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Enabling mmWave spectrum for new uses

Annexes 5-9: supporting information

STATEMENT AND CONSULTATION:

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Contents

Annex

A5. Legal framework

A5.1 Ofcom's statutory powers and duties in relation to spectrum management are set out primarily in the Communications Act 2003 (the "**2003 Act**") and the Wireless Telegraphy Act 2006 (the "**WT Act**").

Duties under the Communications Act 2003

A5.2 Our principal duties under the 2003 Act, when carrying out our functions and exercising our powers, are to further the interests of citizens and consumers, where appropriate by promoting competition. In doing so, we are also required (among other things) to secure the optimal use of spectrum and the availability throughout the United Kingdom of a wide range of electronic communications services.

A5.3 We must also have regard to: (i) the desirability of promoting competition in relevant markets; (ii) the desirability of encouraging investment and innovation in relevant markets; (iii) the desirability of ensuring the security and availability of public electronic communications networks and services; (iv) the different needs and interests, so far as the use of the electro-magnetic spectrum for wireless telegraphy is concerned, of all persons who may wish to make use of it; and (v) the different interests of persons in the different parts of the United Kingdom, of the different ethnic communities within the United Kingdom and of persons living in rural and in urban areas.

A5.4 In performing our duties, we are required under section 3(3) of the 2003 Act to have regard in all cases to the principles under which regulatory activities should be transparent, accountable, proportionate, consistent and targeted only at cases in which action is needed, and any other principles appearing to Ofcom to represent the best regulatory practice.

A5.5 In carrying out certain regulatory functions, including Ofcom's spectrum management functions, section 4 of the 2003 Act requires Ofcom to act in accordance with the following requirements: a) to promote competition in communications markets; b) to promote the interests of all members of the public in the United Kingdom; c) to act in a manner which, so far as practicable, is technology neutral;[1] d) to encourage, to the extent Ofcom considers it appropriate, the provision of network access and service interoperability for the purpose set out in s.4(8);[2] e) to encourage such compliance with certain international standards as is necessary for the purposes set out in s.4(9);[3] and f) to promote connectivity

[1] According to s.4(6A) of the 2003 Act, this requirement does not apply to the imposition, in relation to a wireless telegraphy licence, of a limitation of a kind falling within section 9ZA(1) of the WT Act; or (b) the review, variation or removal of such a limitation.
[2] The purpose of securing: (i) efficiency and sustainable competition, (ii) efficient investment and innovation, and (iii) the maximum benefit for the customers of communications providers and of persons who make associated facilities available.
[3] For facilitating service interoperability, end-to-end connectivity, the changing by end-users of their communications provider, the retention by end-users of their telephone numbers after a change of communications provider; and securing freedom of choice for the customers of communications providers.

and access to very high capacity networks by members of the public and businesses in the United Kingdom.

Duties under the Wireless Telegraphy Act 2006

A5.6 Additionally, in carrying out our spectrum functions we have a duty under section 3 of the WT Act to have regard in particular to: (i) the extent to which the spectrum is available for use, or further use, for wireless telegraphy; (ii) the demand for use of that spectrum for wireless telegraphy; and (iii) the demand that is likely to arise in future for such use.

A5.7 We also have a duty to have regard to the desirability of promoting: (i) the efficient management and use of the spectrum for wireless telegraphy; (ii) the economic and other benefits that may arise from the use of wireless telegraphy; (iii) the development of innovative services; and (iv) competition in the provision of electronic communications services.

Harmonised technical conditions

The 26 GHz band

A5.8 Certain European decisions continue to have effect in domestic UK law, following the UK's exit from the EU, by virtue of section 3 of The European Union (Withdrawal) Act 2018. These include, in particular, the Implementing Decision issued by the European Commission in 2019 to open up the 26 GHz band for wireless broadband under harmonised technical conditions, which was then amended in 2020 (the "**26 GHz Decision**").[4]

A5.9 The 26 GHz Decision harmonises the essential technical conditions for the availability and efficient use of the 24.25-27.5 GHz frequency band (the "**26 GHz band**") in the European Union for terrestrial systems capable of providing wireless broadband electronic communications services (Art. 1) and requires the UK (and the EU Member States) to designate and make available on a non-exclusive basis that frequency band for such systems by 30 June 2020 (Art. 2). Alongside this requirement, Art. 54(1)(b) of the European Electronic Communications Code (EECC)[5] requires Member States to make at least 1 GHz of the 26 GHz spectrum available by 31 December 2020, provided that there is clear evidence of market demand and of the absence of significant constraints for migration of existing users or band clearance. However, in light of Ofcom making the lower 26 GHz band (24.25-26.5 GHz) available for Shared access licences for low power indoor use[6], art. 54(1)(b) of the EECC was not transposed into UK law. [7]

[4] See this unofficial consolidated version of Decision 2019/784, as amended by Decision 2020/590. The UK version of this legislation is set out in S.I. 784/2019 and S.I. 590/2020

[5] A consolidated version of the European Electronic Communications Code is available here.

[6] Ofcom's Statement "Enabling wireless innovation through local licensing", published 25 July 2019, paragraph 5.3.

[7] DCMS's "Government response to the public consultation on implementing the European Electronic Communications Code", published 22 July 2020, pp. 35-36.

A5.10 The 26 GHz Decision also contains provisions about the co-existence between terrestrial systems for wireless broadband and other spectrum users. In particular:

a) it should be analysed at national level whether it is necessary to impose additional technical conditions to ensure appropriate co-existence with other services in the band (Art. 2);

b) terrestrial systems for wireless broadband must appropriately protect other spectrum users operating in the same band or adjacent bands, including certain earth exploration satellite services, radio astronomy services, space research services and satellite systems (Art. 3);

c) fixed links may be allowed to continue to operate within the band, if the terrestrial systems for wireless broadband can co-exist with them through managed shared spectrum use (Art. 4);

d) the number and locations of new earth stations must be determined so as not to impose disproportionate constraints on terrestrial systems for wireless broadband. Subject to market demand, the continued deployment of earth stations must be made possible for certain uses within the 26 GHz band (Art. 5); and

e) the progress on co-existence should be monitored, and the findings reported to the European Commission to allow for a timely review of the 26 GHz Decision (Art. 7).

A5.11 Cross-border coordination agreements should be facilitated to enable the operation of terrestrial systems for wireless broadband (Art. 6).

The 40 GHz band

A5.12 In April 2020, the European Commission issued a mandate to the European Conference of Postal and Telecommunications Administrations ("**CEPT**"), asking CEPT to develop least restrictive harmonised technical conditions allowing use of the 40.5-43.5 GHz band for terrestrial wireless systems capable of providing wireless broadband electronic communications services.[8] On 18 November 2022, CEPT published a report ("**CEPT Report 82**") in response to that mandate and the Electronic Communications Committee ("**ECC**") published a decision ("**ECC Decision (22)06**")[9] reflecting CEPT's harmonised conditions.[10]

A5.13 CEPT Report 82 will form the basis of a harmonising Commission Decision, which is currently in draft form.[11] It is currently expected that a final Commission Decision will be published later this year. For the avoidance of doubt, any such decision will not be part of UK law. However, Ofcom may consider it appropriate to authorise spectrum use of the relevant frequencies on the basis of technical conditions reflecting the CEPT harmonisation (to which the UK has contributed).

[8] CEPT Report 78, annex 1.
[9] ECC Decision (22)06.
[10] CEPT Report 82.
[11] A draft of the Commission Implementing Decision, dated 7 December 2022, is available.

Ofcom's licensing framework

A5.14 Ofcom is responsible for authorising use of the radio spectrum. We permit the use of the radio spectrum either by granting wireless telegraphy licences under the WT Act or by making regulations exempting the use of particular equipment from the requirement to hold such a licence. It is unlawful and an offence to install or use wireless telegraphy apparatus without holding a licence granted by Ofcom, unless the use of such equipment is exempted.[12]

A5.15 The proposals and decisions set out in this document concern (among other things) our approach to existing users of the 26 GHz and 40 GHz bands and the licence conditions to be included in any future licence authorising use of these bands for 5G and other wireless services. Below we explain the legal framework under which we can impose conditions in new spectrum licences and revoke or vary existing licences.

Licence conditions

A5.16 A wireless telegraphy licence may be granted subject to such terms, provisions and limitations as Ofcom think fit (WT Act, s. 9(1)). However, this power is subject to certain constraints. In particular:

a) the terms, provisions and limitations of a spectrum licence must not duplicate the obligations already imposed on the licensee by the general conditions set by Ofcom under section 45 of the Communications Act 2003 (WT Act, s. 9(6));[13] and

b) Ofcom may only impose terms, provisions and limitations which are: a) objectively justified in relation to the network and services to which they relate; b) not unduly discriminatory; c) proportionate to what they are intended to achieve; and d) transparent in relation to what they are intended to achieve (WT Act, s. 9(7)).

A5.17 Section 9(4) of the WT Act sets out a non-exhaustive list of the terms, provisions and limitations that Ofcom may impose.

A5.18 Examples of conditions that we may impose in spectrum licences under s.9 WT Act include:

a) limitations as to the position and nature of a station (s.9(2)(a));

b) limitations as to the apparatus that may be installed or used (s.9(3)); and

c) terms, provisions and limitations as to strength or type of signal, as to times of use and as to the sharing of frequencies (s.9(4)(a)).

Ofcom's powers to vary or revoke licences granted under the WT Act

A5.19 Ofcom has a broad discretion under paragraph 6 of Schedule 1 of the 2006 Act to vary or revoke licences, subject to certain limitations. Specifically, the legislation provides that

[12] Section 8 of the WT Act.
[13] Ofcom's webpage "General Conditions of Entitlement".

Ofcom may not vary or revoke a licence unless the proposed variation or revocation is objectively justifiable (WT Act 2006, para. 6A of Sch. 1). We also have a general duty not to discriminate unduly between operators and to ensure that our interventions are proportionate, consistent and targeted only at cases in which action is needed (2003 Act, s.3(3)). Ofcom must act in accordance with its statutory duties and general legal principles, including the duties to act reasonably and rationally when making decisions and to take account of any legitimate expectations.[14]

A5.20 Schedules 1 of the WT Act set out the process which Ofcom must follow where it proposes to vary or revoke a wireless telegraphy licence. In summary, Ofcom is required to take the following steps (WT Act, para. 7 of Sch. 1):

a) notify the licensee of the reasons for the proposed variation or revocation;

b) specify a period of at least 30 days in which the licensee may make representations about the proposal; and

c) decide whether or not to vary or revoke the licence within one month of the end of that period.

A5.21 Where a proposal to vary or revoke a wireless telegraphy licence is made with the consent of the licensee, Ofcom is not required to follow the above process.

A5.22 Ofcom may include in a wireless telegraphy licence terms restricting the exercise of its power to revoke or vary licences (WT Act, para. 8 of Sch. 1), such as requiring a certain notice period for revoking a licence for spectrum management reasons. However, Ofcom may at any time revoke or vary a licence if it appears to be necessary or expedient in the interests of national security, or for the purpose of securing compliance with an international obligation (WT Act, para. 8(5) of Sch. 1).

Licence awards

A5.23 Ofcom may allocate spectrum by way of auctions having regard to the desirability of promoting the optimal use of spectrum (WT Act, s. 14). In making auction regulations, Ofcom must satisfy itself that the criteria for spectrum allocation are:

a) objectively justifiable in relation to the frequencies to which they relate;

b) not such as to discriminate unduly against particular persons or against a particular description of persons;

c) proportionate to what they are intended to achieve; and

d) in relation to what they are intended to achieve, transparent (WT Act, s.14(3B)).

A5.24 Auction regulations may make provisions with respect to the grant of the relevant licences and also the terms, provisions and limitations subject to which such licences are granted

[14] Further potential limitations may derive from (i) any UK obligations under international agreements, particularly where use of spectrum has been harmonised, and (ii) any ministerial direction under section 5 of the 2003 Act or section 5 of the WT Act.

(WT Act, s. 14(2) and s. 14(3)(h)). When designing competitive awards, Ofcom may impose a specified level of use requirement if doing so would promote the optimal use of spectrum (WT Act, s.14(3C)).

A6. Further details on the method for defining high density areas

A6.1 In this annex, we provide full details of the method we have used to define the high density areas in which we will make mmWave spectrum available by auction, as described in section 4.

Identifying town and cities with potentially high data demand

Major town and cities according to data published by the UK statistics agencies[15]

A6.2 In line with our initial proposals,[16] we have decided to use as our starting point:

a) the Major Towns and Cities ("**MTaC**") dataset[17] published by the Office of National Statistics (ONS) for England and Wales, which categorises as "major towns and cities" the areas of England and Wales with a residential or workday populations of 75,000 people or more; and

b) the areas of Scotland and Northern Ireland with a residential population[18] of 75,000 people or more, using (i) the boundaries for "**Localities**", as used in the National Records of Scotland's Mid-2020 Population Estimates for Settlements and Localities in Scotland[19] and (ii) the boundaries used in the Northern Ireland Statistics and Research Agency's 2015 Settlement Development Limits ("**SDLs**").[20]

A6.3 In summary, we have taken this as our starting point on the basis that: (i) we expect to see new uses of mmWave spectrum to be deployed most extensively in places where there are many people, and therefore high demand for data; (ii) the town and city boundaries defined by the UK statistics agencies were developed specifically to provide a more precise definition of towns and cities than other sources of data which we have considered;[21] and (iii) they are also publicly available and intuitive to use.

A6.4 The MTaC dataset defines the boundaries of the following 112 major towns and cities in England and Wales:

[15] These are the Office of National Statistics (ONS) for England and Wales, National Records of Scotland (NRS) for Scotland and the Northern Ireland Statistics and Research Agency (NISRA) for Northern Ireland.
[16] May 2022 Consultation, paragraphs 4.6-4.10 and A7.13-A7.16.
[17] ONS, "Major Towns and Cities - a new statistical geography".
[18] For Scotland and Northern Ireland, we have used only the residential population because we were unable to determine the workday population of settlements in those areas.
[19] NRS, "Mid-2020 Population Estimates for Settlements and Localities in Scotland", file used was *Localities2020_MHW.shp*
[20] NISRA, "Settlement Development Limits (2015)".
[21] As set out in the May 2022 Consultation (paragraphs A7.5-A7.12), we also considered using grid squares, local authority boundaries and postcode areas but determined these would be less suitable.

Table A6.1: Towns and cities included in ONS' Major Towns and Cities dataset

Barnsley	Cheltenham	High Wycombe	Oxford	Stockport
Basildon	Chester	Huddersfield	Peterborough	Stockton-on-Tees
Basingstoke	Chesterfield	Ipswich	Plymouth	Stoke-on-Trent
Bath	Colchester	Kingston upon Hull	Poole	Sunderland
Bedford	Coventry	Leeds	Portsmouth	Sutton Coldfield
Birkenhead	Crawley	Leicester	Preston	Swansea
Birmingham	Darlington	Lincoln	Reading	Swindon
Blackburn	Derby	Liverpool	Redditch	Telford
Blackpool	Doncaster	London	Rochdale	Wakefield
Bolton	Dudley	Luton	Rotherham	Walsall
Bournemouth	Eastbourne	Maidstone	Salford	Warrington
Bracknell	Exeter	Manchester	Scunthorpe	Watford
Bradford	Gateshead	Mansfield	Sheffield	West Bromwich
Brighton and Hove	Gillingham	Middlesbrough	Shrewsbury	Weston-Super-Mare
Bristol	Gloucester	Milton Keynes	Slough	Wigan
Burnley	Grimsby	Newcastle upon Tyne	Solihull	Woking
Burton upon Trent	Guildford	Newcastle-under-Lyme	South Shields	Wolverhampton
Bury	Halifax	Newport	Southampton	Worcester
Cambridge	Harlow	Northampton	Southend-on-Sea	Worthing
Cardiff	Harrogate	Norwich	Southport	York
Carlisle	Hartlepool	Nottingham	St Albans	
Chatham	Hastings	Nuneaton	St Helens	
Chelmsford	Hemel Hempstead	Oldham	Stevenage	

Source: ONS Major Towns and Cities statistical geography

A6.5 Using the method described above, we have added the following areas in Scotland and Northern Ireland:

Table A6.2: Towns and cities in Scotland and Northern Ireland with a residential population of 75,000 people or more

Scotland	Northern Ireland
Glasgow	Belfast
Edinburgh	Derry/Londonderry
Aberdeen	
Dundee	
Paisley	
East Kilbride	

Source: Ofcom; population data UK Census 2011; Locality boundaries from NRS; SDL boundaries from NISRA

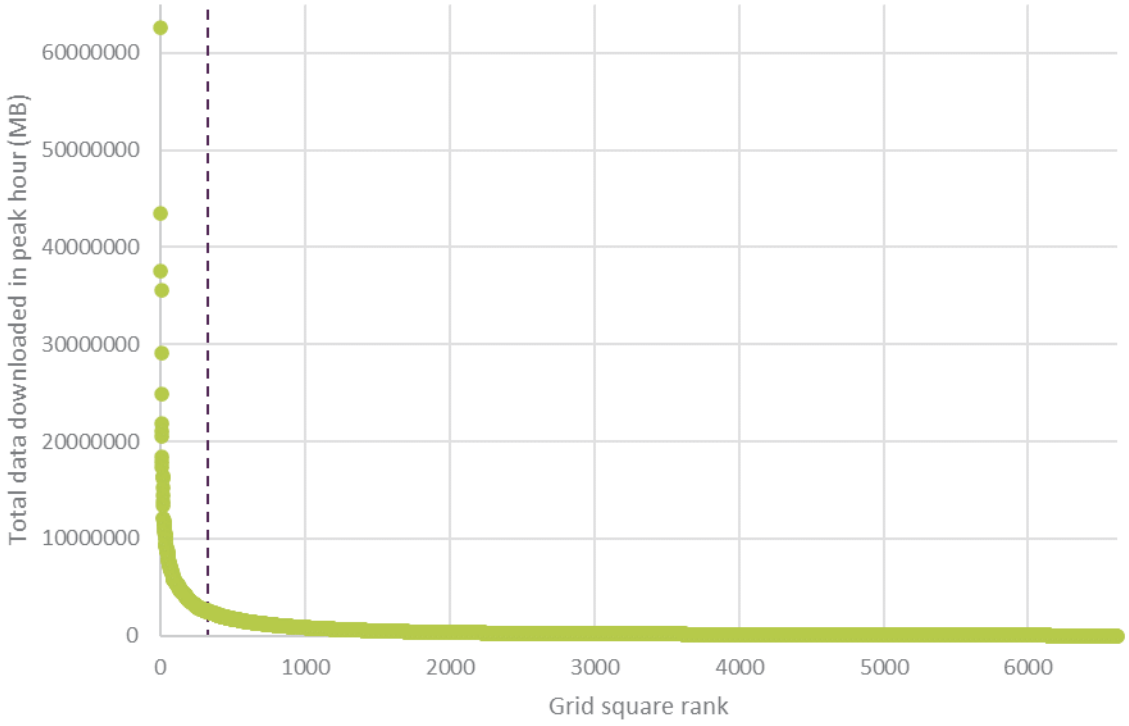
Incorporating additional towns and cities with high data traffic

A6.6 We have incorporated additional towns and cities with high peak hour mobile data traffic following the steps proposed in the May 2022 Consultation,[22] which are summarised below. We have taken this approach on the basis that, as set out in the May 2022 Consultation,[23] we consider that the amount of mobile data used in a town at peak times is also an important indicator of whether that town should be classified as a high density area.

A6.7 Using data obtained through Ofcom's Connected Nations report, we have calculated the total peak hour mobile data downloaded across each 5km grid square in the UK, and mapped out the top 5% of these and plotted the results on a graph in descending order, as shown in Figure 6.1 below. We have mapped out only the top 5% of these 5km grid squares because we consider that there is a reasonable breakpoint in the curve at 5%, where the peak hour data traffic reduces considerably compared to the highest data squares.

[22] May 2022 Consultation, paragraphs A7.17-A7.22.
[23] May 2022 Consultation, paragraph 4.11.

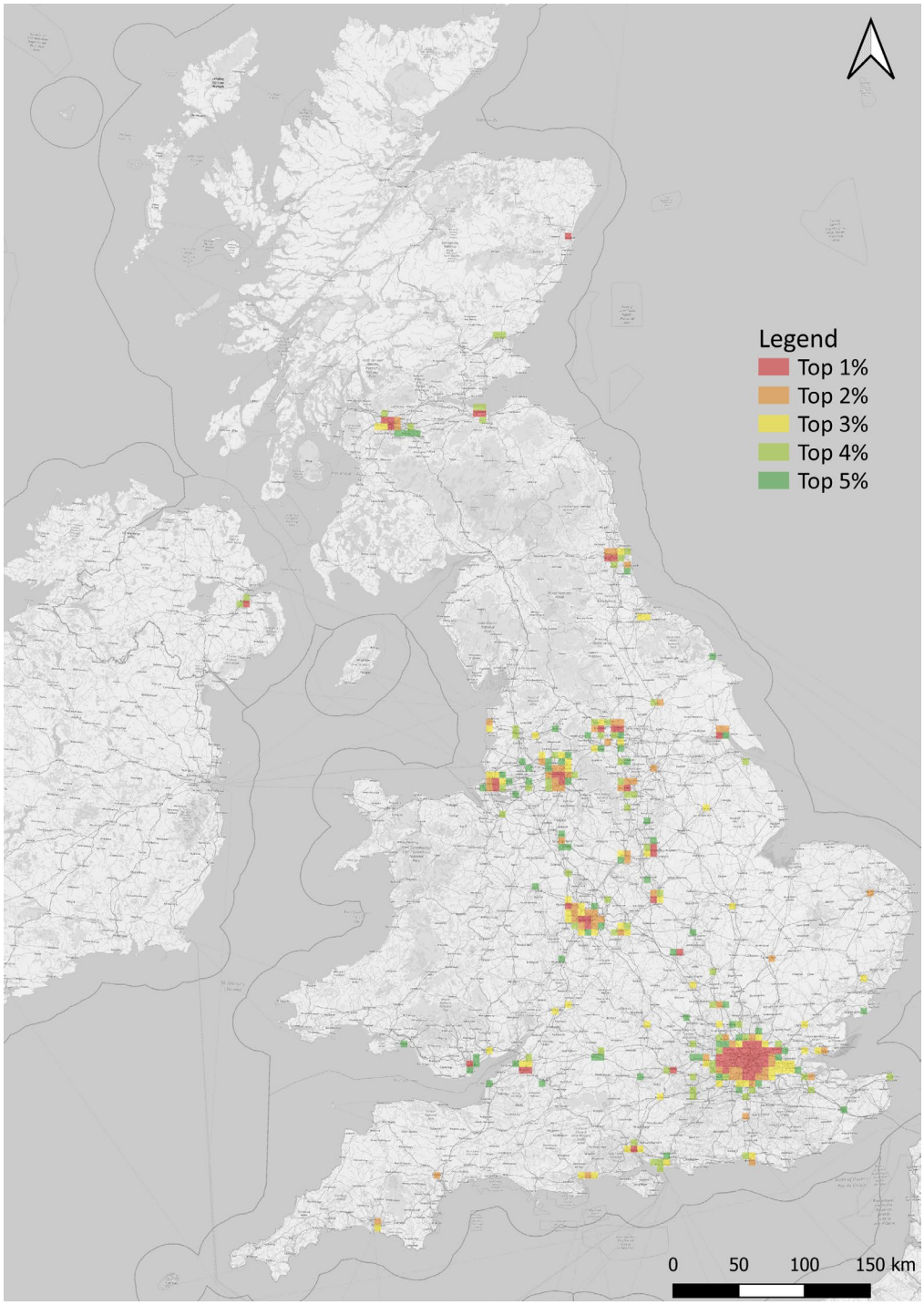
Figure A6.1: Total peak hour data downloaded in 6,613 5km grid squares in the UK, showing vertical line at 5% (331st ranked grid square)



Source: Ofcom

A6.8 The result of this exercise is shown in Figure A6.2 below.

Figure A6.2: Map showing top 5% of 5km grid squares in the UK by total peak hour data traffic



Source: Ofcom; base map © OpenStreetMap contributors; N.B. Orkney and Shetland not shown as no areas there fall within the top 5% of grid squares

A6.9 We have cross-referenced the locations with high data throughput identified through this method with the list of towns and cities with populations of 75,000 people or more. While

most of the locations with high data throughput we identified in this way were already included in the list of towns and cities, a small number of locations were not represented.[24]

A6.10 For these additional locations, we added these to our list, by identifying which city or town the relevant grid square covered.

A6.11 We did this by using boundaries from the same datasets which already formed our list of towns and cities with populations of 75,000 or more:

a) **England & Wales**: we used either Built-up Areas (BUAs)[25] or Built-Up Area Sub Divisions (BUASDs),[26] which are both defined by the ONS based on 2011 Census data. These BUAs and BUASDs are used in the creation of the MTaC dataset, so we consider that it is consistent for us to use these for additional settlements in England & Wales.

b) **Scotland**: we used Localities, as outlined in paragraph A6.2 above.

c) **Northern Ireland**: we would have used SDLs, as outlined in paragraph A6.2, however there were no additional areas in Northern Ireland added through this stage.

A6.12 In some instances, we determined that a single town or city was associated with a high data grid square, as the boundaries outlined above only indicated one BUA, BUASD or Locality within a 5km grid square. However, in other cases the boundaries indicated that it was possible that the high data usage being generated in an area could be attributed to several different areas. This was more prevalent with suburbs of major cities. In these cases, we have not sought to include every BUA, BUASD or Locality which overlaps with a given 5km grid square, but have tried to capture the areas most likely to be associated with the high data traffic. In doing this, the criteria we use to assess whether or not to include a BUA, BUASD or Locality are:

a) **Population**: we have prioritised areas with higher populations over those with lower populations.

b) **Placement in relation to grid square**: an area which has only a small overlap with the high data grid square would be less likely to be included than an area fully within the grid square.

c) **Local features**: we have considered features on the ground in the relevant areas which could drive high data traffic, such as high streets, shopping centres, transport hubs and other sites which could have high enough footfall to account for high mobile data usage.

A6.13 Through this method, we added the following 57 additional locations into our list:

[24] A small number of the final high density areas were included in the MTaC dataset but were not included in the top 5% of 5km squares based on peak hour mobile data. These were Guildford and Woking (both incorporated into Greater London further into the process), Hartlepool (later incorporated into Teesside), Colchester, Harrogate, Hastings, Redditch, Shrewsbury and Southport.

[25] ONS, "Built-up Areas (December 2011) Boundaries V2".

[26] ONS, "Built-up Area Sub Divisions (December 2011) Boundaries."

