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Cost-benefit analysis of options for the 470 – 694 MHz spectrum band

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Cost-benefit analysis of options for the 470 – 694 MHz spectrum band

Bahia, Kalvin and Amaya, Francisco

2023

Abstract

Considerations on the optimal approach for managing spectrum are currently at the forefront of the debate around the sub-1 GHz frequency range between the 470-694 MHz, as Governments decide how best to manage this spectrum over the coming years. We apply a cost-benefit analysis in three synthetic countries in Europe, the Middle East and Africa countries to identify the policies that will maximise the social and economic value of this spectrum. We find that assigning 80 MHz additional of UHF spectrum to mobile would be 6–24 times greater than the costs incurred by the broadcasting sector to maintain the existing number of digital terrestrial television (DTT) programmes. Additionally, in a scenario where the full 470–694 MHz band is assigned to mobile, the benefits are 4–9 times greater for a typical country in Europe and the Middle East. This reflects the growing demand for 5G bandwidth and the general decline in DTT, driven in significant part by the rise of IPTV and on-demand viewing. The results therefore show that the utilisation of more UHF spectrum for mobile use will provide greater value to society than maintaining it for broadcasting.

JEL Classifications: D61 - Allocative Efficiency • Cost–Benefit Analysis; L51 - Economics of Regulation; L96 - Telecommunications

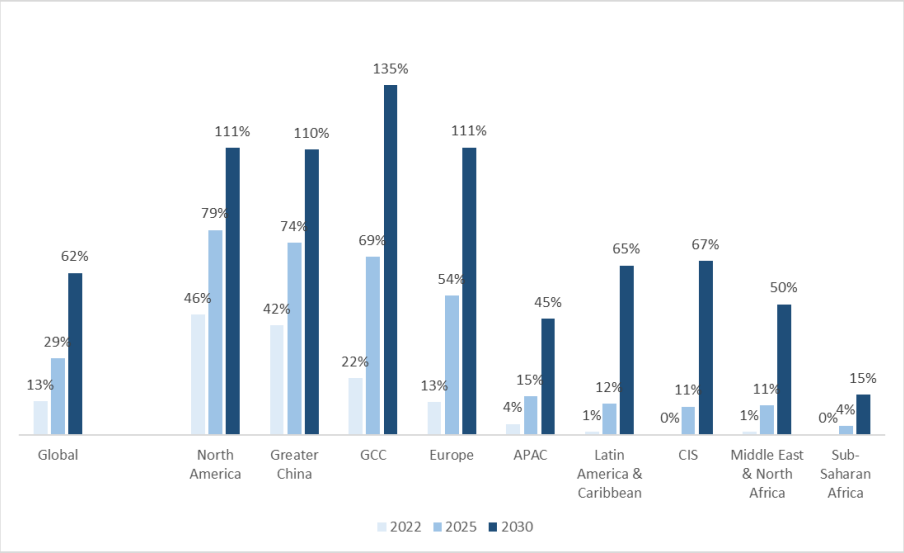
1. Introduction

The role of low-band spectrum in deploying 5G networks

Since the launch of the first 5G networks in 2019, commercialisation has gained momentum, with new network launches and operators scaling services to reach more customers. At the end of 2022, there were 252 commercial 5G networks in 86 countries serving more than 1 billion 5G connections around the world.[1] The Covid-19 pandemic boosted 5G momentum, with many Governments and operators accelerating 5G roll-out to meet the growing demand for enhanced connectivity.

While the next decade will be defined by the 5G era, in the same way that the 2010s were defined by 4G, it will not evolve in the same way across regions. Figure 1 shows that 5G is expected to reach maturity by 2030 in North America, Europe, China and the GCC countries. However, it will continue to grow in many low- and middle-income countries (LMICs) well into the 2030s.

Figure 1: 5G market penetration, 2022-2030



Source: GSMA Intelligence. 5G penetration is calculated as the number of 5G connections by total population. Connections differ from subscribers in that a unique subscriber can have multiple connections, therefore penetration can be greater than 100%.

[1] Source: GSMA Intelligence

Low-band spectrum serves two key requirements for 5G deployments:

- Its superior propagation characteristics make it particularly suitable for providing coverage in rural and remote areas. This is especially important in low- and middle-income countries that have large populations living in rural and sparsely populated areas, as network deployments here are much less economically sustainable. Without sufficient low-band spectrum, rural citizens can be excluded from the latest digital technologies.

- It is better able to penetrate buildings and serve built-up areas, providing 'deep' indoor coverage as well as capacity in urban areas, including locations where people live and work. Depending on the location and residence type, indoor traffic can account for 30–70% of total mobile traffic.[2] Low bands therefore often account for a greater proportion of traffic than they do capacity. Assigning sufficient low-band spectrum is critical to addressing long-term demand for 5G in urban as well as rural areas.

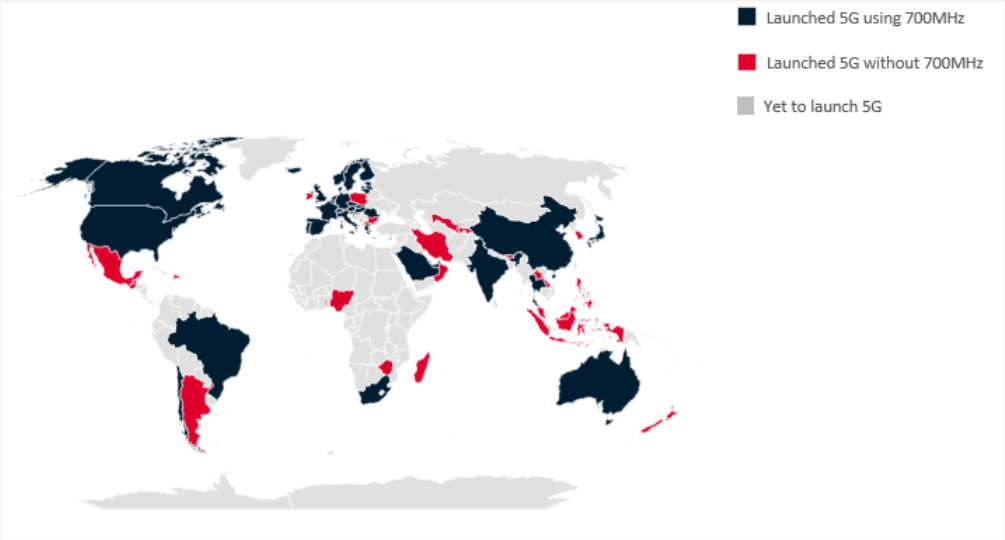
Countries that have assigned the 600MHz and 700MHz band for 5G have achieved quicker roll-out

The 700 MHz frequency band has been the most commonly used low band for 5G – with the exception of North America, where the 600 MHz band is used. Other bands, such as 800, 850 and 900 MHz, are expected to be refarmed for 5G, but in most countries these are still being used for 2G, 3G and/or 4G.[3]

As shown in Figure 2, at the end of 2022, either 600 or 700 MHz was being used for 5G by mobile operators in almost half the countries where 5G has been launched. Figure 3 highlights the importance of assigning these low bands for 5G use. Countries that have deployed 5G using the 600 or 700 MHz bands have achieved significantly higher levels of population coverage than those that have not.

