Spectrum value of 800MHz, 1800MHz and 2.6GHz

A DotEcon and Aetha Report for Ofcom

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Executive Summary

In previous auctions, Ofcom's approach was to set reserve prices at a level that would discourage frivolous bidding, but was not necessarily reflective of the market value of spectrum. Such 'low but non-trivial' reserve prices are entirely appropriate if competition in the auction is expected to be strong across all available lots because prices will ultimate reflect market value regardless of their starting level, and setting low reserve prices avoids the risk of pricing off efficient demand.

Although reserve prices should normally not affect final auction prices and outcomes, setting them at a level that is substantially below market value can produce inefficient outcomes because with starting prices that are substantially below market value bidders may have a stronger incentive to behave strategically to prevent prices from increasing. The proposed auction format for the upcoming award of spectrum in the 800MHz, 1800MHz and 2.6GHz bands is relatively robust in relation to such strategic behaviour, but Ofcom considers that in this particular case setting reserve prices closer to market value might be appropriate.

To inform its decision on reserve prices, Ofcom has commissioned DotEcon and Aetha to

- provide estimates of the market value of the spectrum that will be offered in the forthcoming auction, using a combination of benchmarking (i.e. looking at comparable award processes that have been held elsewhere, and the prices paid by successful bidders in these awards) and business modelling; and
- to recommend appropriate reserve prices should Ofcom decide to set market value reflecting reserve prices.

Additionally, Ofcom has invited a panel of experts with a financial sector background to comment on the methodology adopted by DotEcon and Aetha and on the results obtained in order to gain a financial markets perspective on these issues.

Benchmarking is based on the demonstrated willingness to pay of bidders for comparable frequencies in similar situations, and should therefore in principle produce a reasonable lower bound estimate for the willingness to pay. Business case modelling, by contrast, aims at establishing the maximum amount that bidders could afford to pay whilst maintaining a positive business case (assuming they were able and willing to finance it). We would therefore expect the results from the business case analysis to be above the benchmark valuation.

The challenge that needs to be addressed by any benchmarking exercise is to ensure comparability. This means finding awards that are reasonably similar in every material aspect to the award under consideration, or making adjustments for potential differences between the auctions for which price information exists, and the conditions facing bidders in the forthcoming award in the UK. In doing so, we need to take account of the amount of spectrum that bidders might be expected to acquire in the auction.

Of particular importance are the valuations of bidders who, on the basis of their existing spectrum endowment, would be eligible to opt into bidding for the so-called minimum portfolio packages (MPPs) that form the basis of the 'competition constraints' that Ofcom is proposing to use in the forthcoming auction. These constraints are aimed at ensuring that the market will continue to be served by at least four players who can be classified as credible national wholesalers. Where possible, we distinguish between the valuation of frequencies by a bidder who might be considered to be eligible for opting into bidding for MPPs (typically the incumbent with the lowest market share and limited pre-existing spectrum endowment or a new entrant), and a bidder who would qualify on the basis of its existing spectrum holdings as a credible national wholesaler (typically one of the stronger incumbents with relatively significant market share). For convenience, we use the terms 'small bidder' and 'large bidder' when referring to these different types of bidders.

Given that both 800MHz and 2.6GHz spectrum have been awarded in a number of European countries in a way that is similar to that proposed for the UK, we use data from these recent European awards in order to establish a range for the likely valuation of spectrum in these bands. More specifically, we have used information from the awards in Germany, Sweden, Spain, Italy, Portugal and France in order to establish a range of valuations for 800MHz spectrum. For 2.6GHz spectrum, we rely on information from the recent awards of these frequencies in Germany, Spain, Italy, Portugal, Sweden, Belgium, France, Denmark, and Austria (disregarding the awards in Norway, the Netherlands and Finland because of award-specific factors that suggest that the prices paid in these awards provide a poor indication of the market value of spectrum).

By contrast, there are very few recent auctions in which 1800MHz spectrum has been offered on a technology-neutral basis, and none in which a comparable amount of spectrum to that in the UK was offered. For this reason, we use a broader sample of 1800MHz auctions (and awards of the comparable 1900MHz band overseas) in order to establish an admittedly wide benchmark value range for the 1800MHz spectrum. Our 1800MHz benchmark is based on a sample of 28 awards (in combination with various sub-samples), taking particular account of the auction results in Sweden, Italy and Greece in 2011.

Our benchmark results – expressed as GBP per MHz per capita – are summarised in the table below.

	800MHz	1800MHz	2.6GHz paired	2.6GHz unpaired
Small bidder	£0.253-£0.434	£0.146-£0.219	£0.080-£0.121	£0.011-£0.059
Large bidder	£0.460-£0.714	£0.146-£0.219	£0.087-£0.121	£0.011-£0.059

The lower end of the small-bidder-800MHz benchmark indicates the maximum willingness to pay of a new entrant, which reflects the marginal value for the first 2x5MHz lot, or the average value of 2x10MHz.[1] The upper end indicates the average value of 2x15MHz to the smallest player in a four-player market, which might also be regarded as reflecting the marginal value of a second block to such a bidder. The small-bidder-2.6GHz paired benchmark indicates the average value of 2x20MHz to such a player.

[1] This benchmark is derived from the Swedish 800MHz auction, the lack of transparency in bid data from this auction prevents further interpretation this benchmark value.

The large-bidder- 800MHz benchmark indicates the average value of 2x10MHz; and the large-bidder-2.6GHz paired benchmark reflects the average value of 2x20MHz.[2]

The benchmarks for 1800MHz and unpaired 2.6GHz spectrum are the same for small and large bidders and represent the average value of 1800MHz and unpaired 2.6GHz spectrum across a range of different spectrum endowments.

The business modelling work has sought to develop an indicative estimate of the value of different combinations of spectrum from the perspective of potential bidders in the auction (existing national wholesalers and potential new entrants). Such an exercise is inherently subject to substantial uncertainties owing to the need to make assumptions about each potential bidder's future commercial and technology deployment strategy in the event it acquired a specific combination of spectrum (including the option of not acquiring any spectrum at all).

In view of these inherent uncertainties, our business modelling approach focused on quantifying the impact of the main drivers affecting the value of different amounts of and different combinations of spectrum from the 800MHz, 1800MHz and 2.6GHz bands. The results should not be interpreted as the precise valuation of certain amount/combination of spectrum to different players, or different amounts/combinations of spectrum to a certain player. The models considered the *technical value* of the spectrum (e.g. cost savings in deployment of network coverage from use of lower frequency bands, and cost savings from access to larger amounts of spectrum providing additional capacity at individual base station sites) and the *commercial value* of the spectrum (e.g. ability to capture a larger share of revenues from having better network coverage, greater network capacity and/or being able to offer higher peak data rates to consumers). Our assessment of the technical value of the spectrum covered three widely different scenarios in relation to future network traffic levels. In the case of the 2.6GHz unpaired spectrum, as well as considering its potential use for providing additional network capacity to national wholesalers or supporting the provision of wireless broadband services by a new entrant, we also considered its potential use for providing backhaul connectivity to small cells.

For the avoidance of doubt, the business modelling did not, however, consider any *strategic value* that bidders may place on the spectrum (e.g. benefit of acquiring additional spectrum to keep one or more operators out of the market or to ensure that each operator's spectrum holdings are limited such that their competitive impact is constrained). This is because one of Ofcom's desired outcomes from the auction is to ensure competition between four effective national wholesalers, and the proposed inclusion of spectrum caps and floors in the auction award process reflects this.

Comparing the benchmark results for paired spectrum with those from the business modelling, we find that the highest benchmark values lie below the business case valuations for all established operators (including H3G) in most cases, but not necessarily for new entrants. In particular, the new entrant business cases for the minimum portfolio packages currently considered by Ofcom are negative for a wide

[2] Note that benchmarking produces lower bound estimates as the actual willingness to pay of winning bidders lies above the prices they pay in an auction.

range of assumptions, and are positive only for minimum portfolio packages that include 800MHz spectrum in the low-traffic scenario.

The benchmark value of unpaired spectrum lies above the business case value in most cases, as the value of unpaired spectrum in the business model is largely considered to be the incremental value over and above winning specific packages of paired spectrum. In most of these business cases, given the available paired spectrum, an operator will not be particularly spectrum constrained. Therefore, unpaired spectrum only has an incremental value in the business model under high traffic scenarios.

Our benchmarks in the table above suggest that the value of 800MHz spectrum is approximately two to three times the value of 1800MHz spectrum, and that the value of the latter is roughly double the value of paired 2.6GHz spectrum. The value of unpaired 2.6GHz spectrum is potentially only around an eighth of the value of paired spectrum in the same band. The 800MHz/1800Hz and 1800MHz/2.6GHz relative band values are broadly consistent with the relative valuations produced by the business modelling, though the relative band values from the business modelling are consistently lower than those suggested by the benchmarking exercise. Specifically, the business model relative band values are lower the higher traffic forecasts are as higher frequency spectrum providing additional capacity is more valuable. Thus the difference in relative band value between the benchmarking and business modelling approaches is greatest in the high traffic scenario.

Based on our analysis, we obtain a range of reserve prices that might be set for the different lots that will be offered in the auction. There are a few cases in which the maximum benchmark valuations of a large bidder exceed the business modelling estimates, which suggests that it might be appropriate to set reserve prices towards the lower end of the benchmark range. Further, the Expert Panel recommended a relatively lower reserve price for 1800MHz and paired 2.6GHz spectrum so as to encourage a small bidder to participate in the auction, suggesting that reserve prices might be set closer to the lower end of the benchmark range of a small bidder. Given the uncertainty associated with the 1800MHz valuations, a reserve price even lower than the recommended range could be considered. For 800MHz a reserve price at the top of the recommended range could be justified given prices paid in other European auctions.

Considering the Expert Panel input and the business modelling valuation estimates, and being mindful of the risk of choking off efficient demand, we recommend that reserve prices for the 2.6GHz and 1800MHz bands be set a the lower end of the small bidder benchmark range, whilst the reserve price for 800MHz is set at the mid-point of the small bidder benchmark valuation range. The proposed adjustment for tying a coverage obligation to one of the 800MHz lots takes account of the estimate of the costs of network roll-out required to meet the obligation as proposed by Ofcom in the January 2012 Consultation. Assuming that the obligation would not be assigned to a single 2x5MHz block but rather 2x10MHz of spectrum, the benchmark valuation for a large bidder is used as a starting point.[3]

Our recommendations for the reserve price in GBP per lot are summarised in the table below.

Lot	Reserve price
2x5MHz of 800MHz with no coverage obligation	£217m
2x10MHz of 800MHz with coverage obligation	£180m
2x15MHz of 1800MHz	£276m
2x5MHz of 2.6GHz (paired)	£50.4m

At these suggested reserve price, the business modelling valuations exceed the package cost across the various packages valued and there is little risk that efficient demand will be choked off at these reserve price.

Finally for the unpaired spectrum in the 2.6GHz band, we recommend that Ofcom set reserve prices at a low but non-trivial level due to the high level of uncertainty related to the valuation of these lots.

[3] This is because the top end of this cost estimate would exceed the top end of our benchmark range for a small bidder and would be just above the top end of our benchmark range for a large bidder. Therefore, assigning the coverage obligation to a single 2x5MHz block poses a non-trivial risk of choking off demand for this lot. It would thus be prudent to consider assigning the coverage obligation to a 2x10MHz block instead. A large bidder with a more extensive network is likely to have a lower cost of serving such an obligation, and hence greater likelihood of winning such a block. Therefore, we have based our reserve price recommendations for the lot with coverage obligation on a large bidder's benchmark value.

1 Introduction

1. In previous auctions, Ofcom has adopted an approach of setting "low but non-trivial" (LBNT) reserve prices, i.e. reserve prices that are being set sufficiently high to deter frivolous participation but without any attempt to approximate the market value of spectrum.

2. LBNT reserve prices are typically suitable in auctions that are expected to be competitive, as they minimise the risk of inefficiently pricing off demand through setting reserve prices too high. This should encourage participation and thus increase the competitiveness of the auction, and is a safe strategy if competition in the auction can be expected to lead to market-clearing prices and find the efficient allocation regardless of the level of reserve prices.

3. On the other hand, where there is a risk that the auction might not be competitive, LBNT reserve prices may facilitate distorted auction outcomes. Not only could they result in final auction prices that are significantly lower than market value, but the further reserve prices are from market value, the larger the incentive for bidders to bid strategically. If reserve prices are low, strategic reduction of demand or collusive behaviour can generate large savings compared with competitive market-clearing prices that would have to be paid if competition were to play out, and such strategic bidding can lead to inefficient auction outcomes. Therefore where there is a risk of reduced competitiveness within the auction, there is a case for using higher reserve prices that are close(r) to market prices, taking account of the ever-present risk of inefficiently pricing off demand if the market price estimate used for setting reserve prices is too high.

4. In March 2011, Ofcom launched a first consultation (March Consultation) on the proposed award of 800MHz and 2.6GHz spectrum, which introduced proposals for using an innovative 'competition constraint' in the determination of winners in order to ensure the long-term competitiveness of the UK mobile market. This constraint essentially limits the permissible auction outcomes to those in which post-auction there would be at least four players with sufficient spectrum holdings to be credible national wholesalers of mobile services. Credible national wholesalers are defined with reference to a minimum spectrum endowment (combining existing spectrum holdings and spectrum won in the auction) across the key mobile bands. Thus the competition constraints effectively define spectrum floors that apply to bids made by specific bidders. A second consultation, which Ofcom published in January 2012, also includes proposals for a competition constraint of the same nature.

5. In Ofcom's view, Vodafone, O2 and Everything Everywhere (EE) (in the remainder of this report referred to jointly as "three largest players" or individually as "large bidder") already qualify as credible national wholesalers on the basis of their existing spectrum holdings, regardless of whether they

would win any spectrum in the auction.[4] H3G or a new entrant (in the remainder of this document referred to as the "fourth player" or "small bidder") would only qualify as credible national wholesalers if they were to win enough spectrum in the auction to hold one of a number of so-called "Minimum Portfolio Packages" (MPP) as specified by Ofcom. This means that there would effectively be spectrum reserved for such bidders, although the specific winner of that spectrum, and the combination of frequencies awarded on this basis would be decided through the auction process. Bidders who wish to take advantage of this reservation would need to 'opt in', and the competition constraint would guarantee that at least one such bidder comes away from the auction winning at least the spectrum specified in one of the MPPs. Bidders who choose to opt in will have to submit a bid for each of the MPPs at reserve prices, and therefore be prepared to win any of the MPPs at these prices.

6. Ofcom has considered departing from the use of LBNT reserve prices and setting reserve prices closer to market value. This could improve efficiency by discouraging strategic bidding behaviour for all bidders, and it would also help ensure that only bidders who have a sufficiently strong business case to be a credible national wholesaler in the long term will be attracted by the effective spectrum reservation implicit in the use of competition constraints. Reserve prices that are closer to market value would also reduce the potential for large windfall gains for (some) successful bidders. However, setting reserve prices too high could choke off efficient demand for spectrum, both in terms of incremental spectrum demand from any bidder[5] and demand for MPPs from smaller bidders who are eligible to opt in.

7. Establishing robust estimates of market value for different frequencies, and some indication of the uncertainty surrounding these estimates is crucial in considering the level at which reserve prices might be set (and whether using reserve prices that are closer to market value rather than LBNT reserve prices is appropriate in the first case). Ofcom, has commissioned DotEcon and Aetha to evaluate the market value of 800MHz, 2.6GHz and possibly 1800MHz spectrum to be auctioned in the upcoming award. Specifically, Ofcom has asked DotEcon and Aetha to estimate the value of these relevant spectrum bands to the three largest players (Vodafone, O2 and EE) as well as the fourth player (H3G or a new entrant) in the UK in order to provide a basis for Ofcom's decision on reserve prices.

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[4] The March Consultation identified only Vodafone and O2 as credible national wholesalers on the basis of existing spectrum holdings. Subsequently, in the more recent January 2012 consultation (January Consultation), Ofcom updated its analysis and proposed that EE's existing spectrum holdings would also be sufficient for EE to be a credible national wholesaler.

[5] In this context, it is worth pointing out that under the proposed opportunity cost pricing approach the reserve price of individual lots might not affect the additional cost of winning a larger spectrum package, as package prices must be above package reserve for the entire package only rather than on a lot-by-lot basis. This means that the impact of reserve prices on incremental demand for spectrum is limited, as in many cases the additional cost to successful bidders of winning more spectrum could well be below the reserve price. In those cases where reserve prices risk affecting the amount that is payable by successful bidders, however, concerns about pricing off efficient demand for incremental spectrum need to be considered.

8. This report presents our findings in relation to likely market value of spectrum in the different bands based on:

- benchmarking from international awards;
- business case modelling of existing UK players and potential new entrants; and
- input from a panel of experts with a financial sector background.

9. As part of the project, together with Ofcom, DotEcon and Aetha have established a panel of experts with a background in equity analysis and investment banking for the telecoms industry and a good knowledge of radio spectrum issues ("Expert Panel"). The Expert Panel was asked to provide input, principally in terms of the likely response of financial markets to the reserve prices that might be derived from our analysis. The three Expert Panel members were:

- Jonathan Dann, Director and Head of Telecommunication Services Research Europe, Barclays Capital. Jonathan was previously Executive Director and senior analyst on the European Telecommunications team at JP Morgan and prior to this was a Senior Managing Director at Bear Stearns.
- Andrew Entwistle, Partner and Founding Member, New Street Research. Andrew was previously Head of Incumbent Consultancy team at Analysys Ltd and prior to this held positions at Booz Allen Hamilton, Arthur D Little and Rolls Royce.
- Tim Knowles, Independent M&A advisor. Tim was previously Executive Director at ABN AMRO/RBS and prior to this held positions with Millicom, Maxis (Malaysia), JP Morgan and Credit Suisse.

10. The Expert Panel members provided input to the study through a combination of formal discussions with Ofcom and the project team[6] and other discussions with project team members throughout the study. The Expert Panel provided the team with their views on the overall approach to the study including the detailed benchmarking and business modelling methodologies as well as the overall results and conclusions. DotEcon and Aetha would like to take this opportunity to thank the three panel members for the invaluable information and insights they have provided throughout the study, which had considerable impact on our findings. We have made reference to several of these insights in the relevant sections of this report.

11. Please note that throughout this report our assessments of the market value of the spectrum do not take account of the proposed GBP180 million of funding for managing the mitigation of interference between mobile broadband services using the 800MHz band and Digital Terrestrial Television (DTT). We understand that the Government's latest proposals are that this funding would

[6] Conference call on 27 January, meetings on 15 February and 16 March 2012.

be sourced from the successful winners of 800MHz spectrum but the exact mechanism for doing so (e.g. whether each winner will be required to make a separate payment of its share of the total amount or whether the payment would simply be taken from auction proceeds) is uncertain at present. Our assessments of the market value of 800MHz spectrum in the UK and the potential willingness to pay of bidders have not been adjusted to consider this factor.

12. The remainder of this document is structured as follows:

- In Section2 we describe our approach to estimating the likely value of the relevant spectrum bands for the upcoming auction.
- In Section 3 we present our benchmarking analysis and in Section 4 we summarise the results of our business modelling.
- We compare the valuations from our benchmarking analysis with that from the business modelling in Section 5.
- Section 6 summarises our discussions with the Expert Panel and the views put forward by the experts.
- In Section7 we provide a summary of our findings and set out how these might be used in setting reserve prices, considering also the impact on the market value of spectrum of the likely cost of coverage obligations that might be imposed on winners of 800MHz spectrum as provided by Ofcom.

2 Approach to spectrum valuation for reserve prices

13. The upcoming multiband auction will include:

- 2x30MHz of spectrum available in the 800MHz band;
- 2x70MHz of paired spectrum and 45MHz of unpaired spectrum available in the 2.6GHz band, with the possibility that 2x10MHz of the available paired spectrum could be reserved for low powered use; and
- possibly 2x15MHz of spectrum available in the 1800MHz band if EE does not sell this spectrum privately ahead of the auction.

14. In our benchmarking analysis and business modelling, we estimate the value of 800MHz spectrum, paired and unpaired 2.6GHz spectrum, and 1800MHz spectrum. We do not estimate the value of low powered spectrum used in the 2.6GHz band. There are no available auction benchmarks for low powered use of such spectrum and we do not have enough information about the potential business propositions based on low powered use in the UK to perform robust business modelling for this use.

2.1 Benchmarking and business modelling

15. We use both data from spectrum awards in other jurisdictions and business modelling in order to obtain estimates for the spectrum value to likely bidders.

16. Benchmarking derives estimates of spectrum value from the revealed willingness to pay (WTP) for spectrum in other awards. It is based on prices that have actually been paid by specific buyers (who may already have access to other spectrum) for a certain amount of spectrum in a particular country. When using such price data to derive the likely WTP for spectrum of specific bidders in the UK, it is important to ensure that the comparison is 'like for like' to the greatest extent possible by using only price information from awards that are comparable in all relevant aspects or, where this is not possible, to adjust for differences as best we can. Whilst the strength of the benchmarking approach lies in the fact that it is based on actually demonstrated WTP, its weakness is that meaningful inferences can only be derived if the appropriate adjustments are made, which often requires exercising a certain amount of judgment. It is therefore critical to lay open the underlying assumptions.

17. In using benchmarking we are limited by the available auction data, both in terms of scope (i.e. in relation to the number of comparable auctions) and in terms of the amount of information about the auctions that is in the public domain.

18. Moreover, benchmarking often only produces a lower bound estimate for WTP for spectrum rather than the maximum amount that bidders would have been prepared to pay if prices had risen further as prices in an auction are determined by the marginal bidder and are affected by the intensity of competition in the auction (which might have been reduced for a number of reasons). In addition, in the case of package auctions, we may only infer average package value rather than the value of an individual (marginal) block.

19. Business modelling, by contrast, should be able to reflect market conditions and bidder-specific factors when estimating spectrum value to likely bidders by modelling the business case of each player and deriving the additional value that would be gained from the use of the spectrum. Unlike benchmarking, this approach suggests a maximum WTP for spectrum (namely the largest price that can be accommodated in the business case) and is in theory capable of establishing a more precise and differentiated estimate of spectrum value to likely bidders. In practice, however, it is forward-looking and therefore relies on a potentially even larger number of assumptions than benchmarking. Thus, whilst there is greater flexibility in terms of modelling the value of various spectrum packages that have not been offered or been bid on anywhere else or only in incomparable market environments, the sensitivity of the business modelling approach to the underlying assumptions needs to be taken into account when interpreting results.

20. Overall, both approaches are complementary, and we use the results from benchmarking and business modelling together in order to derive estimates of market value. We expect that business modelling provides a consistently higher estimate of spectrum value than the benchmarking, considering that business modelling provides an indication of maximum WTP whereas benchmarking gives an indication of minimum WTP. A conservative approach for setting reserve prices would thus put stronger emphasis on the benchmarking results and use the business modelling as cross-check.

2.2 Valuation scenarios

21. The January 2012 Consultation proposes to use a common reserve price for both reserved and unreserved spectrum. Also, and in spite of the combinatorial nature of the proposed auction format, it is proposed that reserve prices be set on a 'per lot' basis. Package costs at reserve prices are therefore a linear combination of reserve prices for the individual lots, even though neither bids nor the prices (above reserve) that successful bidders will eventually have to pay need to imply linear lot prices. Thus, per-lot reserve prices need to be compatible with the estimated package value for bidders.

22. Given the proposals to use spectrum floors we differentiate between the spectrum valuation of smaller bidders who would qualify for spectrum reservation within the auction (H3G or a new entrant) and that of larger bidders (Vodafone, O2 and EE) who would not be eligible to opt in but compete for incremental spectrum within the auction.

23. In particular the reserve prices of the MPPs play a pivotal role in our analysis. If reserve prices for individual lots are set too high there is a risk that one or more MPPs become so expensive that no bidder is willing to opt in and place a reserve price bid on all MPPs. In this case, it would not be guaranteed that Ofcom's objective of four credible wholesale operators is achieved in the auction. Table 1 below presents the set of MPPs favoured by Ofcom in the January Consultation. We estimate the fourth player's willingness to pay for these MPPs.

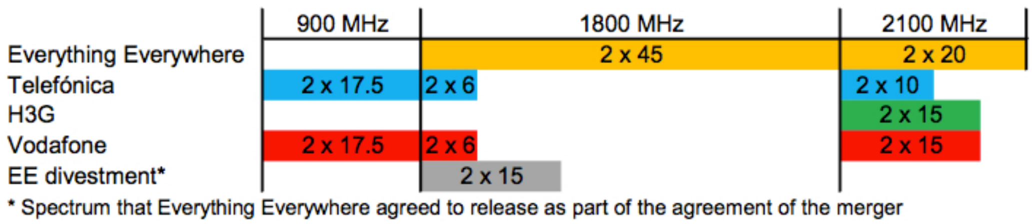
Table 1: Currently proposed MPPs

	800MHz	1800MHz	2.6GHz
MPP1	2x15MHz	NA	NA
MPP2	2x10MHz	NA	2x10MHz
MPP3	NA	2x15MHz	2x10MHz
MPP4	2x10MHz	2x15MHz	NA

24. We also consider the demand for incremental spectrum over and above demand for the MPPs, up to the maximum amount of spectrum for which bidders may bid in the auction. If reserve prices are set at a high level there is a risk that such demand will be choked off.

25. The January Consultation proposes safeguard caps of 2x105MHz overall; and 2x27.5MHz for spectrum below 1GHz. Together with the existing spectrum holdings of the UK operators (shown in Figure 1 below) this gives maximum amounts of spectrum for which the bidders may bid listed in Table 2.

Figure 1: Existing spectrum holdings of UK operators



Source: Figure 4.2 of January Consultation

Table 2: Bidding allowance in the auction given safeguard cap and existing holdings

Operator	Overall	Sub-1GHz
Vodafone	2x66.5MHz	2x10MHz
O2	2x71.5MHz	2x10MHz
EE	2x40MHz	2x27.5MHz
H3G	2x90MHz	2x27.5MHz

26. Given the available spectrum and the likely number of bidders competing for the 800MHz spectrum as well as their relative strength we focus on the value of up to 2x10MHz of 800MHz spectrum for large bidders (Vodafone, O2 and EE). Additionally, as the proposed MPPs in Table 1 contain packages comprising 2x10MHz and 2x15MHz of 800MHz spectrum, we also estimate the value of both 2x10MHz and 2x15MHz 800MHz packages to a small bidder (H3G or a new entrant).

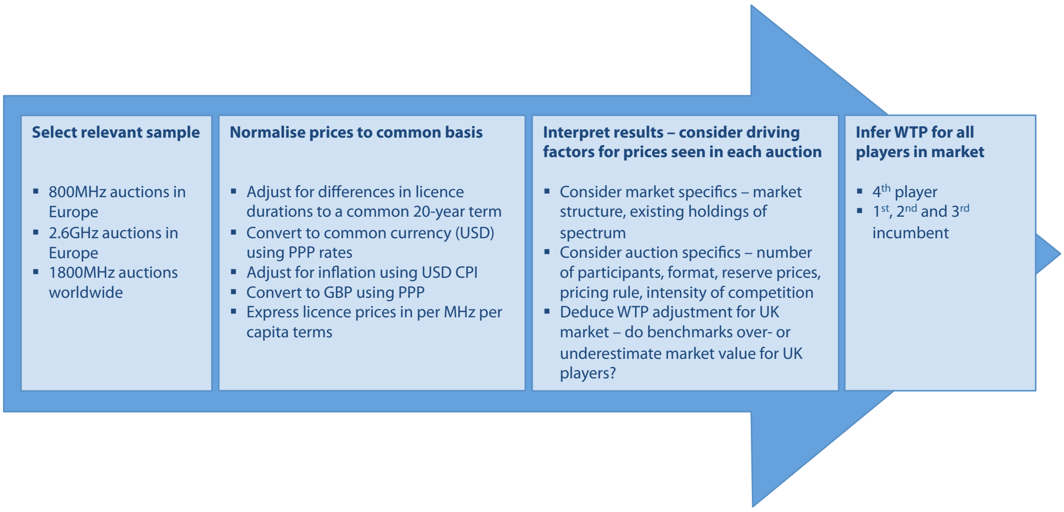
27. With the exception of EE, all bidders can bid for the available spectrum in the 1800MHz band (subject to them meeting the criteria to be the acquirer of this spectrum set out in the Undertakings). If 1800MHz spectrum is available in the auction it will be sold as a single block. We thus estimate the value of 2x15MHz of 1800MHz spectrum for the remaining incumbents and a new entrant.

28. Likewise in the 2.6GHz band, we estimate the value of packages up to and including 2x20MHz of paired 2.6GHz spectrum for all likely bidders. The purchase of unpaired 2.6GHz spectrum is included within the overall safeguard cap, however, without making assumptions about how much unpaired 2.6GHz spectrum bidders will purchase, we estimate the value of packages up to and including 30MHz for existing mobile operators and in the business modelling, the value of a 50MHz package for a new entrant.

3 Benchmarking

29. In this section we present our benchmarking analysis for estimating the value of 800MHz, 1800MHz and 2.6GHz spectrum to likely bidders in the upcoming auction. Figure 2 presents an overview of the process.

Figure 2: Overview of benchmarking analysis



30. In Section 3.1 we describe sample selection, and in Section 3.2 we describe how auction data from other jurisdiction is processed in order to obtain a common basis. We then discuss the 800MHz, 1800MHz and 2.6GHz benchmarks respectively.

3.1 Sample selection

31. The 800MHz and 2.6GHz bands are harmonised LTE bands within Europe. Completed auctions of spectrum in these bands are predominantly European auctions. While there are some countries outside Europe that have auctioned frequencies in these or similar bands designated for the same (LTE) use, for e.g. the 700MHz auction in the US, or Broadband Wireless Access (including 2.6GHz) auction in Hong Kong, the band plans, spectrum packaging and market conditions in these countries often differ substantially from those in Europe. Therefore, compared with 800MHz and 2.6GHz auctions in Europe, these auctions results may not be as instructive, particularly in differentiating between the value of spectrum to large and small bidders.

32. In addition, whilst other frequency bands may appear to be suitable comparators for deriving estimates of 800MHz and 2.6GHz value (for example 900MHz for 800MHz or higher frequency spectrum in the 2.1GHz and 2.3GHz bands for 2.6GHz), one needs to be careful to take full account of similarities and differences. Although in terms of propagation characteristics, 800MHz and 900MHz for example are similar, they are different in terms of available technologies/equipment in the short term, with 800MHz having become available only recently and designated for LTE, whilst in 900MHz there is legacy GSM use and use in the near term may be focused on 3G/UMTS rather than LTE given current equipment availability.

33. Casting the net more widely and including a larger number of awards (i.e. having a larger sample) produces more data points, which should facilitate statistical analysis, but at the same time, adding more awards may simply increase the level of noise in the data and would require a greater number of adjustments to account for differences and variations in market conditions, spectrum characteristics etc. Therefore we focus on a targeted sample of band specific European data to get a 'like-for-like' estimate for 800MHz and 2.6GHz spectrum. The awards in our sample for these bands are:

- 800MHz: Germany, Sweden, Spain, Italy, Portugal, France, Switzerland, and Denmark;
- 2.6GHz: Norway, Sweden, Germany, Italy, Spain, Denmark, Austria, Belgium, Portugal, the Netherlands, Finland, France and Switzerland.

34. Focusing on specific auction results allows us to look more directly at differences between small bidders eligible for opting in and larger bidders. We explicitly consider differences between 'stronger' bidders (e.g. the largest incumbents) in those auctions, who would qualify as national wholesalers on the basis of their pre-auction spectrum holdings, and weaker participants (e.g. the smallest incumbents or new entrants), who can be seen as bidders eligible to opt in.

35. The 1800MHz band can be used for both LTE and GSM applications. There is no 'like-for-like' benchmark for 2x15MHz of 1800MHz spectrum at all within Europe, and it is therefore not possible to adopt the same approach as for 800MHz and 2.6GHz. Therefore for our analysis in the 1800MHz band, we use a sample of global 1800MHz auctions to obtain a central estimate of 1800MHz value. We note that this approach would arguably produce a less precise 1800MHz estimate as compared to our 800MHz and 2.6GHz benchmarks. In establishing suitable reserve prices for 1800MHz spectrum, we will factor in the greater variability in our central estimate of 1800MHz value.

36. We have not restricted our samples with reference to the auction format, nor with regard to the competitiveness of the award, but use this information when interpreting the results.

37. Different auction formats provide different information on bidders' spectrum valuations:

- A Simultaneous Multi-Round Ascending (SMRA) format where the auctioneer increases the round prices of lots (or lot categories) as long as there is excess demand yields information about the lower of the marginal valuation of a bidder for additional lots and the average per-lot value for the combination of lots on which a bidder was active at the point at which she reduced demand.[7] The final auction prices present a minimum WTP for the package won (assuming that the winning bidders have properly managed exposure risk within the auction).

- A combinatorial format allows bidders to make mutually exclusive package bids for spectrum. Combined with a (modified) second price rule this should provide good incentives for bidders to bid true valuations, and bid information could therefore be used to estimate maximum WTP. However actual bid information is often not released into the public domain, and the prices paid by winners for their packages reflect the opportunity cost of awarding a bidder its winning package (i.e. the incremental value of giving the spectrum included in the packages to one or more other bidders).
- In a sealed bid format with a pay-your-bid rule, one needs to take account of bid shading incentives (i.e. the incentive to bid less than one's valuation in order to obtain a surplus in case of winning) in order to infer WTP from the prices paid.

38. Competitive auctions would provide better indications of actual WTP for spectrum than uncompetitive ones where final prices may be close to, or even at reserve and may provide only a loose lower bound for actual WTP. In these cases, information about the methodology used for setting reserve prices may provide some further information, but such information is not always available. For example, the price in an auction where spectrum sells at reserve prices would be a better indication of market value if the reserve price had been set with the objective of reflecting market value rather than at a low but not trivial level.

3.2 Data treatment

3.2.1 Converting to a common basis for comparisons

39. Auction data for our benchmarking analysis is taken from DotEcon's internal Spectrum Awards Database (SAD). Our full data sample consists of 273 award processes across 61 countries worldwide, covering 12,090 licences. Country specific demographic and economic data up to 2010 have been taken from the World Bank's *World Development Indicators* (WDI) database. In addition, we have interpolated any missing demographic and economic data in the WDI database that is missing before 2010, and extrapolated data for 2011 and 2012.