Table A6.3: Additional high-data locations: England and Wales

England and Wales (BUAs and BUASDs)		
Aldershot BUASD	Frimley BUASD	Redhill (Reigate and Banstead) BUA
Altrincham BUASD	Gosport BUASD	Rochester BUASD
Ashford (Ashford) BUASD	Gravesend BUASD	Runcorn BUASD
Ashton-under-Lyne BUASD	Grays BUA	Sale BUASD
Aylesbury BUASD	Hatfield BUASD	Scarborough BUA
Bexley BUASD	Hebburn BUASD	Stafford BUASD
Bluewater Retail Park	Hindley BUASD	Staines BUASD
Bootle BUASD	Ince-in-Makerfield BUASD	Stalybridge BUASD
Camberley BUASD	Jarrow BUASD	Stoke Mandeville BUASD
Clacton-on-Sea BUA	Kettering BUASD	Swanscombe BUASD
Crosby BUASD	Litherland BUASD	Tamworth BUA
Dewsbury BUASD	Loughborough BUA	Thanet BUA
Dukinfield BUASD	Maidenhead BUASD	Tynemouth BUASD
Epsom BUASD	New Addington BUA	Wallsend BUASD
Ewell BUASD	Newbury BUASD	Waltham Abbey BUASD
Farnborough BUASD	Northfleet BUASD	Waltham Cross BUASD
Filton BUASD	Platt Bridge BUASD	Weybridge BUASD

Source: Ofcom; BUA and BUASD boundaries from ONS; Locality boundaries from NRS

Table A6.4: Additional high-data locations: Scotland

Scotland (Localities)		
Bellshill	Carfin	Carfin
Blantyre	Coatbridge	Rutherglen
Bothwell	Hamilton	Uddingston

Source: Ofcom; BUA and BUASD boundaries from ONS; Locality boundaries from NRS

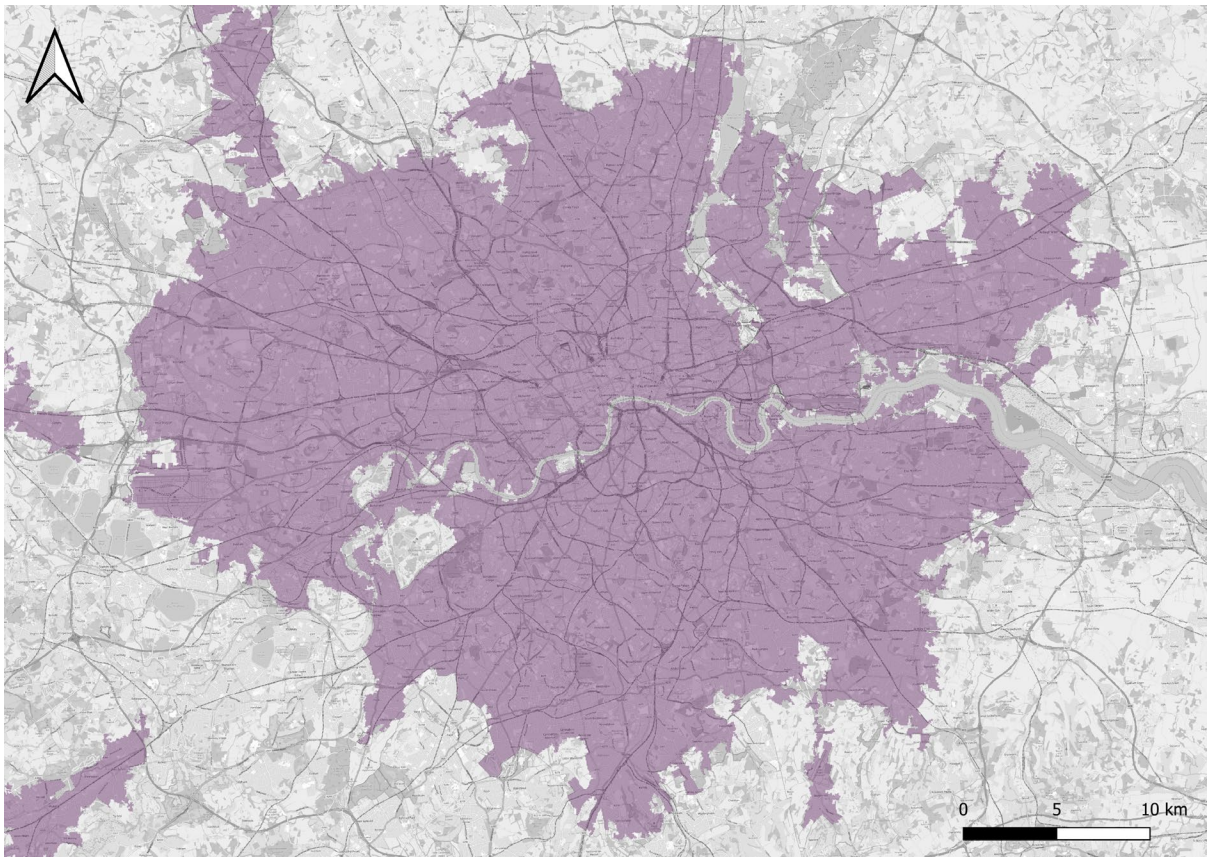
Applying an overlay of 1km grid squares over the pre-defined boundaries established by the UK's statistics agencies

A6.14 As proposed in the May 2022 Consultation,[27] we have applied an overlay of 1km grid squares over the pre-defined boundaries established by the UK's statistics agencies to make the boundaries of high density areas less granular. This is because the boundaries established by the UK's statistics agencies are very granular and leave gaps in some cities.[28]

[27] May 2022 Consultation, paragraphs 4.15-4.19.
[28] This is particularly true for the MTaC dataset, which uses a grid square system with a resolution of 50m.

These gaps often occur where there are large parks, rivers and major roads, as shown in Figure A6.3 below which shows the boundaries of London according to the MTaC dataset.

Figure A6.3: Map showing London boundaries according to Major Towns and Cities dataset



Source: Ofcom; Office for National Statistics licensed under the Open Government Licence v.3.0; base map © OpenStreetMap contributors

A6.15 We consider that these granular boundaries and gaps could limit investment and network deployment, due to the need to avoid interference between users in high and low density areas. Specifically, gaps in high density areas could create "dead zones". These dead zones would technically be low density areas, where holders of award licences would not be authorised to deploy. However, applications for Shared Access licences in these areas to use the same frequencies as nearby award licences would also likely be rejected due to the need to keep distance between users to avoid interference.

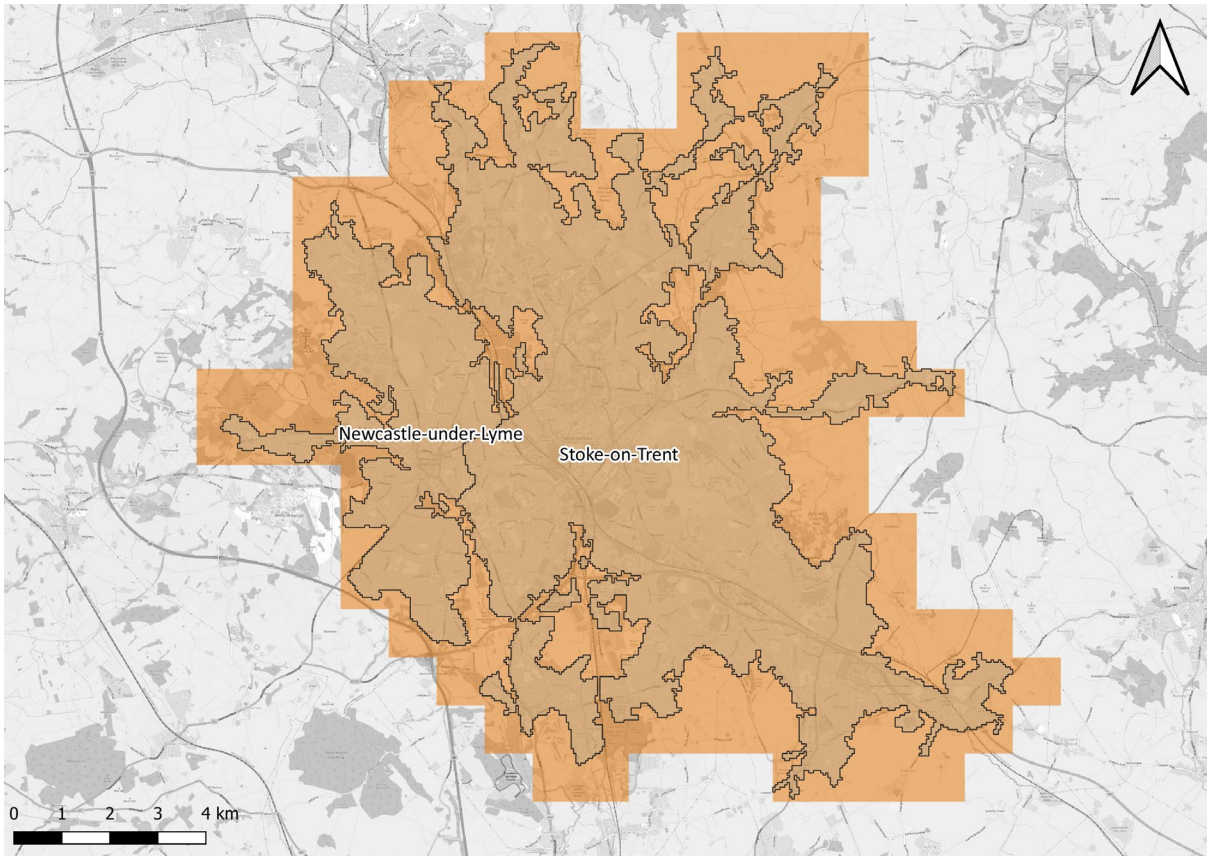
A6.16 In order to simplify and standardise the boundaries of high density areas in all nations, we applied an overlay of 1km grid squares over the towns and cities we identified. Any grid square which contains any part of a town or city's boundaries would therefore be included as part of the relevant high density area. Following on from this, we have also used the same 1km square grid system to fill in any gaps in the high density areas. Specifically, if a 1km grid square not included in a town or city was bounded on three or more sides by squares which were included, that square would be added to the high density area. Additionally, any remaining gaps in high density areas which were wholly enclosed were

also included (e.g. if a 2x2km "gap" existed within the boundaries of a high density area, this also became part of that high density area).

A6.17 Our application of 1km grid squares also has the effect of combining adjacent and neighbouring towns and cities into single, discrete areas. This is the case for any towns and cities which already have shared borders, as well as some of those which are within 2km of each other. Any towns and cities with contiguous borders once this overlay is applied are treated as a single high density area.

A6.18 The map below shows an example of where this methodology combines two adjacent settlements, namely Stoke-on-Trent and Newcastle-under-Lyme, which are combined into a single area. In addition, the grid square overlay simplifies the boundaries of the area and has filled in gaps within the city.

Figure A6.4: Map of Stoke-on-Trent, showing MTaC boundaries (black outline) with 1km grid square overlay (orange area)



Source: Ofcom; Office for National Statistics licensed under the Open Government Licence v.3.0; base map © OpenStreetMap contributors

A6.19 Having applied this overlay, we are left with 107 discrete potential high density areas.

Ranking the areas identified and selecting a cut-off point

Ranking the areas on the basis of peak hour mobile data and base station density

A6.20 As proposed in the May 2022 Consultation,[29] we have ranked the 107 potential high density areas using the following two metrics, which we consider as a good predictor of where mmWave spectrum is likely to be deployed most extensively for new uses:

a) **Base station density**, which shows us where mobile network operators have deployed their current infrastructure most intensively. This metric is comparatively stable from month to month, however it does not show, on its own, how much data traffic is being generated in a given area.

b) **Peak hour mobile data**, which tells us how much data traffic was generated on a given base station site during the busiest hour of the month (in this case, the month the data relates to is May 2021). This metric indicates the maximum mobile traffic generated at any one time, but can fluctuate from month to month. This is because events such as sports matches, festivals, or large outdoor events can drive spikes in mobile data use at a given base station or location.

A6.21 Based on our understanding of how mmWave spectrum is likely to be deployed for new uses (i.e. in boosting the capacity of networks, rather than for improving coverage across a wide area), we consider that it is more appropriate to consider both of these metrics in relation to the busiest areas within a city, rather than as an average across an entire city.[30] Therefore, we have divided up each of the 107 potential high density areas into 1km squares and calculated the base station density and peak mobile traffic in each square, using data obtained for Ofcom's 2021 Connected Nations Report. We then used the highest values for each metric as the result for that city.

A6.22 Calculating the highest mobile base station density and highest peak hour data gives two rankings for each of the 107 potential high density areas, which we then multiplied together to determine a final ranking for each city that takes into account both metrics.[31]

A6.23 For example, of the 107 potential high density areas, Edinburgh ranks 10th for peak hour data and 8th for base station density. Multiplying these ranks together gives a score of 80, which overall ranks Edinburgh 9th across the 107 high density areas. We recognise that there are alternative methods of combining the ranking of individual metrics to determine a combined ranking, such as an additive approach. We have chosen a relatively straightforward multiplicative approach as we consider this is a reasonable option in this

[29] May 2022 Consultation, paragraphs 4.10-4.25 and A7.23-A7.26.
[30] When calculating averages across entire cities, we found that this approach gave us results with an order that did not seem logical. Some larger towns and cities were "penalised" for having a large geographic area and appeared much further down the list than we expected given the size or population of these areas, while some small towns unexpectedly appeared towards the top of the list. We did not consider that these results reflected the likely pattern of mmWave spectrum deployment.
[31] Where there were ties, we chose the high density area with the higher base station number to be higher on the list.

circumstance. We also note that there is relatively strong correlation in the rankings across the two metrics which means the choice of ranking methodology only has a small effect on the result.

A6.24 Table A6.5 below gives a ranked list of all 107 potential high density areas, and outlines which constituent areas have been combined together to form each of the 107 areas (either because these areas share borders, or were combined together by the application of 1km grid squares described above). These constituent areas will all be one of the following:

a) an ONS Major Town or City (**MTaC**);

b) an ONS Built-up Area (**BUA**);

c) an ONS Built-up Area Sub Division (**BUASD**);

d) an NRS Locality in Scotland (**Locality**); or

e) a Northern Irish settlement defined by NISRA's Settlement Development Limits (**SDL**).

Table A6.5: All 107 potential high density areas identified for the May 2022 Consultation, ranked

Rank	Location	Comprised of
1	Greater London	MTaC: Hemel Hempstead, London, Watford; BUAs: Grays, New Addington; BUASDs: Bexley, Bluewater Retail Park, Epsom, Ewell, Gravesend, Northfleet, Staines, Swanscombe, Waltham Abbey, Waltham Cross
2	Greater Manchester	MTaC: Bolton, Bury, Manchester, Oldham, Salford, Stockport; BUASDs: Altrincham, Ashton-under-Lyne, Dukinfield, Sale, Stalybridge
3	Greater Glasgow	Localities: Bellshill, Blantyre, Bothwell, Cambuslang, Carfin, Coatbridge, East Kilbride, Glasgow, Hamilton, Motherwell, New Stevenston, Paisley, Rutherglen, Uddingston, Viewpark
4	Greater Birmingham	MTaC: Birmingham, Dudley, Solihull, Sutton Coldfield, Walsall, West Bromwich
5	Cardiff	Cardiff MTaC
6	Tyne & Wear	MTaC: Gateshead, Newcastle upon Tyne, South Shields, Sunderland; BUASDs: Hebburn, Jarrow, Tynemouth, Wallsend
7	Bristol	Bristol MTaC; Filton BUASD
8	Liverpool	MTaC: Liverpool, Birkenhead; BUASDs: Bootle, Crosby, Litherland
9	Edinburgh	Edinburgh Locality
10	Leeds & Bradford Area	MTaC: Bradford, Halifax, Leeds, Wakefield
11	Sheffield	MTaC: Rotherham, Sheffield
12	Reading	Reading MTaC

Rank	Location	Comprised of
13	Nottingham	Nottingham MTaC
14	Wolverhampton	Wolverhampton MTaC
15	Northampton	Northampton MTaC
16	Southend	Southend-on-Sea MTaC
17	Brighton	Brighton and Hove MTaC
18	Doncaster	Doncaster MTaC
19	Luton	Luton MTaC
20	Coventry	Coventry MTaC
21	Belfast	BELFAST CITY SDL
22	Aberdeen	Aberdeen Locality
23	Stoke-on-Trent	MTaC: Newcastle-under-Lyme, Stoke-on-Trent
24	Leicester	Leicester MTaC
25	Huddersfield	Huddersfield MTaC
26	Guildford, Woking & Weybridge	MTaC: Guildford, Woking; Weybridge BUASD
27	Southampton	Southampton MTaC
28	Colchester	Colchester MTaC
29	Exeter	Exeter MTaC
30	Hull	Kingston upon Hull MTaC
31	Bournemouth & Poole	MTaC: Bournemouth, Poole
32	Rochdale	Rochdale MTaC
33	Newport	Newport MTaC
34	Derby	Derby MTaC
35	Wigan	Wigan MTaC; BUASD: Hindley, Ince-in-Makerfield, Platt Bridge
36	Loughborough	Loughborough BUA
37	Portsmouth & Gosport	Portsmouth MTaC; Gosport BUASD
38	Gloucester	Gloucester MTaC
39	Slough & Maidenhead	Slough MTaC; Maidenhead BUASD
40	Newbury	Newbury BUASD
41	Plymouth	Plymouth MTaC
42	Chester	Chester MTaC
43	York	York MTaC
44	Oxford	Oxford MTaC
45	St Albans & Hatfield	St Albands MTaC; Hatfield BUASD

Rank	Location	Comprised of
46	Peterborough	Peterborough MTaC
47	Shrewsbury	Shrewsbury MTaC
48	Cambridge	Cambridge MTaC
49	Ashford	Ashford (Ashford) BUASD
50	Norwich	Norwich MTaC
51	Milton Keynes	Milton Keynes MTaC
52	Crawley	Crawley MTaC
53	Redhill & Reigate	Redhill (Reigate and Banstead) BUA
54	Medway Towns	MTaC: Chatham, Gillingham; Rochester BUASD
55	Stafford	Stafford BUASD
56	Chelmsford	Chelmsford MTaC
57	Hartlepool	Hartlepool MTaC
58	Preston	Preston MTaC
59	Middlesbrough	MTaC: Middlesbrough, Stockton-on-Tees
60	Swansea	Swansea MTaC
61	Blackpool	Blackpool MTaC
62	Bath	Bath MTaC
63	Dundee	Dundee Locality
64	Basildon	Basildon MTaC
65	Farnborough & Aldershot	BUASDs: Aldershot, Camberley, Farnborough, Frimley
66	Tamworth	Tamworth BUA
67	Dewsbury	Dewsbury BUASD
68	Swindon	Swindon MTaC
69	Lincoln	Lincoln MTaC
70	Chesterfield	Chesterfield MTaC
71	Southport	Southport MTaC
72	Ipswich	Ipswich MTaC
73	Harrogate	Harrogate MTaC
74	Cheltenham	Cheltenham MTaC
75	Bracknell	Bracknell MTaC
76	Basingstoke	Basingstoke MTaC
77	Warrington	Warrington MTaC
78	Redditch	Redditch MTaC
79	Worcester	Worcester MTaC

Rank	Location	Comprised of
80	Hastings	Hastings MTaC
81	St Helens	St Helens MTaC
82	Stevenage	Stevenage MTaC
83	Mansfield	Mansfield MTaC
84	Blackburn	Blackburn MTaC
85	Harlow	Harlow MTaC
86	Thanet	Thanet BUA
87	Darlington	Darlington MTaC
88	Bedford	Bedford MTaC
89	Barnsley	Barnsley MTaC
90	Aylesbury	BUASDs: Aylesbury, Stoke Mandeville
91	Grimsby	Grimsby MTaC
92	Maidstone	Maidstone MTaC
93	Scarborough	Scarborough BUA
94	Kettering	Kettering BUASD
95	Burnley	Burnley MTaC
96	Carlisle	Carlisle MTaC
97	High Wycombe	High Wycombe MTaC
98	Runcorn	Runcorn BUASD
99	Derry/Londonderry	DERRY CITY SDL
100	Nuneaton	Nuneaton MTaC
101	Clacton-on-Sea	Clacton-on-Sea BUA
102	Weston-super-Mare	Weston-Super-Mare MTaC
103	Telford	Telford MTaC
104	Worthing	Worthing MTaC
105	Burton upon Trent	Burton upon Trent MTaC
106	Eastbourne	Eastbourne MTaC
107	Scunthorpe	Scunthorpe MTaC

Source: Ofcom

Selecting a cut-off point

A6.25 In the May 2022 Consultation,[32] we explained that, having identified and ranked a list of 107 potential high density areas, we then considered three possible cut-off points within

[32] May 2022 Consultation, paragraphs 4.26-4.37.

this ranking, noting that after the first 20 areas there is a slower decline in mobile data traffic and base station density. We considered that 20, 40 and 80 areas would be reasonable cut-off points, and expressed an initial preference for 40 areas. We said that, after the top 80 areas in these rankings, we would expect deployments to be fewer and therefore local licences to be sufficient (May 2022 Consultation, paragraph 4.32).

A6.26 As discussed in section 4,[33] in light of stakeholders' comments, we have decided to select the top 80 town and cities from our list of 107 potential high density areas, instead of the top 40 that we initially proposed.

A6.27 As shown in Table A6.6 below, selecting the top 80 areas instead of the top 40 that we initially proposed represents an increase of 1% of the total UK geographic landmass that will be covered (i.e., from 3.1% to 4.1%) and an increase of 8.3% in the proportion of the UK population (i.e., from 38.7% to 47.0%). In short, based on the boundaries we outlined in the May 2022 Consultation, the top 80 areas accounted for 4.1% of total UK landmass (4.14%) and captured 47% of the UK population.

Table A6.6: Population and area statistics for the top 40 and the top 80 high density areas, based on area boundaries in the May 2022 Consultation

	Area (km^2)	Area (% of total)	Population	Population (% of total)
Top 40	7,558.43	3.1	24,429,717	38.7
Top 80	10,047.67	4.1	29,677,833	47.0
Total UK	**242,495.00**	**100**	**63,159,035**	**100**

Source: Ofcom; population statistics from 2011 UK Census

A6.28 Table A6.7 below shows the ranking of the top 80 high density areas which we have decided to select from our initial list of 107 potential high density areas, specifying which areas we have decided to include in addition to the top 40 that we initially proposed. Figure A6.5 is a graphical representation of Table A6.7, showing a map of the top 40 (amber) and top 80 (amber and green) high density areas, based on the boundaries we consulted on in the May 2022 Consultation.

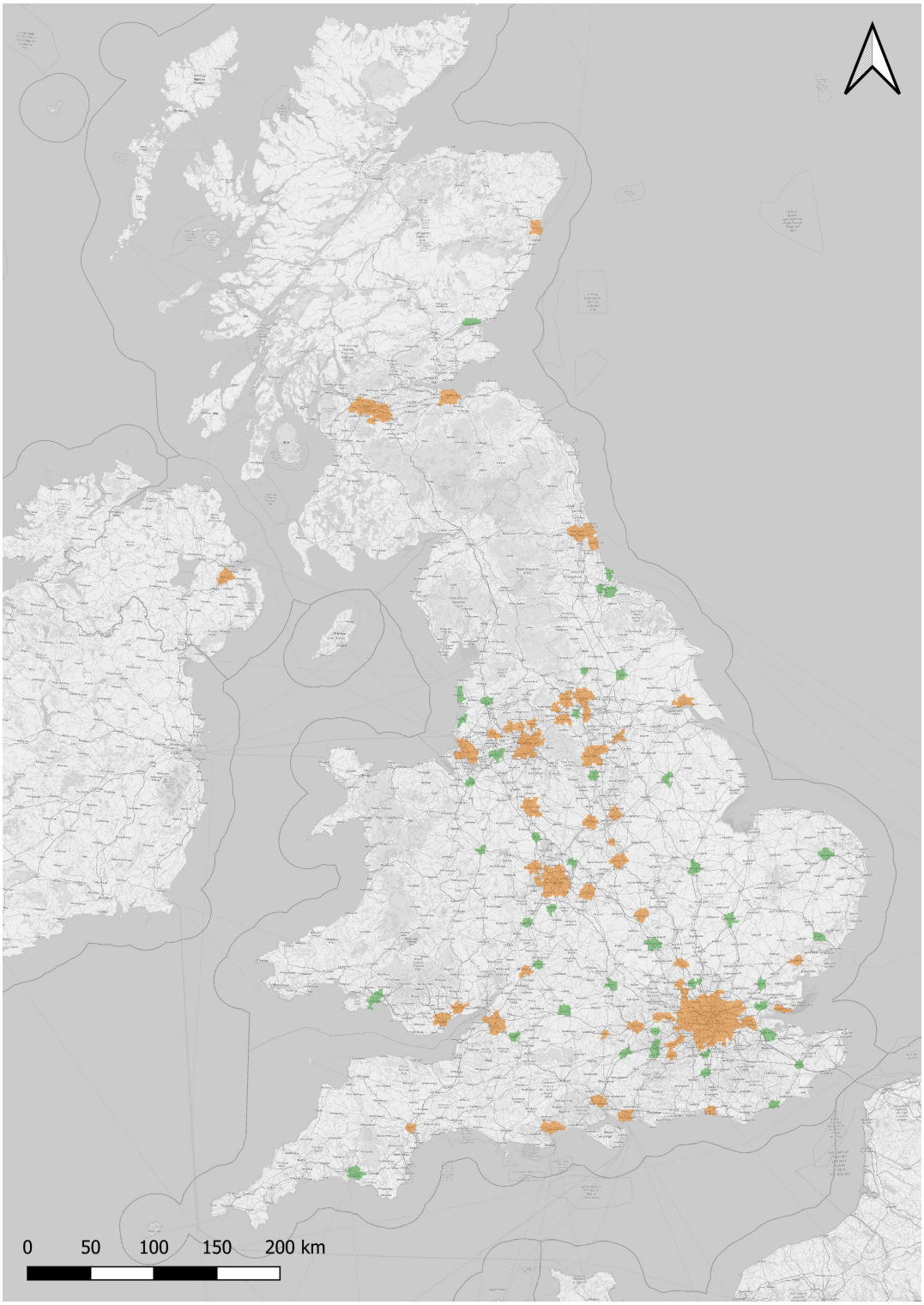
[33] Paragraphs 4.25-4.28.

