Final report for TELUS

Pro-competitive measures and coverage obligations in mid-band auctions

Mark Colville, Janette Stewart, Tom Upton

11 February 2022

Ref: 8884699769-74

Contents

Analysys Mason Limited
St Giles Court
24 Castle Street
Cambridge CB3 0AJ
UK
Tel: +44 (0)1223 460600
cambridge@analysysmason.com
www.analysysmason.com
Registered in England and Wales No. 5177472

1 Executive summary

In the 5G era, the focus of mobile network investment is on deploying new 'mid-band' spectrum as a means of introducing new mobile services. National regulators can opt to make mid-band spectrum available in different ways and may seek to satisfy differing objectives through pro-competition measures and coverage obligations. In its policy and licensing framework for the spectrum in the 3800MHz band, the Canadian government is considering several formulations of these options. As part of its response to the Canadian government's consultation, TELUS has asked Analysys Mason to compare how spectrum in the 3400–4200MHz band has been awarded in 24 high-income countries, which are all members of the Organisation for Economic Cooperation and Development (OECD). A summary of our key findings is as follows:

- **Canada is the only benchmark country using mid-band set-asides for public network operators.** Where set-asides have been used in mid-band auctions, these have generally been for the purpose of reserving a portion of spectrum for local, shared access use (e.g. for private networks, akin to proposals for the 3900–3980MHz band in Canada), which is a materially different form of set-aside.
- **Most OECD countries have used caps on total mid-band spectrum holdings**. Of the 24 countries in the benchmark set, 22 have used (or initially planned to use) auctions to assign mid-band spectrum and most of these **(19/22) have applied spectrum caps in these auctions.**[1]
- **Caps were set at an average level of 108MHz** in the benchmark countries, and **permitted at least 100MHz per operator in all cases other than Australia and New Zealand**, where limited spectrum was available.[2]
- **There are only six benchmark countries (including Canada) where no operator holds 100MHz.**
- In countries where there has been a restricted supply of spectrum, **final auction prices have risen to the highest levels**. Where such scarcity is artificially created (e.g. by set-asides), the high auction prices are no longer reflective of the market value of the spectrum.
- The average price paid in the Canada 3500MHz auction in July 2021 was **the highest in any mid-band auction that we are aware of globally, almost six times the OECD average**.
- Of the 24 countries examined, 12 (i.e. 50%) applied some form of specific coverage obligation to the mid-band spectrum, presenting a somewhat mixed picture. However, **there has been a clear trend towards the inclusion of coverage obligations or incentives in more recent mid-band auctions**, as the band and use cases have been progressively better understood.

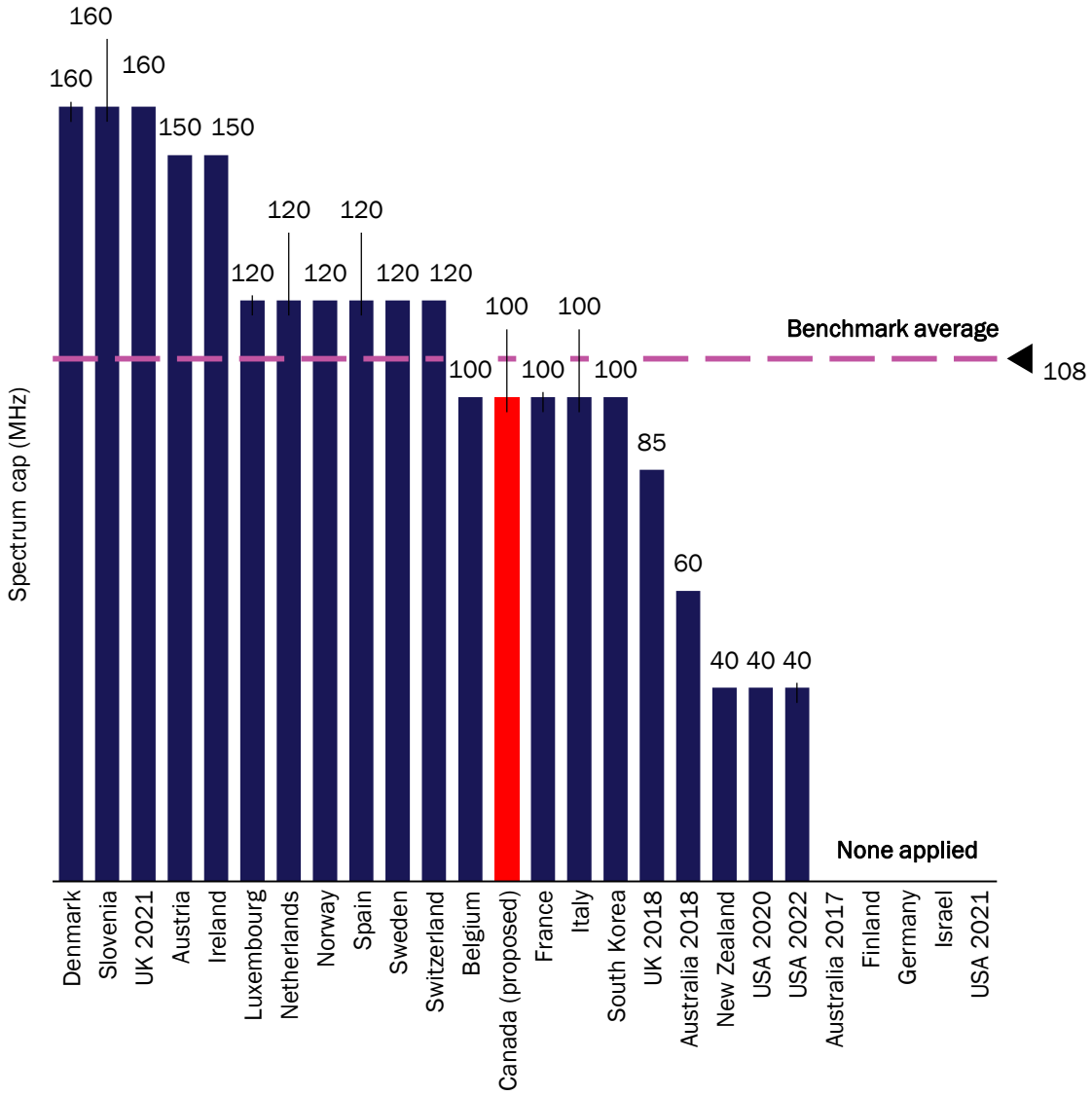
1 An effective cap could also be considered to be in place in the two countries assigning the mid-band spectrum administratively.

2 In the USA, there were caps of 40MHz in two mid-band auctions, but a further auction of 290MHz of spectrum means that no overall cap below this 100MHz level applies when considering the three mid-band auctions in aggregate.

- **Coverage obligations or incentives are an important component of a spectrum auction** for ensuring that spectrum is deployed extensively and in an efficient manner. This is especially true in Canada due both to its unique geography and its use of set-asides.
- **Options for offering coverage incentives rather than just obligations may be relevant and could be explored further in Canada** in the context of the 3800MHz auction.
- **With onerous coverage obligations, final prices paid are typically lower**. This should be factored into reserve prices that are to be set in Canada.

We recommend that the Innovation, Science and Economic Development department of the Government of Canada (ISED) should consider the international best practice set out in this report, in relation to both pro-competitive measures and coverage obligations in mid-band auctions, in finalising the design of the Canadian 3800MHz spectrum auction.

Figure 1.1: Summary of the size of spectrum caps in the benchmark countries using auctions [Source: Analysys Mason, 2022]



2 Introduction

This report sets out the findings of a study conducted by Analysys Mason on behalf of TELUS – to compare pro-competitive measures and coverage obligations associated with the licensing of spectrum in the 3400–4200MHz frequency range in 24 high-income benchmark countries selected from members of the Organisation for Economic Cooperation and Development (OECD), as shown in Figure 2.1.[3]

Figure 2.1: Benchmark countries selected from members of the OECD [Source: Analysys Mason, 2022]

Benchmark countries					
Australia	Austria	Belgium	Canada	Denmark	Finland
France	Germany	Iceland	Ireland	Israel	Italy
Japan	Luxembourg	Netherlands	New Zealand	Norway	Slovenia
South Korea	Spain	Sweden	Switzerland	UK	USA

The 3400–4200MHz spectrum band is often referred to as 'mid-band spectrum', and is the focus of initial 5G deployments in many countries around the world as a means of introducing new mobile services such as smart manufacturing and other Internet of Things (IoT) technologies. It is unique among the principal 5G candidate bands in offering a good combination of capacity and coverage benefits. It provides substantial additional capacity to meet rising demand, together with sufficient reach to enable similar levels of coverage to 4G services (delivered using lower-frequency spectrum) using the existing set of cell-sites.

