The socioeconomic benefits of the 6 GHz band

Considering licensed and unlicensed options

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Executive summary

Considerations on the optimal approach for managing spectrum are currently at the forefront of the debate around the 5925–7125 MHz frequency range as governments decide how best to manage this spectrum over the coming decades. The key consideration is whether to utilise the spectrum for licensed mobile (i.e. 5G new radio (NR) and its evolution) or for unlicensed use (i.e. Wi-Fi 6 and its evolution).

To date, countries that have allocated spectrum in this band have taken divergent approaches. Some have assigned the full 6 GHz band for unlicensed use, while others are considering the full band for licensed use. A third group are allocating the lower part of 6 GHz (5925/5945–6425 MHz) for unlicensed and considering the upper part (6425–7125 MHz) for licensed. Included on the agenda of the next World Radiocommunication Conference (WRC-23) is the IMT identification of 6425–7025 MHz in ITU Region 1 (Europe, the Commonwealth of Independent States, Mongolia, Africa and the Middle East west of the Persian Gulf, including Iraq)[1] and 7025–7125 MHz in all regions.

Governments around the world therefore need to make a carefully considered decision as to what the most efficient use of 6 GHz spectrum will be. It represents the largest remaining single block of mid-band spectrum that can be allocated to licensed mobile or unlicensed services in the foreseeable future. When governments are considering which approach to take, policymakers should conduct a regulatory impact assessment to identify the best policy option for radio spectrum assignments – specifically the policy that will maximise the social and economic value of spectrum. To assist policymakers in performing such an assessment, this report conducts a cost-benefit analysis for different authorisation models for the 6 GHz band.

1 See ITU RR article 5.3 for exact definition

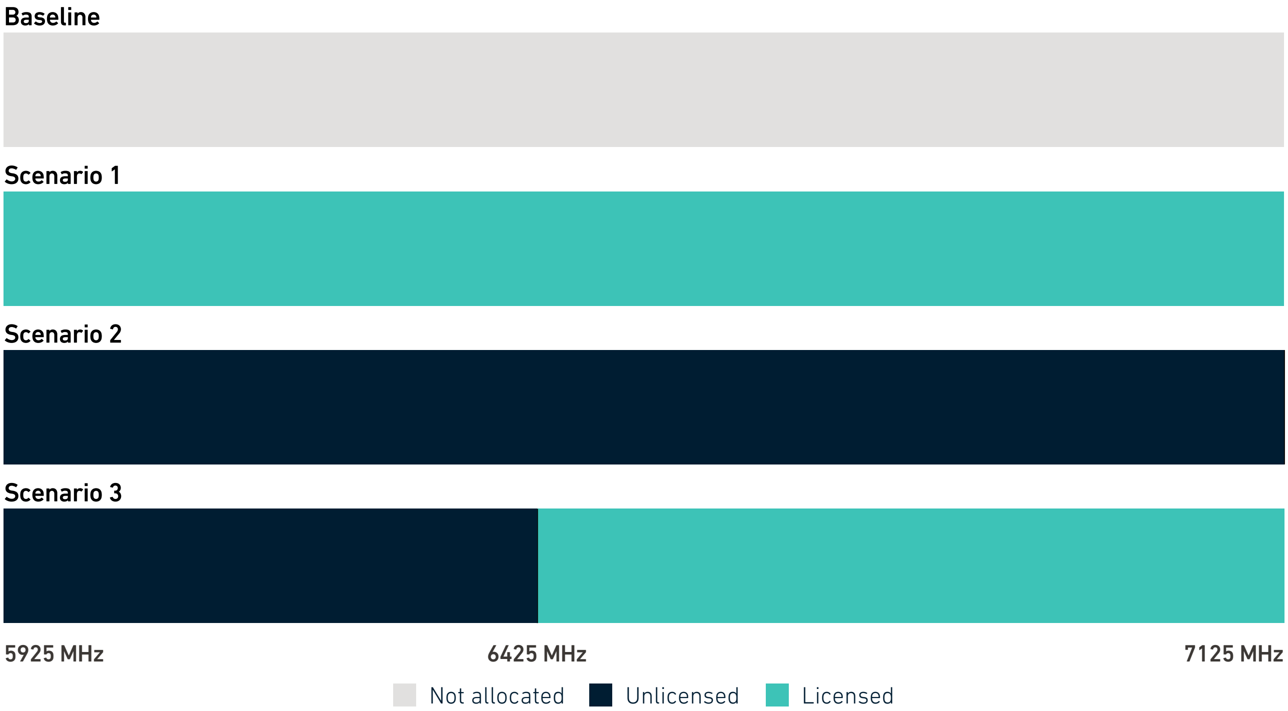
In the case of 5G licensed use, 6 GHz can enable increased wide-area capacity in urban areas for enhanced mobile broadband (eMBB), ultra-reliable low-latency communication (URLLC) and massive IoT (mIoT), as well as the provision of fixed wireless access in small towns and villages. If additional mid-band spectrum is not made available, this could increase the cost of public mobile network deployments – as operators need to densify networks to an extent that may not be economically feasible – or it could result in a degradation in network quality, especially if operators reach the technical limits of network densification. This would mean that consumers would not realise the full socioeconomic benefits of 5G.

In the case of Wi-Fi, if the existing amount of unlicensed spectrum available is not sufficient to meet demand in the medium and long term for households with fast enough fibre-to-the-home/building (FTTH/B) or cable broadband infrastructure, then households will not benefit from the full capabilities of ultrafast fixed broadband (FBB) services and the use cases they can enable.

In this report, we implement a supply and demand framework in the 2021–2035 period to determine where 6 GHz spectrum will have its most productive use. We find that the optimal assignment policy largely depends on the expected adoption of 5G and fixed fibre/cable broadband services in each market, along with the speeds that fixed broadband can offer consumers. The report addresses three policy scenarios, as shown in Figure i.

Figure i

6 GHz policy scenario analysis



Baseline refers to no allocation for either licensed or unlicensed use. In some countries (e.g. within CEPT), the lower frequency boundary is 5945 MHz.
Source: GSMA Intelligence

Key findings

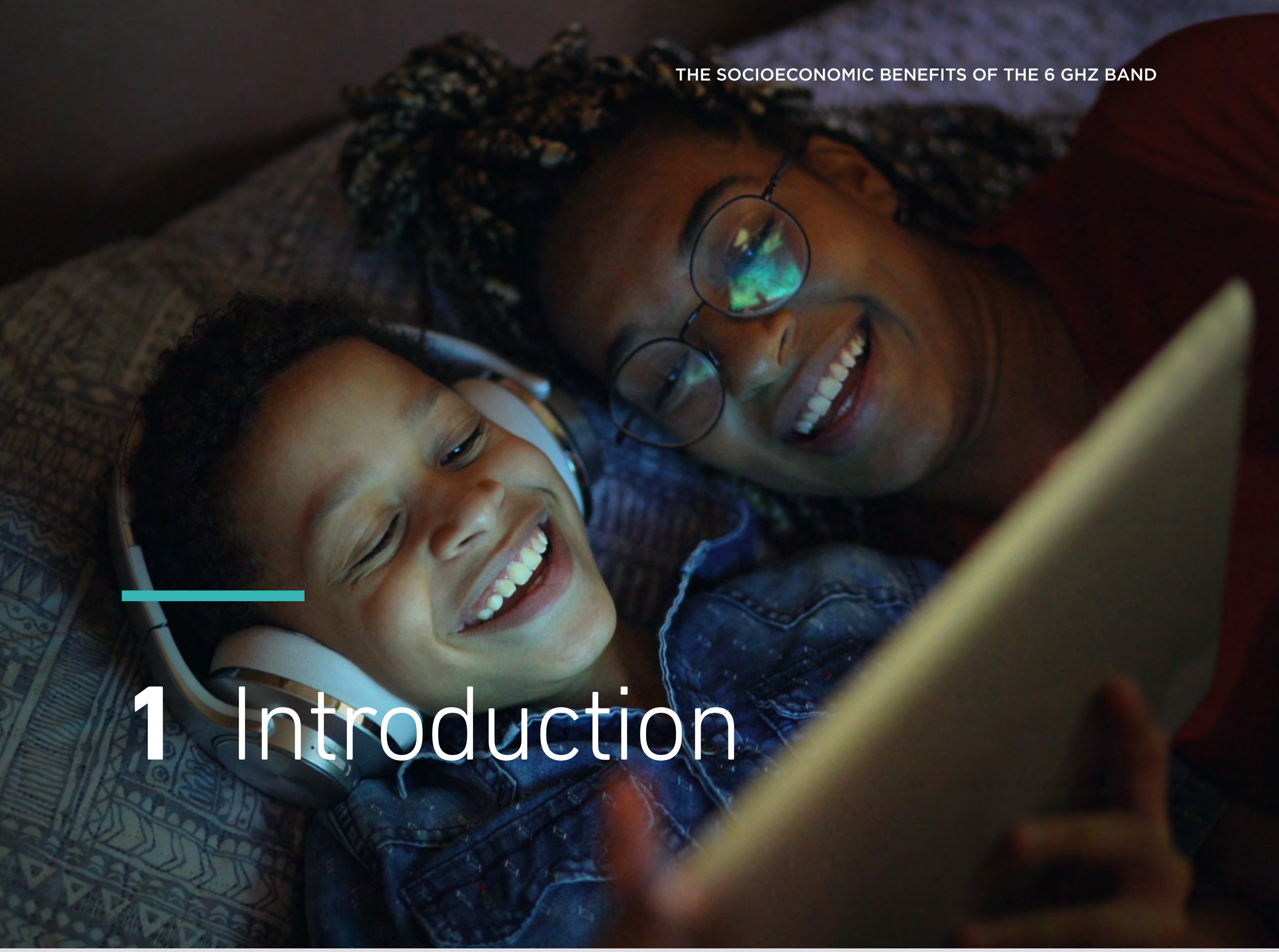
The key factors that impact the benefits of 6 GHz spectrum assignment policies are as follows:

- **Expected adoption of 5G and fixed fibre/cable broadband services:** The expected adoption of 5G and fixed fibre/cable broadband will respectively be the key drivers of demand for licensed and unlicensed use of the 6 GHz band.
- **Fixed broadband speeds:** The existing and future fixed broadband infrastructure in a market will determine the maximum speeds achievable over a Wi-Fi connection and therefore the addressable traffic demand.
- **The existing spectrum availability for licensed and unlicensed use:** Both existing and future spectrum allocation to licensed mobile use and unlicensed use (in bands other than 6 GHz) will determine the supply and capacity constraints relative to broadband traffic demand, and therefore the requirement for additional spectrum from the 6 GHz band.
- **Utilisation of high-band spectrum for licensed and unlicensed use:** The benefits for unlicensed use depends on the utilisation of available and planned high-band spectrum. This includes spectrum within the 57–71 GHz range and potentially other bands in the future. Utilisation of high-band spectrum for Wi-Fi traffic demand will reduce the amount of traffic demand that is reliant on other spectrum bands. Equally, the benefits for licensed use also depend on the utilisation of the licensed mobile high bands (including in the 24–40 GHz range). Although this study considers scenarios where high bands are not utilised by Wi-Fi, it should be noted that this would represent an inefficient use of spectrum. The utilisation of high bands is always considered when analysing the benefits of 5G.

Taking these considerations into account, this report draws the following conclusions:

- In a house dwelling setting, the licensed use of the entire 6 GHz band will deliver the largest benefits across all countries if fixed broadband technologies do not provide maximum user speeds above 5 Gbps. This is because there is already sufficient capacity with existing unlicensed spectrum. The licensed use of the 6 GHz band will still deliver the largest benefits across most countries if in those countries fixed broadband provides maximum user speeds up to 10 Gbps and if up to 30% of Wi-Fi traffic is offloaded to the high bands. Assigning the lower 6 GHz band for unlicensed use and the upper 6 GHz band for licensed use will deliver the largest benefits in some countries, if FTTH/B and cable broadband adoption is widespread, they support maximum user speeds of 10 Gbps and high bands are not utilised by Wi-Fi.
- When carrying out the analysis based on an apartment setting, rather than a house dwelling, we still find that in the majority of countries, the licensed use of the entire 6 GHz band will deliver the largest benefits. For the remaining countries, split use across the 6 GHz band (5925–6425 MHz for unlicensed and 6425–7125 MHz for licensed) would generate the largest benefits.
- Unlicensed use across the whole 6 GHz band was not found to be the most beneficial allocation in any of the considered analyses. Even in countries with very high Wi-Fi demand, allocating an additional 500 MHz of spectrum for unlicensed use in the lower 6 GHz band is sufficient to meet expected demand. This means that there are no additional gains from allocating the full 6 GHz frequency band for unlicensed use.

While the results of this study focus on 24 specific markets (Argentina, Armenia, Australia, Brazil, Colombia, Egypt, France, Germany, Ghana, India, Indonesia, Italy, Japan, Jordan, Kazakhstan, Kenya, Mexico, Nigeria, Qatar, Singapore, South Africa, Thailand, the UAE and Vietnam), the findings and analytical approach are also relevant to other countries that have yet to make a decision on the 6 GHz band.



1 Introduction

Spectrum as a common pool resource

Radio spectrum is used to transfer information wirelessly for many essential services, including mobile networks, satellites, TV broadcasting and defence. As a scarce resource, governments aim to make efficient and effective use of spectrum and ensure it is available for uses that stimulate social and economic progress.[2]

For the majority of bands that are assigned for commercial use, governments assign individual authorisations that allow the licensee to use the spectrum for the duration of the licence over a geographical area. The economic rationale for this is that spectrum is a 'common-pool resource', which means it is non-excludable (it is potentially available for everyone to use) and rivalrous (multiple non-regulated users will suffer from mutual interference). Without assigning an individual usage right, there is a significant risk of multiple unknown individuals trying to use a spectrum band, which would result in signal interference. This would either mean that ultimately no one would benefit from its use, or that it would be used but without any quality of service assurance. Conversely, if spectrum usage rights are assigned, a licensee will have the incentive to make substantial investments if they are able to generate a return on the provision of products and services that use the spectrum.

2 ITU 2015, Handbook on National Spectrum Management

Once it is decided that the assignment of individual usage rights (i.e. a licensed spectrum regime) will be relied upon, the question turns to who (or what) should be granted the right of use. Regulators take into consideration many factors when making such a decision, a key one being how citizens can most benefit from the assignment. In order to achieve this, over the past 20 years, many countries have used market-based processes – particularly auctions – to assign spectrum. This has especially been the case for mobile telecommunications, where operators often engage in a competitive bidding process to acquire spectrum that is then used to deploy networks that provide broadband connectivity and services to consumers and enterprises.[3] A large body of research and empirical evidence has demonstrated the social and economic benefits that arise from mobile connectivity.[4] The latest generation of technology, 5G, has the potential to impact societies even more broadly by driving innovation and transforming the digital landscape across different industries and sectors. [5]

However, governments may not always license spectrum and may choose instead to allow the use of spectrum without needing any kind of individual authorisation (we refer to this as 'unlicensed' use). Under this authorisation regime, usage of spectrum is free as long as the equipment fulfils a set of technical conditions. This could include, for example, restricting transmission power to limit signal interference to other services in the band. On one hand, this has the benefit of facilitating access to spectrum for multiple different types of users, potentially enabling innovation in terms of new products and the involvement of new players. On the other hand, the technical rules that are required to support unlicensed use of spectrum (e.g. radiated power restrictions) lead to some intrinsic limitations, such as the unsuitability for providing wide area coverage, 'on the go' services and predictable quality of service – which in turn will limit the use cases.

One example of such unlicensed use is Wi-Fi, which provides local wireless connections to homes and premises as well as outdoor short-range coverage. Similar to the rapid rollout of mobile technologies, Wi-Fi use has accelerated in the past two decades, with Wi-Fi capabilities introduced into a wide range of products. These have also driven significant economic and social benefits worldwide.

Assigning the 6 GHz band

Considerations on the optimal approach for managing spectrum are currently at the forefront of the debate around the 5925–7125 MHz frequency range (hereafter referred to as the '6 GHz band') as governments decide how best to manage this spectrum going forward. To date, countries that have allocated spectrum in this band have taken divergent approaches. While some countries have assigned the full 6 GHz band for unlicensed use, others are considering the full band for licensed use. A third group are following a 'split-use' approach by allocating the lower part of 6 GHz for unlicensed and considering the upper part for licensed. It should be noted that the large majority of countries globally have not taken decisions on the future use of the upper 6 GHz band.

An important factor to enable the efficient use of spectrum is cross-border coordination between countries, which is addressed by the Radio Regulations from the International Telecommunication Union (ITU). Such regulations ensure that spectrum is used across countries with potentially different services on each side of the border. Furthermore, consistent frequency allocations between countries are important to ensure international harmonised use, which allows for economies of scale in the production and use of devices, equipment and other infrastructure. Included on the agenda of the next World Radiocommunication Conference (WRC-23), which can review and revise the Radio Regulations where necessary, is the IMT identification of 6425–7025 MHz in ITU Region 1 (Europe, the Commonwealth of Independent States, Mongolia, Africa and the Middle East west of the Persian Gulf, including Iraq) and 7025–7125 MHz in all regions.

Governments around the world will therefore need to make a carefully considered decision as to what the most efficient use of 6 GHz spectrum will be. In most

3 Cave and Webb (2015)
4 For example, see GSMA Intelligence (2020b) and ITU (2019)
5 For example, see GSMA (2019) and GSMA Intelligence (2020a)

countries, it represents the largest remaining single block of mid-band spectrum that can be allocated to licensed or unlicensed use. In theory, a well-designed market-based assignment process such as an auction should achieve an efficient assignment that will maximise the net benefit to society. This means that spectrum will be assigned to users that are prepared to pay the highest amount for it and therefore value it the most.

However, if governments believe there is a possibility of market failure – for example, due to a lack of competition or due to innovations and positive externalities from certain use cases of spectrum that are not reflected in the private benefits priced into auction bids – an alternative assignment process should be considered to maximise the net benefit to society. In such cases, the relevant national authority should conduct a regulatory impact assessment, with a consultation process to collect views and evidence from stakeholders, in order to identify the best policy option for radio spectrum assignments other than a market-based approach. This will contribute to the efficiency, transparency, accountability and coherence of public policymaking. It is also in line with international best practice,[6] with the ITU recommending that when there are competing interests for spectrum use, the spectrum management organisation should determine the use or uses that would maximise the societal value of spectrum.

To assist policymakers with such an assessment, this report conducts a cost-benefit analysis for different assignment options for the 6 GHz band. The study focuses on 24 countries across the three ITU Regions where a decision on the allocation of the full band has yet to be taken: Argentina, Armenia, Australia, Brazil, Colombia, Egypt, France, Germany, Ghana, India, Indonesia, Italy, Japan, Jordan, Kazakhstan, Kenya, Mexico, Nigeria, Qatar, Singapore, South Africa, Thailand, the UAE and Vietnam. While the results and discussion are focused on these specific markets, the findings and analytical approach are also relevant to other countries that have yet to make a decision on the 6 GHz band. These can serve as a framework on which to consider the costs and benefits of different 6 GHz policies. The rest of the report is structured as follows: Chapter 2 provides a description of the next generation of mobile and RLAN technologies and their likely relationship with each other; Chapter 3 sets out the analytical approach used in this study; Chapter 4 delivers the key findings; and Chapter 5 presents the report's conclusions. Further details on the methodology and country-specific results are provided in the appendix. To analyse the benefits of the different licensing regimes, the report focuses on 5G mobile technology for licensed use and Wi-Fi for unlicensed use.[7]

Please note that, unless otherwise stated, this report uses the term "5G" to mean "5G NR and its evolution" and the term "Wi-Fi" to mean "Wi-Fi 6 and its evolution".

6 For example, see ITU (2014) and OECD (2020)
7 Unlicensed use refers to the broader family of RLAN technology. This report focuses on Wi-Fi technology.

2 Licensed and unlicensed usage in society

Almost everyone connected is reliant on wireless connectivity

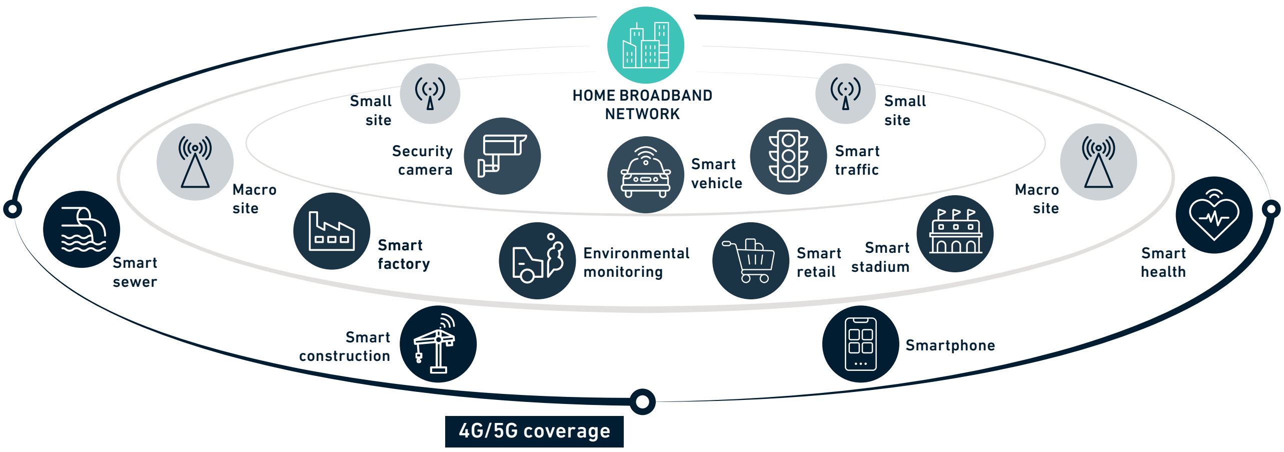
The overwhelming majority of internet users are reliant on at least some form of wireless connectivity. This obviously applies to the 51% of the world's population that uses mobile internet.[8] Mobile technology provides wide area coverage from sites to end users that can either be indoors or outdoors – macro cell sites can provide coverage up to around 15–20 km, and they are supported by backhaul connections over fibre, microwave links and satellite. RLAN provides indoor and outdoor short-range coverage to provide best-effort connectivity to end users – typically up to 50 m indoors and 300 m outdoors (in the case of line of sight).