Table A6.7: High density areas proposed in the May 2022 Consultation, in order of ranking (colours correspond to map below)

Top 40		Top 41-80	
Greater London	Belfast	Plymouth	Blackpool
Greater Manchester	Aberdeen	Chester	Bath
Greater Glasgow	Stoke-on-Trent	York	Dundee
Greater Birmingham	Leicester	Oxford	Basildon
Cardiff	Huddersfield	St Albans & Hatfield	Farnborough & Aldershot
Tyne & Wear	Guildford, Woking & Weybridge	Peterborough	Tamworth
Bristol	Southampton	Shrewsbury	Dewsbury
Liverpool	Colchester	Cambridge	Swindon
Edinburgh	Exeter	Ashford	Lincoln
Leeds & Bradford Area	Hull	Norwich	Chesterfield
Sheffield	Bournemouth & Poole	Milton Keynes	Southport
Reading	Rochdale	Crawley	Ipswich
Nottingham	Newport	Redhill & Reigate	Harrogate
Wolverhampton	Derby	Medway Towns	Cheltenham
Northampton	Wigan	Stafford	Bracknell
Southend	Loughborough	Chelmsford	Basingstoke
Brighton	Portsmouth & Gosport	Hartlepool	Warrington
Doncaster	Gloucester	Preston	Redditch
Luton	Slough & Maidenhead	Middlesbrough	Worcester
Coventry	Newbury	Swansea	Hastings

Source: Ofcom

Figure A6.5: Map showing top 40 (amber) and top 80 (green) potential high density areas, based on boundaries used in the May 2022 Consultation



Source: Ofcom, base map © OpenStreetMap contributors; N.B. Orkney and Shetland not shown as no areas there were designated as high density areas

Adjusting the boundaries of high density areas to be simpler to use

Adjusting the boundaries to be simpler to use

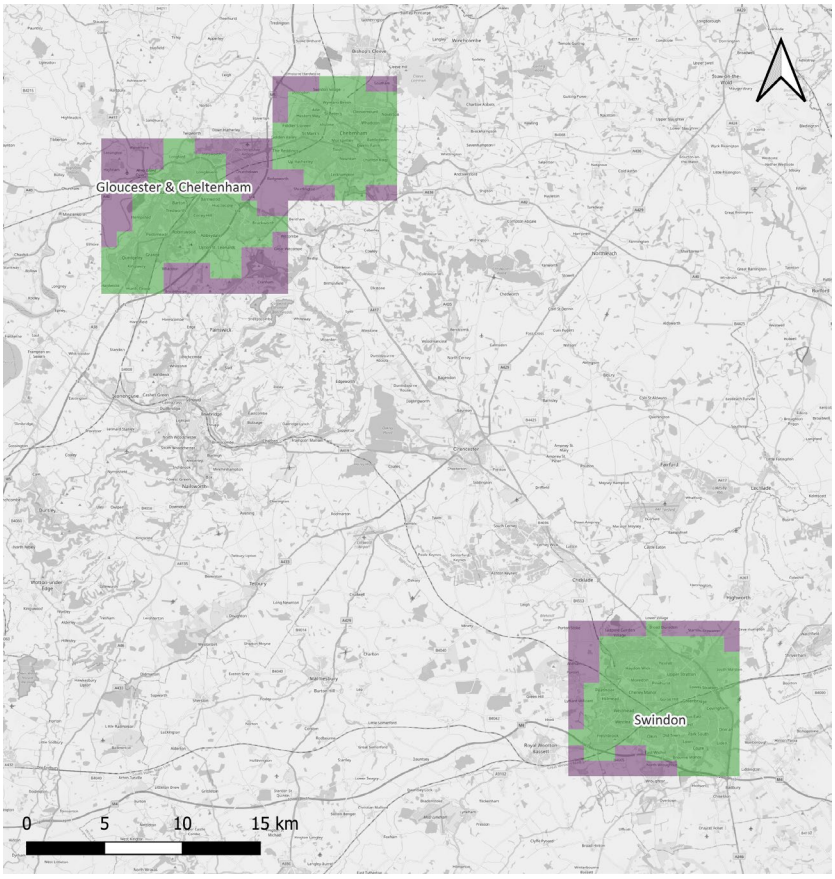
A6.29 As discussed in section 4, BT/EE and Vodafone suggested that the boundaries we had proposed for the high density areas were unduly granular and irregular. In light of these comments, we have decided to further simplify the boundaries of the high density areas.

A6.30 In most cases, we did this by drawing a rectangle, aligned to the Ordnance Survey 1km grid, around the boundary of each area, rather than following the 1km grid squares around the boundary.

A6.31 Where the rectangles created as part of this process overlap (as is particularly the case around the largest urban areas and conurbations), we have combined them together into a single high density area.

A6.32 The result is illustrated in the example below. While we have drawn a simple rectangle around Swindon (which has remained its own discrete area), we have combined Gloucester and Cheltenham together into one area. The original high density areas outlined in the May 2022 Consultation are shown in green, with the new boundaries shown in purple.

Figure A6.6: map showing original (green) and new (purple) boundaries of Gloucester & Cheltenham and Swindon high density areas



Source: Ofcom, base map © OpenStreetMap contributors

Combining nearby areas

A6.33 BT/EE and Vodafone suggested that we should combine clusters of high density areas which were close to each other. They argued that this could enable more efficient use of spectrum than leaving narrow gaps between distinct high density areas. VMO2 made similar comments, and suggested that we might, for example, combine Manchester, Wigan and Rochdale, or the Leeds & Bradford Area and Huddersfield.

A6.34 In light of these comments, we have aimed to keep a minimum distance between separate areas of 4-5km, due to the need for coordination between high density and low density areas, and to avoid creating "dead zones" in between nearby high density areas for award winners within high density areas to observe a field strength limit at the boundary of areas. The 4-5km distance we have used is based on our estimates of the reuse distances between the sorts of systems we expect new mmWave users are likely to deploy. We discuss these use cases in section 2.

A6.35 Doing this meant combining the following areas into one:

a) Middlesbrough and Hartlepool combined into a single area, "**Teesside**"

b) Sheffield and Chesterfield combined into a single area, "**Sheffield City Region**"

c) Bristol and Bath combined into a single area, "**Bristol & Bath**".

A6.36 In some cases, however, we have left nearby areas separate for the following reasons:

a) In a handful of areas, we observed that there were terrain blockers (generally large hills or ridges) between areas, and we determined that these would potentially make it easier to contain emissions within a single area (or on one side of a large terrain feature such as a hill). For this reason, and to avoid including excess amounts of open countryside in the high density areas, we have kept areas apart where there are clear terrain blockers between them. This is the reason we did not combine the Medway Towns into Greater London, or Dover and Folkestone into a single area.

b) In other cases, we observed that due to the application of the 1km square grid, in practice the first kilometre or so of any given area could be mostly countryside. As we are also aiming to avoid creating artificially large high density areas (i.e. allowing Greater London to encompass most of the southeast of England, or including a huge area of the northeast to try to draw a rectangle connecting Sheffield and Doncaster), we took this into account when determining whether to combine certain areas together. It is for this reason that we did not combine Doncaster into Sheffield, or Reading, Bracknell, Crawley or Farnborough & Aldershot into Greater London.

Adjusting the boundaries to include major airports

A6.37 In the May 2022 Consultation,[34] we considered whether we should include some potential demand hotspots (e.g., airports, train stations and sports stadia) by (i) creating specific

[34] May 2022 Consultation, paragraphs 4.38-4.41.

additional high density areas for those locations or (ii) incorporating them into the nearest existing high density area. We provisionally concluded this would not be necessary because (i) the majority of major sports stadia and train stations, and a significant number of major airports, would already be within the high density areas that we initially proposed (i.e., the top 40) and (ii) Shared Access licences should be sufficient to provide spectrum access to those users looking to deploy mmWave spectrum for new uses in any potential demand hotspots falling outside high density areas.

A6.38 All four MNOs argued that we should include specific additional locations that they considered to be important, whether this was additional towns or specific types of site (such as airports, sports stadia or business parks). BT/EE, Vodafone and VMO2 specifically suggested that we should include major airports in our high density areas.

A6.39 In light of those comments, we checked which of the UK's largest airports[35] were included or excluded from the high density areas defined according to the methodology set out above (i.e., by selecting the top 80 areas and simplifying their boundaries). Since we noted that several major UK airports were partially, but not entirely, included within high density areas, we extended the relevant high density areas to fully include these major airports. To ensure proportionality, we did this by adding as little additional space as we could reasonably do, so in some instances we added an entire row or column, while in other cases we added a small additional box. In this way, the following airports became fully included in the high density areas:

a) Aberdeen

b) Bristol

c) Edinburgh

d) Gatwick (included in the Crawley high density area)

e) Leeds-Bradford

f) Manchester

g) Newcastle (included in the Tyne & Wear high density area)

Adding three further high density areas to cover Stansted airport, Dover and Folkestone

A6.40 In response to the stakeholders' comments summarised above, we have also added Stansted Airport, Dover and Folkestone as separate high density areas.

A6.41 We considered it appropriate to add Stansted Airport due to the extremely high passenger numbers at Stansted compared to those for any other airport not already included in the

[35] We did this by looking at any UK airport with more than 1 million passengers based on 2019 passenger figures, the last year before the COVID-19 pandemic had a significant impact on international travel.

high density areas.[36] We added Stansted Airport by drawing a rectangle around the airport's site using the 1km square grid, as we have done with other high density areas.

A6.42 In addition to airports, we identified that some busy ferry ports would be areas of sufficiently high traffic that we would consider them likely targets for mmWave deployment. The busiest passenger ferry port in the UK is the Port of Dover, followed by ports in Southampton and Portsmouth which were already included in our high density areas. We have therefore decided to include the Port and town of Dover (in line with our approach of including entire towns rather than trying to predict exact deployment areas, giving award winners flexibility in how they deploy) in our final high density areas.

A6.43 We have included Folkestone for the same reasons, in this case because of the Folkestone Eurotunnel Terminal, which has a notably larger site than most major rail stations due to the fact that vehicles embark here.

A6.44 In both these cases, the Port and Eurotunnel Terminal each saw between 10 and 11 million passengers in 2019 (as with airports, we used 2019 passenger data as the last year before the COVID-19 pandemic affected international travel).

A6.45 We have therefore decided to include the towns around both of these sites. We did this by using the 2011 Built-Up Area data from the ONS, as we have done for the inclusion of additional towns with high peak hour data traffic. We then used the 1km square grid to draw rectangles around both of these towns, as we have done elsewhere, creating new high density areas for Dover and Folkestone.

Adjusting the boundaries of high density areas to exclude some locations

Adjusting the boundaries to exclude large tracts of land which we consider less likely to attract future deployment of mmWave

A6.46 Some of the adjustments that we have made to simplify boundaries, including drawing rectangles around areas, have resulted in larger high density areas, compared to those that we initially drew sticking closely to the boundaries published by the published by the UK statistics agencies. To mitigate the risk of unintentionally capturing large tracts of land which we consider less likely to attract future deployment of mmWave, we have removed some of the space added as a result of such adjustments around the following areas:

a) Greater London (doing this leads to Basildon and Chelmsford being retained as separate high density areas, rather than being absorbed into Greater London)

b) Greater Manchester

c) Greater Glasgow

[36] In 2019, Stansted Airport saw ~28m passengers; the next largest airport not to already be included in one of the high density areas was Belfast International Airport, which had ~6m passengers the same year.

d) Leeds & Bradford Area

e) Tyne & Wear

f) Greater Birmingham

g) Bristol & Bath

h) Swansea

i) Liverpool

j) Hull

k) Plymouth

A6.47 As explained in paragraph A6.34 above, earlier in the process we had generally ensured that separate high density areas were at least 4-5km apart to facilitate coordination and avoid spectrum lying fallow in some areas. In line with this approach, here we have also aimed to ensure a minimum size of 4-5km in any shape forming part of a high density area, to avoid creating small areas which would have made coordination difficult or lead to dead zones where spectrum might lie fallow, as outlined in more detail below.

Avoid small areas

A6.48 Keeping to the same principle explained in the paragraph above, and at paragraph A6.34, we have tried to ensure a minimum size of 4-5km in either dimension for any individual shape within a high density area. In other words, we have aimed to avoid small "notches" to extend from areas, or narrow "necks" between areas, as these could have led to difficulties in coordination for users. By this stage in the process, there were a small number of necks between areas or notches extending from one side of an area which we then added to or smoothed out, as follows:

a) **Greater Manchester**: some additional space added to the east and west of Rochdale (effectively drawing a rectangle around what was previously the separate Rochdale high density area).

b) **Cardiff & Newport**: an additional block to the east of Cardiff and south of Newport has been added to resolve a thin, 1km neck connecting the two areas. While this is a relatively large additional area, this extends the high density area along the coast and into the Severn Estuary, rather than inland where it would have captured smaller towns which we did not consider would be likely targets for extensive mmWave rollout. Extending the area in this way should allow award winners flexibility without limiting access to other users who might be interested in Shared Access licences on a localised basis (as we currently do not expect any significant use of this band offshore).

A6.49 In two cases we have left an area less than 5km in one dimension as it is:

a) **Leeds & Bradford Area**: a 14x3km block at the south side of Huddersfield is likely to be large enough to not cause any coordination issues either side of the boundary; additionally, extending the rest of the high density area to be level with this would add a disproportionate amount of extra space.

b) **Stansted Airport**: this area is 4x5km in total, but it would not be possible to extend this to a 5x5km square without making a completely arbitrary decision about which side the additional row of squares should go on; the entire airport site is already covered by the 4x5km rectangle.

Adjusting the boundaries to exclude some MOD sites

A6.50 In light of the MOD's needs in relation to two key military sites (RAF Waddington and Royal Military Academy Sandhurst), we have removed:

a) RAF Waddington from the **Lincoln** high density area; and

b) Royal Military Academy Sandhurst and the surrounding area, including training grounds, from the **Farnborough & Aldershot** high density area.

Minor practical amendments

A6.51 We have made a number of small practical amendments to tidy up the shapefiles we produced through this process, to make them consistent and easier to use.

Using the "dissolve" and "multipart-to-single parts" tools

A6.52 We have used the "dissolve" and "multipart to single part" tools within QGIS[37] to convert an original layer on which the high density areas were defined as thousands of individual 1km grid squares, to a layer where each high density area was represented by a single polygon.

Making manual edits in relation to the Tyne & Wear and Bournemouth high density areas

A6.53 We have made some manual edits to the boundaries created by the ONS 1km square grid to simplify the boundaries of two high density areas: Tyne & Wear and Bournemouth. Specifically, we have used the "vertex tool" in QGIS to manually edit the vertices of the shapes representing these areas to extend them into the correct position, using coordinates from existing vertices which were in the right plane on each of the *x* and *y* axis.

Using the British National Grid for the Belfast high density area

A6.54 For our consultation proposals, we had used the Irish National Grid to determine the boundaries of any high density areas in Northern Ireland, which meant that the Belfast high density area was misaligned when compared to all others. To ensure a consistent

[37] QGIS is the mapping software package which we used to create the shapefiles defining the high density areas; other mapping or geospatial information software packages would have the same functionalities, but may give these different names.

approach across all high density areas, we have decided to draw a polygon aligned with the British National Grid for the Belfast high density area.[38]

Simplifying vectors to reduce number of vertices

A6.55 As a final practical step, we have used the "simplify" tool within QGIS to reduce the number of vertices on any high density area. As the polygons representing each high density area had originally been composed of individual 1km squares, the dissolved shapes had retained vertices at the points along the boundary of each area where each 1km square had touched the next. This meant that a simple rectangle could have 30-40 vertices, and a more complex shape such as Greater London was composed of hundreds of individual points. To correct this, we have used the "simplify" tool, with "distance (Douglas-Peucker)" selected as the simplification method and the tolerance set to 1m. This greatly simplified the way the high density area polygons can be described, though it did not alter the shapes themselves.[39]

Maps and list of high density areas

A6.56 Applying the methodology outlined above, we have decided to designate all of the 68 high density areas listed in Table A6.8 below.

Table A6.8: list of all high density areas

Name	Rank	Name	Rank
Greater London	1	Chester	35
Greater Manchester	2	York	36
Greater Glasgow	3	Oxford	37
Greater Birmingham	4	Peterborough	38
Cardiff & Newport	5	Shrewsbury	39
Tyne & Wear	6	Cambridge	40
Bristol & Bath	7	Ashford	41
Liverpool	8	Norwich	42
Edinburgh	9	Milton Keynes	43
Leeds & Bradford Area	10	Crawley	44

[38] We did this by using the "minimum bounding geometry" tool in QGIS, selecting only the Belfast high density area from a layer containing our original top 80 high density areas, then choosing "envelope (bounding box)" from the "geometry type" dropdown. This drew a rectangle around Belfast which was aligned north-south and east-west with all of our other high density areas, and this new feature was added to the shapefile containing the rest of the revised high density areas.

[39] N.B. QGIS has not automatically set one of the corners as the "start" of the shape, so a simple rectangle will generally have six vertices: one for each corner, and two marking the start and end of the shape which overlap with each other, which are generally along one side of the shape somewhere and unfortunately not in a corner. We are not aware of a straightforward fix to this, but consider that this is unlikely to have any material impact on use of the shapefiles.

Name	Rank	Name	Rank
Sheffield City Region	11	Medway Towns	45
Reading	12	Stafford	46
Nottingham	13	Chelmsford	47
Northampton	14	Teesside	48
Southend	15	Preston	49
Brighton	16	Swansea	50
Doncaster	17	Blackpool	51
Luton	18	Dundee	52
Coventry	19	Basildon	53
Belfast	20	Farnborough & Aldershot	54
Aberdeen	21	Swindon	55
Stoke-on-Trent	22	Lincoln	56
Leicester	23	Southport	57
Southampton	24	Ipswich	58
Colchester	25	Harrogate	59
Exeter	26	Bracknall	60
Hull	27	Basingstoke	61
Bournemouth & Poole	28	Warrington	62
Derby	29	Redditch	63
Loughborough	30	Worcester	64
Portsmouth & Gosport	31	Hastings	65
Gloucester & Cheltenham	32	Dover	66*
Newbury	33	Folkestone & Hythe	67*
Plymouth	34	Stansted Airport	68*

*Source: Ofcom; * Added post-consultation in response to stakeholder comments; not ranked along with other areas*

A6.57 Our final high density areas have captured a larger percentage of the UK's population and landmass, as shown in Table A6.9 below:

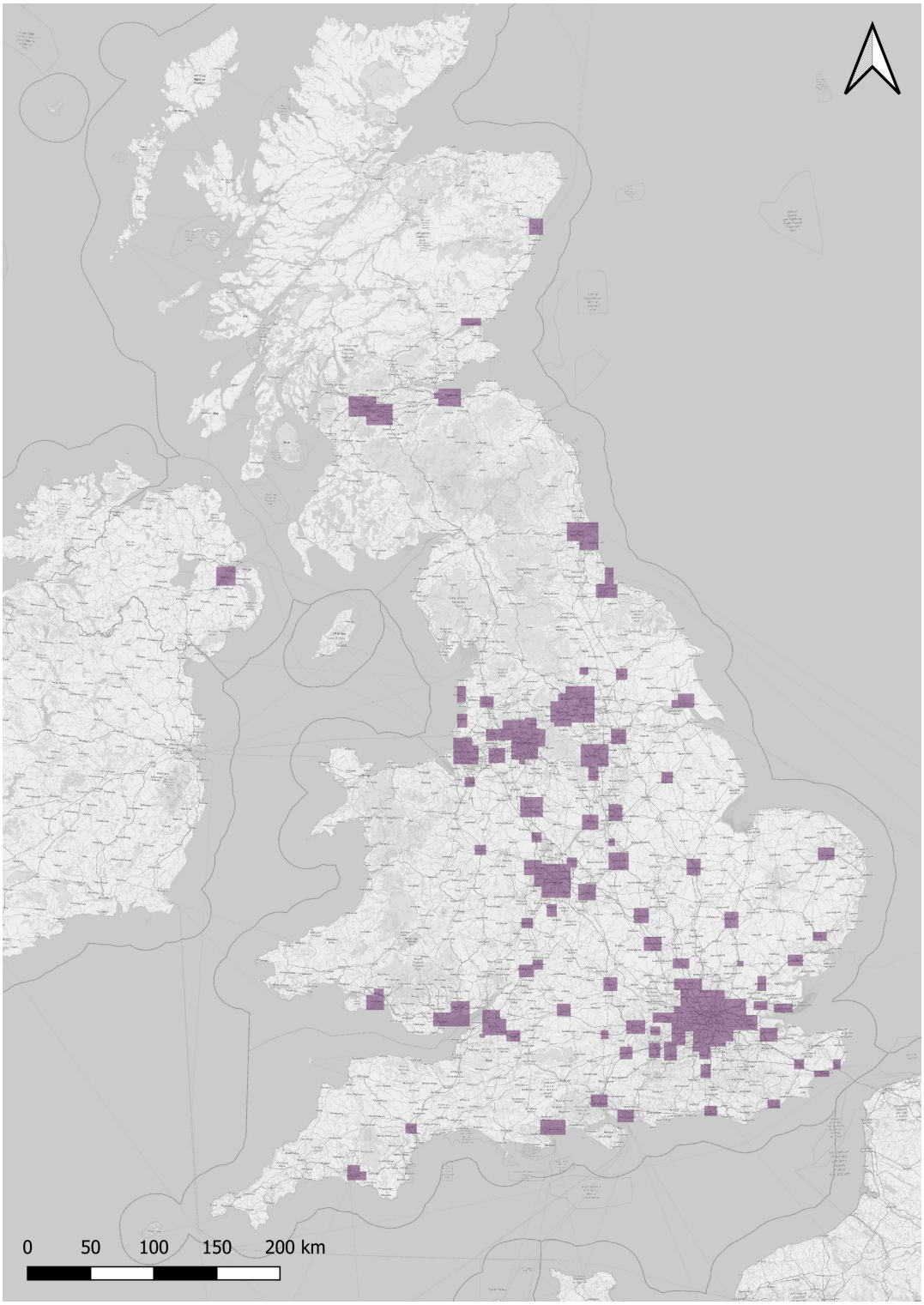
Table A6.9: Population and area statistics for the top 40 and top 80 high density area proposals from the May 2022 Consultation, and from final high density areas

	Area (km^2)	Area (% of total)	Population	Population (% of total)
Top 40 (May 2022 Consultation)	7,558.43	3.1	24,429,717	38.7
Top 80 (May 2022 Consultation)	10,047.67	4.1	29,677,833	47.0
Final high density areas	**15,626.29**	**6.4**	**33,145,706**	**52.5**
Total UK	*242,495.00*	*100*	*63,159,035*	*100*

Source: Ofcom

A6.58 Figure A6.7 below shows a map of all our high density areas.

Figure A6.7: map showing the 68 high density areas that we have decided to designate



Source: Ofcom, base map © OpenStreetMap contributors; N.B. Orkney and Shetland not shown as no areas there have been designated as high density areas

A7. Cost modelling for fixed link clearance within the 26 GHz and 40 GHz bands

A7.1 We have undertaken cost modelling to understand the likely incremental costs that would be incurred by existing fixed link users as a result of Ofcom clearing the 26 GHz and 40 GHz bands of the fixed links which operate in and around high density areas.

A7.2 In the May 2022 Consultation,[40] we outlined our approach to modelling the cost of clearance. In response to our proposals, we received several comments regarding our approach. Some stakeholders suggested we had accurately estimated the costs involved or had used an appropriate assumption for the general replacement timescales for fixed links.[41] However, several other stakeholders disagreed with our cost estimates and suggested that they were too low and did not include certain relevant costs.[42] We have engaged further with some stakeholders to better understand their responses.

A7.3 Following a review of these comments we have updated a number of input assumptions used in our model. We have also revised our "baseline scenario" to include higher ongoing costs, due to stakeholder comments and given the uncertainty associated with the costs of moving individual fixed links.

A7.4 Given the degree of uncertainty around costs, where reasonable we have chosen conservative estimates to ensure that we have factored in the higher end of potential cost scenarios. We consider that the estimates presented in this annex are therefore likely to be overestimates of the costs of clearing fixed links operating in and around high density areas in the 26 GHz and 40 GHz bands.[43] Our revised cost estimates are shown in Table A7.1 below.

A7.5 The results of this modelling exercise inform our assessment of the proportionality of clearing existing fixed links from the 26 GHz band in section 5 and 40 GHz band in section 7.

A7.6 In this annex we set out our overall approach to cost modelling and key modelling assumptions.

[40] May 2022 Consultation, annex 8.
[41] UKWISPA response to the May 2022 Consultation, p. 3, response to Q.10; MLL response to the May 2022 Consultation, p. 8, response to Q.10.
[42] Airwave response to the May 2022 Consultation, p. 6, response to Q.10; BT/EE response to the May 2022 Consultation, pp. 20-21; H3G response to the May 2022 Consultation, p. 44; JRC response to the May 2022 Consultation, p. 5, response to Q.10; techUK response to the May 2022 Consultation, p. 5, response to Q.10, Vodafone response to the May 2022 Consultation, p. 13; [CONFIDENTIAL ✂].
[43] Using the final number of 68 high density areas (HDAs).

Table A7.1: Summary of the present value of costs for clearing the links in and around the 68 high density areas from the 26 GHz and 40 GHz bands

Band	Baseline scenario (£m)
26 GHz	7.6
40 GHz (MBNL)	35.9
40 GHz (H3G)	0.6

Source: Ofcom; N.B. Ofcom baseline scenario including one-off and ongoing costs, discounted over a 20-year time period.

Overall approach

A7.7 The objective of our modelling exercise is to estimate the incremental costs to existing fixed link users to maintain their current service through other means. This allows us to assess the proportionality of our decision to start the statutory process to revoke licences to operate fixed links in and around high-density areas using the 26 GHz band, and the Spectrum Access licences in the 40 GHz band. We investigate incremental costs because the relevant costs for our assessment are the additional costs that would not have been incurred if the user had kept their existing fixed links in the 26 GHz and 40 GHz bands.[44]

A7.8 We are interested in the costs of clearance of fixed links in and around high density areas only, given our decision to allow continued use of the 26 GHz and 40 GHz bands for fixed links in low-density areas as set out in sections 5 and 7.[45] As we are consulting on the method used to determine which links will need to be cleared and which will be able to continue operating, we have retained the approach used for the May 2022 consultation in our modelling, in that we have assumed that all fixed links in the 68 high density areas we have identified in section 4, as well as all fixed links with at least one end within 25km of any of these areas, will need to be cleared. This is a more conservative approach than that on which we are consulting, which is set out in annex 16 and is based on detailed coordination and gives a total of 3,262 MBNL links in the 40 GHz band and 691 links in the 26 GHz band that need to be cleared compared to 3,924 and 835 used in our modelling.

A7.9 The key steps in our modelling set out in the May 2022 Consultation were as follows:

[44] For example, users of fixed links incur maintenance costs in their existing band (i.e. the 26 GHz band and the 40 GHz band) and would expect to also incur maintenance costs for any new fixed link in a new band. However, we would only include maintenance costs if we expected the new maintenance costs to be higher (or lower) than the old maintenance costs, and if that was the case the costs would be calculated from the difference between the expected new maintenance costs and the old maintenance costs.

[45] See paragraph 5.36 for 26 GHz and 7.168 for 40 GHz. We are revoking the 40 GHz licences in their entirety, but we will offer to reauthorise use of the existing 40 GHz licensees existing fixed links which operate outside of high density areas and which are unlikely to receive interference from mobile services operating in high density areas

a) First, at a high level, we identified the most cost-effective migration alternatives for existing fixed link users. This involved considering the options available to users, such as migrating to an alternative spectrum band or to leased lines. The higher expected costs of leased lines meant we focused our subsequent modelling on migrating fixed links to alternative spectrum bands.

b) Second, we estimated the incremental costs that could arise when migrating a fixed link to a new spectrum band. This involved forecasting the incremental operating and capital costs and applying an appropriate discount rate. We estimated the average incremental cost of moving a link by assuming a uniform distribution of ages of links across our assumed asset life of seven years, and then depreciating these links over the five-year notice period for revoking existing licences (the "revocation period"). The remaining un-depreciated value was used as the incremental cost of replacement, to account for the natural replacement of links during the revocation period and that a new link is not a like-for-like replacement of a partly depreciated link.

c) Third, we developed a baseline scenario which assumed that users can move all existing links into a new spectrum band. We then aggregated the estimated one-off costs of moving bands under the different clearance options set out in section 5 of the May 2022 Consultation.[46] [47]

d) Fourth, we developed sensitivities for our analysis to test our modelling assumptions in the baseline scenario.

   i) The first sensitivity was a "higher ongoing costs" scenario to illustrate how the aggregated costs in the baseline scenario could change under alternative modelling assumptions. For the higher ongoing costs scenario, we adapted the baseline scenario so that only a higher cost migration option was available to certain links.

   ii) In the second sensitivity, we applied a longer useful lifetime for existing fixed link equipment to the baseline and higher ongoing cost scenario. In our baseline scenario, we assumed that useful equipment life was seven years but in the sensitivities we assumed 15 years.