[2] See Planning in-building coverage for 5G: from rules of thumb to statistics and AI, Ericsson, 2021; Better Indoor Coverage, Better 5G Networks, Huawei
[3] For further discussion of the specific bands available by region, see Low-band spectrum for 5G, Coleago, 2022

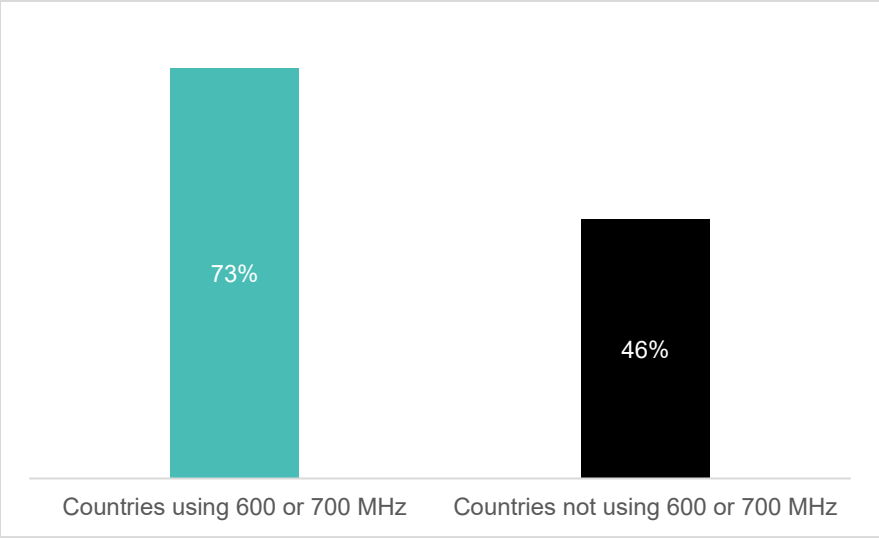
Figure 2: Countries with 5G networks that utilise the 600 or 700 MHz bands (Q4 2022)



Note; analysis is based on at least one operator actively utilising 600 or 700 MHz frequencies to deliver 5G (whether or not it has been identified or assigned for IMT).

Source: GSMA Intelligence.

Figure 3: Average 5G network coverage in countries depending on whether 600 MHz or 700 MHz is being used

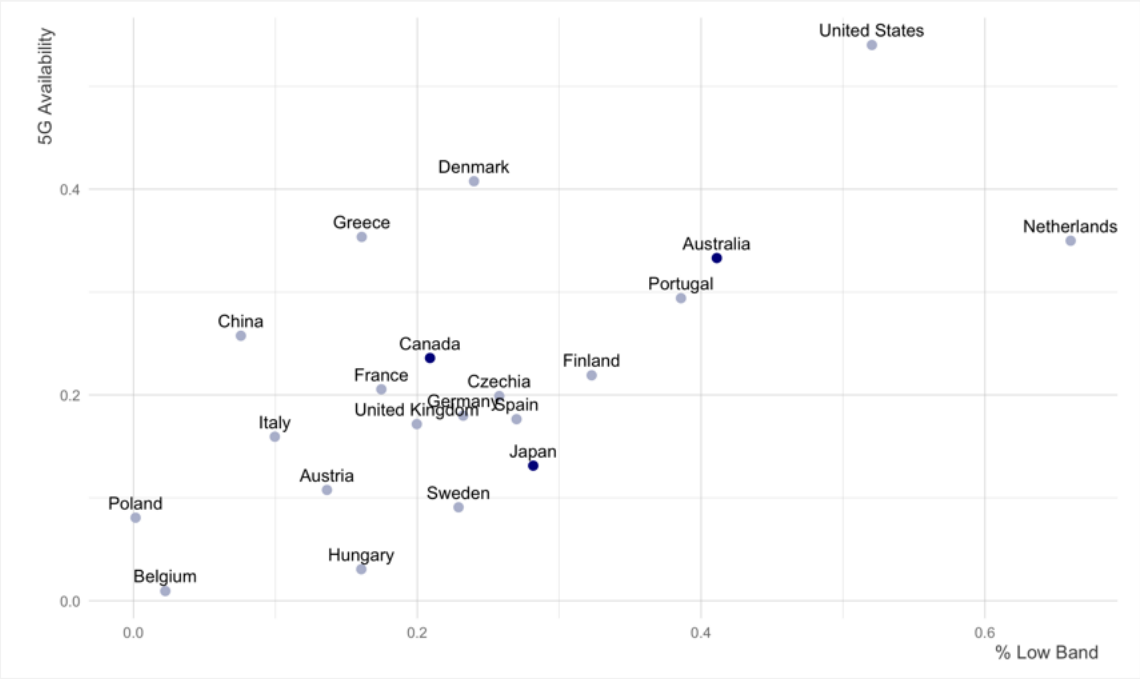


Source: GSMA Intelligence.

Low-bands enable consumers to benefit from a better 5G experience

The importance of low-band spectrum for 5G availability is illustrated in Figure 4, which shows that the countries where consumers are more likely to access a 5G signal are also those where they are more likely to connect using low-band frequencies. The analysis highlights in particular the strong performance of the US in terms of 5G availability. Consumers in the US that have a 5G-capable device are more likely to spend most of their time on a 5G network than those in any other country. One reason for this is that operators can use the 600 MHz band.

Figure 4: 5G availability and use of low-band, Q3 2022

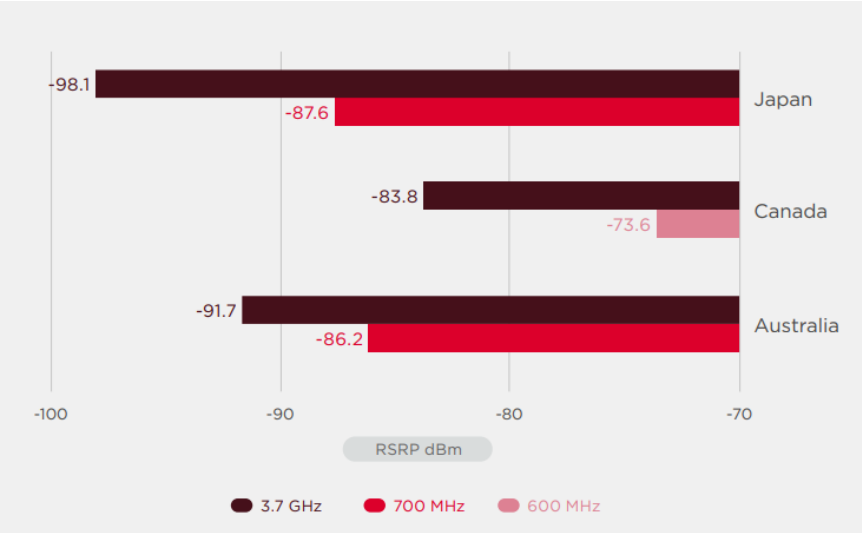


Source: Ookla Speedtest Intelligence®. Availability represents the proportion of users on 5G-Capable devices who spend the majority of their time on a 5G network on their subscriber (SIM) network in Q3 2022. '% Low Band' represents the proportion of device scans that are carried out using low-band spectrum (in 600, 700, 800, 850 or 900 MHz frequencies)

Evidence also shows that low-band frequencies improve user experience, particularly indoors. Figure 5 compares indoor 5G signal strength in the largest cities in Australia, Canada and Japan. Consumers connected using the 700 MHz band in Australia and Japan,

and the 600 MHz band in the case of Canada, had a better quality indoor signal than those connecting in the mid-bands.

Figure 5: Indoor signal strength using low- and mid-band spectrum, Q3 2022



Source: Ookla Speedtest Intelligence®. Analysis is based on weighted average Reference Signal Received Power (RSRP) for all consumer scans in Q3 2022 by frequency band in in-building locations in downtown areas in Sydney (Australia), Toronto (Canada) and Tokyo (Japan).

