5G Spectrum

GSMA Public Policy Position

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Executive Summary

5G supports significantly faster mobile broadband speeds and lower latencies than previous generations while also enabling the full potential of the Internet of Things. From connecting vehicles and transforming healthcare to building smart cities and providing fibre-in-the-air, 5G will be at the heart of the future of communications. 5G is also essential for preserving the future of today's most popular mobile applications – like on-demand video – by ensuring that growing uptake and usage can be sustained.

5G goes beyond meeting evolving consumer mobile demands by also delivering carefully designed capabilities that will transform industry vertical sectors. It introduces a new level of flexibility and agility so the network can deliver customisable services to meet the needs of a huge variety of users and connection types. Features like network slicing and advanced antenna technologies mean industrial sectors can rely on the network delivering precisely what they need – in terms of speed, latency and quality of service.

However, the success of the services is heavily reliant on national governments and regulators. The speed, reach and quality of 5G services depends on governments and regulators supporting timely access to the right amount and type of affordable spectrum, under the right conditions. A variation in the amount of spectrum assigned, and the prices paid, means the potential of 5G services will vary between countries. This, in turn, directly impacts the competitiveness of national economies.

This paper outlines the GSMA's key 5G spectrum positions which focus on the areas where governments, regulators and the mobile industry must cooperate to make 5G a success.

1. **5G needs a significant amount of new harmonised mobile spectrum so defragmenting and clearing prime bands should be prioritised. Regulators should aim to make available 80-100 MHz of contiguous spectrum per operator in prime 5G mid-bands (e.g. 3.5 GHz) and around 1 GHz per operator in high-bands (e.g. mmWave spectrum).**

2. **5G needs spectrum across low, mid and high spectrum ranges to deliver widespread coverage and support all use cases. All three have important roles to play:**

- **Low-bands (e.g. sub-1 GHz) support widespread coverage across urban, suburban and rural areas and help support Internet of Things (IoT) services.**

- **Mid-bands typically offer a good mixture 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 which 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 to maintain 5G quality of service and growing demand, in bands between 3 and 24 GHz.**

- **High-bands are needed to meet the ultra-high broadband speeds envisioned for 5G. Currently, 26 GHz, 28 GHz and 40 GHz have the most international support and momentum.**

3. **WRC-23 will be an essential opportunity to improve 5G coverage, increase affordability through harmonisation and support growing data demand. Governments should engage in the WRC-23 process to ensure that sufficient mid- and low-band spectrum is made available for 5G.**

4. **Exclusively licensed spectrum should remain the core 5G spectrum management approach. Spectrum sharing and unlicensed bands can play a complementary role.**

5. **Setting spectrum aside for verticals in priority 5G bands (i.e. 3.5/26/28 GHz) could jeopardise the success of public 5G services and may waste spectrum. Sharing approaches like leasing are better options where verticals require access to spectrum.**

6. **Governments and regulators should avoid inflating 5G spectrum prices as this risks limiting network investment and driving up the cost of services. This includes excessive reserve prices or annual fees, limiting spectrum supply (e.g. set-asides), excessive obligations and poor auction design.**

7. **Regulators must consult 5G stakeholders to ensure spectrum awards and licensing approaches consider technical and commercial deployment plans.**

8. **Governments and regulators need to adopt national spectrum policy measures to encourage long-term heavy investments in 5G networks (e.g. long-term licences, clear renewal process, spectrum roadmap etc).**

Background

5G is defined in a set of standardised specifications that are agreed on by international bodies – most notably the 3GPP and ultimately by the ITU in 2020. The ITU has outlined specific criteria for IMT-2020 – commonly regarded as 5G – which will support the following use cases:

1. **Enhanced mobile broadband:** Including peak download speeds of at least 20 Gbps and a reliable 100 Mbps user experience data rate in urban areas.[1] This will better support increased consumption of video as well as emerging services like virtual and augmented reality.
2. **Ultra-reliable and low latency communications:** Including 1ms latency[1] and very high availability, reliability and security to support services such as autonomous vehicles and mobile healthcare.
3. **Massive machine-type communications:** Including the ability to support at least one million IoT connections per square kilometre[1] with very long battery life and wide coverage including inside buildings.
4. **Fixed wireless access:** Including the ability to offer fibre type speeds to homes and businesses in both developed and developing markets using new wider frequency bands, massive MIMO and 3D beamforming technologies.[2]

This means 5G can offer a far greater range of capabilities from the outset than any previous mobile technology generation. As a result, 5G not only meets the evolving requirements of consumers, but can also have a transformative impact on businesses to the extent that it is being hailed as vital to the so-called "fourth industrial revolution".[3] 5G is expected to underpin and enable many of the components of this revolution including the Internet of Things, cloud computing, cyber-physical systems and cognitive computing. From automated industrial manufacturing and driverless cars to a vast array of connected machines and sensors, 5G enables smarter and more efficient businesses and industry vertical sectors (e.g. utilities, manufacturing, transport etc).