40. The price data used in our analysis includes annual fees where applicable and where the relevant information is available[8]. Specifically a licence price is

[7] In the case of decreasing marginal valuations, a rational bidder should not bid for lots whose price exceeds the marginal value. With increasing marginal valuation (synergies, complementarities, scale effects), a rational bidder should not pay more per lot than the average lot value. It is worth noting that in this case the bidder would ideally wish to drop demand completely rather than reduce it step-by-step, but SMRA formats do not necessarily provide this opportunity and expose the bidder to so-called aggregation or exposure risks.

calculated as the sum of upfront payments (normally the auction price paid for the licence plus any administrative fees, where applicable) and the discounted stream of annual fees over the life of the licence. Although in principle it would be preferable to use the weighted average cost of capital (WACC) for the particular operator in that particular country in order to calculate the discounted stream of annual fees, such information is not generally available. We therefore use the WACC figure used by Ofcom in setting mobile termination price caps, which has also been used in Aetha's business modelling (namely a nominal WACC of 8.86%).[9] In Annex C we present the results of a sensitivity analysis of varying the discount rate assumption on the licence price (which will obviously be limited to cases where licensees are subject to annual fees or may pay for their licence in instalments). We find that the impact is generally modest, with the exception of the Danish 800MHz auction where varying the discount rate by 5 percentage points (i.e. to 3.86% and 13.86% respectively) led to a change in the prices by +20%/-14% owing to licence fees being paid in annual instalments and also the Belgian 2.6GHz auction where varying the discount rate led to a change in the prices by +10%/-6% owing to significant annual fees.

41. All licence values in our analysis are expressed in terms of GBP (as of May 2012) for a 20 year licence to ensure comparability. The conversion of the price data from the different awards into a common currency and the adjustment for differences in licence terms and inflation has been done as follows:

- Adjustments were made for differing licence terms within the sample (converting prices into equivalent values for a 20-year licence term). Our adjustment for licence duration is based on the NPV calculation of the licence value assuming an equal annual profit stream (π; see Figure 3 below for detailed calculation), again using a nominal WACC of 8.86% as our discount rate). In Annex C, we present the results of a sensitivity analysis of varying the discount rate assumption on the licence price, finding that a 5 percentage points variation in the discount rate results in variations of no more than 8% of our 800MHz and 2.6GHz benchmarks (with the exception of Denmark (800MHz) and Belgium (2.6GHz)) and no more than 15% of our 1800MHz benchmarks.

- Prices were then converted from local currencies into a common currency (USD) using Purchasing Power Parity (PPP) exchange rates to account for price differences and levels of affluence between countries (this expresses prices in nominal USD terms).

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[8] For instance where annual fees are specified as a percentage of total revenue (for instance of the French 800MHz licences), we do not estimate this and hence do not take this into account in our derived licence fees.

[9] See http://stakeholders.ofcom.org.uk/binaries/consultations/mtr/statement/MCT_statement.pdf.

- Prices in nominal US dollars were adjusted for USD inflation[10] using a CPI index, converting prices to May 2012 USD.
- Finally, all prices were converted into Pounds using a USD/GBP PPP rate for 2012.[11]

42. All prices are then converted into per MHz per capita figures for ease of comparison across different countries and licence sizes. Prices in the remainder of this section are expressed in per MHz per capita terms unless otherwise stated.

[10] Inflation has been adjusted using monthly USD Consumer Price Index (CPI) data from the US Bureau of Labour.

[11] The USD/GBP PPP rate for 2012 is not yet available so we use a rate extrapolated from historical PPP rates. Specifically, we apply a PPP rate of 1 USD to 0.67 GBP. Note that the use of PPP rates to convert prices into a common currency as well as adjusting for inflation to present prices in real terms mean that our benchmarks differ to that published in Annex 9 of the January Consultation. In addition, small variations also arise due to differing populations figures used, because, as described above, our figures for 2011 and 2012 have been extrapolated. Further, as far as we understand, Ofcom did not include annual licence fees in its headline figures, nor adjust for varying licence duration.

Figure 3: Licence duration adjustment

A licence with duration D has the following net present value:

$$\text{LicenceFee}_D = \frac{\pi}{\sum_{t=0}^{D-1}\left(\frac{1}{1+8.86\%}\right)^t}$$

Therefore, the annual profit stream can be calculated as:

$$\pi = \frac{\text{LicenceFee}_D}{\sum_{t=0}^{D-1}\left(\frac{1}{1+8.86\%}\right)^t}$$

A licence with a 20-year term should be worth:

$$\text{LicenceFee}_{20\text{ year term}} = \pi \times \sum_{t=0}^{19}\left(\frac{1}{1+8.86\%}\right)^t$$

$$= \text{LicenceFee}_D \times \sum_{t=0}^{19}\left(\frac{1}{1+8.86\%}\right)^t \Bigg/ \sum_{t=0}^{D-1}\left(\frac{1}{1+8.86\%}\right)^t$$

3.2.2 Auction average prices

43. Average auction prices presented in our analysis below are simple frequency band specific auction averages, i.e. the average per MHz per capita price of all licences in the respective frequency band that were sold in the auction.

44. In the case of 2.6GHz spectrum, we additionally differentiate between average paired and unpaired value within an auction except in cases where 2.6GHz spectrum has been sold using a combinatorial format and we are therefore unable to differentiate between the price for paired and unpaired spectrum.

3.3 800MHz benchmarks

45. 800MHz spectrum has been auctioned in seven countries to date:

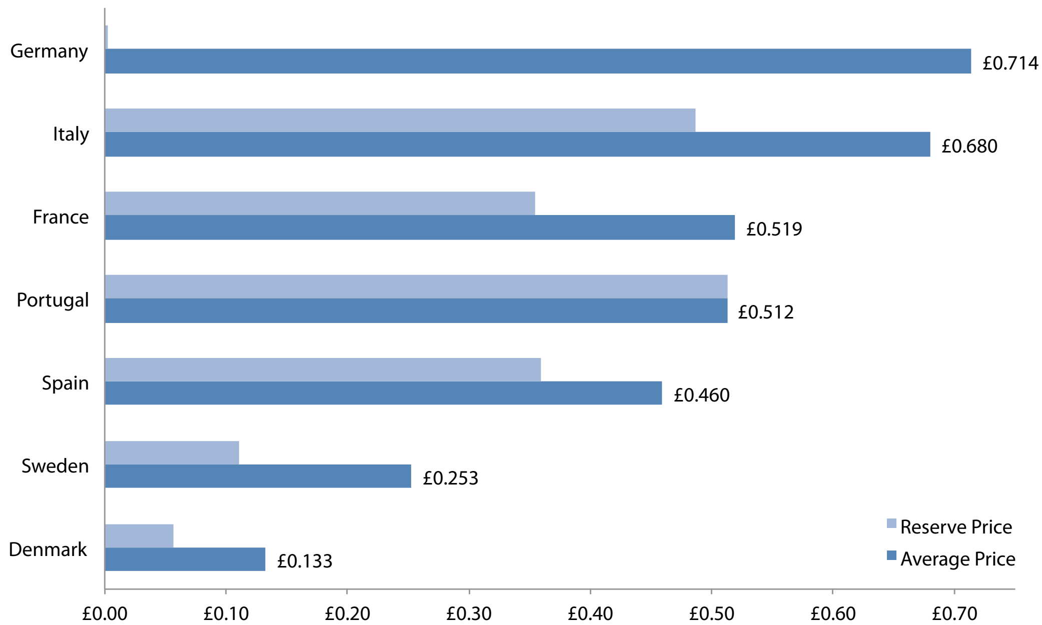
- Germany offered 2x30MHz of 800MHz spectrum as part of its multiband auction in May 2010, using a standard SMRA format;
- in Sweden the spectrum was awarded in a stand-alone in March 2011, using a SMRA with augmented switching[12];

[12] The SMRA with augmented switching differs from the standard SMRA in that it has more flexible rules on switching bids between lots, specifically bidders can switch their bids to different lots irrespective of whether the bid is a standing high bid on a particular lot.

- Spain auctioned the spectrum as part of its multiband award in July 2011, using a standard SMRA format;
- Italy included the spectrum in its multiband award in September 2011, using a standard SMRA format;
- Portugal offered the frequencies as part of its multiband award in November 2011, using a standard SMRA format;
- France sold 800MHz spectrum in December 2011 as part of a two part process for awarding 4G spectrum[13], using a hybrid tender to evaluate bids on the terms of MVNO access offered by the bidder, on the bidder's commitment follow an accelerated rollout schedule in the most sparsely populated parts of the and the financial bid;
- Switzerland included the 800MHz spectrum in its multiband award process in February 2012, using a Combinatorial Clock Auction format; and
- Denmark used a CCA with restricted outcomes to auction off its 800MHz spectrum in a single band award completed in June 2012.

46. Figure 4 below shows the average auction prices achieved in the 800MHz band in these awards (except for Switzerland where a price for 800MHz spectrum cannot be derived because of the combinatorial nature of the award).

Figure 4: 800MHz auction average prices



[13] The 2.6GHz spectrum had been awarded earlier.

Note: Inflation adjusted licence prices (including annual fees), in 2012 GBP, on a per MHz per capita basis, for a normalised licence duration of 20 years.

47. In addition we note that the Finnish government has published a resolution on spectrum policy, which included a decision to auction off the 800MHz band in six lots of 2x5MHz, with a reserve price of €16.67 million per lot[14]. All three national mobile operators in Finland have access to 900MHz and 1800MHz spectrum and jointly hold all the available paired 2.6GHz spectrum in Finland. At an exchange rate of £1 to €1.2 and using a Finnish population of 5.2 million, the proposed 800MHz reserve price is equivalent to £0.267 per MHz per head of population is slightly above the Swedish benchmark in Figure 4 above.

48. Out of seven 800MHz benchmarks available, six represent markets with four existing players; only in Portugal are there only three incumbent operators.[15] In France, the fourth player, Free Mobile, is a relative recent new entrant, having won a 3G licence and entered the market in 2009.

49. Despite most of these benchmarks being from 4-player markets, there were only three winners of spectrum in seven out of the eight auctions (winning 2x10MHz each) while the Danish auction was the first to produce a 2-winner outcome. In fact, only in Germany, Italy, France and Denmark did a fourth player even compete for 800MHz spectrum. In these cases the weakest player ultimately failed to win any 800MHz spectrum, which suggests that its WTP is below that of the stronger incumbents, even though the weakest incumbents that participated had limited access to spectrum below 1GHz at the time of the auction.

50. The range of prices of 800MHz spectrum in Europe is relatively narrow when compared with the prices in the 1800MHz and 2.6GHz bands (see below), but still ranging from £0.13 per MHz per capita in Denmark to just over £0.70 in Germany. The relatively narrow range may be attributed to more competition for the very attractive and comparatively scarce spectrum in this band as well as higher reserve prices that have been adopted, which means that even in the case where there was little competition (as in Spain and Portugal), final licence prices were still comparable with those in countries where competition was more intense.

Germany

51. Germany was the first country to auction its 800MHz spectrum. Winners of 800MHz spectrum were subject to a joint coverage obligation to provide services offering at least 1Mbps download speed to a pre-specified list of areas,

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[14] See http://www.lvm.fi/c/document_library/get_file?folderId=1985456&name=DLFE-15452.pdf&title=Government%20resolution%20on%20spectrum%20policy

[15] Just before the auction the fourth player ZAPP operating a CDMA 450 network announced that it would discontinue its operations using its CDMA 450 network due to being unable to compete with larger operators (see http://www.anacom.pt/text/render.jsp?categoryId=344179). Switzerland, too, only features three incumbent operators, but cannot be included because a benchmark price specifically for 800MHz spectrum cannot be established.

with an emphasis of rolling out to rural areas first. The lowest 800MHz lot adjacent to DTT use was subject to usage restrictions in line with the EC recommendations, but this was not reflected in a lower price (indeed, the edge lot won by O2 Germany was the most expensive 800MHz lot in the auction).[16]

52. All four incumbents participated in the multiband auction, with the weakest incumbent E-Plus failing to win any 800MHz spectrum. E-Plus bid for 2x15MHz of 800MHz spectrum early in the auction while the other three incumbents bid for 2x10MHz of 800MHz spectrum throughout the auction.[17] The last round in which E-Plus was known to be the standing high bidder on 2x15MHz of 800MHz was round 72 of the auction where the lot price was £0.211 per MHz per capita. While it is possible that E-Plus continued to bid on two or three 2x5MHz lots for some further rounds, at most one new bid was received for 800MHz lots consistently from round 74 onwards (with the exception of round 199, where O2 Germany overbid itself on one lot, and placed a new bid on a lot previously held by Vodafone), and E-Plus did not hold a standing high bid in round 91. It is therefore certain that E-Plus did not bid for more than one lot in this band from round 92 onwards. The last time at which E-Plus made a bid for a single block of 800MHz spectrum was in round 215, at a round lot price of £0.671 per MHz per capita.

53. E-Plus came out of the auction winning 2x10MHz in the 1800MHz and 2.1GHz bands, and 2x10 MHz of paired 2.6GHz as well as 10MHz of unpaired 2.6GHz spectrum in the 2.6GHz band. E-Plus had previous spectrum holdings of 2x5MHz of 900MHz and 2x17.4MHz of 1800MHz spectrum. Table 3 below lists E-Plus' spectrum holdings before and after the auction.

Table 3: E-Plus spectrum holdings in Germany

	Pre auction	Post auction
800MHz	NA	Nil
900MHz	2x5MHz	2x5MHz

[16] One needs to be careful, however, when drawing inferences from this fact, as the specific impact of usage restrictions depends strongly on the location of DTT transmission sites that use the adjacent channel. Our understanding is that in Germany these usage restrictions would have applied only in a number of sparsely populated regions so that their commercial impact would be limited (for a discussion see Entscheidung der Präsidentenkammer der Bundesnetzagentur für Elektrizität, Gas,Telekommunikation, Post und Eisenbahnen vom 12. Oktober 2009über die Verbindung der Vergabe von Frequenzen in den Bereichen 790 bis 862 MHz sowie 1710 bis 1725 MHz und 1805 bis 1820 MHz mit dem Verfahren zur Vergabe von Frequenzen in den Bereichen 1,8 GHz, 2 GHz und 2,6 GHz für den drahtlosen Netzzugang zum Angebot von Telekommunikationsdiensten sowie über die Festlegungen und Regelungen für die Durchführung des Verfahrens zur Vergabe von Frequenzen in den Bereichen 800 MHz, 1,8 GHz, 2 GHz und 2,6 GHz für den drahtlosen Netzzugang zum Angebot von Telekommunikationsdiensten, September 2010).

[17] The two largest MNOs – the so-called D-Networks T-Mobile and Vodafone – were limited by spectrum caps to bidding for 2x10 MHz in this band. O2 Germany could have bid for up to 2x15MHz, but chose not to do so.

1800MHz	2x17.4MHz	2x27.4MHz
2.1GHz paired	2x10MHz	2x20MHz
2.1GHz unpaired	5MHz	5MHz
2.6GHz paired	NA	2x10MHz
2.6GHz unpaired	NA	10MHz

Italy

54. Italy's multiband auction used a similar SMRA format to the German auction. There was a block-specific coverage obligation on all 800MHz blocks other than the lowest one, namely to serve towns with less than 3000 inhabitants providing broadband access speeds of 2Mbps (nominal user). There were also usage restrictions on the lowest 800MHz block and this block sold for roughly €15 million less than the other blocks.[18]

55. All four incumbents took part in the auction with the three largest incumbents bidding for 2x10MHz of 800MHz spectrum from the start of the auction. Unlike in Germany however, in the Italian auction, the fourth player – H3G Italia – started bidding on just one 2x5MHz lot (non-bottom block) in the 800MHz band.[19] This may indicate a decreasing marginal valuation with the reserve price of £0.487 per MHz per capita being above its value for the second, but below its value for the first block. But of course this could also indicate a strategic decision to indicate early in the process that H3G Italia would be willing to settle for one block. The three incumbents however continued bidding for 2x10MHz each, and H3G Italia stopped bidding in the 800MHz band at a price of £0.644 per MHz per capita in round 306.

56. In the auction, H3G Italia won 2x10MHz of 2.6GHz spectrum, 2x5MHz of 1800MHz spectrum and 30MHz of unpaired 2.6GHz spectrum. In addition, H3G Italia is expected to receive 2x5MHz of re-farmed 900MHz spectrum and will receive 2x10MHz of refarmed1800MHz spectrum. Table 4 lists H3G Italia's spectrum holdings before and after the auction.

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[18] See Section 3 of the Ministry of Economic Development's decision on the multiband award (*Procedure E Regole Per L'assegnazione E L'utilizzo Delle Frequenze Disponibili In Banda 800, 1800, 2000 E 2600 Mhz Per Sistemi Terrestri Di Comunicazione Elettronica E Sulle Ulteriori Norme Per Favorire Una Effettiva Concorrenza Nell'uso Delle Altre Frequenze Mobili A 900, 1800 E 2100 Mhz*): Delibera N.282/11/Cons, 18 May 2011. As in Germany, the usage restrictions imposed on the 800MHz band were in line with the EC Decision 2010/267/EU of 6 May 2010 on harmonised technical conditions of use in the 790-862 MHz frequency band for terrestrial systems capable of providing electronic communications services in the European Union.

[19] Between rounds 266 and 291 at a price differential of around €30 million, H3G Italia switched to the bottom 2x5MHz block.

Table 4: H3G Italia spectrum holdings

	Pre auction	Post auction
800MHz	NA	Nil
900MHz	NA	Likely to be assigned 2x5MHz
1800MHz	NA	2x5MHz + likely to be assigned 2x10MHz
2.1GHz paired	2x15MHz	2x15MHz
2.1GHz unpaired	5MHz	5MHz
2.6GHz paired	NA	2x10MHz
2.6GHz unpaired	NA	30MHz

France

57. France assigned its 800MHz spectrum in December 2011 following an earlier award of the 2.6GHz band. Each 800MHz licensee was subject to an obligation to cover 98% of the population in mainland France within 12 years from licence issue, and 99.6% within 15 years.[20] In-block emission limits imposed on 800MHz licensees to protect DTT users from interference are as per the EC Decision 2010/267/EU.

58. The 800MHz band was packaged into two 2x10MHz lots at the edge of the band and two 2x5MHz lots in the centre of the band. New entrant and fourth player in the market, Free Mobile, had won a large 2x20MHz package in the 2.6GHz award earlier and its participation in the 800MHz tender would qualify Free Mobile to a roaming deal with whoever won the centre blocks (provided it did not win any 800Mz spectrum). This roaming deal however was not national but rather limited to rural areas where it is not economical to deploy a network using 2.6GHz spectrum. All four market players took part in the tender.

59. The process required bidders to submit tenders specifying whether (a) they would provide MVNO access and (b) they would commit to follow an accelerated rollout schedule in the most sparsely populated parts of the country together with a financial bid for the spectrum concerned. A bidder's agreement to provide MVNO access and the commitment to an accelerated

[20] Coverage was defined in terms of a peak download speed of 30 Mbps for a licensee holding 2x5MHz and 60 Mbps for a licensee holding 2x10MHz or more. At least 95% of connection attempts must be successful, and outdoor coverage must be sustained 24 hours per day.

roll-out were reflected in a "multiplier" applied to the financial bid[21] and successful bidders paid the value of their bid.

60. Bouygues Telecom paid £0.403 per MHz per capita for the bottom 2x10MHz block, Orange paid £0.526 for the top 2x10MHz block while SFR paid £0.629 for the middle two 2x5MHz blocks. All three winners had agreed to provide MVNO access as well as commit to accelerate roll out in rural areas.

61. Although Free Mobile (who currently holds 2x20MHz of 2.6GHz, 2x5MHz of 2.1GHz spectrum and is expected to receive 2x5MHz of 900MHz spectrum) did not win any 800MHz spectrum the fact that it submitted a bid indicates a valuation of 800MHz spectrum above reserve prices (notwithstanding any negative impact the roaming deal entitlement may have had on its valuation of 800MHz spectrum). The lowest reserve price was £0.236 per MHz per capita, and this would therefore indicate a lower-bound of a fourth player's valuation for 800MHz spectrum.

62. In addition, we note that the French 800MHz licensees are subjected to annual fees amounting to 1% of total revenue generated from the use of licenced frequencies. As explained in footnote 8, this is not included in the licence price of the French licence hence our benchmark here presents an underestimate of actual total licence fees in France.

Portugal

63. Only the three incumbent operators in Portugal took part in the multiband auction in November 2011. There was no excess demand in the 800MHz band and spectrum was awarded at reserve prices.

64. Each 800MHz lot had an associated obligation to cover up to 80 parishes where there are currently no mobile broadband coverage. ANACOM will within five months of the issue of licences, compile a list of up to 480 parishes to be covered by the 800MHz licensees (though these licensees may utilise their 900MHz frequencies to provide such coverage as well). Half the list of prescribed parishes must be covered within six months, and the full list within a year after switch off of the analogue TV network in Portugal, scheduled for 26 April 2012. The service to be provided in a coverage area is defined by the maximum access speed subscribed to by the lowest quartile of consumers.

65. Usage of the 800MHz band was restricted to the lower bound of the in-block EIRP limit recommended in Decision 2010/267/EU (56 dBm for 5MHz) on all blocks. At the border to Spain and Morocco a maximum field strength of 25 dBuV/m was allowed.[22]

[21] The multiplier was calculated by taking the inverse of the number of of 2x5MHz spectrum blocks in the bid (i.e. the multiplier was 1+ 1/1 = 2 for bids of on one block, 1+1/2 = 1.5 for bids on two blocks etc.) and applied cumulatively for the undertaking to provide MVNO access and the commitment to accelerated roll-out. So for a bidder bidding on two blocks, the multiplier would be 1.5 * 1.5 = 2.25 if the bid included both commitments, 1.5 if it only included one commitment and 1 if the bidder agreed to neither MVNO access nor accelerated roll-out.

[22] See Section 2 of Annex 1 to Anacom's *Auction Regulation For The Allocation Of Rights Of Use Of Frequencies In The 450MHz, 800MHz, 900MHz, 1800MHz, 2.1GHz and 2.6GHz Bands*.

Spain

66. In Spain, an SMRA format was used to award spectrum in the 800MHz, 900MHz and 2.6GHz bands, with some spectrum in the latter band being offered on a regional basis. Prior to the multiband auction in July 2011, two beauty contests were held for the award of spectrum in the 900MHz and 1800MHz bands.

67. The smallest player, Yoigo, won 2x14.8MHz in the 1800MHz band in exchange for an upfront payment of €42 million and a commitment to invest over €300 million.[23] Prior to winning 1800MHz spectrum, Yoigo held 2x14.8MHz of paired, and 5MHz of unpaired 2.1GHz spectrum. Yoigo did not subsequently participate in the multiband auction. Yoigo CEO Johan Andsjo said that *"Yoigo's decision not to participate in the mobile spectrum auction recently launched by the Spanish government was mainly due to fears of a bad investment. With the price that [the government] has set, if we had bought the frequencies auctioned we would have got return on investment only in ten years. Moreover, the payment had to be made now, while the frequencies cannot be used until 2015"*[24].Yoigo's low valuation, specifically for 800MHz spectrum could however also be due to its earlier acquisition of 2x14.8MHz of 1800MHz spectrum, which may well be better suited to extend its coverage and provide LTE services, given the existing site topology of Yoigo's network (built for utilising its 2.1GHz spectrum).

68. Yoigo's decision not to participate in the auction suggests that the valuation placed on 800MHz spectrum by a fourth player who has acquired a substantial amount of 1800MHz spectrum (2x14.8MHz in this case) in addition to its holdings in the 2.1GHz band could be below the Spanish 800MHz reserve price of £0.359. However, we note that E-Plus in Germany held 2x17.4MHz of 1800MHz spectrum prior to the German auction in addition to its 3G spectrum holdings (and even 2x5MHz of 900MHz spectrum) and yet bid up to £0.671 for a block of 800MHz spectrum. Therefore, it may well be the case that a fourth player with similar pre-auction spectrum holdings to Yoigo and a realistic investment horizon (ten years or more) would have a higher valuation than that suggested by Yoigo's decision not to bid in the auction in combination with the Spanish reserve price.

69. Yoigo's decision not to take part meant that there was only a small amount of competition in the 800MHz band from the remaining incumbents (bidding for 2x10MHz each), driven by the desire to avoid the bottom block which would have been subject to usage restrictions for the protection of adjacent DTT (which were consistent with those set out in the Annex of EC Decision

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[23] See http://www.telegeography.com/products/commsupdate/articles/2011/06/13/yoigo-orange-win-tech-neutral-spectrum/. Orange won 2x5MHz of 900MHz spectrum in exchange for a commitment to invest over €400 million and an upfront payment of €126 million.

[24] See http://www.telecompaper.com/news/spanish-mobile-tariffs-to-drop-by-another-30-yoigo-ceo

2010/267/EU).[25] The bottom 2x5MHz block sold at reserve, €50 million cheaper than the rest of the band.

Sweden

70. PTS conducted a single band auction (having auctioned 2.6GHz earlier in 2008) using a SMRA with augmented switching format. This format allows bidders to withdraw standing high bids from lots if they place new bids for the same number of lots in order to facilitate the acquisition of contiguous spectrum with specific lots in an SMRA. Because blocks in the centre of the band provide more flexibility to bidders (as they can acquire blocks on either side in order to obtain a contiguous holding), this format is normally associated with a "cheaper-block-edge" effect: blocks at the edge of the band sell at a lower price than blocks in the centre as they have a lower "contiguity premium".

71. A coverage obligation to provide "functional" broadband access (defined as providing a 1Mbps indoor download speed at time of award) to fixed dwellings and business premises that do not have broadband access by any other means was imposed on the winner of the top 800MHz block, but the winner could draw down on a fund worth up to SEK300m to serve the coverage obligation.[26]

72. To protect against interference with DTT, in-block EIRP restrictions were set at the upper bound of the range recommended in Decision 2010/267/EU (64 dBm for 5MHz) for all blocks. For the lowest two blocks, radiated power in the downlink may not exceed 56 dBm for 5MHz EIRP, except in the case where vertical polarization was used, in which case the radiated power of a base station transmitter and repeater in the downlink direction of up to 64dBm for 5MHz may be allowed.[27]

73. While there were four players in the Swedish mobile market, there were only three incumbent bidders as Tele2 and Telenor bid jointly in the auction. Incumbents were only allowed to bid for 2x10MHz of spectrum. Two new entrants also took part in the auction but failed to win any spectrum. The lowest 800MHz block sold for almost two thirds less than the rest of the band.

Switzerland

74. Switzerland awarded its 800MHz spectrum using a Combinatorial Clock Auction (CCA) format in a multiband auction. Only the three incumbent operators in Switzerland took part in the auction, and each won 2x10MHz of 800MHz spectrum. Because of the combinatorial nature of the auction, it is not possible to establish a valuation for 800MHz spectrum on the basis of the prices eventually paid by winners. The reserve price of 800MHz in Switzerland

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[25] See paragraph 1 of the Ministry of Industry, Tourism and Trade's auction regulations in BOLETÍN OFICIAL DEL ESTADO, Núm 102, Sec III, 29 April 2011.

[26] This fund value of SEK300m was added to the licence price of the top 800MHz block in this report.

[27] For more details, see Appendix A of PTS' *Open invitation to apply for a licence to use radio transmitter in the 800MHz band*, 13 December 2010.

was significantly lower than the prices achieved in the other European countries, at just under £0.135 per MHz per capita.[28]

75. The coverage obligation for 800MHz licensees in Switzerland was loose compared with other European counties, with licensees required to roll-out and provide coverage to 50% of population by the end of 2018. Similar to Portugal, the in-block EIRP limit was set at the lower end of the range recommended in Decision 2010/267/EU (56 dBm for 5MHz) on all blocks.[29].

Denmark

76. Denmark auctioned off its 800MHz spectrum in June 2012 using a CCA format. The main policy objective of the Danish government for this award was to ensure that 800MHz spectrum would be utilised to improve high speed broadband availability in areas "worst affected" by the current lack of such services (207 identified postcodes). The Danish coverage obligation to provide an average user experience access speed of 10Mbit/s in these areas is the most demanding service requirement of any coverage obligation imposed on 800MHz licensees across Europe. In comparison, Sweden and Germany specified nominal user speeds of 1Mbit/s, and Italy required 2Mbit/s[30]. Given that broadband availability in Denmark is generally very good, the goal of improving high speed broadband availability in Demark is likely to be costly to achieve.

77. This is well reflected in the auction design which aimed at allocating 800MHz spectrum alongside assigning the coverage obligation in an efficient manner. All 800MHz lots were assigned a coverage obligation by default, but bidders could bid for regional exemptions from the coverage obligation alongside the 800MHz spectrum. This would allow the auction mechanism to determine whether the burden of the coverage obligation would be shared, or if one bidder would take up the obligation in all regions.

78. To ensure that the coverage obligation was eventually assigned in all regions, bidders had to make reserve price bids for spectrum without any exemptions, and feasible auction outcomes were restricted to those in which the coverage obligation was assigned to at least one 800MHz licensee in each region. This auction format is thus not unlike the proposed auction format for the upcoming 4G auction in that there were outcome constraints that had to be respected in the determination of winners. The Danish reserve price of

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[28] The 800MHz reserve price was set at CHF21.3 million per 2x5MHz.

[29] See Section 2.3.1 of the Federal Office of Communications' *Invitation to tender for frequency blocks for the national provision of mobile telecommunication services in Switzerland*, 26 November 2010. Licensees must comply with the Block Edge Mask (BEM) requirements prescribed in Annex 3 of the European Communications Committee's Decision of 30 October 2009, on harmonised conditions for mobile/fixed communications networks (MFCN) operating in band 790 – 862 MHz, ECC/DEC/(09)03.

[30] France's specification of a service requirement in terms of theoretical peak speeds of 60Mbit/s, Portugal's service specification defined by the maximum access speed subscribed to by the lowest quartile of consumers and the lack of clarify over the actual service requirement of Spain's coverage obligation leave no grounds for comparison against the Danish coverage obligation.

£0.057[31] was lower than reserve prices set in all other European countries except Germany, presumably reflecting the concern that the coverage obligation might be costly to serve.

79. All four existing players participated in the auction though Telia and Telenor bid together through a joint venture (TT Network). Therefore there were only three bidders. A loose spectrum cap of 2x20MHz was used[32], creating scope for competition despite the low number of bidders. TDC won 2x20MHz of spectrum and has to serve the coverage obligation in all regions while TT Network won the remaining 2x10MHz and will be exempted from coverage obligation. Hi3G failed to win any spectrum. The final auction average price was £0.133, the lowest in Europe to date, with TDC paying £0.188 for its licence while TT paid £0.077.

80. Given the combinatorial nature of the auction format, the second price rule and the restriction on feasible outcomes, it is not possible to deduce likely willingness to pay of bidders from the final auction prices. Bid information is not available, and therefore, the Danish auction result does not provide an additional benchmark on the actual willingness to pay of a small or large bidder. While the prices paid by TDC and TT do provide a lower bound on willingness to pay of a large bidder they are lower than even the reserve prices in other European auctions (with the exception of Sweden and Germany), therefore, we do not consider the Danish benchmark when considering the large and small bidder willingness to pay below.

3.3.1 800MHz value to a large bidder

81. Given the three-winner outcomes in all of the completed 800MHz auctions, the average auction prices of £0.253-£0.714 per MHz per capita provide an indication of the range in which the minimum WTP of the three largest incumbents for 2x10MHz of spectrum. We believe that it is reasonable to focus on such outcomes rather than trying to establish the value of a single 2x5MHz 800MHz block, given that we have not observed any case in which bidders have settled for a single block of 800MHz spectrum (although we have observed bids on single blocks).[33]

82. Given that the marginal bidder in Sweden was a new entrant and that there was not competition amongst the incumbent bidders for incremental spectrum, it is likely that the final auction outcome in Sweden underestimates the value of 800MHz to a large bidder. Germany and Italy, where four established players were competing for spectrum yield the highest spectrum

[31] There were two categories of spectrum lots available – a 2x10MHz "A" lot which is frequency specific, occupying the bottom of the 800MHz band and frequency generic "B" lots, each 2x5MHz making up the rest of the 800MHz band. Each category of spectrum lot has a reserve price of DKK50m and the average reserve price of an "A" lot and a "B" lot in per MHz per head of population terms is £0.057.

[32] This was a pure 800MHz cap rather than a sub-1GHz taking into account bidder's existing 900MHz holdings.

[33] E-Plus bid on a single block up to a price of £0.671 and H3G Italia up to a price of £0.644 per MHz per capita, suggesting that the marginal value of a single block is likely to be well within this range.

valuation for 800MHz. However, it is worth noting that even these auctions only provide an indication of the minimum WTP of the three largest incumbents.

83. However, incumbent spectrum holdings in the UK are rather different from those in Germany and Italy (as well as the other countries). The 900MHz spectrum in the UK is concentrated in the hands of Vodafone and O2 while EE holds a significant part of the 1800MHz band where Vodafone and O2 have just 2x5MHz each.

84. This means that the question of whether 800MHz spectrum is likely to be complementary to, or substitutable for, existing spectrum holdings is important. To the extent that existing 900MHz spectrum is a good substitute for 800MHz spectrum, the prices achieved in the other awards may over-estimate the WTP of Vodafone and O2. If 1800MHz spectrum is a good substitute, similarly the WTP of EE may be over-estimated. On the other hand, if 800MHz spectrum were largely complementary to the existing spectrum holdings of Vodafone, O2 and EE, then the benchmark figures would provide a lower bound estimate of their WTP for this spectrum.

85. Prices from auctions in Germany, Italy, Spain and France would have all factored in the cost of respective coverage obligations that were imposed on the licensees in each country. The average prices from these auctions also reflect the impact of usage restrictions on the value of the bottom 800MHz block(s). This would suggest that actual value of spectrum without any coverage obligation or usage restrictions may be higher, though it is not possible to make an appropriate adjustment without knowing the specific cost of meeting the coverage obligation or the impact of usage restrictions on block value (which may or may not be significant, as the German case suggests).