The context of the report is the consultation on a policy and licensing framework for the 3800MHz band (3650–3900MHz) licences in Canada, published by the Canadian government in December 2021, following the June 2021 auction of the 3500MHz band (3450–3650MHz). The consultation presents the policy objectives for making the 3800MHz band available for flexible use, proposes pro-competitive measures that would be applied in the auction and post-auction marketplace, and the conditions of licence, including the coverage obligations. TELUS requested that we compare the proposals in 24 benchmark countries with those in Canada.

This report compares how spectrum in the 3400–4200MHz range has been awarded in 24 higher-income OECD countries. Our analysis aims to provide a comparison of award mechanisms for spectrum in the 3400–4200MHz range, with regard to:

- The pro-competitive measures applied in spectrum awards, including use of spectrum caps, set-asides and spectrum leasing.

[3] The selected countries are the higher-income OECD countries based on a ranking by GDP by capita. Based on the most-recent published OECD data, the Czech Republic could be included in this list (in place of Spain), but for consistency with our previous work for TELUS, we have retained the same set of countries as was studied last year.

- The coverage obligations attached to licences, such as roll-out obligations, use-it-or-lose-it conditions[4] and other deployment requirements; how the regulator has defined these obligations; and how compliance will be tracked and measured.

- The reserve price and the final prices paid for spectrum licences in each market.

Our focus during this analysis has been to benchmark the approaches followed in the countries under study. Where relevant, we highlight important findings to draw out their potential implications for the upcoming Canadian auction. However, we have not evaluated the market context or undertaken a competition analysis of the Canadian context. Hence, we do not seek to make recommendations on whether or not specific approaches may be appropriate in the Canadian context.

The remainder of this document is laid out as follows:

- Section 3 describes pro-competitive measures applied in auctions in the benchmark countries for mid-band spectrum between 3400MHz and 4200MHz
- Section 4 compares coverage obligations attached to these spectrum licences in the benchmark countries
- Section 5 presents normalised benchmarks of prices paid for mid-band spectrum in the benchmark countries
- Section 6 sets out the key findings of our analysis, and the potential implications for the Canadian 3800MHz consultation proposals.

This report also includes two annexes:

- Annex A provides a high-level summary comparing mid-band auctions in the benchmark countries
- Annex B sets out details of the spectrum caps applied in 3400–4200MHz auctions in each of the benchmark countries.

4 Whereby if an operator fails to deploy spectrum within a set time period the operator can lose access to that spectrum.

3 Pro-competitive measures in auctions of 3400–4200MHz spectrum

In Canada, the Department of Innovation, Science and Economic Development (ISED) issued a consultation on whether to use a spectrum set-aside or a cross-band spectrum cap across the 3500MHz and 3800MHz bands, and whether they should be applied separately or together, as outlined below:

- Option 1: a 50MHz set-aside
- Option 2: a 100MHz cross-band cap across the 3500MHz and 3800MHz bands
- Option 3: a 50MHz set-aside and a 100MHz cross-band cap.

In the remainder of this section, we consider spectrum caps, set-asides and other pro-competitive measures used by regulatory authorities to prevent excessive spectrum concentration (to the detriment of fair and effective competition) that have been applied in our benchmark set of 24 countries.[5]

At the outset, it is important to note that the usage of the 3400–4200MHz range differs across the benchmark OECD countries in that in Europe, only 3400–3800MHz is used for the provision of public network services (mobile or fixed-wireless access (FWA)). The 3800–4200MHz range is not generally used for high-power public mobile services in European countries in order to protect current satellite users of the band. We are now starting to see some European countries, for example the UK and Norway, permitting local (low-power) use in this band, but through a first-come-first-served administrative assignment rather than via auctions.[6] The Radio Spectrum Policy Group (RSPG) of the European Commission is studying the band for shared use as part of the Radio Spectrum Policy Programme (RSPP) and hence we would expect that more European countries are likely to follow similar approaches to the UK and Norway in the coming years. We understand this to be similar to the intended shared access local licensing use of the 3900–3980MHz spectrum in Canada.

As such, mid-band spectrum that is comparable to the 3500MHz and 3800MHz bands in Canada can extend from 3400MHz up to 4200MHz in some OECD markets, but in others (including the whole of Europe) will only extend up to 3800MHz. We take this into account in our benchmarking by considering only the 3400–3800MHz portion of the mid-band in our European benchmark countries.

5 We note that in markets that are already competitive, the aim of any pro-competitive measures should be to protect or maintain the level of competition (rather than to increase it).

6 In Norway, the public consultation on assigning this band states that, though anyone is allowed to apply, the band should not be used to expand coverage or capacity of nationwide mobile networks.

3.1 Most benchmark OECD countries use spectrum caps

Within our 24 benchmark countries, mid-band spectrum has been assigned, or an assignment is planned, in all countries:

- Of these 24 countries, spectrum has been assigned administratively in three cases (Iceland, Japan and New Zealand). However, in New Zealand, the national regulator published auction rules prior to the Covid-19 pandemic, but delays in holding the auction due to the pandemic meant that it ultimately opted to assign the spectrum directly to the mobile operators. For the purposes of our analysis, we have therefore considered the auction rules that were proposed for use pre-pandemic in New Zealand.

- In the 22 countries where auctions have been, or were planned to be, used (or are planned to take place), 19 feature spectrum caps to address potential competition issues from an uneven distribution of spectrum among wireless operators in a given market.[7] We note in this context that the UK and USA have each held more than one 5G auction of mid-band spectrum (as Canada plans to do). In the UK, both auctions have used the same levels of spectrum caps (37% limit on total mobile spectrum holdings), while in the USA, two of the three auctions have included spectrum caps (at the same level of 40MHz within an individual licence area).

- The benchmark set of countries includes two auctions currently being planned. In Belgium, the regulator is set to hold a mid-band auction in 2022 and in the Netherlands, a mid-band auction is planned for later in 2022 but is currently delayed due to legal proceedings related to a mobile satellite service (MSS) Earth station previously authorised to use part of the spectrum. Plans for both auctions involve the use of spectrum caps.

- Overall, in 19 of the 24 countries considered and 21 of the 26 auctions, spectrum caps were or will be imposed.

- In these 21 auctions, a conservative approach to averaging suggests the average cap was 108MHz per operator.[8]

- Of the 22 countries that have so far assigned mid-band spectrum, there are only seven countries, including Canada, where no operator has a contiguous holding of at least 100MHz (Australia,

7 Competition issues might arise through the risk of competition being affected as a result of some operators holding materially more spectrum in total than other players, or through some operators holding more spectrum of a particular type. The latter effect most commonly occurs in relation to holdings of sub-1GHz spectrum, which is not the primary interest of this study. Hence, we are more interested in comparing total spectrum caps between countries, which refer to caps to limit the overall share of spectrum that individual operators can bid for.

8 Note that this average is reduced by inclusion of the USA where 40MHz caps applied in two auctions of 100MHz each, whereas no cap applied in a separate auction of 290MHz of mid-band, meaning that across the three auctions there was effectively no meaningful cap on individual operators. In various countries including the UK and Austria, asymmetric caps applied depending on existing spectrum holdings in other bands: in these cases, we record the cap at the level of the most restrictive cap on the operator with greatest prior spectrum holdings. In the UK case, we also note that the 85MHz cap on EE in the first (2018) auction was effectively an intermediate cap that was raised to a minimum of 160MHz across the whole band for the 2021 auction.

Canada, France, Germany, Italy, New Zealand and Spain). However, in Spain, two operators do hold over 100MHz, but this spectrum is not all contiguous due to fragmentation arising from legacy assignments to FWA operators. In the other six countries, including Canada, the reason is that the total amount of spectrum licensed in the mid-band is less than 100× the number of national mobile operators.[9] Canada will, however, move out of this category once the 3800MHz auction concludes (with a total of 450MHz of mid-band spectrum assigned), meaning that holdings of 100MHz for at least some national mobile network operators (MNOs) would be expected.