The initial 3GPP 5G standard[4] has been submitted as a candidate for IMT-2020 and comprises several different technologies. This includes 5G New Radio (NR) which supports existing mobile bands as well as new, wider ones for 5G. It supports channel sizes ranging from 5 MHz to 100 MHz for bands below 6 GHz, and channel sizes from 50 MHz to 400 MHz in bands above 24 GHz. The full capabilities of 5G are best realised through the wider channel sizes in new 5G bands. The ITU's minimum technical requirements to meet the IMT-2020 criteria – and thus the fastest speeds – specify at least 100 MHz channels per operator. They also specify support for up to 1 GHz per operator[1] in bands above 6 GHz.

The 5G standards also include end-to-end network slicing and mobile edge computing which are vital to supporting the needs of industry vertical sectors. In particular, network slicing will allow operators to create virtual sub-network slices with tailored features for specific types of user or usage requirement. Each slice can have a tailored set of network resources including spectrum bands and channels, radio access, and core network features including security. For example, ultra-low latency and high-availability slices are a good fit for automated manufacturing, connected cars and remote surgery. Contrastingly, IoT networks with vast numbers of sensors and devices like streaming video cameras can be allocated a slice that is tailored for uplink heavy communications.

However, network slicing will only be as flexible and capable as the operators' network and spectrum assets allow. For example, some verticals depend on ultra-low latency capabilities while others need superfast download speeds. Some need highly localised connectivity (e.g. small cells for a factory) while others will need nationwide connectivity (e.g. a vast macro network to support sensors for utility companies). Each of these examples needs different spectrum and network resources. Ultra-low latency services and high-speed broadband services need different spectrum bands as their radio resource requirements are incompatible. Similarly, high-capacity, localised services better suit capacity bands (i.e. above 1 GHz) whereas nationwide services benefit from coverage bands (i.e. sub-1GHz). Mobile operators are the best placed to provide the wide variety of services envisaged, including private networks with leased spectrum in cases where that is needed due to the specific requirements from verticals.

1. Source: ITU report 'Minimum requirements related to technical performance for IMT-2020 radio interface
2. Source: GSMA report: 'Fixed Wireless Access: Economic Potential and Best Practices' (2018)
3. The first industrial revolution is associated with the impact of steam power; the second is linked with science and mass production; and the third was driven by the emergence of digital technology and computing
4. 3GPP Release 15 is the body's first release of 5G specifications , was largely completed in June 2018 and will be submitted as a candidate for the ITU's IMT 2020 (5G) standards

Regulators around the world are actively developing their 5G spectrum plans and some have completed the first assignments. The key focus is on new mobile bands including spectrum in the 3.5 GHz range (i.e. 3.3-3.8 GHz) that has been assigned in numerous countries. But other bands are also being considered. For example:

- Several countries plan to use spectrum in the 4.5-5 GHz range for 5G, including China and Japan;
- A growing number of countries are considering the 3.8-4.2 GHz[5] range, and 5925/6425 – 7125 MHz;
- There is also interest in assigning the 2.3 GHz and 2.5/2.6 GHz bands for 5G.[6]

However, the fastest 5G speeds depend on millimetre wave (mmWave) bands above 24 GHz. At WRC-19, countries supported a globally harmonised identification of 26 GHz, 40 GHz and 66 GHz for IMT. In some parts of the world, it is also possible to start using 50 GHz.[7] At the other end of the spectrum, Europe has prioritised the 700 MHz band for wide area 5G deployments and the US has already licensed the 600 MHz band.

The new 5G bands that regulators are making available also affect how networks are deployed. Prime 5G mid-bands (e.g. 3.5 GHz) and mmWave bands (e.g. 26 GHz and 28 GHz) suits dense 5G small cell networks in urban hotspots where additional capacity is vital. However, these frequency bands can also suit macrocells for wider area coverage – including fixed wireless access – using beamforming. These technological advancements mean that the 3.5 GHz band can provide the same coverage, and use the same cell sites, as the current 2.6 GHz and 1800 MHz mobile bands. The 600 MHz and 700 MHz, on the other hand, support wide area 5G services including the Internet of Things.