The UHF band

In many countries, ensuring that operators have sufficient access to low-band spectrum may require additional frequencies below the 700 MHz band – frequencies commonly used for broadcasting and PMSE services.[4] Governments around the world will therefore need to make a carefully considered decision as to what the most efficient use of this low-band spectrum will be.

For that purpose, regulatory impact assessments can help to determine the spectrum use that delivers the greatest socio-economic benefits. This study provides a cost-benefit analysis (CBA) of sub-1 GHz frequency band options, presenting the results of five scenarios for allocating parts or the totality of the 470–694 MHz band for mobile use in ITU Region 1, through a framework that can be applied in any country.

[4] Programme Making and Special Events (PMSE) equipment includes wireless microphones, in-ear monitors and audio links. The equipment typically uses spectrum for a short-term at a particular time and location (for example at outdoor events), though some uses are more continuous (for example in television studios). It uses spectrum in TV white spaces – that is, spectrum in the 470 – 694 MHz band that is not being utilised locally. The other secondary user of the spectrum is radio astronomy, which uses a narrow 5 MHz band in the 600 MHz allocation.

2. Analytical approach

Producer surplus framework

The decision on how to allocate spectrum in the low-band band between mobile or broadcasting use is not straightforward given the particularities from both type of services. It is therefore important for regulators to carry out a regulatory impact assessment in order to come to an evidence-based decision.

When carrying out a CBA, national regulators can consider the following economic effects:

- **Direct effects** that impact stakeholders directly:
    - **Consumer surplus** – the difference between the price consumers pay and the price they are *willing* to pay for a product or service
    - **Producer surplus** – the amount producers benefit from by selling at a market price higher than the minimum price they would be *willing* to sell for
- **Indirect effects**, which can be generalised as spill-over effects that generate value for the wider economy (i.e. GDP benefits) and society.

Mobile technology is a general-purpose technology that enables economic growth via improvements in productivity and efficiency, and gives social value to consumers. Broadcasting, and DTT in particular, provides consumers with free and universal access to TV and generates social and economic value. Both mobile and broadcasting therefore drive significant consumer surplus, due to the number of consumers willing to pay much more than they do for entertainment, leisure, information and other services.

As the policy being assessed is whether to reallocate spectrum from broadcasting (existing use) to mobile (new use), the main benefit from assigning additional low-band spectrum to provide wireless connectivity is that it can make it less costly to deploy 5G networks in order to meet capacity and coverage requirements. In economic terms, this is represented by a shift in the supply curve. The availability of additional sub-1 GHz spectrum will give operators significant cost savings to be able to add capacity to their 5G networks and extend coverage without having to incur additional opex and capex investment, therefore avoiding any potential pass-through price increases for consumers or quality-of-service degradation.

For the purposes of this CBA, we focus on producer surplus – specifically, the costs that would be saved from using UHF spectrum for either mobile or broadcasting. This is because

consistent and comparable data on producer costs are more readily available than data on consumer willingness to pay, which can vary significantly based on the type of consumer. Furthermore, there is limited recent evidence that allows the indirect economic and social benefits to be considered in a comparable manner between mobile and broadcasting. The costs and benefits of each spectrum policy scenario are estimated using net present value (NPV) between 2021 and 2040.

Regulators in each country would have to consider the costs and benefits for their respective mobile and broadcasting sectors and gather the appropriate economic and technical inputs.[5] For this study, when applying the CBA framework, we consider five specific 'settings'. The assumptions for each setting are detailed in Appendix, but in general they cover the following:

- Setting 1 – allocating 80 MHz of UHF spectrum for a typical country in Europe
- Setting 2 – allocating the full 224 MHz of UHF spectrum for a typical country in Europe
- Setting 3 – allocating 80 MHz of UHF spectrum for a typical country in the Middle East
- Setting 4 – allocating the full 224 MHz of UHF spectrum for a typical country in the Middle East
- Setting 5 – allocating 80 MHz of UHF spectrum for a typical country in Africa.

Assessing the cost-saving benefits for 5G mobile broadband services

To quantify the direct benefits of mobile operators in having additional low-band spectrum to address demand driven by the growth of 5G penetration, we estimate the number of sites needed to meet the ITU Requirements for IMT-2020, specifically 100 Mbps on downlink and 50 Mbps on uplink in urban areas. For rural areas, we assume 5G performance requirements of 20 Mbps on downlink and 10 Mbps on uplink. For each setting, two scenarios are estimated. The first – 'Baseline' – assumes that operators have access to 190 MHz in sub-1GHz bands for the entire period evaluated. The second – 'Scenario' – assumes that an additional 80 MHz of spectrum in the UHF band is allocated to operators so that they have a total of 270 MHz in low bands in Settings 1/3/5, while for Settings 2/4 we assume an

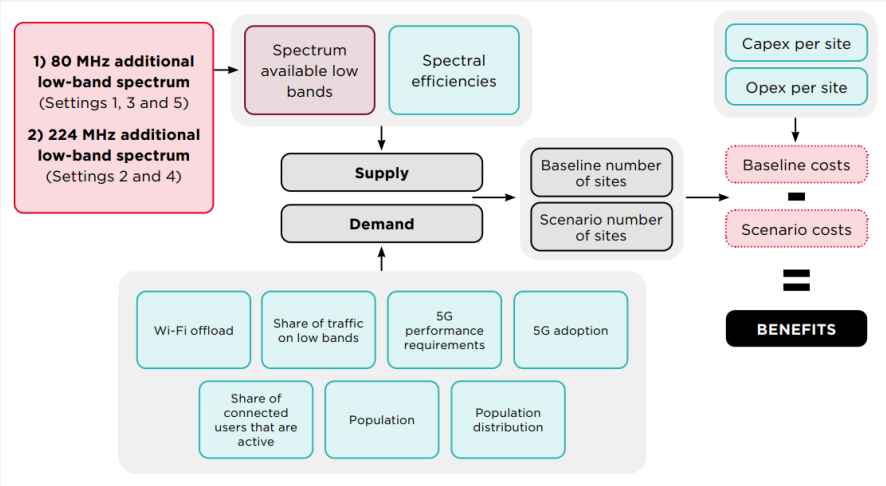
[5] Previous CBAs have been carried out for the 700 MHz band, see for example Decision to make the 700 MHz band available for mobile data, Ofcom, 2014; and The 700 MHz radio frequency band: Results of the Cost Benefit Analysis (CBA) of a change in use of the 700 MHz radio frequency band in Ireland, Comreg, 2015.

additional 224 MHz of spectrum is allocated to operators, such that they have a total of 414 MHz.

When estimating the number of sites, we distinguish between urban and rural areas, since the conditions of deployment are different. In urban areas, we estimate the number of macro-sites that are needed to meet traffic that can only be served by low-band spectrum (e.g. coverage in deep indoor and built-up areas). It is therefore purely capacity driven. In rural areas, we estimate the number of sites needed to cover 99% of the population and to deliver the selected performance requirement. It is therefore both coverage and capacity driven. The difference in sites required to meet the demand in the two cases (Baseline and Scenario), in terms of capex and opex NPV, are the associated benefits for assigning additional UHF spectrum for mobile.

Once the total infrastructure costs at sites required to support the total demand in each of the years have been calculated, the difference or savings in NPV between the two scenarios (baseline and scenario) is calculated with a social discount rate of 3.5%. The following table summarize the methodology used in modelling cost savings for mobile operators (assumptions used in the modeling are detailed in the Appendix).

