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Auction design options for the award of spectrum in the 3.4 – 3.8 GHz and 26 GHz bands

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Summary

This note sets out our recommendations for auction formats that might be used for the award of remaining spectrum in the 3.4 – 3.8 GHz band and the 26 GHz band if a determination is made that the number of rights of use for these frequencies is to be limited and an auction is chosen as the selection process.

Licensing scenarios for the 26 GHz band

We understand that in each of the regions where unsold frequencies in the 3.4 – 3.8 GHz band are available, these will be offered as a single block. For the assignment of frequencies in the 26 GHz band, we consider three licensing scenarios (referred to as 'Modelle' in the main consultation document), namely:

- Scenario A, which is based on the competitive award of spectrum only in High Demand Areas (with spectrum in the remaining parts being licensed through a lightweight administrative procedure), with HDAs being grouped into regions that correspond to the licensing regions used in the 2019 auction;
- Scenario B, where the 26 GHz spectrum will be licensed in many small regions (municipalities above a certain size and administrative regions covering the rest of the country); and
- Scenario C where the 26 GHz spectrum will be offered nationally, but subject to comprehensive coverage obligations and/or obligations to sub-lease the spectrum in rural areas where it is not being used by the licensee.

Relevant factors and candidate auction formats

We discuss the salient factors that are relevant for the choice of an appropriate auction format, including the underlying objectives; the likely lot structure; likely participation and the corresponding structure of valuations that different types of bidders might have for the spectrum; and the potential need for competition safeguards. Based on these factors, we identify the following candidate auction formats:

- a simultaneous multi-round ascending auction (SMRA) in the form of an SMRA-Clock hybrid (as used in Austria for the 700, 1500 and 2100 MHz auction in 2020);
- an alternative SMRA-clock hybrid, the so-called Clock-Plus or enhanced SMRA (ESMRA);
- a simple clock auction, potentially with provisions for exit bids (as used for the 2019 award of spectrum in the 3.4 – 3.8 GHz band);
- a combinatorial clock auction (CCA, as used for the 2014 multi-band auction); or
- a combinatorial multi-round auction (CMRA).

Initial recommendations for the three licensing scenarios

We then assess the relative merits of these different formats and derive our initial recommendations.

For Scenario A, we suggest the use of a simple clock auction with provisions for exit bids to minimise the risk of unsold lots, unless cross-regional synergies are expected to be very strong or there are material concerns about strategic bidding aimed at driving up prices. In the first case, a fully combinatorial format might be needed to address aggregation risks; in the latter case, a format that uses the notion of provisional winning bids (i.e. a simultaneous multi-round auction, in practice in one of its procedurally more efficient variants using a clock mechanism for bid collection) might be preferable. In relation to the mechanism for collecting exit bids, we suggest that the submission of exit bids is deferred until the end of the clock phase at which point it is known whether and for what lot categories exit bids are needed, and what clock bids each bidder has won.

Our recommendations for scenario B are the same, except that we discard the use of a fully combinatorial format (not least because the existence of strong regional synergies would be incompatible with the selection of this licensing model).

In scenario C, we consider that the use of an SMRA (again in one of the procedurally more efficient variants) would be appropriate.

1 Background

RTR is preparing the assignment of spectrum in the 3.4 – 3.8 GHz band that remained unassigned after the auction in 2019 and in the 26 GHz band.

We understand that pursuant to the provisions of the updated telecommunications act (TKG 2021), the use of an auction process will only be considered for frequencies for which it has been determined that the number of rights of use is to be limited. For such scarce frequencies, the use and users that generate the greatest benefits for end users in a competitive downstream market should be identified through a comparative or a competitive selection process (e.g. a beauty contest or an auction).

At this point in time, no decision has been made about whether a comparative or a competitive selection mechanism is needed, or which type of selection mechanism is to be used in relation to either of the two bands. However, to provide clarity to prospective users, we have been asked by RTR to identify potential auction mechanisms for the award of these bands, should frequencies be identified as being scarce and should an auction be chosen as the selection mechanism.

In this note we:

- identify the factors that are relevant for the choice of an appropriate auction format, and shortlist a set of candidate auction formats (Section 2);
- assess the relative merits of shortlisted candidate formats (Section 3); and
- provide our initial recommendations for the different licencing scenarios that might emerge from the consultation process (Section 4).

We assume that the reader is familiar with the basic features of different auction formats, their activity rules, and key concepts such as substitutability and complementarity between individual lots. More detailed descriptions of the working of the different

designs and key concepts can be found in reports prepared for previous consultations.[1]

2 Salient factors for the choice of an auction design

It is well understood that there is no single 'best' auction design. Different formats have their advantages and disadvantages, and the choice of design depends on the specific circumstances of an award such as the objectives of the awarding body, the available spectrum and technical requirements (which affect the appropriate lot structure), the likely participation and structure of valuations and any competition concerns.

In the remainder of this section, we set out our understanding of these salient factors and draw their implications for the choice of auction format.

2.1 Objectives

The use of a competitive selection mechanism implies that there is rivalry amongst spectrum users and/or uses, which needs to be resolved.

The primary objective for any such competitive process is to assign the spectrum in a way that maximises the long-term benefits for end users, which in turn implies that:

- frequencies should be used efficiently to provide high quality services;
- competition in downstream markets should be protected;
- improvements of coverage should be promoted; and
- innovation should be encouraged.

To promote an efficient use of the spectrum, considering the potentially materially different requirements of different uses and/or users, the auction model should provide flexibility for

[1] See:

- Vergabeverfahren 3,4 – 3,8 GHz: Optionen für das Produkt – und Auktionsdesign; or
- Options for the design of the auction in the 700, 1500 and 2100 MHz bands

bidders to assemble the spectrum portfolio that best meets their needs in response to price signals that reflect conflicting demands. Providing this flexibility will typically mean offering the spectrum in small blocks (where demand requires it, on a regional or local basis) with an auction design that supports switching between spectrum portfolios and does not expose bidders to any appreciable substitution or aggregation risks.

It is also desirable for the award process to mitigate uncertainty for bidders, and in particular not to expose bidders to the risk of leaving the auction empty-handed without explicitly accepting such an outcome. Finally, the auction process should minimise mechanical and strategic complexity (though there may be trade-offs between the two), i.e. ensure that the auction rules are reasonably easy to understand and that developing a suitable bid strategy is not overly challenging.