8 GSMA (2021)

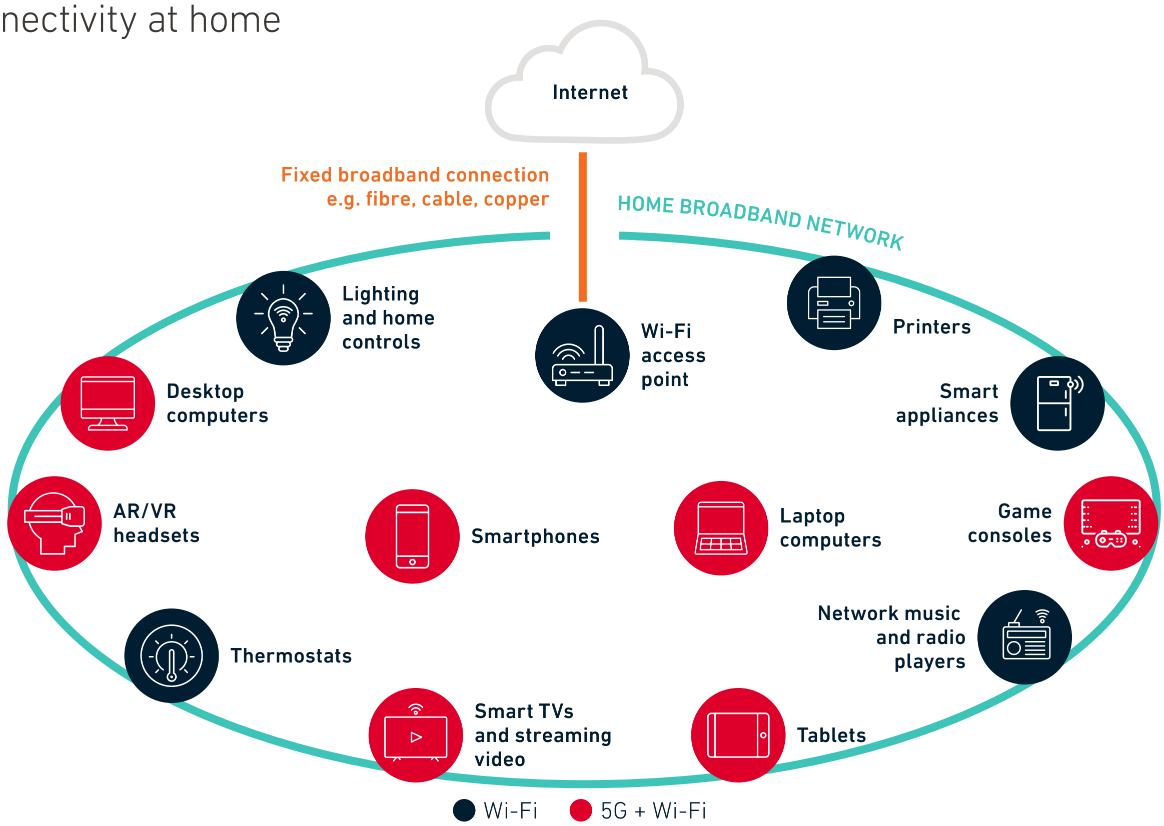
Wi-Fi provides the final link between a wireless-enabled device and a router or access point, which receives a connection over fibre, copper, mobile or satellite (see Figure 2). Mobile also provides wireless connectivity solutions to small, medium and large enterprises, while Wi-Fi is also used by businesses when reliability and latency are not critical.[9]

Figure 1

Mobile connectivity in urban areas



Connectivity at home



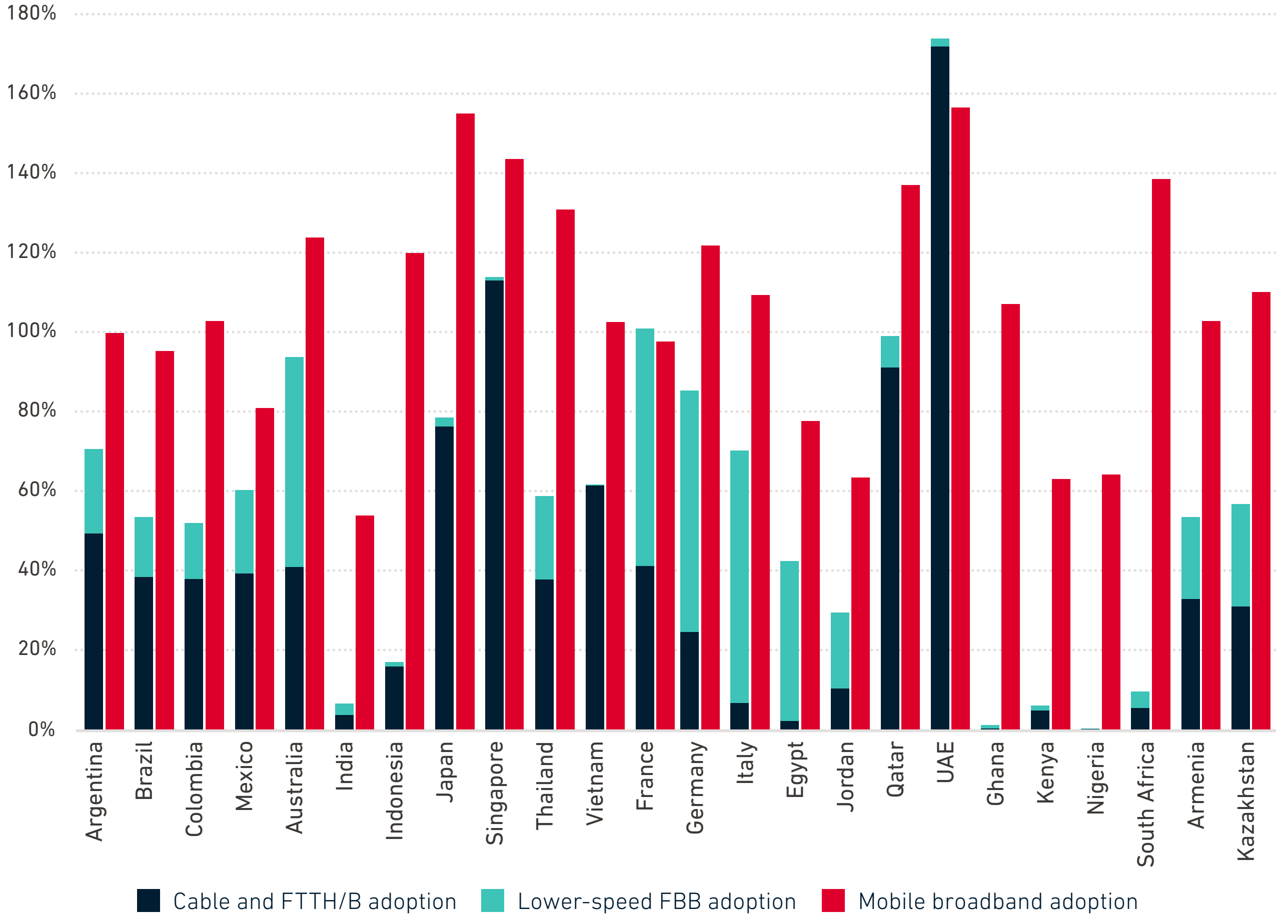
Source: GSMA Intelligence

9 For example, see Nokia 5G and Wi-Fi6 radio: options for operational technology

The role of the two types of connectivity varies by market. In countries with widespread fixed broadband infrastructure, mobile currently tends to provide connectivity 'on the go', especially outdoors, while Wi-Fi use is more common for a significant portion of indoor users. In many countries, however, especially low- and middle-income countries, the adoption of fixed broadband remains limited.[10] Figure 2 shows that most of the 24 countries analysed have high levels of mobile broadband penetration (relative to total population), ranging from 54% in India to 155% in the UAE. By contrast, fixed broadband adoption (relative to total households) ranges from 1% in Ghana to more than 170% in the UAE.

Figure 2

Fixed and mobile broadband adoption in the 24 countries analysed, 2020



Fixed broadband refers to fixed subscriptions to high-speed access to the public internet, at downstream speeds equal to or greater than 256 Mbps. It includes cable modem; xDSL; fibre-to-the-home/building; other fixed (wired) broadband subscriptions; satellite broadband; and terrestrial fixed wireless broadband. 'Cable and FTTH/B' refers to fixed broadband subscriptions using a cable modem or fibre-to-the-home or fibre-to-the-building connection. Lower-speed FBB adoption includes technologies other than FTTH/B and cable. Mobile broadband includes 3G, 4G or 5G technologies that enable high-speed access to the internet.

FTTH/B and cable adoption and lower-speed FBB adoption are based on the number of subscriptions as a proportion of households, while mobile broadband adoption is based on the number of mobile subscriptions as a proportion of total population. As one user can access multiple subscriptions and because both data points include subscriptions for organisations (including businesses and governments), adoption in some countries exceeds 100%.

In the case of UAE and Qatar, we adjusted the estimates as the original calculations suggested that fixed broadband penetration was 150% in Qatar and more than 300% in UAE. For Qatar, we use data from the Communications Regulatory Authority, which is based on households only. For UAE, we adjusted the number of households based on an average household size of 5.3. This gives a fixed broadband penetration rate of 174%, meaning the estimate will include non-residential broadband subscribers.

Source: GSMA Intelligence and ITU World Telecommunication/ICT Indicators Database 2021

10 Outside of residential properties, Wi-Fi can also be used in businesses and in public hotspots. Cisco (2020) forecasts almost 628 million global public Wi-Fi hotspots by 2023. However, use of public Wi-Fi remains much more limited than residential Wi-Fi, even in countries with widespread fixed networks. For example, Katz et al (2021) estimate that just over 4% of Wi-Fi traffic in the US is 'free' traffic. Analysis by OpenSignal of smartphone users in the US suggests that they spend less than 1% of their time connected to public Wi-Fi.

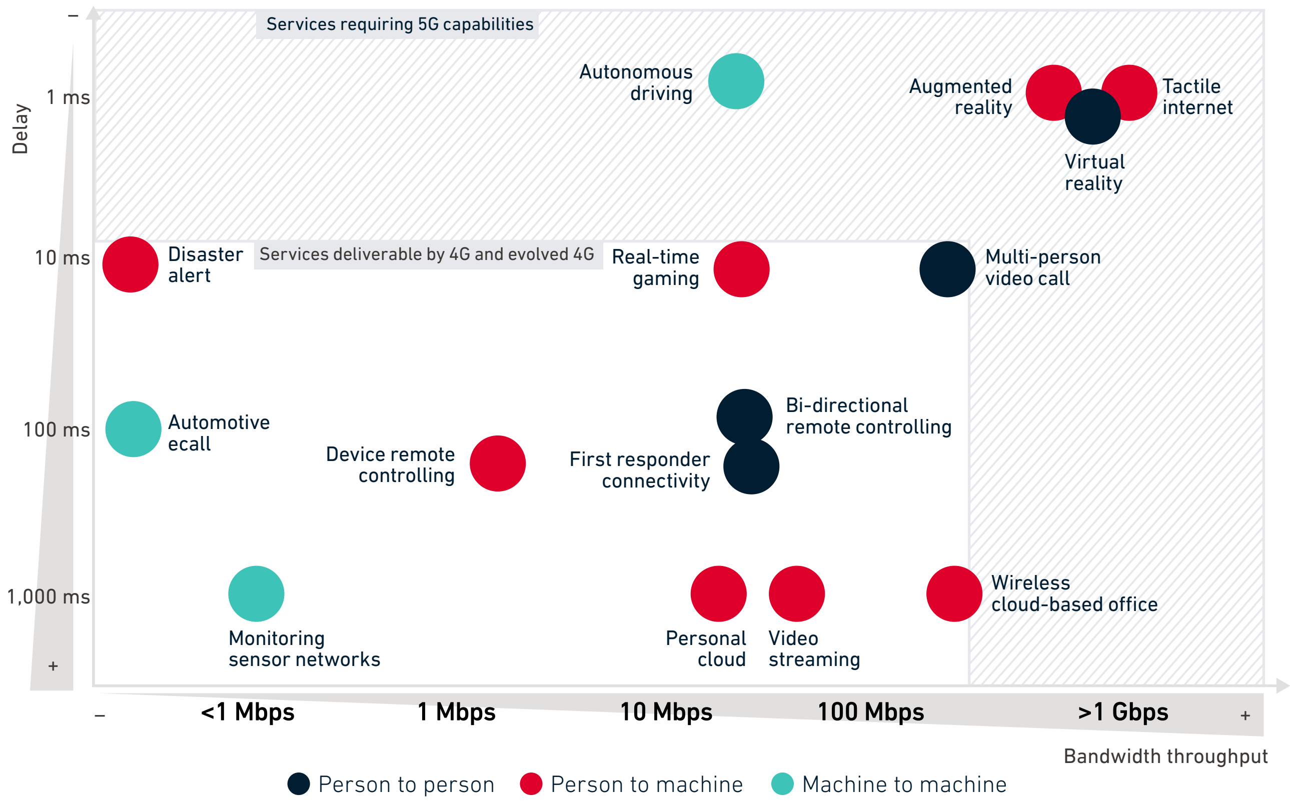
Next-generation technologies

Both mobile and RLAN experience fast-moving technology changes, with new generations coming every 10 years or less. In the case of mobile, 5G is the latest technology and has started being deployed in many markets, offering significantly faster speeds than 4G and allowing for extremely high reliability and very low latency.[11] For RLAN, the rollout of Wi-Fi 6 (or 6E where 6 GHz spectrum is used) also offers faster speeds and lower latencies than previous generations. Appendix A provides further information on the data rates associated with channel bandwidths for Wi-Fi 6, along with the spectral efficiencies for 5G.

Both 5G and Wi-Fi 6 are expected to drive continued increases in traffic. For both types of wireless connectivity, increased demand will come from new users along with consumers using more devices with more advanced capabilities, as well as using their existing devices more intensively (e.g. smartphones, laptops, tablets and smart appliances). This will be driven by HD and UHD content, videos calls and new use cases such as smart glasses, real-time cloud gaming, 360 video and VR/AR devices. There will also be a need for near-ubiquitous connectivity across different devices and locations. It is expected that there will be a significant increase in machine-to-machine (M2M) and IoT devices, such as for smart home, manufacturing and vehicles. Many of the new use cases, including AR/VR, real-time video and gaming, will also require lower latencies (see Figure 3).

Figure 3

Services supported by 5G



Source: GSMA Intelligence

11 For example, see Cellular IoT in the 5G era. Latency refers to the amount of time it takes for data to be transferred across a network.

Demand for both mobile and RLAN will continue to increase

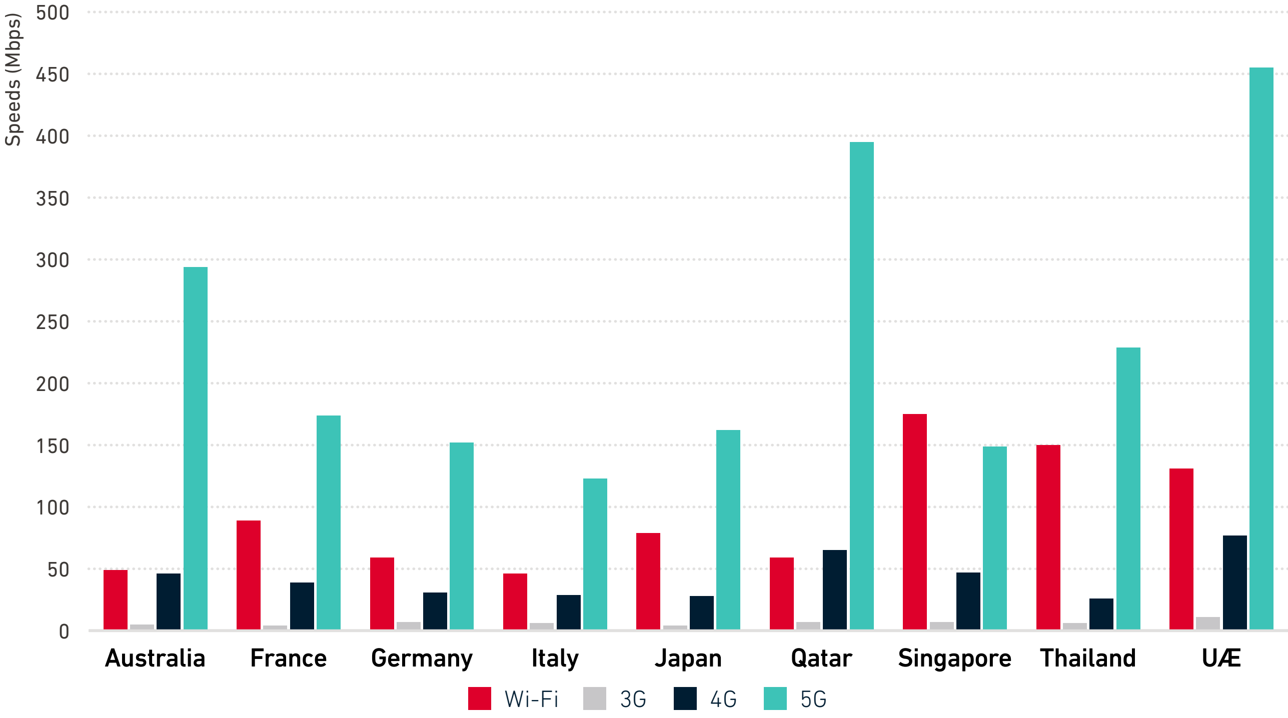
Mobile and RLAN have both seen wide adoption globally, with RLAN being used indoors when there is a fixed-line broadband connection and mobile being used 'on the go' as well as where fixed is not available (or where low fixed-line speeds favour mobile connectivity). This has historically allowed consumers to access faster speeds (compared to 3G for example) and more data when Wi-Fi is available with a fixed broadband connection, including on a mobile device (e.g. smartphone or tablet), as they could use a fixed connection that generally had higher – often unlimited – data volume allowances. However, this is changing with the introduction of 5G.

Both mobile and RLAN demand will continue to grow as the number of wirelessly connected devices increases. RLAN demand will grow in markets where consumers take up faster fixed broadband services (e.g. FTTH/B and cable). In terms of mobile, it is expected that consumers will use more data on 5G relative to 4G and less will be carried over Wi-Fi. This will be driven by two key factors:

- **Faster speeds**: In markets where 5G has been launched, consumers often get significantly better speeds than on 4G and Wi-Fi (see Figure 4).[12]
- **Larger data volumes:** Consumers will have access to greater amounts of data on 5G. In markets where 5G is available, the majority of 5G tariffs offer an unlimited data allowance.[13] Analysis of 5G users across several markets has also shown that consumers use more data than 4G and, in some cases, less Wi-Fi.[14]

Figure 4

Download speeds for 3G, 4G, 5G and Wi-Fi (2021)



Data is provided for the nine countries with 5G adoption greater than 2% at the end of 2021.
Source: GSMA Intelligence analysis, based on Speedtest Intelligence® data provided by Ookla®

12 Given that Wi-Fi often supports the delivery of fixed-line connectivity, speeds will increase going forwards if consumers increase adoption of fibre broadband services.
13 Omdia and Tarifica (2021)
14 For example, Ericsson (2021) shows that 5G users spend more time on a range of uses (including cloud gaming, streaming music and video and using AR/VR) and that one in five users upgrading to 5G have decreased Wi-Fi usage at home and other locations.

Wi-Fi offload and onload

A number of studies have highlighted the role that Wi-Fi can play in reducing the costs of deploying mobile networks. This is because Wi-Fi can meet consumer traffic demand and 'offload' it from mobile networks, thereby avoiding the cost of further network densification. Cisco (2019) estimates that more than half of mobile data is offloaded over Wi-Fi or small cell networks.

While historically consumers have often used Wi-Fi instead of mobile where it is available, particularly at home or in the office, many estimates around Wi-Fi offload are likely to be overstated, as they do not consider the fact that a lot of Wi-Fi usage on mobile devices represents 'additional' traffic rather than 'replacement' traffic. This is because users consume data on Wi-Fi that they would not otherwise consume on mobile, due to historically higher speeds and/or unlimited data.[15] However, this trend is changing with 5G given the faster speeds and higher data allowances enabled, as some consumers may spend more time on 5G at the expense of Wi-Fi. In locations where there is limited fixed broadband access – particularly in low- and middle-income countries – Wi-Fi offload will remain much more limited, with some consumers potentially moving to 'Wi-Fi onload', with the increasing use of 4G- and 5G-enabled access points.[16] Another consideration is that if both 5G and Wi-Fi provide unlimited data, users may find that 5G offers a more seamless experience if Wi-Fi requires multiple authentication procedures.

It has also been suggested that operators could deploy their own Wi-Fi networks (along with other small cells) to increase network capacity at lower cost. This could be further enabled by 5G NR-U, which can operate in unlicensed spectrum bands. In practice, however, there is limited evidence to suggest that operators deploy extensive Wi-Fi networks to increase capacity and meet demand. In South Korea, which has one of the most extensive fibre networks worldwide, offload to operator Wi-Fi networks stood at 1.4% in July 2021, down from 5.6% in 2015.[17] Operators have historically been reluctant to use Wi-Fi as a widespread capacity solution because the traffic is unmanaged and cannot be coordinated.[18] When deploying 5G, given the demanding performance requirements (e.g. near-guaranteed 100 Mbps data rates at any time and location as well as ultra-low latencies) and the desire to deliver network slicing, operators are likely to continue using licensed spectrum that they have complete control over.[19] This is especially likely in countries with limited fixed infrastructure. Furthermore, although the equipment cost of Wi-Fi is lower than deploying a cellular solution, the opex is typically higher and a large number of access points are required – meaning that there is no clear economic case for mobile operators to use unlicensed spectrum for 5G.[20]

When considering options for assigning the 6 GHz band, governments and policymakers have to consider the supply and demand of both mobile and RLAN, and where the spectrum will support the generation of most value. This will depend on the specifics of each market, including current and expected use of 5G and Wi-Fi, the availability of existing spectrum and fixed broadband capabilities.