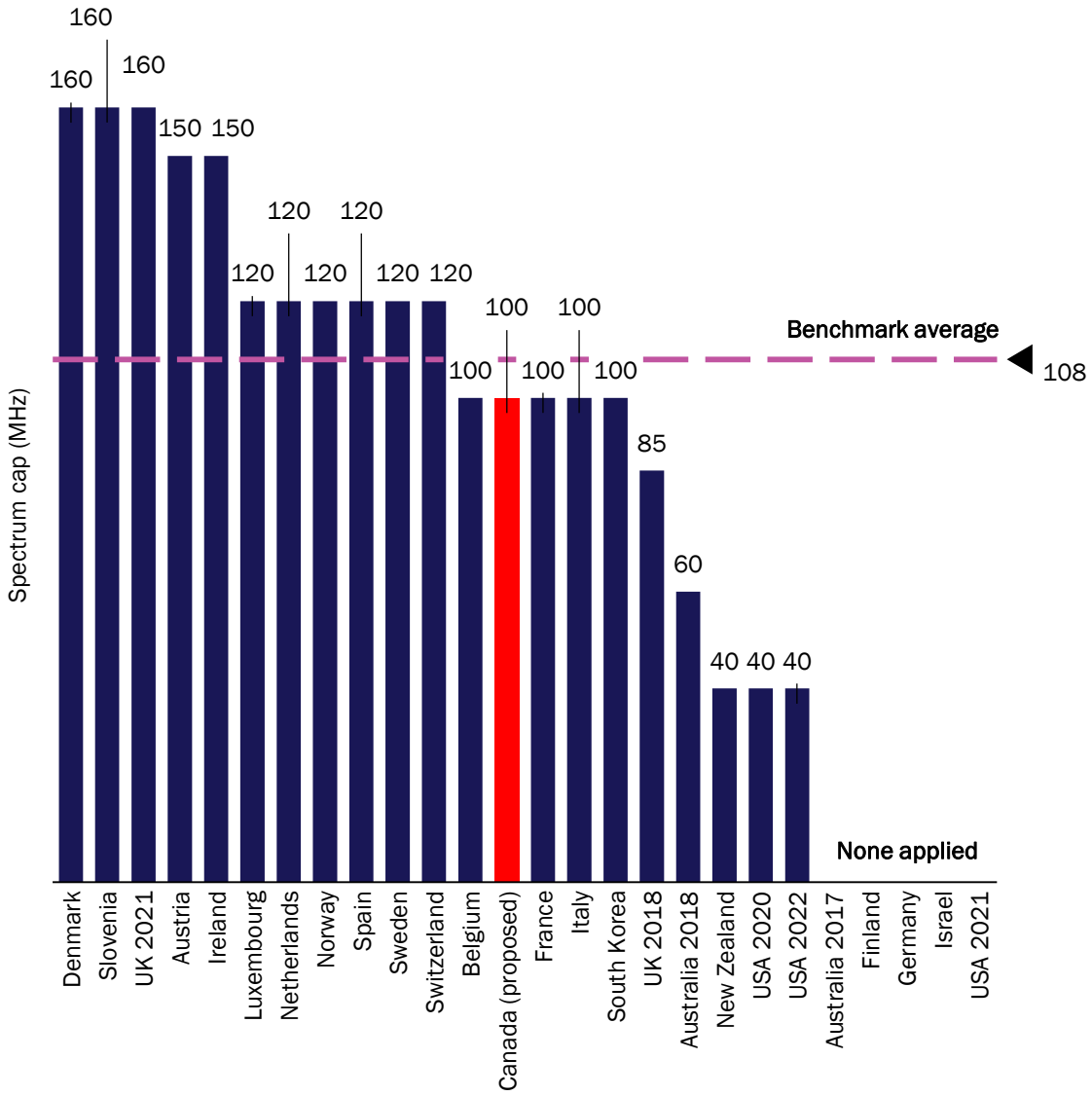
- In nine countries (Austria, Denmark, Finland, Iceland, Israel, Japan, Luxembourg, Slovenia[10] and Sweden), all national MNOs have at least 100MHz of contiguous spectrum in the mid-band. The same outcome is currently expected in Belgium and the Netherlands, given the proposed auction designs and market structures in these countries.

A summary of the nature of the auction and spectrum caps that were applied is shown in Figure 3.1 and further detail is provided in the table in Annex B. The bar for Canada represents the proposed spectrum cap for the upcoming 3800MHz auction, similar to our treatment of the upcoming auctions in Belgium and the Netherlands, rather than representing a cap applied in a previous auction.

9 For example, in Italy there are four national MNOs, but only 200MHz is assigned in total (average 50MHz per MNO). Germany and France are also four-MNO markets, with 300MHz and 310MHz assigned respectively. In New Zealand only 160MHz has been assigned, whilst in Australia only slightly over 125MHz is in use.

10 We exclude the smallest operator, T-2, in Slovenia, which did not acquire any mid-band spectrum.

Figure 3.1: Summary of the size of spectrum caps in the benchmark countries using auctions [Source: Analysys Mason, 2022]



3.2 Canada is the only benchmark country using mid-band set-asides for public network operators

We begin this section by noting that two very different types of set-aside have been used for mid-band spectrum. These set-asides can either be:

- For smaller or regional players (or new entrant) public network operators – i.e. to exclude specific operators, generally larger players, from bidding for a subset of the spectrum.
- To enable the deployment of private networks used by enterprises or industrial companies, rather than for public network operators.

These two types of set-aside are materially different in that in the private network case, spectrum is earmarked for low-power/shared licensing, but is still open to any player wishing to apply for an assignment of the set-aside in a specific local area (e.g. a large MNO can still apply for a local licence to provide a private network to an enterprise customer). Assignments of this type are also typically carried out administratively (e.g. first-come, first-served) rather than through an auction process.

Our analysis shows that only five of the countries investigated have implemented mid-band auction measures in the form of spectrum set-asides. However, in four of these cases, the mid-band spectrum set-aside is to enable the deployment of private networks, rather than for public network operators. **Canada is the only market within the benchmark set where a set-aside for smaller players or (new-entrant) public network operators has been implemented in mid-band spectrum**, as shown in Figure 3.2.

We note that set-asides for new entrants and smaller players have been used in a small number of cases in other mobile spectrum bands (e.g. the 800MHz band in the Netherlands and the UK), but not generally in the mid-bands. Instead, regional licensing has been a more common way to enable smaller regional operators to obtain spectrum. Licences were assigned on a regional basis in Australia, Austria, Canada, Ireland and the USA, in conjunction with spectrum caps in four of these countries (with a set-aside proposed in Canada).

We also note that conditions similar to set-asides have been imposed in some other OECD countries that are not included in our analysis (e.g. Czech Republic). In the Czech Republic auction of 3600–3800MHz spectrum in 2017, 200MHz was made available with spectrum caps of 40MHz for the three incumbent operators and 80MHz for a new entrant. As a result, there was an effective reservation of 80MHz for new entrants. It transpired that two new entrants acquired spectrum: Nordic Telecom 5G won 80MHz and PODA won 40MHz, whilst incumbents O2 and Vodafone won 40MHz each. Fellow incumbent T-Mobile bid but failed to win any spectrum, so in effect the reservation made little difference in that T-Mobile was outbid by new entrants in any event.

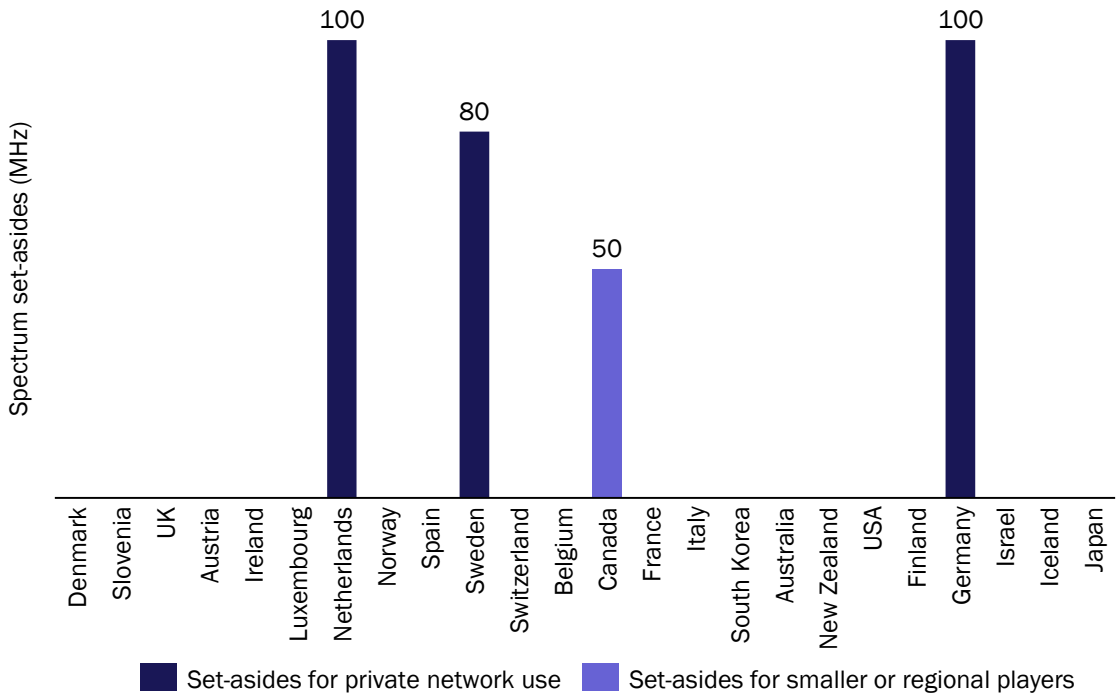
The regulator in the Czech Republic subsequently auctioned additional mid-band spectrum in 2020, in the 3400–3600MHz band, in which all operators (incumbent and the new entrants) acquired additional mid-band spectrum. The 2020 auction included a leasing obligation on two entities to support private 5G deployment. The ‘de facto’ set-aside obligation used in the 2017 auction was not used in the 2020 auction.