2.2 Lot structure

Available spectrum

The following spectrum will be available for assignment:

In the 3.4 – 3.8 GHz band, some spectrum remained unsold in seven regions in 2019. These regions and the amount of spectrum available for award now are shown in Table 1. We understand that the intention is to award the remaining spectrum in each region as a single block to avoid undue fragmentation (which would result in spectral inefficiency). Therefore, the spectrum available in this band will be offered as seven lots, corresponding to each of the regional endowments shown in Table 1.

Table 1: Available spectrum in the 3.4 – 3.8 GHz band

ID	Region	MHz available
A01u	Wien, St. Pölten	40
A01r	Wien, Burgenland, Niederösterreich ohne A01u	10
A04u	Innsbruck+, Bregenz+	60
A04r	Nordtirol, Vorarlberg ohne A04u	60
A05u	Villach, Klagenfurt	60
A05r	Osttirol und Kärnten ohne A05u	60
A06u	Graz	10

In the 26 GHz band, only 1.6 GHz of the total 3.25 GHz comprising 5G band n258 are available for award at present. Of these, 600 MHz at the bottom of the band will be reserved for campus networks and similar applications. 1 GHz at the top of the band (the frequencies overlapping with band n257 used in Japan, North America, and South Korea) will be awarded. The intention is to offer the spectrum in blocks of 200 MHz. There is no expectation of material differences in the value of individual 200 MHz blocks within the band, so they can be treated as identical for the purposes of assigning bandwidth to prospective users.

Award scenarios and lot structures

The presumption is that demand for 26 GHz may be limited in some areas. Therefore, a competitive process may only be necessary for those geographic areas where the spectrum is in fact scarce. However, at this point it is unclear whether and where frequencies in the 26 GHz band are scarce, and to what extent it may be possible clearly to define the geographic areas where spectrum is scarce.

We have therefore been asked to consider three award scenarios (referred to as 'Modelle' in the main consultation document) that differ in terms of the approach to the licensing of 26 GHz spectrum:

- In scenario A, RTR would identify High Demand Areas (HDAs) where the 26 GHz spectrum will be offered in a competitive process with spectrum in the remaining parts of the country, being licensed through a lightweight administrative procedure (local licensing). The HDAs would be grouped into regions with regional boundaries corresponding to those used in the 2019 auction of 3.4 – 3.8 GHz spectrum. This means that there would be up

to twelve lot categories (corresponding to regions containing at least one HDA), with five lots of 200 MHz each.

- In scenario B, the 26 GHz spectrum would be licensed separately for relatively small geographic areas (e.g. municipalities with more than 10,000, or more than 5,000, inhabitants) and a number of administrative areas covering the remaining parts of the country. In this scenario there could be around 200 to 350 local licensing areas, each of which would constitute a separate lot category with five lots of 200 MHz. Such an auction of local licenses would be used if it were difficult to define clearly bounded HDAs but would only be appropriate if cross-regional synergies are limited.
- In scenario C, the 26 GHz spectrum would be licensed nationally, but subject to comprehensive coverage obligations and/or obligations to sub-lease the spectrum in rural areas where it is not being used by the licensee. Therefore, in this scenario we would have a single lot category for 26 GHz spectrum, with five lots of 200 MHz. Scenario C would be appropriate if it were difficult to define clearly bounded HDAs and there were substantial cross-regional synergies for bidders.

The resulting number of 26 GHz lots is shown in Table 2.

Table 2: 26 GHz lots available under different licencing scenarios

	26 GHz licensing regions	Number of 26 GHz lots
Scenario A	up to 12	up to 60
Scenario B	200 to 350	1,000 to 1,750
Scenario C	1	5

2.3 Contiguity requirements

Within-band contiguity

For efficient spectrum use, frequency assignments within each band should be contiguous for each licensee.

Contiguous assignments of frequencies are guaranteed for the newly awarded spectrum in the 3.4 – 3.8 GHz band, as the spectrum will be offered as a single block in each region.

For the 26 GHz band we assume (and recommend) that spectrum be offered initially in the form of frequency-generic

lots in each of the regions (a single region in scenario C). Therefore, each region would constitute a lot category. Winners of frequency-generic lots will then be assigned specific frequencies in a second step (the frequency assignment stage), which could take the form of a single-round sealed-bid process using an opportunity-cost price rule – this approach has been used successfully in past awards in Austria. The price rule gives bidders the opportunity to bid on their preferred frequencies, but only requires winners to pay opportunity costs, which may be negligible if preferences are mutually compatible. However, should there be objections to the use of a second-price rule, it would be straightforward to use a first-price (pay-as-bid) rule instead.

Alignment of spectrum holdings across regions

If cross-regional alignment of assignments will result in lower costs and interference risks, it may in principle also be desirable to aim for an assignment that gives bidders the same frequency in adjacent regions, though this can add substantial complexity to the process.

In relation to 3.4-3.8 GHz spectrum, cross-regional alignment is determined by the existing frequency assignment from the initial auction in 2019. However, licensees would be free to engage in negotiations to re-assign specific frequencies (subject to every licensee retaining their initial bandwidth) where such a re-assignment is mutually beneficial.

In relation to 26 GHz spectrum, benefits from cross-regional assignments are likely to be limited by the propagation characteristics of the spectrum in this band and because areas where the spectrum will be used (regardless of whether they can be clearly defined as HDAs) may be separated from each other by areas of low demand. Given this and taking account of the substantial complexity of solving cross-regional assignment problems (which would in all likelihood be prohibitive in scenario B), there appears to be no case for special rules aimed at maximising such cross-regional alignment. Consequently, we assume that assignment bids would be evaluated separately for each licensing region (regardless of whether these bids are collected simultaneously or sequentially).

2.4 Likely participation and structure of valuations

Likely participation

We understand that there is likely to be interest from the three established mobile operators who may want to acquire

additional mid-band frequencies and 26 GHz spectrum (at least in hotspot areas) for enhanced mobile broadband services (eMBB) and FWA, as well as potential FWA operators who may want to use either band. We also understand that demand from users wishing to deploy campus/private/industrial networks is likely to be negligible, as their requirements will largely be addressed through reserving the lower 600 MHz of the 26 GHz band.

Substitutability

At least prospective FWA users may consider spectrum in the 3.4 – 3.8 GHz band and 26 GHz band as potential substitutes. However, the extent to which there is scope for substitution and actual switching within the auction depends on the licensing scenario:

- In scenario A (where 26 GHz is geographically packaged into regions that match those used in the 2019 award of the 3.4 – 3.8 GHz band), some bidders may consider a 40 or 60 MHz block in the 3.4 – 3.8 GHz band to be a reasonably close substitute for a 200 MHz block of 26 GHz spectrum in the corresponding region and may be prepared to switch readily in response to price changes.
- In scenario B, the scope for cross-band substitution is likely to be limited by the fact that a bidder might need to obtain 26 GHz spectrum in a potentially large number of local licensing areas to obtain similar geographic coverage.
- In scenario C, a national 26 GHz block is unlikely to be a close substitute for a block of 3.4 - 3.8 GHz spectrum in one or more (and perhaps all) of the regions where enough bandwidth is available.

