and then made 3600–3800 MHz available by the end of 2019.

In 2016, the UK initiated work to make spectrum not already assigned for electronic communications services in the 3600–3800 MHz band available for future mobile services including 5G in compliance with 2014/276/EU. In October 2017, the UK confirmed its approach to make the band available for mobile and commenced the statutory process of notifying licensees and grant-holders of the proposed revocations and/or variations to their licences.

Having taken into account stakeholders' representations, in February 2018 the UK published an update outlining the outcome of its decision:

- the UK issued notices to revoke all 24 fixed links licences in the band as proposed, with an effective date of 23 December 2022
- the UK also varied 12 Permanent Earth Station licences
- three grants of recognised spectrum access (RSA) were proposed, with an effective date of 1 June 2020. The UK varied one grant of RSA with an effective date of 1 September 2020.

7 ECC Report 287: Guidance on defragmentation of the frequency band 3400-3800 MHz, CEPT, 2018

2.6 Spectrum allocation: best practices

The GSMA has released a paper outlining best practices for governments and regulators, in part reflecting the renewed focus on auctions as markets across the world prepare for 5G.[8] Spectrum in the majority of countries around the world is assigned by auction, where spectrum fees can include lump-sum payments upfront and then a series of deferred payments. In some cases, annual usage fees are payable.

The paper also addresses a trend towards governments making decisions that artificially inflate spectrum prices, which is strongly linked to slower networks and rollouts as well as worse coverage.[9] This includes artificially restricting the amount of spectrum operators can access, thus inflating demand (e.g. through failure to clear enough spectrum, set-asides or poorly chosen lot sizes), and inflating prices through high reserve prices.

Looking at 5G spectrum band assignments and awards to date, there is significant variation in the amount of spectrum assigned, licensing approaches and prices paid:

- **Band size** – There is a lot of variation at the country and operator levels due to defragmentation and difficulty in clearing the C-band, which in turn is slowing the release and limiting the amount of spectrum assigned. While some countries have released close to all the 3.4–3.8 GHz band in one effort (e.g. Finland), others have adopted a two-phase approach (e.g. Italy, UK and Czech Republic). This means that, at the operator level, spectrum assignments vary significantly: from as little as 20 MHz in Italy to as high as 130 MHz in Finland.
- **Licensing approaches** – While exclusive licensing is still the main 5G licensing mechanism in Europe, interest in spectrum sharing is growing. Countries such as Finland and Italy enforced spectrum-sharing approaches for new 5G spectrum licences, while the UK has started to enable a similar approach for both new and existing assigned bands.

  A new approach seen in some European markets is the setting aside of spectrum in key 5G bands for vertical industries. This is driven by the preference among some verticals to operate their own networks. However, setting aside spectrum for what are likely to be very localised deployments is seen as a risk in two respects: fragmentation and scarcity. The amount of spectrum left to be shared among operators can make it almost impossible to obtain the bandwidth necessary to deliver optimum 5G services and will likely drive up spectrum prices. As an alternative, some countries (e.g. Finland) have chosen a sharing approach where leasing conditions are attached to licences.
- **Spectrum pricing** – Different approaches to licensing have also had a significant impact on the pricing of spectrum. The auctions in Italy and Finland resulted in two starkly different outcomes. While Finland sold 390 MHz of prime C-band spectrum for €77.6 million, in Italy operators paid €4.3 billion for 200 MHz – 56 times the price for half the amount of spectrum. This was driven by the design of the auction – a small amount of spectrum awarded in Italy and the disparity in lot sizes created artificial scarcity and pressure to win the two 80 MHz lots. While operators will typically be prepared to pay more for spectrum in markets where revenues are higher, in Italy and Finland this disparity seems excessive: 2018 mobile sector revenues in Italy were only five times higher than in Finland.

In terms of auction pricing, another notable example is Germany, where reserving spectrum in a key 5G band for vertical industries drove higher prices. This was further compounded by the successful bid of a new-entrant operator (not subject to the minimum coverage obligations imposed on the three incumbent operators). This induced scarcity resulted in mobile operators paying €3.59 billion for 300 MHz of spectrum.

8 Auction Best Practice, GSMA, 2019
9 https://www.gsma.com/spectrum/resources/effective-spectrum-pricing/

Auctioning 3.4–3.8 GHz in Finland

In terms of amount of spectrum and pricing, Finland provides a positive example of a market that has assigned 5G spectrum:

- **Amount of spectrum** – Finland released 390 MHz of spectrum for auction in 2018, with each operator receiving 130 MHz. This is well above the 100 MHz in the mid band recommended by the ITU. Moreover, it is the highest amount of spectrum any operator currently has obtained in the C-band via an auction.
- **Pricing** – On a $/MHz/Pop/Year (PPP) basis, Finnish operators paid only $0.003. This compares to prices paid in Italy of $0.03, Germany $0.01 and Taiwan $0.07 (the latter is the highest globally so far). The comparison with reserve prices is important as Finnish operators paid only marginally higher than the total reserve price, with DNA winning the spectrum at reserve. The total reserve price for all spectrum was €65 million, with total auction proceeds of €77.6 million.

Auctioning 3.4–3.8 GHz in Austria

Austria completed its first 5G spectrum auction in 2019. As with Finland, it is noteworthy in terms of amount of spectrum and pricing:

- **Amount of spectrum** – The three mobile operators in Austria received 100–140 MHz of spectrum, again in line with or in some cases above the 100 MHz recommended level. The auction was structured along regional lines, with Hutchison receiving 100 MHz in every region, T-Mobile 110 MHz and A1 up to 140 MHz in certain areas (including Vienna).
- **Pricing** – The total amount paid in the auction was €188 million. On a $/MHz/Pop/Year (PPP) basis, Austrian operators paid $0.004. This is below a number of other European markets including Italy and Germany.