A7.10 This gave us a total of four scenarios: (i) our baseline scenario; (ii) the higher ongoing costs scenario; (iii) the baseline scenario but assuming a useful equipment life is 15 years; and (iv) the higher ongoing costs scenario but assuming a useful equipment life is 15 years.

A7.11 In this statement, we have continued to use this broad overall approach, adjusted and updated where relevant to account for stakeholders' responses to the May 2022 Consultation and further information gathered from stakeholders.

[46] The options set out were to clear the 26 GHz and 40 GHz bands in the top 20, top 40, or top 80 high density areas, or to clear all fixed links in the band on a nationwide basis.

[47] For the purposes of our revised modelling exercise, we are only considering the cost of clearing existing fixed links in and around high density areas. In all cost scenarios we have used the maximum number of potential links to be cleared in and around high density areas, as described in section 4.

A7.12 For this exercise we are interested in the total costs of clearing existing fixed links from the 26 GHz and 40 GHz bands for making these bands available for new uses. We consider it appropriate and proportionate to do this by estimating the average clearing costs (i.e. the costs that a typical fixed link user is likely to incur) and multiplying this by the total number of links we expect to be affected. As a result, it is possible that individual fixed link users in specific locations and under specific circumstances might face higher or lower costs for moving a fixed link, relative to the average costs which we have estimated.

A7.13 Below, we describe each of the steps and our assumptions in the modelling

Migration alternatives for existing fixed link users

Our proposals

A7.14 In the May 2022 Consultation,[48] we identified two potential migration options for existing fixed links if the 26 GHz and/or 40 GHz bands are cleared. These were:

a) existing users relocate to a different spectrum frequency;[49] and

b) existing users move to a wired fibre connection (i.e. a leased line product).

A7.15 We proposed to estimate the indicative costs of an operator using leased lines provided by Openreach by using data from previous Ofcom market reviews. In Ofcom's most recent market review, the 2021-2026 Wholesale Fixed Telecoms Market Review, we found that in cases where there is no need for 'excess construction charges', the costs of a leased line are likely to be around £3,000-£4,000 for a 5km 1Gbit/s leased line.[50]

A7.16 However, we considered that existing fixed link sites might not necessarily be situated close to the existing Openreach leased line network. Therefore, if a leased line is used to replace an existing fixed link, then a network extension could be required, with associated excess construction charges. We estimated indicative costs of laying a new connection to be about £86,000 per 1km of line.[51] However, we recognised this may be an overestimate for some fixed links if users could make use of existing ducts that may be available.

A7.17 In the May 2022 Consultation, we outlined our estimate of the costs of moving fixed links to a new spectrum frequency. In general, these costs were significantly lower than our expectation for the charges for leased lines. As a result, we considered it appropriate to

[48] May 2022 Consultation, paragraph A8.10.
[49] In the May 2022 Consultation (paragraph A8.10 and footnote 53), we said that we expect users would be able to move their links to a new spectrum band. Based on preliminary analysis, we expect that a combination of the 18, 23 and 38 GHz bands would be the most likely destinations for migrating 26 GHz fixed links. 40 GHz users may also be able to move to other bands in which they have block assigned licences. As part of any migration, they may need to buy new equipment (e.g., transmitter) to be able to operate in the new frequency.
[50] Ofcom's Statement "2021-2026 Wholesale Fixed Telecoms Market Review", published 18 March 2021, estimated the cost of a 5km EAD leased line provided by Openreach with no excess construction charges to be between £3,000-4,000 (graph A9.1).
[51] Ofcom's Statement "Business Connectivity Market Review", published 28 June 2019, estimated that a 1km network extension that requires a new duct would cost about £86,000 (paragraph 6.56).

estimate the cost of clearing fixed links in both the 26 GHz and 40 GHz bands by assuming that all existing fixed links would migrate to a different spectrum band.[52]

A7.18 In doing so, we noted that there may be individual fixed links that could be replaced more cost effectively using a wired leased line connection, either provided by Openreach or by another telecoms provider. We proposed that leased lines would likely to be relevant for only a small number of fixed links and expected that any effect on overall costs to be minimal.

Stakeholder comments

A7.19 BT/EE commented that "many of the existing 40 GHz links would anyway potentially be replaced by fibre within the five-year revocation period".[53]

A7.20 H3G commented that "Ofcom recognises that there could be some instances where MBNL may need to replace a fixed link with a fibre connection. Its view is that this will be the case where it is more cost effective to use fibre backhaul than microwave. Our view is that there could be instances where fibre will be the only option to replace a 40GHz link. [.....] there could be cases where there are no suitable locations for replacement sites or additional hops. Like Ofcom, we would expect fibre costs to be considerable in these areas – in most cases, the reason we use fixed links in the first place is because of the difficulty/cost of fibre backhaul."[54]

Our decision

A7.21 On review of the Openreach price list, for a standard 1 Gbit/s Ethernet leased line (product name EAD 1000), the connection charge from 01/04/2023 is £2,058 and the annual rental is £2,100.[55] This cost for a leased line is lower than that which we had considered for the May 2022 Consultation. We note that this lower leased line cost could mean that, where network extensions are not required, it is likely that it would be cheaper to replace a fixed link with a leased line. This observation is supported, at least in the case of MBNL's 40 GHz links, by BT/EE's comment that there is potential for existing fixed links to be replaced with fibre.

A7.22 Given we plan to clear only the fixed links within the high density areas and surrounding areas, it is likely leased lines would be a possible alternative for the majority of these fixed links without significant network extensions being required. This, coupled with our increased estimates of the costs of building additional hops,[56] suggests that our estimates for the cost of clearance where additional hops are required could be overstated as there may be many cases where it would be more economical to switch to a fibre leased line.

[52] May 2022 Consultation, paragraph A8.12.
[53] BT/EE, p. 26.
[54] H3G, p. 50.
[55] Openreach's webpage "Price list", accessed 27 February 2023: the price applies to any length up to 25km. We note that the list shows details of list prices and it is possible that actual prices may be lower.
[56] Paragraphs A7.87-A7.88.

A7.23 Although we expect the need for network extensions to be limited, we do not have the information to confirm this. Because of this, we have not quantified the potential use of leased lines in our modelling. Instead, we take this information to suggest that our quantified estimate based on modelling additional hops is an upper bound estimate on the cost that will actually be incurred. We discuss modelling additional hops in detail from paragraph A7.72.

A7.24 We have decided as a conservative approach to continue to estimate the cost of clearing fixed links in both the 26 GHz and 40 GHz bands by assuming that all existing fixed links would migrate to a different spectrum band. The potential alternative of using a leased line is just one of the factors indicating that we have adopted a conservative approach to estimating costs.

Estimating costs for existing users that need to migrate to a different spectrum band

A7.25 As explained in the May 2022 Consultation,[57] we have estimated the cost of clearing the 26 GHz and 40 GHz bands by determining the incremental costs associated with moving those fixed links to a different band.

A7.26 When a user moves a fixed link to a new spectrum band it is likely to face two types of costs:

a) The first type would be **one-off transition costs**. For example, this could include replacement of equipment earlier than normal or having to incur additional installation costs from setting up a new link.

b) The second would be **higher ongoing costs** that might arise due to a difference between ongoing costs from operating a fixed link in a new spectrum band compared to the costs of operating in the 26 GHz or 40 GHz band. There could be different reasons why the new band may require higher ongoing costs. For example, more expensive/larger equipment,[58] or needing to use an additional hop[59] with new equipment to maintain the quality of transmission across the fixed link.

[57] May 2022 Consultation, paragraphs A8.14-A8.15.
[58] Larger equipment is likely to require greater space on a tower and therefore higher ongoing rental costs. More expensive equipment will also lead to higher ongoing costs as it will need to be replaced at a higher cost each time the equipment reaches the end of its lifetime. For the purposes of our initial cost estimates, we provisionally assumed the lifetime of equipment is seven years and so it will need to be replaced two times over the 20 year period over which we are assessing costs (March 2022 Consultation, paragraph A8.15 and footnote 56).
[59] Replacing a fixed link with an additional "hop" is where a fixed link is replaced with two fixed links instead of just one. For example, a fixed link could be in locations X and Y. This fixed link could be replaced by two new fixed links, such that one of the new fixed links would connect X and Z, and the other would connect Z and Y. This ensures that X and Y are still connected, but by two fixed links via the intermediary site Z.

Method for estimating one-off transition costs

Our proposals

A7.27 In the May 2022 Consultation,[60] we proposed to estimate one-off transition costs by estimating capital costs for equipment that a user may need to write off, if its licence for a fixed link is revoked and it needs to transition to a different spectrum band. Capital costs will have been already incurred by a user and they will have an expected timeframe (or lifetime) over which they expect to use the equipment before replacing or retiring it. If the clearing of fixed links in and around high density areas in the 26 GHz and 40 GHz bands means that equipment needs to be retired or replaced earlier than expected, then this will result in an incremental cost to the user that would not be incurred if they had been able to continue to use those bands.

A7.28 We proposed to estimate these costs by assessing the difference between a user being able to replace their own equipment according to their normal timeline, and the user having to replace their equipment earlier than scheduled due to their links being cleared from the 26 GHz and 40 GHz bands. We conservatively assumed in this calculation that all telecommunications equipment would need to be replaced when transferring to a new band.

A7.29 To calculate the one-off transition costs, we proposed to do the following:

a) Estimate the average current value of fixed link telecommunications equipment using an estimate for the original capital expenditure and the average current age of the equipment.

b) Determine the annual cost of existing equipment for each year for the remainder of the equipment's lifetime based on the expected depreciation and cost of capital.[61]

c) Consider that existing users could use the five-year revocation notice period to manage the transition to a new spectrum band. We assumed that operators could reduce the need to write off capital equipment by moving an individual link to a new band when it reaches the end of its lifetime. This could be at different points over the course of the five-year revocation period. Given this, we estimated costs on the basis that:

   i) capital costs will only be written off for equipment that has a remaining lifetime at the start of the revocation period that is greater than five years; and

   ii) the capital costs written off for this equipment are based on the value at the end of the five-year revocation period.

[60] May 2022 Consultation, paragraphs A8.16-A8.26.
[61] We used a weighted average cost of capital ("**WACC**") of 5.7% based on the most recent estimate of WACC used for Mobile Network Operators (MNOs) in Ofcom's 2021-2026 Wholesale Voice Markets Review. We considered this appropriate as an estimate for fixed link users given the use of fixed links to provide mobile communication services.

d) Determine the present value of these costs by discounting the costs to a present value using the social time preference rate.[62]

Stakeholder comments

A7.30 H3G[63] argued that the appropriate cost to include should be [CONFIDENTIAL ✂]. Using this approach, H3G estimated the total costs of clearance of all of MBNL's 40 GHz links to be much higher at £84m.[64] In response to a statutory information request, MBNL stated that it would [CONFIDENTIAL ✂]. For this reason, MBNL said that the one-off transition impact should be higher.[65]

A7.31 H3G also said that[66] difficulties in procuring equipment will reduce the proportion of the revocation period that can be used to replace links.

A7.32 VMO2 [CONFIDENTIAL ✂].[67]

Our decision

A7.33 Although we agree that it would not be good business practice to transition links on the final days or weeks of the revocation period, we do not agree that [CONFIDENTIAL ✂]. We also believe that any potential difficulties in procuring equipment would not have a material impact on the revocation period utilisation. We note that we have maintained our increase to the final average per-link costs specifically to account for potential constraints to utilising the full five-year revocation period (see paragraphs A7.66-A7.69 below). We have decided to keep the initial modelling simplification assumption that the full revocation period could be used.

A7.34 However, we have included the assumption that only four years of the revocation period can be utilised in our higher ongoing costs sensitivity scenario which captures the effect of not being able to make effective use of the full revocation period for a variety of reasons, such as needing to complete transition earlier than the final deadline or initial uncertainty over which specific links will need to be transitioned.[68]

A7.35 We disagree with H3G that [CONFIDENTIAL ✂] is the relevant cost to include when considering the cost of clearance, and continue to believe that it is appropriate to account for accumulated depreciation of links. A replaced link will not be a like-for-like swap for the equipment it replaces. This is because it will last longer before needing to be replaced and

[62] We determined the present value of costs by using a social time preference rate ("**STPR**") of 3.5% as suggested by the Treasury Green Book. We applied a STPR to be consistent because we have used the Spackman approach to determine the present value of costs. We said that this is appropriate because we are assessing the costs and benefits from clearing spectrum for public benefit as outlined in a Statement by the Joint Regulators Group (May 2022 Consultation, paragraph A8.18 and footnote 59).
[63] Letter from Luis Lopez Jimenez (H3G) to Gideon Senensieb (Ofcom), dated January 2023.
[64] Letter from Luis Lopez Jimenez (H3G) to Gideon Senensieb (Ofcom), dated January 2023.
[65] MBNL response to Ofcom's statutory information request dated 23 November 2022, p. 10.
[66] H3G, pp. 49-50.
[67] Email from VMO2 to Ofcom, dated 21 November 2022.
[68] As explained in sections 5 and 7, we are still consulting on our coexistence analysis which we will use to determine which fixed links are likely to receive interference from mobile services in high density areas. (See paragraphs 5.85 and 7.169.)

potentially because it will have higher bandwidth capacity or in other ways be superior to the replaced equipment. It would not be appropriate in our view to consider the cost to stakeholders of replacing a nearly-obsolete or nearly-at-capacity link to be the same as the cost of replacing a relatively new link that has significant remaining capacity.

A7.36 We also maintain our view that it is appropriate that the costs of replacement should be discounted to a present value using the social time preference rate. The costs we are considering are likely to be incurred at different times and at least a few years in the future and so the present value of these costs is, in our view, the appropriate measure for aggregating them.

Input assumptions for one-off transition costs calculation

Our proposals

A7.37 The assumptions we used in the May 2022 Consultation[69] to calculate the one-off transition costs are shown in Table A7.2 below.

Table A7.2: Consultation assumptions used as part of the one-off cost calculation

Assumption	May 2022 Consultation
Capital expenditure of equipment	£7,000[70]
Installation cost	50% of capital expenditure[71] [72]
Additional one-off capital costs	-
Lifetime of fixed link equipment	7 years[73]
WACC of fixed link operator	5.7%[74]
Social time preference rate	3.5%[75]

Source: See footnotes in table

A7.38 As well as the assumptions in Table A7.2, consistent with Ofcom's approach in other cases, we also (a) applied straight line depreciation based on the expected lifetime of assets, and

[69] May 2022 Consultation, Table A8.4.
[70] In the May 2022 Consultation (Table A8.4 and footnote 60), we said that our equipment capital expenditure was sourced from a 2015 Plum report for Ofcom produced for the Fixed Wireless Strategy and we assumed that the nominal value from the 2015 report remains appropriate. We considered this is appropriate as the cost trends for telecoms equipment used in the mobile call termination (MCT) model used in the 2021-2026 Ofcom Wholesale Voice Markets Review suggest that cost deflation in equipment in real terms (e.g. due to efficiencies) has been of a similar magnitude to the overall rise in general inflation.
[71] Plum report "Support to Ofcom's review of fees for dixed links and permanent earth stations", published 16 April 2015, p. 114.
[72] 2015 Plum report, p. 114.
[73] 2015 Plum report, p. 15.
[74] 2021-2026 Wholesale Voice Markets Review, p. 55.
[75] HM Treasury, "The Green Book", p. 46.

(b) assumed the age of existing assets was equally distributed across all the fixed links in the 26 GHz and 40 GHz bands.[76]

Stakeholder responses

Capital cost of new fixed link equipment

A7.39 Several stakeholders provided information on the costs of installing new equipment. A summary of this information provided by different stakeholders is shown in Table A7.3 below.

Table A7.3: Capital cost estimates from stakeholders for installing new equipment (£)

	Equipment	Installation and Other	Total capital expenditure
Ofcom May 2022 Consultation	7,000	3,500	10,500
Airwave[77]	[CONFIDENTIAL ✂]	[✂]	[✂]
BT/EE[78]	N/A	N/A	15,000
H3G[79]	[CONFIDENTIAL ✂]	[✂]	[✂]
VMO2[80]	N/A	N/A	[CONFIDENTIAL ✂]
Vodafone[81]	[CONFIDENTIAL ✂]	[✂]	[✂]
MBNL[82]	[CONFIDENTIAL ✂]	[✂][83]	[✂]

A7.40 The table shows that several stakeholders suggested that the capital costs of installing new equipment for a new band at the same site is higher than we consulted on. This is either because they have provided higher estimates for specific types of cost that we have included or suggest that there are additional costs not captured within our original assumption.

[76] For example, in our modelling of active legacy services in the Wholesale Fixed Telecoms Market Review 2021-26 (Annex 14) we used a top-down modelling approach which assumed straight line depreciation. We also calculated asset lives as gross replacement cost divided by depreciation and capex for asset replacement equal to depreciation, which is equivalent to assuming an equal distribution of assets across their lifespan given the use of straight line depreciation (i.e. the same proportion of assets are disposed of each year).
[77] Airwave email dated 08 September 2022 following request for further information on Consultation response.
[78] BT/EE, p. 27.
[79] Letter from Luis Lopez Jimenez (H3G) to Gideon Senensieb (Ofcom), dated January 2023.
[80] Email from VMO2 to Ofcom, dated 21 November 2022.
[81] Vodafone email dated 15 September 2022 following request for further info on Consultation response.
[82] MBNL response to Ofcom's statutory information request dated 23 November 2022, p. 10.
[83] [CONFIDENTIAL ✂]

A7.41 Vodafone considered our cost estimates were too low, partly because "they do not allow for the cost of skilled resource to execute the changes" but noted that any difference was "unlikely to be significant enough to change" our decision making on whether to clear fixed links.[84]

A7.42 UKWISPA considered that our original costs appeared reasonable.[85]

Average lifetime of fixed link equipment

A7.43 Several stakeholders said that our estimate of the average lifetime of fixed link equipment should be longer. We have also followed up with several stakeholders to confirm our understanding of the asset lifetime assumptions they have provided. Table A7.4 below shows a summary of the stakeholder responses.

Table A7.4: Average fixed link lifetime assumptions from stakeholders

Stakeholder	Equipment lifetime assumption (years)	Notes
Ofcom May 2022 Consultation[86]	7	Useful economic life
BT/EE[87]	8	Book life
H3G[88]	[CONFIDENTIAL ✂]	[CONFIDENTIAL ✂]
MLL[89]	5-7	Useful economic life
Vodafone[90]	[CONFIDENTIAL ✂]	Modelling assumption
MBNL[91]	[CONFIDENTIAL ✂]	Modelling assumption
techUK[92]	≥10	Book life

A7.44 However, multiple stakeholders pointed out that the asset lives they had provided were accounting book lives and that in practice many links may continue to be operated after they have been fully depreciated, in some cases by many years. BT/EE commented that "Microwave radio systems are written down over an 8 year period however in many cases, the link will be suitable for the demand and therefore the operational life will be extended,

[84] Vodafone, p. 12-13.
[85] UKWISPA, p.3.
[86] Plum report p.15.
[87] BT/EE, p. 28.
[88] H3G, p. 47.
[89] MLL, p. 8.
[90] [CONFIDENTIAL ✂].
[91] MBNL response to Ofcom's statutory information request dated 23 November 2022, p. 5.
[92] techUK, p. 6.

in some cases the links would be operational for 15 years".[93] MBNL commented that [CONFIDENTIAL ✂]. [94]

A7.45 Some stakeholders have provided evidence of the actual rate of replacement of links in their estates. BT/EE suggested that [CONFIDENTIAL ✂][95] and MBNL provided [CONFIDENTIAL ✂].[96]

A7.46 H3G[97] and MBNL[98] argued that [CONFIDENTIAL ✂].

A7.47 MBNL[99] stated that [CONFIDENTIAL ✂]. Separately, H3G[100] provided [CONFIDENTIAL ✂].

A7.48 MLL commented that we had not taken into account how long the microwave links have been operational and the natural course of refreshing hardware that would occur outside of the influence or impact of policy change.[101]

Other input assumptions

A7.49 No stakeholders commented on our input assumptions in relation to the WACC, social time preference rate or the assumption that installation costs would be 50% of equipment capital expenditure beyond the extent to which they submitted their own estimates of equipment and installation costs.

Our decision

Capital cost of installing new fixed link equipment

A7.50 It is challenging to obtain a clear comparison of costs given the different circumstances of fixed link replacement. In many cases there may be different specifications and equipment size for new links. This may mean that in practice the actual incurred costs will vary between operators. Despite this challenge, the information provided by stakeholders who have recently incurred costs associated with installing fixed links suggests that we may have underestimated the replacement costs for new fixed link equipment within the May 2022 Consultation.

A7.51 We have revised our assumptions to reflect the range of information received since we consulted. We have increased our assumption of the equipment capital expenditure from £7,000 to £9,000, included an additional £3,500[102] and £1,000 for planning and

[93] BT/EE, p. 28.
[94] MBNL response to statutory information request dated 23 November 2022 question 3.
[95] Ofcom meeting of 17 October 2022 with BT/EE.
[96] MBNL response to follow up questions to statutory information request dated 23 November 2022.
[97] Letter from Luis Lopez Jimenez (H3G) to Gideon Senensieb (Ofcom), dated January 2023.
[98] Ofcom meeting of 27 February 2023 with MBNL.
[99] Ofcom meeting of 27 February 2023 with MBNL.
[100] H3G slide pack provided 13 February in response to Ofcom follow up questions.
[101] MLL, p. 8.
[102] We note that in the May 2022 Consultation we recognised that there was likely to be some additional planning and administrative costs associated with replacing links when we set the final one-off transition costs (May 2022 Consultation paragraph A8.24 b).

administrative costs and deployment costs[103] respectively and maintained the 50% uplift on equipment costs for installation costs, which therefore has increased from £3,500 to £4,500.

Average lifetime of fixed link equipment

A7.52 After considering the information from all stakeholders we have decided to increase the assumed average lifetime of fixed links from 7 to 12 years. We have considered several factors in coming to this decision.

a) We remain of the view that stakeholders' assumed lives for these assets is the appropriate starting point as these should reflect their expectations of how long equipment will last in practice. [CONFIDENTIAL ✂]. Evidence on fixed link asset book lives from stakeholders indicates that nine to ten years is an appropriate starting point.

b) Some stakeholders argued that, in practice, their book lives underestimate the actual average lives of these assets. They told us that a significant number of fixed links have a useful life which is longer than the duration over which they are fully depreciated. However, several stakeholders (BT/EE, [CONFIDENTIAL ✂]) have used a modelling assumption for the useful economic life of five to nine years, suggesting that they believe an asset life within this range is appropriate. This evidence suggests that there is a wide but unknown distribution of actual asset lives. Stakeholders advised that this is determined by a variety of factors, including but not limited to equipment failure, capacity upgrades and link ceases (i.e. links that are no longer needed and are ceased without being replaced).

c) The evidence provided by some stakeholders of the actual rate of replacement of links in their estates provided conflicting information. ([CONFIDENTIAL ✂]) We have not made any specific adjustment to our assumptions on the basis of this evidence, due to the conflicting nature of evidence provided by stakeholders.

d) We accept that the impact of [CONFIDENTIAL ✂] may mean that the historic evidence is not a reliable a guide for expected future replacement activity, at least in the short run. However, we note that [CONFIDENTIAL ✂].

A7.53 For the above reasons, we are not able to accurately model the actual distribution of expected asset lives. However, we think it is prudent to extend the assumed asset life further than simply to account for evidence on the book lives of this equipment. This is both to account for a higher amount of residual value remaining in the equipment at the end of the revocation period than would be included were we to use a simple average of 9-10 years, as well as the potential for replacement activity to slow in the near future.

A7.54 In addition to their assumed depreciation period, BT/EE also included in its cost estimate "Pull forward of like for like replacement costs", which BT/EE considered cover the costs of bringing forward the replacement of already depreciated assets. We requested further

[103] Deployment costs mainly cover costs that are only expected to be incurred when a link is initially installed. These costs will include any aircraft (aeroplanes, helicopters and drones, depending on the requirements) costs that might be used to map any obstacles that could impact line of sight.

information relating to these costs from BT/EE[104] and BT/EE told us that [CONFIDENTIAL ✂]. We do not consider the inclusion of these costs to be appropriate. We do not think [CONFIDENTIAL ✂] would be consistent with our view on the average lifetime of equipment as outlined above.

A7.55 In response to MLL's concern that we have not considered how long the microwave links have been operational, this is a simplifying assumption within the model which we believe not to have a material impact of the costs. In response to the second concern, that we have not considered the natural course of refreshing hardware, we took this into consideration when deciding on an appropriate asset life, as described above.

A7.56 Table A7.5 below shows a comparison of the input assumptions we used in the May 2022 Consultation and our 'revised assumptions' (revised assumptions used to arrive at the final costs in this Statement).

Table A7.5: Cost modelling input assumptions used in the May 2022 Consultation and our revised assumptions

Assumption	Initial assumptions (Consultation)	Revised assumptions
Capital expenditure of equipment	£7,000	£9,000
Installation cost	50% of capital expenditure	50% of capital expenditure
Additional capital costs for planning and administration	-	£3,500
Additional one-off capital costs for full link deployment	-	£1,000
Lifetime of telecommunications equipment	7 years	12 years
WACC of fixed link operator	5.7%	5.7%
Social time preference rate	3.5%	3.5%

Source: Ofcom

A7.57 Using these assumptions, we have estimated the value of the capital costs associated with clearing a single fixed link at the end of the revocation period. This value depends on the age of equipment at the start of the revocation period from which its remaining lifetime can be calculated.[105]

[104] Ofcom meeting of 17 October 2022 with BT/EE.
[105] E.g. a new piece of equipment will have a remaining lifetime of twelve years, a one-year-old piece of equipment will have a remaining lifetime of eleven years, etc.

A7.58 Table A7.6 shows our initial estimate of the value of equipment that needed to be written off at the end of the revocation period, based on its remaining lifetime (see Table A8.5 of the May 2022 Consultation). It also shows our revised average estimate taking into account the input assumption changes presented in Table A7.6. The final row in the table shows the estimated average cost of writing off fixed link equipment when moving to a new band during the five-year revocation period.