We understand that there is no technical reason for assuming that spectrum in one licensing region could be substituted for spectrum in another in either band. However, lots in different categories may be substitutes to the extent that bidders face budget constraints that might limit their ability to pursue all their targets. Such bidders might then need to make trade-offs between different spectrum portfolios in response to the development of relative prices. However, at this point it is unclear whether this trade-off would involve spectrum in different bands.

Complementarities

With regional or local licensing of the 26 GHz band in scenarios A and B (and with the regional structure of the 3.4 – 3.8 GHz licences), there may be complementarities between different licensing areas. For example, having sufficient spectrum resources in multiple areas may allow operators to exploit

economics of scale or scope from being able to market a specific service proposition across a wider geographic market or ultimately nationally. Complementarity across 26 GHz regions in scenario B may also arise from the fact that some bidders would consider switching between 3-4 – 3.8 GHz in a region and 26 GHz in a corresponding group of local areas. However, we would expect complementarities in this scenario to be limited: as noted above, using this licensing approach would not be appropriate if there were material cross-regional complementarities.

We understand that there is limited, if any, scope for complementarity across the two bands within the same geographic area. However, if the bands are substitutes (e.g. for deployment of FWA), then any regional complementarities may also apply across bands (i.e. there may be synergy benefits from combining spectrum in the 3.4 – 3.8 GHz band in some regions with 26 GHz spectrum in other areas).

We also understand that within-band complementarities for 26 GHz spectrum are limited. With the proposed block size of 200 MHz, a single block would be usable and even though the incremental value of a second block may be somewhat higher than the value of the first block, the difference should not be material.

Summary

In summary, this means that we expect scope for:

- cross-regional complementarity in the 26 GHz band with regional licensing (i.e. in scenario A; as scenario B would be unsuitable if there were material synergies across licensing regions);
- cross-regional complementarity for the 3.4 – 3.8 GHz spectrum;
- cross-regional, cross-band complementarity between 26 GHz and 3.4 – 3.8 GHz with regional licensing;
- cross-band substitutability between 26 GHz and 3.4 – 3.8 GHz, depending on the regional structure of 26 GHz licensing for some uses; and
- general substitutability between different target portfolios for budget-constrained bidders.

2.5 Competition safeguards

We understand that competition concerns in the 26 GHz band are limited to preventing monopolisation of the band and

foreclosure of a potential pure-play FWA operator by MNOs with fixed network businesses. These concerns should be addressable through simple spectrum caps limiting the number of blocks that can be acquired by a single bidder in any region. We do not discuss the size of these caps in this report.

The spectrum in the 3.4 – 3.8 GHz band in this award only comprises frequencies that remained unassigned in the initial 2019 auction, whose outcome was constrained by pro-competitive measures. As discussed in the main consultation document, no further competition safeguards may be needed for the award of these frequencies, and we do not consider constraints on who might be able to bid for the spectrum in this report.

2.6 Implications for choice of auction format

Simultaneous or sequential auction?

Whether the two bands should be offered simultaneously or separately in the auction is largely determined by whether demand for spectrum in the bands is interrelated because of substitutability or complementarity. Where this is the case, separate auctions are unlikely to produce an efficient outcome and the bands should be offered simultaneously.

This suggests that the safest option is to offer the two bands simultaneously. However, where one can be reasonably confident that demands are independent, and where a separate auction offers the opportunity for substantial simplification, then this option should be considered.

The scope for substitutability and cross-band, cross-regional complementarity in scenario A clearly would seem to require a simultaneous auction.

The case for a simultaneous auction is less clear in scenarios B and C, where the scope for cross-band substitutability is limited and substitutability might only arise from some bidders potentially having to make trade-offs because of budget constraints. In these scenarios separate auctions might be a reasonable option, especially if this makes it possible to use simpler auction formats for each single band.

Open multi-round or sealed bid?

Sealed bid processes tend to be quicker, mechanically simpler, and less susceptible to gaming than open, multi-round processes, which require detailed activity rules that need to be understood and reflected in bid strategies. On the other hand,

strategic complexity may be greater, and the information provided to bidders in the course of an open bidding process can be crucial for achieving an efficient outcome.

A common argument in favour of an open multi-round format is that being able to observe bidding from others can help bidders to adjust their value estimates if there is a common value element to the valuation of spectrum. However, we do not believe this price discovery function to be a particularly strong argument for an open process in this case. This is because there are likely to be only few bidders and their valuations are also strongly affected by bidder-specific factors (such as existing subscriber base, existing network configuration etc.). As a result, there is little scope for any meaningful updating of value estimates based on the bid decisions made by others.

However, the outcome discovery function of an open auction format continues to be an important reason for choosing such a design. In an open multi-round process, bidders will be able to gradually narrow down the range of possible market clearing outcomes and get a better understanding of the number of lots they may be able to win in the various categories.

An efficient outcome can only be achieved if bidders make bids for the lots they should be assigned in an efficient allocation. A sealed bid process provides a single opportunity for bidders to make bids and therefore bidders may need to place many bids reflecting the range of outcomes that might pertain. With no information about what combination of bids might clear the market, there is limited scope for eliminating combinations that are unwinnable and therefore bidders might potentially need to bid on all packages in which they are interested even if their chance of winning them is very small. This is likely to be complicated when there are many lots, as bidders need to consider many alternative lot combinations of potential interest.

Conversely, the outcome discovery process in an open auction may show bidders fairly rapidly what combinations of lots they cannot realistically expect to win so that they can discard these and focus on those that might (still) be winnable.

Particularly, where bidders face budget constraints and are therefore not able to express their full valuations for different packages and the valuation differences between them, being able to adjust bids in view of what outcomes can realistically be expected greatly simplifies bid strategy.

In addition, placing many bids and letting the auction mechanism decide which, if any of these, will be successful, often creates governance problems. Therefore, bidders may prefer to limit the number of bids they make so as to narrow down the possible outcomes, even if this increases the chances of winning a sub-optimal package or leaving the auction empty-handed (and potentially paying a premium for reducing the risk of not winning anything).