Finally, it is possible that spectrum caps on existing operators can deliver something like a set-aside. However, this form of indirect set-aside is likely to have entirely different outcomes at auction from direct set-asides where the remaining spectrum has no, or less-stringent, caps, since the latter can result in high bidding for ultimately highly asymmetric assignments.

In Europe, it is noted that the European Commission has recommended use of the 3800–4200MHz band for ‘local vertical applications’ (specifically low/medium-power base stations, intended for local coverage, potentially for private 5G network deployment for enterprise or industrial users).

Thus, it seems likely that other European markets might follow the direction taken in some European markets already (e.g. UK and Norway) to set aside spectrum in the 3800–4200MHz band for local, enterprise and industrial, networks.[11] Again, we understand this to be similar to the intended shared access local licensing use of the 3900–3980MHz spectrum in Canada, and so European set-aside in the 3800–4200MHz band are not really relevant to the 3800MHz auction in Canada (and hence are not included in Figure 3.2).

Figure 3.2: Summary of the size of spectrum set-asides in the mid-bands in our benchmark countries [Source: Analysys Mason, 2022]



3.3 Other measures

In the benchmark set of countries, three countries have licensed mid-band spectrum with a leasing obligation attached. In Finland and Norway, the entire spectrum assignment contains an obligation to provide industry with local access to the network, and the same applies to a single 60MHz block in Denmark. In countries with leasing obligations, the obligations are described in Figure 3.3.

Figure 3.3: Summary of leasing obligations on spectrum to promote competition [Source: Analysys Mason, 2022]

Country	Other measures taken to promote competition
Denmark	• A single 60MHz block included in the auction of 3410–3800MHz included a leasing obligation where the operator is obliged to lease frequencies within this range to enterprises (or other parties) for the provision of private networks in specific locations

11 RSPG21-024final_RSPG_Opinion_Additional_Spectrum_Needs.pdf (rspg-spectrum.eu)

Country	Other measures taken to promote competition
	• Requests can only be submitted in the first four years of the spectrum licence (i.e. until April 2025) and administered on a first-come-first-served basis
Finland	• As part of the licence agreement for the three 130MHz blocks, operators are obliged to provide a network suited to the needs of private industries under reasonable and non-discriminatory terms
Norway	• Operators are obliged to provide customised solutions upon request for local use (i.e. private 5G networks). As part of this obligation, operators are also required to accommodate requests to lease frequencies within the frequency range licensed to them for deployment of private 5G networks in limited geographical areas, based on market demand

4 Coverage obligations

We understand that ISED is proposing coverage obligations for the licensing of spectrum in the 3800MHz band. These obligations will require licensees to meet different coverage targets in specific geographical areas. Specifically:

- In the Tier 4 service areas of Montreal, Toronto and Vancouver:
  - 90% of the population in its mid-band mobile long-term evolution (LTE) network footprint within five years
  - 97% of the population in its mid-band mobile LTE network footprint within seven years
  - 95% of the population outside the large urban population centres within ten years.
- In tiers that contain a large population centre but excluding Montreal, Toronto and Vancouver:
  - 90% of the population in its mid-band mobile LTE network footprint within seven years
  - 97% of the population in its mid-band mobile LTE network footprint within ten years
  - 95% of the population outside the large urban population centres within ten years.
- In tiers that do not contain a large population centre:
  - 90% of the population in its mid-band mobile LTE network footprint within seven years
  - 97% of the population in its mid-band mobile LTE network footprint within ten years.

In addition, ISED will impose general deployment requirements for minimum levels of population coverage to be achieved within individual service areas by specified dates.

In the remainder of this section, we consider the coverage obligations and roll-out conditions that have been applied in the 24 benchmark countries and then consider, at a high level, the implications for Canadian policy in this area.

4.1 The use of mid-band coverage obligations within the benchmark OECD countries presents a mixed picture

Of the 24 countries examined, a total of 12 (i.e. 50%) applied some form of specific coverage obligation to the mid-band spectrum:

- Nine (Canada, Germany, Iceland, Israel, Japan, the Netherlands, Norway, Slovenia and the USA) applied coverage obligations or offered coverage incentives associated with the full range of mid-band frequencies offered in each market.
- A further three countries applied coverage obligations for entities acquiring certain blocks of spectrum (Denmark, France and Italy).

We note that coverage obligations tend to be more prevalent for lower frequency, and especially, sub-1GHz spectrum in most countries, whilst their usage for mid-band spectrum is more mixed.

Of the mid-band coverage obligations benchmarked, Germany has some of the strictest coverage obligations, requiring 98% of households to be covered in a relatively short time frame (within about 3.5 years from the date of the auction). On the other hand, Iceland (30 sites within a year) and Slovenia (11 cities within five years) arguably have some of the most relaxed obligations (amongst those countries imposing any obligations), although it is difficult to compare precisely how onerous different forms of coverage obligation are since the cost of coverage depends on both geography and demographics, amongst other things.[12]

Whilst most of these countries have applied an obligation, some countries have, in whole or in part, used an incentive mechanism. Incentives for increasing coverage are offered in three countries – Germany, Israel and Norway – and involve a reduction in the spectrum costs if operators can reach certain coverage targets. No target has actually been set in Germany; instead, operators can claim back EUR150 million of spectrum fees, which must be earmarked for investment into highway and motorway coverage.[13]

We note that in other bands, similar incentive mechanisms have also been applied in some benchmark countries. For example, both Austria and Denmark implemented a form of reverse auction for taking on coverage commitments after the spectrum assignment had first been determined via a 'forward' auction. In other words, operators could bid to take on additional coverage commitments, with the lowest bidder receiving a corresponding discount on its spectrum auction fees in exchange for taking on the additional commitments.

Details of the coverage obligations and incentives are collated in Figure 4.1 below. Rows coloured green symbolise where incentives have been used in place of coverage obligations, whilst the orange-coloured row (Germany) denotes that both obligations and incentives were used.

Figure 4.1: Details of coverage obligations and coverage incentives in our benchmark countries [Source: Analysys Mason, 2022]

Country	Coverage obligations/incentives
Canada	• For the 2021 3450–3650MHz auction, as a licence condition, operators are required to meet certain coverage obligations depending on whether the licence area is classed as containing a large population centre or not • General deployment conditions require minimum levels of population coverage (up to 70%) to be achieved within individual service areas by specified dates • Additional coverage requirements apply to mobile LTE service providers:

12 For example, we estimate that the most populous 11 cities in Slovenia are home to less than 30% of the population of 2.1 million.

13 Note that this coverage incentive relating to highways and motorways is separate to the 98% population coverage obligation mentioned above.

Country	Coverage obligations/incentives
	– for areas with a large population centre, 90% coverage of the population in urban areas[14] must be achieved within 5 years and 97% within 7 years; in rural areas, 95% within 10 years – for areas without a large population centre, in urban areas[14] 90% coverage of the population should be achieved within 7 years and 97% within 10 years (but there is no obligation for rural areas) ● These obligations will be calculated based on the most recent census information available at the time
Denmark	● 390MHz (3410–3800MHz) was auctioned in three 80MHz blocks (with coverage requirements), one 60MHz block (with a leasing obligation) and nine 10MHz blocks ● For the three 80MHz blocks, there was an obligation to cover 60% of the population with these frequencies by the end of 2023 and achieve 75% population coverage by the end of 2025 ● For the nine 10MHz blocks, operators are required to have 100 masts equipped with the frequency by the end of 2023 ● In order to validate the coverage requirements, each base station is assigned a coverage radius depending on the population density of the area it is in
France	● In the French auction four 50MHz blocks were assigned, with coverage obligations, to the four existing mobile operators and the remaining 110MHz was auctioned in blocks of 10MHz ● For the four 50MHz blocks with coverage obligations, the spectrum must be deployed, and 5G services provided, on at least 3000 sites by the end of 2022, 8000 by 2024 and 10 500 by 2025
Germany	● Licensees from the June 2019 German auction are required to provide 100Mbit/s coverage to all federal motorways and highways and to at least 98% of households by the end of 2022 ● In order to provide motorway and highway coverage, operators can claim a rebate on up to EUR150 million of the spectrum licence fee (to be invested in providing this coverage) ● New entrants do not have to meet the coverage obligations
Iceland	● As part of the 2020 direct assignment of 3500–3800MHz, short-term licences were extended if, by the end of 2021, the operator offered 5G services to at least 25% of the population (at least 30 sites); each operator was provided with two designated towns in which it had to provide services ● It is expected the licences will be extended, with further obligations required as part of the extension
Israel	● In return for a quick 5G deployment (finished within five years) the regulator offered deployment incentives, principally a reduction in the level of spectrum fees payable annually for the first four years post-award, plus government funding for establishing defined new sites
Italy	● 200MHz (3600–3800MHz) was auctioned via two blocks of 80MHz and two blocks of 20MHz ● For the two 80MHz blocks there were coverage obligations attached ● Operators must provide coverage to a every town/municipality with over 5000 residents, with the regulator providing both winning operators with a list of the areas this obligation entails
Japan	● As part of the beauty contest, operators were required to cover 50% of the population using the frequency within five years