15 For example, see Husnjak et al (2018) and Coleago (2014).
16 Coleago (2020)
17 Source: Korean Ministry of Science and Technology
18 See Coleago (2014) for further discission. Exceptions to this may be in locations where it is difficult to provide a mobile signal, for example on underground transport and in certain indoor venues.
19 For example, see Ericsson (2020), Coleago (2020) and Oughton et al (2021).
20 Ericsson (2020)

3 Analytical approach

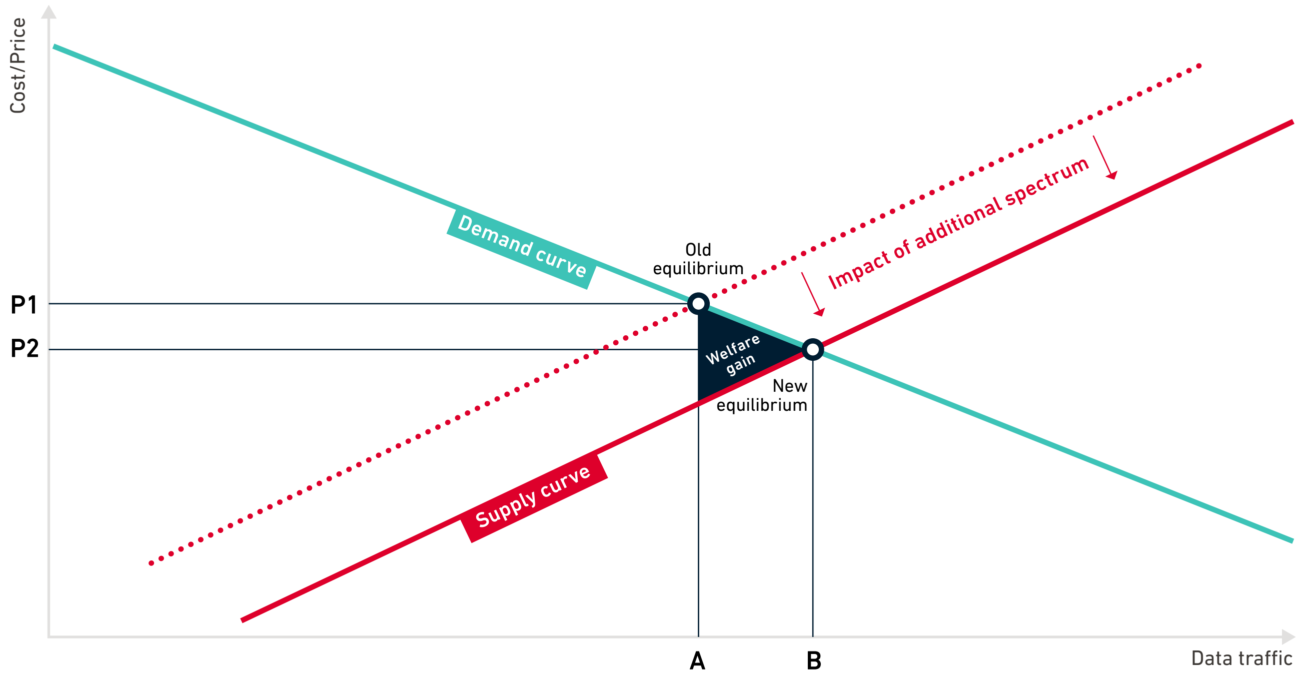
Supply and demand framework

The decision on how to allocate spectrum in the 6 GHz band between licensed or unlicensed use is not straightforward given the different use cases. It is therefore important for regulators to carry out a regulatory impact assessment, along with a stakeholder consultation, in order to come to an evidence-based decision.

We apply a cost-benefit analysis using a supply and demand framework. The main impact of assigning 6 GHz spectrum to provide wireless connectivity is that it can make it less costly to provide capacity. In economic terms, this is represented by a shift in the supply curve (see Figure 5). This has the result of reducing prices and increasing output, driving a gain in economic welfare.

Figure 5

Supply and demand framework



Source: GSMA Intelligence

The welfare gain reflects the increase in consumer surplus (the difference between the maximum price consumers are willing to pay and the actual price they pay) and producer surplus (the difference between the price actually obtained by firms and the minimum they are willing to accept).

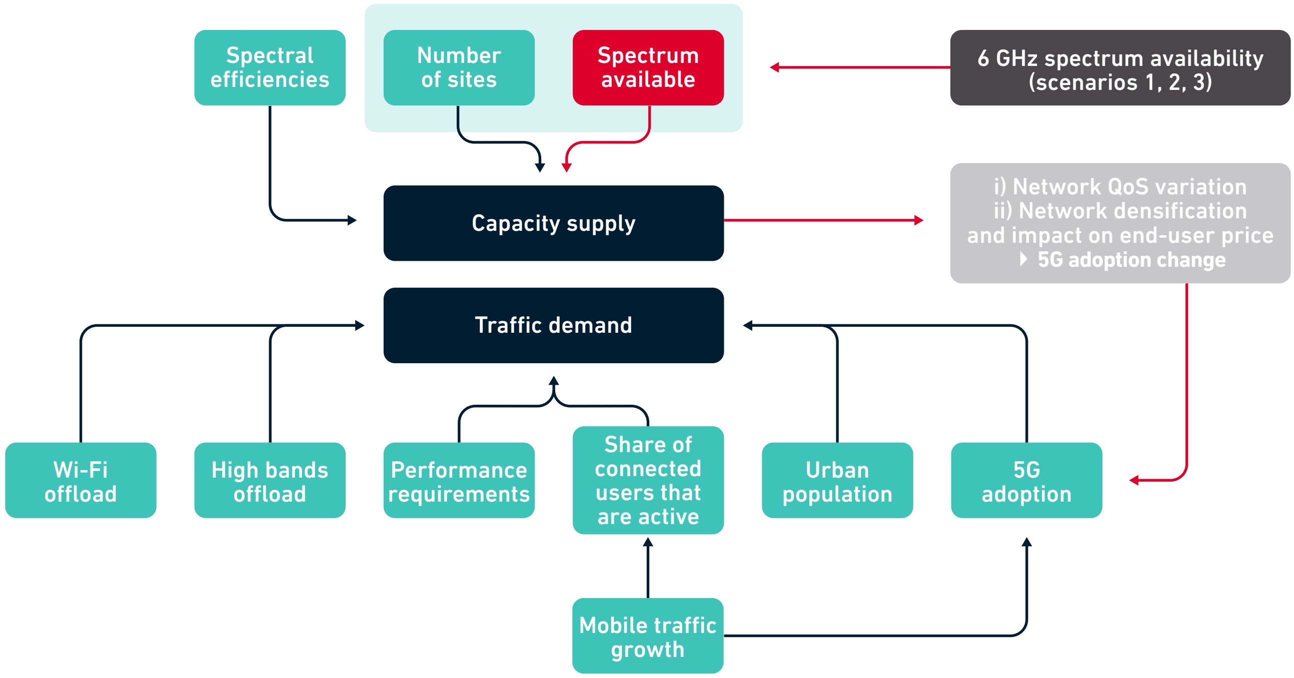
In order to understand which spectrum policy will generate the greatest benefit, we need to take into account the demand and supply conditions in each market, in particular the current and expected demand for 5G and Wi-Fi. This will show where 6 GHz spectrum will have its most productive use. To estimate the impact of assigning additional spectrum for 5G or Wi-Fi, we develop two supply and demand models for network capacity for the period between 2021 and 2035, based on current and expected market growth (see Figures 6 and 7). The appendix provides details of the methodology and assumptions behind each model, but in summary we apply the following approach:

- We estimate 5G and Wi-Fi traffic demand during the period 2021–2035, based on expected adoption of devices, performance requirements and traffic growth.
- We estimate capacity supply based on the amount of spectrum available (or expected to be available) and spectral efficiencies (and number of sites deployed in the case of 5G). This is done three times based on different amounts of 6 GHz spectrum available (see Figure 8).
- If capacity supply exceeds expected traffic demand, then there is no impact. If expected demand exceeds capacity supply, meaning that there is a capacity constraint, then this is assumed to impose a reduction in quality of service for 5G or Wi-Fi.
- A reduction in quality of service is translated to lower adoption of 5G (for mobile) or FTTH/B and cable (for fixed broadband adoption), based on the capacity gap.[21] For example, if there is no capacity gap with the full 6 GHz band assigned to licensed mobile but there is a capacity gap of 20% with no 6 GHz spectrum assigned (i.e. unmet capacity is 20% of total demand), then we assume that 5G adoption falls by 20% in the scenario without any licensed 6 GHz spectrum. A similar approach is implemented for Wi-Fi, where the capacity gap is translated to lower adoption of FTTH/B and cable broadband.
- Lower adoption for 5G or FTTH/B and cable is linked to a reduction in GDP based on empirical research (see the last section in this chapter and the appendix).

21 We translate a capacity gap for Wi-Fi into a lower adoption level for FTTH/B and cable because those are the broadband services that Wi-Fi supports. We do not account for lower adoption of other fixed broadband technologies (e.g. xDSL and FTTC), as Wi-Fi capacity will not be a bottleneck in those cases, given the more limited speeds available.

Figure 6

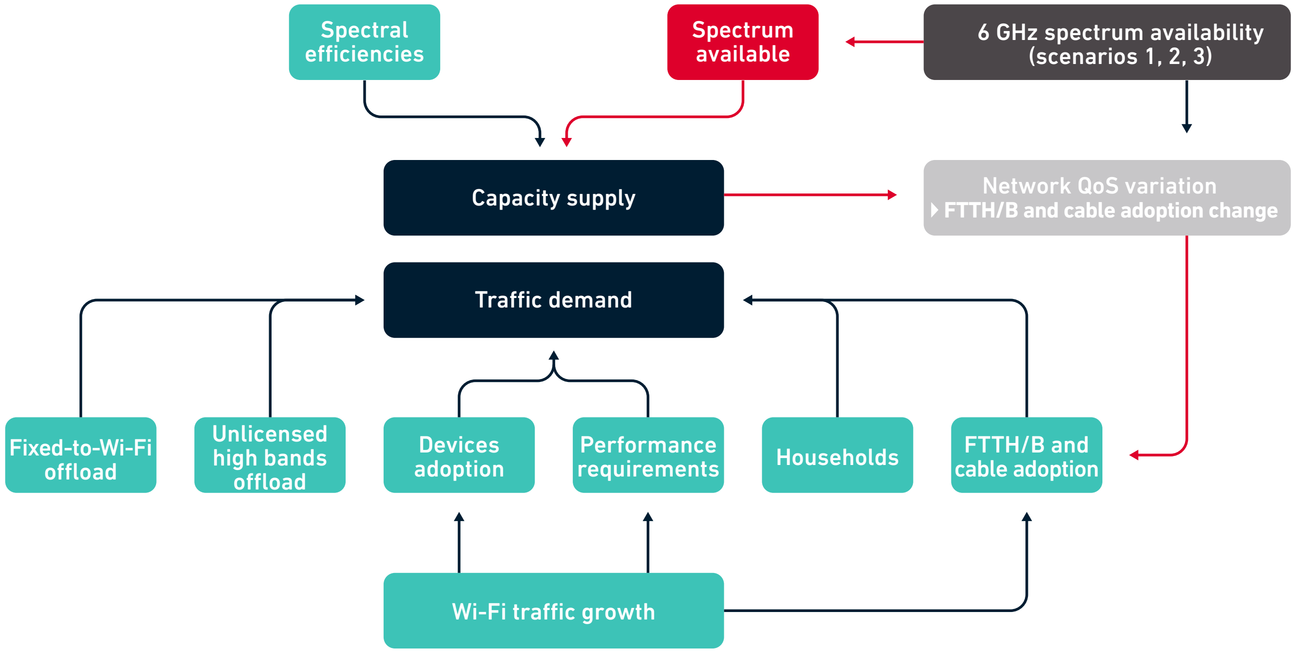
5G traffic demand and capacity supply model



Source: GSMA Intelligence

Figure 7

Wi-Fi traffic demand and capacity supply model

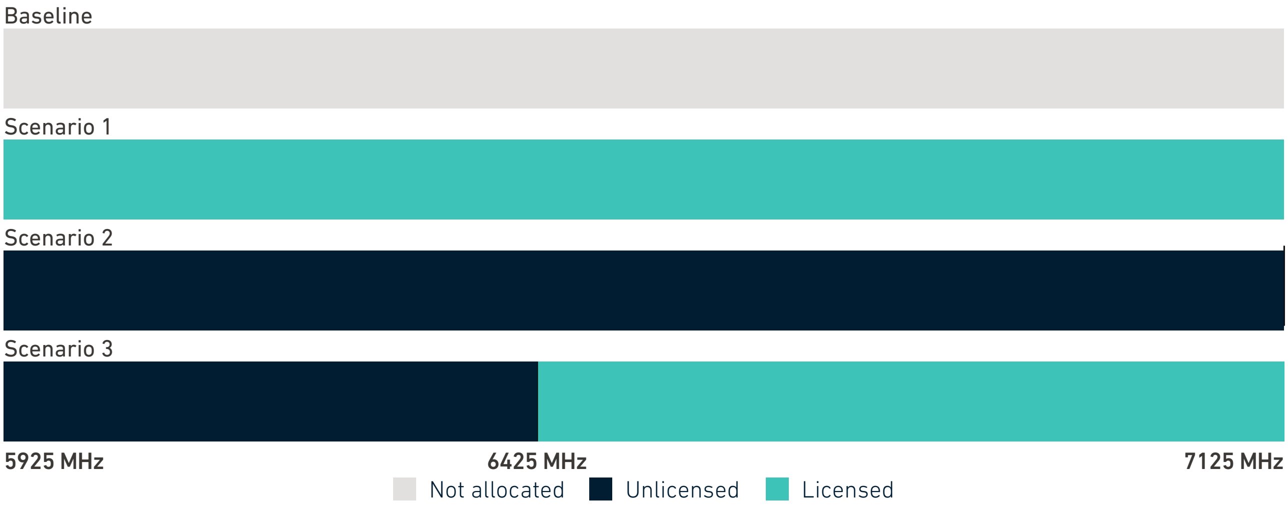


Source: GSMA Intelligence

We consider three policy scenarios for each country, relative to a baseline of no spectrum being allocated for either licensed or unlicensed use (shown in Figure 8). Specifically, we look at the economic benefits of allocating all of the 6 GHz band to licensed (Scenario 1); all of the 6 GHz band to unlicensed (Scenario 2); and the lower part of the band for unlicensed use and the upper part of the band for licensed (Scenario 3). Some of the countries in our study have already allocated the lower part for unlicensed use (e.g. the UAE, France and Germany), which means that Scenario 1 is no longer a policy option. However, we present all the results for illustrative and comparative purposes.

Figure 8

6 GHz scenario analysis



Baseline refers to no allocation for either licensed or unlicensed use. In some countries (e.g. within CEPT), the lower frequency boundary is 5945 MHz.
Source: GSMA Intelligence

Key factors that impact the results

Spectrum availability and efficiencies

The capacity supply of a mobile network depends on the amount of spectrum that operators have access to – more spectrum enables greater throughput and higher data rates. If there is not enough spectrum to meet demand, then network congestion will reduce the quality of service experienced by the device or end user. The capacity of a Wi-Fi network depends on the fixed broadband capability and amount of spectrum Wi-Fi has access to. Given enough fixed broadband speed, additional unlicensed spectrum enables greater throughput and higher data rates.

In the case of licensed mobile, the amount of spectrum assigned varies by country. We assume in each country an amount of spectrum available in the low bands (below 1 GHz), lower mid-bands (1–3 GHz), upper mid-bands (3–6 GHz) and high bands (above 24 GHz). This is based on the existing amount of spectrum, as well as planned spectrum releases in the medium-to-longer term in the specific country.

Wi-Fi can be used in the 2.4 and 5 GHz bands in each of the 24 study countries (and indeed most countries around the world). Generally, around 80 MHz is available for use in the 2.4 GHz band. In the 5 GHz band, the availability of spectrum depends on the country.[22] Furthermore, in order to protect radar services that use the 5 GHz band, some channels have dynamic frequency selection (DFS) requirements. This detects transmissions from radars and, where necessary, requires Wi-Fi devices to switch to a different channel. In some countries, these bands are either lightly used or not used at all,[23] which

22 For example, the 5.8 and 5.9 GHz bands have not been made available in all countries.
23 For example, some Wi-Fi equipment avoids using DFS channels entirely.

impacts the quality of service over Wi-Fi. In particular, where a DFS channel is used and detects a radar, there can be a long period where the channel cannot be used.[24] However, as Wi-Fi demand increases, some regulators are looking to remove some of the DFS requirements within the band.[25]

For the purposes of the model, we assume that all available spectrum will be utilised for 5G and Wi-Fi 6, the most efficient technologies over our period of analysis.[26] In practice, although some operators are looking to switch off legacy 2G/3G networks, this will not happen in the short term in many countries, as operators need to support previous generations and spectrum bands for mobile are not always technology neutral. Similarly, in the case of Wi-Fi, older standards will continue to be used in legacy devices that remain in existing bands.[27] However, our assessment is based on mobile operators and Wi-Fi providers being efficient in the long term. This approach also ensures that spectrum is not assigned for a service on the basis that it is being delivered inefficiently using older technologies, or because the existing bands that have been assigned are not being fully utilised.

In the case of Wi-Fi, all spectrum theoretically available may not be accessible to a specific household due to interference from users nearby (e.g. neighbouring residents). This is reflected in our model via spectral efficiencies, which vary depending on the type of residence being considered. In a house dwelling, where occupants reside in a single building, users are likely to have access to all available Wi-Fi channels with minimal interference, meaning a higher spectral efficiency. By contrast, in a flat or apartment setting, in which occupants live in a building with multiple floors and multiple apartments within a floor, users may not have access to all available channels with minimal interference. In some of our study countries, urban residents mostly live in houses rather than flats or apartments,[28] while in other countries a significant proportion also reside in apartments. We therefore present results for Wi-Fi based on houses in Chapter 4 and on apartments in Chapter 5. Details on the assumptions in each scenario are provided in Appendix A.

Based on the amount of spectrum available and the spectral efficiencies enabled by 5G and Wi-Fi, we assess whether there is sufficient capacity to meet demand for both services over a 15-year period. This is done for each of the policy scenarios highlighted in Figure 8 (i.e. for Wi-Fi we compare supply and demand assuming no 6 GHz spectrum is allocated to Wi-Fi, allocating 1200 MHz for Wi-Fi use and allocating 500 MHz for Wi-Fi use). If there is a capacity constraint at any point (i.e. demand is greater than supply), this is assumed to have a negative impact on 5G and/or Wi-Fi adoption and usage.

Use of high-band spectrum for 5G and Wi-Fi

The deployment of 5G in many countries is using – or is expected to use – high-band mmWave frequencies (e.g. in the 26, 28 and 40 GHz bands). High bands are expected to address specific areas with extreme traffic density and with very high peak data rates.[29] We therefore assume that, over time, 30% of 5G traffic demand will be offloaded to mmWave (see the appendix).

High-band spectrum is also available (or is being considered) for unlicensed use in most countries, particularly in the 60 GHz band (within the 57–71 GHz range). Other high bands may also be made available for unlicensed use in the coming years; for example, the Q-band (42–48 GHz) is already supported by the IEEE standard (802.11aj-2018) together with the 60 GHz band. These frequencies provide propagation properties that allow short-range coverage (e.g. within a room) while easing coordination in terms of interference between adjacent access points, in particular among neighbours in a building block. High bands can therefore be used for Wi-Fi to support connectivity for certain high-capacity use cases, such as AR/VR and a variety of short-range devices.[30] In this study, we look at the impact of assigning 6 GHz for unlicensed use under the assumption that up to 30% of Wi-Fi traffic is offloaded to the high bands. We also model another scenario where the high bands are not used for Wi-Fi. It should be noted, however, that not using the high bands would represent an inefficient use of spectrum.

24 In our model, we assume that half of the channels with DFS requirements can be utilised (see the appendix).
25 For example, see Ofcom (2020)
26 Over the next 10 years, it is possible that new standards will be developed for RLAN (Wi-Fi 7) and mobile (6G). However, given the uncertainty over timing and the specifications, we only model Wi-Fi 6 and 5G in this study.
27 Wi-Fi 6 compatible devices will also be backwards-compatible with holder standards.
28 See for example OECD (2021), UN Habitat (2011) and Statistics South Africa (2020)
29 See Coleago (2020 and 2021) and WPC (2021)
30 For example, see Broadband India Forum (2021), which highlights WiGig as one of the key use cases of V-band spectrum. This can link devices at up to 7 Gbps over a distance of up to 12 metres.

Performance of fixed broadband network technologies will impact Wi-Fi speeds

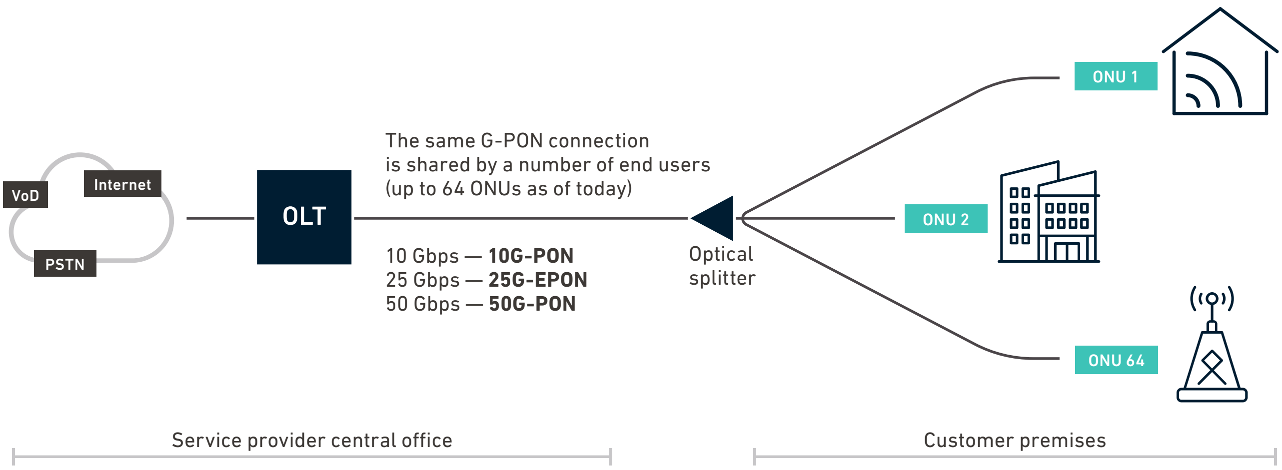
A key consideration in terms of demand for Wi-Fi is that the available data rates are impacted by the capacity of the underlying copper, fibre, microwave or satellite connection. For example, if a user has an ADSL connection, which typically has a maximum speed of 24 Mbps, then this will ultimately constrain the amount of capacity available, regardless of the number of Wi-Fi channels available. Currently, even FTTH/B and cable connections do not typically offer users access to speeds greater than 1 Gbps. In some cases, fixed providers will not offer speeds greater than 50–200 Mbps; in such situations, Wi-Fi (and the spectrum available for Wi-Fi) will not be the capacity bottleneck. Furthermore, as shown in Figure 2, in many of the countries considered in this study, a significant proportion of fixed broadband users are not currently connecting via FTTH/B or cable.