Table A7.6: Cost of writing off fixed link equipment when moving to a new band during a five-year revocation period

Remaining life of equipment at the start of the revocation period	Initial estimate of the value to be written off (May 2022 Consultation)	Revised estimate of the value to be written off
12 years	n/a	£9,544
11 years	n/a	£8,111
10 years	n/a	£6,700
9 years	n/a	£5,311
8 years	n/a	£3,946
7 years	£2,606	£2,606
6 years	£1,290	£1,290
5 years	£0	£0
4 years	£0	£0
3 years	£0	£0
2 years	£0	£0
1 year	£0	£0
Average	**£556**	**£3,126**

Source: Ofcom

A7.59 Our methodology suggests that the average cost of writing off equipment when applying a five-year revocation period would be £3,126. This is an increase from the May 2022 Consultation estimate of £556.[106] We consider this to be a conservative estimate given our choice of asset life and our approach to including costs for all links which may only be relevant for a subset of links.

[106] May 2022 Consultation, paragraph A8.23.

Average estimated cost per link for one-off costs

Our proposals

A7.60 In the May 2022 Consultation,[107] we considered that the calculated value per fixed link presented in the paragraph above could potentially be an underestimate of the average one-off costs for moving fixed links for two main reasons.

a) First, we thought there may be additional planning and administrative costs when moving to a new spectrum band over and above the normal planning and administrative costs which relate to equipment renewal.[108]

b) Second, we assumed the operator could fully utilise the revocation period to manage the transfer to a new spectrum band. However, we thought there may be additional constraints as part of the transfer process. For example, the moving process could potentially be more efficient when moving several links together. Therefore, some links which are not fully depreciated may be moved at the same time as links that have reached the end of their usable life earlier than the end of the revocation period, and this could result in a higher cost than if no migration was required.

A7.61 However, we also recognised that there could also be reasons why the cost could be lower than we suggested. For example, although it may be possible to reuse some equipment in the new spectrum band, we assumed in our modelling that operators would need to obtain new equipment when moving fixed links to alternative frequencies.

A7.62 For the reasons outlined above, we initially proposed that a reasonable baseline assumption for the one-off transition costs of a single existing link should be higher than the £556 calculated. We therefore increased our assumption to a cost of £1,000 per link to reflect these additional factors and the uncertainty in our estimates.

Stakeholder responses

A7.63 Airwave, JRC and [CONFIDENTIAL ✂] raised concerns that additional configuration costs, above the costs included by Ofcom, are required to ensure enhanced operation resilience for fixed links which provide communications for emergency services or are used for critical infrastructure e.g., energy network operation.[109]

Our decision

A7.64 We remain of the view that the calculated value per fixed link could potentially be both an underestimate or overestimate of the average one-off costs for moving fixed links. However, our reasoning for this has slightly changed since the May 2022 Consultation.

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[107] May 2022 Consultation, paragraphs A8.24-A8.26.
[108] As noted in the May 2022 Consultation (paragraph A8.24 and footnote 66), this could potentially include any incremental costs associated with applying and paying for a new spectrum licence in the new band over and above costs that would have been incurred if the user had continued to operate the fixed link in its existing band.
[109] Airwave response to the May 2022 Consultation, p. 6; JRC response to the May 2022 Consultation, p.5; [CONFIDENTIAL ✂].

A7.65 We have now accounted specifically for the large majority of costs we would expect to have been covered by the potential missed costs identified within the May 2022 Consultation by category a) above,[110] covering additional planning and administrative costs. These costs are captured within the additional £3,500 cost uplift we are now assuming.[111] We do not consider it appropriate to further increase the costs per link to account for these costs, as this would result in double counting.

A7.66 We continue to expect costs to be understated as we still assume operators can fully utilise the revocation period to manage the transfer to a new spectrum band. However, there may be additional constraints as part of the transfer process or due to uncertainty over which specific links will be able to continue operating after the revocation period, given our ongoing consultation on which links in the 40 GHz band will be able to be licensed.[112]

A7.67 Airwave, JRC and [CONFIDENTIAL ✂] have identified additional costs that we have not included within our modelling which we did not consider in the May 2022 Consultation. We note that the additional configuration costs claimed by these stakeholders would not be required for all fixed links within the 26 GHz and 40 GHz bands because they are not all used to provide communications for emergency services or critical infrastructure. However, we have made the conservative decision to ensure that an additional increase is factored in when calculating by how much the cost per link should be increased to cover this potential understatement of costs.

A7.68 Consistent with the May 2022 Consultation, we still recognise that there could also be reasons why the cost could be lower than we have suggested. For example, although it may be possible to reuse some equipment in the new spectrum band, we assume in our modelling that operators would need to obtain new equipment when moving fixed links to alternative frequencies.

A7.69 For the reasons outlined above, and in line with the approach that we initially proposed in the May 2022 Consultation,[113] we have decided that a reasonable baseline assumption for the one-off transition costs of a single existing link should be slightly higher than the costs which we have calculated (£3,126 on the basis of our revised estimates). We have therefore increased our assumption to a cost of £3,600 per link to reflect these additional factors and the uncertainty in our estimates. We have applied this uplift and rounding because we consider that the limited available data does not allow us to include these costs specifically within our modelling.[114]

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[110] Paragraph A7.60.
[111] Paragraph A7.51.
[112] See paragraph 7.168-7.174 of section 7.
[113] May 2022 Consultation, paragraph A8.26.
[114] As a sense check on the size of our rounding (£474), we have produced an illustrative example which includes an additional cost per link for additional resilience configuration of £1,000 and assumes that three months of the five year revocation period could not be utilised. Including these costs would result in a similar final cost as our uplifted and rounded estimate. We have produced this estimate as an illustrative example only and note that there are many combinations of assumptions that could be taken for each of the cost elements included in our uplift, and that the specific uplift we have chosen is ultimately a matter of judgment given the limited available data and the uncertainty around these costs. We

A7.70 Finally, we have also included a further £1,000 uplift of costs to account for the possibility of (re)deployment costs being incurred were a full link redeployment required rather than a simpler equipment swap. In paragraph A7.51 above we note that we have updated our costs to account for deployment costs which might only be incurred when a link is initially installed. Were a full link redeployment required rather than an equipment swap, this deployment costs might need to be incurred again.

A7.71 In practice, not all links will require a full link redeployment and costs we have included within "deployment" might not be fully incremental to our decision to clear fixed links. MBNL commented that [CONFIDENTIAL ✂].[115] However, we have conservatively assumed an additional £1,000 uplift will be required for all links that is fully incremental due to our decision to clear fixed links. This results in our final average estimated cost per link for one-off costs being £4,600.

Method for estimating ongoing costs

Our proposals

A7.72 In the May 2022 Consultation,[116] we said that higher ongoing costs could take different forms. For example, licensees could face ongoing costs if they require more expensive equipment (which would then need to be more expensive whenever it needs replacement), more space on towers, or in some circumstances an additional hop if radio waves in the new band do not propagate as far as those in the existing band.

A7.73 We defined ongoing costs as the additional costs to licensees from using a new frequency, as opposed to the total costs that they will incur when operating in a new band. For example, a user of an existing fixed link would face costs related to towers or ongoing maintenance, that we would expect to continue for any new link. Therefore, we only need to include these costs if they are higher for the fixed link in the new spectrum band than they are for the existing fixed link and in that case we would only include incremental costs that arise from moving the links.

A7.74 We flagged that we did not have a clear upper estimate of what the costs could be. But, by way of sensitivity testing, we modelled an illustrative example that reflected what we considered was the top end of plausible costs, noting that costs were likely to be lower in practice.

A7.75 Our illustrative example assumed that 2% of existing links would be subject to the higher costs that arise because they require an additional hop, with the remaining 98% of links not subject to any higher ongoing costs. We chose the costs of installing a new hop as we

have aimed at making a conservative estimate when choosing the uplift to apply. We stress that the £1,000 and three month assumptions are hypothetical assumptions. This example is presented as a cross check of whether the scale of uplift and rounding is reasonable.

[115] Ofcom meeting of 23 February 2023 with MBNL.

[116] May 2022 Consultation, paragraphs A8.38-A8.48.

considered it would be the most expensive situation, which reflects that this is the upper end estimate and that other modifications would be cheaper.

A7.76 To calculate the cost of building a new hop we proposed to use the following approach:

a) estimate the annual equivalent cost for both a new site from the capital expenditure and operating expenditure assumptions listed in Table A7.7 below and assumed all costs were recovered over a 20-year period;[117]

b) determine an annual equivalent cost for telecommunications equipment that would be needed on that site over a 20-year period;[118] then

c) determine the present value of all of these costs by discounting to a present value using the social time preference rate.[119] [120]

A7.77 The list of assumptions we used in the ongoing costs cost calculation for the May 2022 Consultation are shown in Table A7.7 below.

Table A7.7: Ongoing cost calculation assumptions, May 2022

Assumption	Value[121]
Capital costs of rural site	£113,399
Operating costs of rural site	£378
Capital costs of urban site	£11,340
Operating costs of urban site	£5,670
Lifetime of urban and rural sites	20 years
Capital expenditure of equipment (for additional hop)	£7,000
Installation of equipment cost	50% of capital expenditure

[117] We assumed a 50/50 split between rural and urban sites across all our high density area to get an average site cost. We expected new sites might be in rural locations (e.g., around the edge of our cities) which may require the construction of a tower, or within cities, where a new site may be on an existing building. We used a 20-year period to determine costs consistent with the approach for cost estimates set out in the Plum report.

[118] We assumed a seven-year lifetime for equipment so expected it to be replaced twice over the period of 20 years.

[119] We determined the present value of costs by using a social time preference rate of 3.5% as suggested by the Treasury Green Book. We applied a STPR to be consistent because we used the Spackman approach to determine the present value of costs. We deemed this to be appropriate because we are assessing the costs and benefits from clearing spectrum for public benefit as outlined in a Statement by the Joint Regulators Group.

[120] To be conservative, we discounted the additional ongoing costs to a present value based on those costs being incurred at the start of the revocation period. However, we noted that cost related to a new site would not necessarily take place at that time (e.g., costs may be incurred towards the end of the revocation period or at any period during it). We noted this could reduce costs in present value terms compared to our assumption.

[121] The capital expenditure and operating expenditure site costs were sourced from a 2015 Plum report for Ofcom produced for the Fixed Wireless Strategy. However, we increased the nominal cost estimates outlined in the report by 13%. This ensured consistency with the MCT model, which assumed a 2% real increase in site operating expenditure and capital expenditure over the period from 2015 to 2022, and the increase in CPI over the same period.

Assumption	Value[121]
Other operating costs for equipment (infrastructure)	50% of annualised capital expenditure
Other operating costs for equipment (maintenance)	12% of capital expenditure per annum
Lifetime of telecommunication equipment	7 years
WACC of fixed link operator	5.7%
Social time preference rate	3.5%

Stakeholder comments

A7.78 MBNL disagreed with the capital costs we included for building and operating new sites, arguing that in its experience these costs are considerably higher. It provided capital cost estimates of [CONFIDENTIAL ✂] for a rooftop site, [CONFIDENTIAL ✂] for a site requiring street works, and [CONFIDENTIAL ✂] for a greenfield site. It also provided higher rental costs of [CONFIDENTIAL ✂] for each of these site types respectively.[122]

A7.79 MBNL also argued that [CONFIDENTIAL ✂].[123]

A7.80 Stakeholder responses relating to the capital expenditure of equipment and lifetime of equipment have been discussed above in paragraphs A7.39-A7.42 and A7.43-A7.48.

A7.81 H3G suggested that we should have placed a higher weight on our "higher ongoing costs" scenario. It said that "We, therefore, take the 2% figure Ofcom uses in its sensitivity analysis as a central estimate (i.e. the actual figure could plausibly be much higher or lower)."[124]

A7.82 Vodafone commented that we had not justified why 2% was a reasonable estimate of links needing an additional hop in our high-cost scenario.[125]

A7.83 JRC[126] argued that our estimates were inaccurate in their case as they did not have access to the same buying power as the MNOs due to the scale of their organisations.

Our decision

A7.84 We have continued to model additional ongoing costs using new sites for additional hops in a minority of cases despite MBNL's comment that [CONFIDENTIAL ✂]. We have taken this approach as a modelling simplification to cover the range of significant alternative

[122] MBNL response to statutory information request dated 23 November 2022, Q.2.
[123] Ofcom meeting of 27 February 2023 with MBNL.
[124] H3G, p. 48.
[125] Vodafone, p. 13.
[126] JRC response to the May 2022 Consultation, p. 5.

additional costs that may arise in a minority of cases when replacing links. We expect that our estimated additional costs are a conservative estimate.[127]

A7.85 We recognise that there is a lot of uncertainty about how many new hops (or other higher ongoing costs) might be needed when moving a fixed link to a new band. In the May 2022 Consultation,[128] for the purposes of an illustrative higher cost scenario, we determined a 2% value based on our regulatory judgement of fixed link infrastructure. We have decided to continue to use that value because stakeholders provided limited evidence on this assumption.

A7.86 However, we note that such evidence suggests that a 2% value may be a conservative estimate, with fewer additional hops being required in reality. For example, [CONFIDENTIAL ✂]. Nonetheless, recognising the uncertainty in this area, and the suggestion from H3G that it should be considered a central scenario, we have updated our baseline scenario to include the higher ongoing costs.

A7.87 MBNL's cost information points to higher site rental costs for rural sites than we consulted upon. We have updated our assumption for the total site rental from £1,000 to £9,000, but maintained the assumption of an average of three site occupants at each rural site, which is supported by the 2015 Plum report (page 113). This results in our rural site rental cost assumption increasing from £333 to £3,000 p.a.

A7.88 We have also considered the cost information MBNL has provided on site capital expenditure and concluded that it is not a direct comparison of the types of sites we are considering in this part of the modelling. The costs provided relate to sites hosting a wide variety of telecoms equipment rather than just fixed links. Hosting this larger amount of equipment requires larger, more complex and stronger structures than would be needed if only a fixed link were hosted. We have therefore not used the costs provided by MBNL directly. However, we consider that the original assumption for urban capital expenditure could still be an underestimate given the evidence provided, and so as a conservative estimate we have uplifted it by a factor of five in this analysis, from £11,340 to £61,859.

A7.89 In response to JRC, we reiterate that our cost modelling approach estimates the average cost of clearance for a fixed link.

Table A7.8: Summary of assumptions used for the May 2022 Consultation and as revised for our Statement as part of the ongoing cost calculation

Assumption	May 2022 Consultation assumptions	Revised assumptions[129]
Capital costs of rural site	£113,399	£123,718

[127] We also make the conservative assumption within our modelling that any additional hops that would be needed are built at the start of the revocation period. In reality, the build would be spread out across the revocation period dependant on when the links that would require them are transferred.
[128] May 2022 Consultation, paragraph A8.42.
[129] Statement assumptions are presented in 2022 nominal terms whereas the May 2022 Consultation assumptions were presented in 2021 nominal terms.

Assumption	May 2022 Consultation assumptions	Revised assumptions[129]
Operating costs of rural site	£378	£4,579
Capital costs of urban site	£11,340	£61,859
Operating costs of urban site	£5,670	£7,765
Lifetime of urban and rural sites	20 years	20 years
Capital expenditure of equipment (for additional hop)	£7,000	£9,000
Installation of equipment cost	50% of capital expenditure	50% of capital expenditure
Other operating costs for equipment (infrastructure)	50% of annualised capital expenditure	50% of annualised capital expenditure
Other operating costs for equipment (maintenance)	12% of capital expenditure per annum	12% of capital expenditure per annum
Lifetime of telecommunication equipment	7 years	12 years
WACC of fixed link operator	5.7%	5.7%
Social time preference rate	3.5%	3.5%

A7.90 Using the same methodology as proposed in the May 2022 Consultation, but updating the input assumptions as set out in Table A7.8, we have estimated potential ongoing costs for a fixed link that requires a new hop to be £227,228 in present value terms over a 20-year period. This is an increase from the cost calculated in the May 2022 Consultation, which was £163,447.

Baseline scenario for total costs for existing users

A7.91 We have estimated the overall costs for clearing the 26 GHz and 40 GHz bands by developing a baseline scenario that assumes that users are able to move all existing links into a different spectrum band. Different to our baseline scenario in the May 2022 Consultation, we now assume an element of higher costs on an ongoing basis within the baseline scenario. Therefore, the costs incurred in this scenario are the one-off transition costs estimated above for moving a single fixed link into a different band and the estimate for ongoing costs estimated above.

A7.92 We consider this baseline is an appropriate best estimate of costs based on users being able to move their fixed links to Ofcom managed bands, such as the 18, 23 and 38 GHz bands.[130]

A7.93 To estimate the total costs of clearing the 26 GHz and 40 GHz bands of fixed links in and around high density areas we have multiplied our estimate of the one-off transition costs and baseline ongoing costs of a user moving one fixed link by the number of links that need to be moved.

A7.94 The number of links that needs to be moved depends on:

a) the number and location of high density areas; and

b) the extent to which existing fixed links in (and close to) each high density area need to be moved.

A7.95 The exact number of links that need to be moved for each area will depend on the technical characteristics of the individual deployments. Some fixed links outside of a high density area may suffer interference from new users in a high density area. In the May 2022 Consultation we assumed that all fixed links in a high density area and fixed links that have at least one part of the link within 25km of a high density area need to be moved. No stakeholders commented on this approach and we have maintained it in our final analysis. We expect that some, but not all, links in this category will need to be moved, therefore the figure given by this method should be regarded as a conservative estimate.

A7.96 Table A7.9 shows our cost estimates in the baseline scenario for clearing the 26 GHz band and the 40 GHz band of the fixed links in and around high density areas.[131]

Table A7.9: Cost of clearing the 26 GHz and 40 GHz bands of existing fixed links in and around the 68 HDAs in the baseline scenario

Fixed links	Number of fixed links to be moved	Estimated cost of clearance (£m)
26 GHz	835	7.6
40 GHz (MBNL)	3,924	35.9
40 GHz (H3G)	63	0.6

Source: Ofcom; 26 GHz fixed link statistics taken from Ofcom licensing data; MBNL fixed link statistics taken from data provided by MBNL[132]; H3G fixed link statistics taken from data provided by H3G.[133]

[130] The licence fees would change, for existing licence holders in the 40 GHz band, if fixed links were moved to alternative Ofcom-managed fixed links bands. However, as described in section 7 of the May 2022 Consultation, we cannot say at this point whether there is likely to be a material difference between the fees that would apply in an Ofcom-managed band and the annual licence fees in 40 GHz that may be set after 21 February 2023.
[131] We have not considered the impact of MLL's deployments because they do not currently have any active deployment in the 40 GHz band.
[132] MBNL response to Ofcom's statutory information request dated 23 November 2022 p. 10. N.B. the number of fixed links deployed by MBNL in the 40 GHz band has changed relative to the figures we used in the May 2022 Consultation.
[133] H3G response to statutory information request dated 07 February 2022.

Sensitivity analysis

A7.97 We believe our baseline scenario to already be conservative and representative of the likely incremental costs that would be incurred by existing fixed link users as a result of Ofcom clearing the 26 GHz and 40 GHz bands of the fixed links which operate in and around high density areas.

A7.98 However, we recognise that there is some uncertainty about the exact level of additional costs users of fixed links could incur due to the revocation of existing licences. To help understand the potential magnitude of higher costs, we have also developed additional higher cost scenarios to assess how costs could develop in certain circumstances.

A7.99 We have tested four of the assumptions outlined above for our sensitivity scenarios:

a) Our assumption that fixed link equipment has a useful lifetime of 12 years.

b) Our assumption that the full five years of the revocation period can be utilised.

c) Our assumption of total equipment and installation costs.

d) Our assumption for the capital expenditure required when building additional hops.

A7.100 We have tested the first assumption by re-estimating the costs of the baseline scenario assuming a 15-year economic lifetime of fixed link telecoms equipment ("longer equipment lifetime scenario").

A7.101 We have stress tested the remaining three assumptions by, assuming only four years of the five-year revocation period can be utilised, increasing the equipment, planning and administration, deployment and installation costs from £18,000 to £24,000 and using the capital expenditure estimates provided by MBNL for equipment sites. We apply these higher assumptions on top of the "longer equipment lifetime scenario" to generate our "higher costs scenario".

A7.102 This results in us now presenting three scenarios.

a) Our baseline scenario, which now assumes a useful equipment life of 12 years (and which now includes the higher ongoing costs assumptions we set out in the May 2022 Consultation).

b) Our baseline scenario, but assuming a useful equipment life is 15 years.

c) A new higher costs scenario which again assumes useful equipment life is 15 years but also higher equipment capital expenditure. We also assume that the incumbent licensee voluntarily chooses a transition period shorter than the five-year revocation period, and a higher amount for ongoing costs.

A7.103 The range of costs across all three scenarios are presented and assessed when considering our policy decisions.

A7.104 The approach we have taken to develop each of these higher cost scenarios is outlined below.

Methodology to estimate higher costs for the "longer equipment lifetime" scenarios

A7.105 Consistent with the May 2022 Consultation,[134] we have tested our baseline assumption of the expected lifetime of telecommunications equipment. Using an equipment lifetime of 12 years means that when there is a five-year notice period prior to revocation, and assuming an equal age distribution of links, just under half of equipment can be replaced as normal at the end of its lifetime and so the costs of clearing the band of fixed links are relatively low.

A7.106 We have tested this assumption as we consider that there is the potential for equipment to be replaced over a longer period, dependent on different factors including the level of technical change of the equipment. If telecommunications equipment is expected to be used for a longer period, then the costs of migrating to a new band and needing to buy new equipment could materially increase.

A7.107 In the May 2022 Consultation, we considered that it was plausible for fixed link equipment to have an expected useful lifetime longer than our baseline assumption of seven years. Since the May 2022 Consultation, we have increased our baseline assumption to 12 years. Although we consider that it is unlikely that fixed link equipment has an expected useful life longer than 12 years, we have undertaken two additional modelling scenarios where the equipment lifetime is assumed to be 15 years. All other assumptions and the methodology are the same as the baseline scenario to generate our longer equipment lifetime scenario.

A7.108 Under the baseline scenario, when increasing the equipment lifetime to 15 years, our methodology suggests that the average cost of writing off equipment would increase from £3,126 to £3,997.

A7.109 We have increased this to £4,600 for the same reasons given in paragraphs A7.64-A7.69, as we consider the potential for costs to be higher than our estimate still exists when our lifetime assumption is 12 years.

A7.110 We estimate the average cost of building a new hop to be £223,348. As outlined previously, we assume that this cost will apply to only 2% of the number of fixed links.

A7.111 We have used these estimates together with the number of fixed links in and around high density areas operating in the 26 GHz and 40 GHz bands to estimate the total costs in the longer equipment lifetime scenarios as shown in Table A7.10 below.

[134] May 2022 Consultation, paragraphs A8.49-A8.54.

Table A7.10: Cost of clearing the 26 GHz and 40 GHz bands of fixed links in and around the 68 high density areas in the longer equipment lifetime scenarios

Fixed links	Number of fixed to be moved	Longer equipment lifetime scenarios (£m)
26 GHz	835	8.4
40 GHz (MBNL)	3,924	39.5
40 GHz (H3G)	63	0.6

Source: Ofcom; 26 GHz fixed link statistics taken from Ofcom licensing data; MBNL fixed link statistics taken from data provided by MBNL; H3G fixed link statistics taken from data provided by H3G.

Methodology to estimate higher costs for the "higher costs" scenarios

A7.112 All modelling and assumptions are kept the same as the longer equipment lifetime scenario expect for the equipment cost assumption and capital expenditure assumption for hops.

A7.113 For the equipment assumption, this is increased to £13,000. When applying the 50% installation cost assumption and adding the planning and administration and deployment costs (£4,500) this results in the total assumed equipment and installation cost increasing by a third to £24,000.

A7.114 For the additional hops capital expenditure assumption, we use the capital expenditure estimates provided by MBNL for a rural site of [CONFIDENTIAL ✂] and an urban site of [CONFIDENTIAL ✂]. Although we note that these cost estimates were for sites hosting a wide variety of telecoms equipment rather than only fixed links. Using these assumptions provides an absolute top cost for the site capital expenditure.

A7.115 We have used these estimates together with the number of fixed links in and around high density areas operating in the 26 GHz and 40 GHz bands to estimate the total costs in the longer equipment lifetime scenarios as shown in Table A7.11.

Table A7.111: Cost of clearing the 26 GHz and 40 GHz bands of fixed links in and around the 68 high density areas in the higher cost scenario

Fixed links	Number of fixed links to be moved	Higher costs scenario (£m)
26 GHz	835	12.5
40 GHz (MBNL)	3,924	58.8
40 GHz (H3G)	63	0.9

Source: Ofcom; 26 GHz fixed link statistics taken from Ofcom licensing data; MBNL fixed link statistics taken from data provided by MBNL; H3G fixed link statistics taken from data provided by H3G.

A8. Our approach to existing licensees in the 40 GHz band: additional detail on responses

A8.1 This annex discusses responses made by stakeholders regarding our approach to the existing licensees in the 40 GHz band that are not fully addressed in section 7.

A8.2 The issues covered in this annex include:

- H3G's proposals for an incentive auction or voucher scheme;
- a trading scenario proposed by MLL;
- a Vodafone proposal for clearing fixed links in 26 GHz and 40 GHz; and
- responses from satellite stakeholders.

H3G's proposals for an incentive auction or voucher scheme

Stakeholders' comments

A8.3 In its response to the May 2022 Consultation, H3G said that if Ofcom believes central reallocation of 40 GHz spectrum is needed then "an incentive auction is a better way of achieving its objectives while respecting licensees' rights." [135] According to H3G, in such an auction, 40 GHz licensees would voluntarily agree to sell their licences back to Ofcom without the need for five years' notice and, as part of the same auction, new users would then purchase newly-issued licences to use the spectrum released. Auction revenues would be used to fund payments to existing licensees and any relocation costs. [136] H3G commented that "Unlike Ofcom's proposal, an incentive auction would determine not only who the best users for the band are but also the optimal amount of spectrum to be repurposed from fixed links to mobile and other uses".[137]

A8.4 Alternatively, H3G proposed two versions of a voucher scheme, which are essentially further variations of an incentive auction. Specifically, H3G proposed: (i) a voluntary version of a voucher scheme where existing licensees would have the opportunity to put their existing spectrum into the auction[138] and (ii) an alternative version of a voucher scheme where existing licensees would have their licence revoked if they did not consent to putting their spectrum into the auction, and "ALF would be payable during notice period".[139] Under both versions, the existing licensees would receive, in return for putting their spectrum holdings into the auction, "a voucher equal to the value of their spectrum (e.g. H3G would receive 2GHz, MBNL and MLL 500MHz each)."[140] We understand that the

[135] H3G response to the May 2022 Consultation, p.2.
[136] H3G response p.8.
[137] H3G response, p.2.
[138] H3G response, p.27.
[139] H3G submission of 12 October 2022, slide 11.
[140] H3G response, p.27; H3G submission of 12 October 2022, slide 12.

voucher would be equal to the value of the licensee's existing spectrum holdings, as determined through the auction. Specifically, if a licensee wins at the auction an amount of spectrum equal to its voucher (i.e. the same amount of spectrum as it had before the auction), it would pay nothing (and hand back its voucher). However, if a licensee wins more spectrum than it had held before the auction, it would pay the auction price for any additional spectrum. If a licensee wins back less spectrum than it held before the auction, it would receive a payment from Ofcom for the difference between its voucher and the amount of spectrum won, at the price determined by the auction.[141] H3G noted that ALFs could apply after the auction to any 40 GHz retained (i.e. won) by an existing licensee. H3G suggested the voucher scheme would incentivise voluntary surrender of 40 GHz spectrum.[142]

A8.5 While H3G initially invited Ofcom to request new powers to run an incentive auction,[143] in subsequent submissions[144] H3G suggested that Ofcom could use its powers under s.14(5A) of the Wireless Telegraphy Act 2006 (the "**WT Act 2006**"), with consent from the Secretary of State, to (i) impose on the existing holders of the 40 GHz licences "a pre-auction limit of zero (i.e., consent to have their licence revoked in order to participate in auction)" and (ii) "use auction proceeds to compensate an existing licensee for spectrum surrendered to comply with a limit".