In scenario A, assuming that both bands would be offered simultaneously and that there would be some HDAs in each of the twelve regions, there would be more than 68 million possible packages on which a bidder could place a bid even if they were constrained by a cap of two blocks in the 26 GHz band; with a three-block cap, this number would increase to more than 2.1 billion packages.[2] The number of possible packages would be astronomical in scenario B for the 26 GHz band alone.[3] This clearly does not allow bidders to specify a full set of package bids that might be required for an efficient outcome, even if bidders may be able to discard some packages as unrealistic. Therefore, an open process that permits bidders gradually to narrow down the range of likely outcomes is strongly preferable.

Even in scenario C, where the number of packages might be as low as 383 with a two-block cap in a simultaneous award,[4] an open process seems the obvious choice, not least because this also helps bidders to manage budgets and facilitates corporate governance.

Combinatorial or non-combinatorial

Whether a fully combinatorial auction format such as a combinatorial clock auction (CCA) or a combinatorial multi-

[2] With two options for each of the seven 3.4 – 3.8 GHz lots (bid/no bid) and three options for each of the twelve 26 GHz lot categories (bid on one or two lots/no bid), the number of possible packages is given by $2^7 \times 3^{12} - 1 =$ 68,024,447. Increasing the options for each of the twelve 26 GHz lot categories to three (bid on one, two or three lots/no bid), the number of possible packages is given by $2^7 \times 4^{12} - 1 =$ 2,147,483,647.

[3] Assuming that we would be licensing 26 GHz in 200 separate licensing areas, the number of combinations under a two-block cap would be 2.7×10^{95}. If there were 350 licencing areas, then the number of combinations under a two-block cap would increase to 9.8×10^{166}. The number of atoms in the known universe is estimated to be between 10^{78} and 10^{82}.

[4] $2^7 \times 3 - 1 = 383$.

round auction (CMRA) should be used depends on the strength of complementarities. If these are strong, then using a non-combinatorial auction in which bids are not evaluated as package but as bids on individual lots exposes bidders to the risk of winning an unwanted subset of lots or overpaying for the lots they win (if bid amounts reflect the synergistic valuation of complementary lots that the bidder does not win in the end). A limited-combinatorial format such as the simple clock auction (SCA) removes aggregation risks by making bids not committing until the point at which the auction ends, but will not necessarily support an efficient outcome as prices will still largely be linear: although there is scope for some differentiation through exit bids, these will typically result in lower prices for larger packages rather than the discounts for smaller packages that might be required to support an efficient outcome in the presence of strong complementarities.

Combinatorial auctions can also deal with lots that are not complements, so one might argue using a combinatorial auction is the safest choice whenever there is scope for complementarity even if this is uncertain. However, combinatorial auctions tend to be more complex and may raise other concerns, such as a greater difficulty to manage budgets. Where a sealed bid component is involved, there may also be concerns about a reduced ability to retain control over outcomes which in turn may complicate governance. Therefore, our view is that a combinatorial auction should only be used when complementarities are likely to be material and where bidders can be expected to be able to deal with the greater complexity of such formats.

For this award, it is unclear whether complementarities are strong enough to justify the use of a fully combinatorial format. If there are no cross-regional synergies, there would be no reason for choosing a combinatorial format. Even if there are cross-regional synergies, but they are limited (i.e. there is some benefit from obtaining spectrum in multiple regions, but the incremental value on top of the sum of the stand-alone values of spectrum in each region is small), the associated exposure to aggregation risks may be acceptable when compared with the added complexity of a combinatorial format. Moreover, there may be alternative options for mitigating aggregation risks with a lower degree of complexity, such as permitting bidders to specify minimum requirements (overall or for each region) below which they would not be assigned any spectrum.

Candidate auction formats

Taking account of these considerations, we shortlist the following auction formats for this award:

- an SMRA in the form of an SMRA-Clock hybrid (as used in Austria for the 700, 1500 and 2100 MHz auction in 2020); as there are five identical spectrum blocks in each lot category in the 26 GHz band, this format would still have greater procedural efficiency compared with the standard SMRA;
- an alternative SMRA-clock hybrid, the so-called Clock-Plus or enhanced SMRA (ESMRA);
- an SCA, potentially with provisions for exit bids (as used for the 2019 award of spectrum in the 3.4 – 3.8 GHz band) where we consider different variants in relation to the detailed rules for the submission and evaluation of exit bids including the possibility to defer exit bids to a separate round in the case of excess supply in one or more lot categories in the final clock round;
- a CCA, as used for the 2014 multi-band auction); or
- a CMRA as used in recent spectrum awards in Denmark and Norway.

The last two formats are fully combinatorial designs.

The simple clock auction implicitly provides for the evaluation of bids as package bids, albeit with the risk of leaving lots inefficiently unsold because it uses linear prices.

The SMRA variants are non-combinatorial and expose bidders to the risk of winning lot subsets of the lots on which they bid or alternative combinations.

In the following section, we provide a more detailed assessment of these formats and highlight their relative strengths and weaknesses.

3 Assessment of candidate auction formats

3.1 SMRA/SMRA-Clock hybrid

The SMRA is a tried and tested auction format that has been used for the award of radio spectrum for more than two decades. Its key feature is that the auctioneer, after each round, determines standing high bids (provisional winning bids) for the available lots, which become winning bids if no further bids are received in the next round. This means that bidders know at

every point which lots they would win if the auction ended and how much they must pay for these lots.

Risk of unsold lots is minimised, but bidders are exposed to aggregation risks

As standing high bids cannot typically be withdrawn, an advantage of the format is that it minimises the risk that lots remain unsold. Once a lot has received a bid, it will be assigned. The potential downside of this is that bidders may be stuck on lots they no longer want at the prices they have to pay – they are exposed to aggregation risks. In addition, in combination with the activity rules[5], the notion of standing high bids restricts the ability of switching between different lot combinations, as a bidder might hold standing high bids on some, but not all lots in the combination from which she wishes to switch.

The SMRA-Clock hybrid format retains these features but streamlines the bidding process where there are multiple identical lots that can be grouped into lot categories. Rather than inviting bids on individual lots, this variant asks bidders to specify the number of lots they want to acquire in a particular category at the round price. The auctioneer will still identify standing high bids at the end of each round. This format has been used in the recent auction of spectrum in the 700, 1500 and 2100 MHz bands in Austria.