The speeds that are available on a fixed connection are expected to increase going forward.[31] Fibre optics technology for fixed broadband connections has developed rapidly in the last 15 years, with the introduction of a new FTTx technology generation every 8–10 year, which deliver speeds to end users that are four times greater compared to the previous generation. 10G PON technology became available from 2017 and is expected to reach large scale take-up by 2026, delivering up to around 1.3 Gbps on average to end users. The next generation of PON comprises 25G EPON and ITU-T 50G PON, which became available in 2020 and 2021 respectively. 50G PON is expected to deliver around 6.6 Gbps on average to end users. The first products for 50G PON are expected to become commercially available by 2023 and the technology is expected to reach a large-scale market by 2029. Although the ITU-T work towards the standard development has not started, preliminary research is ongoing for the next PON technology generation, which will be required to deliver up to 10 Gbps speeds to residential users if market demand should materialise in the future. The market launch for this new technology is therefore unlikely to occur until the next decade.

This report provides results for different fixed broadband connectivity scenarios, with maximum FBB speeds to end users of 1, 5 and 10 Gbps considered. The scenario associated with each connection speed assumes that such speed applies to all FTTH and cable connections from 2021 (although in practice we do not expect demand to exceed 5 Gbps until at least 2029, even in countries with the highest demand). When considering 10 Gbps, for example, the model assumes that all end users connected to FTTH and cable will be receiving 10 Gbps, although it is unlikely that every FTTH and cable connection would have access to speeds of 10 Gbps.

Figure 9

G-PON technology overview



PON: Passive optical network OLT: G-PON optical line terminal ONU: Optical network unit
Source: Huawei

31 See for example Strategy Analytics (2021), Technology Roadmap for Passive Optical Networks: The Next Step is 50G PON

Modelling the socioeconomic impacts of 5G and Wi-Fi

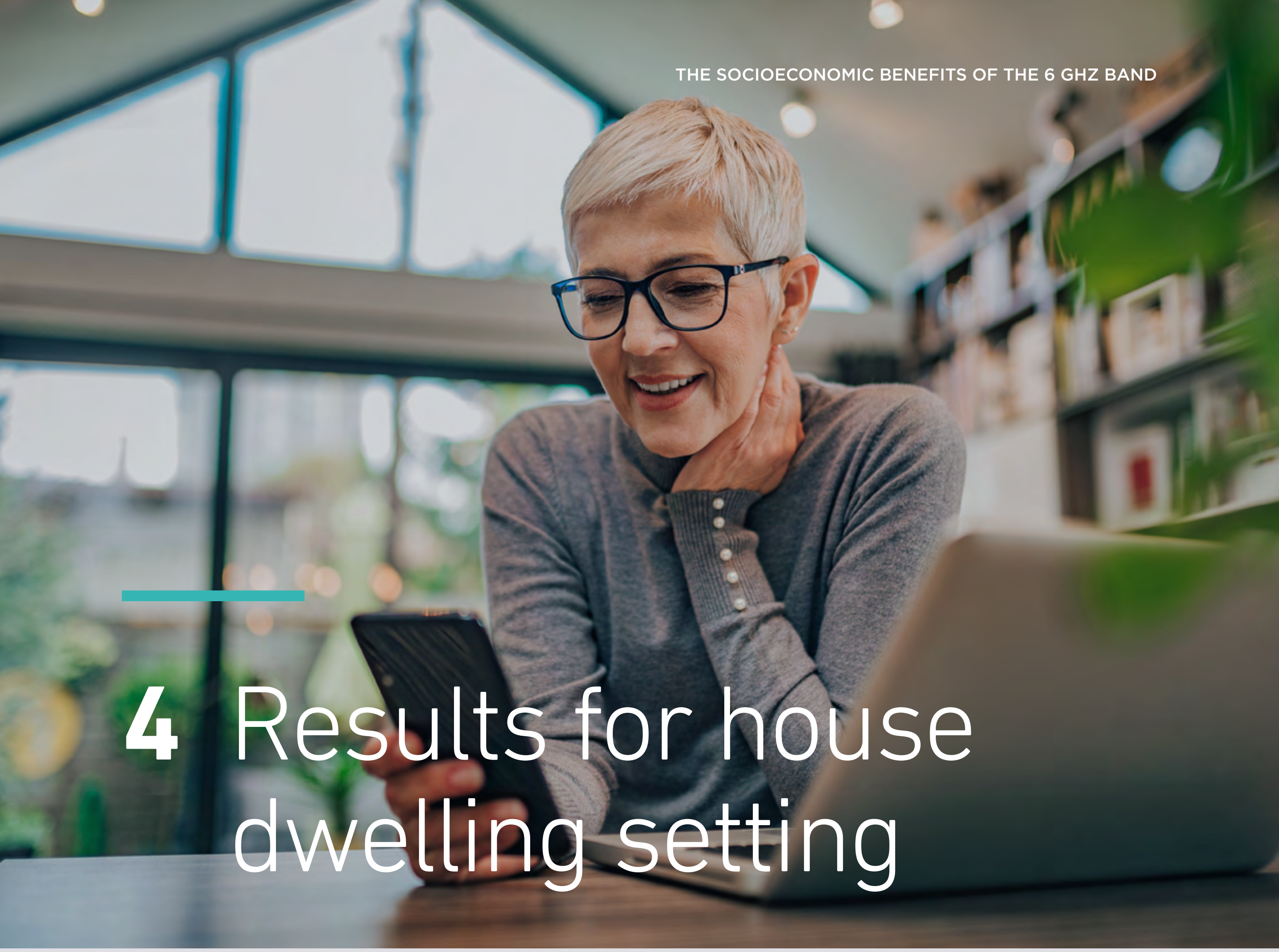
Once we estimate the impact of each policy scenario on 5G and FTTH/B and cable adoption (the latter being impacted by Wi-Fi capacity), the next step is to estimate the wider socioeconomic impacts. Both 5G and fixed broadband are digital technologies that are widely regarded as general-purpose technologies: innovations that reshape the economy, redefining the goods and services that are made, the ways used to produce them and the functioning of the markets that serve them. They drive economic gains because they enable tools and processes for quicker, cheaper and more convenient production, which improves the productivity of firms and workers. They also lower information search and knowledge costs of consumers and producers, enabling new transactions and improving existing ones, thereby stimulating more trade and competition.[32]

A number of studies have found a causal link between the adoption of mobile and fixed internet and GDP, suggesting that a 10% increase in mobile or fixed internet adoption can increase a country's GDP by between 0.5% and 2.5%.[33] In this study, the impact of introducing 5G or faster fixed broadband is unlikely to deliver the same benefit as connecting an individual or business for the first time – rather, the impact will reflect an improvement or 'upgrade' to the technologies that people are already using, for example by offering faster data rates and lower latencies.

A study by GSMA Intelligence (2020b) found that upgrading connections from 2G to 3G and 3G to 4G increased the total economic impact of mobile by about 15%.[34] We therefore assume a similar uplift when estimating the impact of upgrading from 4G to 5G. This allows us to calculate the overall contribution of 5G technology to a country's economy over time.

The incremental economic impact of more/less FTTH/B and cable adoption is assumed to be the same as the impact of 5G. This ensures we apply a consistent approach to both technologies, and it also means the results between scenarios are not sensitive to the specific impact assumption (as it is applied in the same way to 5G and FTTH/B and cable).

32 See GSMA (2020b) and Katz et al (2021)
33 For example, see GSMA Intelligence (2020b) and ITU (2019)
34 For example, if a 10% increase in 2G adoption increases GDP by 1%, then a 10% increase in 2G-to-3G adoption increases GDP by an additional 1% * 15% = 0.15%. This incorporates both direct and indirect economic impacts (see the appendix).



4 Results for house dwelling setting

In this chapter, we present the results of the socioeconomic cost-benefit analysis assuming that all urban residents in each of the 24 countries live in a house dwelling, meaning that they would have access to the full amount of spectrum that is available for Wi-Fi (without suffering from interference between access points).

Assigning the full 6 GHz band for 5G means faster speeds and/or lower costs for mobile users

A mid-band spectrum shortage for 5G would have one of the following two impacts on consumers. Operators would have to densify their networks to cover any capacity gap and maintain 5G performance requirements, which would result in higher annual capital and operational expenditure – some of these cost increases would likely be passed on to consumers in the form of higher prices and delayed rollout, which would impact the adoption and use of 5G. Alternatively, in the absence of densification investments from operators, consumers would experience a degradation in network quality, which would be unavoidable if operators have reached the technical limits of network densification.[35]

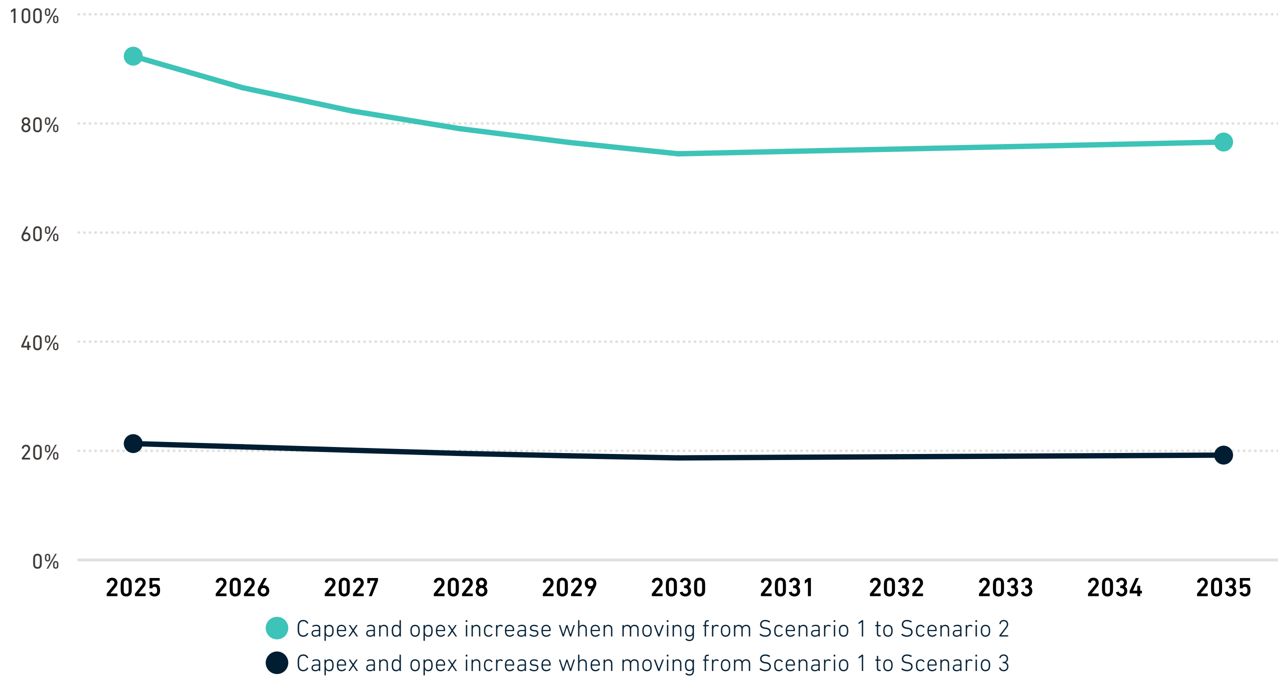
Assuming that densification is feasible from a technical perspective (i.e. inter-cell interference remains at a manageable level and suitable sites can be found, which may not be the case in many areas), Figure 10 presents the average increase in deployment cost across the 24 study countries if no 6 GHz spectrum is assigned for licensed use (Scenario 2) and if 700 MHz of 6 GHz

35 This could be the case in cities with large population densities. See Coleago (2021).

spectrum is assigned for licensed use (Scenario 3) – both are in comparison to a scenario where the full 6 GHz licensed band is used for 5G (Scenario 1). It shows that without any of the 6 GHz spectrum band assigned to licensed use, annual capital and operational expenditure would increase by an average of around 80% compared to a scenario of full allocation of the 6 GHz to licensed use. If 700 MHz out of the 1200 MHz available in the 6 GHz band was assigned to licensed use, costs would increase by an average of around 20% over the period of analysis. These higher rollout costs would likely be partially passed on by operators to consumers in the form of higher prices, which means that, depending on price elasticity of demand assumptions, some consumers would delay their subscription or not adopt 5G services at all.

Figure 10

Average increase in operators' annual capital and operational expenditure in Scenarios 2 and 3 (compared to Scenario 1)



Analysis is presented from 2025, which is when we assume that operators can start to use the 6 GHz band for 5G (see the appendix).
Source: GSMA Intelligence

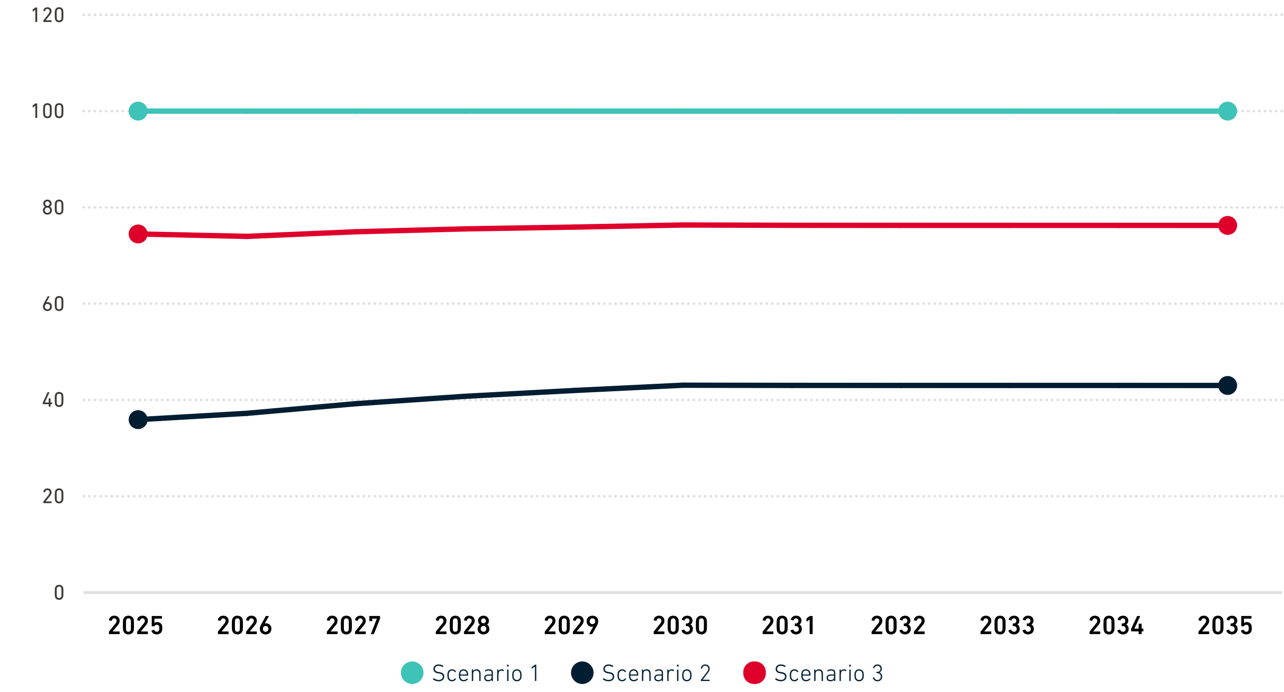
Alternatively, if mobile operators cannot densify their networks to meet traffic demand, then any capacity gap that arises would be absorbed by subscribers in terms of lower speeds. Assuming that the number of subscribers does not change as a result of changes in the quality of service, urban subscribers would experience lower speeds than the IMT-2020 minimum performance requirements (user-experienced data rates of 100 Mbps download and 50 Mbps upload).

Figure 11 presents the average reduction in download speeds across the 24 study countries if no 6 GHz spectrum is assigned for licensed use and if 700 MHz of 6 GHz spectrum is assigned for licensed use. It shows that download speeds would be reduced to an average of less than 50 Mbps without any of the 6 GHz band, or 75 Mbps with 700 MHz of the 6 GHz spectrum band assigned to licensed use over the period of analysis.[36]

36 As explained in Chapter 3 and the appendix, these modelled changes in costs or speeds (depending on network densification assumptions) do not feed into the main cost-benefit analysis – rather, they are translated to a change in 5G adoption. Figures 9 and 10 are illustrative of the potential alternative effects from not assigning the whole of the 6 GHz spectrum band to licensed use.

Figure 11

Average 5G download speeds in Scenarios 1, 2 and 3 (Mbps)



The download speeds refer to those experienced at peak times, rather than average speeds. Analysis assumes no network densification to address the capacity gap (see the appendix). Download speeds for Scenario 1 assume that there is sufficient spectrum in other mid-bands – along with the 6 GHz band – to meet the 100 Mbps requirement. Analysis is shown from 2025, when it is expected that 6 GHz spectrum will be available to use for 5G deployment. The analysis also reflects increasing use of high-band spectrum for 5G, which is why download speeds increase between 2025 and 2030 (see the appendix for further details).
Source: GSMA Intelligence

It should be noted that the 5G traffic demand is based on IMT-2020 minimum performance requirements as defined by the ITU-R in 2017.[37] Such performance requirements are applied for the whole period of interest (2021–2035). This represents a conservative assumption since, over time, administrations could set national targets that go beyond those minimum requirements and considering that new generations for the IMT systems will start becoming available before 2035.

37 Report ITU-R M.2410-0.

Wi-Fi traffic demand is not currently constrained by spectrum

As explained in Chapter 3, the overall level of Wi-Fi traffic depends primarily on two factors: the speeds that are supported by the underlying fixed broadband connection and the adoption of connected devices within households. As shown in Figure 2, there is significant variation in adoption of FTTH/B and cable across the 24 study countries, from less than 1% in Ghana to more than 100% in Singapore and the UAE. Currently, FTTH/B and cable do not typically offer users access to speeds greater than 1 Gbps, and in many cases the available speeds are much less. This means, considering the data rates supported by Wi-Fi, that the spectrum available for Wi-Fi is unlikely to be a bottleneck that limits speeds.

If going forward, however, adoption of FTTH/B and cable increases and if it allows for greater speeds, then the demand on Wi-Fi will also increase, based on the usage and adoption of connected devices within households. The adoption of devices varies significantly across the countries considered in this study. For example, our analysis suggests that the average household in the UAE and Qatar has 11 Wi-Fi devices (including smartphones, tablets, laptops/PCs, smart home devices, AR/VR systems, gaming consoles and smart TVs). These countries will therefore likely have a higher Wi-Fi traffic demand than countries with lower device adoption such as Kenya and Ghana, where the average household has three devices.

In Figure 12, we present Wi-Fi traffic demand for three types of household:

- **Household 1** is based on 11 connected devices being concurrently used (the maximum in our study).
- **Household 2** is based on 6 connected devices being used (the average in our study).
- **Household 3** is based on 3 connected devices being used (the minimum in our study).

We assume that each device requires a data rate of 100 Mbps, and we incorporate annual growth in demand over time to reflect increased data consumption by users, more devices used and an increase in the adoption of FTTH/B and cable broadband (all of which will impact Wi-Fi traffic demand). These demand scenarios are compared to the average amount of Wi-Fi capacity available in our baseline/Scenario 1 (no 6 GHz spectrum), Scenario 2 (1200 MHz available) and Scenario 3 (500 MHz available). While the usage of high bands is currently unknown and the expectation is that this spectrum will be implemented for efficient use of spectrum, we show results in Figure 12A including the use of high-band spectrum and results in Figure 12B without including the use of high-band spectrum.

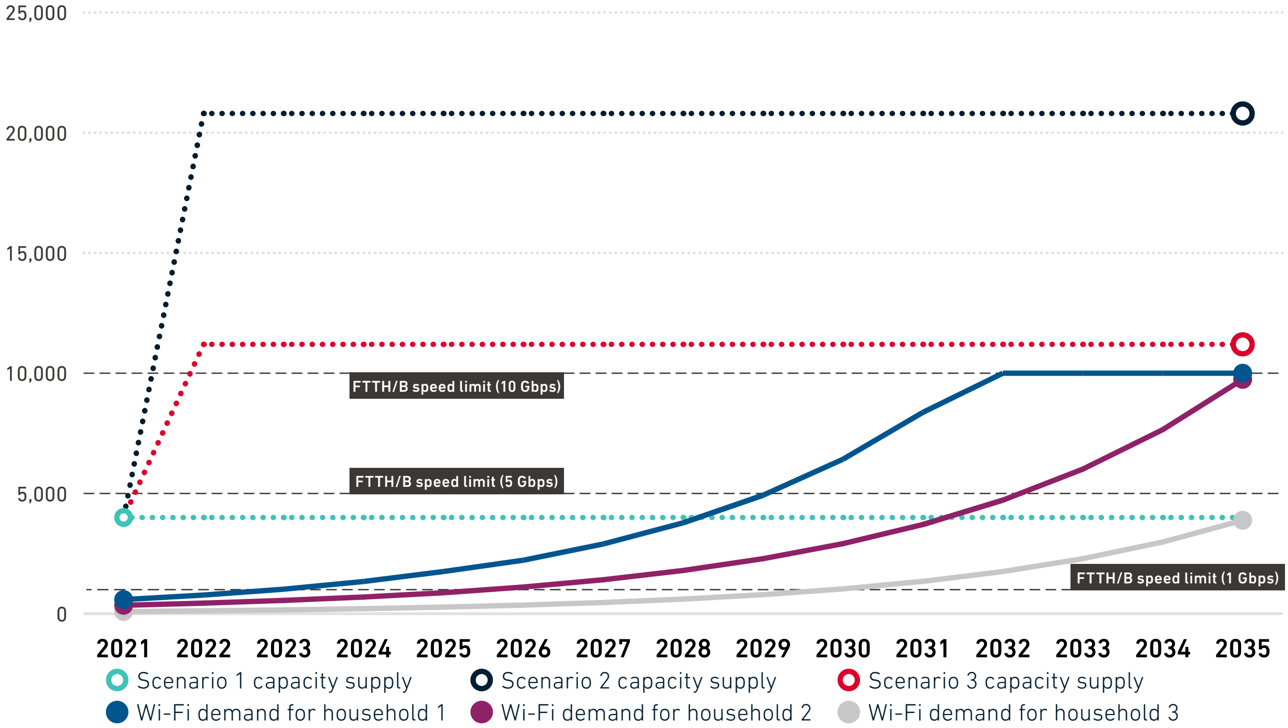
The analysis highlights several key points. First, if FTTH/B and cable do not offer users speeds greater than 1 Gbps, then there is no capacity constraint from existing Wi-Fi spectrum allocations. If fixed broadband speeds provide access to 5 Gbps, there is still sufficient capacity with existing Wi-Fi spectrum, this even holds generally when the high bands are not being utilised. If FTTH/B and cable are able to offer all users access to speeds of 10 Gbps, then there is a capacity constraint that depends on household demand and the utilisation of high bands.