5G is also the first major rollout of Time Division Duplex (TDD) cellular networks in most countries. All 5G bands above 3 GHz – including the vital 3.5 GHz range and mmWave bands – will adopt TDD. This means base stations and end-user devices on TDD networks transmit using the same channel at different times. This can create interference issues within and between different 5G networks. For example, higher power transmissions from base stations on one network can interfere with the ability of base stations on other networks to receive signals from lower power end-user devices.

Effective interference measures require that TDD networks operating in the same frequency range and within the same area are synchronised. Base stations will need to transmit at the same fixed time periods and all 4G and 5G devices transmit at different time periods. The chosen approach to synchronisation impacts the use cases that can be addressed in the band. For example, very low latency 5G applications can't be supported in the same band and area as very fast mobile broadband 5G applications. Mobile operators should be able to overcome this issue by making use of a variety of bands for 5G. Regulators need to consider these technical matters, and their implications, when deciding how to make spectrum available in 5G TDD bands.

5. For example, Japan has already licensed spectrum in the range and the US has advanced plans to conduct an auction to do the same.
6. 'FCC pushing to open up the 2.5 GHz band for 5G', RCR Wireless, 20th June 2019
7. The WRC-19 results are detailed in the 'WRC-19 strikes a good balance, sets stage for mmWave 5G' on the GSMA's website

Positions

1. **5G needs a significant amount of new harmonised mobile spectrum so defragmenting and clearing prime bands should be prioritised. Regulators should aim to make available 80-100 MHz of contiguous spectrum per operator in prime 5G mid-bands (e.g. 3.5 GHz) and around 1 GHz per operator in high-bands (e.g. mmWave spectrum).**
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. 5G is no different. Regulators that get as close as possible to assigning 100 MHz per operator in 5G mid-bands. The tables below illustrate the direct impact on making less spectrum available on speeds (figure 1) as well as network investments (figure 2). And an additional 1 GHz in mmWave bands will best support the very fastest 5G services. These targets are starting to be met with South Korea awarding 100 MHz to two operators (and 80 MHz to the third) in the 3.5 GHz band and 800 MHz per operator in the 28 GHz band in 2018.[8]

   Where 5G spectrum is held back from the market unnecessarily (e.g. through set-asides) then commercial 5G services are likely to suffer and operators may overpay at auctions which risks limiting network investment thus harming consumers.[9] However, although maximising the amount of spectrum released in a 5G band is encouraged, individual lot sizes at auction should be small enough to maximise flexibility. In 5G mid-bands (i.e. 3.5 GHz), equal lot sizes of around 10 MHz[10] each are sensible so bidders can aggregate them to meet their needs, while in the 26 GHz band block sizes of around 100-200 MHz are suitable. Mismatched lot sizes can create artificial scarcity and risk operators being unable to secure their desired amount and also overpaying.

In many countries, there are incumbent users in priority 5G bands so meeting the aforementioned targets 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 range (3.3-3.8 GHz). This can include:

- Providing incentives for incumbents to migrate ahead of awarding the spectrum
- Moving incumbents to alternative bands or within a single portion of the range
- Allow incumbents to trade their licences with mobile operators

If countries are assigning spectrum in one range in multiple phases in order to gradually migrate incumbents (e.g. assigning 3.4-3.6 GHz then 3.6-3.8 GHz), or have incumbent licensees in part of the band, the process should involve re-planning the band afterwards to allow operators to create larger contiguous blocks. Long-term 5G roadmaps should be developed in consultation with stakeholders as soon as possible so operators understand how much spectrum will be made available by when, and what will happen to incumbents to help inform spectrum trading decisions.