A8.6 MLL supported H3G's proposal of an incentive auction or a voucher scheme on the basis that it "would easily resolve the 5-year notice period issue that Ofcom faces with revoking the spectrum". MLL also said that if Ofcom developed an incentive auction solution, this could be used to address future "spectrum allocation issues".[145]

Ofcom's response

A8.7 We recognise that in principle, if the 40 GHz licensees participated in an incentive auction (or the voucher scheme variation proposed by H3G), this could potentially address some of the issues of complexity and uncertainty which we have identified as reasons why we cannot rely on trading of the 40 GHz band to achieve an efficient allocation. In particular, this is because an incentive auction could occur alongside the auction of 26 GHz licences, and an allocation of both bands could be achieved at the same time.

A8.8 However, we consider that an incentive auction or a voucher scheme would have significant disadvantages, and at best limited advantages, compared to the option of revoking and auctioning all licences in the band:

[141] H3G response, p.27; H3G submission of 12 October 2022, slide 12.
[142] H3G submission of 12 October 2022, slide 12.
[143] H3G response, pp. 3 and 25-27.
[144] H3G submission of 12 October 2022, slide 13.
[145] MLL follow-up response of 25 October 2022.

a) As we have discussed, we are concerned that incumbents will not have a sufficient incentive to trade spectrum in the absence of an auction. Likewise, in the voluntary versions of the incentive auction or voucher scheme proposed by H3G, it is not clear that incumbents would have a sufficient incentive to participate, and relinquish spectrum, in an auction. Incumbents may choose not to relinquish the spectrum for strategic reasons, or in order to retain the option of trading at a later date, which could result in the benefits to consumers and businesses being delayed.

b) On the other hand, we do not consider that the version of a voucher scheme proposed by H3G where incumbents are, in essence, forced to put their existing holdings into the auction, would give rise to any benefits over and above option 2, other than that of providing the existing licensees with the opportunity to profit from giving up their licences. As explained in paragraph 7.155, although we recognise that revoking operators' spectrum licences means they will lose the opportunity to profit from giving up those licences, we do not consider that this factor can carry substantial weight in our decision-making.

c) In addition, our preference, where possible, is for a faster and simpler auction design. An incentive auction or voucher scheme would involve more stages[146] than the auction formats we are currently considering, and there is a risk that resolving the complexities this entails would result in a longer timeline for awarding the spectrum.[147] In short, while we acknowledge that H3G's proposal would lessen the impact on existing licensees and might address some issues of uncertainty, we do not consider it would be as likely to achieve our statutory and regulatory objectives as option 2, and we consider its advantages insufficiently certain for it to be preferred.

A8.9 In addition, it is not at all clear to us that we do have the powers to implement H3G's proposals. In particular, in its subsequent submissions,[148] H3G mentioned Ofcom's power (with the consent of the Secretary of State) to permit or require an auction winner to pay the auction fee to another auction winner (s.14(5A) of the WT Act 2006) and suggested that Ofcom could limit to zero the amount of 40 GHz spectrum that the existing licensees of 40 GHz spectrum may hold as a condition of entry into the award process.

A8.10 The payment mechanism set out in s.14(5A) is intended to apply only in specific circumstances, where Ofcom considers it appropriate (i) to limit the frequencies in respect of which a person may hold licences and (ii) to enable such a person to comply with that limit by surrendering a licence.[149] Our view is that the approach suggested by H3G would

[146] And potentially more participants – i.e. including all three of the incumbent licensees

[147] While we recognise the advantage of avoiding the 5 year revocation period, which MLL pointed out, we consider that if award winners wanted to deploy in advance of this they could potentially do so via commercial arrangements with incumbents. In addition, the lack of a five year notice period in an incentive auction could lead incumbent licensees to retain spectrum due to the short-term costs of vacating their spectrum, even if they are not the highest value users in the longer term.

[148] H3G submission of 12 October 2022, slide 13. In addition, H3G provided us with a note of legal advice it had commissioned on Ofcom's powers, see "Advice on Ofcom's power to conduct an incentive auction for 40 GHz" submitted by H3G on 13 October 2022.

[149] Ss. 12(8) and 14(9) of the WT Act 2006.

not be a legitimate use of our powers because such specific circumstances are not applicable here. We note, in particular, that we do not consider it necessary to impose any spectrum cap in our future auction (see section 8). We also note that, even if we were to impose a spectrum cap, according to H3G's proposal, the ("zero" cap) limit on 40 GHz spectrum suggested by H3G would no longer apply once the existing licensees have entered the auction, which is the stage of the award process where a limit on the amount of spectrum that bidders can hold is normally intended to apply. It is also unclear on which basis we would impose a limit equal to zero since it would be significantly lower than any spectrum caps imposed so far and, as acknowledged by H3G, it would effectively amount to requiring the existing holders of the 40 GHz licences to consent to have their licence revoked in order to participate in the auction.[150]

A8.11 For the reasons set out above, although we have given them careful consideration, we do not intend to pursue the alternative options involving an incentive auction or voucher scheme proposed by H3G.

MLL's proposed trades

Stakeholders' comments

A8.12 MLL submitted that "Two simple trades to move the MLL FDD spectrum to the top and bottom of the band would allow FDD services to continue and make the centre of the band available for allocation to TDD-based IMT".[151] Specifically, [CONFIDENTIAL ✂].[152]

A8.13 [CONFIDENTIAL ✂].[153]

Ofcom's response

A8.14 We do not think that MLL's proposed trades would address the issues that we have set out in section 7.[154] While it is possible that a sequence of trades could allow large contiguous blocks in 40 MHz, we do not think the prospect of this is sufficiently likely to enable us to rely on trading to achieve an efficient allocation across both bands, because:

a) [CONFIDENTIAL ✂].

b) The main benefit of MLL's trading scenario appears to be to create an allocation whereby MLL could continue to use spectrum in a Frequency Division Duplex ("**FDD"**) configuration. As discussed in more detail in Sections 2 and 7, we consider that mobile use is the optimal future use of the 40 GHz band. Continued FDD use would not be compatible with this.

A8.15 We also note that [CONFIDENTIAL ✂].

[150] H3G submission of 12 October 2022, slide 13.
[151] MLL response, p.3.
[152] MLL confidential annex "Confidential MLL Telecom Submission to OFCOM 40GHz Spectrum Consultation", slide 35.
[153] MLL confidential annex, slide 36.
[154] Paragraph 7.64.

A8.16 As set out in section 7, while it is possible that a sequence of trades could allow large contiguous blocks in the 40 GHz band, we do not think the prospect of this is sufficiently likely to enable us to rely on trading to achieve an efficient allocation across both bands. MLL's proposal does not change this view.[155]

Vodafone proposal for clearing fixed links in 26 GHz and 40 GHz bands

Stakeholders' comments

A8.17 In its consultation response, Vodafone's support for partial revocation (option 3) was predicated on Ofcom adopting the model Vodafone proposed for 26 GHz fixed links. Vodafone is concerned that by issuing a 5-year revocation notice Ofcom may be causing spectrum to go unused, and that it would be more efficient for Ofcom to issue a revocation notice but with a condition in the new licences that the spectrum be leased to incumbent fixed link users until such a time that the new licensee wishes to deploy. In the 40 GHz band this would mean that, although MLL and H3G would lose their existing licences, existing links would be "grand-fathered" into being individual leases from the new licensee(s) in the 40 GHz band until such time that the new licensee(s) wished to use the spectrum.[156]

Ofcom's response

A8.18 We address Vodafone's proposal for 26 GHz fixed links in section 5 (paragraph 5.32). We do not propose to allow leasing in this band, as explained in detail in section 11 (paragraphs 11.11-11.19). However, there is a route for licensees to agree access to the auctioned spectrum on a commercial basis with the new licensee, facilitated by the Local Access licensing framework. We do not consider that leasing would allow any benefits beyond what could be enabled through the Local Access framework. We also note that reaching commercial agreements with licensees might give incumbent licensees more certainty about access to spectrum than a lease that could expire on short notice.

Responses from satellite stakeholders

Stakeholders' comments

A8.19 Several satellite stakeholders (Amazon, Eutelsat and OneWeb) noted the growing importance of the 33 GHz-75 GHz band (the "**Q/V band**"),[157] including the 40 GHz band, for satellite use cases. They said that the 40 GHz band is expected to be used by fixed satellite

[155] Paragraph 7.69.
[156] Vodafone said it was open to this operating as a formal lease between the licensee and the incumbent, or the fixed link being issued something akin to a Local Access Licence (Vodafone response to the May 2022 consultation, pp. 12 and 14).
[157] Spectrum frequencies between 33-75 GHz are commonly known as Q/V bands. Q band ranges from 37.5 to 43.5 GHz, V band ranges from 47.2-50.2 GHz and 50.4-51.4 GHz are used for satellite.

service ("**FSS**") earth stations, with deployments including gateways and feeder links and customer terminals.[158] Amazon said the need for use of the 40 GHz band for FSS is expected in the near term.[159]

A8.20 Eutelsat argued that the 26 GHz band should be largely sufficient to accommodate current and future demand for new mobile uses, and recommended making only the 26 GHz band available at this stage. Eutelsat said Ofcom should wait for the auction outcome and for deployment and use of the 26 GHz band before considering if demand is sufficient to justify opening the 40 GHz band for new mobile uses.[160]

A8.21 Amazon and GSOA were not against making the 40 GHz band available for mobile in general, but said that Ofcom must ensure that any approach it takes to managing the 40 GHz band permits both mobile and satellite use and allows both to coexist.[161]

A8.22 GSOA responded that "there are a number of requirements related to sharing with satellite services that will need to be taken into account in the design of the UK licence and authorisation regime" for the 40 GHz band. GSOA said that, taking account of Resolution 243 (WRC-19), Draft ECC Decision (22)06 and the planned EU Decision, the 40 GHz band can be assumed to have similar requirements to the 26 GHz band, meaning that the UK licence and authorisation regime for terrestrial mobile services in the 40 GHz band will need to include:

- technical limits and deployment constraints on base stations and their antennas;
- a reporting requirement for the number of base stations deployed; and
- licence conditions to enable sharing with FSS earth stations.[162]

A8.23 Amazon referred to Ofcom's 2022 Space Spectrum Strategy consultation,[163] where we said that access to the 40 GHz band for satellite gateways would be via commercial agreement with existing licensees. Amazon questioned whether we have considered the existing licensees' likelihood to enter into deals with the satellite industry after the band is made available for mobile use.[164] Amazon suggested that management of the whole band by spectrum access licensees via trades and commercial leasing arrangements may not result in optimal management of the band, "especially when there is a large demand for that spectrum, where demand arises from multiple future uses (including mobile and FSS use), and where restricting deployment to certain areas limits provision of services." In its view, in this scenario, "Ofcom management of the band will lead to more efficient outcomes for use of the spectrum, as a regulator is minded to recognise potential consumer societal benefits from assignment of spectrum, as opposed to spectrum access licensees who may

[158] Amazon response to the May 2022 Consultation, p. 1, response to Q.1; Eutelsat response to the May 2022 Consultation pp. 1-2, response to Q.1; OneWeb response to the May 2022 Consultation, pp. 2-3, response to Q.2.
[159] Amazon, p. 1, response to Q.1.
[160] Eutelsat, p. 3, response to Q.2.
[161] Amazon, p. 1, response to Q.1; GSOA response to the May 2022 Consultation, p. 1.
[162] GSOA, p. 2.
[163] Ofcom's Consultation "Space Spectrum Strategy", published 15 March 2022, paragraph 5.11. A statement was published 10 November 2022.
[164] Amazon, p. 2, response to Q.2.

only enter into commercial arrangements with those requesting to use spectrum, on a commercial basis."[165]

A8.24 OneWeb said that any new approach to licensing gateway earth stations in the Q/V band should be based on ensuring access to substantial, contiguous spectrum particularly in the uplink direction for operation of commercial satellite services in the UK.[166]

Ofcom's response

A8.25 In the May 2022 Consultation we noted that there is an allocation for the Earth to space and space to Earth services in the 40 GHz band (paragraphs 7.13-7.14).[167] The responses we received on the growing importance of Q/V band for future satellite use were consistent with responses we received to our recent Space Spectrum Strategy consultation.[168]

A8.26 Regarding Eutelsat's request to award only the 26 GHz band, in section 2 we set our reasons for making the 26 GHz and 40 GHz spectrum available on a similar timeframe.[169]

A8.27 We consider that it should be possible for future mobile services (including 5G) and future satellite services to coexist with coordinated earth stations in the 40 GHz band. As we set out in the May 2022 Consultation,[170] we investigated the coexistence of the Earth to space and space to Earth services with mobile services as part of the studies leading to WRC-19 and concluded the risk of interference to be low.[171]

A8.28 We also (see paragraph 7.14) carried out some compatibility studies between mobile services in the 40 GHz band and uncoordinated earth stations in the adjacent 39.5-40.5 GHz band.[172] The results indicated that no further restriction on unwanted emission limits may be required for adjacent band compatibility.

A8.29 We continue to follow developments in international forums (such as ITU and CEPT) on the compatibility between international mobile communications ("**IMT**") uses in the 40 GHz band and satellite. Please see paragraphs 13.36-13.43 in relation to licence conditions related to antenna pointing.

A8.30 In our recent Space Spectrum Strategy Statement (the "**2022 Space Spectrum Strategy**") we said that we will consult on proposals to license gateway Earth stations (operating with both GSO and NGSO satellites) in key Q/V band frequencies 37.5-40.5, 47.2-50.2, and 50.4-52.4 GHz. We noted that access to the 40.5-43.5 GHz band at present would be via a commercial arrangement with the existing 40 GHz band licensees. However, we noted that

[165] Amazon, pp. 3-4, response to Q.2.
[166] OneWeb, pp. 1-2, response to Q.2.
[167] The frequencies 40.5-41 GHz have an allocation for Fixed Satellite space to Earth, and 42.5-43.5 GHz Fixed Satellite Earth to space. See UK Frequency Allocation Table (UKFAT).
[168] Ofcom's Statement "Space Spectrum Strategy", published 10 November 2022, paragraphs A5.25-A5.32.
[169] Paragraphs 2.68-2.76.
[170] May 2022 Consultation, paragraph 7.13.
[171] ITU, Task Group 5/1 Chairmans Report, "Annex 6: Sharing and compatibility studies of IMT systems and the FSS (Earth to Space) in the 42.5 – 43.5 GHz frequency range", published 21 September 2018.
[172] Input to PT1, ECC PT1(21)195 Updated compatibility study between MFCN in 40.5 - 43.5 GHz and uncoordinated FSS GSO and NGSO Earth Station in the adjacent 39.5 - 40.5 GHz band, 6 September 2021.

we would take the outcome of the May 2022 Consultation into account in developing any further licence proposals.[173]

A8.31 Having decided to start the process for revoking the 40 GHz licences,[174] we will consider how to make these frequencies available for gateway satellite earth stations on a coordinated basis in line with our priority set out in the 2022 Space Spectrum Strategy. As we said in our 2022 Space Spectrum Strategy,[175] satellite stakeholders may find it beneficial to focus on low density areas for future Q/V band gateways, as we intend to award licences for the use of the 40 GHz band in high density areas by auction.

A8.32 In our 2022 Space Spectrum Strategy, we noted comments regarding future access to Q/V band for user terminals. However, we assessed that the technology is still somewhat immature and set out that this is not a priority for us at this time.[176] We note that it would be very difficult to allow two uncoordinated uses (i.e. satellite terminals and mobile) in the same area, and we do not expect uncoordinated terrestrial earth stations will be compatible with mobile in the 40 GHz band.

[173] 2022 Space Spectrum Strategy, paragraphs 4.4-4.5.
[174] See section 7.
[175] 2022 Space Spectrum Strategy, paragraph 4.5.
[176] 2022 Space Spectrum Strategy, annex, paragraphs A5.26 and A5.36.

A9. Illustrative auction procedures

A9.1 As part of our work on the proposed award process, Ofcom has drafted some illustrative procedures, which are set out in this annex. As noted in section 9, these are an initial draft and are being shared as part of this consultation so that stakeholders can obtain a more in depth understanding of our design. The procedures are evolving, and it is quite likely that there will be changes especially when Ofcom commences work on implementing these processes into a statutory instrument. There are strict rules on the drafting of legislation, and it might well be that there are changes and adjustments to the processes that are necessary for that reason. Nevertheless, we considered it helpful to share our current thinking with stakeholders and we would welcome any comments and suggestions on this as part of our consultation exercise.

Lot structure

Use of frequency generic lots

A9.2 The award mechanism would consist of two distinct bidding stages. In the first stage (the "principal stage"), the spectrum available would be offered as frequency "generic" lots grouped into three "lot categories"; one for each of the 26 GHz lower, 26 GHz upper, and 40 GHz frequencies. Each lot would correspond to a contiguous 100 MHz block of spectrum in the relevant lot category. This principal stage would allow Ofcom to determine the number of lots (i.e. the total bandwidth) to be assigned to each bidder in each lot category.

A9.3 The specific frequencies assigned to each winner of generic lots would then be determined in a follow-up "assignment stage". Ofcom would determine, for each frequency lot category, the potential assignment options that would guarantee all winning principal stage bidders receive contiguous assignments.

A9.4 In the event there are several potential assignment options that would guarantee all winning principal stage bidders receive contiguous assignments, such bidders would be invited to bid for their preferred option. Further details on the selection of assignment stage outcomes are provided in the subsection on the assignment stage below.

Lot categories

A9.5 The spectrum available would be offered in the following three generic lot categories, which would all relate to the use of spectrum in "high density areas":

a) 26 GHz lower lots: this lot category would contain fourteen 100 MHz lots of spectrum in the frequency range 25.1-26.5 GHz. During the principal stage, each lot of spectrum would be assigned 1.5 eligibility points;

b) 26 GHz upper lots: this lot category would contain ten 100 MHz lots of spectrum in the frequency range 26.5-27.5 GHz. During the principal stage, each lot of spectrum would be assigned 1.5 eligibility points;

c) 40 GHz lots: this lot category would contain thirty 100 MHz lots of spectrum in the frequency ranges 40.5-43.5 GHz. During the principal stage, each lot of spectrum would be assigned 1 eligibility point.

Applications, initial deposit, overall bid constraint and qualification

A9.6 Applicants would be required to provide Ofcom with certain information in order to apply to participate in the auction. The information to be provided to Ofcom, the deadline for its submission and the form of submission will be specified by Ofcom.

A9.7 Along with their application, applicants would be required to submit an initial monetary deposit of £100,000, which might be forfeited in whole or in part if the applicant subsequently breaches the Auction Regulations. Any interest on deposits would be retained by Ofcom and passed to HM Treasury.

A9.8 After the deadline for applications, Ofcom would notify each applicant of the name of every other applicant and its "associates" (i.e. every person having a material interest in the other applicants). Applicants would then need to ensure they meet the auction rules which would not allow for two or more associated applicants to participate in the auction (the "bidder association rules"). They would need to do so by a deadline specified by Ofcom, and it may be the case that some applicants have to withdraw their application to prevent another applicant from failing to qualify in the auction. Other qualification criteria to ensure that applicants are suitable to hold a licence would also apply. The provisions for qualification are similar to those used in recent awards by Ofcom and will be specified in the regulations made by Ofcom setting out the auction rules (the "Auction Regulations").

A9.9 After the deadline for complying with the bidder association rules, Ofcom would determine which applicants qualify to participate in the auction.

A9.10 To do so, Ofcom may require additional information from specific applicants, which would need to be provided before a deadline specified by Ofcom.

A9.11 Following the last day for withdrawals from the award, Ofcom would determine the list of qualified applicants (i.e. bidders), and return the initial deposit to any applicants who fail to qualify. Only qualified applicants would be allowed to participate in the auction.

A9.12 Before the first round of the auction takes place, each bidder would need to provide an additional deposit to Ofcom of at least £400,000, which would determine the bidder's initial eligibility limit. This would be in addition to the initial monetary deposit of £100,000. The initial eligibility limit would determine the maximum number of bids that the bidder may submit in the first round of the auction.

The Electronic Auction System

A9.13 The auction would be run over the internet using an Electronic Auction System ("**EAS**").[177] No specialist hardware or software would be required on bidder's terminals, as the EAS interface would run on a standard web browser.

A9.14 Ofcom also expects to make a stand-alone version of the software available to applicants, a few days after application. Applicants would be able to login both as bidders and as the auctioneer, allowing them to run internal mock auctions as part of their training.

The principal stage

Overview of the principal stage

A9.15 During the principal stage, bidders may submit bids for the (generic) lots available subject to the prices announced by the auctioneer.

A9.16 Prices would increase in lot categories where there is "excess demand" (i.e. where the aggregate processed demand for spectrum lots is greater than the available supply of lots in a lot category).[178, 179] Bidding would continue as long as there is excess demand in at least one lot category.

A9.17 The principal stage would end when, at the end of a round, aggregate processed demand is less than or equal to the supply of lots in every lot category (i.e. when there is "no excess demand" in every lot category). When the principal stage ends, each bidder would win the number of lots, in each lot category, corresponding to their last processed demand. Winning bidders would be required to pay a price, for each lot that they have won, equal to the final processed price in each lot category.

The bidding process

A9.18 The bidding process in the principal stage would require one or more rounds, each round consisting of a fixed time window during which bidders may submit bids in accordance with prices announced by the auctioneer.

A9.19 During the bidding process, the EAS would assess each bid placed in each lot category in a round and determine the quantity of spectrum lots that have been accepted, for each bidder, at the end of the round ("**the processed demand**"). The bidding process will be explained in detail below.

[177] In the case of proven technical difficulties, a bidder would be provided with alternative means to submit its bids.
[178] Excess demand is calculated as the difference between aggregate processed demand for spectrum lots and the available supply of lots in a lot category. In this document we refer to there being excess demand if the calculation is positive. If instead it is negative or zero, then there is "no excess demand".
[179] By bid processing, we refer to the process of assessing each bid and determining whether the bid can be accepted and, if so, to what degree. For a definition of "processed demand", see paragraph A9.19.

A9.20 A bid is only valid if it is submitted during a round in accordance with the Auction Regulations.

Scheduling of rounds

A9.21 When a round is scheduled, the start and the end time of the round would be announced by Ofcom.

A9.22 We expect to set rounds that last between 15 to 45 minutes, but we may choose different durations. We intend to provide bidders with at least 15 minutes notice before the start of a round.

Round one

A9.23 Before the start of the auction, Ofcom would announce the reserve price for each lot category.

A9.24 Each bidder would submit a deposit of at least £400,000.[180] In the first round, Ofcom would calculate the bidders' initial eligibility based on their deposit and the reserve prices.

A9.25 The initial eligibility would determine the maximum amount of lots bidders may bid for, across lot categories, in the first round.

A9.26 Bidders would then specify the quantity of spectrum they wish to win, in each lot category, at the reserve price.

A9.27 At the end of the round, the processed price in each lot category will be the reserve price.[181] For each bidder, the processed demand at the end of the round will be equal to the bids submitted by the bidder (and accepted by the EAS) in each lot category.[182]

Round two onwards and determination of prices

A9.28 In round two and any following rounds, bidders may submit bids for the (generic) lots available at prices announced by the auctioneer.

A9.29 In the clock auction design, each round would have, for each lot category:

a) **An opening price**: the lowest price bidders may bid for in each round. This is set by Ofcom.

b) **A clock price**: the highest price bidders may bid for in each round. This is set by Ofcom.

c) **A posted price**: the processed price at the end of the round. Once all bids are processed, the posted price will be set as follows:

i) If aggregate demand is greater than available supply, the posted price will be equal to the clock price for the round.

[180] This deposit would be in addition to the initial monetary deposit of £100,000 to be submitted at the application stage.
[181] In the first round, bidders may only bid for lots at the reserve price. At the end of the round, the processed (i.e. closing) price will then be the reserve price.
[182] In the first round, all bids are automatically accepted by the EAS.

ii) If aggregate demand is equal to available supply and at least one bid demanding a reduction of quantity in the lot category was processed, the posted price will be equal to the price associated to the bid which had caused excess demand in that round to drop to zero.

iii) In all other cases, the posted price will equal the opening price.

A9.30 In round two and any following rounds, the EAS would set the opening price for each lot category equal to the posted price of the previous round. The clock price would be set by Ofcom and would always be higher than the opening price. More detailed guidance on price increments will be published by Ofcom closer to the auction (e.g. in the bidder guidance).

A9.31 For each lot category, a bidder may decide to maintain its demand in the round, meaning that the bidder is willing to purchase a quantity of lots equal to the previous round's processed demand at all prices up to and including the round's clock price. Alternatively, a bidder may decide the price at which to change its demand in the round. This price could be any amount in the range between the opening price and the clock price for that round.

Bid submission

A9.32 In any round, bidders can make a single submission of bids using the EAS. [183] Therefore, bidders should submit all of the bids they wish to submit in a given round simultaneously in the same submission. When a round is in progress, each bidder's EAS interface would provide a bid form.

A9.33 To make a submission, a bidder would need to specify the number of lots in each lot category for which they wish to submit a bid at a specified price.[184] A bidder may only bid for a quantity that is greater than 0 and less than or equal to the available supply for the lot category.

A9.34 In the first round, each bidder may only submit a maximum of one bid per lot category. From the second round onwards, each bidder may submit multiple bids in the same lot category. However, a bidder may not submit multiple bids in a single round where this includes both bids to increase demand and bids to decrease demand in the same lot category. In addition, if a bidder maintains demand in a lot category it may not submit any other bids in that lot category.

A9.35 We also note that:

- Where bidders submit bids in a lot category, this must be at a specified price in whole thousands of pounds.[185]

[183] If the standard EAS provided by our supplier allows bidders to change, delete or replace their submissions as often as desired during the clock round and takes the submission of bids present in the system at the end of the clock round as the only binding submission, we would consider adopting the same approach to reduce procurement costs.
[184] For simplicity, we refer to "bid submission" in this document as the act of maintaining, increasing, or decreasing the quantity of lots demanded.
[185] For simplicity, this rule is not taken into account for the examples in this annex.