86. Overall, we believe that the range of benchmark figures excluding Sweden (i.e. £0.460-£0.714 per MHz per capita) is likely to provide a reasonable lower bound on the WTP of large bidders in the UK for 2x10MHz of 800MHz spectrum. This range should of course be checked against the business modelling valuation to ensure that it does not overestimate WTP for 800MHz spectrum.

3.3.2 800MHz value to small bidder

87. Bid data from the German and Italian auctions suggests that the fourth player's marginal value for the first 2x5MHz block ranges from £0.644 (Italy) to £0.671 (Germany) per MHz per capita. In addition, the German bid data suggests that the marginal value of the third 2x5MHz block is somewhat above £0.21 per MHz per capita.

88. Owing to the joint bidding of two large incumbents, the Swedish auction was the only one in which the smaller incumbent (H3G Sweden) won any 800MHz. H3G Sweden paid an average price of £0.159 per MHz per capita in this auction for 2x10MHz of 800MHz spectrum. This value provides a lower bound estimate of the true WTP of the fourth player in the market. Indeed we note that Free Mobile decided to bid in France at reserve prices of £0.236 per MHz per capita for 2x10MHz and £0.354 per MHz per capita for 2x5MHz, which are well above the price paid by H3G in Sweden. Further, assuming a first block marginal

value of £0.658 per MHz per capita (average of marginal values from Germany £0.671 and Italy £0.644) suggests that the average value of 2x10MHz to the fourth player must be at least £0.329 (as the value of the second block cannot be negative).

89. Thus, whilst we have some indication of the marginal value of the first block (£0.658) and the marginal value of the third block (£0.21), we are lacking data on the average value of 2x15MHz for a small bidder (and we do not have any direct information on the marginal value of the second block for a small bidder, other than that the Italian reserve price of £0.487 per MHz per capita would place an upper bound on this value if H3G Italia decided to bid for only one block based on its valuation and not for strategic reasons.

90. Assuming a simple straight line decrease in marginal value between £0.658 for the first block and £0.21 for the third would yield an average value per block of £0.434 for 2x15MHz (which would also be the marginal value of the second block). This would be consistent with the marginal value of this block being below the Italian reserve price.

91. Analysis of new entrant WTP is even more limited, however, we note that the final auction price in Sweden of £0.253 is likely to provide some indication of the maximum WTP of a new entrant given that a new entrant was likely to be the marginal bidder in Sweden. The entrant valuation represents a significant mark down (approximately 50%) of the fourth player's valuation.

92. Therefore, the valuation of a small bidder is estimated to range between £0.253 and £0.434 per MHz per capita.

3.4 1800MHz benchmarks

3.4.1 Benchmarking approach for the 1800MHz band

93. Although traditionally a GSM band, looking forward the 1800MHz is likely to be used for the provision of LTE services. Various operators have stated they will likely use the 1800MHz and the 2.6GHz bands to provide urban and suburban mobile broadband coverage, coupled with rural and suburban coverage being provided through the 800MHz band.[34] EE in the UK has already planned trials in April 2012 to test LTE services using 1800MHz.[35] In Poland CentreNet and Mobyland have together launched LTE services in the 1800MHz band.[36] In Australia Telstra has also started rolling out LTE services using the 1800MHz band and Optus has announced plans to do the same.[37] Mobile broadband services at 1800MHz could be delivered by adapting existing GSM base stations, reducing the need for new site deployment and saving costs.

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[34] Source: 'Mobile Broadband in the 1800MHz Band' (GSMA 2011).

[35] Source: 'Everything Everywhere announces major steps towards a 4G future' (www.everythingeverywhere.com 2012).

[36] Source: '4th commercial LTE network running in Poland' (www.lteworld.org 2010).

[37] Source: 'Optus to rollout 4G LTE, plans 3G upgrade' (www.arnnet.com.au 2011).

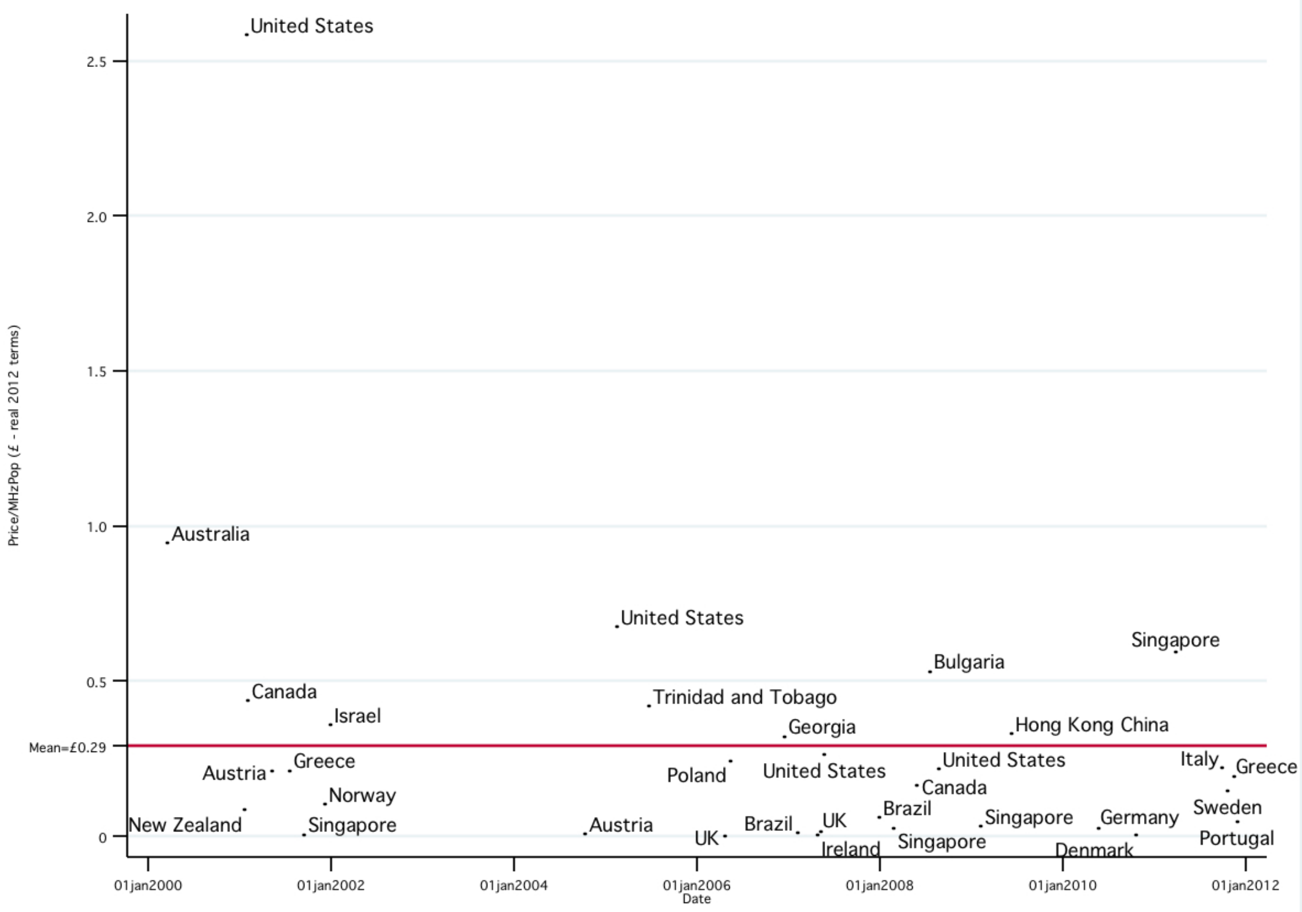
94. There are few auctions of liberalised 1800MHz spectrum in Europe that can provide suitable benchmarks for the 1800MHz spectrum in the upcoming UK auction. Specifically, there are no cases of an operator winning 2x15MHz of liberalised 1800MHz spectrum in any auction in Europe. Lacking any direct comparators, we establish a central estimate of 1800MHz spectrum value using a wider sample of 1800MHz auctions from our Spectrum Awards Database.

95. The majority of 1800MHz auctions in our data set were for non-liberalised spectrum, and the prices paid in these auctions may underestimate the value of liberalised spectrum in the UK. In addition, as our sample contains both competitive and uncompetitive awards, our central estimate of 1800MHz spectrum value may underestimate the market value 1800MHz spectrum to the extent that the expected lack of competitiveness is not reflected in the reserve price settings for these awards. We also note that the two UK awards included in the full set are for a small piece of spectrum with concurrent rights shared by 10 parties in one case and for non-harmonised spectrum in the other case. The prices paid in each auction in our sample are shown in Figure 5 below.

96. We further consider a number of subsamples, looking at average prices paid for liberalised spectrum, prices paid over different time periods and prices paid within Europe. Our benchmarks consider all 1800MHz licences in our Spectrum Awards Database sold through auction as well as 1900MHz licences auctioned in the US, Canada and Trinidad and Tobago, with the 1900MHz band being used for comparable services in these countries.[38]

[38] A full list of 1800MHz and 1900MHz awards in our dataset are listed in Annex A.

Figure 5: Average prices in 1800MHz auctions



97. The average price of 1800Hz licences in the above sample is approximately £0.29 per MHz per capita. The average auction prices in the 1900MHz auctions in the United States in 2001 and Australia in 2000 are considerably higher (£2.58 and £0.94 respectively) than the average auction prices in the rest of the sample, and could have been inflated by the telecoms bubble at the time. It therefore seems to be appropriate to delete these data points as outliers.

98. Also included in our dataset are awards of guard band spectrum (DECT guard block and 1785-1805MHz)[39], which might have uncharacteristically low value owing to severe usage restrictions (shared low powered use or power limits).[40] These data points should also be removed.

99. Excluding these data points produces an average price of £0.212 per MHz per capita, with a standard deviation of 0.189. This yields a 95% confidence interval of £0.138 to £0.285.[41]

100. We further consider the average 1800MHz values for a number of subsamples, namely:

- European auctions since 2000;
- auctions worldwide in the last five years; and
- auctions worldwide since 2010 (all awards in this sample are of liberalised 1800MHz spectrum).

101. The table below shows the average licence price per MHz per capita for various samples.

[39] Namely the UK DECT Guard Block Auction (2006); the Irish 1785-1805MHz auction (2007) and the UK 1795-1805MHz auction (2007).

[40] Averages prices in these auctions range between £0.001-£0.01.

[41] Assuming a t-distribution.

Table 5: 1800MHz sample benchmarks

Samples without outliers	N[42]	Mean	Standard deviation	95% confidence interval*
All auctions since 2000	28	£0.212	0.189	£0.138 - £0.285
European auctions since 2000	12	£0.161	0.147	£0.0675 - £0.254
All auctions in the last five years	18	£0.190	0.174	£0.103 - £0.276
All auctions since 2010 - all awards in this sample are of liberalised 1800MHz spectrum	7	£0.175	0.204	(£0.0136) - £0.363

*Note – we have calculated confidence intervals assuming a t-distribution given the small number of observations in the above samples

3.4.2 Estimating 1800MHz value in the UK

102. The various benchmarks suggest that the average 1800MHz value ranges from £0.161 to £0.212 per MHz per capita. Unsurprisingly, the variance of the smaller subsamples is considerable, with the lower bound of the 95% confidence interval of the smallest sample (All auctions since 2010) being negative. Our benchmarks suggests that 1800MHz prices within Europe are generally lower than in other regions, indeed our sample of European auctions above yields the lowest mean of all the samples considered. Given the nature of this benchmarking exercise, it is not possible to differentiate between the valuation of small bidders and large bidders.

103. The prices seen in the Italian (£0.219 per MHz per capita) and Swedish (£0.146 per MHz per capita) auctions[43] are very similar to the benchmark figures and fall within the 95% confidence interval of our largest sample (all auctions since 2000).Therefore, we consider the range of £0.146 to £0.219 to be an appropriate benchmark for the value of 1800MHz spectrum.

104. We also note that a recent report by Plum Consulting for the Australian Department of Broadband Communications and the Digital Economy[44] suggests a valuation of AUS $0.23 (£0.15[45]) per MHz per capita for 1800MHz in

[42] Total number of auctions in the sample. See Annex A for full list of auctions included within each sample.

[43] These two auctions are recent auctions for liberalised 1800MHz spectrum that might be considered competitive. The Portuguese auction does not provide much insight into the value of 1800MHz given low reserve prices and the lack of competition. All 1800MHz lots in this auction sold at the reserve price, further there were 3 unsold lots of 2x5MHz due to spectrum caps not allowing any of the bidders to acquire additional 1800MHz spectrum.

[44] http://www.dbcde.gov.au/__data/assets/pdf_file/0015/144222/Plum-Consulting-Valuation-of-public-mobile-spectrum-at-1710-1785-MHz-and-1805-1880-MHz.pdf.

[45] Assuming an exchange rate of AUS $1 to £0.65.

June 2011, based on the results of a benchmarking analysis. This is consistent with the lower end of our benchmark range (though we are unable to establish whether Plum's benchmarking exercise is comparable to ours). In addition, Plum modelled the business case of a hypothetical operator in a 3-player market, and despite all the caveats about the applicability of this modelling to the case of the UK[46], Plum derived a "cost reduction value" (i.e. the infrastructure cost savings associated with having more spectrum) of AUS $0.14 (£0.09[47]) and a "full enterprise value" (total net present value of the business) of AUS $0.47 (£0.31) per MHz per capita, Based on this analysis, Plum recommended a licence renewal price of AUS $0.23 (£0.15) in 2013 prices.

3.5 2.6GHz benchmarks

105. Over the last five years a number of European countries have awarded spectrum in the 2.6GHz band:

- Norway, Sweden and Finland were the first countries to auction 2.6GHz spectrum in 2007, 2008 and 2009 respectively, all using a SMRA with augmented switching format in a single band award. In Norway, a semi-fungible lot structure allowed for competition between FDD and TDD users for available spectrum.
- Similarly, Denmark, Austria and the Netherlands held single band awards for 2.6GHz spectrum but these countries used a CCA format in their respective auctions in 2010.
- Germany, Spain, Portugal and Italy then followed suit, auctioning 2.6GHz as part of multiband awards using a standard SMRA format.
- France held a hybrid tender for her 2.6GHz award, evaluating bids on the basis of the terms of MVNO access that bidders were prepared to offer, which was used as a multiplier on their financial bid.
- Belgium held a single band award in 2011 using an SMRA format with discretionary bidding and a lot structure that was dependent on the number of participants.
- Most recently, Switzerland awarded 2.6GHz spectrum as part of its multiband auction via a CCA. The combinatorial nature of the auction format prevents us from deriving the price paid for 2.6GHz spectrum in the Swiss auction.

106. Unlike the case of 800MHz where regulators often set higher reserve prices to reflect the likely higher market value, for the 2.6GHz band reserve prices were mostly set at a LBNT level. Auction results thus vary greatly in line with the level of competitiveness. In the Netherlands, the lack of competitiveness

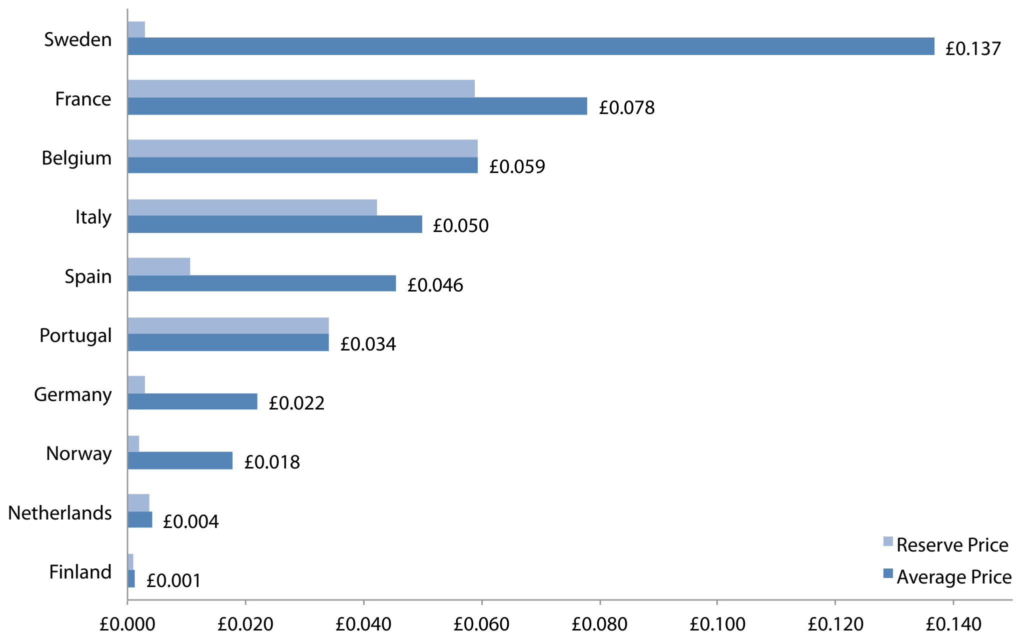
[46] For example, given the differences in geography and demography between Australia and the UK, the value of 1800MHz spectrum may be very different, as may be market conditions.

[47] In the 'medium market scenario' which is assumed to give the "best estimate" of cost reduction value.

within the auction was a direct result of the government's policy objective of introducing new players in the Dutch mobile market by imposing tight spectrum caps on bidders, whilst in other countries the lack of competitiveness was simply the result of the small number of players in the market.

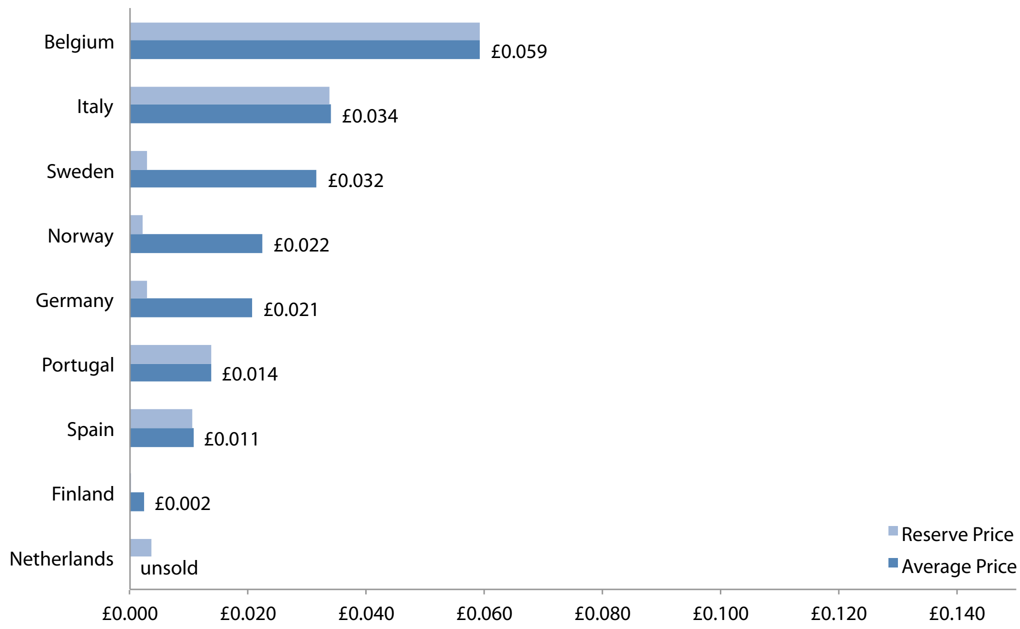
107. Figure 6 shows that the average price of paired spectrum in Europe ranges from £0.001 per MHz per capita (Finland) to £0.137 (Sweden). Figure 7 indicates an average price of unpaired spectrum between £0.002 per MHz per capita (Finland) and £0.059 (Belgium). Average prices for paired and unpaired spectrum cannot be observed directly in Denmark and Austria given the combinatorial auction format and the fact that both paired and unpaired spectrum was sold[48], but average auction prices were £0.0936 and £0.0230 respectively.

Figure 6: Average prices for paired spectrum in the 2.6GHz band



[48] While the Dutch 2.6GHz auction also followed a combinatorial format, bidders only won packages of paired spectrum with the unpaired going unsold. Therefore, in the case of the Netherlands 2.6GHz auction, it is possible to derive the average auction price of paired spectrum.

Figure 7: Average prices for unpaired spectrum in the 2.6GHz band



3.5.1 Description of awards

Norway, Netherlands and Finland

108. Norway was the first country to auction its 2.6GHz band, offering 2x40MHz of paired spectrum, 2x30MHz of fungible spectrum (i.e. spectrum that could be used for FDD or TDD) and 50MHz of unpaired spectrum in each of six regions. There were eight participating bidders in the auction and six winners. The number of bidders and winners however may overstate the level of competition in the auction as half these winners won a small amount of sub-national spectrum. The majority of the available paired spectrum went to the two incumbent mobile operators (all 2x40MHz of available paired spectrum, except for 2x5MHz in one region and 2x20MHz out of the 2x30MHz of fungible spectrum was won by the two mobile operators) while Craig Wireless won all (50MHz) of the unpaired spectrum nationally. Perhaps the most telling sign that the auction was not particularly competitive was that one of the fungible lots remained unsold in three regions despite the relatively large number of bidders and winners. The Norwegian auction was also the first 2.6GHz auction in Europe, hence it is likely that bidders faced considerable uncertainty over their valuations in this auction. Therefore we consider that the prices from the Norwegian auction do not provide an appropriate benchmark.

109. In the Netherlands, following last minute intervention by the Dutch Parliament, very tight caps were imposed on bidders. These caps were the result of a parliamentary decision to encourage market entry and essentially reserved some spectrum for entrants because the four incumbents together would not have been able to buy up all available spectrum. The caps severely limited the maximum possible demand from the four existing incumbent

operators; for example, one of the incumbents was confined to bidding for only 2x5MHz of paired spectrum. Competition for incremental spectrum was therefore extremely limited.

110. Finland only had three incumbent operators and thus experienced low levels of competition. Additionally it used a peculiar variant of the SMRA switching rules that enabled bidders to manipulate prices down as well as up, so despite having one more incumbent bidder than Norway, the impact of added competition on prices was not realised and available spectrum sold very close to reserve price. In fact unpaired spectrum sold for a higher per MHz price than paired spectrum, casting serious doubt on using Finland as an appropriate benchmark.

111. For the reasons discussed, we consider that the auctions in Norway, Netherlands and Finland should be regarded as outliers, and we disregard their results as potential benchmarks for the likely value of 2.6GHz spectrum in the UK to both large and small bidders.

Multi-band SMRA awards: Germany, Spain, Italy, and Portugal

112. Germany, Portugal, Spain, and Italy awarded the 2.6GHz band as part of a multiband award. All four countries used variations of the SMRA format. Italy and Portugal set high reserve prices, while Germany and Spain used relatively low reserve prices. Competition for 2.6GHz spectrum was very limited in all four awards.

113. Two particular features of the multiband SMRA format may have affected bidding behaviour and prices for 2.6GHz band:

- Spectrum caps were defined across multiple bands. If these overall caps are too tight bidders may not be able to express their full demand across all bands. This can lead to reduced demand or even unsold spectrum in the band that is considered to provide the least value (i.e. the one with the lowest value relative to its price). For example, there was unsold 2.6GHz spectrum in Spain (30MHz unpaired) and Portugal (25MHz unpaired).[49]

- Point-based activity rules were used in all multiband SMRA awards. With such activity rules bidders may employ so-called ‘parking’ strategies, where bids are placed on relatively cheap lots to maintain eligibility and hence flexibility to bid on high-value lots later during the auction. The lower the price of the spectrum, the more attractive it would be to the incumbent to ‘park’ eligibility in the band. The 2.6GHz band was relatively cheap in the multiband auctions, in particular compared with the sub-1GHz spectrum included, and might therefore have been used for parking eligibility. One indication that parking strategies may have affected observed prices is a lack of price differentiation between paired and unpaired spectrum in the 2.6GHz bands. While one would expect

[49] In Italy all 2.6GHz spectrum was sold but 15MHz of unpaired 2000MHz spectrum remained unsold.

paired spectrum to be more expensive than unpaired spectrum[50], parking strategies pick the cheapest lots to park eligibility regardless of whether it is paired or unpaired spectrum and thus drive up prices uniformly.

114. Germany realised the lowest average price for 2.6GHz spectrum, not just of the multiband SMRA awards but of all auctions considered in the benchmarking data set. Both paired and unpaired spectrum sold at approximately the same average price (£0.022 and £0.021 respectively), and all four bidders acquired unpaired spectrum. This suggests that prices were driven mostly by bidders trying to 'park' eligibility rather than genuine demand for incremental spectrum.[51]

115. Spain sold spectrum packaged in 5 national 2x10MHz lots as well as a number of regional lots in two different sizes (2x10MHz and 2x5MHz). Only three of the four national mobile network operators participated in the auction. Yoigo, the fourth and by far the smallest mobile network operator in Spain, abstained from the auction. Therefore, there was sufficient paired spectrum available for all three participating incumbent operators to acquire 2x20MHz each, although not all of it was offered on a national basis. This meant that one operator had to assemble regional lots to acquire a 2x20MHz national footprint. Vodafone decided early in the auction to bid on regional lots, and was then unable to switch freely between regional and national lots as a result of withdrawal penalties, the activity rule and spectrum caps. Therefore, while Vodafone faced relatively strong competition from the regional cable operators for the regional spectrum, there was little competition for the national 2.6GHz lots. Vodafone ended up paying over 40% more than the other two incumbent operators for a 2x20MHz national footprint. Overall, while there was some competition for paired spectrum from the regional cable operators, final auction prices in Spain were still below those in Italy and Belgium where there was very little competition amongst existing incumbents for spectrum and spectrum sold close to, or at reserve prices. The unpaired spectrum remained unsold in the auction but was sold in a follow-up auction for £0.011 for just above reserve price.

116. Portugal used tight spectrum caps. As only three bidders took part in the auction there was no excess demand, and both paired and unpaired spectrum

[50] *"There is greater interest in paired spectrum in the 2.6 GHz band among established cellular operators than in unpaired spectrum, and provided there are several such operators, higher prices will be paid for the former than the latter. The reason for the greater interest is to facilitate backward compatibility with existing FDD networks through the least expensive terminals."* (Global View Partners for the GSMA, "The 2.6GHz Spectrum Band", December 2009). This is also supported by auction results showing that more often than not it is unpaired spectrum that remains unsold (Hong Kong BWA auction in 2009, Netherland in 2010 and Spain and Portugal in 2011) even though there is generally more paired spectrum available in the 2.6GHz band.

[51] Germany is the only multiband SMRA for which round-by-round standing high bids are reported. This data could potentially give further insights into the participants' bidding behaviour. However, because of the limited amount of competition in this band the round-by-round data provides no valuable information.

sold at reserve prices for £0.034 and £0.014 respectively. One 25MHz lot of unpaired spectrum remained unsold.

117. Italy realised prices just above its (relatively high) reserve price level. The paired spectrum sold for an average of £0.050 (with a reserve price of £0.042). The unpaired spectrum in Italy was sold essentially at reserve price to the fourth player, H3G Italia.

Single-band SMRA awards: Sweden and Belgium

118. Sweden awarded the 2.6GHz band in a single-band auction in 2008, using a SMRA format with very loose caps. The auction average price of £0.137 per MHz per capita for paired 2.6GHz spectrum is the highest in our sample. All four incumbents participated in the auction and the auction ended with the fourth player winning a smaller package of 2x10MHz while the other three incumbents won 2x20MHz each. The unpaired spectrum was bought by Intel for £0.032, well above reserve price but significantly below the price for paired spectrum. It is likely that Intel was competing with H3G for this spectrum, as H3G eventually bought it from Intel two years after the auction. The price paid in Sweden thus indicates an upper bound for the fourth player's WTP. However, Intel never implemented its business proposition (which most likely would have been as WiMax infrastructure provider rather than as mobile network operator with retail operation). Intel's WTP in the auction is thus not necessarily a reliable indication for the valuation of a mobile network operator. It is not known how much H3G paid Intel for the spectrum subsequently.

119. Given the SMRA format, the observed average price marks the point at which the weakest bidder reduces demand such that overall demand can be satisfied. The final prices in the Swedish auction thus provide some indication of the fourth player's marginal valuation for the third or fourth block of 2x5MHz as well as a lower bound estimate of the top three incumbents' WTP for 2x20MHz as well as the fourth player's WTP for 2x10MHz. Here we note that:

- the fourth player (H3G Sweden) paid an average price of £0.146 for its 2x10MHz package – this provide a lower bound estimate to the fourth player's WTP for 2x10MHz;
- the average value of the lots on either side of the package won by H3G Sweden was £0.144 – this provides an upper bound estimate to the marginal value of the third and/or fourth block to the fourth player.
- The average price of the 2x20MHz purchased by the top three incumbents was £0.135 – this provides a lower bound estimate the top three incumbents' WTP for 2x20MHz.

120. However, it is also important to consider a number of specific factors when interpreting the Swedish auction results:

- The Swedish award in 2008 was a relatively early auction of 2.6GHz spectrum in Europe. Bidders in the Swedish auction would thus have faced higher value uncertainty than bidders in later awards who benefitted from the price discovery in the earlier auctions. However, value uncertainty may lead both to over- and undervaluation, so that the net impact of the higher value uncertainty is not clear.

- Relative to multi-band awards, bidders' valuations may be depressed by the higher aggregation risk faced in single band awards, particularly where there is a significant time gap between the awards of complementary or substitutable spectrum bands. In the case of Sweden, this effect would be more pronounced given how early the 2.6GHz band was auctioned.

- Perhaps more importantly, the Swedish award took place before the EC recommendation for facilitating the release of the digital dividend, which means that spectrum in the 2.6GHz band may have been considered more important for the future provision of 4G services. Combined with a fairly competitive award (in contrast to Norway, which auctioned off the band even earlier), this could explain the high price.[52] For this reason more recent auctions might more closely reflect the current market value of paired spectrum (though not necessarily of unpaired spectrum, as the availability of digital dividend spectrum is unlikely to have a strong impact on the valuation of such spectrum).

121. Belgium similarly conducted a single band award using a SMRA with discretionary bidding to allocate both paired and unpaired 2.6GHz spectrum. Belgium had high reserve prices (reserve price plus discounted stream of annual licence fees) mainly due to the significant annual fees imposed on the licensees. The lot structure used in the auction was dependent on the number of participating bidders. There were two 2x5MHz lots at the upper and lower end of the bands, while the centre of the band was partitioned into

- three blocks of 2x20MHz if there were fewer than four participating bidders; and

- four blocks of 2x15MHz if there were four or more participants.

122. Five bidders qualified for the auction, so the second lot structure was chosen. One bidder (potential new entrant Craig Wireless) did not submit any bids, and as a result of lot structure, spectrum caps and the presence of only three incumbent bidders interested in paired spectrum meant that 2x15MHz of spectrum went unsold. There was excess supply of paired spectrum in the auction and all other lots sold essentially at reserve price.[53] A new entrant BUCD BVBA bought the single 45MHz lot of unpaired spectrum at reserve price.

Single-band sealed bid: France

123. The French award was a sealed bid process with four individual lots of paired spectrum (two lots of 2x15MHz and two lots of 2x20MHz). France did not offer

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[52] Moreover, the Swedish auction ended in May 2008, well before the global financial crisis and the widespread recession that broke out at the end of that year.

[53] Note that with the spectrum caps in place, there would have been unsold spectrum even if the case where there had been only three participants, as no bidder could bid for one of the edge blocks and for a centre block.

any unpaired spectrum in this band. There were four participants who submitted sealed bids that consisted of a financial offer and, optionally a covenant to carry MVNOs on the network.

124. The auction used a first price rule, so the submitted bids need to be interpreted as shaded-down indications of true valuation. The fact that SFR – one of the larger incumbents – won one of the small lots at reserve price without any commitment to carry MVNO traffic suggests that the incentives to shade bids were substantial (reflecting the expectation of bidders that competition would not be strong).

125. The average price of paired 2.6GHz spectrum realised in the French auction is £0.078. Excluding the lot that was sold at reserve price yields an average price of £0.084. All winning bids except SFR's bid at reserve price included a commitment to carry MVNOs, which may have reduced bidder's valuations.

126. On the other hand, the fact that the fourth player, Free Mobile would be entitled to a roaming deal on another operator's 800MHz network should it win some 2.6GHz spectrum may have inflated Free Mobile's valuation for 2.6GHz spectrum in this award. However, given that bids from Bouygues Telecom and Orange exceed Free Mobile's bid on a per MHz basis, it does not seem like Free Mobile's bid was artificially inflated. Indeed, Free Mobile's bid of £0.080 for one of the large blocks was smaller than both Orange's bid of £0.084 for a large block and Buoygues Telecom's bid of £0.089 for a small block.

127. The fact that Bouygues Telecom did not outbid Free Mobile on the large lot confirms our assumption that (strong) bidders face decreasing incremental valuation for 2x20MHz.

128. Finally, we note that the nature of the separate awards for 2.6GHz and 800MHz spectrum may have introduced some level of uncertainty and hence created aggregation risk[54] that could have depressed bidders' 2.6GHz valuations in the French tender.

Combinatorial awards of paired and unpaired spectrum

129. Austria and Denmark used a CCA format with relatively similar rules for the award of paired and unpaired 2.6GHz spectrum in a single-band award process, but with markedly different outcomes. Although it is difficult to separate out prices for paired and unpaired spectrum in these awards, the Danish auction provides some indication.

130. The Danish award was held as combinatorial auction in CCA format with an opportunity cost reflecting second-price rule. All four incumbents participated in the auction. Three of them won the maximum amount of 2x20MHz while the fourth player, H3G, won 2x10MHz. All bidders except TDC, won unpaired spectrum as part of their winning package. Table 6 presents the outcome of the Danish auction.

[54] Risk of winning only a sub-set of desired frequencies.

Table 6: Danish 2.6GHz auction result

Bidder	Paired (MHz)	Unpaired (MHz)	Average package price per MHz per capita	Average package reserve price per MHz per capita
H3G	2x10	25	£0.012	£0.011
TDC	2x20	Nil	£0.141	£0.011
Telenor	2x20	10	£0.115	£0.011
Telia	2x20	15	£0.106	£0.010

131. Given the spectrum caps on bidders, the Danish results seem to have been determined by the attempt by H3G to compete for additional paired spectrum, and it is for this reason that we can deduce prices for paired and unpaired spectrum from the auction results.