We find the following, assuming that FTTH/B and cable are able to offer all users access to speeds of 10 Gbps by 2035:

- If the high bands are utilised (Figure 12A), in household 1 (with high demand in the study) demand exceeds capacity supply from 2030; in household 2 (with average demand in the study) demand exceeds supply from 2033; and in household 3 (with low demand in the study) there is no capacity gap at all.
- If the high bands are not utilised (Figure 12B), in household 1 demand exceeds capacity supply from 2029; in household 2 demand exceeds supply from 2032; and in household 3 there is no capacity gap. At the point where demand exceeds capacity there would be a reduction in the quality of service experienced by the consumer.
- Independent of the utilisation of the high bands, in the case of households 1, 2 and 3, there is sufficient Wi-Fi capacity during the whole period with 500 MHz of spectrum assigned in the 6 GHz band.

Figure 12A

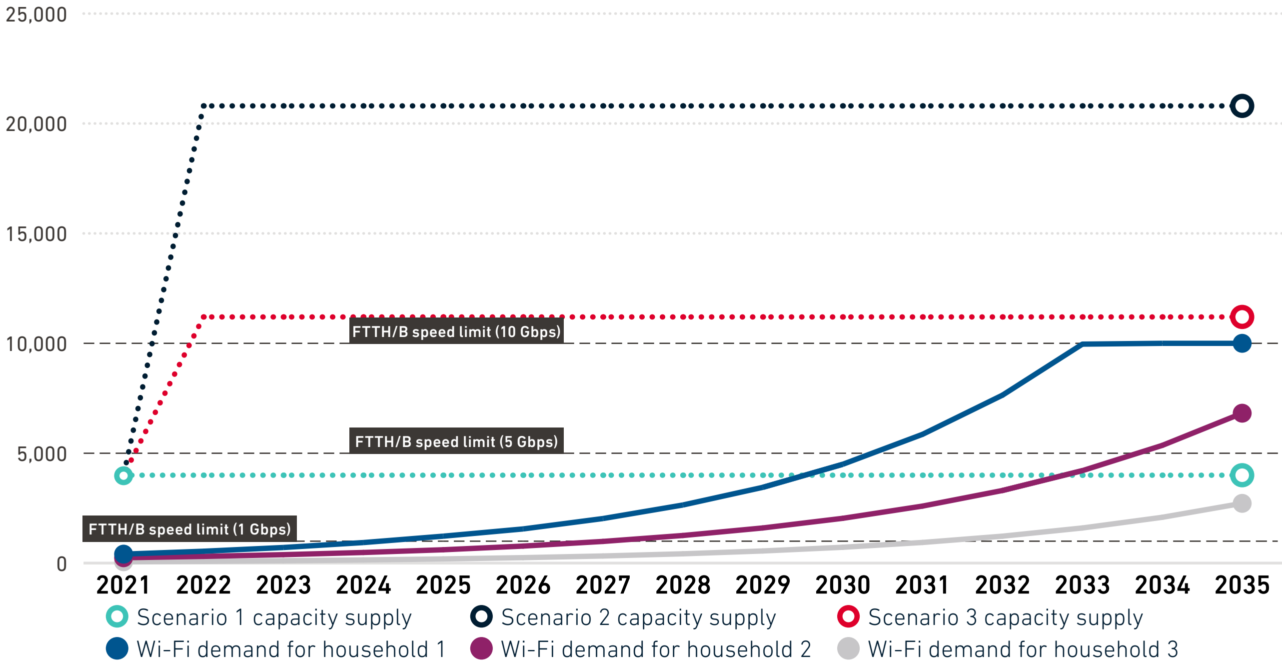
Total Wi-Fi traffic demand and capacity supply (Mbps), with high bands utilised – house dwelling setting



Analysis assumes that 30% of Wi-Fi traffic is offloaded to the high bands.
Source: GSMA Intelligence

Figure 12B

Total Wi-Fi traffic demand and capacity supply (Mbps), with no high bands utilised – house dwelling setting



Analysis does not incorporate capacity from high-band spectrum.
Source: GSMA Intelligence

The socioeconomic impacts of three 6 GHz spectrum policy scenarios

The allocation of 6 GHz spectrum that gives the greatest benefit depends on the expected capacity supply gaps for 5G and Wi-Fi traffic demand. In addition, the expected developments in fixed broadband technology are a key factor for Wi-Fi – specifically the penetration and speeds that FTTH/B and cable can offer users. Lastly, the usage of the high bands is also critical for the Wi-Fi analysis.[38]

Figure 13 presents the results of the cost-benefit analysis for the three scenarios based on the following assumptions:

- The maximum fixed broadband user speed is 1 Gbps to all FTTH/B and cable users.
- The maximum fixed broadband user speed is 5 Gbps to all FTTH/B and cable users, with up to 30% of Wi-Fi traffic offloaded to the high bands.
- The maximum fixed broadband user speed is 10 Gbps to all FTTH/B and cable users, with up to 30% of Wi-Fi traffic offloaded to the high bands.
- The maximum fixed broadband user speed is 5 Gbps to all FTTH/B and cable users, with no Wi-Fi traffic offloaded to the high bands.
- The maximum fixed broadband user speed is 10 Gbps to all FTTH/B and cable users, with no Wi-Fi traffic offloaded to the high bands.

If fixed broadband does not allow the majority of users to have speeds faster than 1 Gbps then Scenario 1 (assigning 5925–7125 MHz for licensed) will deliver the greatest benefit across all countries. This is because there is already sufficient capacity with existing unlicensed spectrum. This is also the case if fixed broadband enables speeds up to 5 Gbps for all countries and if the high bands can be utilised for up to 30% of Wi-Fi traffic. Even if fixed broadband speeds reach up to 10 Gbps, Scenario 1 still delivers the greatest benefit in most countries.[39]

If high-band spectrum is not used for Wi-Fi and if fixed broadband speeds are able to reach 5 Gbps, then Scenario 1 still drives the greatest benefit in most countries. The only assumption where this result substantively changes is if fixed broadband speeds eventually reach 10 Gbps for all citizens with an FTTH/B and cable connection and if no high-band spectrum is utilised for Wi-Fi. In that case, Scenario 3 (500 MHz for unlicensed and 700 MHz for licensed) generates the highest benefit in countries where a capacity gap for Wi-Fi materialises and where there is (or expected to be) significant FTTH/B and cable adoption.

If the high bands are not available or utilised to address a portion of Wi-Fi traffic demand, and if fixed speeds are able to reach 10 Gbps, allocating the full 6 GHz to licensed mobile (Scenario 1) will still drive the greatest benefit for countries with relatively high expected 5G penetration compared to their predicted Wi-Fi traffic demand and FTTH/B and cable adoption. This is the case in Ghana, Kenya, Jordan, Nigeria, South Africa, Egypt and Indonesia.

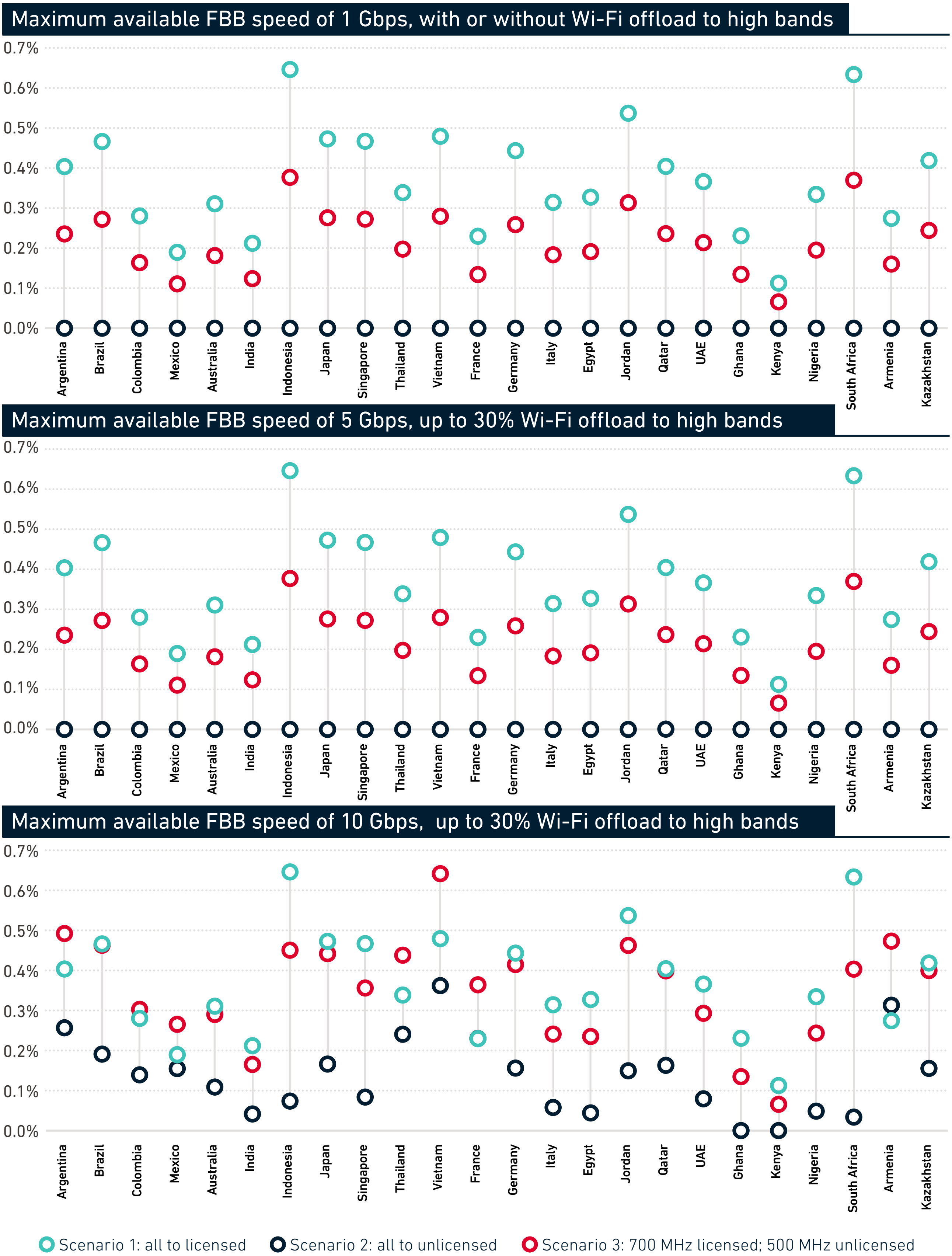
For all countries, there is never a scenario where the allocation of the full 6 GHz band to unlicensed use (Scenario 2) generates the greatest benefit to society. This is driven by the analysis highlighted in Figure 12 – even in countries with very high Wi-Fi demand, allocating an additional 500 MHz of spectrum for unlicensed use in the 6 GHz band (as reflected in Scenario 3) is sufficient to meet expected demand. This means that there are no additional gains from allocating all 6 GHz for unlicensed as per Scenario 2.

38 Note that it is always assumed that mmWave will be used for 5G where it is available.
39 For the countries where this is not the case, Scenario 3 produces the greatest benefit. If FTTH/B and cable support maximum speeds of 10 Gbps, Scenario 1 would produce the greatest benefit if high-band spectrum was able to offload 32–50% of traffic, depending on the country.

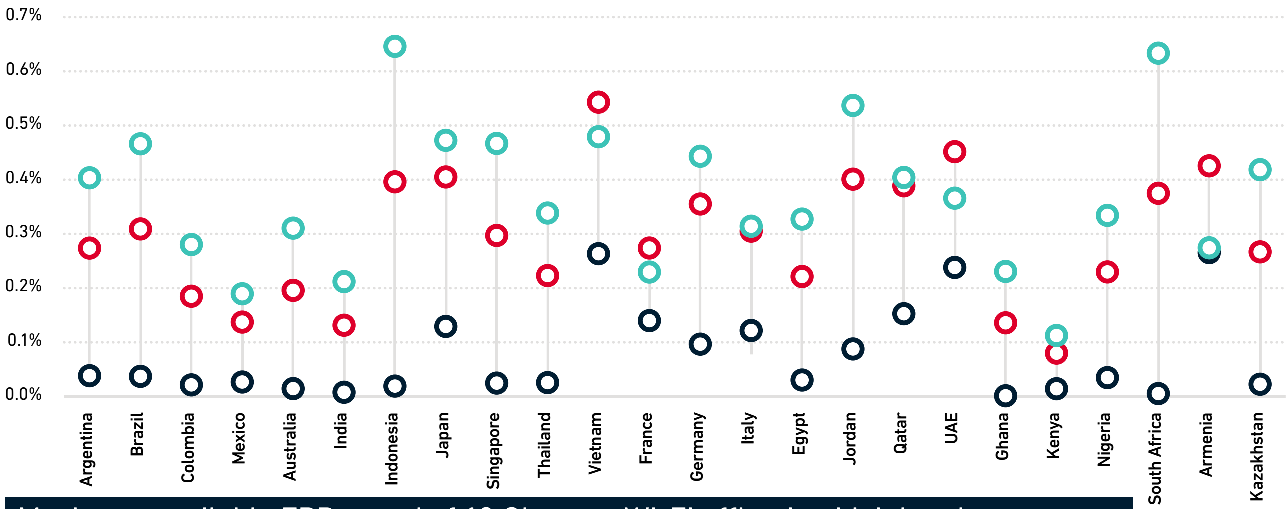
Figure 13

Summary of economic benefits by scenario and country – house dwelling setting

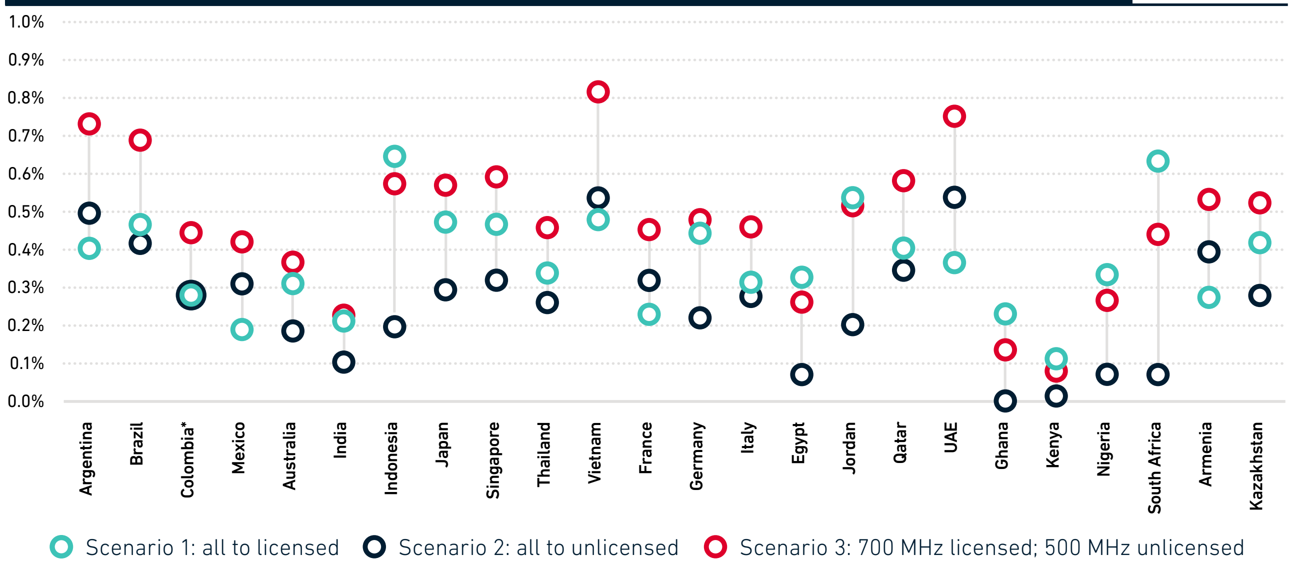
Proportion of expected GDP in 2035



Maximum available FBB speed of 5 Gbps, no Wi-Fi offload to high bands



Maximum available FBB speed of 10 Gbps, no Wi-Fi offload to high bands



The results represent the net present value (NPV) of economic benefits over the 2021–2035 period, expressed as a proportion of expected GDP in 2035 for each country.
The five sets of results adjust assumptions related to Wi-Fi and fixed broadband (the amount of high bands utilised and the maximum speeds available). Therefore, the results of Scenario 1 (where the full licensed band is allocated for 5G) are the same.
* Scenarios 1 and 2 give similar benefits and so overlap on the graph.
Source: GSMA Intelligence

5 Results for apartment setting

In this chapter, we present the results of the socioeconomic cost-benefit analysis assuming that all urban residents in each of the 24 countries live in a flat or apartment, meaning that they would not have access to the full amount of spectrum that is available for Wi-Fi (due to interference). It will overstate the potential benefits of assigning additional spectrum for unlicensed use in the 6 GHz band, as a large proportion of urban residents in the study countries live in houses (for example more than half in Australia, France, South Africa and Indonesia).[40] However, we present the results because the apartment setting will be relevant for some of the urban areas considered in this report. For the purposes of quantifying the economic benefits of 5G, we assume these are the same regardless of whether a consumer is in a house dwelling or an apartment.

40 See for example OECD (2021), UN Habitat (2011) and Statistics South Africa (2020)

Wi-Fi traffic demand is not constrained by spectrum (apartment setting)

In Figure 14, we present Wi-Fi traffic demand for three types of apartment residences (similar to the analysis presented in Chapter 4):

- **Apartment 1** is based on 11 connected devices being concurrently used (the maximum in our study).
- **Apartment 2** is based on 6 connected devices being used (the average in our study).
- **Apartment 3** is based on 3 connected devices being used (the minimum in our study).

For each apartment type, Wi-Fi capacity is constrained compared to a house dwelling due to interference from neighbouring Wi-Fi users. We represent this by means of a lower spectral efficiency and base those on Qualcomm (2016) (see Appendix A). Consistently, we also use more refined demand assumptions (see Appendix A). This is needed because the demand projections assumed in Figure 12 are not compatible with the spectral efficiencies available in an apartment. We then incorporate annual growth in demand over time to reflect increased data consumption by users, more devices being used and an increase in the adoption of FTTH/B and cable broadband.

The analysis shows the following:

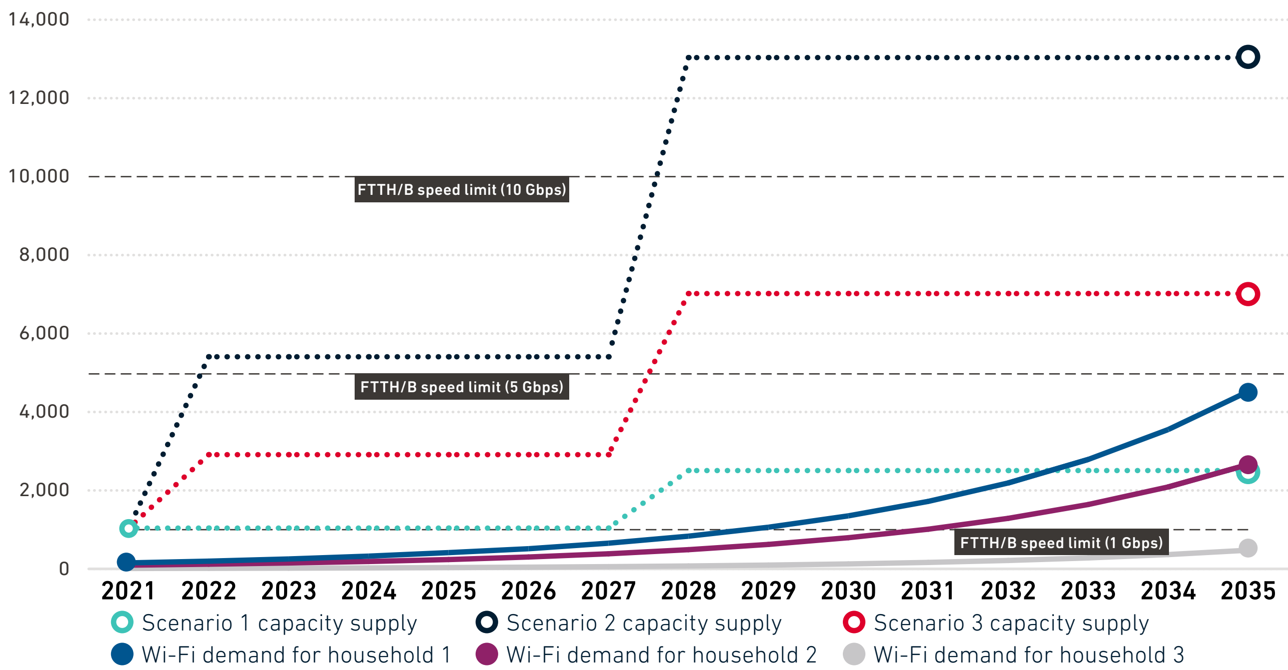
- First, if FTTH/B and cable do not offer users speeds greater than 1 Gbps, then there is no capacity constraint from existing Wi-Fi spectrum allocations. If fixed broadband speeds provide access to 5 Gbps, there is a capacity constraint that depends on household demand and the utilisation of high bands.

We find the following, assuming that FTTH/B and cable are able to offer all users access to speeds of 5 Gbps:

- If the high bands are utilised (Figure 14A), in apartment 1 (with high demand in the study) demand exceeds capacity supply from 2033; in apartment 2 demands exceeds supply from 2035; and in apartment 3 there is no capacity gap at all.
- If the high bands are not utilised (Figure 14B), in apartment 1 demand exceeds capacity supply from 2032; in apartment 2 demand exceeds supply from 2034; and in apartment 3 there is no capacity gap.
- Independent of the utilisation of the high bands, in the case of apartments 1, 2 and 3, there is sufficient Wi-Fi capacity during the whole period with 500 MHz of spectrum assigned in the 6 GHz band.