14 For deployment within the existing mid-band mobile LTE network footprint as of 5 June 2019.

Country	Coverage obligations/incentives
Netherlands	• The Netherlands plans to auction 300MHz (3450–3750MHz) in three blocks of 60MHz and 12 blocks of 10MHz • For the 60MHz blocks, operators will be required to cover at least 324km^2 (0.8%) within two years and 3216km^2 (8%) within five years • For the 10MHz blocks, operators must cover at least 54km^2 (0.1%) within two years and 536km^2 (1.3%) within five years
Norway	• 400MHz (3400–3800MHz) was auctioned in four blocks of 40MHz and 24 blocks of 10MHz between four operators • In order to incentivise coverage, operators can obtain a discount on the auction price by providing 100Mbit/s coverage in rural areas • To validate the fulfilment of the obligation, the Norwegian Communications Authority will carry out a detailed coverage survey
Slovenia	• 380MHz (3420–3800MHz) was auctioned in blocks of 10MHz as part of a multi-band auction • As part of the licence, operators were required to provide 5G services to 11 major cities (constituting less than 30% of the population) within five years
USA	• In 2020, 70MHz of spectrum between 3550MHz and 3650MHz was auctioned across 3233 areas in blocks of 10MHz • Following the 2020 auction, licensees must provide substantial service in the licensed area • Failure to fulfil the obligation will result in the licence being forfeited and the operator will be ineligible to regain the spectrum • In 2021, 280MHz (3700–3980MHz) was auctioned in 14 blocks of 20MHz over 406 areas • Following the 2021 auction, licence winners must provide reliable signal coverage using the frequency to 45% of the population within eight years and to at least 80% of the population within 12 years • Operators are required to demonstrate compliance by filing construction notification with the Federal Communications Commission and using census data as evidence for the population coverage • An auction of 100MHz (3450–3550MHz) occurred in early 2022 in blocks of 10MHz using the same 3233 areas used in 2020 • Following the 2022 auction, licensees must provide reliable signal coverage to 45% of the population in the area within five years and 80% within eight years (this is a shorter time frame than for the 2021 auction) • If a licensee fails to meet the criterion of 45% coverage within five years, the time frame for the second target of 80% coverage is reduced by one year (from eight years to seven years from when the term began • If a licensee fails to achieve the second target, it will lose the spectrum and be unable to regain it

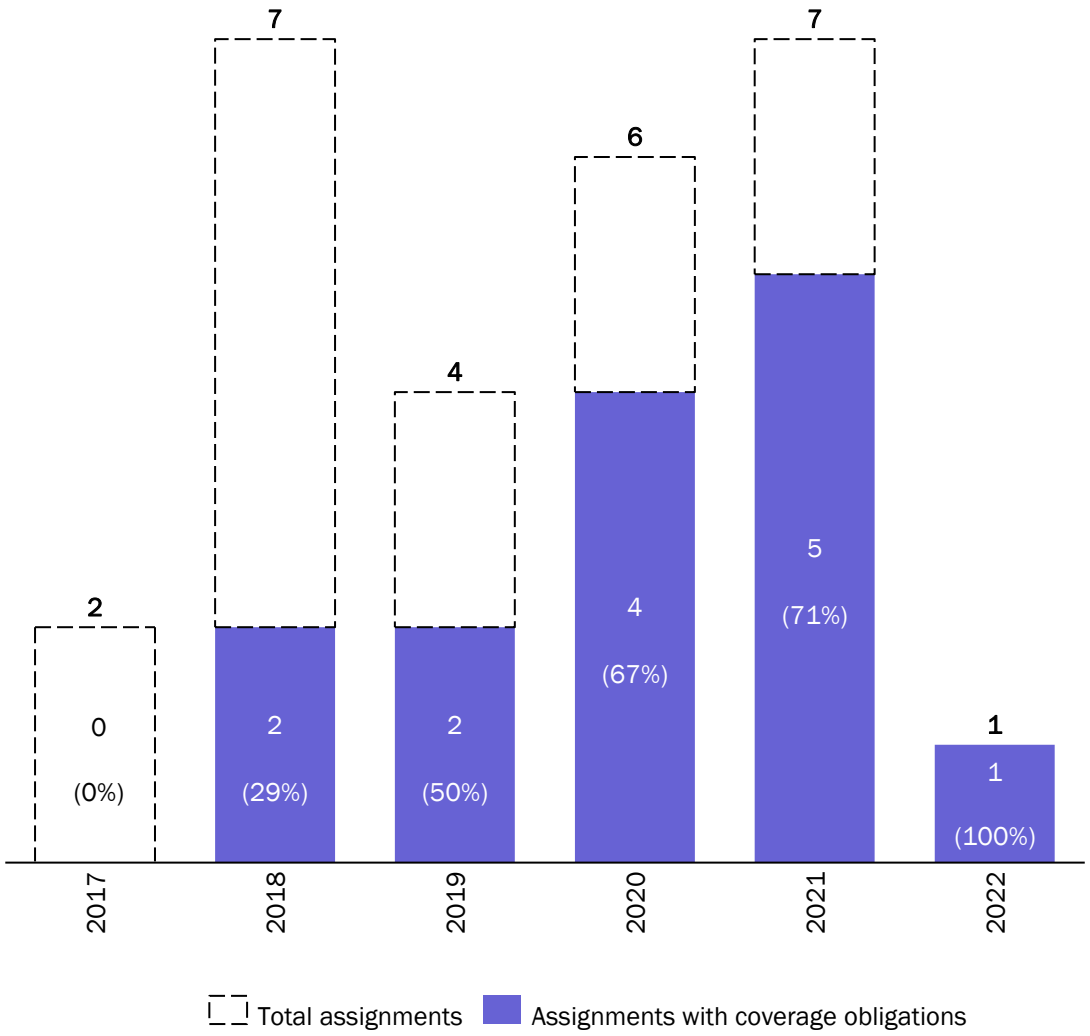
4.2 The inclusion of coverage obligations/incentives in Canada makes sense, but there are options for how these could be implemented

Coverage obligations or incentives are an important component of a spectrum auction for ensuring that spectrum is deployed extensively and in an efficient manner. This is especially true in Canada, a country that includes a very large rural area, since commercial incentives to expand coverage may be lower than in other countries. It is also especially important in the context of pro-competitive measures, and set-asides in particular. In the 3500MHz auction in Canada, set-asides were used, and there is a possibility that they will be used again in the 3800MHz auction.

Both of the above factors therefore point towards the particular importance of the inclusion of coverage obligations or incentives to ensure that the spectrum in the Canadian 3800MHz auction is used efficiently, and that the public benefit to the greatest extent possible from the licensing.

Internationally, there is a mixed picture regarding the inclusion of mid-band coverage obligations or incentives within the benchmark OECD countries. However, in part this is due to the use cases for the band not being as well understood by regulators or operators when initial assignments took place. There has been a clear trend towards the inclusion of coverage obligations or incentives in more recent mid-band auctions, as the band and use cases have been progressively better understood, as shown in Figure 4.2.

Figure 4.2: Proportion of benchmark spectrum assignments including a coverage obligation or incentive by year [Source: Analysys Mason, 2022][15]



Whilst the inclusion of a coverage obligation or incentive in Canada appears to make sense, the form of asymmetric obligations (applied for 3500MHz and proposed for 3800MHz) in Canada is relatively unusual, at least in mid-band spectrum. This is in the sense that the coverage requirements increase for operators with a greater LTE network footprint. With this type of obligation, care is needed, especially in the context of national roaming obligations being in place, as is the case in Canada, to ensure that all licensees have the right incentives to roll out networks extensively. An asymmetric coverage obligation combined with a national roaming service may run the risk of smaller operators lacking sufficient incentive to provide extensive coverage on their own networks. This risks an inefficient use of the spectrum that is proposed to be set aside for smaller operators in Canada if smaller operators do indeed lack incentive to invest in their own network build (and thereby only use their licensed spectrum within a potentially small portion of the licensed area).