More recently, certain local government bodies in Austria have announced plans to subsidise 5G deployments. Between 1 July 2020 and 30 June 2022, Vienna's municipal government will subsidise 240 5G sites per operator, with a payment of €5,000 per year for five years (€25,000 per site). This equates to a total subsidy of €19.8 million. To qualify for this payment, the sites must be situated on municipal properties.

2.7 Future spectrum options: WRC-23 and beyond

The World Radiocommunication Conference 2023 (WRC-23) will be a key opportunity to address outstanding issues around spectrum for 5G networks.

While the previous conference, WRC-19, identified high-capacity spectrum for 5G, WRC-23 will address mid- and low-band frequencies. It will also seek to realise further harmonisation and thus improve the affordability of new services. Bands under consideration at WRC-23 in ITU Region 1 are 470–960 MHz, 3300–3400 MHz, 3600–3800 MHz, 4800–4990 MHz and 6425–7125 MHz.

Spectrum in the 3.5 GHz range (3.3–4.2 GHz) provides a good balance of coverage and capacity and, as outlined previously, is already being used for commercial 5G services in a growing number of countries. Further harmonisation of this range will be possible at WRC-23.

2.8 Spectrum sharing solutions

The growth in mobile data traffic – a trend set to accelerate with the widespread launch of 5G networks – means operators require access to growing amounts of spectrum to meet demand.

While clearing the relevant spectrum bands should always be the primary objective, spectrum sharing can be a solution where clearing a band is not possible or will take time. Spectrum sharing can allow mobile operators to access additional spectrum in certain locations and at times when other services are not using it.

The potential to share between mobile networks and incumbent users depends on the services themselves, the extent of their deployment and the type of sharing envisioned (co- or adjacent channel).

Table 3

Co-existence potential between 5G and incumbent services in the 3300–4200 MHz band

Incumbent service	Co-channel	Adjacent channel
FSS (limited FSS earth station deployment)	Yes, with detailed coordination / mitigation measures	Yes, with detailed coordination / mitigation measures
FSS (ubiquitous FSS deployment, e.g. TVROs and VSATs)	No	Yes, with suitable guard band
FS (limited FS deployment of point to point links)	Yes, with detailed coordination / mitigation measures	Yes, with detailed coordination / mitigation measures
FS (ubiquitous FS deployment of point to point links)	No	Yes, with suitable guard band
FS (FS point to multipoint / BWA)	Yes, with mitigation measures e.g. synchronisation	Yes
Radiolocation / Radars	Possibly, with detailed coordination	Probably, with detailed coordination

Source: GSMA Note: FSS = fixed satellite service, FS = fixed service.

Despite its potential usefulness in select situations, there has been relatively limited adoption of spectrum sharing to date. Initial trials have provided valuable lessons for regulators to take forward as they look to use sharing to support the growing popularity of 5G networks. Simple geographical sharing can be adopted in cases where incumbent service deployment can be geographically limited or relocated to rural areas only. The spectrum made available could then be used in city centres and urban areas for 5G deployments, with an adequate separation distance between the mobile and incumbent services.

The GSMA has highlighted the importance of developing a sharing framework, which controls who can share the band and defines usage rights and limitations.[10] Variables usually include the following:

- **The number of access tiers** – Two-tier models include the incumbent and one class of shared user. Some models add a third tier with further reduced access rights (e.g. low-power uses).
- **Access guarantees** – The framework outlines the access guarantees that the tiers of users can expect. These can include traditional licensing to provide strong guarantees and high quality of service (QoS).
- **Access terms, technical conditions and fees (if any)** – These define over what geographic area users may operate and, where necessary, for how long and at what cost (e.g. when a tier is licensed). This includes technical conditions (e.g. power levels) that affect coverage.

There are three main types of spectrum sharing:

- **CBRS-type approaches** – The planned Citizens Broadband Radio Service approach in the US in the 3.5 GHz band aims to support three tiers using dynamic sharing.
- **Licensed shared access** – Incumbent licence holders can sub-license spectrum to other users in a controlled manner. This model was initially developed in Europe for the 2.3 GHz band. It has two tiers for the incumbent and secondary users (e.g. mobile operators), with the latter permitted to use the spectrum in areas where it is available.
- **Concurrent shared access (e.g. club licensing)** – Unlike the approaches outlined above, this only allows one class of user but permits them to share spectrum with each other in a coordinated way. This allows sharing between mobile operators to improve data speeds and spectrum efficiency.

Sharing techniques such as licensed shared access (LSA) could also offer a solution. These involve active control of interference through the use of geolocation databases and sensing technologies. Examples of initiatives involving such techniques include the use of CBRS in the 3.5 GHz band in the US and the LSA framework in the EU. However, there is still a degree of scepticism over these models; more confidence and trust will be required for these to become mainstream. LSA has not yet been implemented in the 3.5 GHz band but could be a solution in markets such as Russia where fully clearing the band proves to be unachievable. As 5G evolves, there may be a bigger role for more flexible sharing frameworks in more markets.

While spectrum sharing offers potential, it cannot replace the need for exclusively licensed mobile spectrum. The global success of mobile services rests on a foundation of exclusively licensed spectrum as it supports widespread services and the certainty needed for long-term, heavy network investment and high-quality service. However, sharing can play a complementary role to traditional spectrum licensing by allowing mobile services to access new bands where there are no reasonable alternatives.

10 Spectrum Sharing, GSMA, 2019

2.9 Challenges in utilising the 4.8 GHz band

The 4800–4990 MHz band (also referred to as the 4.8 GHz band) was first identified for IMT[11] at WRC-15, but only in three countries. IMT identification was also agreed with strict power flux density (PFD) limits,[12] which would make use of this band challenging for outdoor, macro-cells. In addition, countries wishing to use the band for IMT were required to coordinate with neighbours and not to cause unacceptable interference. One requirement is that IMT stations shall not claim protection from stations of other applications of the mobile service.