The advantage of this variant is that bidding is simplified by indicating the number of lots in a category demanded at a specific price rather than selecting individual lots. As a result, the long tail typically associated with the resolution of excess demand in standard SMRAs is somewhat shortened if there are many identical lots and few bidders. Specifically, the number of rounds required for the price of all lots in a particular lot

[5] The SMRA is typically run with activity rules that prevent bidders from increasing demand as the auction progresses. Such rules ensure that bidding is progressive and that the process reveals information about demand. In the simplest case, bidders cannot increase their activity from one round to the next, where activity is measured by the sum of eligibility points of lots on which the bidder holds standing high bids or places new bids.

Some relaxation of the activity rules is possible, for instance providing bidders with a few 'waivers' that allow the bidder to maintain its permitted activity for the following round, even if it does not make the corresponding bids in the round in which waiver is used. Another relatively common relaxation is to have a reduced activity requirement, essentially allowing a bidder to maintain its permitted activity for future rounds as long as current activity is above a certain proportion, with future permitted activity reduced pro-rata if current activity falls below.

category to increase by one increment if there is excess demand of one lot is determined by the number of bidders rather than the number of lots.[6]

Ranking bidders vs. ranking bids

It is possible to use a queueing method to assign standing high bids to bidders. Under this approach, we would keep the bids from each bidder together and rank them *en bloc* by bid amount and then at random. By doing this, the number of bidders who would be provisionally winning only some of the lots on which they bid can be limited to at most one in each lot category. However, a potential disadvantage of this queuing approach is that bidders who have only some of their bids designated as standing high bids may gain additional information about the bidding behaviour of others when the number of bidders is known (and even more so if spectrum caps vary across bidders).

For example, consider the case of five lots and three bidders, each subject to a three-block cap. Suppose that standing high bids are established by ordering bids by bidder (as was the case in the recent Austrian 700/1500/2100 MHz auction). After a round with aggregate demand for seven blocks, a bidder who has placed a bid on three blocks and has all of them designated as standing high bids knows only that the other bidders collectively must be bidding for four lots but does not know whether these bids split three/one or two/two. By contrast, if the bidder holds standing high bids on two blocks, she knows that the other bids must be split three/one as a bid for three lots from a single bidder ranked above is the only way in which this can happen.

Such an asymmetric disclosure of information can be avoided if standing high bids are determined by ranking individual bids by bid amount and then at random. This will mean that more bidders are exposed to the risk that only some of their bids designated as standing high bids.

[6] This is because bidders who make bids at the round price for a given lot category are also required to raise any standing high bids they hold in that category. Therefore, a bidder who is only standing higher bidder on some of the lots she wishes to acquire in a category will need to bid for all the lots she wishes to acquire at the new round price, rather than only for those where she does not hold the standing high bid. By contrast, with bids on individual lots only a single lot may have a price increment applied every round.

Speed benefits of hybrid format are limited in this award

For this award, the benefits from speeding up the bidding process relative to a standard SMRA when there is little excess demand are likely to be limited as the number of lots in each category is not much larger (and in the 3.4 – 3.8 GHz band smaller) than the number of bidders.

3.2 Clock-plus/ESMRA

Like the SMRA-Clock hybrid format, the Clock-Plus/ESMRA auction collects bids using a clock price mechanism – the auctioneer announces a clock price for each lot category and bidders respond by stating the number of lots they wish to acquire. However, there is no explicit designation of standing high bids. Rather, standing high bids are defined implicitly by restrictions on the ability of bidders to reduce demand, only applied at the point at which a lot category would otherwise go into excess supply.

Specifically, a bid that involves a reduction in demand in a lot category relative to the previous round will only be accepted to the extent that this does not create excess supply. This means that bidders are effectively committed to taking lots on which they have placed a bid in previous rounds (even if they no longer wish to acquire those lots) if they could otherwise be unsold, much like the notion of standing high bids in the SMRA (and the SMRA-Clock hybrid).

Differentiation between submitted and processed bids creates uncertainty

One main difference to the SMRA-Clock hybrid is that in this design the bids submitted by the bidder may not be accepted in full and thus the bids that will be processed by the auction system may be different. Consider the simple example where a bidder bids on three lots in a particular lot category (say category A) in round n where the price is 100. Assume that there is excess demand of two lots in this round. In the next round, at a price of 110, the bidder no longer wishes to acquire any lots and therefore reduces demand to zero.

- If all other bidders maintain their bid decisions, then this demand reduction would leave excess supply of one lot and will therefore not be fully accepted. Instead, the bidder remains 'on the hook' for one lot at a price of 100.
- However, if other bidders increased their demand in lot category A, the demand reduction could be accepted in full.
- Conversely, if other bidders also reduced demand in category A, the bidder may be retained on more than one

lot, depending on the order in which bids are being processed.[7]

The same principle applies to demand reductions in combination with switches. Suppose that in the above example the bidder wishes to switch to category B and increase her demand in this category by three lots (assuming for the sake of simplicity that all lots have the same number of eligibility points). As standard activity rules apply, the demand increase will only be processed to the extent to which the demand reduction can be accepted. If the bidder is retained on one lot in category A where she submitted a demand for zero lots, she will only be able to increase demand in category B by two lots.

Although the level of excess demand at the end of a round provides the bidder with information about what demand changes may be processed, there remains some uncertainty over the extent to which demand reductions and switches will be accommodated. This is because the extent to which submitted bids will be processed depends on the bids submitted by other bidders and the processing order. For example, consider that two bidders attempt to reduce demand and that the order in which their bids are being processed is determined at random, the bidder whose bid is being processed second may have the request to reduce demand partly or fully denied where it would have been accommodated in full if the bid had been processed first.

This uncertainty does not exist in the SMRA-Clock hybrid, where standing high bids are determined at the end of the round in which the bidder submitted the corresponding bids. Therefore, bidders know what standing high bids they have when deciding whether to reduce or switch demand.

[7] To permit bidders to have some control over the order in which bids are processed, bids that are associated with a change in demand can be submitted at a price between the previous round clock price (also referred to as the 'start price' of the round) and the current clock price, so the bidder could state that it wishes to maintain its demand up to a price of 102 and then reduce to zero. These prices are then used to determine the order in which bids are processed. Where there are multiple lot categories with potentially very different absolute prices, the prices specified in the bidder's bids will be converted into price points that measure the position within the interval defined by start price and clock price, e.g. (bid price – start price)/(clock price – start price) yielding a price point between zero and one.