15 Note that 2022 excludes planned future auctions where coverage obligations are not yet fully determined, although they are expected in the Netherlands, but the situation is less clear in Belgium.

We have not carried out a full review of the Canadian market or the most appropriate form of coverage obligations to implement, but we note that options for offering coverage incentives rather than just obligations may be interesting and could be explored further in Canada in the context of the 3800MHz auction. For example, partial rebates on the (high) spectrum auction prices that are expected when rolling out networks more extensively could be effective in encouraging multiple operators to expand their networks.

5 Prices paid

From the auctions investigated in this report, a benchmark of auction prices is provided in this section. We have calculated auction prices on a normalised basis, for a 20-year licence duration, expressed in 2022 real terms.[16,17]

The results can be seen in Figure 5.1, expressed in CAD/MHz/pop for comparison with the proposed level of reserve prices in Canada. We have not included spectrum awarded via direct assignments (Iceland, Japan, New Zealand), upcoming auctions (Belgium, the Netherlands), or auctions in which there is little public data (Israel) in this benchmarking assessment.

As shown in Figure 5.1, Canadian spectrum prices in the 3500MHz auction are almost six times the OECD benchmark average (or over seven times the average excluding Canada). The average price paid at Canada's July 2021 auction, CAD2.34/MHz/pop.[18] was also the highest price paid of any mid-band auction to date in our analysis. It was 64% higher than the average price paid in the USA, the next highest average price paid in any country, around ten times higher than in France and eleven times higher than in the UK 2018 auction (which was itself around double the price of the UK 2021 auction) and thirty-three times higher than in Finland.

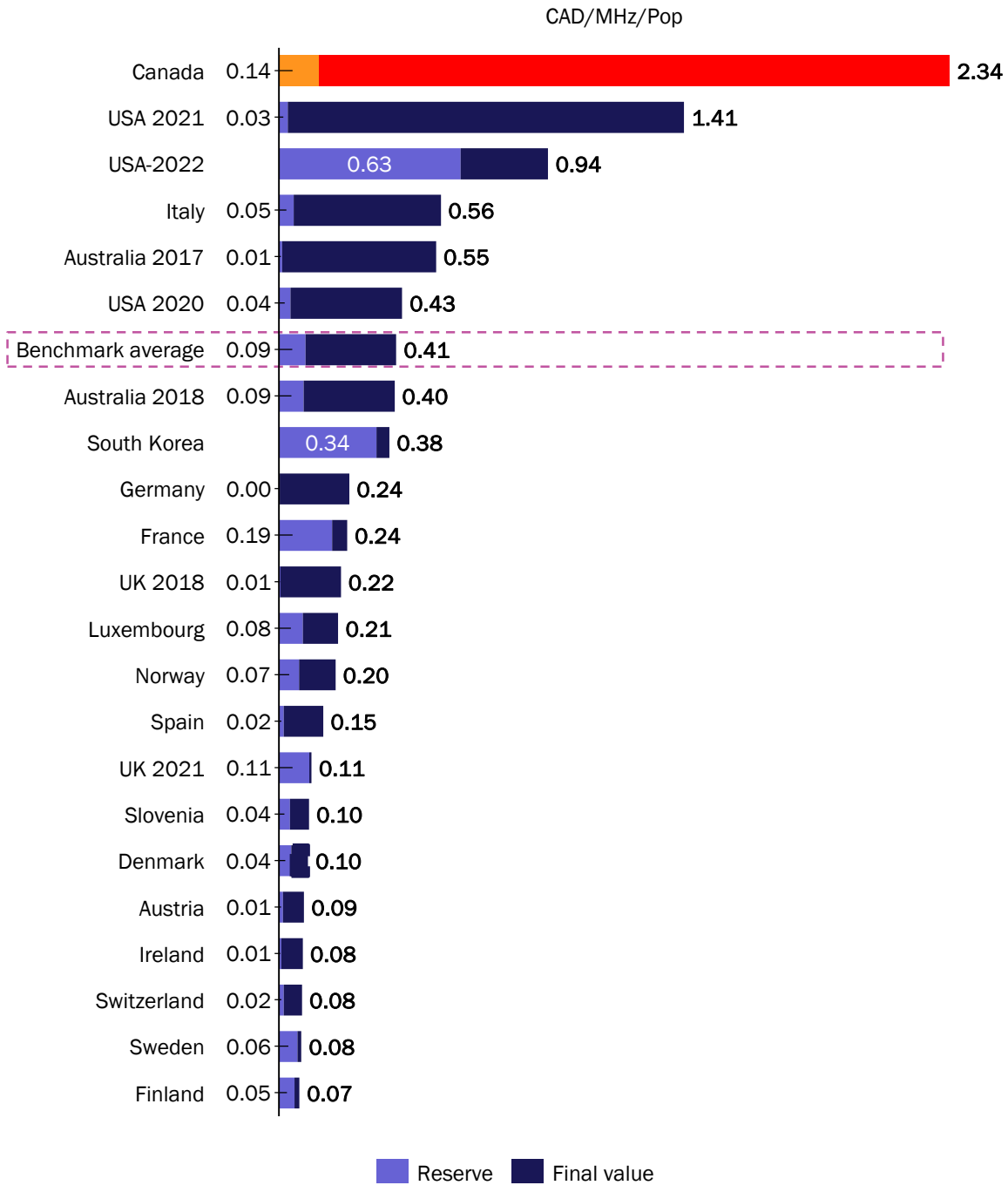
This high price was achieved despite coverage obligations, which can reduce the value of spectrum licences for operators, being in place.

16 Our normalisation also expresses the values normalised for the bandwidth offered in the auction and population of each market (i.e. values are expressed per MHz/pop), as well as accounting for any annual licence fees payable in addition to the up-front auction cost, which are amortised over the 20-year normalised term.

17 We note that the UK and USA offer indefinite licences. In the UK, annual licence fees at full market value of the spectrum are expected to be paid after the expiry of the 20-year initial term (but the licensee nonetheless benefits from a kind of option value on retaining the licences). In the USA, however, there has historically been a high expectation of renewal beyond the initial term, and in general only low or zero administrative licensing fees for renewed spectrum. This normalisation methodology may therefore somewhat overstate licence fees (for the fixed initial term) in the case of the USA in particular.

18 We note that the price paid in this auction by existing national operators in Canada (that were not able to benefit from set-asides) was CAD3.27/MHz/pop.

Figure 5.1: Final prices and reserve prices for mid-band auctions [Source: Analysys Mason, 2022][19,20]



19 The reserve price for Germany is CAD0.003/MHz/pop (rounded to 0.00 in our diagram).

20 The price of mid-band spectrum cannot be disaggregated for Denmark, the total price across all spectrum frequencies was 2.36× the reserve price, which under the high-level assumption of the same proportional increase over reserve price in each band, would imply CAD0.10/MHz/pop.

The 2022 USA auction's reserve price was the highest in the benchmarks shown in Figure 5.1, at CAD0.63/MHz/pop, almost double the next highest of South Korea, although this is largely due to a mechanism to transition incumbent users of the spectrum. Apart from the USA 2022 auction and the South Korean auction, reserve prices have not exceeded CAD0.20/MHz/pop in any benchmark country.

The reserve prices at the 3500MHz auction in Canada varied, according to location, from CAD0.24/MHz/pop down to CAD0.05/MHz/pop. The national weighted average was CAD0.14, which is higher than the final prices in eight of the benchmark auctions.

Across the auctions, the average reserve price was CAD0.091/MHz/pop and the average final price of spectrum was CAD0.409/MHz/pop. Therefore, for a 10MHz block auctioned for an area containing 2 million people, the average reserve price would be CAD1.810 million and the average final price would be CAD8.172 million.

ISED's proposals for the 3800MHz auction in Canada, which match the approach followed for the recent 3500MHz auction, include reserve prices of:

- CAD0.232/MHz/pop for service areas with a population over 2 million
- CAD0.1/MHz/pop for service areas with a population over 1 million but less than 2 million
- CAD0.065/MHz/pop for service areas with a population under 1 million that contain one or more metropolitan areas
- CAD0.051/MHz/pop for all other service areas.