At WRC-19, the use of the band was revised. A number of new countries signed up to use IMT in the band, including Russia. All the countries that applied before the WRC were allowed to waive the PFD restrictions, making macro-cell, outdoor 5G possible in the band. However, the need to coordinate with concerned countries – as well as the clause stating that IMT stations shall not claim protection from stations of other applications of the mobile service – remained in place. A number of additional countries wished to sign up to use the band at WRC-19 but were not given a waiver for the power limit. The long-term future of the band will be discussed at WRC-23.

At present, the international picture is fragmented, with two sets of countries allowed to use the spectrum for mobile in two different ways. The different conditions mean it will be difficult to build common equipment for these two groups. There is also a third group of countries that wish to have other services protected in this spectrum band.

While 11 countries are not subject to the PFD limit today, WRC-23 will decide if conditions for the band can be softened more widely. Should that not be the case, development of the mobile ecosystem may be stifled (even though there is significant population within those 11 countries). It is worth noting that the group of countries not wishing to develop the band for 5G includes many early-adopter countries which have elsewhere been crucial in creating scale and driving down equipment costs. They include countries in Europe and parts of East Asia; at least in the short to medium term, the 4.8 GHz band is not likely to get the support of these countries in its entirety.[13]

Although Russia is not required to meet the PFD limits today, ITU RR footnote 5.441b states it must still coordinate with its neighbours when deploying 5G in the band; this will limit deployment in Russia geographically. The coordination distances required are up to 450 kilometres from the border.

This requirement is stipulated through the application of ITU provision RR 9.21, which applies *'for any station of a service for which the requirement to seek the agreement of other administrations is included in a footnote to the Table of Frequency Allocations referring to this provision'*.[14]

Each base station using this frequency within stipulated distance from the border must be coordinated with affected neighbouring countries. In the case of 4.8–4.99 GHz, the footnote[15] in the ITU regulations stipulates that coordination must be carried out with any other systems of the mobile service, including aircraft communications systems.

Further to this requirement, decisions from WRC-19[16] stipulate the distances from the border where coordination is required. These are 300 kilometres from a land border or 450 kilometres from a sea border in order to protect aircraft systems. A distance of 70 kilometres from the border is stipulated for coordination with ground-based systems in other countries. The principal impediment to IMT is thus essentially the aircraft systems that are used in parts of Europe, as they will be allowed to insist that no IMT base stations in Russia interfere with their networks up to 450 kilometres from their border.

11 IMT is the generic ITU name for 3G/4G mobile broadband services, and more recently 5G mobile services.
12 ITU RR FN 5.441B states that countries using the spectrum had to ensure *'power flux-density (PFD) produced by this station does not exceed −155 dB(W/(m² · 1 MHz)) produced up to 19 km above sea level at 20 km from the coast'*.
13 Although, in the US, the FCC is considering making a portion of this band from 4940–4990 MHz available.
14 ITU Radio Regulations, Article 9, Provision RR 9.21
15 RR FN 5.441b
16 See 'resolves' 3 and 4 of Resolution 22. (WRC-19)

International regulation of 4800–4990 MHz for 5G is thus still in flux, with no certainty expected for at least the next three years. Given its existing use for other services, softening of the current regulations is by no means guaranteed in 2023. By this point, it will be clearer as to whether or not sufficient scale has been realised to allow for affordable, mass-market 5G.

Table 4

Status of the 4.8–4.99 GHz band by country

Original countries (WRC-15) – not subject to PFD limit, must coordinate with neighbours	Cambodia, Laos, Vietnam
New countries (WRC-19) – not subject to PFD limit, must coordinate with neighbours	Armenia, Brazil, Cambodia, China, Kazakhstan, Laos, Russia, South Africa, Uzbekistan, Vietnam, Zimbabwe
Countries allowed to use (WRC-19) – subject to PFD limit and neighbour coordination	Angola, Azerbaijan, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Côte d'Ivoire, Democratic Republic of Congo, Democratic People's Republic of Korea, Djibouti, Eswatini, Gabon, Gambia, Guinea, Iran, Kenya, Kyrgyzstan, Lesotho, Liberia, Malawi, Mauritius, Mongolia, Mozambique, Nigeria, Sudan, Tanzania, Togo, Uganda, Zambia

Source: GSMA

Markets that are already using the 4.8–4.99 GHz band for 5G, or preparing to do so, include the following:

- Taiwan's government has announced plans to release 100 MHz of spectrum in the 4.8–4.9 GHz band for public and private organisations to test 5G applications.
- In China, the Ministry of Industry and Information Technology (MIIT) awarded China Mobile spectrum in the 4.8–4.99 GHz band, while China Broadcasting Network (CBN) also received spectrum in the 4.9–4.96 GHz band.
- Hong Kong Telecom (HKT) and China Mobile Hong Kong were each awarded 40 MHz of 5G spectrum in the 4.9 GHz band. The two companies indicated they will use the spectrum to increase the overall capacity of their networks, with HKT noting its relevance for two regions where the presence of satellite earth stations could interfere with the use of the 3.5 GHz band. All four mobile operators in Hong Kong also hold a total of 200 MHz of spectrum in the 3.5 GHz band.
- In Japan, the 4.6–4.89 GHz band is due to be awarded in future to support private local 5G networks, with regulatory approval for the band's use to be confirmed later in 2020. NTT DoCoMo holds 100 MHz for 5G in the 4.5–4.6 GHz band. The 4.9–5 GHz band is also available for unlicensed use, but operators must register beforehand.