Figure 14A

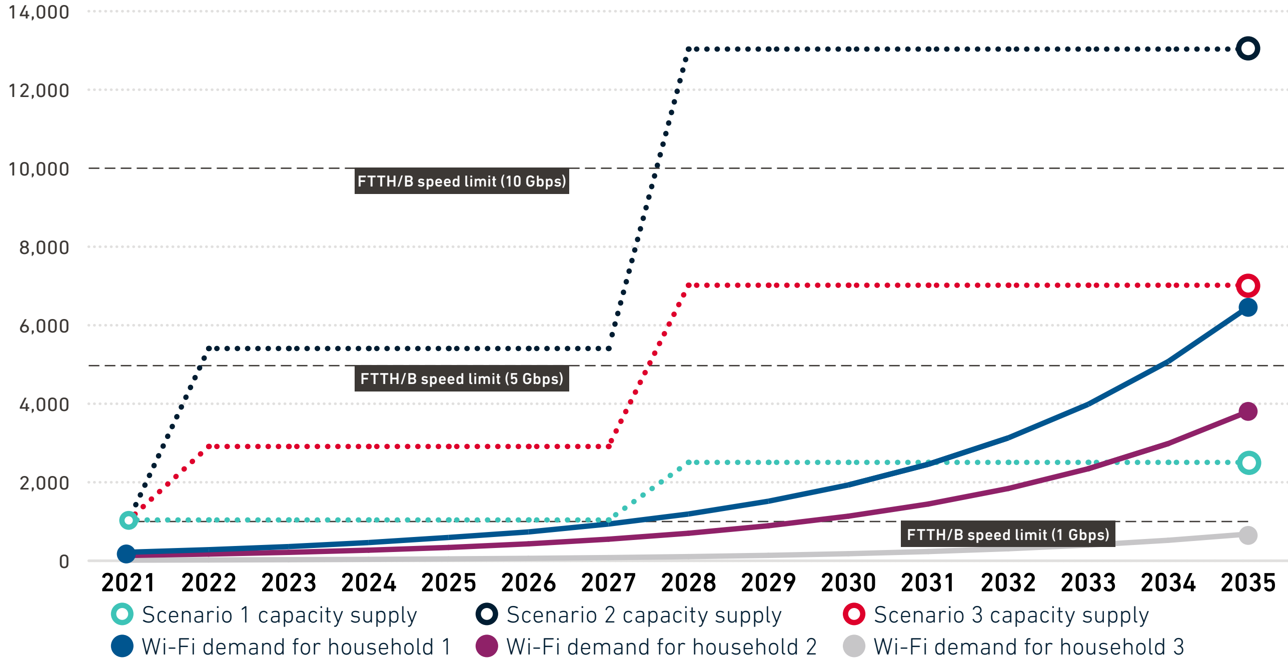
Total Wi-Fi traffic demand and capacity supply (Mbps), with high bands utilised – apartment setting



Source: GSMA Intelligence

Figure 14B

Total Wi-Fi traffic demand and capacity supply (Mbps), with no high bands utilised – apartment setting



Source: GSMA Intelligence

The socioeconomic impacts of three 6 GHz spectrum policy scenarios

Figure 15 presents the results of the cost-benefit analysis for the three 6 GHz policy scenarios based on the following assumptions:

- The maximum fixed broadband user speed is 1 Gbps to all FTTH/B and cable users, with up to 30% of Wi-Fi traffic offloaded to the high bands.
- The maximum fixed broadband user speed is 5 Gbps to all FTTH/B and cable users, with up to 30% of Wi-Fi traffic offloaded to the high bands.
- The maximum fixed broadband user speed is 10 Gbps to all FTTH/B and cable users, with up to 30% of Wi-Fi traffic offloaded to the high bands.
- The maximum fixed broadband user speed is 5 Gbps to all FTTH/B and cable users, with no Wi-Fi traffic offloaded to the high bands.
- The maximum fixed broadband user speed is 10 Gbps to all FTTH/B and cable users, with no Wi-Fi traffic offloaded to the high bands.

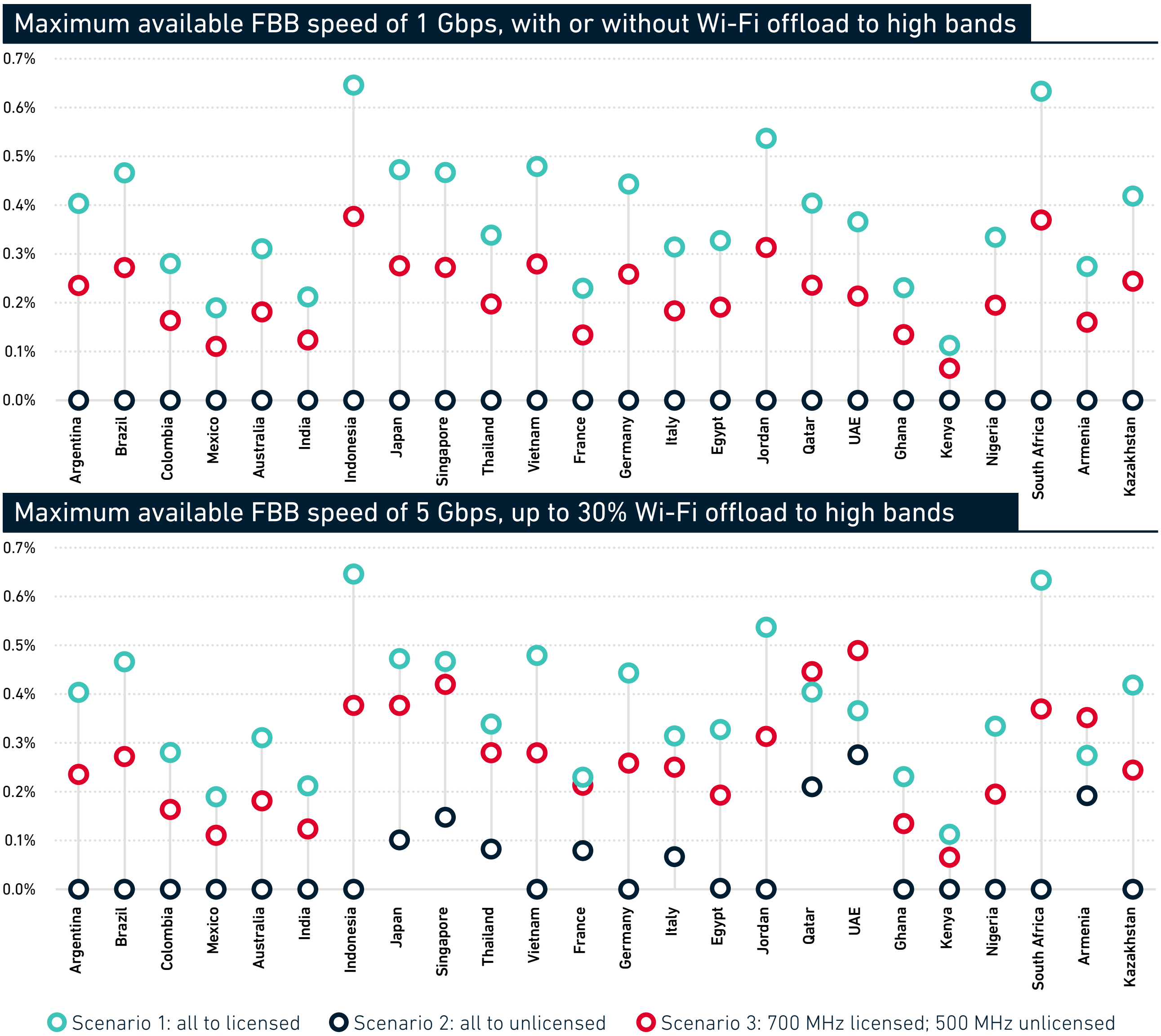
Similar to the house dwelling setting in Chapter 4, if fixed broadband does not allow all users to have speeds faster than 1 Gbps, then Scenario 1 (assigning 5925–7125 MHz for licensed use) will deliver the greatest benefit across all countries. If fixed broadband enables speeds up to 10 Gbps for all citizens and if the high bands can be utilised for up to 30% of Wi-Fi traffic, then Scenario 1 remains the optimal policy in all countries, with the exception of UAE, Qatar and Armenia, where Scenario 3 delivers the greatest benefit. If fixed broadband enables speeds up to 10 Gbps for all citizens and if the high bands are not utilised for any Wi-Fi traffic, then Scenario 1 delivers the greatest benefit in 17 countries and Scenario 3 delivers the greatest benefit in 7 countries.

This analysis shows again that, even in countries with very high Wi-Fi demand, there is no result where the allocation of the full 6 GHz band to unlicensed use (Scenario 2) generates the greatest benefit to society. Therefore, allocating an additional 500 MHz of spectrum for unlicensed use in the 6 GHz band (as reflected in Scenario 3) is sufficient to meet expected demand. This means that there are no additional gains from allocating all 6 GHz for unlicensed as per Scenario 2.

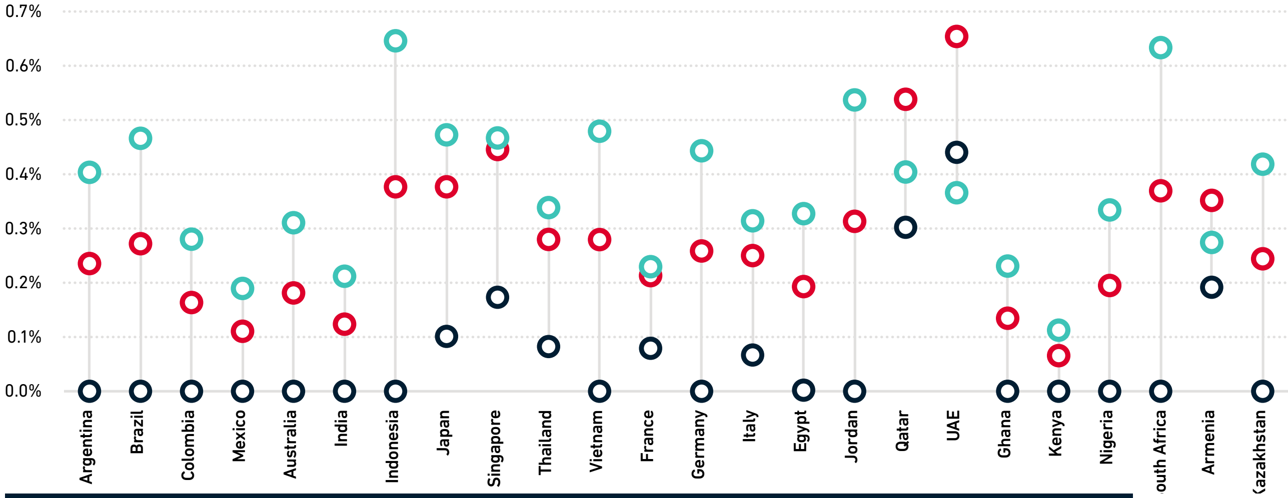
Figure 15

Summary of economic benefits by scenario and country (proportion of expected GDP in 2035) – apartment setting

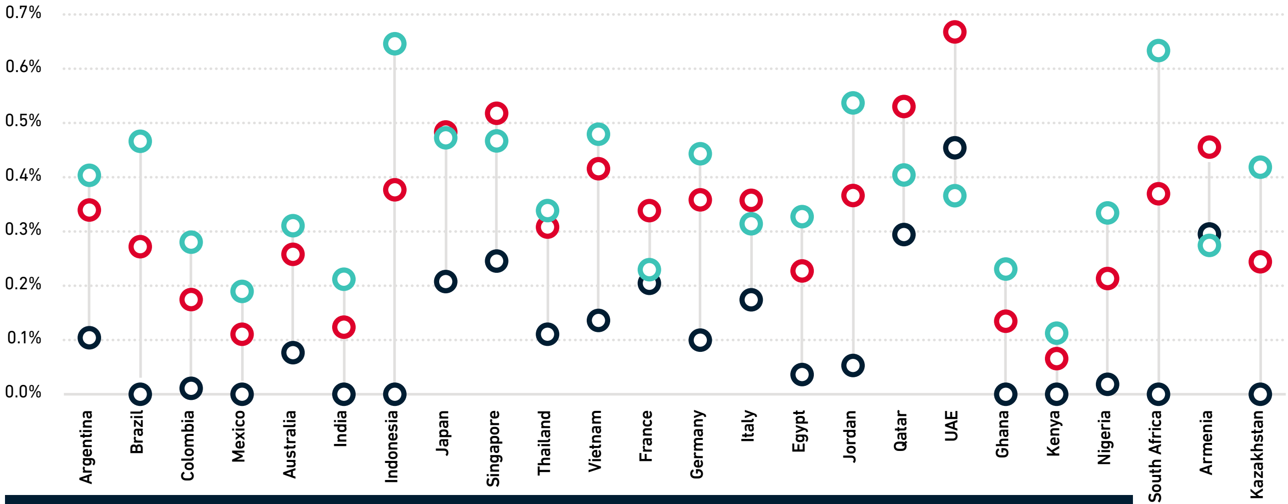
Proportion of expected GDP in 2035



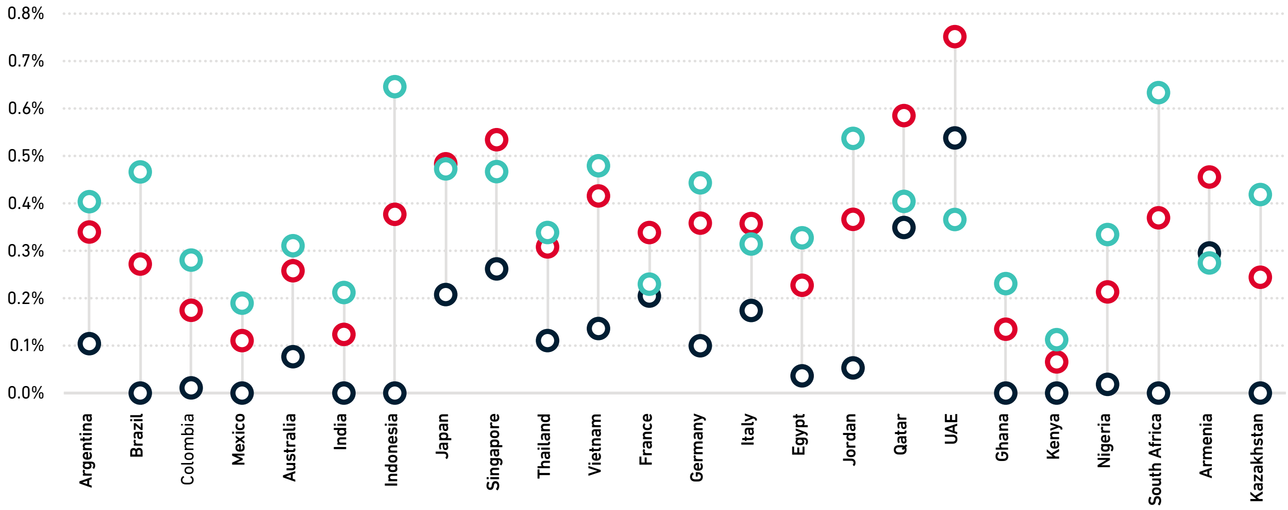
Maximum available FBB speed of 10 Gbps, up to 30% Wi-Fi offload to high bands



Maximum available FBB speed of 5 Gbps, no Wi-Fi offload to high bands

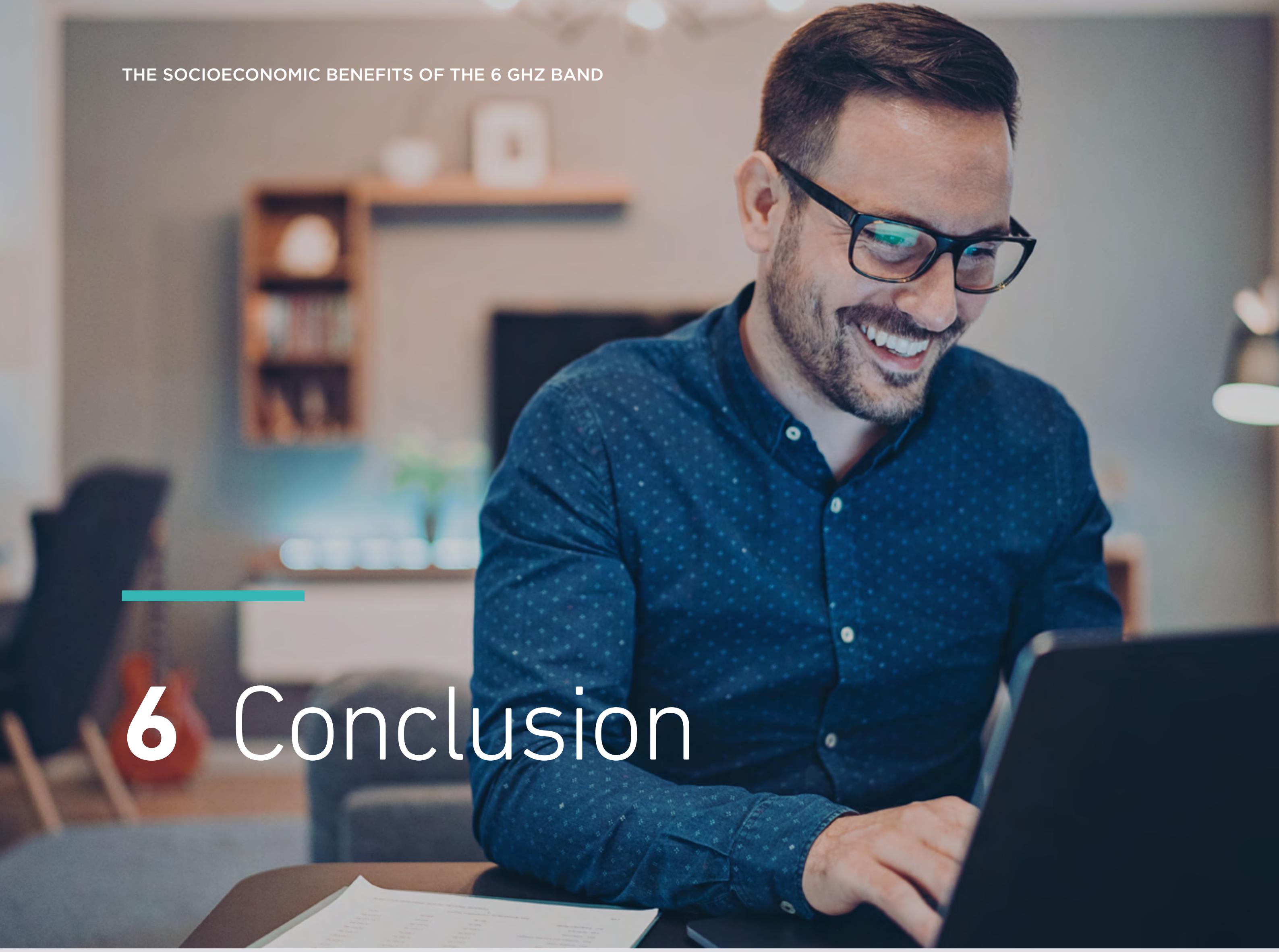


Maximum available FBB speed of 10 Gbps, no Wi-Fi offload to high bands



Scenario 1: all to licensed   Scenario 2: all to unlicensed   Scenario 3: 700 MHz licensed; 500 MHz unlicensed

The results represent the net present value (NPV) of economic benefits over the 2021–2035 period, expressed as a proportion of expected GDP in 2035 for each country.
The five sets of results adjust assumptions related to Wi-Fi and fixed broadband (the amount of high-band spectrum utilised and the maximum speeds available). Therefore, the results of Scenario 1 (where the full licensed band is allocated for 5G) are the same.
Source: GSMA Intelligence



6 Conclusion

Spectrum policymakers face an important decision in the coming years as they look to decide the optimal approach for managing spectrum in the 5925–7125 MHz frequency range. This report carries out a cost-benefit analysis of different assignment options in 24 countries where a decision on the allocation of the full band has yet to be taken. While they are specific to those markets, the findings are also relevant to other countries.

Overall, we find that the optimal assignment policy primarily depends the expected adoption of 5G and fixed fibre/cable broadband services in each market, the speeds that fixed broadband can offer consumers, the existing and future spectrum availability for licensed and unlicensed use, and usage of high bands by 5G and Wi-Fi. In relation to the latter, we note that in most countries, 5G has access to (or is expected to have access to) high-band frequencies above 24 GHz. This spectrum is expected to address specific areas with extreme traffic density. Similarly for Wi-Fi, while it will not be possible to meet all Wi-Fi demand with high-band spectrum, this spectrum can still support connectivity for certain use cases requiring extremely high throughput such as AR/VR.

Taking the above considerations into account, this report draws the following conclusions:

- In a house dwelling setting, the licensed use of the entire 6 GHz band will deliver the largest benefits across all countries if fixed broadband technologies do not provide maximum user speeds above 5 Gbps. This is because there is already sufficient capacity with existing unlicensed spectrum. The licensed use of the 6 GHz band will still deliver the largest benefits across most countries if in those countries fixed broadband provides maximum user speeds up to 10 Gbps and if up to 30% of Wi-Fi traffic is offloaded to the high bands. Assigning the lower 6 GHz band for unlicensed use and the upper 6 GHz band for licensed use will deliver the largest benefits in some countries, if FTTH/B and cable broadband adoption is widespread, they support maximum user speeds of 10 Gbps and high bands are not utilised by Wi-Fi.
- When carrying out the analysis based on an apartment setting, rather than a house dwelling, we still find that in the majority of countries the licensed use of the entire 6 GHz band will deliver the largest benefits. For the remaining countries, split use across the 6 GHz band (5925–6425 MHz for unlicensed and 6425–7125 MHz for licensed) would generate the largest benefits.
- Unlicensed use across the whole 6 GHz band was not found to be the most beneficial allocation in any of the considered analyses. Even in countries with very high Wi-Fi demand, allocating an additional 500 MHz of spectrum for unlicensed use in the lower 6 GHz band is sufficient to meet expected demand. This means that there are no additional gains from allocating the full 6 GHz frequency band for unlicensed use.

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Appendix A Methodology

To estimate the impact of assigning additional spectrum in the 6 GHz band for licensed or unlicensed (modelled via 5G or Wi-Fi in this study), we develop two traffic demand and capacity supply models for the period between 2021 and 2035.