Speed benefits are retained

At the same time, the fact that there are no explicit standing high bids means that prices can increase more quickly if there is excess demand in a lot category (as there are no standing high bids that might be retained at the previous round price), and also that switches may be implemented more quickly than in the SMRA-Clock hybrid. In the above example, the switch from A to B may be completed fully in one round if coincidentally other bidders increased their demand in category A. In the SMRA-Clock hybrid, the bidder would only be able to move two lots and would then have to wait to be outbid before switching the third lot.[8]

3.3 Simple clock auction

This format works without the designation of standing high bids, whether explicitly or implicitly. Again, the auctioneer announces a price for lots in each category and bidders nominate, their demand. Prices for lot categories with excess demand go up from round to round. Bidding ends when there is no excess demand in any of the lot categories. Up to this point, bidders are free to choose whichever combination of lots they wish to acquire at clock prices constrained only by activity rules (analogous to those used in the SMRA).

No aggregation risks, but risk of unsold lot and greater scope for strategic bidders who might not want to win in certain lot categories

Therefore, this format does not expose bidders to aggregation risks as they will only ever win the combination of lots on which they have placed a bid in the last clock round. Instead, the presence of material synergies will increase the risk of unsold lots. For example, in the presence of cross-regional synergies, a bidder may drop demand to zero across several regions if she cannot longer afford to acquire spectrum in one of them, which may result in excess supply in regions where demand might have already matched supply.

Another reason for lots remaining unsold is that multiple bidders might reduce demand in a particular category (or

[8] Note that this does not make switching a combination of lots more or less likely unless bidders are discounting the risk of having a switch not processed fully (or mistakenly ignore this risk). A bidder wanting to switch out more lots from a category than there is excess demand in a Clock-Plus/ ESMRA will need to rely on the expectation that other bidders switch into this category in the same way that a bidder with standing high bids in an SMRA needs to rely on the expectation of being outbid on the remaining standing high bids.

individual bidders want to reduce demand by multiple lots) at the same time – often called 'price overshoot'. This is more likely when price increments are large. The outcome will be inefficient if some or all the unsold lots could have been assigned at intermediate prices. The problem of price overshoot can be addressed by permitting bidders to submit exit bids when they drop demand, as we discuss below. However, even with exit bids it may not be possible for bidders to make bids that reflect synergistic valuations because of the largely linear nature of clock prices and restrictions on exit prices.

A further consequence of bids not being committing until the auction ends is that bidders may bid strategically on lots that they do not wish to win to drive up prices for others. Even though such a strategy is not riskless, being able to reduce demand to zero as long as the auction does not close creates opportunities for such behaviour.

Provision for exit bids to address price overshoot

Exit bids allow bidders to specify the price(s) between the clock price of the previous round and the current clock price at which they would still maintain their demand, in full or in part. If bidders place exit bids the auctioneer can use them to construct a demand curve that result in market clearing if all bidders have decreasing marginal valuations for lots in each category, and if their demand is not affected by tight budget constraints.[9]

Whilst the notion of exit bids is conceptually straightforward, there are several questions that need to be addressed.

The first two questions, which are somewhat inter-related, are:

- whether exit bids should be interpreted as bids for larger packages or bids for incremental lots; and
- whether exit bids should only be considered if the auction ends in the round in which they were placed or retained and used in determining final outcomes regardless of when they were made.

Clearly, retaining exit bids throughout the auction (rather than discarding them if the auction proceeds to further rounds) will reduce the likelihood of ending up with unsold lots. However, in this case exit bids should be for incremental lots, to ensure that

[9] For example, when bidders face budget constraints they may need to reduce demand in a particular lot category without there being a price increase and without being able to place an exit bid.

exit prices only apply to lots that would remain unsold at clock prices (otherwise winning exit bids could be lower than some of the unsuccessful clock bids). Also, where exit bids are retained for later rounds, it seems reasonable to allow bidders to edit or withdraw such bids, so that they can manage their financial exposure as clock prices increase. The following example illustrates these points:

Consider the case of three bidders (X, Y and Z) competing for five lots. All bidders start bidding on three lots.

Assume that in round n, at a price of p_n both X and Y reduce their demand to two lots and place an exit bid. Depending on the interpretation of exit bids, this could be (a) an exit bid for three lots at p_e^i for $i \in \{X, Y\}$ with $p_{n-1} \leq p_e^i < p_n$ or (b) an exit bid for a third lot at this price in addition to a bid for two lots at the clock price. Assume that Z continues to bid on three lots so the auction continues.

Suppose that after some more rounds Z eventually drops out completely at a clock price of p_N without placing any exit bids (e.g. because Z might require at least three lots).

If we only considered exit bids in the round in which they were placed and discarded them if the auction continues, one lot would remain unassigned. However, if we can use one of the 'old' exit bids, we can assign all lots by giving a third lot to whoever placed the higher exit bid. Let us assume that this was placed by X, i.e. $p_e^X > p_e^Y$.

Under interpretation (a), this would require us to assign the three lots to X at a price substantially lower than the price that Z would have been willing to pay for three lots, given that Z kept bidding on three lots at prices above p_n. If we use the lowest accepted exit bid to set the price of all lots, we will also assign the two lots to Y at a price well below the price at which Z has placed bids for a larger quantity.

Under interpretation (b), we would assign all clock bids at the final clock price and incremental lots at the exit bid price, so X would obtain two lots at p_N and the third lot at p_e^X. Assigning X two lots at the final clock price reflects that X had to outcompete Z on those two lots; Assigning a third lot to X at the lower exit price reflects that Z is not willing to take up a single lot at that price.

With assigning clock bids at final clock prices and applying exit bid prices to incrementl lots there may however be an issue if X

has a budget $B < 2p_N + p_e^X$ at which she cannot afford the third lot even at the reduced price. To avoid exposure to the risk of havint to exceed her budget, we need to permit the bidder to withdraw her exit bid or, if possible within her budget, reduce the bid amount to the lowest amount at which the exit bid could have been placed (i.e. p_{n-1}).

The difference between the two interpretations will obviously be relatively small when considering exit bids from the most recent round but will become larger if we consider exit bids from many rounds in the past. Therefore, when exit bids remain alive throughout the auction, it would be more appropriate to use interpretation (b).

Treatment of exit bids under the activity rules

Where there are multiple lot categories and demand reductions in one category may be accompanied by increases in another (i.e. switching), there is the question whether exit bids should count towards a bidder's activity.

One would not necessarily expect bidders wanting to place exit bids in the lot category where they reduce demand because the decision to switch between category A and category B indicates that, at prevailing prices, the bidder wants to win more lots in B and fewer in A. However, the question remains whether a bidder should be permitted to place exit bids when switching (perhaps combined with restrictions on whether such exit bids would be winnable). Being able to do so would help with reducing the risk of unsold lots, as the following example illustrates.