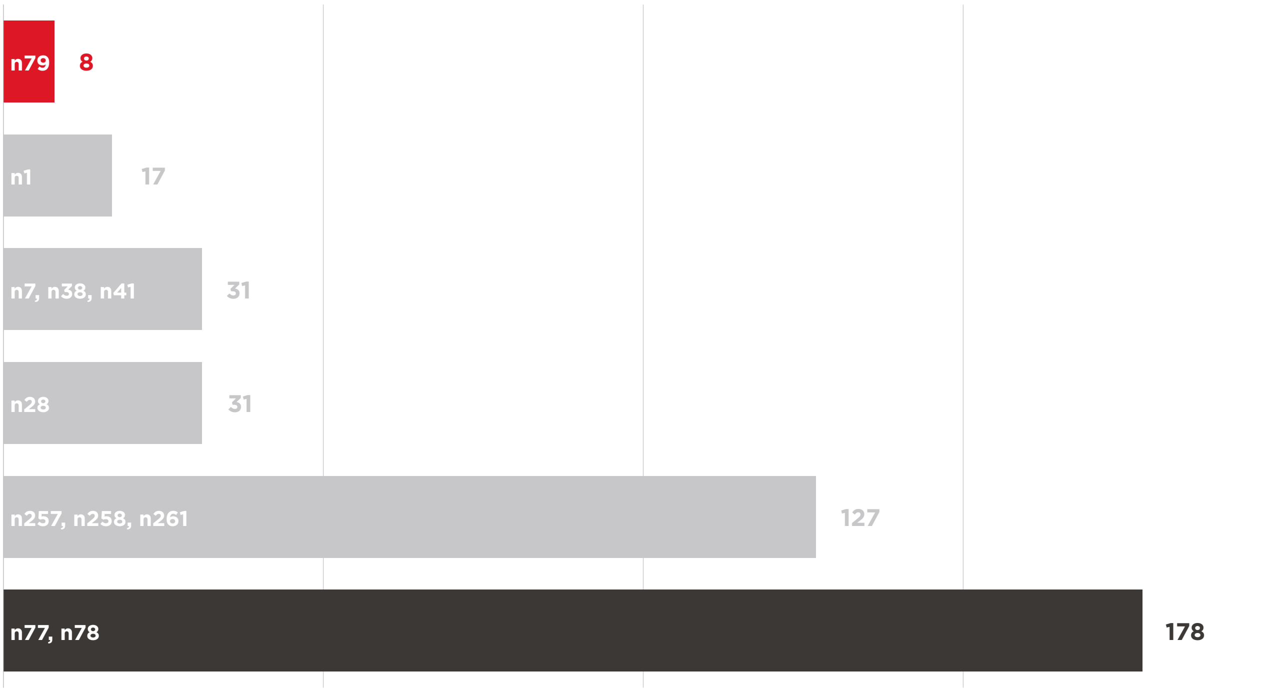
From the information above, it is important to note that in all cases 4.8–4.99 GHz spectrum has been allocated primarily as a back-up or supplementary band to 3.5 GHz, or for specific localised use cases. In Hong Kong and Japan, the main use case is localised private network deployments, with additional use in Hong Kong to provide eMBB coverage in specific locations where there is an issue with satellite interference.

China Mobile will use the 4.8–4.99 GHz spectrum it received for campus networks and localised indoor use, while its main 5G deployment will use the 700 MHz and 2.6 GHz bands. China Mobile has signed a co-construction and network sharing agreement with CBN to build a 700 MHz 5G network, using the 80 MHz of spectrum in this band already assigned to CBN. CBN intends to use the spectrum received in the 4.8–4.99 GHz band to provide interactive broadcast and TV services.

In terms of the relevant spectrum bands in use for 5G at present, data from the GSA shows that the vast majority of operators across the world are using the 3.5 GHz band (identified as n77 or n78). As of August 2020, there were 178 operators investing in the C-band. Some 127 operators were utilising the 24250–29500 MHz bands (n257, n258 or n261). Only a handful of operators were using the n79 band (4400–5000 MHz).