132. The prices paid by a bidder in the CCA reflect the opportunity cost of awarding a particular package to this bidder. With the three larger incumbents winning the maximum amount of paired spectrum allowed under the spectrum caps, it should therefore not be surprising that H3G was paying close to reserve price, with the difference being due to the opportunity cost of winning unpaired spectrum (though it is not obvious whether this is driven by denying TDC access to unpaired spectrum or by reducing the amount of unpaired spectrum that Telenor and Telia won). Assuming that H3G won its paired spectrum at reserve prices, this suggests that H3G paid an average price of £0.012 for its unpaired spectrum. This value would represent the incremental WTP for unpaired spectrum from one of the other three incumbents (i.e. the value for packages with the same amount of paired spectrum but more unpaired spectrum[55] than in their winning packages).[56]

133. Further, given the similarity in package prices paid by the incumbents, it would seem that the opportunity cost of these incumbents' packages is imposed by H3G's bid for a larger package (2x15MHz but more likely 2x20MHz).[57] The average price paid by the top three incumbents in Denmark would thus provide a rough estimate to H3G's incremental value for the larger package (2x15MHz or 2x20MHz) over and above that of its winning package (2x10MHz

[55] While it is possible that this package contains less paired and more unpaired spectrum than the bidder's winning package, it is considered unlikely that a bidder would make a higher bid for a package with less paired but more unpaired spectrum.

[56] This incumbent is likely to be Telia, given the slight difference in its final package (DKK336,331,000) price relative to Telenor (DKK333,333,000) and TDC (DKK333,333,000). If so, £0.012 would thus represent Telia's WTP for additional unpaired spectrum over and above the first 15MHz.

[57] Here, again given the slight discrepancy in final package price of Telia versus that of Telenor and TDC it is possible that H3G bid for more than one package comprising 2x20MHz of paired spectrum (with various amounts of unpaired spectrum) or other bidders (Telenor and/or TDC) made multiple bids for packages comprising 2x20MHz (with various amounts of unpaired spectrum).

with 25MHz unpaired). TDC, Telenor and Telia paid on average £0.121 per MHz per capita for their winning packages. Assuming that H3G's bids are reflective of its valuations for the underlying spectrum, this can be seen as an indication of H3G's value for incremental spectrum over and above the 2x10MHz in its winning package (including potentially higher demand for unpaired spectrum). This value is likely to be largely attributable to the third or fourth 2x5MHz block.[58] This marginal value of £0.121 is not too far from that suggested by the Swedish auction (£0.144), though it does suggest that the prices in the Swedish auction were slightly inflated.

134. Ignoring the value of unpaired spectrum in the package, the package prices paid by the larger incumbents also present a lower bound on their WTP for 2x20MHz (as actual bids cannot have been any lower than these opportunity cost prices).

135. As in the case of Sweden, Belgium and France and Austria (see below), we note that valuations in the Danish auction may have been depressed by any aggregation risk that bidders may have faced in terms of uncertainty associated with the availability of 800MHz spectrum and details of the award.

136. Austria used a CCA to auction 2.6GHz spectrum in 2010. There were four bidders participating in the Austrian 2.6GHz auction. T-Mobile, A1 and H3G won 2x20MHz each, while Orange won 2x10MHz. A1 and H3G also won 25MHz of unpaired spectrum each as show in Table 7 below.

Table 7: Austria 2.6GHz auction result

Bidder	Paired (MHz)	Unpaired (MHz)	Average package price per MHz per capita	Average package reserve price per MHz per capita
Orange	2x10	Nil	£0.0216	£0.0043
T-Mobile	2x20	Nil	£0.0303	£0.0043
A1	2x20	25	£0.0220	£0.0043
H3G Austria	2x20	25	£0.0183	£0.0043

137. Unlike the Danish auction, prices per MHz per population paid for different packages in the Austria auction are quite similar. In addition, prices for both packages with and without unpaired spectrum exceed reserve prices by some margin. T-Mobile paying the highest per MHz per population for its package of 2x20MHz compared with A1 and H3G suggests that there was more competition for paired than unpaired spectrum.

[58] Assuming that H3G's valuation for unpaired spectrum is likely to be lower than for paired spectrum, H3G's marginal valuation of the third and fourth 2x5MHz lot is could be higher if the opportunity cost includes the value placed upon greater amounts of unpaired spectrum by H3G than the 25MHz that it has won.

138. As bidders could bid for up to 2x30MHz in this auction and Orange did not win any unpaired spectrum, it is likely that the price paid by Orange for its 2x10MHz (£0.0216) approximates the incremental value of spectrum over and above 2x20MHz to one or more of the other three bidders.[59] Given other benchmarks of incumbent's WTP for 2x20MHz, this would suggest decreasing marginal valuations for spectrum over and above 2x20MHz.

139. It may be that T-Mobile's package price was pushed up either by Orange bidding for a larger package of paired spectrum (2x15MHz and above) or bids for packages including 2x25MHz or 2x30MHz from A1 and H3G. Therefore, one cannot conclude from the auction results that Orange competed for larger packages (over 2x10MHz) of paired spectrum.

140. Finally, we note that A1 paid a higher price for the same package than H3G (the difference being £0.0037 per MHz per capita). As A1 has won both paired and unpaired spectrum, this difference could be driven by the value of incremental paired spectrum over and above 2x20MHz from one or more of the other three bidders or by additional unpaired spectrum over and above the holdings in the bidders' winning packages.

141. Overall, given the relatively loose spectrum cap of 2x30MHz, and the auction prices, little can be deduced in relation to the WTP for paired and unpaired 2.6GHz spectrum from the Austrian auction.

3.5.2 Conclusion on 2.6GHz spectrum benchmark value

Paired spectrum

142. Given the limited competition for spectrum in this band in most of the auctions that we have observed so far, the prices realised provide a conservative estimate of the value of 2.6GHz spectrum to both large and small bidders.

143. The Swedish auction results may overstate the current market value, given that the Swedish auction took place as a single band award before the financial crisis and without any certainty over the release of the Digital Dividend spectrum.

144. The French auction yields two lower bounds:

- £0.080 per MHz per capita for a small bidder's valuation for 2x20MHz; and
- £0.087 per MHz per capita for a strong incumbent's valuation for 2x15MHz or 2x20MHz.

These valuations are above the prices achieved in all other auctions with the exception of Sweden, and might therefore be taken as the best indication of valuation.

[59] This could be the marginal value of the fifth block from one or two of the other three bidders or the marginal value of the fifth and sixth block from one of the other three bidders.

145. The Danish auction suggests prices that broadly support these valuations, indicating that an upper bound for the marginal value of the third and possibly fourth 2x5MHz block to the fourth player is roughly £0.121.

Unpaired spectrum

146. There is very little reliable information about the value of unpaired 2.6GHz spectrum in the benchmarking data set. Only two out of the seven available awards provide more insight to actual WTP than a loose lower bound based on low but non-trivial reserve prices. Due to the small number of suitable award we do not distinguish between estimates for large and small bidders.

147. The observed prices range from £0.011 to £0.059 per MHz per capita. The top of the range is set by the reserve price in the non-competitive Belgian auction, where a new entrant bought the unpaired spectrum. The lower end of the range consists of non-competitive awards, where prices are determined by the reserve price and the need for parking strategies.

148. Only in Italy and Sweden was there competition for unpaired spectrum. Both auctions realised very similar prices (£0.034 and £0.032 respectively). As the fourth player bought 30MHz of spectrum at this price in Italy, but stopped competing for 50MHz in Sweden, this yields a lower bound for the value of 30MHz to the fourth player, and an upper bound on its incremental value for 40MHz or 50MHz.

149. The bidding behaviour in Sweden, and the relation between the Belgian and Italian results would suggest that a new entrant has a higher WTP for unpaired spectrum than the incumbent mobile operators. As incumbent mobile operators acquire paired spectrum in these auctions however, this comparison suggests that the average value of unpaired spectrum to the new entrant exceeds the incremental value of unpaired spectrum over and above that of the paired spectrum acquired by the incumbent mobile operator.

150. Given the lack of suitable benchmarks, the fact that unpaired 2.6GHz spectrum is not included in any of the MPPs and uncertainty over the likely bidders for this spectrum, we do not differentiate between the valuation of small and large bidders in our benchmark range for unpaired 2.6GHz spectrum. However, we note that the top end of our benchmark range of £0.059 may overstate the valuation of a mobile operator when this operator also acquires paired spectrum.

151. In addition, because the bulk of the licence fee in Belgium was associated with annual fees and the licence issued in Belgium has a 15-year term, varying the discount rate applied in our data treatment would have a significant impact on the Belgian licence price as discussed in Annex C. Therefore uncertainties over the appropriate discount rate in our analysis adds further uncertainty to the top end of the benchmark range for unpaired 2.6GHz spectrum, which should be taken into account when setting an appropriate reserve price.

3.6 Benchmarking conclusions

152. The valuations of the different bands derived from our benchmarking analysis for large and small bidders are presented in Table 8 below. As we noted above, we expect the benchmark to undervalue H3G's WTP for the relevant spectrum in the UK, but there is greater uncertainty about how well

international benchmarks proxy the WTP of the large bidders and of a new entrant.

Table 8: Benchmark valuations of relevant spectrum

	800MHz	1800MHz	2.6GHz paired	2.6GHz unpaired
Small bidder (fourth player)	£0.253-£0.434	£0.146-£0.219	£0.080-£0.121	£0.011-£0.059
Large bidders (top three incumbents)	£0.460-£0.714	£0.146-£0.219	£0.087-£0.121	£0.011-£0.059

153. The multiband auction in Switzerland finished in February 2012. While, it is not possible to derive frequency specific prices due to the combinatorial nature of the Swiss auction format, Table 9 below compares the per MHz per capita licence prices against the benchmark package value as suggested by our small and large bidder benchmarks in Table 8 above. There are stark differences between the prices paid by the operators in the Swiss auction. Orange and Swisscom won their packages at prices just above reserve, suggesting that these operators did not face much competition for their packages. Comparatively, Sunrise, seem to be the only operator that faced competition for its package (paying a premium over reserve for its package) and would provide the only relevant benchmark here.

154. Sunrise paid £0.20 per MHz per capita for its package, which falls in the lower half of the large bidder benchmark range and the upper half of the small bidder benchmark range. The Swiss result therefore appears to be consistent with our benchmark range.

Table 9: Swiss auction results

	Orange	Sunrise	Swisscom
800MHz	2x10MHz	2x10MHz	2x10MHz
900MHz	2x5MHz	2x15MHz	2x15MHz
1800MHz	2x25MHz	2x20MHz	2x30MHz
2.1GHz	2x20MHz	2x10MHz	2x30MHz
2.6GHz (paired)	2x20MHz	2x25MHz	2x20MHz
2.6GHz (unpaired)	0	0	45MHz
Licence price per MHz per capita	£0.0632	£0.197	£0.0922
Reserve price per MHz per capita	£0.0587	£0.0767	£0.0649
Small bidder benchmark package price*	£0.141-£0.222	£0.135-£0.214	£0.106-£0.178
Large bidder benchmark package price*	£0.182-£0.273	£0.176-£0.264	£0.133-£0.212

*These package prices ignore the 900MHz, 2.1GHz and unpaired 2.6GHz holdings of these operators

155. In addition, further uncertainty of the benchmarks may arise from varying some of the assumptions underlying the data treatment in our analysis. As noted in Section 3.2, the prices above have been derived using a discount rate of 8.86% to include annual fees and to adjust for different licence durations or where the price may be paid in instalments. The impact of varying the discount rate by 5 percentage points (that is using a discount rate of 3.86% and 13.86% respectively) on our benchmarks is presented in the tables below while our full sensitivity analysis can be found in Annex C.

Table 10: Effect of varying discount rates on licence prices in the 800MHz bands

Licence duration (years)	800MHz auctions	Variation in prices when varying the discount rate by ±5 percentage points
15	Germany,	-5% to +8%
15	Portugal	-5% to +8%
18	Italy	-2% to +3%
18	Spain	-2% to +3%
20	France	0%
22	Denmark	-13% to +17%
25	Sweden	-6% to + 4%

Table 11: Effect of varying discount rates on licence prices in the 2.6GHz bands

Licence duration (years)	2.6GHz auctions	Variation in prices when varying the discount rate by ±5 percentage points
15	Belgium	-11% to +19%
15	Germany	-5% to +8%
15	Portugal	-5% to +8%
15	Sweden	-5% to +8%
16	Austria	-4% to +6%
18	Italy,	-2% to +3%
18	Spain	-2% to +3%
20	Denmark	-2% to +4%
20	France	0%
25	Sweden	-5 to +8%

Table 12: Effect of varying the applied discount rate on 1800MHz benchmark sample means

	Variation in sample mean when varying the discount rate by ±5 percentage points
All Auctions including outliers	-9% to +14%
All Auctions Ex Outliers	-8% to 13%
All European since 2000	-3% to +5%
All auctions since 2006	-7% to +11%

All auctions since 2010	-9% to +15%

156. Overall, with the exception of the Belgian 2.6GHz and Danish 800MHz auction (which do not feature in our final reserve price recommendations in Section 7.3)[60], varying the discount rate by ±5 percentage points results in variations of up to -6%/8% of our 800MHz and 2.6GHz benchmarks and up to -9%/15% of our 1800MHz benchmarks.

[60] In both Belgium and Denmark, significant proportions of the licence fee are paid later into the licence term thereby increasing the impact of varying the discount rate on licence prices. Specifically, in Belgium, annual fees were significant while in Denmark, bidders were allowed to pay 80% of the licence fee in eight annual instalments. Further the adjustment of licence duration also has an effect on the impact of varying the discount rate on the Belgian 2.6GHz and Danish 800MHz licence prices given the duration of these licences.

4 Business modelling

157. In this section we present details of our overall approach to the business modelling (Section 4.1), details of the specific approach utilised for the valuation of 800MHz, 1800MHz and 2.6GHz paired spectrum (Section 4.2), details of the approach utilised for the valuation of the 2.6GHz unpaired spectrum (Section 4.3) and a high-level summary of the results (Section 4.4).

4.1 Overall modelling approach

158. Our overall approach has been to consider the incremental value that different combinations of 800MHz, 1800MHz and 2.6GHz spectrum bring to a potential bidder's business. We assess this incremental value by calculating the change in free cash flow generated by the business as a result of having access to the spectrum, on a net present basis over the period of the licence. In practical terms this additional value is typically generated in one of three ways:

- **Technical value**: This comprises the cost savings that can arise from access to spectrum for additional capacity and/or coverage purposes. For example having access to 800MHz spectrum can reduce the cost of covering less populated regions as well as providing enhanced indoor coverage, compared to use of higher frequencies where additional base station sites would need to be deployed to gain equivalent levels of coverage. The costs savings arise in the form of both capital expenditure saved from not deploying new sites (e.g. civil works, radio equipment, antennas) and on-going operational expenditure savings (e.g. site rentals, equipment maintenance). Access to additional higher frequencies (such as 1800MHz and 2.6GHz) typically provides additional capacity which would otherwise require additional cell sites to be deployed to make greater use of the available frequencies.

- **Commercial value**: This comprises the revenue gain that would arise from having access to particular spectrum. Typically such commercial value could arise in several ways: higher numbers of customers, higher spending of customers (e.g. on new services) and greater retention of customers (i.e. lower customer churn rates). In this assessment we consider that the most likely use of the 800MHz, 1800MHz and 2.6GHz bands is for the deployment of next generation mobile technology, for example based on the LTE standard. The availability of such technology in advance of a competitor (for example through use of the auctioned 800MHz, 1800MHz and 2.6GHz spectrum rather than waiting for an operator's existing spectrum holdings to be refarmed) may result in market share and revenue gains. Additionally, increased amounts of spectrum may provide additional commercial value – for example access to 2x20MHz of contiguous spectrum could allow the full benefits of LTE to be achieved in terms of peak data rates and capacity. Again this may have an impact on customer take-up, market share and expenditure per customer which would ultimately flow through to the operator's profitability (which we consider in terms of discounted free cash flow).

- **Strategic value**: There may be wider strategic considerations for an organisation participating in an auction – for example the benefit of acquiring additional spectrum to keep a potential new entrant out of the market or ensure its spectrum holdings are limited such that its competitive impact in the medium-term is hindered.

159. Our assessments have focused on the first two sources of value (technical value and commercial value). We have not considered strategic value as one of Ofcom's desired outcomes from the auction is to have four competing national wholesalers and Ofcom has proposed the inclusion of spectrum caps and floors in the auction award process to reflect this.

160. Our modelling work aims to focus on the main driver(s) that affect the value of different combinations of spectrum to potential bidders (including the existing four national wholesalers and potential new entrants). We have not sought to undertake a precise valuation of the spectrum (considering second-order effects etc) since:

- inherently we are making assessments about the strategies each user of spectrum would adopt under alternative spectrum scenarios – these may differ in practice
- there are many market development variables (e.g. future mobile traffic levels, timescale for availability of LTE technology in individual bands, value placed by end user on higher data rates etc) which have a high degree of uncertainty.

Financial parameters

161. As discussed in the previous section, we assess the incremental value of different combinations of spectrum by calculating the net present value of incremental free cash flow over the period of the licence. In the case of the licences to be awarded by Ofcom, the licences are of indefinite duration, but with an initial licence period of 20 years during which time no annual fees for the spectrum are payable and the reasons for varying or revoking the licence do not include spectrum management reasons. Following the initial 20 year licence period, Ofcom is able to charge annual fees for the use of the spectrum and is also able to vary or to revoke the licence for spectrum management reasons. In view of this we undertake our assessment of the value of the licence by modelling the incremental cash flows over the initial 20 year period of the licence and do not include a 'terminal value' assessment of the value beyond this period.

162. The Weighted Average Cost of Capital (WACC) utilised for our assessments is 8.86%. This is based on advice from members of the Expert Panel to use the same rate as utilised by Ofcom for its other assessments, for example in the calculation of mobile termination rates[61]. Ofcom has utilised a real rate of

[61] See Ofcom, 'Wholesale mobile voice call termination: Statement – Non-confidential version', 15 March 2011.

return of 6.2% in this work, with a long-term inflation assumption of 2.5% per annum, thereby equating to a nominal WACC of 8.86%. This is in line with our initial proposal to utilise a nominal discount rate of 9% which drew upon our knowledge of the assumptions other European mobile operators have used.

163. In summary, all net present valuations presented in this report are the NPV over 20 years (2013-2032) discounted to 2012 using a WACC of 8.86%, unless otherwise stated.

Evolution of UK mobile market

164. As detailed in the sections below, our modelling approach is to assess the impact of alternative configurations of spectrum on potential acquirers of the spectrum against a 'base case'. In this section we present the assumptions we have made when developing the market evolution underlying this base case. In this scenario we assume that there are four competing national wholesalers each of whom has sufficient spectrum to offer a broadly comparable service offering to consumers in the medium-term – specifically we assume that each of the four existing national wholesalers is in the medium-term able to deploy a 2x20MHz LTE carrier using high-frequency spectrum (covering the most densely populated areas) and a 2x10MHz LTE carrier using low frequency spectrum through a combination of spectrum acquired at the auction and the national wholesaler's existing spectrum holdings.

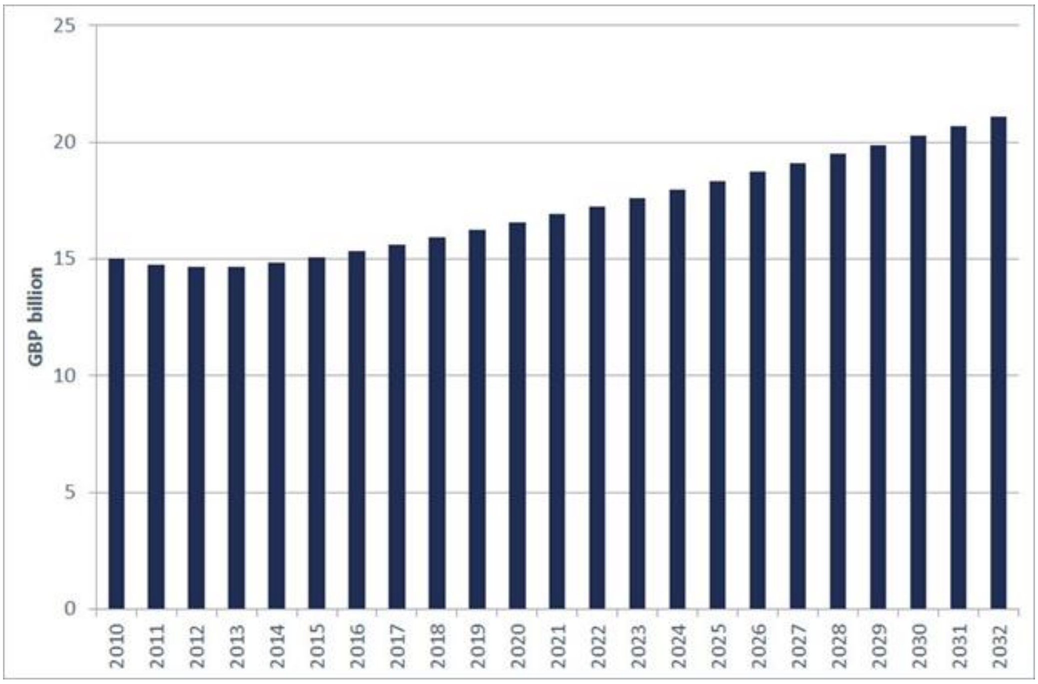
165. Our long-term forecast for the evolution of total UK mobile market revenues is based on the following assumptions:

- the UK populations grows to 72.1 million by 2032
- the proportion of individuals (users) aged 16 and above taking up mobile service increases from 89% to 95% by 2032
- spending per user increases by 1% per annum in nominal terms.

166. In the period to 2017, we have modified our forecasts to take account of the impact of mobile termination rate reductions in line with forecasts of this impact that have been developed by Barclays Capital.

167. Our forecast is shown in Figure 8 with total UK mobile market revenues projected to rise from approximately GBP15 billion in 2010 to approximately GBP21 billion (in nominal terms) by 2032.

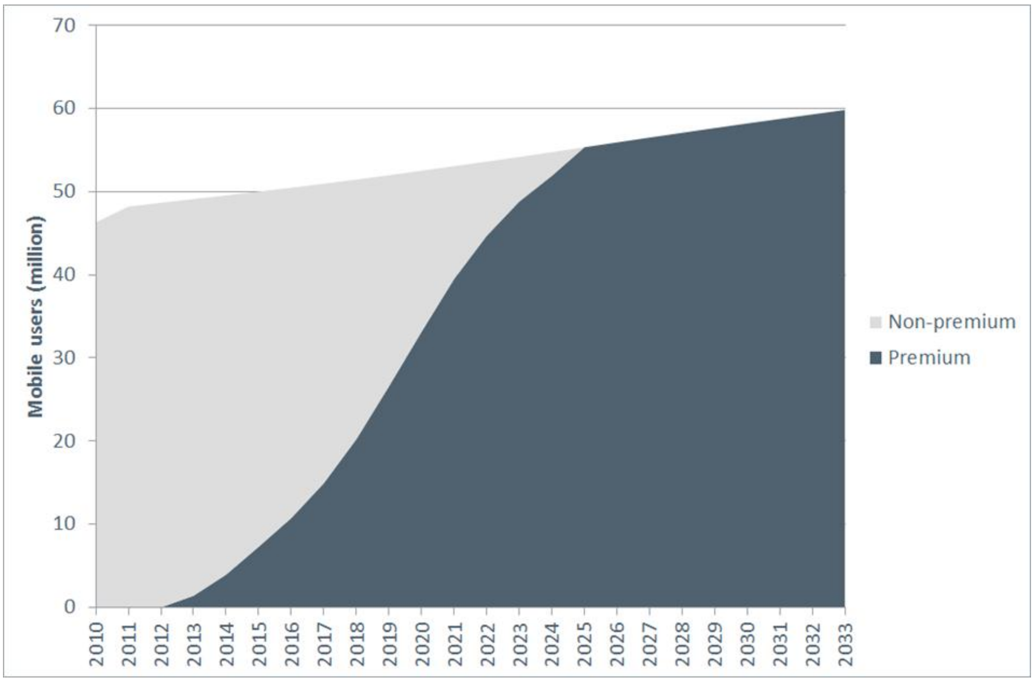
Figure 8: Forecast evolution of total UK mobile market revenues



168. In our base case scenario, we consider the rate at which revenue would migrate from being generated on GSM and UMTS networks to being generated on LTE networks, as subscribers migrate through obtaining devices which are compatible with the latest network technologies. As discussed above, this migration profile assumes a scenario where four national wholesalers will deploy competing LTE networks. The evolution of subscribers to next-generation networks is shown in Figure 9 below. Please note that we label subscribers that would be generated on LTE networks in this 'base case' scenario as "Premium segment" subscribers as in some of the spectrum scenarios we utilise for the valuation of spectrum, we estimate that proportion of these subscribers could still be retained by an operator that has deployed the latest 3G technologies in the absence of appropriate/sufficient spectrum for an LTE deployment.

169. For the purposes of assessing the revenue that would be generated on LTE networks, we assume that Premium segment subscribers each spend 20% more than the average mobile subscriber (Premium and Non-Premium segments combined).

Figure 9: Forecast migration of mobile users to LTE networks (premium users) under 'base case' scenario



170. In view of the uncertainty over the future evolution of traffic levels on mobile networks, we have developed a range of forecasts in the form of low, medium and high scenarios of traffic per user showing traffic to be carried on the mobile network (i.e. traffic off-loaded onto home or public WiFi networks and femtocells are excluded from this forecast). Following feedback from the Expert Panel, we updated the low forecast to be more conservative (i.e. fewer GBs per month per subscriber) in order to reflect a wider range of potential outcomes. The traffic forecasts from 2012 to 2033 are shown in Figure 10 below. We have also compared these forecasts against the growth rates implied by a number of third party forecasts of mobile traffic levels for the medium-term, as shown in Figure 11.

Figure 10: Forecast long-term evolution of mobile traffic levels

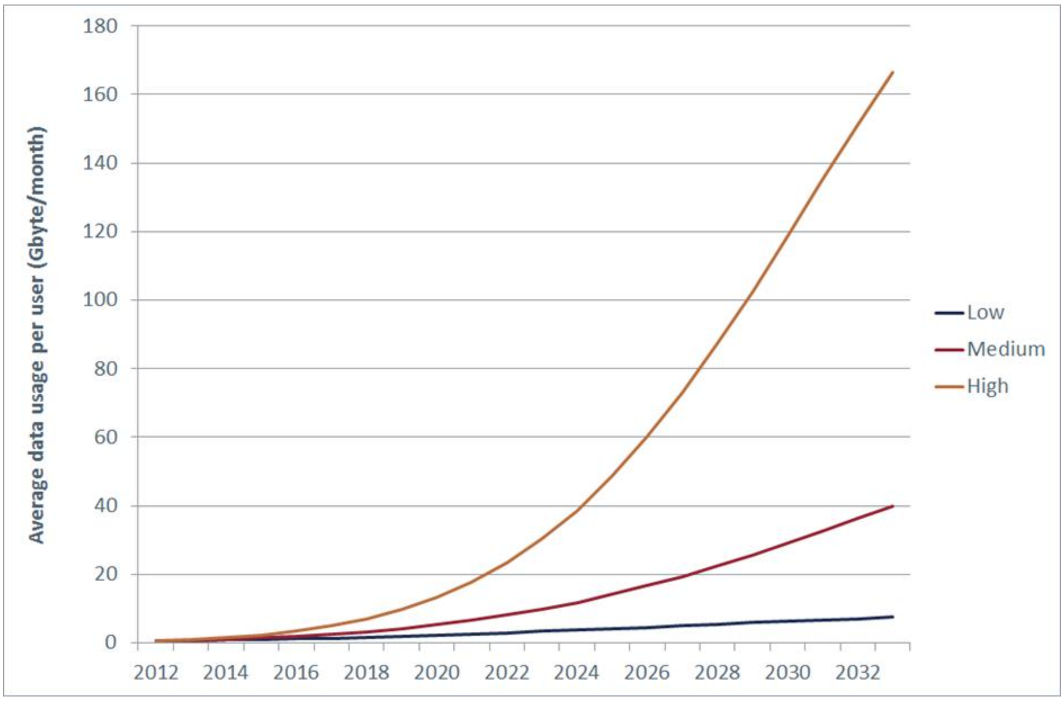
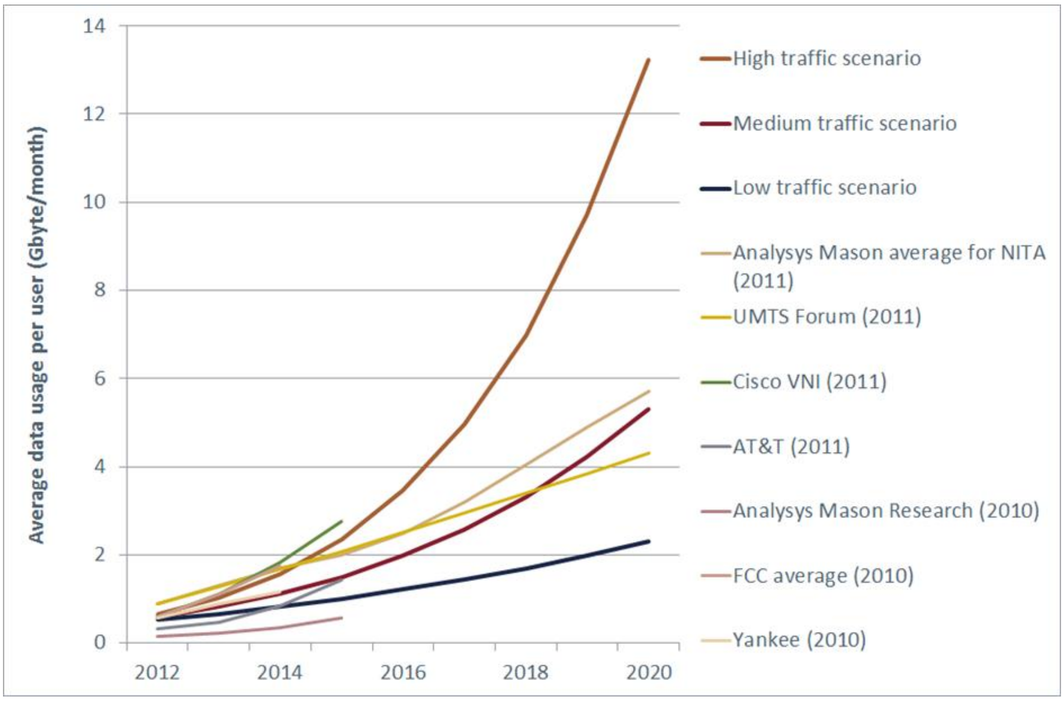


Figure 11: Comparison of medium-term mobile traffic level projections against third party forecasts



171. In the following sections, we detail how these 'base case' forecasts of revenues and traffic on mobile networks are utilised to develop valuations of alternative

combinations of paired spectrum (Section 4.2) and the unpaired spectrum (Section 4.3).

4.2 Approach to valuation of 800MHz, 1800MHz and 2.6GHz paired spectrum

4.2.1 Approach to valuation of spectrum for existing national wholesalers

172. In this section we describe our approach to assessing the value of spectrum from the perspectives of the four existing national wholesalers – namely Vodafone, Telefonica O_2, Everything Everywhere and H3G.

173. As discussed in Section 4.1, our overall approach is to assess the commercial and technical value that would be derived by each of the national wholesaler from different combinations of spectrum acquired at the auction. We start with the overall market forecast developed for the 'base case' and calculate differences in revenue and traffic levels arising under alternative spectrum configurations and the implications in terms of changes to the free cash flow generated by the business.

174. Please note that the intention of the valuation models is to assess the value of alternative spectrum scenarios to each national wholesaler, on the assumption that each national wholesaler is a credible provider of the services in the UK market – the models are not seeking to address whether this statement is correct.

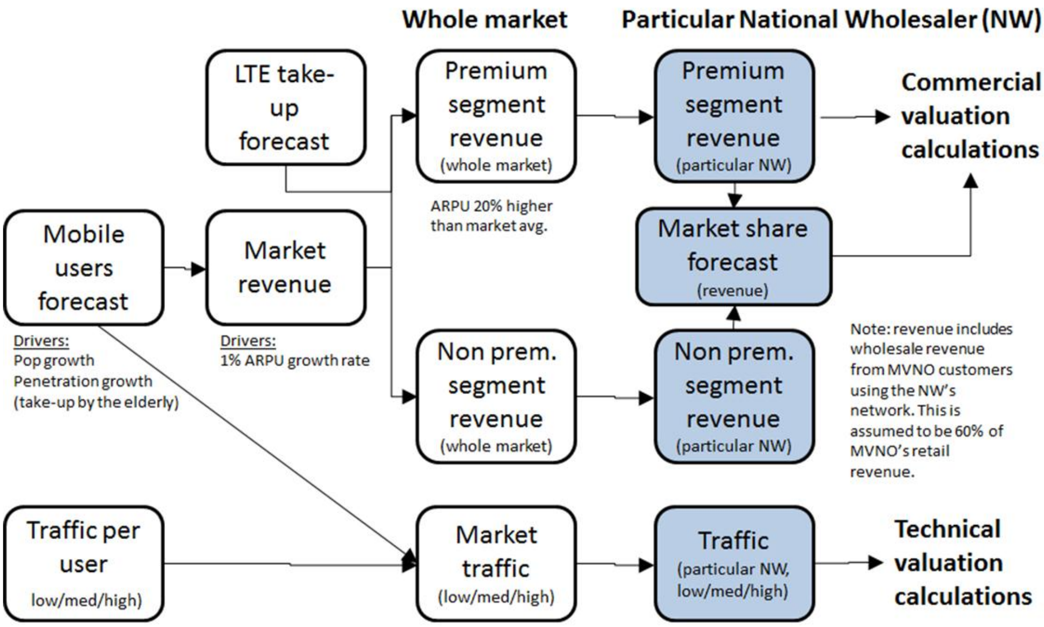
Assessment of national wholesaler revenues in base case scenario

175. Figure 12 below summarises the approach we have utilised to project the evolution of revenues and traffic levels for each of the national wholesalers. We start with the base case overall market revenue forecast and assume each national wholesaler captures a certain share of revenues, as described below.