Figure 6: Cost savings approach of having additional spectrum in the UHF band



Source: GSMA Intelligence

Assessing the cost to DTT and PSME services of repurposing UHF spectrum

On the other hand, the costs are primarily related to repurposing DTT and PMSE services,[6] which currently operate in the UHF band in ITU Region 1. For this estimation, the objective is to assess the costs of repurposing such that the consumer and DTT providers can maintain the same level of broadcast output in terms of national, regional and local TV programmes. This is known as the 'least cost approach' (LCA). An alternative response to having less spectrum for DTT is that providers may reduce output (i.e. the number of channels), which would lower costs but also revenues. As there is less data available on the revenue side, we focus on the LCA.

To estimate the DTT and PSME costs associated with repurposing spectrum in the UHF band for mobile, the methodology follows three main stages. First, it estimates the spectrum demand for broadcasters, which depends on the number of multiplexes and programmes (or channels) in the baseline. Second, and after evaluating the spectrum demand for the baseline case, it assesses the technical alternatives or upgrades that broadcasters can implement to keep the same number of programmes with less spectrum. The key broadcast modelling assumptions, including the broadcast characteristics for each setting, are detailed in the Appendix.

Following a reduction in the amount of UHF spectrum available for broadcasting and PMSE, the following options are considered:

1. **Move to a reduced band**: In this case, the broadcaster would migrate services in the 600 MHz band to other UHF bands given that even with the loss of spectrum, they can maintain the same number of programmes.

2. **Upgrade to DVB-T2:**[7] Given that DVB-T2 can achieve a higher programme capacity per multiplex, this upgrade allows broadcasters to potentially deliver the same number of programmes with less spectrum.

3. **Upgrade to SFN**[8] **and DVB-T2**: If, after the implementation of DVB-T2 technology, broadcasters cannot maintain the same number of programmes as the baseline, they could implement a single frequency network (SFN) alternative, which increases the

[6] Programme Making and Special Events (PMSE) equipment includes wireless microphones, in-ear monitors and audio links. The equipment typically uses spectrum for a short-term at a particular time and location (for example at outdoor events), though some uses are more continuous (for example in television studios). It uses spectrum in TV white spaces – that is, spectrum in the 470 – 694 MHz band that is not being utilised locally. The other secondary user of the spectrum is radio astronomy, which uses a narrow 5 MHz band in the 600 MHz allocation.
[7] DVB-T2 refers to the latest broadcasting transmission standard. The previous standard is DVB-T, which carries less capacity per multiplex.
[8] Most broadcasting networks in Region 1 are multi-frequency networks (MFNs), where neighbouring transmitter sites broadcast on different frequencies to avoid interference at the receiver. This means that not all available frequencies are used at each tower. In SFNs, the same content is broadcast in the same frequencies in neighbouring cells, thereby enabling greater spectral efficiency.

spectrum efficiency of the broadcasting network. We assume that implementing this technology involves adding one additional DVB-T2 multiplex (i.e. one SFN mux, rather than re-planning the entire broadcast network as an SFN, which would be a much more complex undertaking).

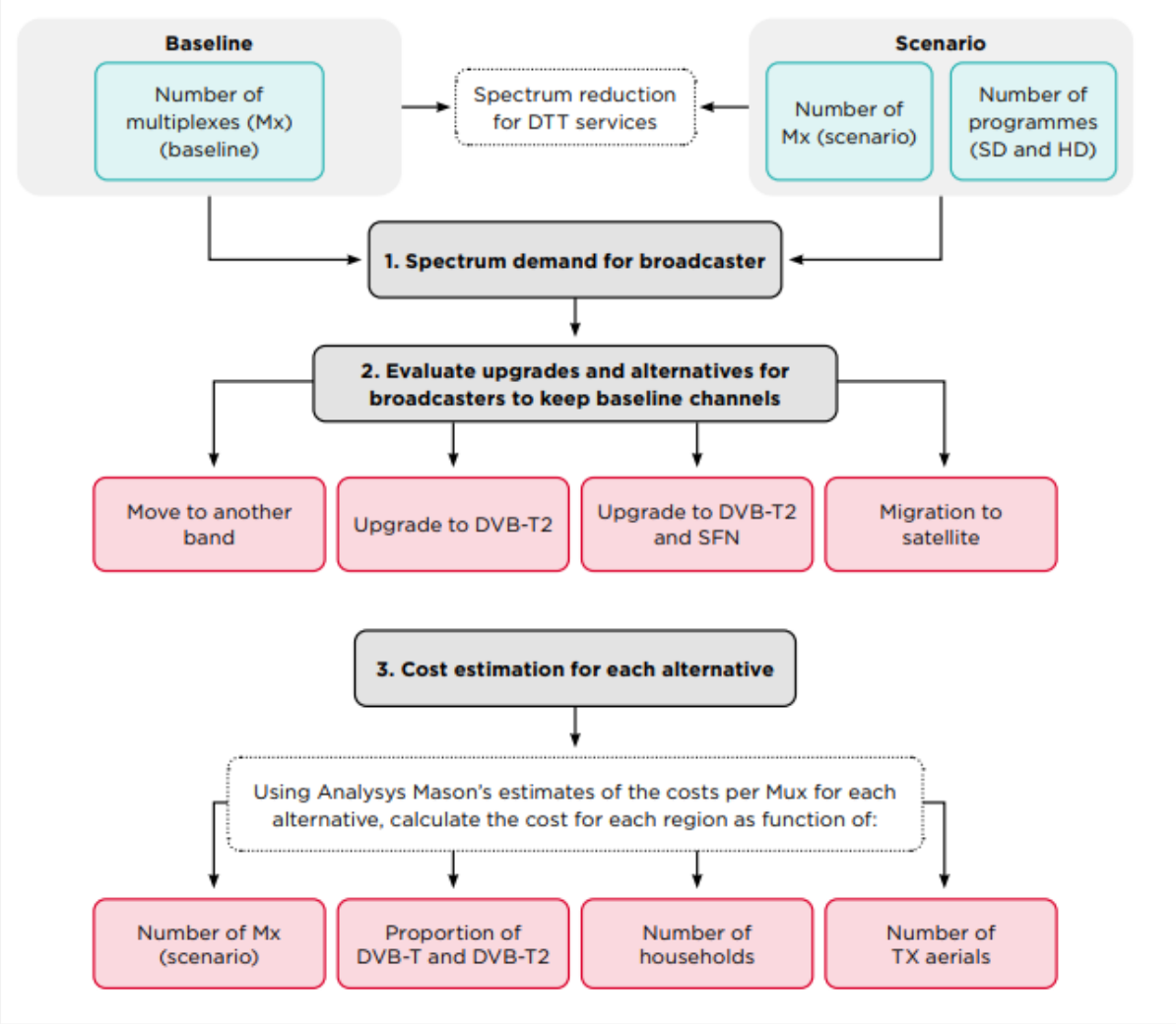
4. **Migration to another platform**: After evaluating and implementing the three previous upgrades, if there are still programmes not able to be transmitted, this alternative involves moving the programmes to a satellite broadcasting network. An alternative migration platform would be IPTV, but there is currently insufficient data to assess this option, so we assume migration is to satellite.