Figure 8

5G spectrum band usage



Source: GSA Note: Includes deployed, licensed or under consideration

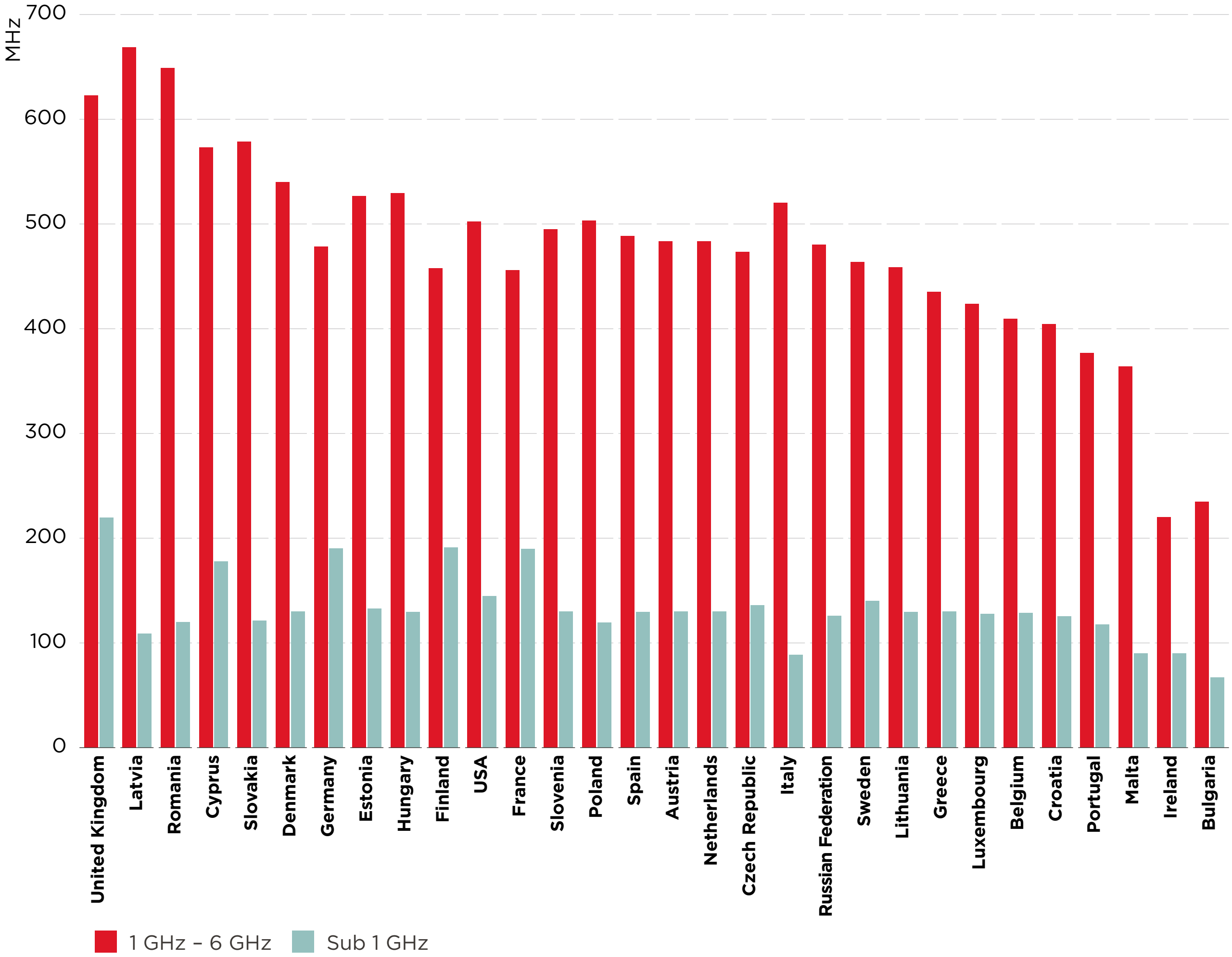
2.10 Spectrum holdings by market

One of the main challenges for the Russian operators looking to extend LTE coverage is the limited amount of spectrum in the sub-1 GHz band. There are strict limitations on the operation and location of base stations in the 800 MHz band due to its use by government services. In practice, these restrictions make it challenging for most of the operators to use this band for both narrowband and wideband radio technologies. For mid-band spectrum, the situation is better – though there are still restrictions on certain bands and in some specific geographical locations. At the regulatory level operators should get an agreement on the admissible technical parameters of base stations. These could diminish the economic feasibility of base station deployment, with limited output power and coverage resulting in lower levels of QoS for customers.

Figure 9 shows total nationwide spectrum assignments, excluding mmWave, across the EU 27, the UK, Russia and US. In Russia and the US, where licences are assigned regionally, the nationwide spectrum holdings are determined by applying a population-weighted average to the regional-level spectrum data. This avoids double counting regional licences and therefore enables cross-country comparison. Many of the countries have already assigned up to 100 MHz of 5G spectrum per operator in the mid-band and up to 1000 MHz in mmWave bands, but these are not included in the graph to enable comparison with Russia.

Figure 9

Total spectrum assignments by country: neutral/2G/3G/4G (excluding 5G)



Source: GSMA

3 Development of the 5G ecosystem

Telecoms is a highly capital-intensive industry. Having sufficient scale can provide huge benefits for all stakeholders as the 5G ecosystem continues to evolve, including operators, consumers and enterprises.

Globally, rising 5G adoption, at least where focused on harmonised spectrum bands, will bring significant economies of scale by reducing deployment costs and increasing the number of affordable devices available. Scale can also have a country-specific component. Individual markets with sufficient scale can significantly influence the global trajectory of 5G development and are themselves able to achieve low unit costs of network rollout. Looking back at the evolution of 4G, the US market played a central role in the evolution and maturity of 4G networks. This helped the US drive international standards and realise significant scale economies for the US operators and broader mobile ecosystem.

A similar pattern is emerging with 5G, as leadership in 5G adoption sees the greatest scale achieved in components and devices built to the specifications of the leading countries' spectrum bands. The 3.5 GHz band is clearly emerging as the band of choice across most markets currently deploying 5G. It is inevitable that both consumer devices and radio network components will see the greatest availability in this band, especially compared to bands with limited adoption.

3.1 Operator economics and 5G

Operators need to generate appropriate returns on the sizeable investments required for 5G. Significant new investments are needed at a time when many operators are still looking to fully monetise their investments in LTE networks – a situation that certainly applies in Russia.

An already challenging operating outlook is further clouded by the Covid-19 pandemic and resultant lockdown, which has affected all the Russian operators and in some cases led them to withdraw financial guidance for the year.

The higher capex levels required for 5G will be driven by a range of factors. For example, the use of higher frequency spectrum bands with shorter ranges will mean 5G needs network densification to meet coverage objectives. Given that potential ranges for mmWave spectrum could in some cases be as low as 100 metres, this will require the construction of a large number of small cells, especially to enable mobile use in buildings.

Network densification raises the need for high capacity and reliable transport solutions, in addition to extra sites. While transport for fronthaul (connections from the antenna to controllers) will grow in importance in the 5G era, over the next few years the biggest transport requirement will be for backhaul. The costs of adding new sites will vary between countries but also between operators. The degree of densification will also reflect, in part, use cases and market demand, as well as the specific spectrum bands available in each market.

A particular challenge facing mobile operators as they contemplate future investment levels concerns the scale and cost of moving to a fully virtualised 5G network architecture, as well as the cost of deploying additional features such as edge computing capabilities. Operators would typically seek a robust business case with clearly identified revenue sources and sizes before embarking on significant new investments, such as the move to deploy distributed edge/cloud infrastructure. While this may appear prudent from a purely financial perspective, it can create inertia around new initiatives. In the rapidly evolving world of 5G and industry digitisation, it may lead to operators foregoing the opportunity completely. This may be a particular challenge in Russia, which is likely to trail the global and regional leaders in 5G deployments and as a result risk missing the opportunity to gain new revenues from emerging 5G services.

3.2 5G device costs and availability

5G handsets were initially priced at a significant premium to 4G devices, with a number over $1,000 and most in excess of $750, at a time when the wider trend in smartphone prices has been steadily downwards in terms of average selling price (ASP). The cost of 5G devices is now beginning to fall, with lower cost devices emerging in China in particular (at prices of $300–600).