FIGURE 1

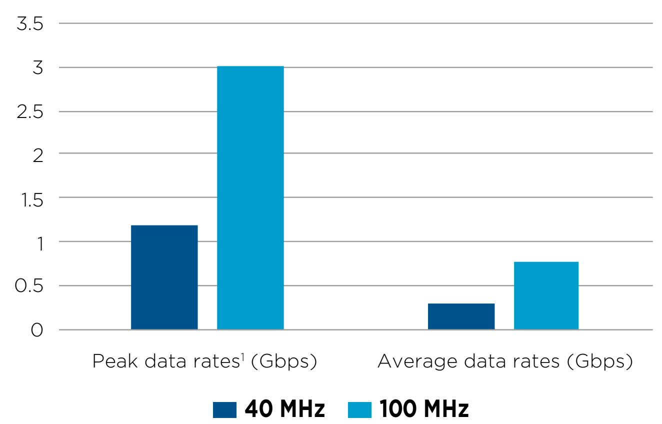
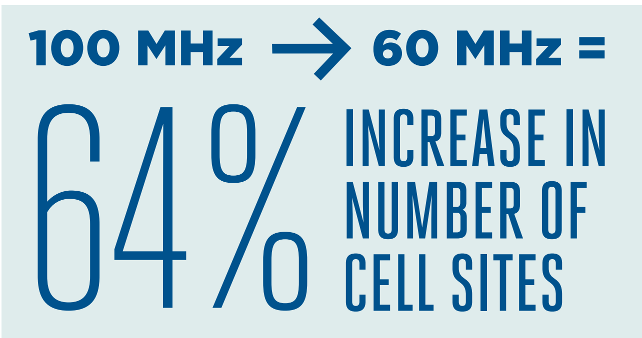


FIGURE 2



8. Source: RCR Wireless, 'South Korea completes 5G spectrum auction'
9. See position 6
10. Much larger block sizes (e.g. 50-100 MHz) would generally only suit mmW bands (e.g. 26/28/40 GHz)

2. **5G needs spectrum across low, mid and high spectrum ranges to deliver widespread coverage and support all use cases. All three have important roles to play:**
   Low-bands are needed to extend high speed 5G mobile broadband coverage across urban, suburban and rural areas and to help support IoT services: 5G services will struggle to reach beyond urban centres and deep inside buildings without this spectrum.

   A portion of UHF television spectrum should be made available for this purpose through the second digital dividend.[11] The European Commission supports the use of the 700 MHz band for 5G services[12] and in the United States T-Mobile is using the 600 MHz band for 5G across the country.[13]

   Mid-bands typically offer a good mixture of coverage and capacity for 5G services: It is vital that regulators assign as much contiguous spectrum as possible in the 3.5 GHz range (3.3 GHz-4.2 GHz). The 2.3 GHz and 2.6 GHz bands should also be licensed to operators for 5G use. Existing mobile licences should also be technology neutral to allow their evolution to 5G services. In the long term, more spectrum will be needed to maintain 5G quality of service and growing demand, in bands between 3 and 24 GHz. This includes more spectrum in the 3.5 GHz range, 6 GHz and 10 GHz, which are all part of the WRC-23 process.

   High-bands are needed for 5G services such as ultra-high-speed mobile broadband: 5G will not be able to deliver the fastest data speeds without these bands. It is vital that governments award spectrum that has been globally identified for IMT (e.g. 26 GHz and 40 GHz) and additionally make the 28 GHz band available where possible. The 26 GHz and 28 GHz bands have especially strong momentum and as they are adjacent they support spectrum harmonisation and therefore lower handset complexity, economies of scale and early equipment availability.

3. **WRC-23 will be an essential opportunity to improve 5G coverage, increase affordability through harmonisation and support growing data demand. Governments should engage in the WRC-23 process to ensure that sufficient mid- and low-band spectrum is made available for 5G.**
   WRC-19 identified high capacity spectrum for 5G. It is now important that governments and regulators work on 5G coverage spectrum: mid-band and lower frequencies are required. 5G coverage can be improved through further harmonisation of these frequencies at WRC-23 and its preparatory meetings.

   The bands under consideration at WRC-23 are 470-960 MHz, as well as ranges in 3 GHz, 6 GHz, and 10 GHz. They all have a role to play in ensuring 5G reaches all users.

   The need to identify more spectrum below 1 GHz has to be met in order to spread the benefits of 5G to rural areas and accelerate Internet of Things (IoT) growth.

   Spectrum in the 3 GHz range (from 3.3-4.2 GHz) provides a good balance of coverage and capacity and is already being used for commercial 5G services in some countries. Further harmonisation of this range will be possible at WRC-23. Spectrum in the 6 and 10 GHz ranges is required to enhance 5G connectivity.

   Ensuring that sufficient channel bandwidth is available for operators will boost 5G network performance, bring down deployment costs and drive significant economic benefit. International harmonisation will help make the best possible mobile services available for everyone and everything.