The overall approach is summarised in Figure 7. It should be noted that the above are not the only ways broadcasters could respond to a reduction in UHF spectrum. One alternative could be to upgrade to more efficient video compression technologies (e.g. H.265 or H.266), which reduces the capacity required by a service, meaning that more programmes can be carried within the same capacity. Another option would be to operate the entire broadcasting network as a single frequency network (SFN), rather than a multi-frequency network (MFN). In the majority of countries, this should provide sufficient capacity to deliver existing programme output without spectrum in the 614–694 MHz frequency range. However, this would require significantly more complex deployment and network planning, it would severely limit regional programming and would require coordination with neighbouring countries.[9] As we do not have sufficient cost data or network information for a full SFN, we are unable to model this option in our framework, but it is something national regulators could do.

Another option could be to change the broadcasting network topology – for example, using low power, low tower networks (LPLT) or medium power, medium tower networks (MPMT), rather than high power, high tower (HPHT). The use of HPHT enables coverage of large areas with less equipment (and therefore less cost) but reduces the amount of spectrum reuse. Moving to LPLT or MPMT increases frequency reuse and therefore spectral efficiency.[10] Similar to the 'full SFN' option, we did not have enough information to model this option, but it is an alternative that regulators could consider.

[9] See Study on the use of the sub-700 MHz band (470-694 MHz), European Commission, 2022
[10] See Study on the use of the sub-700 MHz band (470-694 MHz), European Commission, 2022

Figure 7: Broadcast cost methodology and approach



Source: GSMA Intelligence

In order to estimate the implementation costs of each of these options, we used the costs set out in the Analysys Mason & Aegis System (2013) study for Ofcom (hereafter referred to as the 'Analysys Mason & Aegis System study') that assessed the opportunity cost of DTT and digital audio broadcasting spectrum in the UK.[11] In particular, it considered the four different responses by the broadcasting sector if they had less UHF spectrum and estimated the cost of each one based on the LCA approach. A list of the costs considered are

[11] Opportunity cost of the spectrum used by digital terrestrial TV and digital audio broadcasting. Final report for Ofcom. Analysys Mason, Aegis System, 2013

presented in Figure 8, while the costs are shown in Figure 9. The study considered a four-year duration for managing the different options.

To apply these estimates to our study, we converted the cost per multiplex to US dollars in 2021 (adjusting for inflation as the original costs were based on 2015 prices). Each cost was then split based on costs associated with households (e.g. replacement CPE, domestic aerial changes and publicity) and those associated with the broadcasting network (e.g. re-engineering transmitters, re-planning).

For each Setting, based on what the optimal response is to a reduction in UHF spectrum (move to a reduced band, upgrade to DVB-T2, upgrade one mux to SFN or migrate to satellite), we took the updated 2021 cost from the Analysys Mason & Aegis System study and adjusted the household costs based on the number of households and the transmission costs based on the number of transmitters. For example, in Setting 1, we assume 3.1 million households and 229 transmitters. The UK had around 27 million households in 2021, while the Analysys Mason study was based on 1,160 DTT tower sites operating in the UK. Therefore, for Setting 1, we adjust household costs by a factor of 3.1/27 = 0.11 and we adjust the transmission costs by a factor of 229/1160 = 0.20.

Lastly, we also factored in the use of interleaved spectrum, particularly what is used by programme making and special events (PMSE). Based on the costs of moving PMSE services to an alternative band that were estimated by the Analysys Mason & Aegis System study, we applied the same uplift. For example, if the mitigation costs for PMSE was equal to 1% of the cost of the DTT mitigation cost in the Analysys Mason & Aegis System study, then we apply a 1% uplift to the initial cost.

Figure 8: Broadcast costs items per upgrade and alternative

Move to another band	Upgrade to DVB-T2	Upgrade to SFN (one Mx)	Migration to satellite
• Costs of domestic aerial changes • Costs of re-engineering TX aerials • Costs of re-planning • Costs associated with publicity	• Cost of replacement CPE • Costs of domestic aerial changes • Costs of re-engineering TXs • Costs of re-engineering TX aerials • Costs of re-planning • Costs associated with publicity • Loss (savings) from transmission	• Cost of replacement CPE • Costs of domestic aerial changes • Costs of re-engineering TXs • Costs of re-engineering TX aerials • Costs of re-planning • Costs associated with publicity • Loss (savings) from transmission	• Cost of household conversión • DTT future costs • DTT future revenues • Costs associated with publicity

Source: Analysys Mason & Aegis System (2013)

Figure 9: DTT and PSME cost assumptions based on Analysis Mason & Aegis System (2013)

Mitigation response	Indicative average annual cost per mux (£ million for 2015)	Indicative average total cost per mux in four years (£ million for 2015)	Total cost (£ million for 2021)	Total cost ($ million for 2021)	Total cost HH ($ million for 2021)	Total cost network ($ million for 2021)	PSME uplift
Switch the DTT platform to a satellite	£52.8	£211.2	£235.7	$324.1	$131.26	$192.88	0.75%
Upgrade muxes to DVB-T2	£19	£76	£84.8	$116.6	$79.93	$36.71	1.7%
Upgrade muxes to SFN and DVB-T2	£21.9	£87.6	£97.7	$134.4	$113.10	$21.34	2.3%
Move channels to the 600 MHz band	£12.1	£48.4	£54.0	$74.3	$58.28	$16.00	2.8%

Source: GSMA Intelligence based on data provided in Analysys Mason & Aegis System (2013)

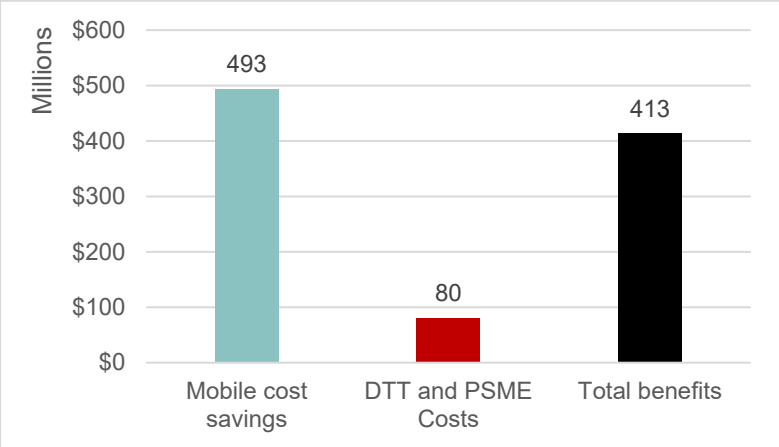
3. Results for each of the five settings considered

In this chapter, we present the results of the cost-benefit analysis. The costs and benefits of each setting are estimated using net present value (NPV) between 2021 and 2040. The benefits are based on mobile network capex and opex savings delivered by greater low-band spectrum access in both urban and rural areas. On the other hand, costs are based on repurposing DTT and PMSE services which currently operate in the 470–694 MHz UHF band. They are estimated based on a requirement for DTT providers to maintain the same level of broadcast output in terms of national, regional and local TV programmes.

Setting 1: modelled on a typical country in Europe assigning the 600 MHz band

Under this setting, the benefits from assigning 80 MHz of UHF spectrum to mobile would be 6 times greater than the costs incurred by the broadcasting sector to upgrade all multiplexes to DVB-T2, which would offer the same number of programmes as the baseline (or status quo).