The higher costs of 5G devices generally reflect high component costs, significant upfront R&D spend and greater complexity due to the need to incorporate multiple antennas capable of operating at the various frequencies used. In the short term, the lack of scale in manufacturing will also drive higher costs until adoption is more widespread.

The radio modem and antennas required for 5G are more expensive than for 4G. For example, the prices of 5G chipsets from Qualcomm and MediaTek, the two biggest providers of smartphone processors, are estimated to be $60–80 more than those for 4G. As well as antenna complexity, the costs of baseband units and RF power amplifiers[17] are also typically higher.

5G device costs have already started to fall, as scale economies are realised and the range of vendors supplying 5G devices grows. The readiness and availability of integrated processors (application and baseband) should also help lower the cost of 5G. However, 5G RF front end (RFFE) costs are likely to remain significantly elevated relative to 4G predecessor modules, due to their complexity (5G core basebands currently cost around twice as much as those for 3G/4G devices).

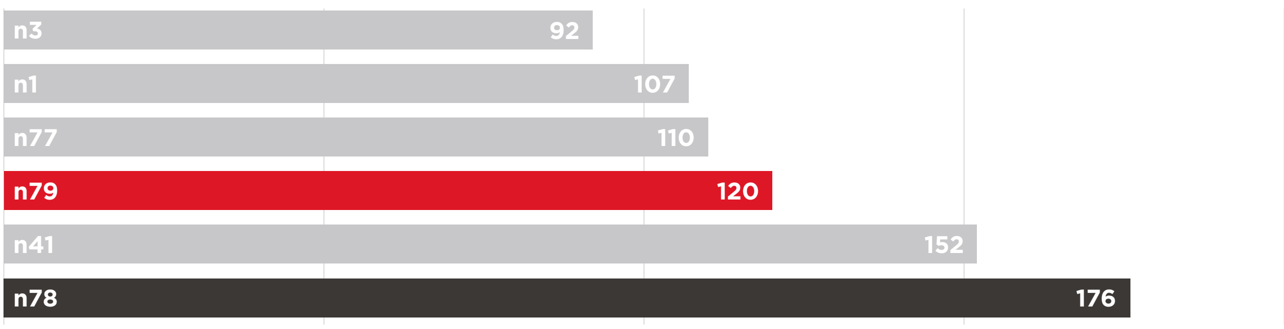
The major benefits to using global, standardised variants of key smartphone components are increased scale in production and the need for fewer design teams. These benefits will generally outweigh certain higher upfront costs, such as incorporating multiple antennas and the larger area of printed circuit board required to support these components.

Data from the GSA shows that at the end of July 2020, 364 5G devices had been announced (including regional variants), of which 162 were commercially available. Note that these device numbers covered a broad range of categories, including smartphones but also hotspots; customer premise equipment (CPE), tablets and notebooks; modules; dongles and gateways; and drones and robots. In aggregate, around 45% of the devices were phones and just over a quarter were CPE, especially for FWA.

Most of the announced devices support low- and mid-band spectrum (sub-6 GHz). In total, 176 devices have been announced with support for band n78 (3300–3800 MHz) – nearly 47% higher than the number of devices announced with support for band n79 (4.4–5.0 GHz). Indeed, of those devices indicated as available for n79, a significant proportion are CPE and FWA devices rather than handsets.

Figure 10

5G devices by band



17 Semiconductor device that converts an electrical signal into a radio signal

Source: GSA

3.3 The Russian device market

The Russian equipment market in terms of both handsets and CPE is fully harmonised with Europe for previous mobile generations (2G, 3G and 4G). When looking forward to 5G, smartphones will generally be expected to meet certain key LTE specifications:

- support for LTE bands 1/3/7/20
- LTE carrier aggregation (LTE CA), including the aggregation of two, three and four component carriers
- LTE radio performance to be adequate at every band that the device supports
- voice over LTE (VoLTE) and voice over Wi-Fi (VoWiFi) – important additional functions that a 5G device would be expected to support.

The growing number of spectrum bands brought into use by 5G means that, unlike the situation with 4G, there will be few (if any) truly global devices. It is unlikely to prove cost effective to design and build handsets that can support all the bands in use globally. As a result, where devices are sourced from vendors primarily serving a non-European market, not all the features highlighted above may be present. For example, a number of Chinese smartphones do not support LTE band 20 (800 MHz), which is a common 4G band in Europe and Russia.

As well as different 5G band preferences across regions, operators are today deploying 5G NSA. NSA uses an LTE anchor band for control and a wider 5G band to achieve higher data rates. This will require devices to interact with both 5G and LTE bands, adding complexity to the RF engineering in the device. Devices will need to support the implementation of multi-band CA combinations, particularly on the uplink.

There are currently only a few devices on the market that support n79 as well as the legacy LTE bands 7, 20 and 38 used in Russia. In the absence of global devices, the solution to this challenge would likely be for Chinese vendors to adapt their smartphone SKUs to include the features outlined above as required for the Russian market. At present, there are no signs of any widespread move to implement such design changes, and vendors are unlikely to consider this until there is clarity on band assignments in Russia and a spectrum roadmap. While addressable from a technology perspective, the extra complexity will add to the cost of devices due to the scale issue outlined earlier.

3.4 Encryption and the challenges of domestic standards

Various mobile standards organisations in Russia are working on the draft national legal act (NLA) for 5G smartphones. Following an initial agreement between the Ministry of Communications and the Ministry of Economic Development, subsequent coordination with the FSB (Security Services) introduced a new requirement (no.19) to support the national encryption algorithm:

> The protection of subscriber and signal traffic in the radio channel between the subscriber terminal and the base station should be ensured using cryptographic information protection means, including those with confirmation of compliance with the security requirements for KS3 class information established by the federal executive body in the field of security.

In practice, this request could lead to the Russian market adopting a non-harmonised approach to cryptography. 5G security is specified in the 3GPP TS 33.501 specification (security architecture and procedures for 5G system – Release 15). 5G security is based on proven algorithms that are already in use in 4G networks and devices. These are encryption algorithms based on SNOW 3G, AES-CTR and ZUC; and integrity algorithms based on SNOW 3G, AES-CMAC and ZUC. The key generation function is based on the secure HMAC-SHA-256 algorithm.