11. The second digital dividend is the 700 MHz band in Europe, the Middle East and Africa and the 600 MHz band in the Americas and Asia-Pacific
12. 'European Commission stakes out 700 MHz band for 5G' – Telecom TV (2016)
13. See T-Mobile's 5G coverage map online

4. **Licensed spectrum should be the core 5G spectrum management approach. Spectrum sharing and unlicensed spectrum can play a complementary role.** Licensed spectrum is essential to guarantee the necessary long-term heavy network investment needed for 5G and to deliver high quality of service. The risks surrounding network investment are significantly increased without the assurances of long-term, reliable, predictable, spectrum access. Licensed spectrum, which enables wider coverage areas and better quality of service guarantees, has been central to the growth of widespread, affordable mobile broadband services.

   Unlicensed spectrum is also likely to play a complementary role by allowing operators to augment the 5G user experience by aggregating licensed and unlicensed bands. Combining licensed and unlicensed spectrum maximises the use of unlicensed spectrum while minimising the risk of delivering a poor user experience if the bands are congested.

   Spectrum sharing frameworks can also play a complementary role but must be carefully designed to avoid undermining the potential of 5G.[14] Where clearing a band is not feasible, sharing can help open up access to new spectrum for 5G in areas where it is needed but is under-used by current incumbent users. However, prospective bands for sharing must be harmonised and available in the right amounts, in the right areas and at the right times to support 5G. To justify widespread heavy network investments, mobile operators need assured access to significant amounts of licensed spectrum for a sufficient duration (e.g. 20 year licences).

   Regulators should permit operators to voluntarily share spectrum with each other to help support super-fast 5G services, more efficient spectrum usage and to extend the benefits of network sharing arrangements. This should include permitting operators to enter into voluntary commercial agreements to lease their spectrum to other types of operators, such as enterprises, which want to build their own private networks. However, other approaches which undermine operators' certainty of access to spectrum, such as mandating that existing licensed spectrum is shared in ways that create an uncertain business environment, risk jeopardising planned long-term, wide area 5G network investment. Sharing may not always possible due to several reasons including planned coverage improvements, including those required by licence obligations, or due to the risk of interference in nearby areas.

   More complex, three-tier sharing regimes with set-aside spectrum for General Authorised Access[15] may limit, or eliminate, the potential for 5G services in the band. For example, the CBRS approach planned in the United States is unlikely to support high-speed 5G services, as there is only a limited amount of licensed spectrum available. Sharing models can also make it difficult to coordinate 5G networks to avoid interference as synchronising many different 5G networks that are used for different purposes can be challenging as their configurations may be incompatible.

14. See the GSMA's spectrum sharing position paper for more information
15. E.g. Licence-exempt spectrum but that may require registration on a spectrum access system database

5. **Setting spectrum aside for verticals in priority 5G bands (i.e. 3.5/26/28 GHz) could jeopardise the success of public 5G services and may waste spectrum. Sharing approaches like leasing are better options where verticals require access to spectrum.**
   Spectrum that is set-aside nationally for vertical industries in priority 5G bands (i.e. 3.5/26/28 GHz) poses several threats to the wider success of 5G. Set-asides can limit the assignment of sufficiently large contiguous blocks to allow mobile operators to deliver the fastest 5G services. They can also undermine fair access to spectrum by providing certain users with privileged access instead of participating in competitive awards. Set-asides also create artificial scarcity which risks inflating spectrum prices which can in turn lead to reduced investment in 5G networks and potentially higher consumer prices. Regulators should especially avoid set-asides where it will mean they cannot meet the aim of making available 80-100 MHz per operator in priority mid-bands (e.g. 3.5 GHz) and around 1 GHz in mmWaves (e.g. 26 or 28 GHz). For all of these reasons, it is advised that set-asides should not be used. Market mechanisms are instead best placed to decide who would be using the spectrum more efficiently. At a minimum, a comprehensive cost-benefit analysis compared with use in public mobile services and allocation through market-based awards should be done to justify a set-aside.

   More widely, set-asides for restricted use cases can lead to inefficient spectrum usage. Vertical industries are unlikely to use spectrum in priority 5G bands very widely across countries, so national set-asides are likely to go unused in many areas. Instead, mobile operators can provide customised 5G services for verticals who can then benefit from network slicing, small cells, wider geographical coverage, as well as the larger and more diverse spectrum assets, as well as deployment experience, at mobile operators' disposal. Mobile operators are the best placed to provide the wide variety of services envisaged, including private networks provisioning with leased spectrum in cases where is needed due to the specific requirements from verticals.