Figure 10: CBA results for Setting 1



Source: GSMA Intelligence

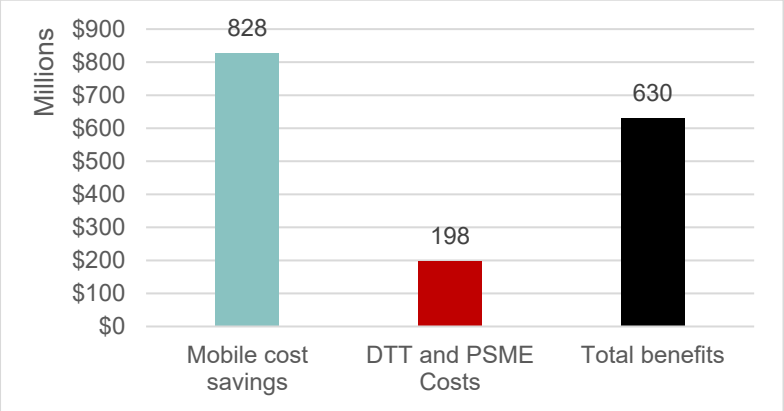
Setting 2: modelled on a typical country in Europe assigning the 470–694 MHz band

The results for this setting show that the benefits in the mobile sector would be 4 times greater than the costs associated with migrating DTT programmes to another platform.[12] In practice, if DTT viewership continues to decline and broadcasters begin to move the majority

[12] For the purposes of this CBA, we quantify the cost of migrating DTT channels to satellite due to the availability of data (see Appendix 2). However, alternative migration options are available (particularly IPTV) and could be assessed by national regulators.

of their programming to other platforms, whether IPTV, satellite or cable, then some of the costs associated with this option could be over-stated as there would be fewer programmes to migrate. However, given the potential social impact that closing the DTT platform could have, there may be other mitigation costs necessary to follow through with this option.

Figure 11: CBA results for Setting 2

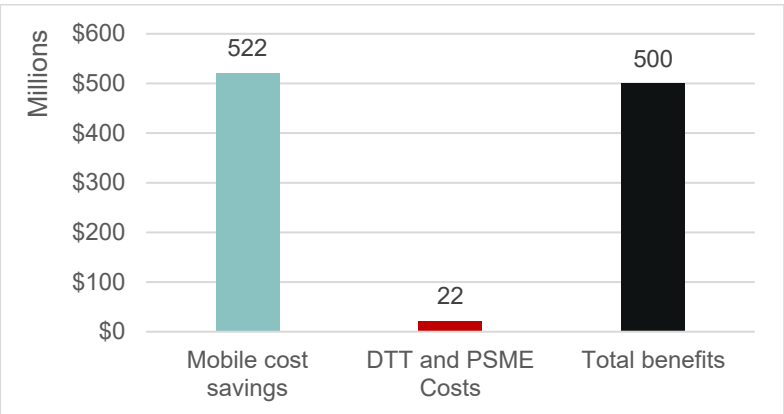


Source: GSMA Intelligence

Setting 3: modelled on a typical country in the Middle East assigning the 600 MHz band

The benefits from assigning 80 MHz of UHF spectrum to mobile under this setting would be almost 24 times greater than the costs incurred by the broadcasting sector from moving channels in the 614–694 MHz frequencies to a lower band. This is driven by the strong expected growth in 5G demand in the region and the fact that there are far fewer DTT programmes to manage compared to countries in Europe and Africa, meaning the mitigation costs of repurposing the spectrum are significantly lower.

Figure 12: CBA results for Setting 3

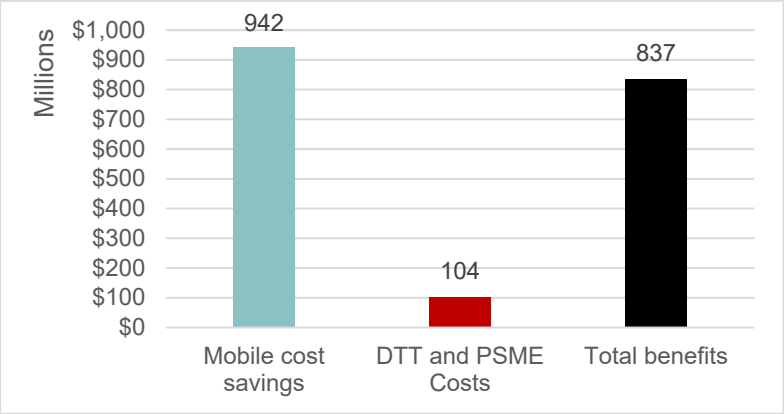


Source: GSMA Intelligence

Setting 4: modelled on a typical country in the Middle East assigning the 470–694 MHz band

The results for this setting show that the benefits in the mobile sector would be 9 times greater than the cost associated with migrating DTT programmes to another platform. This is again driven by expected 5G demand and the more limited number of DTT programmes to migrate.

Figure 13: CBA results for Setting 4

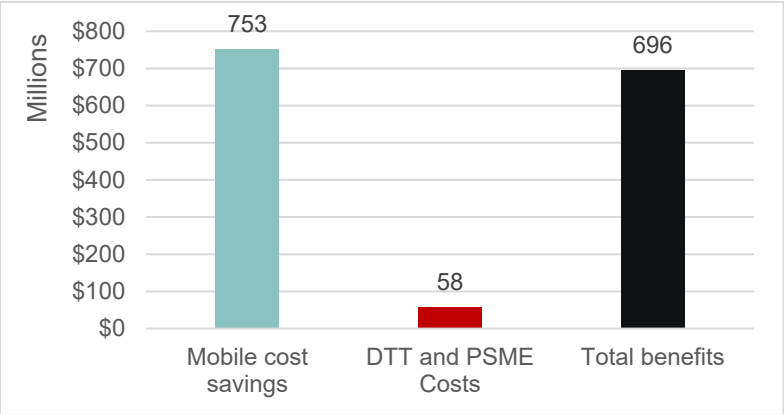


Source: GSMA Intelligence

Setting 5: modelled on a typical country in Africa assigning the 600 MHz band

The benefits from assigning 80 MHz of UHF spectrum to mobile would be 13 times greater than the costs incurred by the broadcasting sector from adding a single frequency network (SFN) multiplexer, which would offer the same number of programmes as the baseline. The benefits from assigning 80 MHz of additional sub-1 GHz spectrum for mobile are even greater than in the settings based on other regions due to the large proportion of the African population that lives in rural areas, which are best covered using low-band spectrum.

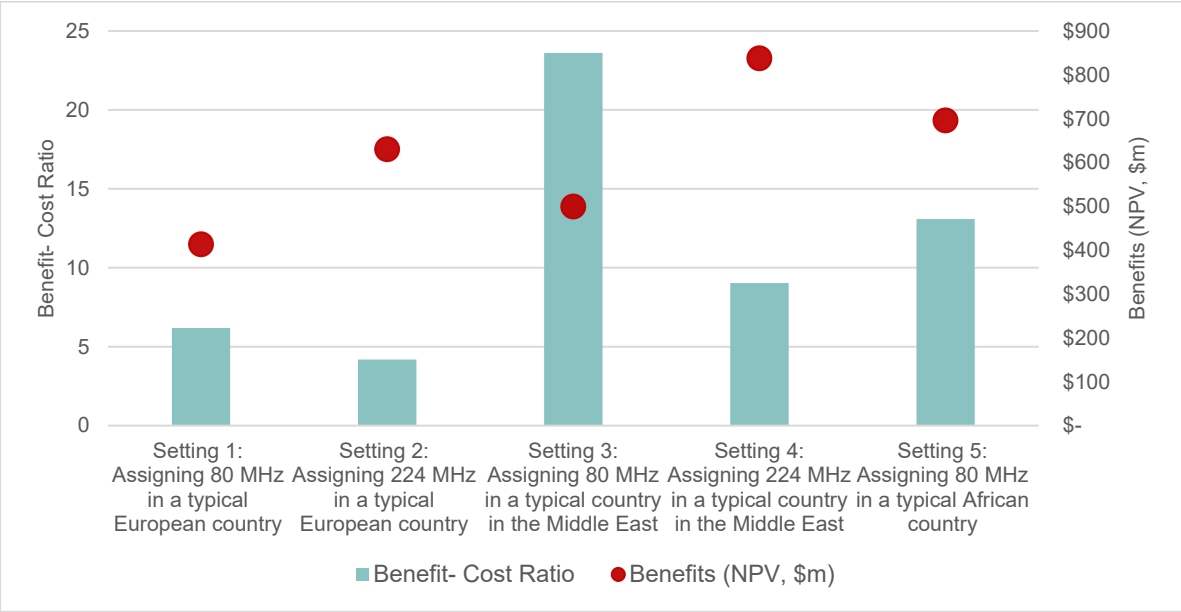
Figure 14: CBA results for Setting 5



Source: GSMA Intelligence

The following chart summarizes the NPV in millions of the benefits and the benefits -costs ratio for each of the settings considered in this report:

Figure 15: Results of cost-benefit analysis in the UHF band



Source: GSMA Intelligence

Trends in DTT and mobile usage

The results of the CBA are partly driven by the longer term trends in DTT and mobile usage. In most countries in Europe and the Middle East, DTT networks were launched in the 2000s or early 2010s to replace analogue broadcast networks as part of the digital switchover (DSO) process. In Sub-Saharan Africa, some countries have completed DSO, but many have found the analogue switch-off process more challenging and are still completing their migrations.[13]

DTT has played an important role in delivering both public and commercial broadcasting services, but its use is far from universal. It is not the primary TV platform in most European countries, and in half of the region it is the primary TV platform in fewer than 20% of households.[14] Over the same period, there has been a significant increase in the share of IPTV. Going forward, the EC expects this to continue. IPTV households will increase from around 45 million to more than 60 million by 2030. Meanwhile, other platforms are expected to decline, especially DTT.[15] There has also been significant growth in the number of households subscribing to video on-demand (e.g. Netflix, Amazon Prime Video, Apple TV+ and Disney+), with the number of SVOD households in the EU increasing from 39 million in 2017 to 133 million in 2021 (or from around 20% household penetration to approximately 65%).[16]

Similar trends for DTT have been observed in the Arab states, where it accounts for less than 20% of primary TVs.[17] In Africa, the trends in terrestrial TV are not the same as in Europe or the Middle East, but fewer channels are typically used, so less spectrum is required.[18] In some countries, the DTT platform has either been shut down already (e.g. in Switzerland) or there are plans scale it down, especially where there are a limited number of channels and multiplexes. As a result, many broadcasters are focusing fewer resources on linear TV channels and more on IPTV and on-demand content.[19]

By contrast, demand for mobile data and services continues to increase. The number of 5G connections in Europe, the Middle East and Africa is forecast to grow from 100 million in 2022 to 1.3 billion in 2030, a 13-fold increase. Ericsson's mobile data traffic forecasts suggest that, in the same regions, monthly mobile data traffic will increase from 20 EB per

[13] Digital Switchover in Sub-Saharan Africa: Bringing Low-Band Connectivity Within Reach, GSMA, 2022
[14] European Audiovisual Observatory
[15] Study on the use of the sub-700 MHz band (470-694 MHz), European Commission, 2022
[16] European Audiovisual Observatory. Further trends in TV viewership can be found in Study on the use of the sub-700 MHz band (470-694 MHz), European Commission, 2022
[17] Terrestrial broadcasting and spectrum use in the Arab states, Plum Consulting, 2015
[18] Digital Switchover in Sub-Saharan Africa: Bringing Low-Band Connectivity Within Reach, GSMA, 2022
[19] For further details, see The future use of UHF spectrum in ITU Region 1, Plum Consulting, 2021

month to more than 72 EB per month in 2028, driven by continued internet and video demand, as well as new use cases such as augmented and extended reality applications.[20] The growth in mobile demand is therefore in contrast to the declining trend in DTT viewership.

[20] Ericsson Mobility Report, November 2022

4. Conclusion

In many countries, to realise the full socio-economic benefits of 5G, additional spectrum is required in frequencies below the 700 MHz band. Having access to greater sub-1 GHz spectrum will allow mobile operators to dedicate further capacity to 5G at both existing and new sites. Where there is existing coverage, operators may be unable to provide the capacity upgrades needed to meet 5G performance requirements without additional low-band spectrum. In rural areas, adding base stations to increase capacity is often not affordable, while in urban areas operators may have reached the technical limits of densification. The only way to increase capacity and offer the speeds needed is to utilise additional low-band spectrum at existing base stations.

The results of the CBA in this study highlight the size of the cost savings from assigning additional UHF spectrum to operators for a typical country in Europe, the Middle East and in Africa when deploying 5G networks. Without this spectrum, operators would incur higher costs, which would have implications for the affordability of 5G and reduce adoption and therefore the wider socio-economic benefits. Alternatively, they may decide not to incur the additional costs, particularly if the deployments are technically or financially unsustainable; in this case, consumers will not get the quality of service they need to fully benefit from 5G (i.e. slower speeds, higher latencies and less availability).

In each of the settings considered in the CBA in this report, the cost savings generated from assigning additional UHF spectrum to mobile significantly exceed the costs that would be incurred to ensure consumers are able to continue accessing the broadcasting services they demand. This reflects the growing demand for 5G bandwidth and the general decline in DTT, driven in significant part by the rise of IPTV and on-demand viewing. However, the results of a CBA will be specific to the circumstances of each market, depending on the level of expected 5G adoption, the population level and distribution, and the expected reliance on DTT for TV viewership. It is therefore clear from this study that a uniform approach to UHF spectrum use across all countries needs to be avoided where possible. Governments should pursue the spectrum policies that generate the most economic and social value for their populations.

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Appendix

Table A1: Mobile technical and spectrum assumptions

Assumption	Value	Source
	Supply factors	
Low-band spectrum available in baseline	190 MHz	3GPP sub-1GHz bands in ITU region 1[21]
Low-band spectrum available in scenario	270 MHz in Settings 1/3/5 414 MHz in Settings 2/4	In Settings 1/3/5, we assume an additional 80 MHz spectrum in the 614–694 MHz range. In Settings 2/4, we assume an additional 224 MHz spectrum in the 470–694 MHz range.
Share of mobile traffic served by low bands in urban areas	10%	Coleago (2022), Low-band spectrum for 5G The estimated share of traffic on low bands is between 10% and 20%. We use the lower bound to be conservative.
Share of mobile traffic served by low bands in rural areas	50%	Frontier Economics (2015)[22]
Loading factor	85%	GSMA (2022)[23], Analysis Mason (2014)[24] and Frontier Economics (2015)
Low-band spectral efficiency for 5G (downlink and uplink)	1.8 bits/s/Hz We assume that in the long-run all sub-1GHz spectrum uses 5G	Coleago (2022), Low-band spectrum for 5G
Number of sectors per macro cell	3	GSMA (2022)[25]
Downlink / uplink ratio	1:1	GSMA (2022)[26]
Asset life	10 years	GSMA (2022)[27]