5G traffic demand and capacity supply model

Figure A1 illustrates the structure of the 5G model. It works as follows:

- 5G traffic demand in urban areas[41] is driven by (i) expected 5G adoption, (ii) the minimum ITU-R performance requirements of IMT-2020[42] (100 Mbps download speeds and 50 Mbps upload speeds[43]), (iii) Wi-Fi offload, (iv) high bands offload, (v) urban population and (vi) the share of connected users that are active.[44] We also assume a growth in traffic demand over time, to reflect increased data use by 5G users.
- 5G capacity supply is driven by (i) the amount of spectrum available, (ii) the number of sites deployed and (iii) spectral efficiencies.
- We estimate the number of sites needed to meet traffic demand given the 5G spectral efficiencies for all available spectrum and based on three scenarios on the amount of licensed spectrum available within the 6 GHz band for 5G: 1200 MHz (5925–7125 MHz), 700 MHz (6425–7125 MHz) and zero.

41 We focus on urban areas, as this is where capacity is most needed and where 6 GHz can be used for wide-area cellular networks.
42 Report ITU-R M.2410-0.
43 Such performance requirements are applied for the whole period (2021–2035). This represents a conservative assumption since over time administrations could set national targets that go beyond those minimum requirements and considering that new generations for the IMT systems will become available before 2035.
44 This share refers to concurrent demand from connected 5G users during the busy period. For example, a share of 5% means that up to 5% of all 5G users will be using their devices simultaneously.

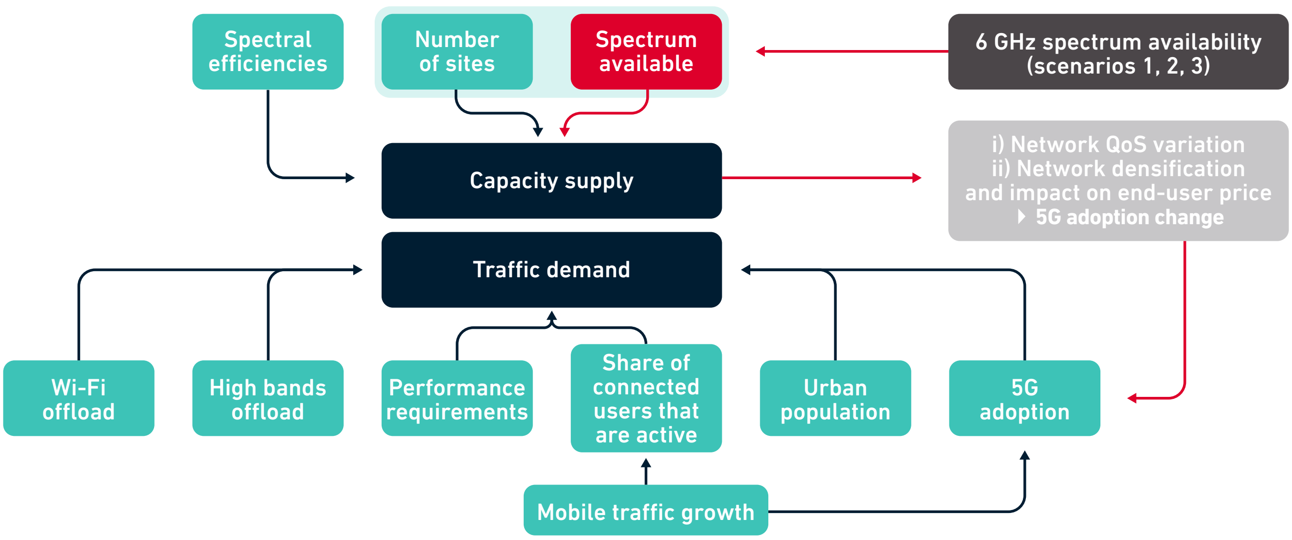
- We then compare the scenarios where 1200 MHz of spectrum is available for licensed use against the scenarios where 700 MHz and no spectrum are available for licensed use. There are three possible outcomes:
  - i Operators do not densify their networks, while the capacity increases, which means that traffic demand exceeds capacity supply and consumers suffer a reduction in quality of service (i.e. receive less than 100 Mbps download and 50 Mbps upload), which can be reflected in 5G take-up.
  - ii Operators densify the network to meet demand, meaning more sites that incur higher cost. These costs are assumed to be (partially) passed on to the consumer, which reduces 5G take-up.[45]
  - iii A combination of (i) and (ii).

Under approach (i), in order to estimate the impact of assigning less than the complete 6 GHz band for 5G, we translate a reduction in quality of service to a reduction in 5G adoption. This works by assuming that if operators have access to zero or 700 MHz of 6 GHz licensed spectrum, they would deploy the same number of sites as if they had access to 1200 MHz – but with the result of suffering a reduction in network quality. We assume that each reduction in 100 Mbps in downlink capacity (the IMT-2020 minimum performance requirement) is associated with one less 5G user in practice (i.e. they could be considered as a 4G user instead). To provide an illustrative example, if total traffic demand was 1,000 Mbps and having no 6 GHz spectrum meant supply was 800 Mbps,[46] the model assumes there would be two fewer 5G users. The rationale for this is that if users do not have access to 100 Mbps, then they do not have a 5G service.[47] Another way of saying this is that we adjust 5G adoption based on the capacity gap. For example, if there is no capacity gap with the full 6 GHz band assigned to licensed mobile but there is a capacity gap of 20% with no 6 GHz spectrum assigned (i.e. unmet capacity is 20% of total demand), then we assume that 5G adoption falls by 20% in the scenario without any licensed 6 GHz spectrum.

Alternatively, approach (ii) would assume that operators increase capacity by densifying the network with less spectrum at higher cost – this would be (partially) passed on to consumers, which would reduce demand and therefore 5G adoption. However, it is possible that the required densification may not be feasible from an interference perspective (i.e. requiring too many sites in a given area). We therefore model the economic impacts based on a reduction in quality of service, which is also consistent with the approach to modelling Wi-Fi in this report. As a sensitivity check, we implemented the 'densification approach' as an alternative strategy, and the impacts on 5G adoption were comparable to modelling based on approach (i).

Figure A1

5G traffic demand and capacity supply model



Source: GSMA Intelligence

45 Assumptions on pass-through and demand elasticities are based on Ernst & Young and GSMA (2020).
46 Or anywhere between 800 and 899 Mbps
47 As noted in Coleago (2020), for applications and use cases that require a minimum speed, not having the required speed is the same as not having coverage at all.

Table A1

5G model data inputs

Input	Data	Source
5G spectral efficiencies DL/UL (bps/Hz)	Low band: 1.8/1.8 Lower mid-band: 2.2/2.5 Upper mid-band: 6.0/4.1 High band: 6.0/4.1	Coleago (2021)
Number of sites	Country-specific assumptions. The number of sites is calculated based on how many sites are needed to meet expected demand, given spectral efficiencies and the amount of spectrum available. The model incorporates both macro cell sites and small cell sites.	GSMA Intelligence
Spectrum available	Country-specific assumptions. Existing and planned spectrum assignments by country, including other mid-band spectrum in 3.3–4.2 GHz bands and mmWave spectrum. Where mmWave spectrum is either currently available or expected to be assigned for 5G, we assume that it will offload 30% of traffic demand by 2030.	GSMA Intelligence, Coleago (2021) and national regulators
Wi-Fi offload	50% This is the proportion of 5G traffic that is offloaded to Wi-Fi.	GSMA Intelligence[48]
Performance requirements	100 Mbps download speeds 50 Mbps upload speeds	IMT-2020 requirements. Report ITU-R M.2441-0 (11/2018)
Share of connected users who are active	5% in 2021. This reflects the concurrent demand from connected 5G users during the busy period. For example, a share of 5% means that up to 5% of all 5G users will be using their devices simultaneously. Growth in the share of connected users that are active is reflected in the mobile traffic growth assumptions (see below).	Coleago (2020) and Oughton et al (2021)
5G adoption and urban population	Country-specific assumptions. Expected take-up of 5G services combined with urban population produces the number of urban 5G users over time.	GSMA Intelligence
Mobile traffic growth	Country-specific assumptions, with a range of 20–40% traffic growth per year. This reflects the increase in traffic demand over time. It will be driven by (and therefore account for) a combination of increased consumption per user, an increase in the share of connected users and an increase in non-human users (e.g. IoT).	GSMA Intelligence, Ericsson

48 Cisco (2020) reported that offload traffic was just over 50% in 2020 and that offload is expected to reach 71% for 5G. However, given that such estimates likely overstate actual mobile-to-Wi-Fi offload as it includes additional traffic and the fact that 5G may reduce the amount of time spent on Wi-Fi (see Chapter 2), we assume 50% offload.

Wi-Fi traffic demand and capacity supply model

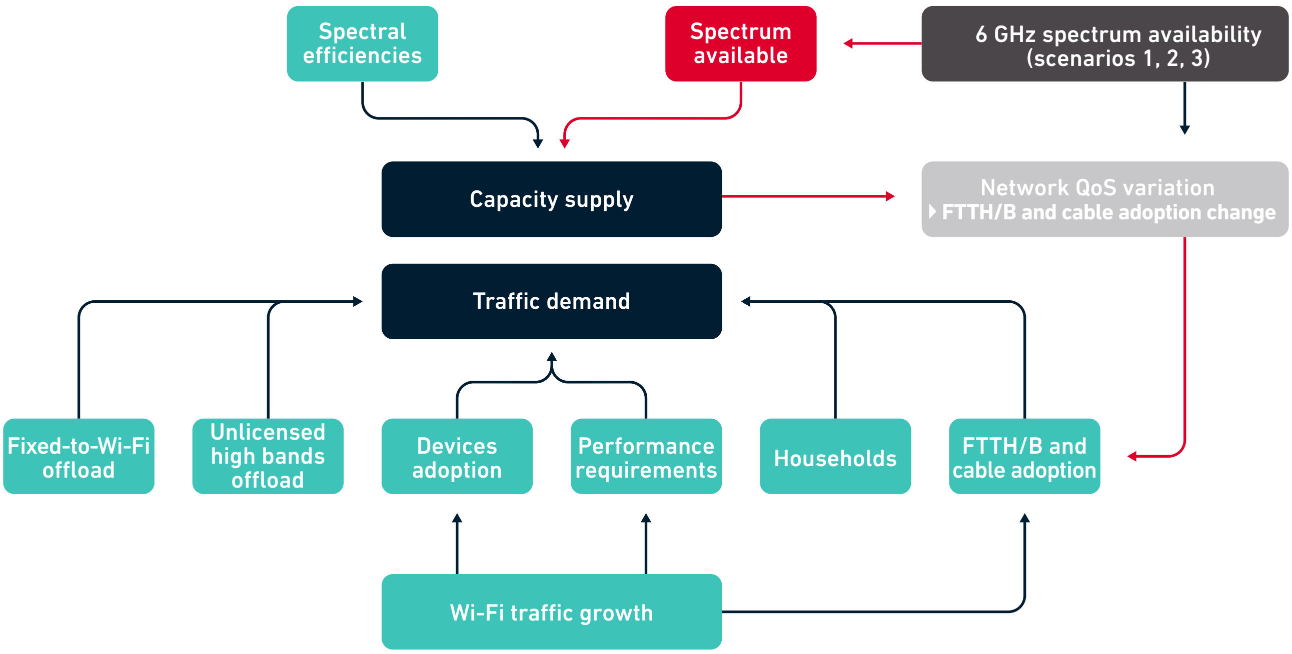
Figure A2 illustrates the structure of the Wi-Fi model. It is based on demand in residential premises and works as follows:

- Wi-Fi traffic demand is driven by (i) fixed broadband adoption (in particular FTTH/B and cable),[49] (ii) the adoption of various devices in each household (smartphones, tablets, laptops/PCs, smart home devices, AR/VR systems, gaming consoles and smart TVs), (iii) performance requirements for each device and (iv) proportion of fixed and cellular traffic that is loaded onto the Wi-Fi network (Wi-Fi offload), (v) high band offload and (vi) number of households. We also assume a growth in demand over time, to reflect increased data use and device adoption by consumers.
- Wi-Fi capacity supply is driven by (i) the amount of spectrum available and (ii) spectral efficiencies.
- We compare Wi-Fi traffic demand and capacity supply over the period of analysis for three scenarios that are determined by the amount of 6 GHz available for unlicensed use: 1200 MHz (5925–7125 MHz), 500MHz (5925–6425 MHz) and zero. For each scenario, if traffic demand exceeds capacity supply, then there is a reduction in quality of service experienced by the consumer. If capacity exceeds demand, then there are no impacts.

In the case of residential Wi-Fi, addressing capacity constraints by 'densifying the network' (i.e. adding more access points) may not be feasible given potential interference. We therefore model the impact of a capacity constraint based on a reduction in network quality in a similar manner to 5G. For example, if there is a capacity gap of 20% with no 6 GHz spectrum allocated for unlicensed use, then we assume that FTTH/B and cable adoption falls by 20% in that scenario.

Figure A2

Wi-Fi traffic demand and capacity supply model



Source: GSMA Intelligence

49 Other fixed technologies based on DSL and FTTC do not allow for fast enough speeds where Wi-Fi could be a potential capacity bottleneck.

Table A2

Wi-Fi model data inputs

Input	Data	Remarks and source
Wi-Fi 6 Spectral efficiencies (bit/sbps/Hz), house dwelling(Mbps)	15 bps/Hz	MCS Index. Assume 1024-QAM, 5/6 coding, 2 spatial streams* and 0.8µs guard band using 802.11ax.
Wi-Fi 6 Spectral efficiencies (bps/Hz), apartment	3.9 bps/Hz in 2021–2027 9.4 bps/Hz in 2028–2035	Spectral efficiencies are based on the scenarios considered in Qualcomm (2016), with a 3-story apartment building with 10 apartments on each floor. Each apartment consists of 4 rooms and the total size is 10m × 10m. For the first half of the period (2021–2027), we take the average spectral efficiency in Configurations A and B, assuming 2 antennas per STA and 4 antennas per AP. For the second half of the period (2028–-2035), we take the spectral efficiency in Configuration B and assume 4 antennas per STA and 4 antennas per AP Our study applies these spectrum efficiencies for the 2.4, 5 and 6 GHz bands.
Spectrum available	Country-specific assumptions. Existing unlicensed spectrum assignments by country in the 2.4 and 5 GHz bands. For DFS channels in the 5 GHz band, we assume 50% utilisation.[50] For high-band offload, we present one set of results where up to 30% of Wi-Fi traffic is offloaded to the high bands and another set of results where no Wi-Fi traffic is offloaded to the high bands.	Linux wireless regulatory database and national regulators
Fixed-to-Wi-Fi offload	The proportion of fixed traffic that is delivered over Wi-Fi. This excludes any fixed data traffic that is transmitted to a device via a cable or wired connection from the access point.	GSMA Intelligence and Katz et al (2021)
Device adoption	Country-specific assumptions. Average number of devices used per household (includes smartphones, laptops/computers, tablets, gaming consoles, smart TVs, AR/VR systems and other smart-home devices).	GSMA Intelligence, ITU, Strategy Analytics

50 For example, if there is an 80 MHz channel available but it has a DFS requirement, then we assume the data rate offered is 1200 Mbps × 50% = 600 Mbps.

Input	Data	Remarks and source
Performance requirements	See next section	
FTTH/B and cable adoption and households	Country-specific assumptions. Expected take-up of FTTH/B and cable-based fixed broadband, as a proportion of households in each country. When combined with the number of households, this produces the number of FTTH/B and cable subscriptions over time. Three maximum available fixed broadband speeds are considered: 1 Gbps, 5 Gbps, 10 Gbps	GSMA Intelligence and ITU
Wi-Fi traffic growth	Country-specific assumptions, ranging between 20–40% traffic growth per year. This reflects the increase in traffic demand over time. It will be driven by (and therefore account for) a combination of increased consumption per device, increased performance requirements and increase in the number of devices used.	GSMA Intelligence, Huawei, Cisco, Analysys Mason

* Wi-Fi 6 technology enables eight spatial streams, which would increase the assumed data rates fourfold (e.g. 9.6 Gbps for a 160 MHz channel, which is often the headline rate referred to). However, the majority of existing devices (and many home access points) are limited to two streams. While this may change going forward, we assume two spatial streams to ensure we do not overestimate the amount of capacity available. In terms of actual throughput that can be made available, there are products available on the market that can achieve 10 Gbps and more by using spectrum from the 2.4 and 5 GHz bands.[51]

Demand for Wi-Fi

On the demand side, when considering a house dwelling, we assume a requirement of 100 Mbps downlink per device. In the analysis for an apartment, we use more refined demand assumptions for each device, as shown in Table A3. This is needed because the demand projections assumed for a house dwelling are not compatible with the spectral efficiencies available in an apartment.

Table A3

Current performance requirements per device (2021)

Device	Required peak data rate (Mbps)
Smartphone	30
Tablet	30
PC/Desktop	30
Gaming console	30
AR/VR system	100
Smart TV (8K)	100
IoT (smart home)	5

Source: GSMA Intelligence, Ericsson and Huawei

51 For example, a Huawei commercial router can use a combination of channels from the 2.4 GHz (40 MHz channel) and 5 GHz (160 MHz channel) bands to achieve 10.75 Gbps speeds (see Huawei AirEngine 8760-X1-PRO).

Modelling the socioeconomic impacts of 5G and Wi-Fi

Once we estimate the impact of each of the three scenarios on 5G and FTTH/B and cable adoption, the next step is to estimate the wider socioeconomic impacts. Both 5G and fixed broadband are digital technologies that are widely regarded as general-purpose technologies: innovations that reshape the economy, redefining the goods and services that are made, the ways used to produce them and the functioning of the markets that serve them. They drive economic gains because they enable tools and processes for quicker, cheaper and more convenient production, which improves the productivity of firms and workers. They also lower information search and knowledge costs of consumers and producers, enabling new transactions and improving existing ones, thereby stimulating more trade and competition.[52]

A number of studies have found a causal link between the adoption of mobile and fixed internet and GDP, suggesting that a 10% increase in mobile or fixed internet adoption can increase a country's GDP by between 0.5% and 2.5%.[53] In this study, the impact of introducing 5G or faster fixed broadband is unlikely to deliver the same benefit as connecting an individual or business for the first time – rather, the impact will reflect an improvement or 'upgrade' to the technologies that people are already using, for example by offering faster data rates, lower latencies and higher reliability.

Quantifying the economic benefits of 5G and Wi-Fi is a challenging task, given the new use cases they are expected to enable. There are four broad categories of use cases that 5G is expected to enable (see Table A4). Estimating the impact of each of these on a country-level basis would require a number of assumptions that are likely to be speculative. We therefore take an approach that is based on existing empirical evidence.

Table A4

5G use cases: description and relevance for business users

Description	Business need examples	Vertical examples
Enhanced mobile broadband (eMBB)		
5G will provide the capacity to handle growing data traffic and grant operators an opportunity to develop new and improved services to consumers. This will enable a new range of applications, including highly reliable mobile internet services for mass gatherings and sports events – where current mobile technology is often stretched to the limit of its capabilities – and AR/VR applications that improve the customer experience, such as in retail by supporting or even replacing traditional showrooms.	Immersive experience (AR/VR) 4K/8K streaming on mobile Increased service capacity Broadband to public transport	Retail, public administration, arts and events
Fixed wireless access (FWA)		
5G will allow network operators to deliver ultra-high-speed broadband to suburban and lower-density areas, supporting home and business applications where fibre is prohibitively expensive to lay and maintain. This will allow broader communities to be connected to the internet via an ultra-fast and reliable connection, bringing applications such as telemedicine and remote education to more people. 5G FWA can therefore provide the benefits of fibre-like connectivity to peri-urban areas, busy small towns and villages.	Alternative to fibre connection Dynamic hotspots Stationary monitoring networks	Education, healthcare, public administration, utilities

52 See GSMA (2020b) and Katz et al (2021)
53 For example, see GSMA Intelligence (2020b) and ITU (2019)

Ultra-reliable low-latency communication (URLLC)	Business need examples	Vertical examples
Low latency and high reliability will enable new applications in the fields of manufacturing, logistics, health and transportation. These applications include autonomous driving, connected robotic applications, AR/VR, drones and surgical/medical remote operations.	Autonomous driving Safety-critical applications Remote manufacturing Remote healthcare Edge computing	Manufacturing, utilities, oil and gas, transport, healthcare
Massive IoT (mIoT)		
5G will be able to facilitate a large network of IoT devices, supporting the creation of smart cities, smart infrastructures and, in the utility sector, smart grids capable of self-identifying issues on the networks. In the agricultural sector, farmers will benefit from the potential of a vast collection of sensors located directly in fields that are able to identify with pinpoint precision which areas need water, have disease or require pest management.	Remote object manipulation Advanced manufacturing Smart cities	Agriculture, utilities, manufacturing, public administration

A study by GSMA Intelligence (2020b) found that upgrading connections from 2G to 3G and 3G to 4G increased the economic impact of mobile by around 15%.[54] We therefore assume a similar uplift when estimating the impact of upgrading from 4G to 5G. As this reflects the overall impact of a technology upgrade on GDP growth, it will capture both 'direct' and 'indirect' impacts. Direct economic impacts include the value-add of firms in the mobile ecosystem, including operators, handset manufacturers, equipment and infrastructure vendors and content providers. The 'indirect' economic impacts include wider productivity benefits that mobile drives in other sectors.