Implementing requirement 19 will make it impossible for vendors to certify 5G terminal equipment in Russia. No vendors of chipsets, infrastructure and terminal equipment support non-standard encryption algorithms. Rather, they all adhere to the 3GPP standards, which is the foundation for telecommunications equipment compatibility in markets across the world.

There are examples from other regions of countries looking to develop their own standards, including Japan and China.

Japan: Future Of Mobile Access

Against a backdrop of a strong manufacturing sector and clear patent ecosystem, in 2001 Japan introduced a version of the 3G technology that diverged from 3GPP, called Future of Mobile Access (FOMA). The technology was accepted by the ITU as an IMT-2000 air interface. However, the lower quality of the specifications owing to the lack of sufficient peer review resulted in NTT Docomo reverting in 2004 to the pre-existing 3GPP specifications. This incurred significant costs for the operator. In the process, suppliers of FOMA-compliant equipment such as NEC, Hitachi and Fujitsu had to split their resources across the two variants, which contributed to them losing their leading positions in the telecoms vendor community.

China: TD-SCDMA

The Chinese government asked China Mobile to deploy a TD-SCDMA network, with the operator receiving a licence from the MIIT to operate this technology in 2009, following limited trials. TD-SCDMA was a domestic standard developed in China, with the additional support of Siemens. The air interface was accepted by ITU as part of IMT-2000.

In contrast, China Telecom and China Unicom were assigned licences to operate CDMA2000 and W-CDMA networks respectively. These were both international standards, though ratified by different international bodies, namely 3GPP2 and 3GPP respectively. Despite considerable investment by China Mobile and other local ecosystem players (press reports suggested total investments in excess of $30 billion), China Mobile announced in 2014 that it would phase out its TD-SCDMA network as part of its transition to 4G.

Requiring vendors to support different product lines (equipment compliant to two different sets of standards) will lead to an inevitable impact on prices, availability and time to market as more interoperability testing will be needed.

The position of the GSMA is to support all governments that encourage national research and development efforts, particularly currently with 5G. However, it remains key that such efforts are aligned with international standards or gain subsequent recognition at an international level. The GSMA position always emphasises the benefit of globally harmonised standards in developing an ecosystem capable of supporting not only economies of scale but also future research for delivering ongoing improvements.

Collaboration within the framework of international standards will allow Russia to grow its influence on the international stage and support the creation of strong manufacturing companies, while still giving the flexibility to allow improvements to the country's technology roadmap when required.

With regard to the specific issue of encryption in 5G networks, the GSMA would recommend that the Russian authorities clarify whether the existing 3GPP security standards for 5G NR meet the specific requirements for KSZ class information, as established by the federal executive body in the field of security. If this proves to be the case, there is no need for an additional cryptographic element in the network. If it proves not to be the case, the best course of action would be for the Russian authorities to work alongside the 3GPP organisation and its relevant channels and specifications groups in order to strengthen the encryption algorithms.

4 Total cost of ownership model comparing the two spectrum ranges

The GSMA Intelligence model looks in detail at the relative cost differences of deploying 5G in Moscow in two separate spectrum ranges, namely 3.5 GHz and 4.8 GHz. The model presents the potential costs of deploying and operating an NSA 5G network over the period 2023–2030.

The geographic focus is the wider Moscow area (an area of 1,030 square kilometres, bounded by the Moscow Ring Road), including both dense urban areas and lower density, residential areas. The model uses a bottom-up approach to estimate the total capex and opex of the four federal Russian mobile network operators. This allows a comparison of the aggregate costs associated with deploying 5G in 3.5 GHz versus 4.8 GHz.

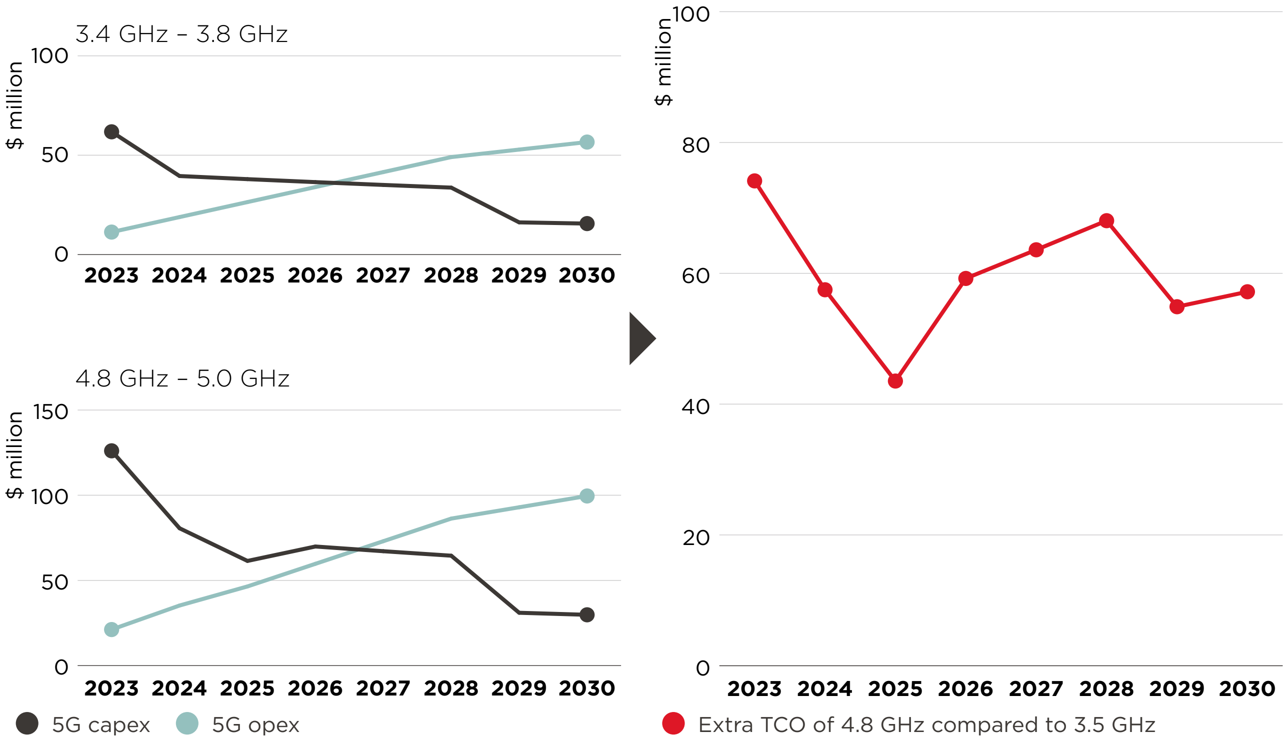
The modelling process captured data points and inputs from a range of external sources, and drew upon expertise within the GSMA and the broad range of data and modelling work available within GSMA Intelligence. Interviews were conducted with major equipment vendors, garnering further inputs to identify the main drivers of 5G total cost of ownership (TCO) in the two ranges.