176. For the development of the base case, as indicated above, we have assumed that the distribution of spectrum following the auction is such that each national wholesaler is in the medium-term able to deploy a 2x20MHz LTE carrier using high-frequency spectrum (covering the most densely populated areas) and a 2x10MHz LTE carrier using low frequency spectrum through a combination of spectrum acquired at the auction and the national wholesaler's existing spectrum holdings. The distribution of the spectrum to be awarded at the auction would therefore be as follows:

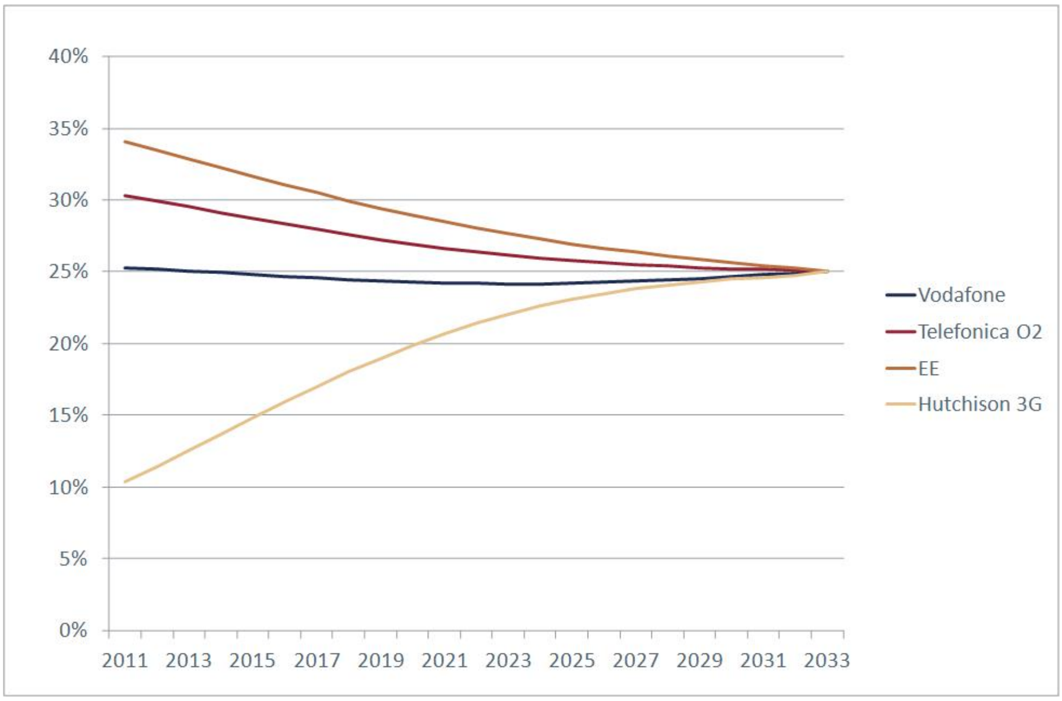
- Vodafone: 2x10MHz of 800MHz spectrum and 2x20MHz of 2.6GHz spectrum [note that these spectrum holdings are interchange with the holdings of Telefonica O_2 as the above scenario would still be met]
- Telefonica O_2: 2x15MHz of 1800MHz spectrum and 2x10MHz of 2.6GHz spectrum
- Everything Everywhere: 2x10MHz of 800MHz spectrum and 2x10MHz of 2.6GHz spectrum
- H3G: 2x10MHz of 800MHz spectrum and 2x20MHz of 2.6GHz spectrum.

Figure 12: Approach to forecasting of revenues and traffic levels for each national wholesaler under base case scenario



177. Under this base case scenario, we initially assumed that each national wholesaler tends towards an equal (25%) market share of revenues over time, as shown in Figure 13.

Figure 13: Forecast evolution of wholesale market shares for national wholesalers in 'base case'



178. It was subsequently felt that a 25% market share would probably over-estimate H3G's own ambitions for the market and consequently we have subsequently revised our valuation estimates for H3G to reflect a base case of 18% revenue share. Following discussions with the Expert Panel, we also developed results for H3G in a scenario where its base case market share was broadly flat with its current position (approximately 10% share of market revenues).

179. Whilst consideration of a 10% market share for H3G does not necessarily imply that each of the other three existing national wholesalers would necessarily value spectrum utilising a higher market share (30% rather than 25%), as part of our sensitivity analysis, we have undertaken valuations under the alternative spectrum scenarios for Vodafone, Telefonica O_2 and Everything Everywhere assuming long-term market share of 30%.

180. When calculating each national wholesaler's revenue for the purpose of the business modelling exercise, we have made a further adjustment to take account of existence of the major MVNOs[62] (e.g. Virgin Mobile and Tesco Mobile). We assume that each national wholesaler continues to host the same proportion of MVNO customers as is currently the case and deduct the share of retail revenue that we estimate would remain with the MVNO (we estimate this to be 40% of retail revenues). Consequently our revenue forecast for each national wholesaler comprises 100% of the retail revenues associated with the wholesaler's own retail customers and 60% of the retail revenues associated with the mobile users who are on MVNOs operating on the wholesaler's network.

181. We have estimated future traffic levels carried by each of the national wholesalers in the base case scenario taking account of the share of wholesale subscribers carried by each national wholesaler and the existing distribution of network traffic (which we assume to migrate to share of revenue over time).

182. The revenue and traffic projections developed for each of the national wholesalers as part of the base case scenario are then used as the basis for assessment of the commercial and technical value of alternative spectrum configurations, as detailed below.

Strategies of the national wholesalers under alternative spectrum scenarios

183. A key component of the business modelling process has been to make assumptions in relation to the network deployment strategies that would be adopted by each of the national wholesalers under the alternative configurations of spectrum that they may acquire in the auction (alternative spectrum scenarios). Particular consideration has been given to the deployment that would occur in the event that each national wholesaler failed to acquire any spectrum in the auction.

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62 Due to lack of a central source of data on the number of subscribers to smaller MVNOs in the UK, we were not able to take account of this in our assessments. We consider this to be a second-order effect which does not materially impact on the study's recommendations.

184. Our general guiding principle has been to assume that each operator will seek to deploy the highest performance LTE carrier across the widest possible coverage area as soon as it has sufficient spectrum to do so and the technology is available in the particular frequency band. This is on the basis that over the long-term, the revenue/commercial benefits outweigh the capital and operating expenditure of such an approach. This assessment is dependent on the assumptions made in relation to the importance of network overage and offering the highest bandwidth LTE carrier which are discussed further below. When analysing the results of the business modelling, we noted that in a few cases, this general assumption did not bear out (i.e. the cost of deploying a higher bandwidth carrier was more than the revenue benefit of doing so). In practice, the higher bandwidth carrier would be deployed in part of the coverage footprint of the operator (e.g. specific urban areas such as the centre of London, Birmingham, Manchester etc), however our business modelling approach does not consider specific geographic areas so we are unable to quantify the benefits of this and instead note that our estimate of the value of the spectrum should be considered to be a lower bound estimate as a result of this factor.

185. Annex B.1 presents details of the specific assumptions we have made in relation to the network deployment scenarios for Vodafone, Telefonica O_2, Everything Everywhere and H3G.

Assessment of commercial value

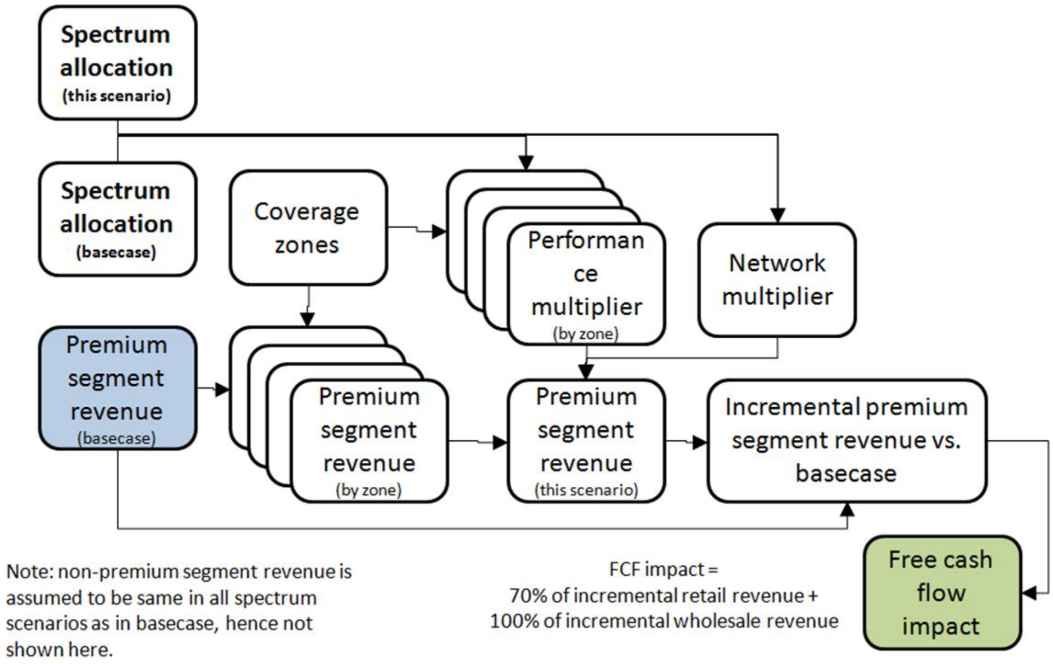
186. Our approach to the assessment of commercial value under the alternative spectrum scenarios for each national wholesaler is summarised in Figure 14 below. In summary we assess this in a number of stages:

- we start with the base case revenue of the national wholesaler for the premium segment (note that non-premium segment revenues are not impacted by the alternative spectrum scenarios so do not impact on commercial value)
- under each spectrum scenario, we assess the total amount of revenue available to the national wholesaler in view of its spectrum holdings by considering the amount of revenue that can be addressed by each frequency band held by the national wholesale ("**coverage zones**")
- within each "coverage zone", we consider what bandwidth of spectrum is available to the national wholesaler for the deployment of LTE in each spectrum scenario compared to the bandwidth available for LTE in the base case and adjust the revenue projection for the coverage zone accordingly in line with a "**performance multiplier**"
- we consider the overall highest data rate supported by the network in each spectrum scenario and compare this to be base case and adjust the revenue projections for all coverage zones in line with a "**network multiplier**"
- finally, in assessing the impact of changes in revenue to free cash flow, we assume that 30% of any incremental retail revenue (from each national wholesaler's own end customers) would be incurred as costs

associated with acquiring this revenue (e.g. subscriber acquisition/retention, customer service etc).

187. Each of the above stages is discussed in detail in Annex B.2.

Figure 14: Approach to assessment of commercial value of alternative spectrum combinations



Assessment of technical value

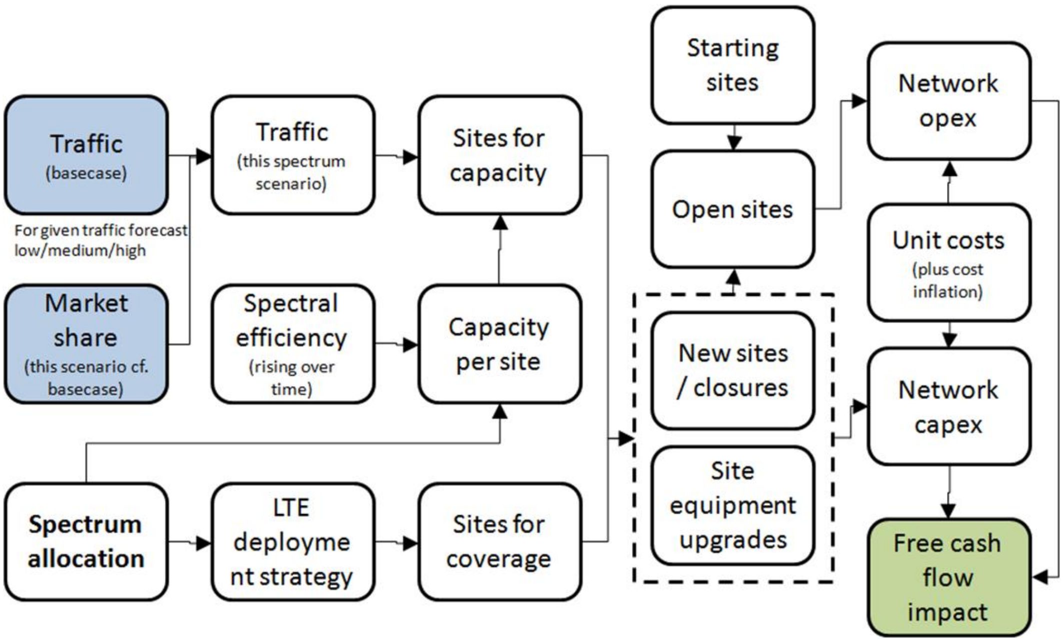
188. The assessment of technical value generated by different combinations of spectrum considers two main sources of value across the spectrum scenarios:

- cost savings (capital expenditure and operating expenditure) resulting from the additional capacity provided by new spectrum and the migration to LTE technology – thereby resulting in less need for additional traffic carriers to be deployed at existing sites and also fewer new sites needing to be brought into operation to order to support the forecast levels of network traffic
- cost savings resulting from the decommissioning of a proportion of coverage sites in the event that H3G is able to acquire 800MHz spectrum[63].

[63] We also considered whether Everything Everywhere could benefit from such cost savings however our modelling indicated that such savings were limited in comparison with the commercial benefit to Everything Everywhere of deploying a full 2x20MHz LTE carrier across its 1800MHz network footprint.

189. Our overall approach is shown in Figure 15. For each spectrum scenario, we assess the number of sites required for the initial deployment of LTE under each spectrum scenario and then compare the network capacity that is available on the existing network/new LTE network with the traffic to be supported (as determined by the subscriber numbers and traffic per subscriber). In the event that there is insufficient network capacity to support the level of demand, additional LTE (or HSPA+) capacity is deployed at existing cell sites using the spectrum that is available. At the point at which the available spectrum has been exhausted, new sites are opened. In the event that existing sites are not required for network capacity or coverage, they are decommissioned. We compare the overall capital and expenditure projections for the network (discounted cash flows from 2013 to 2032) across different spectrum scenarios (in particular to the case where no additional spectrum is available to the national wholesaler from the auction) to assess the technical value generated by each combination of spectrum.

Figure 15: Approach to assessment of technical value of alternative spectrum combinations



190. Further details of our approach to the assessment of technical value can be found in Annex B.3.

4.2.2 Approach to valuation of spectrum to a potential new entrant

191. Our assessment has considered the potential value of the paired spectrum to a new entrant. For this purpose we take the case of such a new entrant being an existing operator with a fixed telecoms network which also has a current MVNO service offering. Examples of such an operator include Virgin and BT.

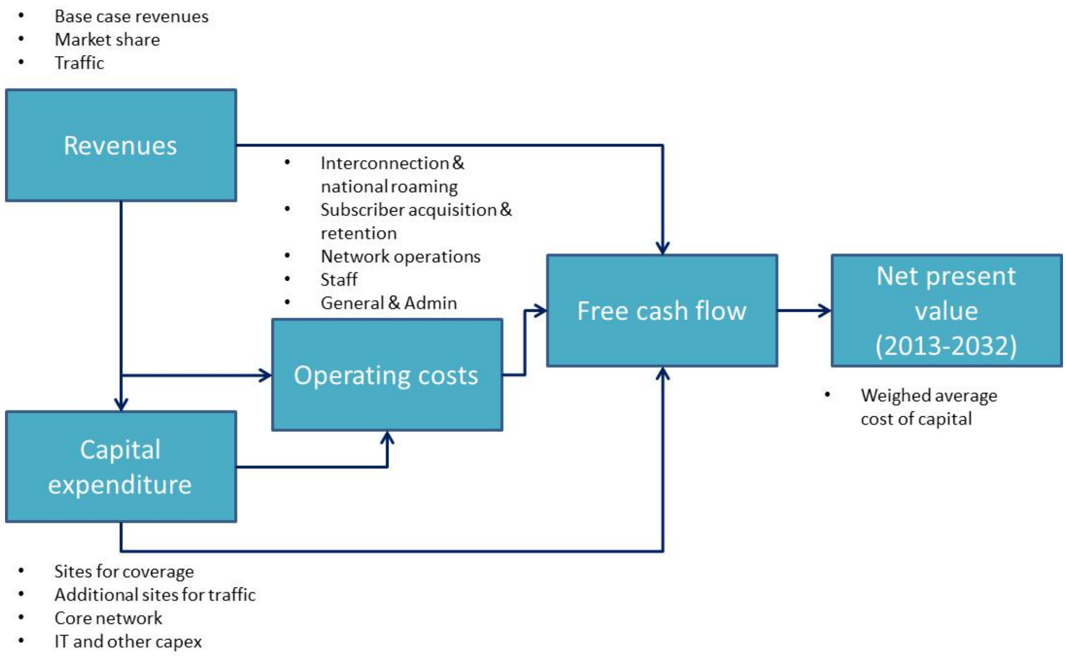
192. To assess the value of spectrum to such an organisation, we model the free cash flows that would be generated in the event that the organisation became a national wholesaler, deploying its network in 2013 and 2014 and

commercially launching service in 2015 (immediately migrating its existing MVNO customer base over). We compare this free cash flow against the free cash flow the organisation could make by continuing as an MVNO to assess the incremental cash flow resulting from acquisition of the spectrum. For the purposes of assessing the free cash flow that would be generated from continuing operations as an MVNO, we assume that 10% of revenues would flow through to free cash flow.

193. We have not considered any incremental value to the fixed operator arising from greater customer loyalty (i.e. lower churn) amongst its fixed operations subscriber base arising from the launch of a full mobile business as we assume that a large part of this effect would occur through quad-play offers which could be provided by the fixed operator continuing its MVNO business.

194. Our approach to modelling the new entrant business is summarised in Figure 16. For the purposes of assessing the impact of alternative spectrum scenarios, we adopt the same process utilised for calculating the commercial value and technical value for the existing network wholesalers. For the case of the new entrant, we assume that the 'base case' spectrum holding amounts to 2x10MHz of 800MHz spectrum and 2x20MHz of 2.6GHz spectrum.

Figure 16: Approach to modelling of new entrant business



195. Further details of the assumptions underlying our modelling of the business case for the new entrant can be found in Annex B.4.

4.3 Approach to valuation of 2.6GHz unpaired spectrum

196. In seeking to develop business models for the value of the 2.6GHz unpaired spectrum, we sought to identify potential uses of the band including:

- use by one or more of the national wholesalers to provide additional capacity spectrum to supplement their paired spectrum holdings
- use by a potential new entrant
- use to provide the backhaul connection between small cell sites and the central nodes (we note that Vodafone Spain is currently utilising 2.6GHz unpaired spectrum for this purpose).

197. Each of these uses of the spectrum is by no means certain, however we have sought to develop estimates of the value of the spectrum in the event that it were put to each of the uses detailed above.

198. Details of the specific approaches utilised for the valuation of unpaired spectrum for the three uses detailed above can be found in Annex B.5.

4.4 Results

199. In this section we provide an overview of the main results of our assessment of the value of spectrum to the existing national wholesalers and potential new entrants. The main valuations are presented in this section for the paired 800MHz, 1800MHz and 2.6GHz spectrum and for the unpaired 2.6GHz spectrum.

4.4.1 800MHz, 1800MHz and 2.6GHz paired spectrum

200. In this section we present the results for a wide range of alternative spectrum scenarios under the three modelled traffic levels. Table 13, Table 14 and Table 15 present the valuations under the low, medium and high traffic scenarios. The main points that can be drawn from the results are as follows:

- The valuations of each of the existing national wholesalers to particular spectrum combinations vary considerably in view of the varying existing holdings of each existing wholesaler.
- Everything Everywhere's valuations generally tend to be the lowest of the four existing national wholesalers in view of Everything Everywhere's extensive existing spectrum portfolio. The differences in valuation between the different spectrum packages are smaller than for Vodafone and Telefonica O_2, again as a result of the relative strength of Everything Everywhere's existing spectrum holdings.
- The valuations for H3G are generally higher than would initially be expected (typically the smallest existing national wholesaler has a lower valuation on spectrum than its competitors as a result of its smaller existing subscriber base and therefore lower economies of scale to benefit from the new spectrum holdings (e.g. ability to fund advertising, subscriber acquisition etc). H3G in the UK only holds 2.1GHz spectrum and has no spare spectrum to provide additional network capacity or to support the operation of two network technologies concurrently. Consequently a high-value is placed on any additional spectrum as this will allow the operator to efficiently migrate to LTE – and consequently the difference in valuations between different spectrum packages are relatively small.

- The valuations for the new entrant are relatively low – as would be expected.

Table 13: Valuations for paired spectrum (all figures are Net Present Value from 2013 to 2032) – low traffic scenario

800MHz/ 1800MHz/ 2.6GHz Paired MHz	Vodafone	O2	EE	H3G (10% share)	H3G (18% share)	New entrant (15% share)
10/0/20	£1,961m	£1,777m	£1,294m	£1,259m	£2,319m	£1,018m
10/0/15	£1,399m	£1,276m	£1,294m	£1,056m*	£1,913m	£910m*
10/0/10	£966m	£901m	£1,294m	£1,056m	£1,798m	£910m
0/15/20	£2,376m	£2,051m	N/A	£1,016m*	£1,714m	(£1,668m)*
0/15/15	£2,376m	£2,051m	N/A	£1,016m	£1,709m	(£1,668m)
0/15/10	£2,376m	£2,051m	N/A	£1,016m	£1,709m	(£1,668m)
15/0/20	N/A	N/A	£1,412m	£1,960m*	£2,936m*	£1,289m*
15/0/15	N/A	N/A	£1,412m	£1,960m	£2,936m	£1,289m
15/0/10	N/A	N/A	£1,412m	£1,960m	£2,936m*	£1,284m
5/15/20	£2,376m*	£2,051m*	N/A	£1,296m	£2,367m	£665m*
5/15/15	£2,376m*	£2,051m*	N/A	£1,270m	£2,183m	£665m
5/15/10	£2,376m*	£2,051m*	N/A	£1,270m	£2,183m	£664m
5/0/20	£1,521m	£1,380m	£1,057m	£986m	£1,874m	£509m
5/0/15	£968m	£888m	£1,057m	£745m	£1,479m	£399m
5/0/10	£344m	£323m	£1,057m	£488m	£1,063m	£226m
10/15/0	£2,439m	£2,133m	N/A	£1,347m	£2,309m	£984m
15/0/0	N/A	N/A	£1,412m	£1,960m	£2,936m	£1,146m
10/0/0	£966m	£901m	£1,294m	£1,056m	£1,798m	£552m

Note: The '' in this table and the following tables refers to cases where the figure we have quoted in the table can be considered a lower bound valuation. This is because our modelling work has identified that the deployment of a higher data-rate LTE carrier across the coverage footprint associated with the particular spectrum combination would result in a new loss of free cash flow. In such a circumstance the national wholesaler would deploy the higher data rate carrier in a limited sub-set of the coverage area (to maximise profit) however our modelling approach is unable to quantify the net benefit of such a deployment.*

Table 14: Valuations for paired spectrum (all figures are Net Present Value from 2013 to 2032) – medium traffic scenario

800MHz/ 1800MHz/ 2.6GHz Paired MHz	Vodafone	O2	EE	H3G (10% share)	H3G (18% share)	New entrant (15% share)
10/0/20	£2,141m	£2,070m	£1,285m*	£1,367m	£2,319m	£331m
10/0/15	£1,568m	£1,551m	£1,285m*	£1,153m*	£1,913m	(£2m)
10/0/10	£1,070m	£1,094m	£1,285m*	£1,153m*	£1,798m	(£320m)
0/15/20	£2,559m	£2,356m	N/A	£1,102m*	£1,714m	(£1,892m)*
0/15/15	£2,552m	£2,341m	N/A	£1,102m	£1,709m	(£1,892m)
0/15/10	£2,539m	£2,311m	N/A	£1,099m	£1,709m	(£2,061m)
15/0/20	N/A	N/A	£1,408m*	£2,022m*	£2,936m*	£702m
15/0/15	N/A	N/A	£1,408m*	£2,022m	£2,936m*	£546m
15/0/10	N/A	N/A	£1,408m*	£2,022m*	£2,936m*	£283m
5/15/20	£2,559m*	£2,356m*	N/A	£1,405m	£2,367m	£256m
5/15/15	£2,552m*	£2,341m*	N/A	£1,354m	£2,183m	£171m
5/15/10	£2,539m*	£2,311m*	N/A	£1,351m	£2,183m	£6m
5/0/20	£1,685m	£1,645m	£1,043m	£1,094m	£1,874m	(£259m)
5/0/15	£1,115m	£1,124m	£1,041m	£853m	£1,479m	(£660m)
5/0/10	£464m	£524m	£1,039m	£597m	£1,063m	(£1,267m)
10/15/0	£2,619m	£2,413m	N/A	£1,437m	£2,309m	£56m
15/0/0	N/A	N/A	£1,408m	£2,022m	£2,936m	(£667m)
10/0/0	£1,031m	£1,024m	£1,285m	£1,153m	£1,798m	(£2,070m)

Table 15: Valuations for paired spectrum (all figures are Net Present Value from 2013 to 2032) – high traffic scenario

800MHz/ 1800MHz/ 2.6GHz Paired MHz	Vodafone	O2	EE	H3G (10% share)	H3G (18% share)	New entrant (15% share)
10/0/20	£2,827m	£3,040m	£1,416m	£2,837m	£4,914m	(£1,362m)
10/0/15	£2,193m	£2,440m	£1,398m	£2,619m*	£4,405m	(£2,012m)
10/0/10	£1,606m	£1,876m	£1,357m	£2,619m*	£4,083m	(£2,828m)
0/15/20	£3,320m	£3,426m	N/A	£2,526m*	£4,470m	(£2,956m)
0/15/15	£3,216m	£3,292m	N/A	£2,526m	£4,314m	(£3,132m)
0/15/10	£3,093m	£3,129m	N/A	£2,511m	£4,164m	(£3,655m)
15/0/20	N/A	N/A	£1,550m	£3,441m*	£5,435m*	(£815m)
15/0/15	N/A	N/A	£1,536m	£3,441m*	£5,435m	(£1,215m)
15/0/10	N/A	N/A	£1,515m	£3,441m*	£5,267m	(£1,877m)
5/15/20	£3,320m*	£3,426m*	N/A	£2,854m	£5,118m	(£926m)
5/15/15	£3,216m	£3,299m	N/A	£2,759m	£4,809m	(£1,179m)
5/15/10	£3,093m	£3,164m	N/A	£2,743m	£4,685m	(£1,615m)
5/0/20	£2,285m	£2,511m	£1,165m	£2,557m	£4,366m	(£2,050m)
5/0/15	£1,645m	£1,890m	£1,129m	£2,308m	£3,841m	(£2,884m)
5/0/10	£914m	£1,173m	£1,078m	£2,051m	£3,180m	(£4,218m)
10/15/0	£3,181m	£3,232m	N/A	£2,855m	£4,694m	(£2,004m)
15/0/0	N/A	N/A	£1,486m	£3,441m	£4,737m	(£4,195m)
10/0/0	£1,292m	£1,402m	£1,307m	£2,619m	£3,323m	(£6,985m)

201. These valuations have been used to estimate the incremental value of 2x5MHz of 800MHz, 1800MHz and 2.6GHz spectrum to each of the bidders. These valuations can be seen in Table 20 (low traffic scenario), Table 21 (medium traffic) and Table 22 (high traffic).

Table 16: Incremental valuations for paired spectrum (all figures are Net Present Value from 2013 to 2032)– low traffic scenario

Increment	Vodafone	O2	EE	H3G (10% share)	H3G (18% share)	New entrant (15% share)
800MHz increments						
5/0/10 to 10/0/10	£622m	£578m	£237m	£568m	£735m	£684m
5/0/15 to 10/0.15	£431m	£388m	£237m	£311m	£434m	£497m
5/0/20 to 10/0/20	£440m	£397m	£237m	£273m	£445m	£509m
10/0/10 to 15/0/10	N/A	N/A	£118m	£904m	£1138m	£374m
10/0/15 to 15/0/15	N/A	N/A	£118m	£904m	£1023m	£393m
10/0/20 to 15/0/20	N/A	N/A	£118m	£701m	£617m	£271m
1800MHz increments (normalised to 2x5MHz block of 1800MHz spectrum)						
10/0/0 to 10/15/0	£491m	£411m	N/A	£97m	£170m	£144m
5/0/10 to 5/15/10	£677m	£576m	N/A	£261m	£373m	£146m
5/0/15 to 5/15/15	£469m	£388m	N/A	£175m	£235m	£89m
5/0/20 to 5/15/20	£285m	£224m	N/A	£103m	£164m	£52m
2.6GHz increments						
10/0/10 to 10/0/15	£433m	£375m	£0m	£0m	£115m	£0m
10/0/15 to 10/0/20	£562m	£501m	£0m	£203m	£406m	£108m
15/0/10 to 15/0/15	N/A	N/A	£0m	£0m	£0m	£5m
15/0/15 to 15/0/20	N/A	N/A	£0m	£0m	£0m	£0m
0/15/10 to 0/15/15	£0m	£0m	N/A	£0m	£0m	£0m
0/15/15 to 0/15/20	£0m	£0m	N/A	£0m	£5m	£0m
5/0/10 to 5/0/15	£624m	£565m	£0m	£257m	£416m	£173m
5/0/15 to 5/0/20	£553m	£492m	£0m	£241m	£395m	£110m

Table 17: Incremental valuations for paired spectrum (all figures are Net Present Value from 2013 to 2032)– medium traffic scenario

Increment	Vodafone	O2	EE	H3G (10% share)	H3G (18% share)	New entrant (15% share)
800MHz increments						
5/0/10 to 10/0/10	£606m	£570m	£246m	£556m	£735m	£947m
5/0/15 to 10/0.15	£453m	£427m	£244m	£300m	£434m	£658m
5/0/20 to 10/0/20	£456m	£425m	£242m	£273m	£445m	£590m
10/0/10 to 15/0/10	N/A	N/A	£123m	£869m	£1138m	£603m
10/0/15 to 15/0/15	N/A	N/A	£123m	£869m	£1023m	£548m
10/0/20 to 15/0/20	N/A	N/A	£123m	£655m	£617m	£371m
1800MHz increments (normalised to 2x5MHz block of 1800MHz spectrum)						
10/0/0 to 10/15/0	£529m	£463m	N/A	£95m	£170m	£709m
5/0/10 to 5/15/10	£692m	£596m	N/A	£251m	£373m	£424m
5/0/15 to 5/15/15	£479m	£406m	N/A	£167m	£235m	£277m
5/0/20 to 5/15/20	£291m	£237m	N/A	£104m	£164m	£172m
2.6GHz increments						
10/0/10 to 10/0/15	£498m	£457m	£0m	£0m	£115m	£318m
10/0/15 to 10/0/20	£573m	£519m	£0m	£214m	£406m	£333m
15/0/10 to 15/0/15	N/A	N/A	£0m	£0m	£0m	£263m
15/0/15 to 15/0/20	N/A	N/A	£0m	£0m	£0m	£156m
0/15/10 to 0/15/15	£13m	£30m	N/A	£3m	£0m	£169m
0/15/15 to 0/15/20	£7m	£15m	N/A	£0m	£5m	£0m
5/0/10 to 5/0/15	£651m	£600m	£2m	£256m	£416m	£607m
5/0/15 to 5/0/20	£570m	£521m	£2m	£241m	£395m	£401m

Table 18: Incremental valuations for paired spectrum (all figures are Net Present Value from 2013 to 2032)– high traffic scenario

Increment	Vodafone	O2	EE	H3G (10% share)	H3G (18% share)	New entrant (15% share)
800MHz increments						
5/0/10 to 10/0/10	£692m	£703m	£279m	£568m	£903m	£1390m
5/0/15 to 10/0.15	£548m	£550m	£269m	£311m	£564m	£872m
5/0/20 to 10/0/20	£542m	£529m	£251m	£280m	£548m	£688m
10/0/10 to 15/0/10	N/A	N/A	£158m	£822m	£1184m	£951m
10/0/15 to 15/0/15	N/A	N/A	£138m	£822m	£1030m	£797m
10/0/20 to 15/0/20	N/A	N/A	£134m	£604m	£521m	£547m
1800MHz increments (normalised to 2x5MHz block of 1800MHz spectrum)						
10/0/0 to 10/15/0	£630m	£610m	N/A	£79m	£457m	£1660m
5/0/10 to 5/15/10	£726m	£664m	N/A	£231m	£502m	£868m
5/0/15 to 5/15/15	£524m	£470m	N/A	£150m	£323m	£568m
5/0/20 to 5/15/20	£345m	£305m	N/A	£99m	£251m	£375m
2.6GHz increments						
10/0/10 to 10/0/15	£587m	£564m	£41m	£0m	£322m	£816m
10/0/15 to 10/0/20	£634m	£600m	£18m	£218m	£509m	£650m
15/0/10 to 15/0/15	N/A	N/A	£21m	£0m	£168m	£662m
15/0/15 to 15/0/20	N/A	N/A	£14m	£0m	£0m	£400m
0/15/10 to 0/15/15	£123m	£163m	N/A	£15m	£150m	£523m
0/15/15 to 0/15/20	£104m	£134m	N/A	£0m	£156m	£176m
5/0/10 to 5/0/15	£731m	£717m	£51m	£257m	£661m	£1334m
5/0/15 to 5/0/20	£640m	£621m	£36m	£249m	£525m	£834m

202. Table 19 summarises the average incremental value of 2x5MHz of spectrum in the 800MHz, 1800MHz and 2.6GHz band under all three traffic scenarios together with the ratio of the valuations across the different spectrum bands. In the low traffic scenario the ratio between the value of 800MHz spectrum and 1800MHz amounts to approximately 1.8:1, whilst the ratio between the value of 1800MHz spectrum and 2.6GHz spectrum amounts to approximately 1.8:1 (note these numbers are averages of the incremental valuation results shown above – in practice the specific value of an incremental blocks depends upon the other elements of the spectrum package). In the high traffic scenario, the ratio between the value of 800MHz spectrum and 1800MHz spectrum falls to approximately 1.2:1 whilst the ratio between the value of 1800MHz spectrum and 2.6GHz spectrum falls to approximately 1.4:1. The ratios in the medium traffic scenario are broadly in the middle of range of ratios between the low and high traffic scenarios.