The benefit at country level is calculated as a function of 5G penetration rate, as follows:

t = time **i = country** **α = 5G adoption rate[55]** **β = 5G productivity impact**

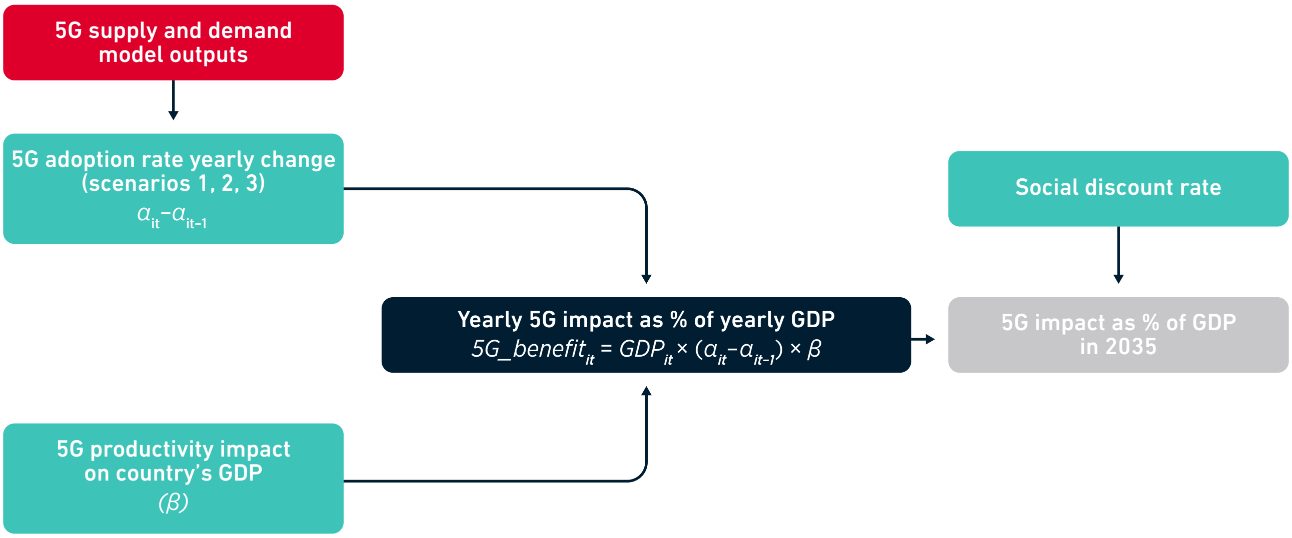
$$Total\_Benefit_{it} = GDP_{it} \times (\alpha_{it} - \alpha_{it-1}) \times \beta$$

The α parameter is based on the 5G long-term forecasts for each country, while for the β parameter, the model assumes a value of 0.02 for low-income countries, 0.015 for middle-income countries and 0.008 for high-income countries. This reflects the fact that mobile broadband has been found to have larger impacts in lower-income countries.[56]

54 For example, if a 10% increase in 2G adoption increases GDP by 1%, then a 10% increase in 2G-to-3G adoption increases GDP by an additional 1% * 15% = 0.15%.
55 This reflects the expected level of 5G adoption (number of 5G users relative to population) in each country over time.
56 See ITU (2019)

Figure A3

Modelling the socioeconomic impacts of 5G



Source: GSMA Intelligence

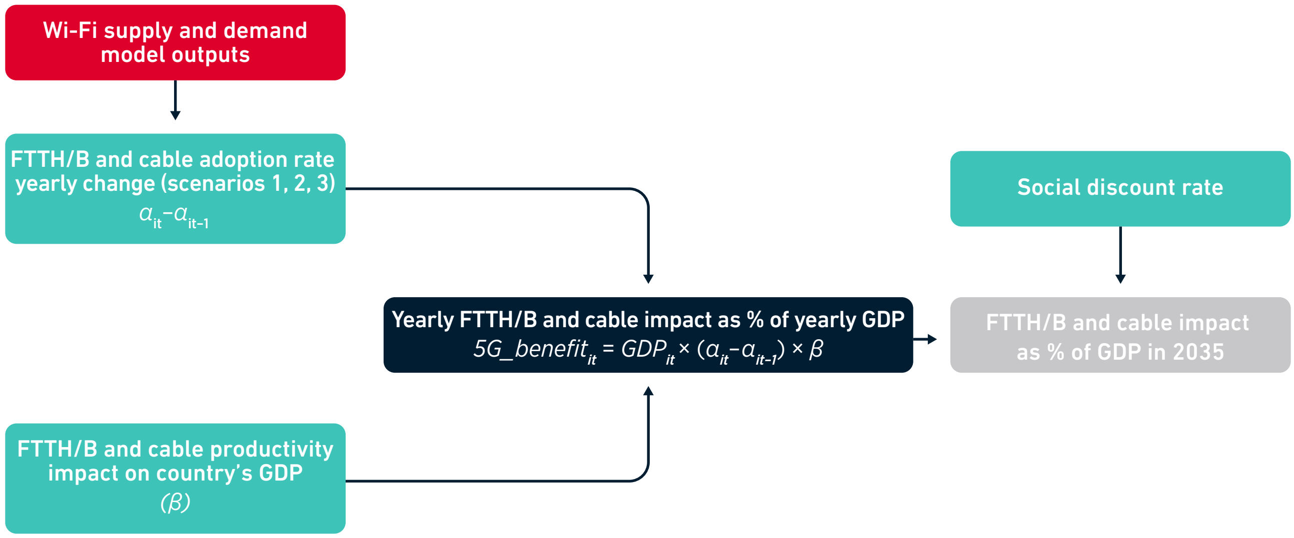
This allows us to calculate the overall contribution of 5G technology to a country's economy in each year. We then aggregate the overall economic benefit in the 2021–2035 period by taking the net present value of economic benefits, using a social discount rate of 3.5%. In our presentation of results, we express this as a proportion of expected GDP in 2035.

In practice, this potentially represents a conservative approach to estimating the economic impacts of 5G because, by basing it on the impact of upgrading from 2G to 3G and 3G to 4G, it is more likely to capture use cases around eMBB and could understate the impact of FWA, URLLC and mIoT. However, we prefer to apply a conservative approach given the lack of clear and quantifiable estimates around all the use cases.

The incremental economic impact of more/less FTTH/B and cable adoption is assumed to be the same as the impact of 5G. For example, if a 10% increase in 5G penetration drives a 0.15% increase in GDP, then we assume that a 10% increase in FTTH/B and cable penetration also drives a 0.15% increase in GDP. This ensures we apply a consistent approach to both technologies, and it also means the results between scenarios are not sensitive to the specific impact assumption (as it is applied in the same way to 5G and Wi-Fi). This methodology means that the estimated economic impacts of assigning 6 GHz for Wi-Fi in each country may differ from other studies that have sought to estimate the benefits of a similar policy.

Figure A4

Modelling the socioeconomic impacts of Wi-Fi



Source: GSMA Intelligence

Both models of 5G and Wi-Fi supply and traffic demand are based on urban demand and residential requirements respectively. We then apply the economic impact analysis based on overall 5G and FTTH/B and cable adoption. This captures the economic impacts that are consistent with existing evidence, as the empirical literature demonstrating the impact of mobile and fixed broadband on GDP is almost entirely based on broadband adoption at the individual (or household) subscription level.

Focus on capacity

When modelling the impacts of 6 GHz spectrum assignment on 5G and Wi-Fi, we focus on capacity rather than coverage – the assumption being that assigning additional upper mid-band spectrum will primarily allow operators to improve wide-area 5G capacity and Wi-Fi providers to deliver faster speeds with greater capacity. Expanding wireless coverage, particularly in rural areas, generally requires low-band spectrum (below 1 GHz). Some studies have suggested that assigning 6 GHz for unlicensed use may enable wireless internet service providers (WISPs) to expand coverage and help close the digital divide.[57] While it is unlikely that the propagation characteristics of the 6 GHz band will enable the expansion of 5G and Wi-Fi coverage, the additional capacity would support more users at faster speeds, including in peri-urban areas, busy small towns and villages.

Given the experience of worldwide network deployments to date, it is reasonable to assume that, going forward, mobile technologies relying on licensed spectrum will play a much bigger role than technologies relying on unlicensed spectrum in closing the digital divide, especially in rural and remote areas. Mobile technologies currently account for 85% of all broadband subscriptions in developing countries and almost 99% in Africa.[58] By contrast, fixed wireless broadband[59] solutions currently account for less than 0.5% of broadband subscriptions worldwide.[60] Networks that use Wi-Fi or other unlicensed technologies can offer specific last-mile solutions to areas with unique geographical, commercial and/or logistical challenges.[61] However, they are unlikely to achieve large scale in most countries, especially those lacking a widespread fixed network. In those cases, improved Wi-Fi capacity is most likely to benefit users with an existing home fibre or cable connection.

57 For example, see Katz et al (2021)
58 ITU World Telecommunication/ICT Indicators (WTI) Database 2021
59 Fixed wireless broadband subscriptions refer to fixed wireless internet subscriptions with an advertised download speed of at least 256 kbps. This includes fixed WiMAX and fixed wireless subscriptions (whether they are supported by 4G, 5G or Wi-Fi). It excludes occasional users at hotspots.
60 ITU World Telecommunication/ICT Indicators (WTI) Database 2021
61 GSMA (2019b) and GSMA (2020)

Meanwhile, one of the main use cases of 5G is fixed wireless access (FWA), which has the potential to scale rapidly over the next decade. For example, Ericsson (2021) forecasts just over 230 million FWA connections by 2027, almost a threefold increase on 2021. In particular, countries with limited fixed networks, or where xDSL remains the predominant fixed technology (including in several high-income countries), are starting to see strong growth in FWA.[62] This is likely to continue in markets where the cost of deploying FTTH/B and cable networks are prohibitive and where 5G FWA can enable the rollout of fast (above 100 Mbps) and more cost-efficient fixed broadband connectivity.[63] Therefore, to the extent that 6 GHz could contribute to closing the digital divide, it is more likely this would be achieved by assigning it for licensed 5G than unlicensed use.

Use of high-band spectrum

The deployment of 5G in many countries is using – or is expected to use – high-band mmWave frequencies (for example in the 26, 28 and 40 GHz bands). High bands are primarily effective at addressing specific areas with extreme traffic density and with very high peak data rates.[64] We therefore assume that, over time, 30% of 5G traffic demand will be offloaded to mmWave.

High-band spectrum is also available (or is being considered) for unlicensed use in most countries, particularly in the 60 GHz bands, and additional bands may be available for unlicensed usage towards 2035. This means it could be used for Wi-Fi. Similar to 5G, high bands for Wi-Fi can support connectivity for certain high-capacity use cases, such as AR/VR and a variety of short-range devices.[65]

As part of our analysis, we look at the impact of assigning 6 GHz for unlicensed use under the assumption that up to 30% of Wi-Fi traffic is offloaded to the high bands. We also model another scenario where high bands are not used for Wi-Fi. As we show in Chapter 4, the extent to which this spectrum is used for Wi-Fi has a significant impact on the potential benefits of assigning 6 GHz for unlicensed use. It should be noted that not using the high bands would represent an inefficient use of spectrum.

Timing of 6 GHz use

In most countries, spectrum in the 6 GHz band is currently used for fixed satellite services (FSS) and fixed services (including mobile backhaul). Studies to ensure co-existence with these services, and in particular with FSS UL (Earth to space direction), are ongoing in the ITU towards WRC-23 and thus it is likely that 6 GHz will be available for large scale 5G commercial deployments from 2024/2025 when WRC-23 has concluded. We therefore assume that 6 GHz will be available for licensed use from 2025 in our model. In terms of using 6 GHz for unlicensed use, we assume it would be possible on a shorter time frame, starting in 2022, given the availability of Wi-Fi 6E equipment. For the sake of countries that see the need for additional spectrum towards 2030, we also ran the analysis assuming that the 6 GHz band would not be available for licensed use until 2030. This did not impact our main findings, in terms of the optimal policy scenarios.

62 GSMA Intelligence (2021)
63 For example, Coleago (2020) states that the cost of connecting a building with 5G FWA in rural areas is 50–80% lower compared to fibre.
64 See Coleago (2020 and 2021) and WPC (2021)
65 For example, see Broadband India Forum (2021), which highlights WiGig as one of the key use cases of V-Band spectrum. This can link devices at up to 7 Gbps over a distance of up to 12 metres.

Appendix B
Detailed country results for house dwelling setting

Appendix B presents the results of the cost-benefit analysis for the three policy scenarios in each country. Each chart presents a set of six results, based on the following assumptions:

- The maximum available fixed broadband speed is 1 Gbps to all FTTH/B and cable users, with up to 30% of Wi-Fi traffic offloaded to the high bands.
- The maximum available fixed broadband speed is 5 Gbps to all FTTH/B and cable users, with up to 30% of Wi-Fi traffic offloaded to the high bands.
- The maximum available fixed broadband speed is 10 Gbps to all FTTH/B and cable, with up to 30% of Wi-Fi traffic offloaded to the high bands.
- The maximum available fixed broadband speed is 1 Gbps to all FTTH/B and cable, with no Wi-Fi traffic offloaded to the high bands.
- The maximum available fixed broadband speed is 5 Gbps to all FTTH/B and cable, with no Wi-Fi traffic offloaded to the high bands.
- The maximum available fixed broadband speed is 10 Gbps to all FTTH/B and cable, with no Wi-Fi traffic offloaded to the high bands.

Figure B1

Summary of economic benefits by scenario and country – house dwelling setting

Proportion of expected GDP in 2035


Indonesia
Japan
Singapore
Thailand
Vietnam
France
With high-band offload
No high-band offload
1 Gbps
5 Gbps
10 Gbps
1 Gbps
5Gbps
10 Gbps
0.0%
0.1%
0.2%
0.3%
0.4%
0.5%
0.6%
0.7%
0.8%
Scenario 1: all to licensed
Scenario 2: all to unlicensed
Scenario 3: 700 MHz licensed; 500 MHz unlicensed


Germany
Italy
Egypt
Jordan
Qatar
UAE
With high-band offload
No high-band offload
1 Gbps
5 Gbps
10 Gbps
1 Gbps
5Gbps
10 Gbps
0.0%
0.1%
0.2%
0.3%
0.4%
0.5%
0.6%
0.7%
0.8%
Scenario 1: all to licensed
Scenario 2: all to unlicensed
Scenario 3: 700 MHz licensed; 500 MHz unlicensed

The results represent the net present value (NPV) of economic benefits over the 2021–2035 period, expressed as a proportion of expected GDP in 2035 for each country. The five sets of results adjust assumptions related to Wi-Fi and fixed broadband (the amount of 60 GHz utilised and the maximum speeds available). Therefore, the results of Scenario 1 (where the full licensed band is allocated for 5G) are the same.
Source: GSMA Intelligence

Appendix C Detailed country results for apartment dwelling setting

Appendix C presents the results of the cost-benefit analysis for the three policy scenarios in each country, based on an apartment setting. Each chart presents a set of six results, based on the following assumptions:

- The maximum available fixed broadband speed is 1 Gbps to all FTTH/B and cable users, with up to 30% of Wi-Fi traffic offloaded to the high bands.
- The maximum available fixed broadband speed is 5 Gbps to all FTTH/B and cable users, with up to 30% of Wi-Fi traffic offloaded to the high bands.
- The maximum available fixed broadband speed is 10 Gbps to all FTTH/B and cable, with up to 30% of Wi-Fi traffic offloaded to the high bands.
- The maximum available fixed broadband speed is 1 Gbps to all FTTH/B and cable, with no Wi-Fi traffic offloaded to the high bands.
- The maximum available fixed broadband speed is 5 Gbps to all FTTH/B and cable, with no Wi-Fi traffic offloaded to the high bands.
- The maximum available fixed broadband speed is 10 Gbps to all FTTH/B and cable, with no Wi-Fi traffic offloaded to the high bands.

Figure C1

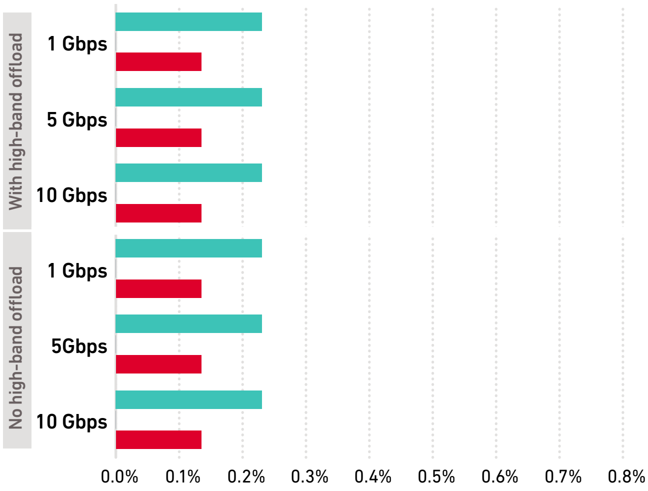
Summary of economic benefits by scenario and country – for apartment setting

Proportion of expected GDP in 2035

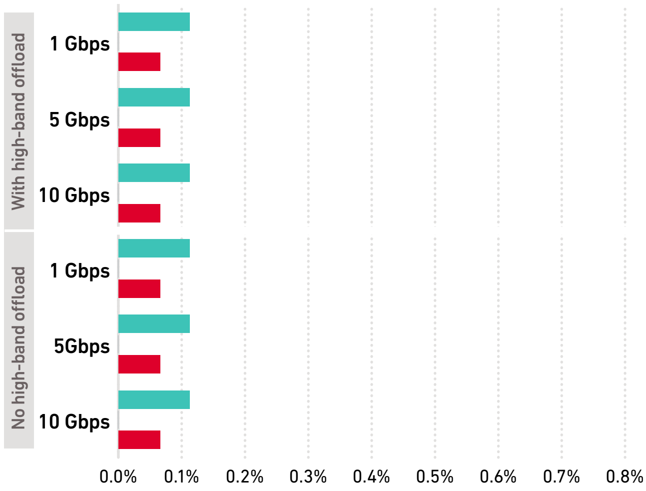

Indonesia
Japan
Singapore
Thailand
Vietnam
France
With high-band offload
No high-band offload
1 Gbps
5 Gbps
10 Gbps
5Gbps
0.0%
0.1%
0.2%
0.3%
0.4%
0.5%
0.6%
0.7%
0.8%
Scenario 1: all to licensed
Scenario 2: all to unlicensed
Scenario 3: 700 MHz licensed; 500 MHz unlicensed


Germany
Italy
Egypt
Jordan
Qatar
UAE
With high-band offload
No high-band offload
1 Gbps
5 Gbps
10 Gbps
5Gbps
0.0%
0.1%
0.2%
0.3%
0.4%
0.5%
0.6%
0.7%
0.8%
Scenario 1: all to licensed
Scenario 2: all to unlicensed
Scenario 3: 700 MHz licensed; 500 MHz unlicensed

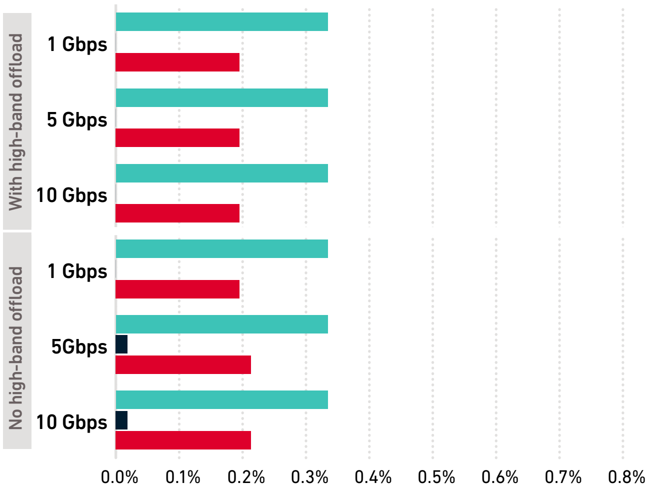
Ghana



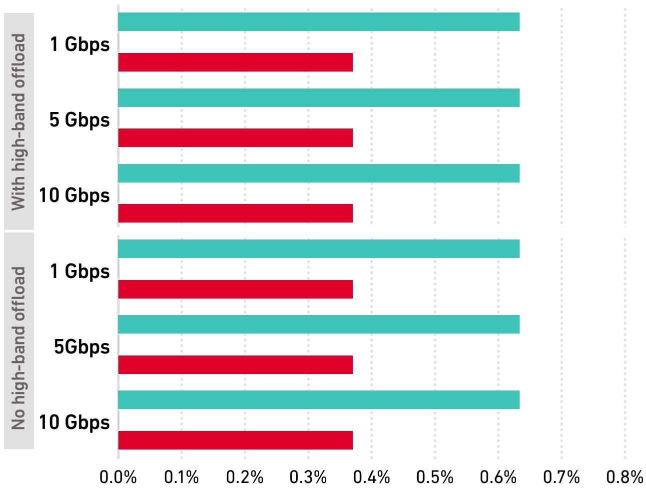
Kenya



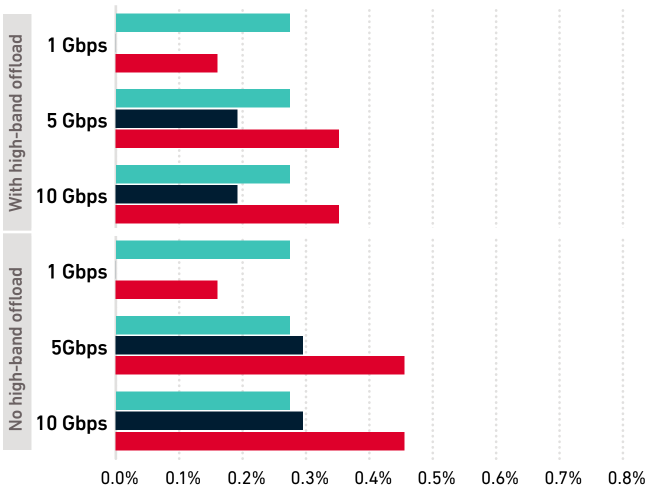
Nigeria



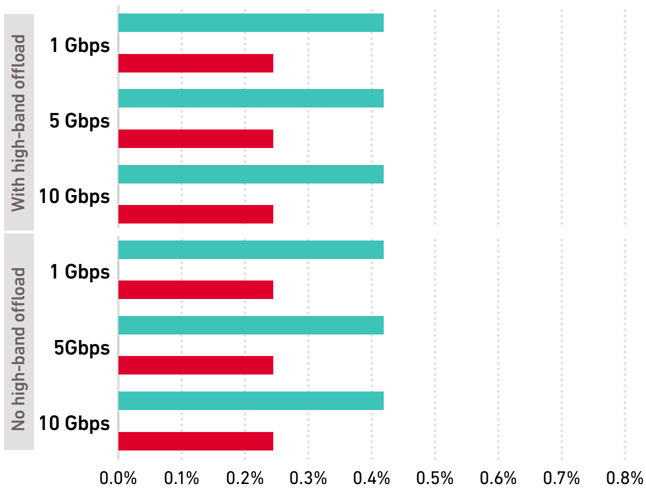
South Africa



Armenia



Kazakhstan



Scenario 1: all to licensed   Scenario 2: all to unlicensed   Scenario 3: 700 MHz licensed; 500 MHz unlicensed

The results represent the net present value (NPV) of economic benefits over the 2021–2035 period, expressed as a proportion of expected GDP in 2035 for each country. The five sets of results adjust assumptions related to Wi-Fi and fixed broadband (the amount of 60 GHz utilised and the maximum speeds available). Therefore, the results of Scenario 1 (where the full licensed band is allocated for 5G) are the same.
Source: GSMA Intelligence

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