Voluntary spectrum sharing approaches are preferable to set asides as they can be used to support all potential 5G users, including verticals. For example, MNOs can be permitted to lease their spectrum assets so that verticals can build their own private 5G networks. The Finnish regulator chose to adopt this approach instead of a vertical set-aside and sharing agreements between a national MNO and specialist vertical micro-operator is already in place in Sweden.[16] Given the high risk that set-aside spectrum may go unused it is sensible for regulators to prepare to allow it to be made available through market mechanisms should this prove to be the case (e.g. a sunset clause).

Mixing industrial and commercial networks in a band through set-asides present signicant technical deployment challenges which could result in harmful interference or limit the 5G services that can be supported. For example, all 5G networks in a band are likely to need to be synchronised which means very high speed public broadband networks could not co-exist with very low latency industrial networks in the same area. At the very least, the users of vertical set-asides need to coordinate with 5G commercial networks to mitigate interference. Existing studies show that a separation distance of 14km would be needed between unsynchronised 5G networks in adjacent spectrum, and 60km for networks in the same spectrum (i.e. co-channel).[17] In practice, this would create serious restrictions on where 5G deployments can happen and which use cases can be supported.

16. 'Three Sweden leases public spectrum for private usage' May 28, 2019
17. See ECC REP 296 which considers separation distances between unsynchronised 5G macro networks

6. **Governments and regulators should avoid inflating 5G spectrum prices as this risks limiting network investment and driving up the cost of services. This includes excessive reserve prices or annual fees, limiting spectrum supply (e.g. set-asides), excessive obligations and poor auction design.**
   Governments and regulators should assign 5G spectrum to support their digital connectivity goals rather than as a means of maximising state revenues. Effective spectrum pricing policies are vital to support better quality and more affordable 5G services. High spectrum prices are linked to more expensive, slower mobile broadband services with worse coverage.[18] The causes of very high prices are typically policy decisions that appear to prioritise maximising short-term state revenues over long-term socio-economic benefits. To avoid this, governments and regulators should:
   - Set modest reserve prices and annual fees, and rely on the market to determine spectrum prices
   - Avoid limiting the supply of 5G spectrum as scarcity can lead to excessive prices. A particular concern is set-asides for verticals or new entrants in core 5G bands (i.e. 3.5 GHz and 26/28 GHz)
   - Carefully consider the auction design[19] to avoid unnecessary risks for bidders (e.g. avoiding mismatched lot sizes, which create artificial scarcity, and first-price, sealed bid auctions)
   - Develop and publish a 5G spectrum roadmap with the input of stakeholders to help operators plan for future availability
   - Consult with stakeholders on the award rules as well as the licence terms and conditions take them into account when setting prices

7. **Regulators must consult 5G stakeholders to ensure spectrum awards and licensing approaches consider technical and commercial deployment plans**
   The decisions regulators face around 5G spectrum are complex and have a major impact on the quality of services and the use cases that can be supported. For example, if spectrum licence areas are very small then it may be impossible to support 5G deployments using macrocells, including fixed wireless access, as well as in-band backhaul. It is important that consultations are held to discuss planned deployments and how they may be impacted by very localised, regional or nationwide spectrum licensing. These should include technical deployment considerations including the required measures to minimise interference. It will be especially important to discuss how to manage synchronisation in order to best serve the interests of 5G operators.

8. **Governments need to adopt national spectrum policy measures to encourage long-term heavy investment in 5G networks (e.g. long-term licences, renewal process, spectrum roadmap etc).**
   5G network deployments require significant network investment. The speed of rollouts, quality of service and coverage levels will all be compromised without sufficient investment. Governments and regulators can encourage high levels of investment by adopting important spectrum policies including:
   - Supporting exclusive, long-term 5G mobile licences with a predictable renewal process
   - Producing a national broadband plan including 5G which details activities and timeframes
   - Publishing a 5G spectrum roadmap
   - Ensuring all mobile licences are technology neutral to speed up wide area 5G rollouts and encourage improved spectrum efficiency

18. GSMAi (2018) 'Spectrum pricing in Developing Countries' & NERA (2017) 'Effective Spectrum Pricing'
19. See the GSMA's 'Auction best practice' position paper (2019)

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