- Bidders may not submit bids in a lot category at a price lower than the opening price and higher than the clock price for the round;
- Bidders may not submit different bids in the same lot category for different quantities at the same price;
- Bidders may not submit different bids in the same lot category for the same quantity at different prices.
- Bidders may not submit different bids in the same lot category for the same quantity at the same price.
- During the bidding process, when a bidder indicates the quantity of lots requested, the EAS will automatically set the bidding price (i) to the opening price, if this is the first submitted bid in the lot category, or (ii) to a price increment higher than the price associated to the bidder's previous bid in the lot category, in any other case. The bidder may then decide to leave it as such or change the price up to, and including, the clock price.
- In order to be accepted, a bid may not cause excess demand to drop, or drop further, below zero.
- In the case of multiple bids to increase in the same lot category, the total amounts of lots requested, at higher prices, must be higher than the total amounts of lots requested at lower prices.
- In the case of multiple bids to decrease in the same lot category, the total amounts of lots requested, at higher prices, must be lower than the total amounts of lots requested at lower prices. An example is provided in box 1 below.

Box 1: Example of multiple bids in the same lot category

Suppose that, in the previous round, the bidder's processed demand in one lot category is 4 lots and the posted price is 100. In the current round, the opening and clock prices are 100 and 110 respectively. The bidder wishes to submit the following bids:

- Bid for 2 lots at the price of 105; and
- Bid for 1 lot at the price of 104.

Table A9.1 shows the price and quantities associated with the simple bids that the bidder wishes to submit.

Table A9.1: Summary of simple bids the bidder wishes to submit

Price	Quantity
100	4
104	1
105	2

Thus, the bidder is requesting, at price 105, a quantity of spectrum higher than that they are requesting at price 104 (the bid for 1 lot should have been submitted at a price higher than 105). The EAS will not accept these bids and therefore will not process them.

Instead, the following bids (for example) would be accepted, and therefore, processed by the EAS:

- Bid for 2 lots at the price of 104
- Bid for 1 lot at the price of 105.

Bidding and types of bids

A9.36 When submitting a bid, bidders must specify:

- The lot category to which the bid applies.
- The number of lots for which they wish to submit a bid. Where bidders fail, in the round, to submit a bid for a lot category for which they had positive demand in the previous round, the system would process the "missing bid" as if the bidders had requested a quantity of 0 lots at the opening price. The missing bid would be processed like any other bid.
- The corresponding price.[186]
- The type of bid. Bidders may choose to submit simple bids or "all or nothing" bids.[187] By default, bids are submitted as simple bids.

A9.37 There are two types of bids available to bidders:

a) Simple bids

b) All or nothing bids

A9.38 After the first round, a bidder may submit both simple bids and all or nothing bids for lots in each lot category.

Simple bids

A9.39 A simple bid requests a number of lots in a lot category at a specified price. It can be used to:

a) Maintain demand from a previous round (i.e. a request for the same number of lots processed in the previous round). The bid would be interpreted by the EAS as a bidder's willingness to purchase the processed demand from the previous round at a price up to and including the clock price of the current round.

[186] In the first round, bids may only be submitted at the reserve price.
[187] In the first round, bidders may only submit a simple bid per lot category.

b) Increase demand at a specified price (i.e. a request for a higher number of lots than was processed in the previous round).[188] This price can be any price between, and including, the opening price and clock price. The bid would be interpreted by the EAS as a bidder's willingness to purchase any quantity between the previous processed demand and the new increased requested amount, with a preference for the increased amount.[189]

c) Decrease demand at a specified price (i.e. a request for a lower number of lots than was processed in the previous round).[190] This price can be any price between, and including, the opening and clock price. The bid would be interpreted by the EAS as a bidder's willingness to purchase:

   i) The last processed demand at a price higher than (or equal to) the opening price and lower than the specified price.[191]

   ii) Any number of lots between (and including) the last processed demand and the new decreased amount at the specified price, with a preference for lower amounts of lots.[192]

   iii) The new decreased amount at a price higher than the specified price and up to, and including, the clock price.

A9.40 Simple bids to increase or decrease demand may be accepted in full, partially, or not at all, depending on a bidder's eligibility limit and whether or not there is sufficient excess demand in the relevant lot category.

A9.41 Examples of simple bids are provided in box 2 below.

[188] Or a request for a higher number of lots than a bid in the same round at the closest lower specified round price to this bid.
[189] Note that increases in demand are processed regardless of whether the price specified is reached. The price only affects the placement of the bid in the queue for bid processing, which is discussed later in the annex.
[190] Or: a request for a lower number of lots than a bid in the same round at the closest lower specified round price to this bid.
[191] In this case, by "last processed demand", we mean the last number of lots that has been accepted for the bidder. This could be the processed demand at the end of the previous round as well as any processed demand in the current round.
[192] See footnote 191.

Box 2. Examples of simple bids

Simple bid to maintain previous demand in the current round.

Suppose a bidder has ended the previous round with a demand of 5 lots at the posted price of 100.[193] In the current round, the opening price and clock prices are 100 and 110 respectively.

The bidder requests to maintain previous demand at the new round prices. This would be interpreted by the EAS as follows:

- For all prices between (and including) 100 and 110, the bidder would be willing to buy up to 5 lots.

Simple bid to increase previous demand in the current round.

The bidder requests to increase previous demand by 2 lots (so that the bid is for 7 lots) at the price of 105. This would be interpreted by the EAS as follows:

- For all prices between (and including) 100 and 110, the bidder would be willing to buy any number of lots between 5 and 7, with a preference for the higher amount of lots.[194]

Simple bid to decrease previous demand in the current round.

The bidder requests to reduce previous demand by 2 lots (so that the bid is for 3 lots) at the price of 105. This would be interpreted by the EAS as follows:

- If the price is between 100 and 104, the bidder would be willing to buy 5 lots.
- If the price is equal to 105, the bidder would be willing to buy any number of lots between (and including) 3 and 5, with a preference for the lower amount of lots.
- If the price is between 106 and 110, the bidder would be willing to buy 3 lots.

All or nothing bids

A9.42 All or nothing bids request a number of lots in a lot category at a specified price. They are either accepted in full or not accepted at all.

A9.43 All or nothing bids may be used to decrease, but not increase or maintain, demand in a lot category.

A9.44 An example of all or nothing bid is provided in box 3 below.

[193] For all examples of simple bids in box 2, we assume that prices may only take integer values (i.e. a price of 100.5 would not be accepted by the EAS and therefore the bid would not be processed).
[194] Note that the increase in quantity requested applies at all prices, even below price 105, which is the price the bid was specified at. This is because increases in demand are processed regardless of the price specified. The price only affects the placement of the bid in the queue for bid processing, which is discussed later in the annex.

Box 3. Example of all or nothing bid.

Suppose a bidder has ended the previous round with a demand of 5 lots at the posted price of 100. In the current round, the opening price and clock price are 100 and 110 respectively.

The bidder submits an all or nothing bid to decrease previous demand by 2 lots (so that the bid is for 3 lots) at the price of 100. This would be interpreted by the EAS as follows:

- If excess demand allows for the bid to be accepted in full (that is, processing the bid in its entirety would not cause excess demand in the lot category to drop below or further below 0), then the EAS would reduce demand by 2 lots. Consequently, the bidder's processed demand at the end of the round will be 3 lots. 195, 196
- If excess demand does not allow for the bid to be accepted in full (that is, processing the bid in its entirety would cause excess demand in the lot category to drop below or further below 0), then the EAS would reduce demand by 0 lots. Consequently, the bidder's processed demand at the end of the round will be 5 lots.

Eligibility rule

A9.45 As previously mentioned, each lot of spectrum within the three lot categories would be assigned:

a) 1.5 eligibility points for a lot of 26 GHz lower

b) 1.5 eligibility points for a lot of 26 GHz upper

c) 1 eligibility point for a lot of 40 GHz

A9.46 In each principal stage round, the bidder's submitted bids must be such that if all the bidder's bids were accepted, the bidder would not exceed its eligibility limit for that round. In practice this is checked by ensuring that the "sum of eligibility points" must not exceed the bidder's eligibility limit. The sum of eligibility points, for a bidder, is calculated by adding together the eligibility points associated with the bid submitted at the highest specified price in each lot category.

A9.47 In the first round, the eligibility limit is calculated based on the bidder's deposit and the reserve prices.

A9.48 For round 2 and each round following that, the eligibility limit for the round will be equal to the sum of the eligibility points associated with the bidder's processed demand in the previous round.

A9.49 An example of how eligibility points and the eligibility limit is calculated is provided in box 4 below.

[195] Note that whether or not an all or nothing bid is accepted in full or not accepted at all would only depend on the implications for excess demand, and would not depend on eligibility. This is because an all or nothing bid is a bid to decrease, so accepting an all or nothing bid can never result in an eligibility limit being exceeded.
[196] Note that the all or nothing specified bid price is the opening price, 100, which is why we have not written further interpretations from the EAS. If the bid price were higher, it would be necessary to state these.

Box 4. Eligibility rule.

Suppose a bidder has ended the previous round with a processed demand of 5, 5, and 7 lots in 26 GHz lower, 26 GHz upper, and 40 GHz respectively. Thus, their eligibility limit for the current round would be 5x1.5 + 5x1.5 + 7x1 = 22 eligibility points.

Example 1

Suppose, in the current round, the opening and clock prices equal:

- 100 and 110 respectively for 26 GHz lower
- 150 and 165 respectively for 26 GHz upper.
- 50 and 55 respectively for 40 GHz.

The bidder wishes to submit the following bids:

- A simple bid for 3 lots at price 105 in 26 GHz lower.
- A simple bid for 3 lots at price 160 in 26 GHz upper.
- A simple bid for 15 lots at price 53 in 40 GHz.

The sum of eligibility points associated with the bidder's bids would equal 3x1.5 + 3x1.5 + 15x1 = 24. Thus, as it exceeds 22, the EAS will not accept the bids and therefore it would not process them.

Example 2

Suppose, in the current round, the opening and clock prices are as in example 1.

The bidder wishes to submit the following bids:

- A simple bid for 3 lots at price 105, and a simple bid for 1 lot at price 107 in 26 GHz lower.
- A simple bid for 3 lots at price 160, and a simple bid for 0 lots at price 163 in 26 GHz upper.
- A simple bid for 15 lots at price 53 in 40 GHz.

The sum of eligibility points associated with the bidder's bids would equal 1x1.5 + 0x1.5 + 15x1 = 16.5. Thus, as it does not exceed 22, the EAS will accept the bids and therefore it would process them.

The EAS will accept these bids, and therefore it would process them, even though a subset of these bids would exceed the bidder's eligibility limit.

Price points

A9.50 Simple bids to maintain are always processed first.

A9.51 From round 2 and onwards, submitted bids to decrease or increase would be processed by the EAS in ascending order of price points. [197] In the event of multiple bids with the same price point, a random number would be assigned to each of those bids, and they would be processed according to these random numbers, in ascending order.

[197] Bid processing only comes into effect from round 2 onwards. In the first round, all bids are automatically fully accepted, because the EAS would stop any bid that exceeds eligibility from being submitted, and because there is no previous excess demand (thus, round 1 bids cannot cause excess demand to drop below or further below zero).

A9.52 The price point is a percentage calculated as the ratio of the difference between bid price and the opening price and the difference between the clock price and the opening price, i.e. the bid price minus the opening price, divided by the clock price minus the opening price.

A9.53 In the examples above, if the bid price, opening price and clock prices are 105, 100, and 110 respectively, the price point would amount to 50% (e.g., [105 – 100] / [110 – 100]).

Processing of bids

A9.54 After each round, once all bids have been submitted, the EAS would assess each bid and determine whether the demand should be accepted fully, partially, or not at all (in the case of simple bids) or whether the demand should be accepted fully or not at all (in the case of all or nothing bids).

A9.55 A submitted simple or all or nothing bid would be accepted fully only if doing so would not cause excess demand to drop below (or further below) zero and if it would not cause the bidder's eligibility limit to be exceeded.

A9.56 Whenever a submitted simple bid cannot be accepted fully, the EAS would check whether it can be accepted partially. The increase or decrease in processed demand requested by the submitted bid would be incrementally tested, lot by lot, to determine whether parts of the bid can be accepted. That is, each incremental part of the bid will be accepted up until:

i) an extra processed lot would cause excess demand to drop below (or further below) 0; or

ii) an extra processed lot would exceed the bidder's eligibility limit.

A9.57 At this point, the EAS would process only the part of the bid that can be accepted. The unprocessed demand change would be put back into the queue in the same position at the same specified price. Thus, we say that the submitted bid has been accepted partially.[198]

A9.58 An example of partially accepted simple bid is provided in box 5 below.

[198] In practice, the bid will be put back into the queue unchanged as bids are defined as a quantity requested at a specified price (e.g. 2 lots at price 105), rather than changes in demand (e.g. decrease in demand by 3 at price 105).

Box 5. Example of partially processed simple bid.

Suppose a bidder has ended the previous round with a processed demand of 5 lots at the posted price of 100. In the current round, the opening price and clock prices are 100 and 110 respectively. Excess demand in the lot category (as of the end of the previous round) is 2 lots. The bidder requests to reduce previous processed demand by 3 lots (so that the bid is for 2 lots) at the price of 105. All other bidders maintain demand in the lot category.

Accepting the submitted bid in its entirety would cause excess demand to drop below 0 (i.e. excess demand of -1). As the simple bid cannot be accepted fully, the EAS checks whether it can be accepted partially and processes the bid in the following way:[199]

- The bidder's request to decrease its demand by 1 lot is accepted as it would reduce excess demand to 1.
- The bidder's request to decrease its demand by an additional lot (thus, by a total of 2 lots) is accepted as would reduce excess demand to 0.
- The bidder's request to decrease its demand by an additional lot (thus, by a total of 3 lots) is not accepted as it would cause excess demand to drop below 0 to -1.

Thus, at a price of 105, only the bidder's request to decrease demand by 2 lots is accepted. The unprocessed demand for a further decrease by an additional 1 lot (which would leave the bidder with a total processed demand of 2 lots instead of 3 lots (at the price of 105) remains in its place in the queue.[200]

A9.59 In each round, simple bids to maintain demand would be processed first. All bids to decrease or increase demand would then be processed in ascending order of price points. The EAS arranges all bids to decrease or increase demand, in ascending order of price points, into a "queue". The order of bid processing would remain the same throughout the round.[201] The EAS would attempt to process each bid in the queue in order, starting with the first bid in the queue.

A9.60 Specifically, the EAS would check whether the unprocessed bid can be fully accepted and accept it in full if it is. If it cannot be fully accepted, the EAS would then accept it to the maximum it can be, if any. The part of the bid that is accepted would leave the queue while the unprocessed demand would stay in its place in the queue. If the bid cannot be accepted (either in full or partially), then it would remain in the queue in its entirety.

A9.61 Whenever a bid is either fully or partially accepted, the queue would be re-tested from the beginning to determine whether any bids corresponding to unprocessed demand have become fully or partially acceptable. The first bid in the queue to have become fully or partially acceptable would be processed using the procedure in paragraph A9.60. The procedure would be repeated and the re – testing of the queue continue until:

[199] As it is a bid to decrease, it will always be within the bidder's eligibility limit for the round.
[200] The "queue" is explained further in paragraph A9.59.
[201] That is, the unprocessed demand is put back into the queue, in the same order as it was before the start of bid processing.

a) all bids from the round have been processed; and

b) no bids in the queue are fully acceptable; and

c) no bids in the queue are partially acceptable.

A9.62 At this point, all bids remaining in the queue would be discarded.

A9.63 In practice, the EAS will execute the queue as follows:

a) Process all bids to maintain demand.

b) Collect all remaining bids to decrease or increase demand and calculate their price points.

c) Sort all bids in ascending order based on their price point into a "queue".[202]

d) Process the first bid in the queue (or go to step *(f)* if there are no more fully or partially acceptable bids in the queue):

i) If the bid is accepted in full, remove the bid from the queue and return to step *(d)*.

ii) If the bid is accepted partially, remove the part of the bid that can be accepted from the queue and leave the part of the bid corresponding to any unprocessed demand in its place in the queue. Then, move to step *(e)*.

iii) If the bid cannot be accepted at all, leave the bid in its place in the queue. Then, move to step *(e)*.

e) Process the next bid in the queue (or go to step *(f)* if there are no more bids in the queue):

i) If the bid is accepted in full, remove the bid from the queue and return to step *(d)*.

ii) If the bid is accepted partially, remove the part of the bid that can be accepted from the queue and leave the part of the bid corresponding to any unprocessed demand in its place in the queue. Then, return to step *(d)*.

iii) If the bid cannot be accepted at all, leave the bid in its place in the queue. Then, return to step *(e)*.

f) Discard all bids remaining in the queue.[203]

Information released at the end of each principal stage round

A9.64 At the end of each round, the EAS would process the submissions in the round and determine whether a further round is needed. Once Ofcom is satisfied that the round has run correctly, it will approve the round result and information about a completed round would be made available to bidders.

[202] In the event of multiple bids with the same price point, each of these bids would be assigned a random number, and they will be sorted in ascending order based on the random numbers.

[203] Before discarding the bids, the EAS will check that all bids from the round have been processed and no bids in the queue can be fully or partially accepted.

A9.65 If a further round is needed, the following information would be made available to each bidder on the EAS interface before the start of the next round:

i) a summary of bids submitted by the bidder in the most recent round;

ii) the processed demand of the bidder for each lot category in the most recent round;

iii) the posted price for each lot category in the most recent round;

iv) the opening and clock prices for each lot category for the next principal stage round;

v) the bidder's eligibility limit for the next principal stage round; and

vi) the excess demand for each lot category in the most recent round.

A9.66 No information would be released about the bids submitted by the other bidders.

End of the bidding process

A9.67 The principal stage bidding process would end when, at the end of the round, aggregate processed demand is less than or equal to the supply of lots in every lot category (i.e. when there is no excess demand in every lot category).

Determination of winning quantities and prices

A9.68 At the end of the bidding process, bidders will win a quantity of lots corresponding to their processed demand in the final round. Winners of spectrum will be required to pay an amount equal to the last processed demand multiplied by the posted price in each lot category.

Information released at the end of the principal stage

A9.69 Once the principal stage has ended, the following information would be made available to each bidder on the EAS interface:

a) a message informing the bidder that the principal stage has ended; and

b) the bidder's total number of lots won in each lot category and the associated price.

A9.70 No further information would be released about the number of lots won in each lot category and the associated price for other bidders.

Box 6: Worked up example of principal stage

The example illustrates how bidding would work in the principal stage. For simplicity, we only use two lot categories in this example (26 GHz lower and 40 GHz), instead of the 3 lot categories in the auction. This example assumes two bidders (A, and B) and the same lot structure of the award (14 lots available in 26 GHz lower and 30 lots in 40 GHz). The bids and prices for each round are purely illustrative and they are summarised in Table A9.2 below.

After having submitted a deposit, bidder A and bidder B begin the auction with an eligibility limit of 40 and 25 points respectively.

Round 1

In round 1, the reserve prices equal 100 for 26 GHz lower and 50 for 40 GHz. The submitted bids are as follows:

- Bidder A requests 14 lots in 26 GHz lower and 19 lots in 40 GHz.
- Bidder B requests 10 lots in 26 GHz lower and 10 lots in 40 GHz.

At the end of the round, the processed demands are as follows:

- Bidder A's processed demand is 14 lots in 26 GHz lower and 19 lots in 40 GHz.
- Bidder B's processed demand is 10 lots in 26 GHz lower and 10 lots in 40 GHz.

At the end of the round:

- The posted price is 100 for 26 GHz lower, and excess demand is 10.
- The posted price is 50 for 40 GHz, and the excess demand is -1.
- Bidder A's eligibility limit for the next round is 40 (14 x 1.5 + 19 x 1).
- Bidder B's eligibility limit for the next round is 25 (10 x 1.5 + 10 x 1).

Round 2

In round 2, the opening and clock prices equal 100 and 110 for 26 GHz lower and 50 and 55 for the 40 GHz band. The submitted bids are as follows:

- Bidder A submits a simple bid to decrease its demand in 26 GHz lower by 3 lots (so that the bid is for 11 lots) at price 105 and a simple bid to maintain its demand of 19 in 40 GHz.
- Bidder B submits a simple bid to decrease its demand in 26 GHz lower by 2 lots (so that the bid is for 8 lots) at price 107 and a simple bid to increase its demand in 40 GHz by 3 lots (so that the bid is for 13 lots) at price 54.

The EAS collects all bids to decrease and to increase and calculates the price points:

- Bidder A's bid in 26 GHz lower is assigned a price point equal to (105 – 100) / (110 – 100) = 50%
- Bidder B's bid in 26 GHz lower is assigned a price point equal to (107 – 100) / (110 – 100) = 70%
- Bidder B's bid in 40 GHz is assigned a price point equal to (54 – 50) / (55 – 50) = 80%.

Next, the EAS arranges the bids, in ascending order of price points. The bids are arranged in the following order: bidder A's bid in 26 GHz lower, bidder B's bid in 26 GHz lower, bidder B's bid in 40 GHz.

The bid processing works as follows:

a. Bidder A's bid in 40 GHz is processed first, as it is a bid to maintain the previous demand. It is accepted fully and leaves the queue.

b. Bidder A's bid in 26 GHz lower is processed. The bid is fully acceptable as it is within the bidder's eligibility limit for the round and does not cause excess demand to drop below (or further below) 0. The bid is accepted fully and leaves the queue.

c. Bidder B's bid in 26 GHz lower is processed. The bid is fully acceptable, is accepted fully and leaves the queue.

d. Bidder B's bid in 40 GHz is processed. The bid is fully acceptable, is accepted fully and leaves the queue.

At the end of the round, the processed demands are as follows:

- Bidder A's processed demand is 11 lots in 26 GHz lower and 19 lots in 40 GHz.
- Bidder B's processed demand is 8 lots in 26 GHz lower and 13 lots in 40 GHz.

At the end of the round:

- The posted price is 110 in 26 GHz lower, and excess demand is 5 lots.
- The posted price is 55 in 40 GHz, and excess demand is 2 lots.
- Bidder A's eligibility limit for the next round is 35.5 (11 x 1.5 + 19 x 1).
- Bidder B's eligibility limit for the next round is 25 (8 x 1.5 + 13 x 1).

Round 3

In round 3, the opening and clock prices equal 110 and 121 for 26 GHz lower, and 55 and 60 for 40 GHz. The submitted bids are as follows:

- Bidder A submits a simple bid to decrease its demand in 26 GHz lower by 2 lots (so that the bid is for 9 lots) at price 113 and a simple bid to maintain its demand of 19 in 40 GHz.
- Bidder B submits an all or nothing bid to decrease its demand in 26 GHz lower by 2 lots (so that the bid is for 6 lots) at price 115, an all or nothing bid to decrease its demand in 26 GHz lower by a further 2 lots (so that the bid is for 4 lots) at price 117 and a simple bid to increase its demand in 40 GHz by 6 lots (so that the bid is for 19 lots) at price 58.

After the EAS collects all bids and calculates the price points, the bid processing order is as follows: (i) firstly, bidder A's bid in 26 GHz lower (27%), (ii) secondly, bidder B's bid in 26 GHz lower at price 115 (45%), (iii) then, bidder B's bid in 40 GHz (60%), and (iv) finally, bidder B's bid in 26 GHz lower at price 117 (64%).

The bid processing works as follows:

a. Bidder A's bid in 40 GHz is processed first, as it is a bid to maintain the previous demand. It is accepted fully and leaves the queue.

b. Bidder A's bid in 26 GHz lower is processed. The bid is fully acceptable, is accepted fully and leaves the queue.

c. Bidder B's all or nothing bid at price 115 in 26 GHz is processed. The bid can be fully accepted, so it is accepted in its entirety and leaves the queue.

d. Bidder B's bid in 40 GHz is processed. The bid cannot be fully accepted, as it would exceed the bidder's eligibility limit for the round, but it can be partially accepted. Therefore, Bidder B's demand is increased by 3 lots and the bid for a further increase by 3 lots remains unprocessed, standing in the queue.

e. Bidder B's all or nothing bid at price 117 in 26 GHz is processed. The bid is not accepted at all as it would cause excess demand to drop below 0 (excess demand would be -1). The bid cannot be accepted partially as it is an all or nothing bid.

f. The queue is reassessed from the beginning, starting from bidder B's bid in 40 GHz and ending with bidder B's all or nothing bid at price 117 in 26 GHz lower. No more bids can be accepted. Bid processing ends and the remaining bids in the queue are discarded.

At the end of the round, the processed demands are as follows:

- Bidder A's processed demand is 9 lots in 26 GHz lower and 19 lots in 40 GHz.
- Bidder B's processed demand is 6 lots in 26 GHz lower and 16 lots in 40 GHz.

At the end of the round:

- The posted price is 121 for 26 GHz lower, and excess demand is 1 lots.
- The posted price is 60 in 40 GHz, and excess demand is 5 lots.
- Bidder A's eligibility limit for the next round is 32.5.
- Bidder B's eligibility limit for the next round is 25.

Round 4

In round 4, the opening and clock prices equal 121 and 133 for 26 GHz lower and 60 and 66 for 40 GHz. The submitted bids are as follows:

- Bidder A submits a simple bid to decrease its demand in 26 GHz lower by 5 lots (so that the bid is for 4 lots) at price 125 and a simple bid to decrease its demand in 40 GHz by 2 lots (so that the bid is for 17 lots) at price 60 (the opening price).
- Bidder B submits a simple bid to decrease its demand in 26 GHz lower by 2 lots (so that the bid is for 4 lots) at price 121 (the opening price) and a simple bid to decrease its demand in 40 GHz by 3 lots (so that the bid is for 13 lots) at price 60 (the opening price).

The EAS collects all bids, calculates the price points, and organizes the queue in the following order: bidder B's bid in 26 GHz lower (0%), bidder B's bid in 40 GHz (0%), bidder A's bid in 40 GHz (0%), and bidder A's bid in 26 GHz lower (33%).

The bid processing works as follows:

a. Bidder B's bid in 26 GHz lower is processed first. The bid cannot be fully accepted, but it can be partially accepted. Bidder B's demand is reduced by 1 lot and the bid for a further reduction by 1 lot remains in the queue.

b. Bidder B's bid in 40 GHz is processed. The bid is fully accepted and leaves the queue.

c. The queue is reassessed from the beginning. As the remaining part of bidder B' bid in 26 GHz lower remains not acceptable, bid processing continues to the next bid.

d. Bidder A's bid in 40 GHz is processed. The bid is fully accepted and leaves the queue.

e. The queue is reassessed from the beginning. As the remaining part of bidder B's bid in 26 GHz lower remains not acceptable, bid processing continues to the next bid.

f. Bidder A's bid in 26 GHz lower is processed next. The bid is not accepted at all. The bid remains in the queue.

g. The queue is reassessed from the beginning. No more bids can be accepted. Bid processing ends and the remaining bids in the queue are discarded.

At the end of the round, the processed demands are as follows:

- Bidder A's processed demand is 9 lots in 26 GHz lower and 17 lots in 40 GHz.
- Bidder B's processed demand is 5 lots in 26 GHz lower and 13 lots in 40 GHz.

At the end of the round:

- The posted price is 121 in 26 GHz lower, and excess demand is 0 lots.
- The posted price is 60 in 40 GHz, and excess demand is 0 lots.
- Bidder A's eligibility limit for the next round is 30.5.
- Bidder B's eligibility limit for the next round is 20.5.

The principal stage ends as there is no excess demand in any lot category. Bidders win their last processed demand and pay – for each lot – the corresponding posted price.