Consider the case of two lot categories A and B and a bidder who has a valuation for three lots but is indifferent in relation to the lot category. Suppose that the valuations for the first, second and third lot are 115, 110 and 105 respectively. Suppose that prices are 100 for lots in category A and 105 for lots in category B. At these prices, the bidder will demand three lots in category A and none in category B.

Now suppose that there is excess demand of two lots in category A and that the clock price increases to 120 whilst it remains unchanged at 105 in lot category B. The bidder now switches its entire demand to lot category B. If other bidders do not change their demand, this will leave lot category A with excess supply of one lot at a price of 120.

Assume that because of this switch, the price in lot category B now increases to 125. The bidder now reduces demand to zero.

She may place exit bids at prices between 105 and 115[10] in category B, some of which may become winning bids if the demand reduction leaves excess supply in category B. Regardless of this, however, there is one unsold lot in category A because of the bidder having switched from A to B. This lot could and, from an efficiency perspective, should be allocated to the bidder unless she wins three lots in category B. This would have been possible if the bidder, upon reducing demand in category A, had placed exit bids at prices between 100 and 105[11], which could now be considered.

Therefore, the question is whether the bidder should have been able to place exit bids in category A when switching, even though the switch was not accompanied by an overall reduction in demand.

As noted above, even if permitted to do so, the bidder may not have been willing to place an exit bid if this could lead to her winning more than three lots, for which she might not have any value or sufficient budget. To address this concern, the bidder would need some reassurance that she will not win more lots than she was bidding on when switching.

To this end, it might be appropriate to apply eligibility constraints when evaluating whether specific exit bids should be winning, but not to apply such constraints when bidders place exit bids, i.e. not count exit bids towards activity. In the above example, this would mean that the number of lots assigned to the bidder in relation to its exit bids in category A would depend on whether she also wins lots in category B, as the total number of lots assigned cannot exceed three.

Compulsory or optional exit bids?

Finally, one might consider whether exit bids should be compulsory rather than optional (or whether a bidder should be assumed to have submitted default exit bids at the previous round price), ensuring that we always collect demand for additional lots when bidders reduce demand. Compulsory exit

[10] The exit bid amount would be constrained by the clock price of the current round, i.e. 125. This constraint is not binding, however, as the largest value the bidder has for a single block is 115.

[11] Again, the constraint on the exit bid amount is given by the clock price in this round for category A, which is 120, but for a bidder with this valuation structure the effective limit on the willingness to pay for additional lots in this category is given by the clock price in category B.

bids would also address concerns about bidders placing strategic price-driving bids in lot categories where they do not wish to win any lots. However, making exit bids compulsory would re-introduce aggregation risks as bidders could potentially win unwanted subsets of lots through exit bids. Compulsory exit bids can also be problematic for budget constrained bidders, who may still have demand at clock prices but may not be able to afford to win exit bids alongside their clock bid.

Aggregation risks arising from compulsory exit bids may not be an issue in the current award if synergies are simply cross-regional across all regions rather than within groups of regions. In this case, the risk of winning unwanted subsets could be eliminated by stipulating that the requirement to submit exit bids does not apply when the bidder reduces demand to zero in all regions (and that, in the case that exit bids were carried forward by default, at this point all previously submitted exit bids would also automatically be cancelled). However, if there is a finer structure to cross-regional synergies, this simple solution could not be applied.

In summary, there are various options for the specific rules governing exit bids, ranging from the very simple provisions for permitting bidders to place exit bids that may be used only if the auction ends after the respective round with excess supply in the corresponding lot category (or lot categories) to more complex settings in which exit bids remain alive and could be changed or withdrawn, potentially subject to constraints linked to activity rules.

Deferred exit bids in the case of unsold lots

If we reject compulsory exit bids because they re-introduce aggregation risks and focus on optional exit bids for incremental lots that would stay alive throughout the auction but could be amended and withdrawn, we can greatly simplify the process by deferring the submission of such bids until after a round in which there is no further excess demand at clock prices.

If there are then some lot categories in which there is excess supply, we can invite bidders to place their exit bids for additional lots, subject to constraints equivalent to those that would apply to exit bids if they had been placed during the auction (i.e. exit prices must not above the clock prices in the round in which the bidder reduced demand and not below the clock prices in the corresponding preceding round).

The auctioneer would then assign the unsold lots to the combination of exit bids that generates the greatest value, subject to no bidder winning more than permitted under any applicable spectrum caps and not exceeding the level of eligibility it had when starting to reduce demand in any of the categories for which such bids can be placed.

An advantage of this approach is that exit bids will only need to be collected if there are indeed unsold lots after the last clock round and that bidders know exactly how many lots they win with their clock bid and how many additional lots they could, at most, win in each category when placing their exit bids. At this point, the financial commitment from winning clock bids is known and bidders can determine whether and what bids to place given their available budget.

Consider, for example, that we have two unsold lots in a particular lot category. Consider a bidder who has started to bid on four lots in this category and eventually won a single lot with its final clock bid. Over the course of bidding, the bidder has reduced clock demand from four to three in round X at a price of p_X, from three to two lots in round Y at a price of p_Y and from two to one in round Z at a price of p_Z.

Such a bidder could place bids for one (additional) lot at a price that is less than p_Z and not lower than p_{Z-1} and a price for a second (additional) lot that is less than p_Y and not below p_{Y-1}. There would be no option to submit a bid for a third additional lot as such a bid could never be accommodated with the lots available.

Deferring the submission of bids for lots that would otherwise remain unsold until the end of the clock stage has the benefit of avoiding the need for complex rules about submission and withdrawal of exit bids and avoids any need for the bidder to track exit bids that may never become relevant.

3.4 Combinatorial clock auction

The combinatorial clock auction combines a simple clock auction without exit bids with a combinatorial sealed bid stage. This removes aggregation risks and, as the format supports non-linear prices – minimises the risk of unsold lots. The format also addresses concerns about switching impediments that might limit the set of spectrum portfolios for which bidders can express their valuations in non-combinatorial formats.

However, the mechanics of the CCA are clearly more complex than those of the SMRA or the simple clock auction.

Bidders have also expressed discomfort with respect to the sealed bid aspect of the auction, which exposes them to uncertainty about the lots they will eventually win and the price they may need to pay. Bidders have also objected to the opportunity cost-based pricing rule used in the CCA on the grounds that it creates governance problems, as the optimal bid strategy may require making bids that are much higher than what the bidder expects to have to pay. These issues are of greater concern to bidders facing relatively tight budget constraints.