Table 19: Ratio of incremental valuations across 800MHz, 1800MHz and 2.6GHz bands

		Traffic scenarios			**Overall average**
		Low	Medium	High	
Average value	800MHz	£490m	£522m	£607m	£540m
	1800MHz	£277m	£342m	£492m	£370m
	2.6GHz	£156m	£208m	£343m	£236m
Ratios	800MHz to 1800MHz	1.8	1.5	1.2	1.5
	1800MHz to 2.6GHz	1.8	1.6	1.4	1.6
	800MHz to 2.6GHz	3.1	2.5	1.8	2.5

4.4.2 2.6GHz unpaired spectrum

203. The results of our assessment of the use of unpaired 2.6GHz spectrum by a national wholesaler to provide additional capacity spectrum are shown in Table 20, Table 21 and Table 22 under the low, medium and high traffic scenarios, respectively.

204. It can be seen that the 2.6GHz unpaired spectrum does not have any additional value in the low traffic scenario, has modest value in the medium traffic scenario and is potentially very valuable in the event that the high traffic scenario were realised.

Table 20: Valuation of unpaired 2.6GHz spectrum for use by national wholesalers for additional network capacity (all figures are Net Present Value from 2013 to 2032) – low traffic scenario

800MHz/ 1800MHz/ 2.6GHz Paired MHz	Unpaired 2.6GHz spectrum (MHz)	Vodafone (25% share)	O2 (25% share)	EE (25% share)	H3G (18% share)
10/0/0	+0	£966m	£901m	£1,294m	£1,798m
10/0/0	+10	£966m	£901m	£1,294m	£1,798m
10/0/0	+20	£966m	£901m	£1,294m	£1,798m
10/0/0	+30	£966m	£901m	£1,294m	£1,798m
10/0/10	+0	£966m	£901m	£1,294m	£1,798m
10/0/10	+10	£966m	£901m	£1,294m	£1,798m
10/0/10	+20	£966m	£901m	£1,294m	£1,798m
10/0/10	+30	£966m	£901m	£1,294m	£1,798m
10/0/20	+0	£1,961m	£1,777m	£1,294m	£2,319m
10/0/20	+10	£1,961m	£1,777m	£1,294m	£2,319m
10/0/20	+20	£1,961m	£1,777m	£1,294m	£2,319m
10/0/20	+30	£1,961m	£1,777m	£1,294m	£2,319m
0/15/10	+0	£2,376m	£2, 051m	N/A	£1,709m
0/15/10	+10	£2,376m	£2, 051m	N/A	£1,709m
0/15/10	+20	£2,376m	£2, 051m	N/A	£1,709m
0/15/10	+30	£2,376m	£2,051m	N/A	£1,709m

Table 21: Valuation of unpaired 2.6GHz spectrum for use by national wholesalers for additional network capacity (all figures are Net Present Value from 2013 to 2032) – medium traffic scenario

800MHz/ 1800MHz/ 2.6GHz Paired MHz	Unpaired 2.6GHz spectrum (MHz)	Vodafone (25% share)	O2 (25% share)	EE (25% share)	H3G (18% share)
10/0/0	+0	£1,031m	£1,024m	£1,285m	£2,182m
10/0/0	+10	£1,055m	£1,071m	£1,285m	£2,299m
10/0/0	+20	£1,078m	£1,118m	£1,285m	£2,367m
10/0/0	+30	£1,085m	£1,135m	£1,285m	£2,377m
10/0/10	+0	£1,070m	£1,094m	£1,285m	£2,330m
10/0/10	+10	£1,070m	£1,105m	£1,285m	£2,346m
10/0/10	+20	£1,072m	£1,116m	£1,285m	£2,354m
10/0/10	+30	£1,072m	£1,120m	£1,285m	£2,356m
10/0/20	+0	£2,141m	£2,070m	£1,285m	£2,930m
10/0/20	+10	£2,141m	£2,070m	£1,285m	£2,930m
10/0/20	+20	£2,141m	£2,070m	£1,285m	£2,930m
10/0/20	+30	£2,141m	£2,070m	£1,285m	£2,930m
0/15/10	+0	£2,539m	£2,311m	N/A	£2,254m
0/15/10	+10	£2,539m	£2,319m	N/A	£2,254m
0/15/10	+20	£2,541m	£2,330m	N/A	£2,254m
0/15/10	+30	£2,541m	£2,334m	N/A	£2,254m

Table 22: Valuation of unpaired 2.6GHz spectrum for use by national wholesalers for additional network capacity (all figures are Net Present Value from 2013 to 2032) – high traffic scenario

800MHz/ 1800MHz/ 2.6GHz Paired MHz	Unpaired 2.6GHz spectrum (MHz)	Vodafone (25% share)	O2 (25% share)	EE (25% share)	H3G (18% share)
10/0/0	+0	£1,292m	£1,402m	£1,307m	£3,323m
10/0/0	+10	£1,513m	£1,750m	£1,333m	£3,920m
10/0/0	+20	£1,715m	£2,033m	£1,392m	£4,263m
10/0/0	+30	£1,865m	£2,236m	£1,412m	£4,475m
10/0/10	+0	£1,606m	£1,876m	£1,357m	£4,083m
10/0/10	+10	£1,729m	£2,063m	£1,357m	£4,302m
10/0/10	+20	£1,863m	£2,242m	£1,374m	£4,481m
10/0/10	+30	£1,967m	£2,379m	£1,381m	£4,604m
10/0/20	+0	£2,827m	£3,040m	£1,416m	£4,914m
10/0/20	+10	£2,910m	£3,163m	£1,416m	£5,037m
10/0/20	+20	£3,014m	£3,301m	£1,416m	£5,158m
10/0/20	+30	£3,096m	£3,407m	£1,416m	£5,245m
0/15/10	+0	£3,093m	£3,129m	N/A	£4,164m
0/15/10	+10	£3,205m	£3,294m	N/A	£4,311m
0/15/10	+20	£3,333m	£3,462m	N/A	£4,443m
0/15/10	+30	£3,435m	£3,594m	N/A	£4,536m

205. The results of our assessment of the value of unpaired 2.6GHz spectrum to a potential new market entrant are shown in Table 23 and Table 24, using weighted average cost of capital assumptions of 8.86% and 11%, respectively.

206. It can be seen that the business case is generally negative except in cases where a high number of subscribers are secured and the 50MHz of unpaired spectrum is available. Even if these cases, the valuations are relatively modest.

Table 23: Valuation of unpaired 2.6GHz spectrum for use by potential new market entrant (all figures are Net Present Value from 2013 to 2032) – WACC of 8.86%

Subscribers in 2032	50MHz of unpaired spectrum	25MHz of unpaired spectrum
1 million	(£219m)	(£219m)
2 million	£43m	(£139m)
3 million	£244m	(£166m)

Table 24: Valuation of unpaired 2.6GHz spectrum for use by potential new market entrant (all figures are Net Present Value from 2013 to 2032) – WACC of 11%

Subscribers in 2032	50MHz of unpaired spectrum	25MHz of unpaired spectrum
1 million	(£194m)	(£194m)
2 million	£17m	(£121m)
3 million	£182m	(£135m)

207. The results of our assessment of the value of the 2.6GHz unpaired spectrum assuming it is used to provide backhaul connectivity to between 500 and 1000 small cells fall within the range £5 to £46 million. Overall, it can be seen that the valuations are relatively modest.

208. In summary it can be seen that the valuation of 2.6GHz unpaired spectrum is relatively modest under most potential use scenarios. The potential value of the spectrum is high (hundreds of millions of Euros) in the situation where traffic levels on mobile networks are at the higher-end of the range.

5 Valuation of available spectrum

209. In this section, we compare the valuations from the benchmarking exercise against the spectrum value estimates from the business modelling. As explained in Section 2.1, we would expect the business modelling valuations to be consistently above the estimates obtained from benchmarking, and we therefore compare the highest valuation suggested by the benchmarking exercise for both a small *and* a large bidder against the business modelling valuations. We consider valuations from the low, medium and high traffic demand scenarios as bidders' valuations for some packages may be higher or lower under a heavier traffic demand scenario.

210. In the case of H3G's valuation, we adopt a conservative position and use valuations assuming that H3G maintains its current revenue share of 10% in the long term. For the new entrant, we use a valuation assuming that the entrant gains a long term revenue share of 15%. A lower market share would yield negative business cases.

211. Based on benchmark valuations in Table 8 above, this maximum spectrum value is:

- £0.434 for 800MHz for a small bidder, and £0.714 for a large bidder;
- £0.219 for 1800MHz;
- £0.121 for paired 2.6GHz; and
- £0.059 for unpaired 2.6GHz.

212. We calculate the value of spectrum packages on the basis of these benchmark figures assuming a UK population of 63 million.[64]

213. The benchmark valuations suggest that the fourth player more often than not has the lowest willingness to pay for all relevant spectrum bands concerned. Therefore, the fourth player's valuation of the relevant spectrum sets a bound on maximum spectrum value that should not choke off efficient demand from small and large bidders.

214. Table 25 compares the benchmark valuations of the MPP packages against the value of H3G and the new entrant from the business modelling.

[64] CIA World Factbook, see: https://www.cia.gov/library/publications/the-world-factbook/geos/uk.html

Table 25: MPP valuations – fourth player and new entrant

800MHz/ 1800MHz/ 2.6GHz	Benchmark value	H3G (Low/Medium/High traffic scenario)	New entrant (Low/Medium High traffic scenario)
MPP1 (15/0/0)	£820m	£1,960m	£1,146m
		£2,022m	(£667m)
		£3,441m	(£4,195m)
MPP2 (10/0/10)	£699m	£1,056m	£910m
		£1,153m	(£320m)
		£2,619m	(£2,828m)
MPP3 (0/15/10)	£566m	£1,016m	(£1,688m)
		£1,099m	(£2,061m)
		£2,511m	(£3,655m)
MPP4 (10/15/0)	£961m	£1,347m	£984m
		£1,437m	£56m
		£2,855m	(£2,004m)

Note: Numbers in brackets represent a negative value.

215. The business modelling valuations for H3G are consistently above the benchmark estimates, even in the low traffic demand scenario where valuations for H3G are most conservative.

216. However, the new entrant has decreasing valuations in the heavier demand scenarios and has mostly positive valuations under the low traffic scenario only. Even with the traffic scenario that produces the highest new entrant valuations, the business case for MPP3 (0/15/10) is negative, which means that there is no set of reserve prices that would provide an incentive for a new entrant to opt in, even though the business model valuations are higher than our benchmark valuations for MPP1, MPP2 and MPP4. Overall, the business modelling valuations for the new entrant suggests that this set of MPPs might not be particularly suited for a new entrant business case while business modelling valuations for H3G exceeds the top end of our benchmark value even in the most pessimistic business case scenario.

217. Table 26 compares the benchmark valuations of various spectrum packages against the business modelling results in the low, medium and high traffic scenario for different bidders.

Table 26: Comparison of bidders' valuation in all three traffic demand scenario

800MHz/ 1800MHz/ 2.6GHz	Benchmark value: large bidder/small bidder	Vodafone	O_2	EE	H3G
		Low/Medium/High traffic scenarios			
10/0/20	£1,205m/£852m	£1,961m £2,141m £2,827m	£1,777m £2,070m £3,040m	£1,294m £1,285m* £1,416m	£1,259m £1,367m £2,837m
10/0/15	£1,128m/£776m	£1,399m £1,568m £2,193m	£1,276m £1,551m £2,440m	£1,294m £1,285m* £1,398m	£1,056m* £1,153m* £2,619m*
10/0/10	£1,052m/£699m	£966m £1,070m £1,606m	£901m £1,094m £1,876m	£1,294m £1,285m* £1,357m	£1,056m £1,153m* £2,619m*
0/15/20	£719m/£719m	£2,376m £2,559m £3,320m	£2,051m £2,356m £3,426m	N/A N/A N/A	£1,016m* £1,102m* £2,526m*
0/15/15	£643m/£643m	£2,376m £2,552m £3,216m	£2,051m £2,341m £3,292m	N/A N/A N/A	£1,016m £1,102m £2,526m
0/15/10	£566m/£566m	£2,376m £2,539m £3,093m	£2,051m £2,311m £3,129m	N/A N/A N/A	£1,016m £1,099m £2,511m
15/0/20	£1,654m/£1,125m	N/A N/A N/A	N/A N/A N/A	£1,412m £1,408m* £1,550m	£1,960m* £2,022m* £3,441m*
15/0/15	£1,578m/£1,049m	N/A N/A N/A	N/A N/A N/A	£1,412m £1,408m* £1,536m	£1,960m £2,022m £3,441m*
15/0/10	£1,502m/£973m	N/A N/A N/A	N/A N/A N/A	£1,412m £1,408m* £1,515m	£1,960m £2,022m* £3,441m*
5/15/20	£1,169m/£992m	£2,376m* £2,559m* £3,320m*	£2,051m* £2,356m* £3,426m*	N/A N/A N/A	£1,296m £1,405m £2,854m
5/15/15	£1,092m/£916m	£2,376m* £2,552m* £3,216m	£2,051m* £2,341m* £3,299m	N/A N/A N/A	£1,270m £1,354m £2,759m
5/15/10	£1,016m/£840m	£2,376m* £2,539m* £3,093m	£2,051m* £2,311m* £3,164m	N/A N/A N/A	£1,270m £1,351m £2,743m
5/0/20	£755m/£578m	£1,521m £1,685m £2,285m	£1,380m £1,645m £2,511m	£1,057m £1,043m £1,165m	£986m £1,094m £2,557m
5/0/15	£679m/£502m	£968m £1,115m £1,645m	£888m £1,124m £1,890m	£1,057m £1,041m £1,129m	£745m £853m £2,308m
5/0/10	£602m/£426m	£344m £464m £914m	£323m £524m £1,173m	£1,057m £1,039m £1,078m	£488m £597m £2,051m
10/15/0	£1,314m/£961m	£2,439m £2,619m	£2,133m £2,413m	N/A N/A	£1,347m £1,437m

		£3,181m	£3,232m	N/A	£2,855m
15/0/0	£1,349m/£820m	N/A N/A N/A	N/A N/A N/A	£1,412m £1,408m £1,486m	£1,960m £2,022m £3,441m
10/0/0	£900m/£547m	£966m £1,031m £1,292m	£901m £1,024m £1,402m	£1,294m £1,285m £1,307m	£1,056m £1,153m £2,619m
30MHz of unpaired 2.6GHz spectrum	£112m/£112m	£0 £0 - £54m £269m - £573m	£0 £0m - £111m £367m - £834m	£0 £0 £0 - £105m	£0 £0 £23m - £469m

* Indicates a lower bound estimate, see note in Table 13, red fonts highlight the instances where the business case valuation is lower than the maximum benchmark value.

218. With regard to paired spectrum, the table shows the following:

- H3G's business modelling valuations are consistently (and in most cases, substantially) higher than the maximum benchmark valuations across all packages and traffic scenarios.
- Vodafone, O2 and EE's business modelling valuations are almost always higher (substantially in some cases, but only marginally in others) than maximum benchmark valuations. There are, however, some exceptions.
- For Vodafone and O2, the valuation of packages consisting of 2x10MHz of 2.6GHz and 2x5MHz of 800MHz is up to 46% lower than the benchmark value in the low and medium traffic scenarios (but not in the high traffic scenario). Also, the valuation of 2x10MHz of 2.6GHz combined with 2x10MHz of 800MHz is up to 14% below the benchmark value in the low traffic scenario (but not in the medium or high traffic scenario). The valuation of packages with more spectrum in the 2.6GHz band then exceeds benchmark valuations, suggesting the presence of some synergistic effects in relation to these spectrum combinations.
- For EE, the valuation of packages with 2x10MHz or more of 2.6GHz spectrum in addition to 2x15MHz of 800MHz spectrum falls below our maximum benchmark valuations by up to 15% in some traffic scenarios, The valuation of packages with the same amounts of 2.6GHz spectrum but less 800MHz spectrum is above benchmark valuations. This is possibly driven by the low incremental value of a third block in the 800MHz band.

219. In addition, the marginal valuations of 800MHz and 2.6GHz lots from the business model (listed in Table 16, Table 17 and Table 18 above) are lower than the maximum benchmark values in a number of cases.

220. In the case of 800MHz spectrum:

- In the low traffic scenario, Vodafone and O2's marginal valuation for the second and third block where it also wins 2x15MHz or 2x20MHz of 2.6GHz spectrum falls below the maximum benchmark value of a large bidder. This is also the case for O2 in the medium traffic scenario (though it still lies in the upper half of the large bidder benchmark range) while Vodafone's marginal valuations for these blocks in this case are just above maximum benchmark value. Finally, in the high traffic scenario, marginal values exceed the benchmark value throughout.

- EE 's marginal valuation for the second and third 2x5MHz lot alongside winning 2x10MHz, 2x15MHz or 2x20MHz of 2.6GHz spectrum is lower than the maximum benchmark valuation of a large bidder under all traffic scenarios. In fact, its marginal valuation for these blocks is also lower than the minimum benchmark value for a large bidder, and in the case of the third 2x5MHz block, marginal valuations are often lower than even the minimum benchmark value for a small bidder.

221. In the case of 2.6GHz spectrum:

- Vodafone and O2 have a low marginal value for the third and fourth block of 2.6GHz spectrum if they also win 2x15MHz of 1800MHz spectrum in the medium traffic demand scenario, with marginal value being lower than even the minimum benchmark value of a small bidder.

- EE has a positive but low marginal value for the third and fourth block of 2.6GHz spectrum combined with winning 2x5MHz, 2x10MHz or 2x15MHz of 800MHz spectrum in the high traffic scenario. EE's marginal valuations here are often lower than even the minimum benchmark value of a small bidder.

222. In addition, the business modelling sometimes yields a value for spectrum portfolios that are lower than the value of a marginally smaller portfolio. This would suggest that the value of incremental spectrum is negative, which is of course unrealistic.[65] In these cases, the business modelling results for the larger portfolios are replaced with the values for the smaller portfolios, which provide a lower-bound estimate of the value of the large portfolio. Doing this will obviously produce marginal values of zero. We have not included these cases in the list above because the results are obviously driven by the granularity of the model and provide no information about actual marginal values. We note, however, that the model may more generally produce marginal block valuations that are an underestimate, as it does not capture the potential of deploying a higher data-rate LTE carrier only in areas where additional capacity is required rather than across the entire footprint.

223. The value of unpaired 2.6GHz spectrum is modelled as incremental value over and above winning the following Paired Spectrum Packages (PSP) defined in duplex MHz of 800MHz/1800MHz/2.6GHz frequencies:

- PSP1: 10/0/0;

[65] As explained in Section 4.4.1 above, this is because the modelling identifies that the deployment of a higher data-rate LTE carrier across the coverage footprint associated with the particular spectrum combination would result in a new loss of free cash flow where as in reality, the operator will only deploy the higher data rate carrier in a limited sub-set of the coverage area, thereby incurring lower cost and not resulting in a loss of cash flow from deployment. This tends to be more prevalent in the lower traffic scenarios.

- PSP2: 10/0/10;
- PSP3: 10/0/20; and
- PSP4: 0/15/10.

224. There is no positive valuation for unpaired spectrum in the low traffic scenario for any of the operators; in the medium traffic case, there is a positive valuation for Vodafone and O2 but not EE or H3G, and the valuation is low, and indeed lower than the benchmark value. Only in the high traffic scenario are business case valuations for unpaired spectrum substantial – the valuations of Vodafone and O2 in this case always exceeds our benchmark value; H3G's valuation only exceeds the benchmark value in the case of PSP1 and PSP2while EE's valuation is always below the benchmark value.

225. In terms of a new entrant business case for TDD LTE with unpaired 2.6GHz spectrum, the new entrant's valuation is only positive if it acquired the entire 50MHz block *and* can gain at least 2 million subscribers by 2032. The corresponding valuation is £43m assuming a nominal WACC of 8.86%. The new entrant valuation only exceeds benchmark value (£180m for 50MHz) in the optimistic scenario where this operator is able to gain 3 million subscribers by 2032–the corresponding valuation is £244m assuming a nominal WACC of 8.86%.

226. In terms of unpaired 2.6GHz spectrum being used for backhaul, the valuation from the business modelling is between £5m to £46m (see Section 4.4.2) which is well below our benchmark valuation.

227. Overall, any conservative business modelling scenario yields a valuations for unpaired spectrum that is below the benchmark value of £0.059 per MHz per head of population. Therefore, the upper end of our benchmark range for unpaired spectrum may overstate WTP of likely bidders in the UK, particularly given the uncertainty surrounding the Belgian benchmark binding the top of our benchmark range for unpaired 2.6GHz spectrum.

6 Expert Panel

228. In this section we provide a summary of the main insights from our discussions with the Expert Panel. These insights have been incorporated in earlier parts of the report.

6.1 Objectives of the reserve price

229. The Expert Panel noted Ofcom's objectives in respect of the auction and the priorities between these objectives where the setting of the reserve price could potentially create a conflict between some of the objectives. In particular the Expert Panel noted Ofcom's desire to ensure that the reserve prices do not choke off demand inefficiently or hinder market entry. The Expert Panel also noted Ofcom's objective of maintaining competition in the downstream market by ensuring that four viable national wholesalers will emerge from the auction.

230. In view of the low likelihood of new entrants seeking to become a national wholesaler, the Expert Panel noted that H3G was the most likely fourth player. The impact of the reserve prices on H3G's participation in the auction and its willingness to opt in for all MPPs was therefore discussed in detail.

6.2 Benchmarking approach and results

231. The Expert Panel warned against placing too much reliance on any individual auction's results given the particular circumstances applicable in each case, which may be different to those of the upcoming UK auction. As relevant factors the Expert Panel noted existing spectrum allocations, number of market players, degree of competition in the auction, level of reserve price, obligations on or limitations of use of the spectrum, timing of the auction, general level of competition between the players in the market etc.

232. The Expert Panel considered that the relativities across the benchmarking results for the different bands seemed reasonable overall (i.e. 800MHz is worth twice as much as 1800MHz, 1800MHz is worth twice as much as 2.6GHz). However, the Expert Panel commented on potentially differing perceptions by financial analysts (see below).

6.3 Business modelling approach and results

233. The Expert Panel provided input on the base case assumptions for the business modelling of the value of the different spectrum packages to the potential bidders. This led to the revision of several of the parameters including adjustments to take account of the impact of mobile termination rate cuts in the short-term, flatter revenue growth profile in the long-term, and adjustments to the low traffic scenario to make it even lower.

234. The Expert Panel noted that the importance of peak data rates arising from the LTE carrier bandwidth available to a national wholesaler is probably less important in the UK than in other markets (e.g. USA, Singapore). Compared with these markets, network capacity and peak speeds have not yet been a significant element of focus in marketing/advertising campaigns in the UK.

235. The Expert Panel also commented on the modelled scenario for H3G. First it was discussed whether an 18% long-term market share may be too optimistic for the business – but at the same time the Expert Panel noted that the objective of the business modelling exercise was to undertake valuations from the perspective of the bidders in the auction rather than from the "conservative" position of a financial analyst.

236. In line with the business modelling results, the Expert Panel agreed that it was reasonable to find that H3G's implied valuation of the spectrum to be higher than that indicated by European benchmark levels for valuations of the fourth operator due to the difference in existing spectrum holdings.

237. The Expert Panel also considered what might be H3G options in the event that it did not acquire any spectrum in the auction. One possibility would be to run the business for cash in the short-term and ultimately for Hutchison Whampoa (the parent company) to seek to sell the business. However, the parent company's value expectations may not align with that of potential acquirers, especially if H3G's spectrum holdings were limited. The Expert Panel also noted that Hutchison Whampoa has recently been taking a more active approach in respect of its 3G businesses (e.g. recent mergers in Austria and Australia) and that taking a 'long-term approach' with its businesses has been seen to generate value.

6.4 Financial markets' perspective

238. In the view of the Expert Panel, the financial markets would expect operators in the UK to pay for spectrum in line with the prices seen in other competitive European auctions. For example, an outcome for the 800MHz band which involved the operators paying around EUR0.60 to EUR0.80 per MHz per capita would be seen as a reasonable outcome.

239. The Panel concluded that H3G was unlikely to be willing to pay the full price for spectrum suggested by the findings from the business modelling exercise. In particular, in relation to the 800MHz band, the Expert Panel noted that other (competitive) European auctions have typically provided a "graceful exit" route from bidding for sub-1GHz spectrum for the fourth operator. The Expert Panel argued that in the case of the UK auction, the 1800MHz spectrum could be considered as the "consolation prize" for the operator that lost the bidding for 800MHz spectrum.

240. The Expert Panel noted that whilst the engineering analysis supported a ratio of 2:1 between the 1800MHz and 800MHz band and a similar ratio between the 2.6GHz and 1800MHz band, many financial analysts would not take account of this in their assessments. In particular such analysts would typically consider higher frequency spectrum (including 1800MHz) to be worth a tenth of the price of 800MHz spectrum. The Expert Panel referenced the commentary made by financial analysts following E-Plus's exit from the German auction without acquiring any 800MHz spectrum.

241. The financial markets' perception of the relative value of different spectrum bands might affect bidders' willingness to pay, in order to meet shareholders' demands. Consequently, the Expert Panel's view was that Ofcom should take the financial markets' perspective into account and consider setting a low reserve price for the 1800MHz band.

242. The Expert Panel also noted that the 1800MHz band is the band with the highest uncertainty regarding its market value, due to the limited availability of relevant benchmarks and the resulting statistical sensitivity of the benchmarking results. In view of this the Panel noted that "eyebrows are likely to be raised" if Ofcom were to set a high reserve price for this band.

243. The Expert Panel also noted that spectrum acquisition in Europe is considered by financial analysts differently to spectrum acquisition in the USA where the financial market is more accepting of the need for operators to buy spectrum wherever they can at whatever price – in view of the looser regulatory environment there (and the perpetual/ technology neutral nature of spectrum licences).

244. With regard to the recent multiband auction in Switzerland the Panel noted that the use of a complex auction design presents added risks in respect of how an unexpected outcome could be perceived by the markets.

6.5 General advice for setting of reserve prices

245. Given the degree of uncertainty and variability in the underlying analysis the Expert Panel felt that Ofcom may want to err on side of caution in setting reserve prices. In the Panel's opinion Ofcom may want to consider reserve prices at the lower end of benchmarks, in particular if the priority would be to ensure H3G's participation in the auction.

7 Methodology for setting reserve prices

246. In this section, we set out our proposed methodology for setting reserve prices based on our benchmarks, the business modelling results and input from the Expert Panel, comprising the following steps:

- identify all categories of spectrum that may require individual reserve prices as a result of value differences;
- for each category, consider whether it is appropriate to set reserve prices based on market value, or at a LBNT level, based on weighing the efficiency benefits of setting higher, market value reserve prices against the risk of choking off efficient demand;
- for categories where market value based reserve prices should be used, derive an appropriate reserve price (range) based on benchmark results, considering Ofcom's objectives for the upcoming award, input from business modelling and the Expert Panel.

247. Below we describe these steps in more detail below and make several recommendations.

7.1 Reserve price categories

248. Setting a common reserve price across lots with significant value differences may price off efficient demand for lower value lots if set at the higher value, or have potential efficiency costs (in terms of inviting strategic demand reduction for the higher value lots, for example) if set at the lower value. This means that reserve prices should be determined for categories of lots with (largely) similar values, whilst recognising that trying to account for small value differences on the basis of uncertain market value estimates would be an attempt at spurious precision.

249. The different spectrum bands (800MHz, 1800MHz and 2.6GHz) are obvious candidates for reserve price categories. However some of the bands would have to be split into more than one category:

- **800MHz:** Additional categories in the 800MHz band should be introduced if some lots are affected by coverage obligations or usage restrictions that have a substantial impact on value. We understand that Ofcom proposes to apply coverage obligations to one 800MHz lot only. The effect of such coverage obligations on the valuation of this lot is discussed in Section 7.4. In some EU Member States the lots at the bottom of the band are affected by heavier usage restrictions to protect adjacent Digital Terrestrial Television (DTT) use at the bottom of the band. However, we understand from Ofcom that this should not cause significant variance in value of these lots relative to the rest of the band in the UK.
- **1800MHz:** Given that the 1800MHz band would be offered as a single lot, there is no need for any further differentiation.

- **2.6GHz:** Owing to the substantial differences in terms of available technologies and supported services, the band should be split into categories for paired and unpaired spectrum. The paired 2.6GHz spectrum might need to be split further if Ofcom were to decide that 2x10MHz of the available paired spectrum should be reserved for low power use, with such spectrum being in a separate category.

7.2 Recommendation for categories with market-value oriented reserve prices

250. We start from the presumption that reserve prices should be set with reference to the market value of spectrum, with appropriate safeguards for not pricing off efficient demand, except in cases where the market value of spectrum cannot be established or is subject to uncertainty of a magnitude that there are substantial risks of choking off inefficient demand when starting from market value-based prices. In these cases, LBNT prices should be used instead.

251. There is considerable uncertainty over the valuation of 2.6GHz spectrum for low power use and we are unable to derive a valuation for this from the benchmarking exercise (as explained in Section 2). We therefore recommend that a LBNT reserve price be used should Ofcom decide to reserve spectrum for low power use in the 2.6GHz band.

252. For all other categories above the benchmarking in Section 5 yields valuation ranges for setting reserve prices. However, in the case of unpaired 2.6GHz spectrum, there is very limited benchmark information available. Moreover, the business modelling produces relatively low estimates for the value of this spectrum, and there is also uncertainty over the likely bidders for this spectrum. Therefore, a LBNT reserve price might best be used for this band. The Expert Panel agreed with this view.

7.3 Reserve price recommendations

253. Reserve prices affect participation and may impact demand for spectrum in the auction. In the case of a package-bidding auction, the impact of reserve prices is on the selection of packages for which bids are being made, with bidders being expected to make bids for any package they might potentially wish to win.

254. In an auction, a bidder is aiming to maximise its payoff – i.e. the difference between the value of the package the bidder eventually wins, and the price it has to pay. Because a bidder does not know for certain which (if any) package he will ultimately win, or at what final price, the bidder should have an incentive to make bids on all packages that are capable of creating a surplus, i.e. on all packages for which his absolute valuation exceeds the package cost (as discussed further in Annex D). Moreover, whilst the proposed UK rules require that the bid made for any particular package exceeds the value of the package at reserve prices, there is no requirement that a bid for a larger package must exceed the bid for a smaller package by the value of the additional lots, valued at reserve price (i.e. a bid for a package containing X and Y does not need to be higher than a bid for a package containing only X by the reserve price of Y). Therefore, in looking at the appropriate reserve price levels

and the risk of pricing off efficient demand, it is appropriate to look at package valuations (rather than marginal block valuations) and comparing these with the costs of packages at the level of proposed reserve prices.

255. Particular attention should be given to:

- the risk of discouraging participation from bidders who would have to opt in to acquire any of the MPPs; and
- the risk of pricing off demand for smaller packages which might fit better with other bids, thus increasing the risk of having spectrum unsold inefficiently.

256. On a cautious basis, in developing our recommendations we place more emphasis on the results of the international benchmarking and, in light of the substantial uncertainty around the different scenarios we developed, we use the business modelling as a cross-check. In Section 5 we have compared the valuation of the MPPs from the business modelling with the cost of the MPPs if prices were set at the upper end of our benchmarks for small bidders. This suggests that setting prices at this level would not discourage H3G from opting in (although a new entrant might be discouraged, though the problem arises from the negative valuation of such a bidder regardless of reserve price). This suggests that using the upper end of the benchmark range for a small bidder as a starting point should be safe with regard to the first of the two risks identified above.

257. At these prices, the results from the business modelling suggest that the valuation of all packages is above the package price, with the exception of the valuation of packages of 2x5MHz of 800MHz spectrum and 2x10MHz of 2.6GHz spectrum for Vodafone and O_2 (although their valuation for packages with more 2.6GHz spectrum would then be substantially above the package price) in the low traffic scenario. This means that setting prices at this level might discourage bids from Vodafone and O_2 for packages containing a smaller number of blocks in the paired 2.6GHz band.

258. The options for mitigating this risk are either to set lower prices for both 800MHz and paired 2.6GHz, or to dramatically lower the price of 2.6GHz spectrum. Using the upper end of the small bidder benchmark range for 800MHz (£0.434 per MHz per capita), one would have to set a reserve price for paired 2.6GHz spectrum at around 68% of the lower end of the small bidder benchmark range (£0.039 per MHz per capita) in order not to discourage bids on packages containing one block of 800MHz spectrum and two blocks of 2.6GHz spectrum. Alternatively, setting the 800MHz price in the middle of the range (£0.344 per MHz per capita), and the 2.6GHz price at the bottom of the range (£0.080 per MHz per capita) would have a similar effect.

259. Where exactly the reserve price should be set within (or relative to) the valuation range depends primarily on the confidence in the range estimate. Confidence in the valuation ranges can be derived from the quantity and quality of the available data (see Section 3), from cross-checking with the business model (see Section 5), and from the input of the Expert Panel (see Section 6).

260. Specifically, although business modelling valuation exceeds our benchmark valuations by some margin in most cases, bidders may not necessarily be able to bid their full valuation as they could face budget constraints. Also, the uncertainty inherent in both benchmarking and business modelling valuations would suggest that it would be prudent to leave a sufficient margin of error.

261. The Expert Panel felt that it should be possible to justify a price for 800MHz at the high-end of the proposed benchmark range for a small bidder. This would be in line with the expectation of the financial markets since this is lower than the prices paid by the parent companies of the likely bidders in other European auctions.