Compared to the benchmarks from other countries described above, these reserve prices are higher than the benchmark average of CAD0.091/MHz/pop, noting that in most benchmark countries reserve prices are not differentiated by region. Again, this is despite the planned inclusion of coverage obligations in the Canadian 3800MHz auction, which are only incorporated (and often less stringently than in Canada) in half of the benchmark countries.

6 Conclusions

From our analysis, we have found that:

Spectrum set-asides are not commonly used in mid-band auctions, with spectrum caps being the most widely used pro-competitive approach for auctioning this type of spectrum

Our analysis shows that of the 24 countries in the benchmark set, 22 have used (or initially planned to use) auctions to assign mid-band spectrum and most of these (19/22) countries have applied spectrum caps in these mid-band auctions to avoid uneven distribution.

The caps, set at an average level of 108MHz, permitted at least 100MHz per operator in all cases other than Australia, New Zealand and the USA, although in the USA there was no overall cap below this level when considering the three mid-band auctions in aggregate. Caps allowing at least 100MHz per operator align with recommendations from 5G equipment vendors for cost-efficient mid-band deployment.

There are only six benchmark countries (including Canada) where no operator holds 100MHz, which in all cases is due to a relative lack of mid-band spectrum assigned to date. This will no longer be the case in Canada following the 3800MHz auction, at which point it would therefore be expected that at least some national MNOs should hold 100MHz of mid-band spectrum.

Spectrum was set aside in five countries, four for private networks and only in one (Canada) for smaller or new players operating public networks.

Regional licensing has been a more common way to enable smaller regional operators to obtain spectrum. Regional assignments were held in Australia, Austria, Canada, Ireland and the USA.

Another form of pro-competitive measure seen in some benchmark countries is spectrum leasing either to provision services for enterprise and industrial users, or to lease them spectrum in specific areas, reducing the need to set aside spectrum specifically.

Higher spectrum prices tend to occur in countries where spectrum set-asides have applied, or where there has been spectrum scarcity for other reasons

Our analysis also shows that for any countries with a restricted supply of spectrum, final auction prices have risen to the highest levels (and furthest above the regulator's reserve price).

The highest auction prices have been observed where a set-aside for smaller players was used (Canada), and where supply was heavily restricted (Australia, Italy and the USA). The approach to spectrum packaging has also contributed to very high spectrum prices in some countries (e.g. Italy).

Where such scarcity is artificially created by set-asides or other spectrum packaging approaches such as in Italy, the high auction prices are no longer reflective of the market value of the spectrum but rather are driven to an artificially high level. Although not the subject of this report, it is noted that this may have negative implications for the sustainability of licensees, their ability to invest in network deployment or the level of retail prices.

In the Canadian 3500MHz auction, the average price paid was the highest price paid in any mid-band auction that we are aware of globally

In this context, we observe that in the Canadian 3500MHz auction in July 2021, the average price paid (CAD2.34/MHz/pop) was the highest price paid in any mid-band auction considered in this report (and that we are aware of globally). The price was almost six times the OECD benchmark average (or over seven times the average excluding Canada). It was 164% of the average price paid in the USA, the next highest average price paid in any country, around ten times higher than in France and thirty-three times higher than in Finland.

Coverage obligations are an important component of mid-band auctions and may have benefits in the Canadian 3800MHz auction, but would be expected to reduce the price that operators are willing to pay for spectrum

Of the 24 countries examined, a total of 12 (i.e. 50%) applied some form of specific coverage obligation to the mid-band spectrum, presenting a somewhat mixed picture. However, in part this is due to the use case for the band not being as well understood by regulators or operators when initial assignments took place. There has been a clear trend towards the inclusion of coverage obligations or incentives in more recent mid-band auctions, as the band and use case have been progressively better understood.

Coverage obligations or incentives are an important component of a spectrum auction for ensuring that spectrum is deployed extensively and in an efficient manner. This is especially true in Canada, a country that includes a very large rural area, since commercial incentives to expand coverage may be lower than in other countries. It is also especially important in the context of pro-competitive measures, and set-asides in particular. In the

3500MHz auction in Canada, set-asides were used, and there is a possibility that they will be used again in the 3800MHz auction.

We have not carried out a full review of the Canadian market or the most appropriate form of coverage obligations to implement, but we note that options for offering coverage incentives rather than just obligations may be relevant and could be explored further in Canada in the context of the 3800MHz auction. For example, partial rebates on the (high) spectrum auction prices that are expected when rolling out networks more extensively could be effective in encouraging multiple operators to expand their networks.

Compared to other countries considered, the reserve prices proposed in the Canadian auction are relatively high

Onerous coverage obligations correspond to lower final auction prices, as bidders will factor the obligation costs into their bids. This should be factored into reserve prices that are to be set in Canada.

In this context, we note that the reserve prices for the Canadian 3800MHz auction are high compared to the benchmark average of CAD0.091/MHz/pop, noting that in most benchmark countries reserve prices are not differentiated by region. The national weighted average of reserve prices in the 3500MHz auction in Canada was CAD0.14, which is higher than the final prices in eight of the benchmark auctions, with a similar set of reserve prices by region proposed for the 3800MHz Canadian auction.

Annex A Summary table comparing mid-band auctions

Selected benchmark countries	Date(s) of principal auctions or assignment	Total MHz	Total MHz not set aside for local or new entrants, or shared	Duration of licences (years)	Benchmark price paid at[21] (CAD/MHz/ pop)	Number of MNOs with contiguous 100MHz on national basis
Australia	Oct-17 and Dec-18	125[22]	125	11	0.548 and 0.403	0
Austria	Mar-19	390	390	20	0.087	3
Belgium	2022	390	390	20	TBD[23]	TBD
Canada	Jul-21	111	64	20	2.337	0
Denmark	Apr-21	390	390	21	0.101	3
Finland	Oct-18	390	390	15	0.071	3
France	Oct-20	310	310	15	0.238	0
Germany	Jun-19	400	300	20	0.245	0
Iceland	Apr-20	300	300	1.5	-	3
Ireland	May-17	350	350	15	0.083	2
Israel	Aug-20	300	300	10	n/a	3
Italy	Oct-18	200	200	19	0.564	0
Japan	Apr-18 and Apr-19	700	700	5 and 5	n/a	4
Luxembourg	Jul-20	380	380	20	0.206	3
Netherlands	2022	400	300	20	TBD	TBD
New Zealand	Jul-20	160	160	2	n/a	0

21 Where known.

22 Plus a very small amount of spectrum assigned regionally between 3400MHz and 3575MHz, which we have not included in the national total assignment.

23 To be determined.

Selected benchmark countries	Date(s) of principal auctions or assignment	Total MHz	Total MHz not set aside for local or new entrants, or shared	Duration of licences (years)	Benchmark price paid at[21] (CAD/MHz/ pop)	Number of MNOs with contiguous 100MHz on national basis
Norway	Sep-21	400	400	20	0.197	3
Slovenia	Apr-21	380	380	20	0.105	3
South Korea	Jun-18	600	600	10	0.385	2
Spain	Jul-18	380	380	20	0.154	0
Sweden	Jan-21	400	320	25	0.078	3
Switzerland	Feb-19	300	300	15	0.080	2
UK	Apr-18 and Mar-21	390	390	20 and 20	0.216 and 0.113	1
USA	Sep-2020, Feb-21 and Jan-22	480	480	10, 15 and 15	0.429, 1.412 and 0.938	1

Annex B Benchmark of 3400–4200MHz spectrum caps

Country	Year of spectrum award	Spectrum cap used	Nature of the mid-band auction, and details of caps applied
Australia	2017 and 2018	Yes	• In 2017, a multiband auction was held for residual spectrum which included 14 geographical area blocks in the mid-band. These blocks varied in size from 2.5MHz to 32.5MHz and, whilst no competition limits were imposed, the holdings counted towards the spectrum cap in the 2018 auction. • Overall, this auction of regional blocks (unsold in an original auction to fixed wireless providers in 2000) has assigned very little mid-band spectrum to MNOs • In 2018, 125MHz (3575–3700MHz) was auctioned in 25 blocks of 5MHz in an auction referred to as the 3.6GHz auction • Four operators acquired spectrum in the auction • Spectrum blocks were offered across 14 geographical areas • **No single bidder could acquire more than 60MHz in each metropolitan area or more than 80MHz in other regional areas** • The caps were designed to restrict the amount of spectrum a single bidder could acquire from the 3.6GHz band auction, taking account of existing spectrum holdings across the 3400–3700MHz band • At the end of the auctions, the **four operators typically held between 50MHz and 90MHz** each across the different geographies • 3800–4000MHz is available for local licensing for private network use, whilst there are plans to assign 3700–3800MHz for wide area (public mobile) use, but this has not yet happened
Austria	2019	Yes	• 390MHz (3410–3800MHz) was auctioned in 10MHz blocks, with licences offered on a regional basis • Three national operators and four regional operators won spectrum in the auction • **A1 and T-Mobile (the two largest nationwide operators) were not permitted to bid for more than 150MHz of spectrum** and other operators could not acquire more than 170MHz • Across the different geographies the **three national operators received between 100MHz and 140MHz each**
Belgium	2022 (planned)	Yes	• In 2022, Belgium is expected to auction 390MHz (3410–3800MHz) in two blocks of 20MHz and 35 blocks of 10MHz