- Bidder A wins 9 lots in 26 GHz lower and 19 lots in 40 GHz. Bidder A pays 2109 (9 x 121) + (17 x 60).
- Bidder B wins 5 lots in 26 GHz lower and 13 lots in 40 GHz. Bidder B pays 1385 (5 x 121) + (13 x 60).

Table A9.2: Summary of bids and prices for each principal stage round.

26 GHz lower						
Round	**Price**	**Bid**		**Excess Demand**	**Eligibility**	
		A	**B**		**A**	**B**
1 submitted	100 (reserve price)	14	10		40 (eligibility used)	25 (eligibility used)
1 processed	100 (posted price)	14	10	10	40 (eligibility limit)	25 (eligibility limit)
2 submitted	100 – 110	11 (at 105)	8 (at 107)		35.5	25

	(opening – clock)				(used)	(used)
2 processed	110 (posted)	11	8	5	35.5 (limit)	25 (limit)
3 submitted	110 – 121	9 (at 113)	6 AON (at 115) 4 AON (at 117)		32.5	25
3 processed	121	9	6	1	32.5	25
4 submitted	121 – 133	4 (at 125)	4 (at 121)		23	19
4 processed	121	9	5	0	30.5	20.5
40 GHz						
Round	**Price**	**Bid**		**Excess Demand**	**Eligibility**	
		A	**B**		**A**	**B**
1 submitted	50 (reserve price)	19	10		40 (eligibility used)	25 (eligibility used)
1 processed	50 (posted price)	19	10	-1	40 (eligibility limit)	25 (eligibility limit)
2 submitted	50 – 55 (opening – clock)	19	13 (at 54)		35.5 (used)	25 (used)
2 processed	55 (posted)	19	13	2	35.5	25
3 submitted	55 – 60	19	19 (at 58)		32.5	25
3 processed	60	19	16	5	32.5	25
4 submitted	60 - 66	17 (at 60)	13 (at 60)		23	19
4 processed	60	17	13	0	30.5	20.5

The assignment stage

A9.71 The specific frequencies assigned to bidders who have won lots in the principal stage would be determined in the assignment stage.

A9.72 The assignment stage would comprise of multiple rounds, where each round would have a sealed bid auction format with a second price rule. Bidders would place bids on their preferred frequencies, and the EAS would identify the highest value combination of bids which could be accommodated.

A9.73 Upon completion of the assignment stage, the EAS would calculate the final price to be paid by each bidder that has won spectrum. The final price would combine the base price, resulting from the principal stage of the auction, and any additional prices arising from the assignment stage.

A9.74 Further information on the assignment stage is found in the following sections. As we as illustrative examples of the assignment stage mechanism.

Permissible assignment plans

A9.75 For each lot category, the EAS would only consider assignment plans in which each bidder is assigned a contiguous frequency block which corresponds to the bandwidth it won in the principal stage, and in which any unallocated spectrum forms a contiguous frequency block. These are defined as "**permissible assignment plans**".

A9.76 If there is only one permissible assignment plan that meets these requirements, then bidders would be assigned the frequencies corresponding to the lots they won in the relevant lot category in accordance with this permissible assignment plan. If there are multiple permissible assignment plans that meet these requirements, then bidders who would be assigned alternative frequencies under these different plans would be invited to submit bids for assignment stage options. A bidder's contiguous frequency block within a permissible assignment stage plan is defined as an "assignment stage option".

A9.77 If a bidding process for the assignment stage is needed, Ofcom would schedule multiple rounds of bidding (the "**assignment rounds**") in which the relevant bidders may submit bids (the "**assignment stage bids**") for their preferred assignment options.

A9.78 The EAS would then determine the permissible assignment plan that would maximize the value of accepted bids for the 26 GHz and 40 GHz bands. Bidders may then be required to pay a price (the "**additional price**"), on top of the prices payable by them from the principal stage, for the frequencies they are assigned (i.e. when they submitted a winning bid for the assignment stage option which corresponds to the winnings permissible assignment plan and other bidders had made a bid greater than zero bid for an assignment stage option that was not compatible with the winning permissible assignment plan).

A9.79 Bidders do not have to submit assignment stage bids to be assigned the lots they won in the principal stage. Bidding in the assignment stage is optional.

A9.80 The assignment stage rounds for the 26 GHz and 40 GHz bands are described below.

Assignment stage rounds for the 26 GHz band

A9.81 Ofcom would run up to three assignment stage rounds:

i) An initial assignment stage round for the initial assignment of lower frequencies in the 26 GHz band (25.1-26.5 GHz).

ii) An initial assignment stage round for the initial assignment of the upper frequencies in the 26 GHz band (26.5-27.5 GHz).

iii) A final assignment stage round for the final assignment of the entire 26 GHz band (25.1-27.5 GHz).

A9.82 These assignment stage rounds would run sequentially after the principal stage. The final 26 GHz assignment stage round would only take place if the initial assignment stage rounds do not produce an assignment that gives all bidders contiguous holdings. Otherwise, if all bidders have contiguous holdings after the initial assignment stage rounds, this assignment will apply for the entire licence duration.[204]

A9.83 Below we go through the assignment stage mechanics depending on how many bidders win spectrum in both the 26 GHz lower and upper lot categories in the principal stage.

26 GHz assignment stage mechanics

A9.84 In the case that no bidder has won both 26 GHz lower lots and 26 GHz upper lots,

i) In the initial assignment stage round for the 26 GHz lower, only bidders who have won 26 GHz lower lots would bid for assignments in that lot category.[205]

ii) In the initial assignment stage round for the 26 GHz upper, only bidders who have won 26 GHz upper lots would bid for assignments in that lot category.

iii) The final assignment stage round would not take place.

A9.85 In the case that only one bidder has won both 26 GHz lower lots and 26 GHz upper lots, that bidder would automatically be assigned the uppermost frequencies in the 26 GHz lower lot category and the lowermost frequencies in the 26 GHz upper lot category. Following this:

i) In the initial assignment stage round for the 26 GHz lower, bidders who have won only 26 GHz lower lots could bid only for assignments in the lower portion of that lot category.[206]

[204] Each assignment stage round will not be run if there is only one permissible assignment plan available. In this case, each bidder will be automatically assigned the frequencies corresponding to the lots they won in the relevant lot category in accordance with this assignment.
[205] 26 GHz lower lot category refers to frequencies in the 25.1-26.5 GHz range, 26 GH upper lot category refers to frequencies in the 26.5-27.5 GHz range.
[206] The lower portion of the lot category, in this case, indicates the frequencies below those automatically assigned to the bidder which has won lots across both the 26 GHz lower and the 26 GHz upper lot categories.

ii) In the initial assignment stage round for the 26 GHz upper, bidders who have won only 26 GHz upper lots could bid only for assignments in the upper portion of that lot category.[207]

iii) The final assignment stage round would not take place.

A9.86 In the case that multiple bidders have won both 26 GHz lower lots and 26 GHz upper lots, the assignment options available to these bidders would not overlap with the assignment options available to bidders who have only won 26 GHz lower lots or 26 GHz upper lots. Specifically, the frequencies would be assigned in the following way:

i) In the initial assignment stage round for the 26 GHz lower, bidders who have won only 26 GHz lower lots could only bid for assignments in the lower portion of that lot category. Conversely, bidders who have won both 26 GHz lower lots and 26 GHz upper lots could only bid for frequencies in the upper portion of the 26 GHz lower.

ii) In the initial assignment stage round for the 26 GHz upper, the bidder who has won the uppermost portion of the 26 GHz lower would automatically be assigned the lowermost portion of the 26 GHz upper. Conversely, bidders who have won only 26 GHz upper lots could only bid for assignments in the upper portion of that lot category. Bidders who have won both 26 GHz lower lots and 26 GHz upper lots, but have not won the uppermost portion of the 26 GHz lower lot category could only bid for assignments in the remaining part of the band.

iii) In the final assignment stage round, bidders who have won lots in both the 26 GHz lower and upper lot categories could only bid for the upper portion of 26 GHz lower and the lower portion of the 26 GHz upper.[208]

A9.87 In the presence of any unsold lot:

i) Any unsold lot in the 26 GHz lower lot category would be placed as one contiguous block at the lowermost portion of the 26 GHz band.

ii) Any unsold spectrum in the 26 GHz upper lot category would be placed as one contiguous block at the uppermost portion of the 26 GHz band.

Assignment stage round for the 40 GHz band

A9.88 For the 40 GHz band, Ofcom would run one single assignment stage round during which bidders would submit bids for their preferred permissible assignment stage plan, spanning the entire band. All bidders would win contiguous blocks of spectrum and the assignment would apply until the end of the licence term.

[207] The upper portion of the lot category, in this case, indicates the frequencies above those automatically assigned to the bidder which has won lots across both the 26 GHz lower and the 26 GHz upper lot categories.
[208] Bidders who won spectrum in only 26 GHz lower or 26 GHz upper would not participate in the final assignment stage round.

A9.89 The assignment stage round for the 40 GHz band would take place simultaneously to the first assignment stage round for the 26 GHz band, which is the initial assignment stage round for the 26 GHz lower (25.1-26.5 GHz).

Assignment stage bids

A9.90 The EAS will determine the permissible assignment stage plans and the assignment options available to each bidder. An example of permissible assignment stage plans and assignment options is provided in Box 7 and Table A9.3 below.

A9.91 If there are several permissible assignment stage plans for a band, then at least two bidders would have multiple assignment stage options in that band. Any such bidders would have the opportunity to express their preferences for those options in the form of assignment bids.

A9.92 An assignment stage bid consists of:

a) an assignment stage option; and

b) a bid amount, specified in pounds, and which must be in whole thousands of pounds and at least zero.

A9.93 Submitting an assignment stage bid establishes a commitment to pay an additional price that would not exceed the bid amount in the event that the bidder is assigned the frequencies specified in the corresponding assignment stage option.

A9.94 Bidders do not have to submit assignment stage bids to be assigned the lots they won in the principal stage. Participation in the bidding process of the assignment stage is optional. If a bidder chooses not to submit a bid in the assignment stage round, the EAS would interpret this as the bidder having submitted a bid of zero for all potential assignment stage options and would proceed to identify the highest value combination of all bids as normal.

Box 7. Permissible assignment stage plans and assignment options.

Consider two principal stage winning bidders (A, and B) in an auction for the 40 GHz band. Suppose, for simplicity, that there are 10 lots in 40 GHz and that in the principal stage:

- Bidder A wins 5 lots;
- Bidder B wins 5 lots.

The EAS identifies two permissible assignment stage plans (assignment 1 and 2 in Table A9.3 below) in which each bidder is assigned a contiguous frequency block which corresponds to the bandwidth it won in the principal stage (i.e. 5 lots each). Within each permissible assignment stage plan, bidder A's permissible assignment stage option is highlighted in yellow (see Table A9.3) and bidder B's is highlighted in red.

That is, bidder A has two permissible assignment stage options:

- Lower frequencies in assignment 1;
- Upper frequencies in assignment 2.

Similarly, bidder B has two permissible assignment stage options:

- Upper frequencies in assignment 1;
- Lower frequencies in assignment 2.

Table A9.3: Example of permissible assignment stage plans and assignment options.

	40 GHz									
	Lower frequencies					Upper frequencies				
Assignment 1			**A**					**B**		
Assignment 2			**B**					**A**		

Scheduling of the assignment stage rounds

A9.95 We would run the previously mentioned assignment stage rounds in the following order:

a) Initial assignment stage round for the 26 GHz lower (25.1-26.5 GHz) and a parallel assignment stage round for the 40 GHz. These would run at the same time.

b) Initial assignment stage round for the 26 GHz upper (26.5-27.5 GHz).

c) Final assignment stage round for the entire 26 GHz band (25.1-27.5 GHz).[209]

A9.96 When each assignment stage round is scheduled, the following information would be made available to each bidder:

[209] This round may not take place. See paragraph A9.82.

a) the start and the end time for the round; and

b) the assignment stage options that the bidder may bid for.

Bid submission

A9.97 When an assignment stage round is in progress, participating bidders may submit a single list of assignment stage bids using the EAS.

A9.98 The interface of the EAS would provide an assignment stage form that lists all assignment stage options available to the bidder. To submit its list of assignment stage bids, a bidder would need to enter the bid amount for each one of the assignment stage options it wishes to bid for in its assignment stage form (the bid amount for any options left blank would be set to zero).

A9.99 Any bidder who fails to submit a list of assignment stage bids before the end of the assignment stage round would lose the opportunity to submit assignment stage bids. In this case, the bid for all of its assignment stage options would be set to zero by default.

Determination of the winning permissible assignment plan

A9.100 The winning bids in each assignments stage round would be calculated independently for each lot category.

A9.101 The EAS would sum up the bid amounts of the bids that can be accepted in each alternative permissible assignment stage plan. The winning permissible assignment plan would be the one that yields the greatest value of accepted bids. If there are multiple permissible assignment plans that yield the greatest value, one of these would be selected as the winning permissible assignment plan at random.

Determination of additional prices

A9.102 The determination of additional prices is calculated independently for each lot category. The total additional price to be paid by a bidder would be equal to the sum of the additional prices (if any) payable by the bidder as a result of the initial assignment stage round for the 26 GHz lower frequencies, the initial assignment stage round for the 26 GHz upper frequencies, the final assignment stage round for the entire 26 GHz band, and the single assignment stage for the 40 GHz.

A9.103 Additional prices to be paid by winning bidders for the specific frequencies awarded to them in the assignment stage are based on the concept of opportunity cost.

A9.104 For each lot category, the opportunity cost of assigning a subset of bidders their assignment stage option in the winning permissible assignment plan is calculated as the difference between: [210]

[210] Each subset can consist of one or multiple bidders.

a) the highest value of bids that could be achieved across all alternative permissible assignment plans if all the bids from the bidders in the subset were set to zero; and

b) the sum of bid amounts of bids that are accepted from bidders that are not included in the subset in the winning permissible assignment plan.

A9.105 For any given frequency range, the additional prices must satisfy the following conditions:

a) the additional price for each bidder cannot be negative; and

b) the additional price for each bidder cannot exceed the bid amount specified by the bidder for the assignment stage option it is assigned in the winning permissible assignment plan.

Box 8: worked up example of assignment stage

Consider four principal stage winning bidders (A, B, C, D) in an auction for the 26 GHz band and 2 lot categories (26 GHz lower and upper). This example assumes the same structure of the award for the 26 GHz band (14 lots available in 26 GHz lower and 10 lots available in 26 GHz upper). Bids are purely illustrative.

Suppose that in the principal stage:

- Bidder A wins 6 lots in 26 GHz lower and 6 lots in 26 GHz upper;
- Bidder B wins 6 lots in 26 GHz lower and 2 lots in 26 GHz upper;
- Bidder C wins 2 lots in 26 GHz lower and 0 lots in 26 GHz upper;
- Bidder D wins 0 lots in 26 GHz lower and 2 lots in 26 GHz upper.

Multiple bidders (A and B) have won spectrum in both 26 GHz lower and 26 GHz upper.

Initial assignment stage round for 26 GHz lower

Permissible assignment stage plans:

The EAS determines that there are two permissible assignment stage plans, as shown in Table A9.4 below. For easy visualization, we highlight bidder A's permissible assignment options within those plans in yellow, bidder B's in red, bidder C's in green, and bidder D's in purple.

Table A9.4: Permissible assignment stage plans and assignment options for the initial assignment stage round for 26 GHz lower.

	26 GHz lower (GHz)						
	25.1-25.3	25.3-25.5	25.5-25.7	25.7-25.9	25.9-26.1	26.1-26.3	26.3-26.5
1	C	A			B		
2	C	B			A		

- Bidder C would automatically be assigned the lower portion of the 26 GHz lower lot category (25.1-25.3 GHz).
- Bidder A and B would be presented with the permissible assignment options of 25.3-25.9 GHz, and 25.9-26.5 GHz.

Assignment stage bids

Each bidder bids for their assignment options within the two permissible assignment stage plans (as shown in Table A9.5 below)

- Bidder A bids 0 for the 25.3-25.9 GHz frequencies, and 70 for the 25.9-26.5 GHz frequencies.
- Bidder B bids 0 for the 25.3-25.9 GHz frequencies, and 50 for the 25.9-26.5 GHz frequencies.
- Bidder C is presented with only one permissible assignment option, which is the 25.1-25.3 GHz frequencies. For this reason, they cannot bid.

Table A9.5: Assignment stage bids.

	26 GHz lower (GHz)						
	25.1-25.3	25.3-25.5	25.5-25.7	25.7-25.9	25.9-26.1	26.1-26.3	26.3-26.5
1	C – 0	A – 0			B – 50		
2	C – 0	B – 0			A – 70		

Determining the winning permissible assignment stage plan

The EAS determine which of the permissible assignment stage plans yields the highest total value:

- Option 1 yields a total value of 0+0+50 = 50.
- Option 2 yields a total value of 70.

Thus, in this case the winning permissible assignment stage plan is Option 2 as it yields the highest value of 70.

Determining the prices

The price paid by each bidder is equal to the opportunity cost of assigning them the frequencies in their permissible assignment options within the winning permissible assignment stage plan. It is calculated by sequentially reducing all bids from the bidder's in question to 0 and recalculating the hypothetical winning permissible assignment stage plan. [211] Where another bidder would receive, in the hypothetical winning permissible assignment stage plan, a set of frequencies different from that it will receive in the real winning permissible assignment stage, the EAS calculates the difference between (i) its bid for the frequency it would have won in the hypothetical winning permissible assignment stage plan and (ii) its bid for the set of frequencies it wins in the real winning permissible assignment stage plan.

We start by reducing bidder A's bids to 0 (as shown in Table A9.6 below).

Table A9.6: Assignment stage bids, reducing bidder A's bids to 0.

	26 GHz lower (GHz)						
	25.1-25.3	25.3-25.5	25.5-25.7	25.7-25.9	25.9-26.1	26.1-26.3	26.3-26.5
1A	C – 0	A – 0			B – 50		
2A	C – 0	B – 0			A – 0		

When this is done, option 1A becomes the winning permissible assignment stage plan as it yields the highest total value of 50. As we compare it to option 2 (the winning permissible assignment stage plan), we see that:

- Bidder B would have won the 25.9-26.5 GHz frequencies, worth to them 50. Instead, they won the 25.3-25.9 GHz frequencies, worth to them 0. Thus, 50 – 0 = 50.
- Bidder C would have won the same frequencies (25.1-25.3 GHz) in both options. Thus, 0 – 0 = 0.

As a result, Bidder A is required to pay 50 + 0 = 50.

We then reduce bidder B's bids to 0 (as show in Table A9.7 below).

Table A9.7: Assignment stage bids, reducing bidder B's bids to 0.

26 GHz lower (GHz)

[211] Following from the description in paragraph A9.104, in this case each subset contains only one bidder.

	25.1-25.3	25.3-25.5	25.5-25.7	25.7-25.9	25.9-26.1	26.1-26.3	26.3-26.5
1B	C – 0	A – 0			B – 0		
2B	C – 0	B – 0			A – 70		

When this is done, the winning assignment remains option 2. Thus, bidder B is required to pay 0.

The final winning frequencies and corresponding prices to pay are thus the following:

- Bidder A wins the 25.9-26.5 GHz frequencies and pays 50.
- Bidder B wins the 25.3-25.9 GHz frequencies and pays 0.
- Bidder C wins the 25.1-25.3 frequencies GHz and pays 0.

Initial assignment stage round for 26 GHz upper

Permissible assignment stage plans:

The EAS determines that there is one permissible assignment stage plan, as shown in Table A9.8 below.

Table A9.8: Permissible assignment stage plans and assignment options for the initial assignment stage round for 26 GHz upper.

	26 GHz upper (GHz)				
	26.5 – 26.7	26.7 – 26.9	26.9 – 27.1	27.1 – 27.3	27.3 – 27.5
1	A			B	D

In round 1, bidder A won the 25.9-26.5 GHz frequencies (i.e. the uppermost part of the 26 GHz lower). Thus, bidder A will automatically be assigned the lowermost part of the 26 GHz upper.

Bidder D could bid only for assignments in the upper portion of the 26 GHz upper. This is because bidder D only won spectrum in the 26 GHz upper.

As there is only a single permissible assignment plan, bidders will be automatically assigned the frequencies without bidding in round 2. Thus,

- Bidder A is assigned the 26.5-27.1 GHz frequencies and pays 0.
- Bidder B is assigned the 27.1-27.3 GHz frequencies and pays 0.
- Bidder D is assigned the 27.3-27.5 GHz frequencies and pays 0.

Final assignment stage round for the entire 26 GHz band

Permissible assignment stage plans

The EAS determines that there are two permissible assignment stage plans, as shown in Table A9.9 below.

Table A9.9: Permissible assignment stage plans and assignment options for the final assignment stage round for 26 GHz.

	26 GHz											
	25.1-25.3	25.3-25.5	25.5-25.7	25.7-25.9	25.9-26.1	26.1-26.3	26.3-26.5	26.5-26.7	26.7-26.9	26.9-27.1	27.1-27.3	27.3-27.5
1	C	A					B				D	
2	C	B					A				D	

Only bidder A and B participate in round 3. This is because these bidders have won lots in both the 26 GHz lot categories and are the only bidders with non-contiguous holdings. Bidder C and D will keep the frequencies won during the initial assignment stage rounds, at the lowermost and uppermost of the 26 GHz band respectively.

Assignment stage bids

Each bidder bids for their permissible assignment options within the two permissible assignment stage plans (see Table A9.10):

- Bidder A bids 0 for the 25.3-26.5 GHz frequencies, and 40 for the 26.1-27.3 GHz frequencies.
- Bidder B bids 10 for the 25.3-26.1 GHz frequencies, and 0 for the 26.5-27.3 GHz frequencies.

Table A9.10: Assignment stage bids.

26 GHz

	25.1-25.3	25.3-25.5	25.5-25.7	25.7-25.9	25.9-26.1	26.1-26.3	26.3-26.5	26.5-26.7	26.7-26.9	26.9-27.1	27.1-27.3	27.3-27.5
1	C	A - 0					B - 0				D	
2	C	B - 10				A - 40					D	

Determining the winning permissible assignment stage plan

The winning permissible assignment stage plan is Option 2 as it yields the highest value of 50. Option 1 yields a value of 0.

Determining the prices

The prices to be paid are determined with the same process as before. The final winning frequencies and corresponding prices to pay are thus the following:

- Bidder A wins the 26.1-27.3 GHz frequencies and pays 0.
- Bidder B wins the 25.3-26.1 GHz frequencies and pays 0.

Therefore, at the **end of the assignment stage**:

- Bidder A wins the 25.9-27.1 GHz frequencies for the initial licence and the 26.1-27.3 GHz frequencies for the final licence. It pays 50 (in addition to what was paid in the principal stage).
- Bidder B wins the 25.3-25.9 GHz frequencies and the 27.1-27.3 GHz frequencies for the initial licence and the 25.3-26.1 GHz frequencies for the final licence. It pays 0 (in addition to what was paid in the principal stage).
- Bidder C wins the 25.1-25.3 GHz frequencies for the entire licence duration. It pays 0 (in addition to what was paid in the principal stage).
- Bidder D wins the 27.3-27.5 GHz frequencies for the entire licence duration. It pays 0 (in addition to what was paid in the principal stage).

Deposits

Top up deposits during principal stage

A9.106 At any point during the principal stage, Ofcom may require a bidder to increase its deposit up to an amount equal to the bidder's processed demand from the previous round multiplied by the relevant lot categories' posted prices.

A9.107 In the event Ofcom requires one or more bidders to increase its deposit, Ofcom would specify a deadline for the relevant bidders to make any additional deposits, and provide details of how to make the additional deposit.

A9.108 If the relevant bidder does not provide Ofcom with the top up deposit as required, it would not be allowed to submit a principal stage form in the next principal stage round nor in any subsequent principal stage round. In addition, the bidder would also be unable to submit an assignment stage form in the assignment stage and shall be deemed to have made a valid bid for a value of zero pounds for each of its assignment stage options.

A9.109 The bidder would not be excluded from the award process for not having provided the sufficient top up deposit, and it would still win its last processed demand (if any) in the final principal stage round. However, the bidder would not be granted a licence for its final processed demand lots unless it provides Ofcom with the total auction sum payable, following the end of the assignment stage.

Required final principal stage deposit

A9.110 At the end of the principal stage, by a deadline to be specified by Ofcom, bidders need to have on deposit at least the sum of the total base price for each of the 26 GHz lower, 26 GHz upper, and 40 GHz lot categories.[212]

A9.111 If the bidder does not provide Ofcom with the required final principal stage deposit, it would not be excluded from the award process. However, it would not be allowed to submit assignment stage bids and would be deemed to have made valid assignment stage bids with a value of zero pounds for all its assignment stage options.

Required assignment stage deposit

A9.112 For each assignment stage round, by a deadline to be specified by Ofcom, bidders need to have on deposit at least the sum of the total base price for each of the 26 GHz lower, 26 GHz upper, and 40 GHz lot categories (see A9.110), previous assignment stage round additional prices (if any), plus the amount corresponding to the bidder's highest assignment stage bid for the assignment stage round in question.

A9.113 If the bidder does not provide Ofcom with the assignment stage deposit, all the assignment stage bids for the assignment stage round in question submitted by the bidder (if any) would be deemed to be invalid.

A9.114 As a result, the bidder would be deemed to have made a valid assignment stage bid with a value of zero pounds for all available assignment stage options in that round.

Total auction sum

A9.115 After the end of the assignment stage, Ofcom will notify each bidder of the total auction sum payable by them.

A9.116 Where a bidder's total auction sum is less than the amount it has on deposit, Ofcom would specify a deadline by which it must pay the difference between the amounts.

A9.117 A bidder that does not provide the total auction sum payable by the deadline will not be entitled to the grant of any licences, nor a refund of its deposit. Such bidder will also remain liable to pay the difference between its deposit and its total auction sum payable.

[212] A bidder's total base price is the sum of the amounts payable in each lot category where the bidder has won any lot(s), calculated as the number of lots associated with a bidder's last processed bid in the principal stage multiplied by the corresponding posted price for the lot category.

Extraordinary events

A9.118 Ofcom retains powers to address extraordinary events that might otherwise compromise the auction, including:

a) rescheduling a round that has been scheduled and has not yet started;

b) rescheduling the end of a round in progress;

c) cancelling a round in progress;

d) cancelling one or more completed rounds and rolling back to a previous round;

e) suspending the auction;

f) cancelling the auction;

g) cancelling some or all bids submitted by one or more bidders in earlier rounds; and

h) excluding one or more bidders from the auction.

A9.119 Bidders who breach the Auction Regulations may forfeit part or all of their deposit.

Information released at the end of the auction

A9.120 The auction ends with the completion of the grant stage. At this point, the following information would be released to all bidders:

a) the frequencies assigned to each bidder that has been awarded spectrum; and

b) the price paid by each bidder that has been awarded spectrum, including a breakdown of that bidder's base price and any additional prices.

A9.121 After the auction, Ofcom would also publish a range of information on its website, including:

a) the names of the winning bidders and the frequencies won by those bidders (and licence fees paid);

b) the names of those winning bidders (if any) that failed to pay their total auction sum on time and who therefore failed to obtain licences in the auction, despite making winning bids; and

c) details of all principal stage bids and assignment stage bids.