262. The Expert Panel were concerned that even the bottom end of the range for the 1800MHz band would be regarded by many financial analysts as high in the event that H3G acquired this spectrum as a "consolation prize" for not obtaining 800MHz spectrum. The Expert Panel felt that given the considerable uncertainty about the benchmarking value of spectrum in this band and in light of the low prices paid in other major auctions (e.g. Germany), it might be appropriate to consider a reserve price lower than the bottom end of the benchmark range. For the 2.6GHz band, the Expert Panel considered that a reserve price at the lower end of the benchmark range for 2.6GHz paired spectrum would be appropriate.

263. In light of these considerations, and taking account of the views put forward by the Expert Panel, the proposed methodology produces the following recommendations for reserve prices:

- For the paired 2.6GHz spectrum, the reserve price might be set in the region of the lower end of the benchmark range for small bidders. Assuming a UK population of 63 million, the lower end benchmark of £0.080 per MHz per capita would suggest a ***reserve price of £50.4m for a lot of 2x5MHz in the 2.6GHz band***.

- For the 1800 MHz spectrum, the reserve price might be set in the region of the lower end of the benchmark range (and potentially below that level). The lower end benchmark of £0.146 per MHz per capita would suggest a ***reserve price of £276m for a lot of 2x15MHz in the 1800MHz band***.

- For 800MHz spectrum, while a price at the upper end of the benchmark range for small bidders might be appropriate in isolation, this would create a risk of discouraging bids for smaller packages by some of the established players which may ultimately lead to spectrum left unsold. In order to mitigate this risk, considering the business modelling valuations for these packages, the price for 800MHz spectrum could to be set around the middle of the small bidder benchmark range. The middle value of the benchmark range of £0.344 per MHz per capita would suggest a ***reserve price of £217 million for a 2x5MHz lot in the 800MHz band without coverage obligations***.

264. At these suggested reserve prices, the 800MHz reserve price is just under 2.4 times that of the 1800MHz reserve price (on a comparable 2x5MHz basis) and the 1800MHz reserve price is 1.8 times the suggested 2.6GHz reserve price. This is consistent with the relative band value ratios suggested by the

benchmarking valuations (2-3 times for 800MHz to 1800MHz and roughly double for 1800MHz to 2.6GHz) but above the relative ratios suggested by the business modelling (1.5 for 800MHz to 1800MHz and 1.6 for 1800MHz to 2.6GHz).

265. At these suggested reserve prices, the business modelling valuations for all packages estimated are higher than the respective package cost and hence these reserve prices are unlikely to choke off efficient demand for the available spectrum.

7.4 Impact of coverage obligation on 800MHz

266. In the March 2011 Consultation, Ofcom proposed a coverage obligation to provide "mobile telecommunications services with a sustained downlink speed of not less than 2Mbps with a 90% probability of indoor reception to an area within which at least 95% of the UK population lives by the end of 2017".[66] In the March Consultation, it was considered that it would be commercially profitable for an operator to roll out to an area covering 95% of the population by deploying 800MHz on existing sites. Therefore the coverage obligation proposed in the March Consultation was not considered to be particularly onerous as it would be commercially profitable to extend coverage to 95% of the population.

267. Subsequently, in the January 2012 Consultation, having considered the views of the House of Commons, Culture, Media and Sport Select Committee (the Select Committee) as well as many respondents to the March Consultation, Ofcom considered the case for extending the obligation to 98% of population. In preparing its report, the Select Committee was informed[67] of the cost estimates of this coverage obligation submitted by Arqiva as well as the mobile operators. These ranged from £200m to £540m[68], although this range includes cost estimates to extend the coverage obligation to 99% of population.

268. A reasonable estimate of the cost of a 98% population coverage obligation should range from £100m to £400m as the cost estimate provided by

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[66] See paragraph 1.36 of January Consultation.

[67] House of Commons, Culture, Media and Sport Committee, Spectrum, Eight Report of Session 2010-12, 25 October 2011, http://www.publications.parliament.uk/pa/cm201012/cmselect/cmcumeds/1258/1258.pdf (referred to as House of Commons Report)

[68] House of Commons Report, Ev 48, 5 July 2011, Q289, Ed Richards: ":*"We have been listening to the evidence that people have been giving you, and I think you have heard a range of numbers somewhere between £200 million and £540 million, to take you from 95% to 98% or 99%."*

Vodafone (and supported by O2) of £540m[69] may not reflect the cost of meeting the coverage obligation by an operator with a well maintained, efficient network: John Cresswell of Arqiva estimated that the 99% coverage obligation will cost around £200m to £230m, with Guy Laurence of Vodafone stating that a further £140 million in operating expenditure would be required to achieve 99% coverage.[70]

269. We note that in October 2011, the government has committed to invest up to £150m to improve mobile coverage in the UK where existing mobile coverage is poor or non-existent, with an aim to extend mobile coverage to 99% of the UK population. To this end, Ofcom is also keen to leverage on the infrastructure build funded by the government to extend 4G coverage over and above existing 2G coverage particularly in current mobile voice 'not-spots'. Therefore, a second option for the coverage obligation considered by Ofcom is to provide mobile broadband service as defined in paragraph 266 above extending as far as current 2G coverage, in addition, where the infrastructure procured by government funding can support 4G network equipment, the licensee with the coverage obligation would extend 4G coverage to these areas.

270. In this second option, the bulk of the cost associated with the coverage obligation over and above coverage in commercially profitable areas would presumably be associated with providing additional coverage in the current mobile voice 'not-spots' which should be eliminated with the help of government funding, as an operator may reach existing 2G coverage by deploying 800MHz on existing sites. In addition, the bulk of roll out cost is often associated with infrastructure built which will be government funded.

271. Therefore, while it is not clear what a full estimate of cost of this coverage obligation would be, one could expect it to be lower than the first option of providing coverage to 98% of population given the government funding involved. Without prejudice to the coverage obligation option on which Ofcom will ultimately decide, we assume that the cost of such a coverage obligation on the 800MHz licensee will lie between £100m to £400m.

272. We understand that it is yet to be decided if the coverage obligation will be imposed on a 2x5MHz or 2x10MHz lot. In Table 27 below, we net off the estimated cost of this coverage obligation from our benchmark value of

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[69] Kevin Russell from H3G suggested that *"to go from 97% to 98%, we estimate probably would incrementally cost about £100 million in terms of sites. To go to 99%, we think it would incrementally cost about £270 million."* Comparing this to the upper end of the cost estimates by Vodafone and Telefonica, H3G further remarks that *"[T]he scale of investment required by Telefonica and Vodafone to achieve coverage levels upwards of 95% is far above what Three considers to be necessary. In their oral evidence, Telefonica calculated that it would cost an additional £540 million of public investment to provide indoor coverage to 98% of the UK population. Three calculates that it would cost £270 million of public investment to provide 99% of indoor coverage. The difference in projected costs, we believe, is the result of under-investment of Telefonica and Vodafone in their network infrastructure rather than, as suggested by Vodafone and Telefonica, the perceived difficulties in the UK's planning regime."* (House of Commons Report, Ev 12, 21 June 2011).

[70] Paragraph 66 of House of Commons Report

2x5MHz and 2x10MHz of 800MHz for both small and large bidders (see Table 8), assuming a UK population of 63 million.

273. If the cost of meeting the coverage obligation were at the upper end of the range of estimates, they would exceed even the very top end of our small bidder valuation and the bottom end of our large bidder valuation for 2x5MHz of 800MHz spectrum. Only when the cost of the obligation is spread across the value of a larger (2x10MHz) spectrum block does the large bidder have a positive valuation for this spectrum lot even at the upper end of coverage obligation cost estimates.

Table 27: 800MHz valuation net of coverage obligation

Valuation	Large bidder	Small bidder
Value of 2x5MHz without any coverage obligation	£290m - £450m	£159m - £273m
Value of 2x5MHz with coverage obligation costing £100m	£190m - £350m	£59m - £173m
Value of 2x5MHz with coverage obligation costing £400m	(£110) - £50m	(£241m) - (£127)m
Value of 2x10MHz without any coverage obligation	£580m - £900m	£318m - £546m
Value of 2x10MHz with coverage obligation costing £100m	£480m - £800m	£218m - £446m
Value of 2x10MHz with coverage obligation costing £400m	£180m – £500m	(£82m) - £146m

274. Given that the coverage obligation is proposed to be assigned to only one licensee, what matters here is to ensure that the lot with the coverage obligation does not go unsold. This means that at least one bidder (be it large or small) has a positive valuation for the lot with the coverage obligation at reserve prices. The comparison of values in Table 27 suggests that as a conservative approach, the coverage obligation should be imposed on a 2x10MHz lot to ensure that this lot is not inefficiently unsold. The reserve price should not be set higher than suggested by the bottom end of the large bidder benchmark. At a benchmark value of £0.460 per MHz per capita, and a cost of £400 million, this would suggest a ***reserve price of £180m for 2x10MHz with a coverage obligation in the 800MHz band***.

275. We note that at this reserve price as well as that for the other spectrum categories suggested above, the business modelling valuations are consistently above the package cost even after adjusting for the cost of meeting coverage obligation of £400m. This would imply that no efficient demand for this lot should be choked off with a reserve price of £180m for this lot.

Annex A 1800MHz benchmark samples

In this Annex we provide a list of the awards for the various samples we use in our benchmarking exercise for the 1800MHz band in Section 3.4.1.

A.1 All auctions since 2000 including outliers

Award Name	Country	Date
PCS 2000 auction	Australia	15-Mar-00
Auction 3: 1710 - 2300 MHz	New Zealand	18-Jan-01
Auction 35 - C and F Block Broadband PCS	United States	26-Jan-01
Additional PCS Auction	Canada	01-Feb-01
GSM 1800 Auction	Austria	07-May-01
2G and 3G	Greece	17-Jul-01
2G Auction	Singapore	11-Sep-01
GSM 1800 Auction	Norway	06-Dec-01
2G/3G Auction	Israel	26-Dec-01
GSM 2004 Auction	Austria	11-Oct-04
Auction 58 - Broadband PCS	United States	15-Feb-05
GSM Auction	Trinidad and Tobago	23-Jun-05
DECT Guard Block Auction	UK	20-Apr-06
GSM 1800	Poland	15-May-06
GSM 1800 MHz	Georgia	15-Dec-06
GSM Auction	Brazil	07-Feb-07
1785-1805 MHz	Ireland	27-Apr-07
1785-1805 MHz	UK	09-May-07
Auction 71 - Broadband PCS	United States	21-May-07
2G Licences	Brazil	27-Dec-07
Public Cellular Mobile Telecommunications Services Auction	Singapore	22-Feb-08
AWS auction	Canada	27-May-08
Bulgaria 4th GSM License	Bulgaria	18-Jul-08
Auction 78 - Broadband PCS	United States	20-Aug-08
1800MHz auction	Singapore	04-Feb-09
1800MHz auction (expansion)	Hong Kong China	10-Jun-09
Auction of spectrum in the 800MHz, 1800MHz, 2.1GHz and 2.6GHz bands	Germany	21-May-10
1800MHz	Denmark	18-Oct-10
1800MHz	Singapore	28-Mar-11
Italian 4G Auction	Italy	29-Sep-11
Swedish 1800MHz	Sweden	17-Oct-11
Greek 900 and 1800	Greece	14-Nov-11
Portuguese 4G Multiband Auction	Portugal	28-Nov-11

A.2 All auctions since 2000

Award name	Country	Date
Auction 3: 1710 - 2300 MHz	New Zealand	18-Jan-01
Additional PCS Auction	Canada	01-Feb-01
GSM 1800 Auction	Austria	07-May-01
2G and 3G	Greece	17-Jul-01
2G Auction	Singapore	11-Sep-01
GSM 1800 Auction	Norway	06-Dec-01
2G/3G Auction	Israel	26-Dec-01
GSM 2004 Auction	Austria	11-Oct-04
Auction 58 - Broadband PCS	United States	15-Feb-05
GSM Auction	Trinidad and Tobago	23-Jun-05
GSM 1800	Poland	15-May-06
GSM 1800 MHz	Georgia	15-Dec-06
GSM Auction	Brazil	07-Feb-07
Auction 71 - Broadband PCS	United States	21-May-07
2G Licences	Brazil	27-Dec-07
Public Cellular Mobile Telecommunications Services Auction	Singapore	22-Feb-08
AWS auction	Canada	27-May-08
Bulgaria 4th GSM License	Bulgaria	18-Jul-08
Auction 78 - Broadband PCS	United States	20-Aug-08
1800MHz auction	Singapore	04-Feb-09
1800MHz auction (expansion)	Hong Kong China	10-Jun-09
Auction of spectrum in the 800MHz, 1800MHz, 2.1GHz and 2.6GHz bands	Germany	21-May-10
1800MHz	Denmark	18-Oct-10
1800MHz	Singapore	28-Mar-11
Italian 4G Auction	Italy	29-Sep-11
Swedish 1800MHz	Sweden	17-Oct-11
Greek 900 and 1800	Greece	14-Nov-11
Portuguese 4G Multiband Auction	Portugal	28-Nov-11

A.3 European auctions since 2000

Award name	Country	Date
GSM 1800 Auction	Austria	07-May-01
2G and 3G	Greece	17-Jul-01
GSM 1800 Auction	Norway	06-Dec-01
GSM 2004 Auction	Austria	11-Oct-04
GSM 1800	Poland	15-May-06
Bulgaria 4th GSM License	Bulgaria	18-Jul-08
Auction of spectrum in the 800MHz, 1800MHz, 2.1GHz and 2.6GHz bands	Germany	21-May-10
1800MHz	Denmark	18-Oct-10
Italian 4G Auction	Italy	29-Sep-11
Swedish 1800MHz	Sweden	17-Oct-11
Greek 900 and 1800	Greece	14-Nov-11
Portuguese 4G Multiband Auction	Portugal	28-Nov-11

A.4 All auctions in the last five year (since 2006)

Award name	Country	Date
GSM 1800	Poland	15-May-06
GSM 1800 MHz	Georgia	15-Dec-06
GSM Auction	Brazil	07-Feb-07
Auction 71 - Broadband PCS	United States	21-May-07
2G Licences	Brazil	27-Dec-07
Public Cellular Mobile Telecommunications Services Auction	Singapore	22-Feb-08
AWS auction	Canada	27-May-08
Bulgaria 4th GSM License	Bulgaria	18-Jul-08
Auction 78 - Broadband PCS	United States	20-Aug-08
1800MHz auction	Singapore	04-Feb-09
1800MHz auction (expansion)	Hong Kong China	10-Jun-09
Auction of spectrum in the 800MHz, 1800MHz, 2.1GHz and 2.6GHz bands	Germany	21-May-10
1800MHz	Denmark	18-Oct-10
1800MHz	Singapore	28-Mar-11
Italian 4G Auction	Italy	29-Sep-11
Swedish 1800MHz	Sweden	17-Oct-11
Greek 900 and 1800	Greece	14-Nov-11
Portuguese 4G Multiband Auction	Portugal	28-Nov-11

A.5 All auctions since 2010 (all observations in this sample are of liberalised 1800MHz spectrum)

Award name	Country	Date
Auction of spectrum in the 800MHz, 1800MHz, 2.1GHz and 2.6GHz bands	Germany	21-May-10
1800MHz	Denmark	18-Oct-10
1800MHz	Singapore	28-Mar-11
Italian 4G Auction	Italy	29-Sep-11
Swedish 1800MHz	Sweden	17-Oct-11
Greek 900 and 1800	Greece	14-Nov-11
Portuguese 4G Multiband Auction	Portugal	28-Nov-11

Annex B Additional details of business modelling approach

This Annex provides additional details of the business modelling approach we have utilised. The specific sub-sections of this Annex should be read in combination with Section 4 of this report.

B.1 Deployment strategies of the existing national wholesalers

Figure 17 below summarises the alternative network deployment scenarios for Vodafone (assuming a 'base case' scenario where Vodafone acquires 2x10MHz of 800MHz spectrum and 2x20MHz of 2.6GHz spectrum). In this base case, we assume that Vodafone would deploy LTE utilising its newly acquired 800MHz and 2.6GHz spectrum holdings during 2013, with commercial launch of services from 2014. Spectrum from Vodafone's existing bands would be refarmed as required for capacity purposes. Note that whilst we have made assumptions regarding the dates for closure of Vodafone's 2G and 3G networks, the business modelling results are not particularly sensitive to these assumptions.

In the case where Vodafone fails to acquire any spectrum at the auction, we assume that Vodafone would initially deploy a 2x5MHz LTE carrier using its 1800MHz holdings in 2013 and would begin to deploy LTE in the 900MHz band as LTE technology became widely available in the band and the fall-off in 2G traffic levels allowed this.

Figure 17: Network deployment plans for Vodafone under alternative spectrum scenarios

Paired spectrum acquired (800/1800/2.6)	Network deployment assumptions
10/0/20 (Base case)	• 2012: Deploy HSPA+ in 900MHz band • 2013: Deploy 10MHz LTE carrier using 800MHz band and 20MHz LTE carrier using 2.6GHz band • Re-farm remaining 900MHz spectrum for LTE as required for additional network capacity and to create a full 2x20MHz LTE carrier once carrier aggregation technology is available • 2020: Switch-off 2G network • 2025: Switch-off 3G network
0/0/0 (None)	• 2012: Deploy HSPA+ in 900MHz band in 2012 • 2013: Deploy 5MHz LTE carrier using 1800MHz spectrum • 2017: Deploy 10MHz LTE carrier using existing 900MHz spectrum holdings • Additional capacity enhancement costs incurred due to limited spectrum holdings
0/15/10	• **Alternative base case scenario for Vodafone** (if Telefonica O_2 gets 0/15/0) • As for 10/0/20 but in 2013 deploy 20MHz LTE carrier using 1800MHz band (including the deployment of additional new base station sites to enhance network coverage with 1800MHz spectrum) and in 2017 deploy 10MHz LTE carrier using existing 900MHz spectrum holdings to cover 'low frequency zone'
5/15/20	• As for 0/15/10 but deploy 5MHz LTE carrier using 800MHz spectrum in 2013 • Additional 2.6GHz capacity used to provide additional capacity when required
5/0/20	• As for 0/15/10 but deploy 20MHz carrier using 2.6GHz band in 2013 and 5MHz carrier using 800MHz spectrum
10/0/0	• As for 0/0/0 but deploy 10MHz carrier using 1800MHz spectrum in 2013

Figure 18 below summarises the alternative network deployment scenarios for Telefonica O_2 (assuming a 'base case' scenario where O_2 acquires 2x15MHz of 1800MHz spectrum and 2x10MHz of 2.6GHz spectrum). In this base case, we assume that O_2 would deploy LTE utilising its newly acquired 1800MHz spectrum across its existing network footprint and also deploying additional new base station sites to provide a high-level of network coverage using 1800MHz spectrum. O_2 would then deploy a 2x10MHz LTE carrier using refarmed 900MHz spectrum as LTE technology became widely available in the band and the fall-off in 2G traffic levels allowed this. As for Vodafone, note that we have made assumptions regarding the dates for closure of O_2's 2G and 3G networks, the business modelling results are not particularly sensitive to these assumptions. In the case where O_2 fails to acquire any spectrum at the auction, we assume a similar deployment strategy to that described above for Vodafone.

Please note that the above 'base case' deployment strategies for Vodafone and Telefonica O_2 are inter-changeable since either would allow each operator to offer in the medium-term a 2x20MHz LTE carrier in urban areas and a 2x10MHz LTE carrier across the entire coverage footprint of any national wholesaler.

Figure 18: Network deployment plans for Telefonica O_2 under alternative spectrum scenarios

Paired spectrum acquired (800/1800/2.6)	Network deployment assumptions
0/15/10 (Base case)	• 2012: Deploy HSPA+ in 900MHz band • 2013: Deploy 20MHz LTE carrier using 1800MHz band (including the deployment of additional new base station sites to enhance network coverage with 1800MHz spectrum) • 2017: Deploy 10MHz LTE carrier using existing 900MHz spectrum holdings to cover 'low frequency zone' • 2020: Switch-off 2G network • 2025: Switch-off 3G network
0/0/0 (None)	• 2012: Deploy HSPA+ in 900MHz band in 2012 • 2013: Deploy 5MHz LTE carrier using 1800MHz spectrum • 2017: Deploy 10MHz LTE carrier using existing 900MHz spectrum holdings • Additional capacity enhancement costs incurred due to limited spectrum holdings
10/0/20	• **Alternative base case scenario for Telefonica O_2** (if Vodafone gets 0/15/0) • As for 0/15/10 but in 2013 deploy 10MHz LTE carrier using 800MHz band and 20MHz LTE carrier using 2.6GHz band
5/15/20	• As for 0/15/10 but deploy 5MHz LTE carrier using 800MHz spectrum in 2013 • Additional 2.6GHz capacity used to provide additional capacity when required
5/0/20	• As for 0/15/10 but deploy 20MHz carrier using 2.6GHz band in 2013 and 5MHz carrier using 800MHz spectrum
10/0/0	• As for 0/0/0 but deploy 10MHz carrier using 1800MHz spectrum in 2013

Figure 19 below summarises the alternative network deployment scenarios for Everything Everywhere (assuming a 'base case' scenario where Everything Everywhere acquires 2x10MHz of 800MHz spectrum and 2x10MHz of 2.6GHz spectrum). In this base case, we assume that Everything Everywhere would deploy a 2x20MHz LTE carrier during 2012 using its existing 1800MHz spectrum holdings and then deploy a 2x10MHz LTE carrier utilising its newly acquired 800MHz spectrum to provide improved coverage (in rural areas and also deeper indoor coverage generally). Other spectrum (e.g. the 2.6GHz spectrum acquired in the auction) would be used as required to provide additional network capacity. As for Vodafone and Telefonica O_2, note that whilst we have made assumptions regarding the dates for closure of Everything Everywhere's 2G and 3G networks, the business modelling results are not particularly sensitive to these assumptions.

In the scenario where Everything Everywhere fails to acquire any additional spectrum in the auction, then we assume it would supplement its initial LTE deployment in 2012 (as for the 'base case' scenario) with additional capacity as required from its existing 1800MHz and 2.1GHz spectrum holdings.

Figure 19: Network deployment plans for Everything Everywhere under alternative spectrum scenarios

Paired spectrum acquired (800/1800/2.6)	Network deployment assumptions
10/0/10 (Base case)	• 2012: Deploy 20MHz LTE carrier using existing 1800MHz spectrum holdings • 2013: Deploy 10MHz LTE carrier using 800MHz band to cover 'low frequency' coverage areas • Utilise 2.6GHz spectrum for additional network capacity as required • 2020: Switch-off 2G network • 2025: Switch-off 3G network
0/0/0 (None)	• 2012: Deploy 20MHz LTE carrier using existing 1800MHz spectrum holdings • Re-farm remaining 1800MHz and 2.1GHz spectrum for LTE when possible • Additional capacity enhancement costs incurred due to limited spectrum holdings
15/0/10	• As for 10/0/10 but in 2013 deploy 15MHz LTE carrier using 800MHz band
5/0/10	• As for 10/0/10 but in 2013 deploy 5MHz LTE carrier using 800MHz band
15/0/0	• As for 10/0/10 but in 2013 deploy 15MHz LTE carrier using 800MHz band and 2.6GHz spectrum is NOT available to provide additional network capacity
10/0/0	• As for 10/0/10 but 2.6GHz spectrum is NOT available to provide additional network capacity

Figure 20 below summarises the alternative network deployment scenarios for H3G (assuming a 'base case' scenario where H3G acquires 2x10MHz of 800MHz spectrum and 2x20MHz of 2.6GHz spectrum). In this base case, we assume that H3G would deploy LTE utilising its newly acquired 800MHz and 2.6GHz spectrum holdings during 2013, with commercial launch of services from 2014. Spectrum from 2.1GHz would be refarmed when possible for LTE.

In the scenario where H3G fails to acquire any additional spectrum in the auction, then we believe this would provide immense challenges for the company due to limitations in network capacity and insufficient spectrum holdings to support the operator of two network technologies in parallel. As a consequence, H3G would lose some customers due to capacity shortages and also the need to free spectrum-up to deploy an LTE carrier. We anticipate that H3G would seek to deploy a 2x5MHz LTE carrier in its existing 2.1GHz spectrum holdings as traffic levels allowed, migrating to a full 2x20MHz carrier in the 2.1GHz band around 2020. These steps would incur the costs of subsidising customer devices in order to free-up sufficient spectrum from legacy 3G services.

Figure 20: Network deployment plans for H3G under alternative spectrum scenarios

Paired spectrum acquired (800/1800/2.6)	Network deployment assumptions
10/0/20 (Base case)	• 2013: Deploy 10MHz LTE carrier using 800MHz band and 20MHz LTE carrier using 2.6GHz band • Re-farm 2.1GHz spectrum when possible
0/0/0 (None)	• 2012: Deploy DC-HSPA+ in 2.1GHz band • 2013: Major impact on business due to limited network capacity and insufficient free spectrum for technology migration. Customer base losses due to limited network capability/traffic capacity - Deploy 5MHz LTE carrier in 2.1GHz band as traffic levels allow • 2020: Deploy 10MHz LTE carrier in 2.1GHz band (subsidise customer devices to allow this)
0/15/20	• 2013: Deploy 15MHz carrier using 1800MHz band and 20MHz carrier using 2.6GHz band • Re-farm 2.1GHz spectrum when required • 2025: Switch-off 3G network
0/15/15 & 0/15/10	• As for 0/15/20 but only deploy in 2.6GHz band when capacity is required. Additionally there is scope for decommissioning some 2.1GHz coverage sites at time of 3G switch-off (2025)
15/0/20	• As for 10/0/20 but deploy 15MHz carrier using 800MHz spectrum in 2013
5/15/20	• As for 0/15/20 but deploy 5MHz carrier using 800MHz spectrum in 2013
5/0/20	• As for 10/0/20 but deploy 15MHz carrier using 800MHz spectrum in 2013
10/15/0	• 2013: Deploy 10MHz LTE carrier using 800MHz band and 15MHz LTE carrier using 1800MHz band. Scope for decommissioning some 2.1GHz coverage sites at time of 3G switch-off.
15/0/0	• 2013: Deploy 15MHz LTE carrier using 800MHz band. Scope for decommissioning some 2.1GHz coverage sites at time of 3G switch-off in low traffic scenario
10/0/0	• 2013: Deploy 10MHz LTE carrier using 800MHz band

B.2 Assessment of commercial value

Coverage zones

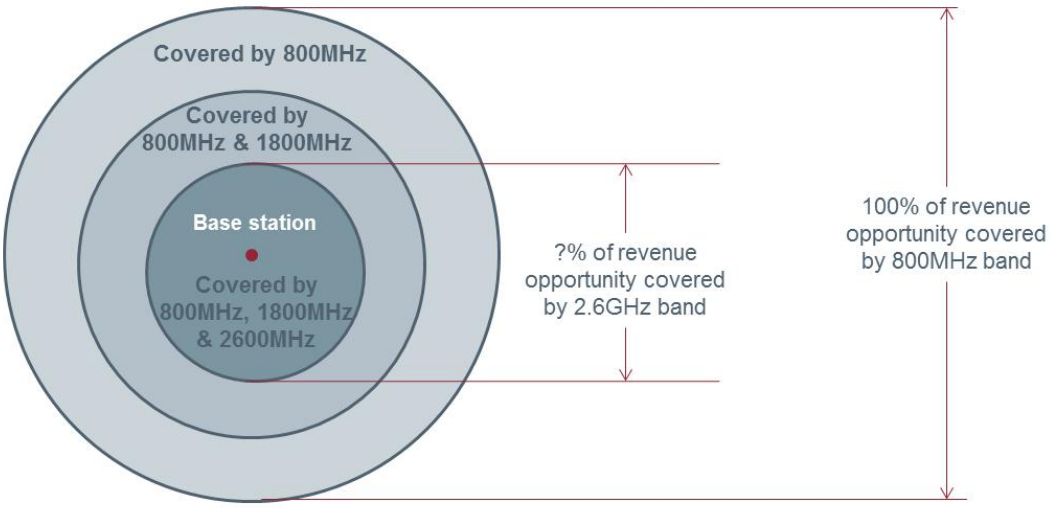
Spectrum bands differ in their propagation characteristics – signals at lower frequencies travel further and penetrate walls easier. Thus a network operator with access to low frequency spectrum will have an advantage over a national wholesale with high frequency spectrum in that the operator will be able to provide improved rural and indoor coverage. In practice network operators are likely to utilise a combination of frequency bands on their cell sites – high frequencies will provide capacity in the 'centre' of cells , whilst low frequencies will provider wider coverage.

As shown in Figure 21 below, if a national wholesaler is only able to deploy LTE using a high frequency band, then the coverage provided by that band will limit the amount of revenue available to the operator[71]. Assessment of the impact of high and low

[71] Note that in some areas it will be economic for the national wholesaler to deploy additional high frequency sites to cover those areas which fall outside the coverage range of a site optimised for a low frequency network. This is taken into account as part of our assessment of the amount of revenue available to each national wholesaler with specific frequency bands.

levels of coverage on the amount of revenues that are generated by a national wholesaler is not a straightforward effect. Whilst high frequencies may result in lower levels of rural and indoor coverage, typically the high frequencies will be deployed in the most populated areas where the average user expenditure on mobile may be higher than for customers living in less populated/more rural locations. Additionally, deep indoor coverage may not be that critical for customers since a large proportion of indoor use of mobile services tends to be at home and at work where often there are other options for data connectivity of mobile devices (e.g. WiFi, femtocells).

Figure 21: Illustration of impact of frequency bands on coverage and addressable market revenues



The benefit/drawbacks of a particular frequency band will vary between national wholesalers depending on their existing network architectures. For example, a national wholesaler with an existing grid of network sites designed for high frequencies will be better placed to make use of those high frequencies that a national wholesaler who has a grid of sites designed for low frequency operation.

We have made assumptions about the anticipated economically beneficial levels of deployment of cell sites for coverage by each of the existing national wholesalers utilising different frequency bands, taking account of each national wholesaler's existing network assets. These assumptions are shown in Figure 22.Note that we have assumed that H3G will continue to have access to the sites that are part of its network sharing agreement with Everything Everywhere.

Figure 22: Number of base stations deployed by each existing national wholesaler to provide coverage using each frequency band

	Vodafone/Telefonica O_2			Everything Everywhere			Hutchison 3G		
	Total	Urban	Rural	Total	Urban	Rural	Total	Urban	Rural
900/800 MHz	5,400	2,400	3,000	5,400	2,400	3,000	5,400	2,400	3,000
1800MHz	10,800	4,800	6,000	10,800	4,800	6,000	9,800	4,800	6,500
2.1GHz	8,850	5,850	3,000	11,850	5,850	6,000	12,350	5,850	6,500
2.6GHz	9,000	6,000	3,000	14,100	8,100	6,000	12,350	5,850	6,500

We have made assumptions about the % share of market revenues that are addressable by each national wholesaler using each frequency band and these are shown in Figure 23 below. Please note that the assumptions in this table have been developed for assessments of alternative spectrum configurations in scenarios where the operator is a credible national wholesale e.g. as a result of its overall spectrum holdings. For example if the operator were to only have access to 2.6GHz spectrum, then it is unlikely to be able to address the percentages of the total revenue opportunity detailed in Figure 23.

Figure 23: Assumptions on share of market revenues available to operators using different frequency bands

National wholesaler	2.6GHz	2.1GHz	1800MHz	900/800MHz
Vodafone/Telefonica O_2	60%	65%	90%	100%
Everything Everywhere	75%	83%	90%	100%
Hutchison 3G	70%	85%	92%	100%

Performance multiplier (in each coverage zone) and overall network multiplier

A national wholesaler's spectrum holdings (existing and acquired in the auction) will determine the highest peak data rates the wholesaler can offer in each coverage zone. Offering a higher or lower peak data rate relative to the other national wholesaler could impact on the wholesaler's share of revenues through:

the gain or loss of some users who seek the highest data rates

higher/lower revenues from individual users (e.g. through discounted/premium pricing as a result of having an inferior/superior service compared with market competitors).

Unfortunately there is no consumer data available on the impact of these effects. Consequently we have made assumptions about the impact of different data rates on the revenue share which a national wholesaler could capture drawing on our experience of working with European mobile operators undertaking similar assessments.

We have assessed the performance impact of different LTE carrier bandwidths (and the use of the latest versions of HSPA+ as an alternative) in two ways – by considering the national wholesaler's proposition in each coverage area (defined by frequency band) in each spectrum scenario relative to the base case – and also by considering the overall peak data rate offered on the wholesaler's network (regardless of frequency band).

In relation to the performance multiplier used in each coverage zone, we have utilised the multipliers shown in Figure 24 below. It should be noted that as low frequency coverage areas overlap those of high frequencies, we consider the highest data rate available in any area e.g. if an operators has 2x10MHz of 800MHz spectrum, 2x15MHz of 1800MHz spectrum and 2x10MHz of 2.6GHz spectrum available for LTE deployment, then we assume a 2x15MHz carrier is available across the 1800MHz zone (which encompasses the 2.6GHz coverage zone) and a 2x10MHz carrier is available in the remainder of the 800MHz footprint that falls outside 1800MHz coverage.

In respect of the peak data rate offered across the whole network of the national wholesaler, we have used a multiplier (overall network multiplier) which applies to revenues across the national wholesaler's entire network. The aim of this assumption is to capture the impact of the marketing benefit/dis-benefit of the overall maximum data rate available on the operator's network which could then form the basis of the national wholesaler's advertising – regardless of which areas the peak data rate was actually available in. The multipliers we have used are also shown in Figure 24 below.

Figure 24: Performance multiplier (for each coverage zone) and overall network multiplier assumptions

Channel bandwidth	Peak data rate	Performance multiplier (by coverage zone)	Network multiplier
LTE 2x20MHz	150 Mbps	100%	100%
LTE 2x15MHz	112.5 Mbps	95%	98%
LTE 2x10MHz	75 Mbps	85%	97%
LTE 2x5MHz or DC-HSPA+ 2x10MHz	37 Mbps/42 Mbps	65%	96%
HSPA+	21 Mbps	30%	95%

Please note that:

- The performance multipliers (by coverage zone) are shown relative to a 2x20MHz LTE carrier. They are applied in each coverage area relative to the actual expected peak data rate within the coverage zone (e.g. the base case market scenario assumes only a 2x10MHz LTE carrier will be deployed in the 800MHz/900MHz bands so the multiplier for the 800MHz coverage zone in the spectrum scenario under consideration is compared to the 85% multiplier that is applicable to the 800MHz coverage zone in the base case)
- Multipliers are 'dampened' so they are effective over an extended period of time (i.e. the impact on revenue share is not immediate in one year)
- The largest possible LTE carrier in the 900MHz band is assumed to be 2x10MHz as per 3GPP Release 8 and 9 specifications
- In the longer-term, the performance multiplier is scaled back towards 1 to reflect the expected introduction of carrier aggregation technology which will allow operators to aggregate spectrum across different bands to form wider carrier widths.