There have been attempts to address some of these issues through changing activity rules. In a modified version, the so-called Enhanced CCA ('ECCA'),[12] a stricter activity rule is used for both the clock rounds and the supplementary round, and a modified pricing rule is applied. The activity rule is based on the general axiom of revealed preference[13] that imposes tighter constraints on the additional bid amounts that can be placed on larger packages. Given these tighter constraints, the ECCA rules then determine prices using the highest valuations that the other bidders could possibly make for packages that incorporate the lots won by a bidder given the clock bids that they have made, rather than the supplementary bids actually made by the other bidders. In the clock rounds bidders will be informed before each clock round about the amount by which their base price would be lower than their bid, given the choices made by other bidders so far.

[12] The most fully articulated description of the specifics of this format can be found in the consultation document issued by the Canadian Department for Innovation, Science and Economic Development (ISED) for the 600 MHz auction (ISED, Consultation on a Technical, Policy and Licensing Framework for Spectrum in the 600 MHz Band, Annex C, https://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf11316.html#sC).

[13] Bidders may submit bids for package that exceed their eligibility, but only if all bids submitted by the bidder since the last round in which it had sufficient eligibility to bid on this package are consistent with truthful bidding based on some implied set of valuations. The requirement of consistency of all bid decisions from the round in which the bidder would last have been able to bid on a specific package based on its eligibility with an underlying set of valuations is also extended to supplementary bids.

Should the clock round end without any unsold lots, prices would simply be determined by applying the respective discounts to the final clock bids (i.e. by calculating the most that other bidders could possibly bid for the lots won by a particular bidder) without the need for running a supplementary round. By implication, a supplementary round would only be needed if there were unsold lots at the end of the clock stage.

These modifications are intended to make the clock stage more relevant and limit the role of the supplementary round to assigning lots that might otherwise remain unsold and to reduce the scope for strategic bidding, thus improving price discovery. However, they also add to the complexity of the format.

An alternative approach (the 'exposure pricing' approach adopted in Ireland for an upcoming multi-band auction) is to provide more information to bidders about the price they might expect to pay during the clock rounds. Under this approach, bidders are informed in each round about the minimum discount from clock prices they would enjoy if the auction were to end after this round without any unsold lots. However, rather than setting final prices at the theoretical maximum, final prices would still be calculated based on actual supplementary bids, which might lead to lower prices.[14]

3.5 Combinatorial multi-round auction

The Combinatorial Multi-Round Ascending (CMRA) auction is also based on the clock auction and, like the CCA, allows bidders to place bids on packages other than their clock packages. However, unlike the CCA, such additional bids can be submitted alongside clock bids (called 'headline bids') in the clock rounds, subject to similar constraints to those that apply to supplementary bids in the CCA. Not relying on a sealed bid round, the format does not expose bidders to the risk of not winning any spectrum unless they explicitly stop making bids at round prices and unlike the CCA it uses a pay-as-bid rule rather than an opportunity cost-based pricing rule used.

[14] See https://www.comreg.ie/publication/multi-band-spectrum-award-information-memorandum-and-draft-regulations-the-700-mhz-duplex-2-1-ghz-2-3-ghz-and-2-6-ghz-bands

At the end of each round, the auctioneer establishes the value-maximising combination of bids, taking at most one bid from all headline bids and additional bids submitted by a bidder. If there is a value-maximising combination that includes a bid from each bidder, the auction ends. Otherwise, the auctioneer determines the lot categories where the demand from different bidders clashes and increases the price of these categories.

This means that, unlike the standard clock auction, the CMRA does not necessarily end when there is no excess demand in any of the clock categories. Rather, bidding can carry on beyond this point when there all the value-maximising combinations (involving additional bids) would leave out one or more of the bidders who are still bidding at clock prices. Alternatively, bidding may end even if there is excess demand from headline bids if it is possible to obtain the maximum value with bids from all bidders by selecting additional bids.

The CMRA also eliminates aggregation risks as bidders can only win packages on which they have explicitly placed bids. It should therefore perform well in the presence of complementarities.

However, as bidders can place bids on smaller packages at reduced prices while maintaining demand on their headline bids, the format may be more susceptible to bidders reducing demand to keep prices low. As such a strategy does not involve an irreversible loss of bidding eligibility as would be the case in the simple clock auction or the various SMRA variants, it becomes less risky.

4 Initial recommendation

Based on the foregoing review of different formats, our initial recommendations for the different award scenarios are as follows:

4.1 Scenario A

There could be complementarities across regions that suggest that bidders would be exposed to aggregation risks with a format that (explicitly or implicitly) creates standing high or provisional winning bids.

If these risks are material and there are concerns about unsold lots, a fully combinatorial format (e.g. CMRA or CCA) would be justified.

If these risks were material, but the risk of some lots remaining unsold is acceptable and concerns about vexatious bidding aimed at driving up prices are limited, a simpler format such as the SCA could be used. To minimise the risk of unsold lots, we suggest including an additional round for the submission of exit bids in the case of excess supply in one or more lot categories after the clock rounds (this would be a simple replacement for optional exit bids that are retained throughout the auction unless withdrawn).

If concerns about price driving are material or if aggregation risks are negligible, a format that relies (explicitly or implicitly) on the notion of standing high bids/provisional winning bids would be appropriate. The choice between the SMRA-Clock Hybrid and the Clock-Plus/ESMRA depends on the relative importance given to the residual uncertainty about switching opportunities that remains in the latter versus the speed benefits that are retained.

4.2 Scenario B

The main driver for the recommendation of a format in scenario B is the large number of lot categories in the 26 GHz band and the presumption that cross-regional synergies and cross-band substitution are limited.

In this case, we suggest a very simple format such as the SCA, again with the option of an additional round for inviting exit bids for lots that would otherwise remain unsold after the final clock round.

Alternatively, if there is an overriding concern about unsold lots and the risk of bidding to drive up prices, a format that limits the scope for demand reduction by defining provisional winning bids would seem appropriate. Given the large number of lot categories, the speed benefits offered by the Clock-Plus/ESMRA seems to deserve greater weight than the uncertainty created by the potential difference between submitted and processed demand, and we suggest using this format.

4.3 Scenario C

For scenario C, we suggest the use of an SMRA or one of the variants, noting, however, that these would only make a difference in relation to the 26 GHz band, where there are five identical lots. For the 3.4 – 3.8 GHz band it would not make a difference whether we use a traditional SMRA or an SMRA-Clock hybrid, as the spectrum in this band would be offered as seven specific lots in either case.