[21] For further details, see Low-band spectrum for 5G, Coleago, 2022
[22] A cost benefit analysis of the change in use of the 700 MHz radio frequency band in Ireland: A report prepared for Comreg, Frontier Economics, 2015
[23] Vision 2030: mmWave Spectrum Needs: Estimating High-Band Spectrum Needs in the 2025-2030 Time Frame, GSMA, 2022
[24] Assessment of the benefits of a change of use of the 700MHz band to mobile, Analysys Mason report for Ofcom, 2014
[25] Maximising the socio-economic value of spectrum: A best practice guide for the cost-benefit analysis of 5G spectrum assignments, GSMA, 2022
[26] Maximising the socio-economic value of spectrum: A best practice guide for the cost-benefit analysis of 5G spectrum assignments, GSMA, 2022
[27] Maximising the socio-economic value of spectrum: A best practice guide for the cost-benefit analysis of 5G spectrum assignments, GSMA, 2022

Wi-Fi traffic offload	70% This is a very conservative assumption, as in practice Wi-Fi offload of mobile data is likely to be much less (see GSMA (2022)[28]).	GSMA (2022)[29] based on Cisco estimates
Urban capex and opex per site	$50,000 capex $12,500 opex	Coleago (2021)[30] and Oughton et al (2022)[31]
Rural capex and opex per site	$59,000 capex $14,750 opex Costs are assumed to be 18% higher than in urban areas.	GSMA (2019)[32]
Demand factors		
Urban downlink/uplink 5G performance requirement	100 Mbps downlink 50 Mbps uplink	ITU-R M.2410-0 (11/2017)
Rural downlink/uplink 5G performance requirement	20 Mbps downlink 5 Mbps uplink	Coleago (2022) suggested that operators are aiming for rural cell edge speeds between 10 and 30 Mbps for 5G. We therefore assume the mid-point.
5G penetration	Settings 1 and 2 – median forecast 5G penetration in Europe in 2021–2040 Settings 3 and 4 – median forecast 5G penetration in Middle East and North Africa in 2021–2040 Setting 5 – median forecast 5G penetration in Sub-Saharan Africa in 2021–2040	GSMA Intelligence forecasts
Activity factor (this refers to the proportion of 5G connections concurrently active in the peak hour)	10%	GSMA Intelligence
Urban population	Settings 1 and 2 – median forecast of urban population in Europe 2021–2040. In 2021, this was 6.4 million. Setting 3 and 4 – median forecast of urban population in the Middle	UN World Population Prospects and World Bank Forecasts

[28] The socioeconomic benefits of the 6 GHz band Considering licensed and unlicensed options, GSMA Intelligence, 2022
[29] Maximising the socio-economic value of spectrum: A best practice guide for the cost-benefit analysis of 5G spectrum assignments, GSMA, 2022
[30] Estimating the mid-band spectrum needs in the 2025-2030 time frame, Coleago, 2021
[31] Policy choices can help keep 4G and 5G universal broadband affordable, Technological Forecasting and Social Change Volume 176, Oughton et al, 2022
[32] Closing the Coverage Gap: How Innovation Can Drive Rural Connectivity, GSMA, 2019

	East and North Africa 2021–2040. In 2021, this was 10.1 million Setting 5 – median forecast of urban population in Sub-Saharan Africa 2021–2040. In 2021, this was 8.1 million.	
Rural population	Settings 1 and 2 – median forecast of rural population in Europe 2021–2040. In 2021, this was 2.3 million. Setting 3 and 4 – median forecast of the rural population in the Middle East and North Africa 2021–2040. In 2021, this was 1.8 million. Setting 5 – median forecast of the rural population in Sub-Saharan Africa 2021–2040. In 2021, this was 9.9 million.	UN World Population Prospects and World Bank Forecasts
Rural population distribution	This is needed to estimate the number of sites to cover rural populations. We select three countries that are most similar to the urban/rural population and 5G demand assumptions in the four settings. We then use their population distributions to estimate the number of sites needed to cover rural populations with 5G networks and provide 20 Mbps downlink. The countries are: • Hungary for Settings 1 and 2 • UAE for Settings 3 and 4 • Zambia for Setting 5	European Commission, Global Human Settlement Layer
Cell radius	To estimate the number of sites needed to cover rural populations, the model requires an assumption regarding the typical distance that a macro-site in rural areas can reach. We assume a distance of 8.5 kilometres when using 700 MHz bands (in the Baseline) and 10.5 kilometres when using 600MHz bands (in the Scenario).	Coleago (2022), Low-band spectrum for 5G and ZTE (2013)[33]

[33] APT 700MHz: Best Choice for nationwide coverage, ZTE, 2013

Table A2: Broadcasting technical and spectrum assumptions

Assumption	Value	Source
Number of national multiplexes (muxes) in Baseline	Settings 1 and 2: five national muxes. This is the median value for countries in Europe. Setting 3 and 4: four national muxes. This is the median value for countries in the Middle East and North Africa. Setting 5: four national muxes. This is the median value for countries in Sub-Saharan Africa.	VVA and LS Telcom (2022)[34], ITU (2021)[35], and TMG and GSMA (2022)[36]
Number of national multiplexes (muxes) in scenario	We assume that a spectrum reduction of 80 MHz in low bands represents a 35% reduction of available muxes in the scenario Setting 1: four national muxes. Setting 3: three national muxes. Setting 5: three national muxes. Settings 2 and 4: zero national muxes	VVA and LS Telcom (2022), ITU (2021), and TMG (2022)
Number of programmes	Settings 1 and 2: 51 programmes. This is the median value for Europe. Setting 3 and 4: 11 programmes. This is the median value for countries in the Middle East and North Africa. Setting 5: 48 programmes. This is the median value for Sub-Saharan Africa. These include free-to-air and pay-TV programmes, as well as national and regional programmes.	VVA and LS Telcom (2022), ITU (2021), and TMG (2022)

[34] VVA and LS Telcom. (2022). Study on the use of the sub-700 MHz band (470-694 MHz). European Commission
[35] Spectrum requirements for terrestrial television broadcasting in the UHF frequency band in Region 1 and the Islamic Republic of Iran, ITU, 2021
[36] Digital Switchover in Sub-Saharan Africa, GSMA, TMG, 2022

HD/SD programme split	Settings 1 and 2: 10 in HD and 41 in SD. This is the median value for Europe. Setting 3 and 4: 11 in HD. This is the median value for the Middle East and North Africa. Setting 5: 10 in HD and 38 in SD. This is the median value for Sub-Saharan Africa. These include free-to-air and pay-TV programmes, as well as national and regional programmes.	VVA and LS Telcom (2022), ITU (2021), and TMG (2022)
Number of broadcasting transmitters	Settings 1 and 2: 229 transmitters. This is the median value for Europe. Settings 3 and 4: 98 transmitters. This is the median value for the Middle East and North Africa. Setting 5: 100 transmitters. This is the median value for Sub-Saharan Africa.	VVA and LS Telcom (2022) and ITU (2021)
Number of households	Settings 1 and 2: 3.1 million households. This is the median value for countries in Europe. Settings 3 and 4: 3.9 million households. This is the median value for the Middle East and North Africa. Setting 5: 3.5 million households. This is the median value for Sub-Saharan Africa.	ITU statistics
Multiplex data rate	DVB-T: 24 Mbps DVB-T2: 40Mbps	ITU (2021) Report ITU-R BT.2302-1
Bandwidth required per programme	SD: 2.2 Mbps (This means DVB-T can carry 10-11 SD programmes and DVB-T2 can carry 18 SD programmes.) HD: 6 Mbps (This means DVB-T can carry 3-4 HD programmes and DVB-T2 can carry 6 HD programmes)	ITU (2021) Report ITU-R BT.2302-1
Video compression	We assume that the video compression technology used is MPEG4 (H.264)	