The Expert Panel noted that unlike other markets (e.g. the USA and Asian markets such as Singapore), the national wholesalers in the UK has mostly not sought to compete through comparison of network peak data rates and performance.

These multipliers are then used to assess the difference in revenues for the spectrum scenario being considered compared with the base case. After allowing for the costs associated with acquiring these revenues, the commercial value (increased/decreased) of each spectrum scenario relative to the base case can be calculated.

B.3 Assessment of technical value

Initial LTE network deployment (for coverage)

As discussed in the commercial value section, we seek to ensure the highest-speed technology is deployed in each coverage zone (e.g. if a national wholesaler has 2x10MHz of 800MHz and 2x20MHz of 2.6GHz spectrum available for LTE deployment, we assume the wholesaler will deploy a 2x20MHz LTE carrier in all of the 2.6GHz coverage area and a 2x10MHz LTE carrier across the entire 800MHz footprint). The underlying assumption is that the revenue gains from such an approach are greater than the additional costs of deploying LTE using multiple bands on individual cell sites. Whilst our modelling has shown this is generally the case, in some instances (particularly where low market shares are being modelled), there are some instances where the cost of deployment outweighs the revenue gain resulting in negative values from having access to additional spectrum. In such a situation, the national wholesaler is likely to deploy LTE in multiple bands in the main populated areas (e.g. centres of cities) – the extent of the roll-out depending on the precise revenue gain to be generated. Unfortunately our business modelling approach does not allow us to model deployments in specific geographic areas e.g. individual cities, and therefore our estimation of the value of incremental spectrum in such situations assumes that such deployment does not occur at all and therefore our valuations can be considered a lower bound estimate of the value of the spectrum in such circumstances.

For each of the national wholesalers, network deployment is assumed to occur during 2013, with services being commercially available from 2014. The exception is Everything Everywhere, who we assume will deploy LTE using its existing 1800MHz holdings in 2012 (subject to regulatory approval), with commercial launch in 2013.

The number of sites in which we assume LTE will be initially deployed has been detailed above. As discussed earlier, these assumptions take account of the current network configurations of each of the existing national wholesalers.

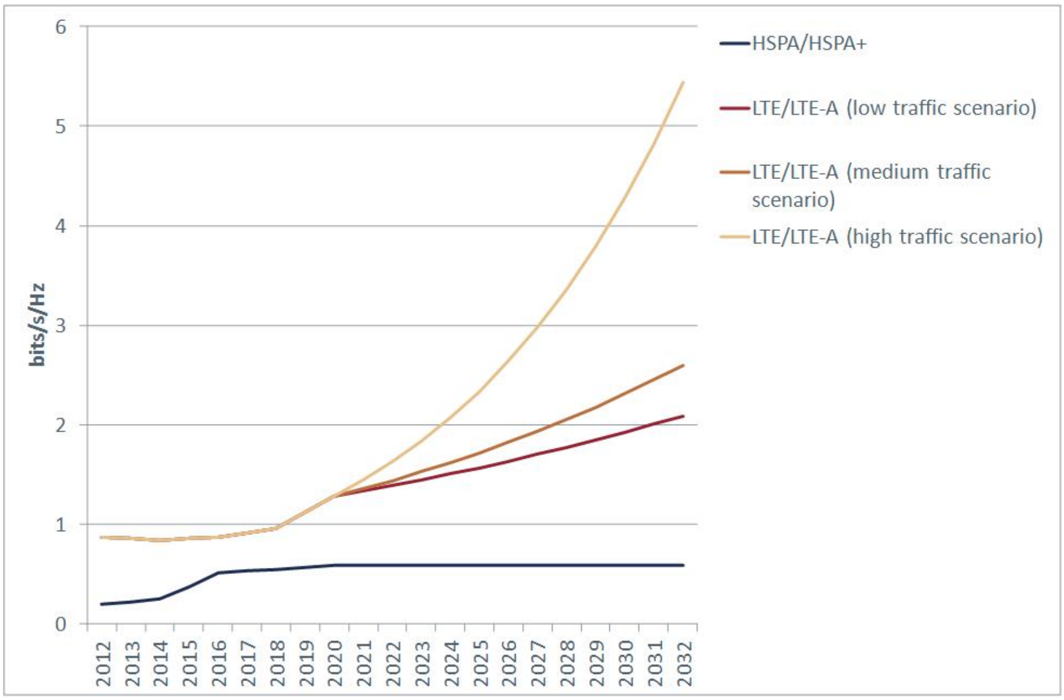
Please note that we assume all operators are in the process of deployed single RAN technology (where GSM, UMTS and LTE equipment co-exist in the same base station unit) across their network footprint and therefore do not consider this cost in our models since this is common to all spectrum scenarios.

Capacity upgrades

As discussed above, we assume the initial LTE deployment is determined by network coverage which maximises the revenue potential of the operator. Additional capacity is then deployed to meet demand by upgrading existing sites to utilise any spectrum available for LTE and HSPA services. New cell sites are deployed at the point at which all spectrum assets have been deployed at existing cell sites.

Our assessment focuses on the modelling of the downlink capacity between base stations and subscriber devices since this typically dominates network planning in data-driven networks. Traffic is considered in one pool across both the LTE and HSPA+ network of a national wholesaler - though we assume different capacity levels for each of these technologies. We assess the amount of network traffic than be supported by each cell site (assuming three sectors at each site) by considering the spectral efficiency of each technology. These assumptions take account of both the evolution of network technology as well as the pace of adoption by subscribers. Our spectral efficiency assumptions are summarised in Figure 25 below. The forecasts up to 2020 are based on assessments undertaken by Real Wireless[72] to reflect the expected end-user device mix and usage patterns of a real-world commercial deployment. HSPA/HSPA+ figures reflect dominance of 3GPP Release 8 in the device mix by 2020, and a blend including earlier Releases before that. Beyond 2020, our LTE projections assume that LTE-Advanced technologies progressively dominate the device mix. The range between scenarios reflects different possible configurations of LTE-Advanced as enumerated by Real Wireless, with 'typical expected rollout' figures used for the medium traffic scenario.

Figure 25:Forecast evolution of spectral efficiency (bit/s per Hz)



Source: Aetha Consulting, Real Wireless

We have calibrated our high-level traffic forecasts and the spectral efficiency projections utilised for the high scenario to ensure these are reasonable in terms of the implications for future network deployment – specifically we have set our scenarios such that the high traffic scenario would allow the network wholesaler with the strongest spectrum holdings to take traffic levels up to a level which are supported by its base station network (with a moderate number of additional new sites being added for capacity) – allowing us to assess the implications for the other national wholesalers in such a situation.

Site decommissioning

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[72] See Real Wireless, '*4G Capacity Gains*', Report for Ofcom, Version 1.5, 27 January 2011.

One driver for site decommissioning is the potential benefit to H3G from acquiring 1800MHz and 800MHz spectrum at the auction allowing it to close sites it had previously deployed in rural areas to provide widespread network coverage. This is estimated to apply to a total of 1500 sites if H3G's spectrum from the auction includes 1800MHz spectrum but no 800MHz spectrum, and a further 2000 sites (i.e. a total of 3500) if H3G's spectrum from the auction includes 800MHz. In order to ensure H3G's existing customers which remain on 3G do not experience any degradation in coverage levels, we assume that these sites cannot be decommissioned until the 3G network has been shut down (which we model as being in 2025).

Another driver for site decommissioning is in the low traffic scenarios where the move to highly spectrally efficient technologies such as LTE and LTE-Advanced, coupled with the large amount of available spectrum for mobile services, could allow a network wholesaler to reduce the number of sites required for network operation. In this case we model site closures in situations where our calculations indicate that the sites would not be required (to provide additional network capacity) for a minimum of six years ahead.

Assumptions underlying assessment of technical value

For the purposes of modelling network traffic levels and the capacity of the network, we assume that:

- 80% of the traffic is generated in urban areas
- downlink traffic is the limiting factor and we model this assuming that 80% of the total forecast traffic per subscriber is generated on the downlink
- busy hour traffic accounts is equal to 7.5% of total daily traffic
- in view of uneven loading across cell sites across a national wholesaler's footprint, we assume that the maximum utilisation is 70% of the total capacity of the cell site.

The main cost assumptions we have used for the technical value modelling are as follows:

- we assume that the cost of a new site is GBP150 000 in capital expenditure in 2011 (increasing at 1.5% per annum in nominal terms) and on-going site operating costs are GBP15 000 per site per annum (increasing in line with inflation)
- we assume that the initial upgrade of a base station site to LTE technology (for line cards, antenna equipment etc) will cost GBP20 000 per site (remaining constant in nominal terms over time) for equipment and GBP15 000 per site for labour (increasing over time with inflation).
- we assume that the cost of deploying LTE or HSPA+ capacity upgrades on existing sites (using new frequencies) will cost GBP 20 000 per site (remaining constant in nominal terms over time) and that no additional labour costs are required as these upgrades could be undertaken as part of on-going site maintenance/management activities

- we assume that the decommissioning of a site will incur a one-off cost of GBP30 000 (increasing over time with inflation) and will lead to annual cost savings of GBP15 000 per site (increasing over time with inflation).

B.4 Valuation of paired spectrum from new entrant perspective

The main assumptions underlying our modelling of the business case for a new entrant national wholesaler are as follows:

- Timing of network deployment and launch:

We assume the new entrant deploys its network in 2013 and 2014 with full commercial launch at the start of 2015

- Revenue projections:

We have developed valuation cases assuming the new entrant achieves an overall share of market revenues in the long-term of 10%, 15% and 20%

- Operating expenditure projections:

We model interconnection and national roaming costs as amounting to 15% of revenues in the short-term falling to 10% of revenues in the long-term

We model subscriber acquisition and retention costs (including marketing and advertising costs) as amounting to GBP200 per gross addition (increasing at approx 0.8% per annum to reflect that approx one-third of the cost relate to items that would be subject to an increase in price in nominal terms in line with inflation). We assume a subscriber churn rate of 27.5% (slightly lower than market average to reflect our assumption that the most likely new entrant will have an existing fixed telecoms business and will have lower churn levels through the introduction of family plans etc)

Network costs are modelled assuming GBP15 000 operating costs per site, increasing in line with inflation

We model staff costs as amounting to GBP45 000 per member of staff (fully loaded cost including employers' national insurance, benefits etc) increasing in line with inflation, and calculate the number of subscribers by assuming a subscriber to staff ratio which starts at 800 and increases to 2000 over time. Note that we assume a minimum of 300 staff are employed in 2013 and 600 staff are employed in 2014

All other costs (including general and admin) are modelled as being 75% of staff costs

- Capital expenditure projections

Site deployment costs are assumed to amount to GBP150 000 per site (increasing at 1.5% per annum in nominal terms) and core network costs are calculated as being 67% of radio access network costs. We assume a maximum of 2000 sites can be deployed in 2013 and a further 3000 sites in 2014 and beyond. Whilst we have assumed that the new entrant builds out its own sites, it is possible that the new entrant would share sites with the existing network operators on commercial terms.

IT-related capex is assumed to amount to 2.5% of revenues per annum with a minimum level of GBP10 million

- Financial parameters:

We apply the same weighted average cost of capital utilised for the modelling of the business case from the perspectives of the existing national wholesalers (namely 8.86%).

In respect of market share, we have modelled three alternative scenarios for the evolution of the market share of the new entrant (10%, 15% and 20% share of market revenues in the long-term).

B.5 Valuation of unpaired 2.6GHz spectrum

Use by national wholesaler to provide additional capacity spectrum

We have utilised the business models developed for the assessment of the technical value of paired spectrum for each of the national wholesalers to quantify the incremental value of having access to the 2.6GHz unpaired spectrum. When assessing the traffic capacity that can be carried by an unpaired 2.6GHz LTE carrier on each base station site, we assume the same spectral efficiency for paired LTE, but adjusted to assume that (i) 90% of the capacity from the unpaired spectrum is used for the downlink and (ii) the TDD variant of LTE is 80% as efficient at any given point in time as the FDD variant.

Use by a potential new entrant

We have considered the use of 2.6GHz unpaired spectrum by a potential new market entrant. Here we consider that the most likely business case for such a new entrant would be to offer wireless broadband services to consumers and small businesses as substitute or as a complementary service offering to home broadband services. In view of the propagation characteristics of the 2.6GHz band, we have assumed that the service is deployed in the main urban centres only (2000 base station sites in total).

We have utilised a similar business modelling approach to that adopted for the new entrant utilising paired spectrum, namely to model the whole business case for the operator (revenues, capital expenditure, operating expenditure) in order to assess the free cash flows generated by the business. In this particular case, we assume the next best alternative is to "do nothing" i.e. we consider the whole net present value of free cash flows of the business as being the potential value of the spectrum under this use.

Use for backhaul connectivity

We understand that Vodafone Spain is currently utilising unpaired 2.6GHz spectrum to provide the backhaul link to small cell sites and that the principal advantages of using the 2.6GHz band are the speed at which the link can be deployed (analogous to the speed of deployment of a microwave link over leased line/fibre) and the fact that a non-line of sight link can be used (whereas high frequency microwave requires line of sight links).

We have sought to estimate the value of 2.6GHz unpaired spectrum being used for backhaul links by assessing the cost savings in the event that such links were used in place of (i) Ethernet links over fibre and (ii) two 'daisychained' microwave links each with line of sight (two links being required as line of sight is not available between the base station and central node). We model the cost savings that would arise under alternative combinations of these two types of next best alternative.

Annex C Discount rate sensitivities

In this annex we present the results of a sensitivity analysis on the discount rate applied in our data treatment to derive our benchmarks. We apply discount rates:

- when discounting annual fees or licence fee instalments to net present value terms, where we should ideally apply the WACC that would be appropriate for an efficient operator in the specific country, which is unfortunately unavailable; and
- when adjusting for differences in licence durations to normalise licence prices to a common 20-year period. We amortise a licence price into constant annual profit streams and adjust to a 20-year term using the net present value adjustment specified in the main body of the report. Here a real discount rate should be applied to account for any inflationary effects. In addition, where the profit stream departs from constant annuities this could also be reflected in the discount rate applied.

In both these calculations however, we apply a discount rate of 8.86% using the same nominal WACC as in our business modelling (which is also the WACC used by Ofcom in deriving the price caps on MTRs for the charge control period of April 2011 to March 2015). Given this, it would seem prudent to identify the variation in licence prices that would result from varying the discount rate in both these calculations.

We first analyse the impact of varying the discount rate assumption when accounting for annual fees or paying the licence fee in instalments in Section C1, and then analyse the impact of varying the discount rate assumption on the licence duration adjustment in Section C2. As in our main report all prices presented in this Annex are in real 2011 GBP per MHz per capita.

C.1 Sensitivity analysis on non-duration adjusted licences

To analyse the impact of varying the discount rate on the net present value of a licence price in the case of annual fees or paying the licence fee in instalments, we compared the non-duration adjusted licence prices. Note that this adjustment would thus only affect licences with annual fess or where the licence fee may be paid in instalments.

In this sub-section we conduct a sensitivity analysis on non-duration adjusted licences by varying the discount rate (8.86%) applied by ±5 percentage points. Table 28 presents the licence prices of 800MHz and 2.6GHz licences that have annual fees. Table 29 presents sample means for each of the 1800MHz benchmark.

Overall we note that the discount rate applied has a small impact on the non-duration adjusted licence price of our benchmarks. In the 800MHz band the impact was significant in the case of Denmark with prices varying by up to 20%, this is due to 80% of the licence fee being paid in annual instalments. There is no impact on all other 800MHz benchmarks as none of the other benchmark awards included annual fees. In the 2.6GHz band, the impact is the largest in the case of Belgium where annual fees made up a significant portion of total licence price, thought the effect in this case is still limited to a variation of up to 10%. Finally in our 1800MHz benchmarks, varying the discount rate has a small impact on our derived sample means limited to a maximum 3% variation.

Table 28: Auction average prices for 800MHz and 2.6GHz auctions where licences had annual fees (discount rate applied in brackets)

	Belgium - 2.6GHz paired	Denmark - 2.6GHz	Denmark – 800MHz
Auction average price (3.86%)	£0.0705	£0.0974	£0.1554
Auction average price (4.86%)	£0.0678	£0.0964	£0.1503
Auction average price (5.86%)	£0.0653	£0.0956	£0.1454
Auction average price (6.86%)	£0.0631	£0.0948	£0.1409
Auction average price (7.86%)	£0.0611	£0.0942	£0.1367
Auction average price (8.86%)	£0.0594	£0.0936	£0.1328
Auction average price (9.86%)	£0.0578	£0.0930	£0.1290
Auction average price (10.86%)	£0.0564	£0.0926	£0.1255
Auction average price (11.86%)	£0.0551	£0.0921	£0.1222
Auction average price (12.86%)	£0.0539	£0.0917	£0.1191
Auction average price (13.86%)	£0.0529	£0.0914	£0.1161
Percentage change by varying discount rate by ±5 percentage points	-6% to 10%	-2% to 4%	-14% to 20%

Table 29: 1800MHz benchmark sample means

	All Auctions including outliers	All Auctions Excluding Outliers	All European since 2000	All auctions since 2006	All auctions since 2010
No of auctions present in sample which have licences with annual fees	8	7	1	4	1
Sample mean (3.86%)	£0.2310	£0.1774	£0.1544	£0.1601	£0.1273
Sample mean (4.86%)	£0.2300	£0.1762	£0.1540	£0.1593	£0.1272
Sample mean (5.86%)	£0.2292	£0.1752	£0.1536	£0.1587	£0.1272
Sample mean (6.86%)	£0.2283	£0.1742	£0.1533	£0.1580	£0.1272
Sample mean (7.86%)	£0.2276	£0.1733	£0.1530	£0.1574	£0.1271
Sample mean (8.86%)	£02268	£0.1725	£01527	£0.1569	£0.1271
Sample mean (9.86%)	£0.2262	£0.1717	£0.1524	£0.1564	£0.1271
Sample mean (10.86%)	£0.2256	£0.1709	£0.1522	£0.1559	£0.1271
Sample mean (11.86%)	£0.2250	£0.1703	£0.1520	£0.1554	£0.1270
Sample mean (12.86%)	£0.2244	£0.1696	£0.1517	£0.1550	£0.1270
Sample mean (13.86%)	£0.2238	£0.1690	£0.1515	£0.1546	£0.1270
Percentage change in sample mean when varying discount rate by ±3 percentage points	-1% to 2%	-2% to 3%	-1% to 1%	-1% to 2%	0%

C.2 Sensitivity analysis for duration adjusted prices

In this sub-section we present the results of varying the discount rate applied when calculating duration adjusted licence prices. Below, we vary the discount rate from the 8.86% applied in our original analysis by ±5 percentage points.

The greater the difference in licence duration from 20 years the larger the impact of varying the discount rate applied in this calculation will have on duration-adjusted licence prices.

Table 23 and Table 31 present licence prices for the 800MHz and 2.6GHz bands respectively.

Table 30: 800MHz auction average prices with varied discount rates (discount rate applied in brackets)

	Denmark	France	Germany	Italy	Portugal	Spain	Sweden
Licence duration (years)	22	20	15	18	15	18	24.75
Auction average price (3.86%)	£0.1554	£0.5193	£0.7713	£0.7007	£0.5537	£0.4734	£0.2365
Auction average price (4.86%)	£0.1503	£0.5193	£0.7574	£0.6958	£0.5437	£0.4701	£0.2404
Auction average price (5.86%)	£0.1454	£0.5193	£0.7449	£0.6913	£0.5347	£0.4671	£0.2440
Auction average price (6.86%)	£0.1409	£0.5193	£0.7335	£0.6872	£0.5266	£0.4643	£0.2473
Auction average price (7.86%)	£0.1367	£0.5193	£0.7232	£0.6835	£0.5192	£0.4618	£0.2502
Auction average price (8.86%)	£0.1328	£0.5193	£0.7139	£0.6802	£0.5125	£0.4596	£0.2529
Auction average price (9.86%)	£0.1290	£0.5193	£0.7055	£0.6772	£0.5065	£0.4576	£0.2552
Auction average price (10.86%)	£0.1255	£0.5193	£0.6979	£0.6745	£0.5010	£0.4557	£0.2574
Auction average price (11.86%)	£0.1222	£0.5193	£0.6911	£0.6721	£0.4961	£0.4541	£0.2592
Auction average price (12.86%)	£0.1191	£0.5193	£0.6849	£0.6699	£0.4917	£0.4526	£0.2609
Auction average price (13.86%)	£0.1161	£0.5193	£0.6793	£0.6680	£0.4877	£0.4513	£0.2624
Percentage change in prices when varying discount rate by ±5 percentage points	-13% to 17%	0%	-5% to 8%	-2% to 3%	-5% to 8%	-2% to 3%	-6% to 4%

Table 31: 2.6GHz auction average prices with varied discount rates (discount rate applied in brackets)

	Austria	Belgium	Denmark	France	Germany	Italy	Portugal	Spain	Spain (2nd auction)	Sweden
Licence duration (years)	16	15	20	20	15	18	15	18	18	15
Auction average price (3.86%)	£0.0245	£0.0705	£0.0974	£0.0780	£0.0232	£0.0489	£0.0352	£0.0469	£0.0110	£0.1401
Auction average price (4.86%)	£0.0241	£0.0678	£0.0964	£0.0780	£0.0228	£0.0485	£0.0346	£0.0466	£0.0109	£0.1376
Auction average price (5.86%)	£0.0238	£0.0653	£0.0956	£0.0780	£0.0224	£0.0482	£0.0340	£0.0463	£0.0108	£0.1353
Auction average price (6.86%)	£0.0235	£0.0631	£0.0948	£0.0780	£0.0221	£0.0479	£0.0335	£0.0460	£0.0108	£0.1333
Auction average price (7.86%)	£0.0233	£0.0611	£0.0942	£0.0780	£0.0218	£0.0477	£0.0330	£0.0458	£0.0107	£0.1314
Auction average price (8.86%)	£0.0230	£0.0594	£0.0936	£0.0780	£0.0215	£0.0474	£0.0326	£0.0455	£0.0107	£0.1297
Auction average price (9.86%)	£0.0228	£0.0578	£0.0930	£0.0780	£0.0212	£0.0472	£0.0322	£0.0453	£0.0106	£0.1282
Auction average price (10.86%)	£0.0226	£0.0564	£0.0926	£0.0780	£0.0210	£0.0470	£0.0319	£0.0451	£0.0106	£0.1268
Auction average price (11.86%)	£0.0224	£0.0551	£0.0921	£0.0780	£0.0208	£0.0469	£0.0315	£0.0450	£0.0105	£0.1256
Auction average price (12.86%)	£0.0223	£0.0539	£0.0917	£0.0780	£0.0206	£0.0467	£0.0313	£0.0448	£0.0105	£0.1244
Auction average price (13.86%)	£0.0222	£0.0529	£0.0914	£0.0780	£0.0205	£0.0466	£0.0310	£0.0447	£0.0105	£0.1234
Percentage change in prices when varying discount rate by ±5%	-4% to 6%	-11% to 19%	-2% to 4%	0%	-5% to 8%	-2% to 3%	-5% to 8%	-2% to 3%	-2% to 3%	-5% to 8%

Table 32 presents licence prices for each of the 1800MHz benchmark samples.

Table 32: 1800MHz benchmark sample means with varying discount rates (discount rate applied in brackets)

	All Auctions including outliers	All Auctions Ex Outliers	All European since 2000	All auctions since 2006	All auctions since 2010
Sample mean (3.86%)	£0.3273	£0.2399	£0.1684	£0.2097	£0.2011
Sample mean (4.86%)	£0.3176	£0.2330	£0.1666	£0.2050	£0.1946
Sample mean (5.86%)	£0.3087	£0.2268	£0.1649	£0.2007	£0.1888
Sample mean (6.86%)	£0.3007	£0.2212	£0.1634	£0.1967	£0.1836
Sample mean (7.86%)	£0.2935	£0.2161	£0.1620	£0.1930	£0.1789
Sample mean (8.86%)	£0.2869	£0.2115	£0.1608	£0.1897	£0.1747
Sample mean (9.86%)	£0.2809	£0.2071	£0.1597	£0.1866	£0.1709
Sample mean (10.86%)	£0.2755	£0.2035.	£0.1587	£0.1838	£0.1674
Sample mean (11.86%)	£0.2706	£0.2001	£0.1578	£0.1811	£0.1643
Sample mean (12.86%)	£0.2662	£0.1969	£0.1570	£0.1788	£0.1615
Sample mean (13.86%)	£0.2621	£0.1940	£0.1562	£0.1766	£0.1589
Percentage change in sample mean varying discount rate by ±5%	-9% to 14%	-8% to13%	-3% to 5%	-7% to 11%	-9% to 15%

Overall, varying the discount rate has a larger impact on licence prices via the licence duration adjustment than when discounting the stream of annual fees as analysed in Section C.1 above.

In the 800MHz benchmarks, varying the discount rate applied by ±5 percentage points caused the largest variation in the case of Denmark, as mentioned in earlier this is due to licence fees being paid in annual instalments. Licence prices of all other awards varied by no more than 8% in countries where the licence duration is very different to a 20-year term, i.e. Portugal and Germany.

In the case of our 2.6GHz benchmarks, varying the discount rate by ±5 percentage points has the largest impact in the case of Belgium because of significant annual fees in combination with the 15-year licence term. The other 2.6GHz benchmarks however are affected similarly to the 800MHz benchmarks of no more than 8%.

Finally in the case of our 1800MHz benchmarks, varying the discount rate applied by ±5 percentage points affects our sample means by up to 15%.

Annex D Reserve price and demand for marginal lots in a combinatorial auction

In this Annex, we discuss the impact of reserve price levels on demand for marginal lots in a CCA format, particularly under the context of reserve price exceeding the marginal value of a lot. Our discussion begins by examining the relation between reserve price levels, marginal lot value and the surplus maximising package of a bidder; followed by a discussion on how absolute rather than marginal valuations of a package affects bidding incentive in a CCA.

D.1 Reserve prices and the surplus maximising package

The final price a bidder pays will determine his payoff on a package, therefore the reserve price has no impact on the payoff a bidder enjoys from winning a package when the final price exceeds reserve. In particular, the proposed pricing rule in the UK auction allows for a price differential between a large and a small package to be less than the reserve price of the differential lots between the large and small package (for instance, the final price differential between a 3 and 2 lot package can be less than the reserve price of one lot). This implies that even in the case where the marginal value of the last lot of a package being lower than reserve price (for instance in our example above, the marginal value of the third block in a 3-lot package is less than reserve), it is possible that the payoff a bidder enjoys from winning the larger package may be higher than that of the smaller package at final prices.

The impact of reserve price on a bidder's payoff of a package is therefore only relevant where spectrum is awarded at reserve price – which may be particularly relevant for opt-in bidder (fourth player) with the implementation of the spectrum floor in the UK auction and the use of opt-in bids, or under scenarios of low competition, where the reserve price is the final package price and determines the payoff a bidder enjoys from winning a package. The surplus maximising package of a bidder given a linear lot price (as in the case of the primary rounds) would depend on the valuation structure of a bidder. In the box below, two examples demonstrate the surplus maximising package with an increasing and a decreasing marginal valuation structure.

In the case of increasing marginal valuations, a bidder's surplus maximising package would be the largest package a bidder can bid for.

In the case of decreasing marginal valuations, a bidder surplus maximising package would be the package where the marginal value of the last lot is lower than linear lot price. However, the bidder's payoff from winning a larger package (whilst not surplus maximising) could be positive and significant. In the case where the marginal value of the first block is lower than reserve price, than there is no package that would yield a positive payoff for the bidder.

In both cases, the bidder will enjoy positive surplus as long as the linear lot price does not exceed the average package value.

In both examples below, we assume a reserve price of 50 per lot.

Bidders with increasing marginal valuations

The bidder's marginal valuations, package valuations and resulting payoffs at reserve prices for a bidder with increasing marginal valuations is tabulated below.

Table 33: Increasing marginal valuations

Lots in package	1	2	3	4
Marginal valuation for last lot	60	100	200	300
Package valuation	60	160	360	660
Average value per lot	60	80	120	165
Package price	50	100	150	200
Payoff at reserve price	10	60	210	460
Average payoff per lot	10	30	70	115

In this constructed example above, the bidder has increasing marginal valuations which implies that the bidder's average value per lot is also increasing. Therefore, as long as reserve price is above the marginal value of the first lot, the bidder's surplus is highest for the largest package. In the case where reserve price is above the marginal value of the first lot(s) under this valuation structure, the bidder's payoff from the(se) package(s) will be negative. For instance if reserve price is 65, then the bidder's pay off from the single lot package is negative, in this case, the bidder will not bid for the 1-lot package as winning this package yields a negative surplus, making the bidder worse off than not winning anything. If reserve price was even higher at 80 (less than the bidder's marginal value of the second block of 100), the bidder gets zero payoff from the 2-lot package and would be indifferent between bidding and not bidding for this package, and for the same motivations as before not bid for the single lot package either..

Therefore, with an increasing marginal valuation, at reserve prices, the bidder will enjoy a positive pay off by bidding up to the point with the linear lot price meets the average value of the package. In the case of a 1-lot package, the package marginal and average values are the same.

Bidders with decreasing marginal valuations

The marginal valuations, package valuations and resulting payoffs at reserve for a bidder with decreasing marginal valuations is tabulated below.

Table 34: Decreasing marginal valuations

Lots in package	1	2	3	4
Marginal valuation for last lot	300	200	100	40
Package valuation	300	500	600	640
Average value per lot	300	250	200	160
Package reserve price	50	100	150	200
Payoff at reserve price	250	400	450	440
Average payoff per lot	250	200	150	110

In this example of decreasing marginal valuations above, the marginal valuation of the first, second and third blocks are higher than the reserve price of a lot while the marginal value of the fourth block falls below reserve price. The surplus the bidder enjoys on all packages however is positive, though the payoff of for the package of four lots is lower than the smaller package of three lots. In this case, the profit maximising package is the 3-lot package. Note however that while the 4-lot package would generate lower surplus than the 3-lot package, the bidder's payoff from this package is higher than the 1-lot and 2-lot packages.

Therefore in the case of decreasing marginal valuations, the bidder can bid for its surplus maximising package by bidding up to the point where the marginal valuation of the last lot exceeds reserve price (in our example above, the 3-lot package would be surplus maximising as the marginal value of the fourth block is below reserve). Note that despite not being the surplus maximising package, the payoff from the 4-lot package is positive and higher than the 2-lot and 1-lot packages.

D.2 Reserve price and bidding incentives a CCA

One of the main benefits of a combinatorial auction format is that it allows for non-linear prices to clear the market, that is, bidders pay an opportunity cost reflecting price for their package and may each pay varying average price per lot. Therefore, in the CCA bidders need not to worry about the price paid per lot but can focus on their valuation for the whole package relative to the price for the whole package. This means that a bidder will enjoy a positive payoff from winning a package if his absolute valuation for the package is higher than the cost of the package.

In a combinatorial auction, particularly in a complex auction with many package options that a bidder may win, it is not straight forward for a bidder to predict what their winning package would be or the price they would have to pay for this package and hence the payoff they would enjoy from this package. The counterfactual of not winning any spectrum in an auction is a distinct possibility for a bidder. Where the probability of winning a particular package is independent of winning another package, expected surplus is maximised by bidding for as many packages as the bidder has a positive valuation for at the package cost, as this increases the likelihood of enjoying a non-zero surplus.

To this end, while the bidder may choose to bid for the package for which it enjoys the highest surplus from in the primary rounds based on the linear lot price as described in the section above, the bidder would bid for other packages for which it would enjoy a positive payoff from winning in the supplementary round. Therefore, the level of reserve price would not impact the market clearing outcome as long as it does not choke off efficient demand by exceeding average package value. To the extend that there is strong common value uncertainty and price discovery is important in the primary rounds, the reserve price should not exceed the marginal value of marginal lot to the strongest loser so as to allow for price discovery.

D.3 Conclusion

For an auction with package bidding the marginal value of individual lots in a package is of little importance as long as the package's overall payoff (or equivalently the average payoff per lot) remains positive.[73] Therefore, it is average package value rather than marginal lot value that is of concern when considering the impact of reserve prices on choking off demand in a combinatorial auction format. In particular, if the reserve price were very close to the *average value per lot*, then a marginal lot value below reserve price could turn the overall payoff negative as it drags the average package value below the reserve price per lot.

We illustrate this with an example. A bidder with the valuations given in the table below would not bid on the package with 4 lots as it has a negative payoff at reserve price. The reserve price of 50 is above the marginal value of the fourth lot. However the real problem is that the reserve price is close to the average value of *any* of the bidder's packages, including the package with 1 lot only, therefore a smaller marginal value for the fourth block drags the average package value of the 4-lot package below reserve prices, yielding a negative payoff to the bidder for this package.

Table 35: Reserve price close to average valuation

Lots in package	**1**	**2**	**3**	**4**
Marginal valuation for last lot	55	51	47	43
Package valuation	55	106	153	196
Average value per lot	**55**	**53**	**51**	**49**
Package reserve price	50	100	150	200
Payoff at reserve price	5	6	3	-4
Average payoff per lot	5	3	1	-1

In light of these considerations, the cases where the business modelling valuations suggest marginal values for particular spectrum blocks that are below the reserve price should not raise concerns about pricing off efficient demand.

[73] A thought experiment without spectrum caps and under the assumption of free disposal shows that if undue weight were given to the marginal lot in large packages, reserve prices would have to be set to zero in order not to curtail demand. In such an extreme setting bidders would like to add an unlimited number of marginal lots to any package even if their marginal value is infinitesimally close to zero.