The model splits the Moscow region into three categories based on the anticipated level of data traffic and the need for network capacity. Based on the research undertaken, GSMA Intelligence identified the different 5G site density requirements (5G sites per square kilometre) to provide suitable 5G coverage for different areas for both examined spectrum bands. There was a clear consensus from all the interviewees and other sources that deploying 5G in the 4.8 GHz band will require a higher site density in all deployment scenarios. GSMA Intelligence calculated an average of these different sources and used it to forecast the needed site numbers for three scenarios: standard outdoor (ICNIRP limits), SANPIN (Russian EMF limits) and deep indoor (satisfying indoor 5G demand in dense urban areas).

5G base station deployment costs and operating costs depend heavily on the choice of frequency, as well as the amount and nature of existing infrastructure on the ground. In situations where operators need to deploy greenfield sites, the TCO will include the costs of acquiring new sites, providing passive infrastructure and new backhauling. In a brownfield scenario, the new radio equipment can piggyback on the existing passive infrastructure and backhauling, with a related reduction in cost. The modelling highlighted the fact that the additional costs of deploying densified greenfield sites in the 4.8–4.99 GHz range (due to the greater need for network densification) are one of the major drivers of the 3.5 GHz range's relative cost-efficiency.

Figure 11

5G deployment cost and additional TCO in Moscow



Source: GSMA

According to the standard outdoor scenario, deploying and operating an NSA 5G network between 2023 and 2030 using the 4.8 GHz band would cost Russian operators 84% more compared to the 3.5 GHz range. For the scenario with the deep indoor coverage, this increases to 117%.

The difference in TCO is driven by three key factors:

- The higher densification requirement in the 4.8 GHz band. This reflects the law of physics and more limited propagation characteristics of spectrum in this band.
- The ecosystem and vendor supply of equipment is significantly limited in the 4.8 GHz band, as outlined earlier in the report. With the clear majority of operators globally using the 3.5 GHz range, most vendors are currently offering advanced solutions supporting this band. In contrast, vendors have more limited offerings and significantly less experience with large-scale deployments in the 4.8 GHz band.
- A number of technical experts highlighted the potential increase in energy consumption. To cover the same area and transfer the same amount of data, the 4.8 GHz band is expected to use more energy, reflecting the relative immaturity of the products and ecosystem support.

It is important to highlight that in addition to the model outputs, all the technical experts consulted for this exercise emphasised that the 4.8 GHz band is sub-optimal for large-scale, coverage-focused 5G deployments. This is consistent with the analysis earlier in the report, which notes that to date 4.8 GHz has been licensed either as an additional, capacity-focused, complementary layer to support other bands or for campus-based private 5G networks.

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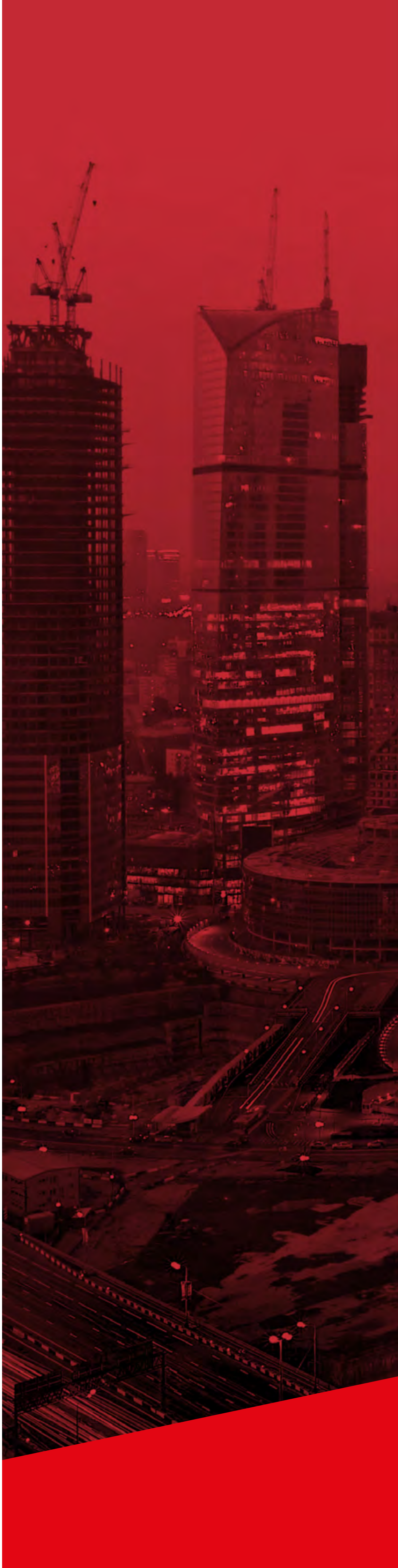

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