Country	Year of spectrum award	Spectrum cap used	Nature of the mid-band auction, and details of caps applied
			• Three existing mobile operators and one or more new-entrant operators are expected to bid in the auction • **A spectrum cap of 100MHz will be applied**
Canada	2021	No	• Spectrum between 3450MHz and 3650MHz was available in the 2021 3500MHz auction, due to existing assignments, for each of the 172 areas there was between 30MHz and 140MHz of spectrum available in blocks of 10MHz • **No spectrum cap was applied** • Given the geographical nature of the auction, no operator won spectrum across the entire country with Bell typically getting at least 30MHz outside of Quebec
Denmark	2021	Yes	• 390MHz (3410–3800MHz) was auctioned in three 80MHz blocks (with coverage requirements), one 60MHz block (with a leasing obligation) and nine 10MHz blocks • This spectrum was acquired by three operators • A **spectrum cap of 160MHz was applied** • **At the end of the auction Hi3G held 120MHz, TDC net secured 130MHz and a joint venture between Telenor and Telia won 140MHz**
Finland	2018	No	• 390MHz (3410–3800MHz) was auctioned in three blocks of 130MHz • Three operators acquired spectrum in the auction • No spectrum cap was applied, but as the number of blocks matched the number of existing operators, the structure suggested one overwhelmingly likely outcome (which indeed materialised) with **all three operators winning 130MHz** (i.e. this was an effective spectrum cap)
France	2020	Yes	• 310MHz (3490–3800MHz) was auctioned • Initially, each of the four operators was granted 50MHz (with coverage obligations) • Operators then bid on a further 11 blocks of 10MHz each • A **total cap of 100MHz** across the two auction phases was placed on each operator • At the end of the auction, **all four operators acquired between 70MHz and 90MHz** of spectrum
Germany	2019	No	• 300MHz was auctioned between 3400MHz and 3700MHz, with an additional 100MHz reserved for local (private network) use and to be authorised administratively outside of the auction structure

Country	Year of spectrum award	Spectrum cap used	Nature of the mid-band auction, and details of caps applied
			• The 300MHz that was auctioned was split into one block of 20MHz and 28 blocks of 10MHz • Four operators acquired spectrum in the auction with **two operators receiving 90MHz of spectrum and the other two operators receiving 50MHz and 70MHz respectively** • **No spectrum cap was applied**
Iceland	2020	Direct assignments made to operators	• In mid-2020 the Icelandic regulator assigned 300MHz (3500–3800MHz) to the three mobile operators • **Each operator received 100MHz of spectrum**
Ireland	2017	Yes	• 350MHz (3410–3435MHz and 3475–3800MHz) was auctioned on a regional basis • The 3410–3435MHz part consisted of one 25MHz block and the remainder was divided into 5MHz blocks • There were five winners, consisting of the three existing MNOs plus a fixed-wireless access (FWA) operator and a new-entrant wholesale-only network operator • A **spectrum cap of 150MHz** was applied • **Vodafone acquired the most spectrum with between 85MHz and 105MHz, Three acquired 100MHz nationwide, Meteor acquired between 80MHz and 85MHz**, Airspan achieved between 25MHz and 60MHz, and Imagine acquired 60MHz but only in rural areas
Israel	2021	No	• 300MHz (3500–3800MHz) was auctioned between three operators • **No spectrum cap** was applied • **All three operators acquired 100MHz**
Italy	2018	Yes	• 200MHz (3600–3800MHz) was auctioned via two blocks of 80MHz and two blocks of 20MHz • There were four winning bidders, acquiring licences for one block each • A **spectrum cap of 100MHz** was applied, accounting for existing 3400–3600MHz holdings • **Two operators won 80MHz and the other two operators won 20MHz**

Country	Year of spectrum award	Spectrum cap used	Nature of the mid-band auction, and details of caps applied
Japan	2016 and 2019	No	• Over two beauty contests[24] (2016 and 2019) all the spectrum between 3400MHz and 4100MHz has been assigned between four operators, each of which now holds at least 100MHz • **Rakuten, the newest entrant, holds 100MHz whilst the three more established operators hold between 180MHz and 240MHz** • No blocks of contiguous holdings are over 100MHz, with all four operators holding at least one 100MHz contiguous block
Luxembourg	2020	Yes	• 330MHz (3420–3750MHz) was split into five blocks of 40MHz and 13 blocks of 10MHz • It was auctioned between three operators • A **spectrum cap of 120MHz** per operator was imposed on the auction • **Two operators won 110MHz, a third operator won 100MHz** and 10MHz was won by an internet operator. A fifth bidder failed to win any spectrum
Netherlands	Planned for 2022, but likely to be delayed	Yes	• The Netherlands auction of what is referred to as the 3.5GHz band is currently postponed due to legal proceedings relating to incumbent use of the band and presence of a mobile satellite service Earth station in one location in the Netherlands • The original plan for the auction was to assign 300MHz (3450–3750MHz) in three blocks of 60MHz and 12 blocks of 10MHz • A **spectrum cap of 120MHz** was to be applied
New Zealand	2020	Yes	• In May 2020, the New Zealand regulator cancelled the (then) upcoming 3.5GHz auction in favour of direct assignment • In the planned auction, 160MHz (3590–3750MHz) would be split into 16 blocks of 10MHz • **A spectrum cap of 40MHz was to be applied (which would have likely ensured all four operators received 40MHz)** • **Vodafone already held 65MHz of spectrum. Two operators were assigned 60MHz and the fourth operator was assigned 40MHz**

24 A form of administrative assignment of spectrum licences, where the distribution of licences is not purely dependent on financial bids, but also on other factors such as coverage commitments, business plans, financial robustness assessments, etc.

Country	Year of spectrum award	Spectrum cap used	Nature of the mid-band auction, and details of caps applied
Norway	2021	Yes	• 400MHz (3400–3800MHz) was auctioned in four blocks of 40MHz and 24 blocks of 10MHz between four operators • A **spectrum cap of 120MHz** was applied • **One operator acquired the 120MHz cap, two operators acquired 100MHz and the fourth operator received 80MHz** • 3800–4200MHz is available for local licensing for private network use
Slovenia	2021	Yes	• 380MHz (3420–3800MHz) was auctioned in blocks of 10MHz as part of a multi-band auction • Of the four MNOs in the country, three acquired spectrum in this band • A spectrum cap of 160MHz was applied • Two operators won 140MHz and the third operator received 100MHz
South Korea	2018	Yes	• 280MHz (3420–3700MHz) was auctioned in 10MHz blocks between three operators • A spectrum cap of 100MHz was applied with two operators acquiring spectrum up to the cap and the third (LGU+) acquiring the remaining 80MHz • In 2022, the 3400–3420MHz block is set to be granted to LGU+ to bring all three operators to a total holding of 100MHz, with the cost of this 20MHz block being based on the prices in the previous auction
Spain	2018	Yes	• 200MHz (3400–3600MHz) of spectrum was auctioned in 5MHz blocks • Only three of the four MNOs bid for (and won) spectrum • A spectrum cap of 120MHz in the 3400–3800MHz range (including existing holdings)[25] was applied • The fourth operator, MasMovil, instead of bidding for spectrum, purchased two FWA operators, both of which held 40MHz licences in the 3600–3800MHz range • In 2021, two blocks of 10MHz that were left over from the previous auction were auctioned • Across the entire mid-band, the four operators received between 80MHz and 110MHz each with two operators holding over 100MHz
Sweden	2021	Yes	• 320MHz (3400–3720MHz) was auctioned in blocks of 20MHz

25 The other 200MHz in the range had previously been assigned to fixed wireless operators, which were mostly acquired by MNOs in the run up to the auction.

Country	Year of spectrum award	Spectrum cap used	Nature of the mid-band auction, and details of caps applied
			• Two of the country's mobile operators operate via a joint initiative and so bid for spectrum collectively • Three licences were assigned, with one operator acquiring 120MHz, and the joint-venture company and the fourth operator obtaining 100MHz • A broadcast and telecoms network operator in the Swedish market obtained 80MHz in the 2300MHz band • A spectrum cap of 120MHz per operator was applied on the 3400–3720MHz band
Switzerland	2019	Yes	• 300MHz (3500–3800MHz) was split into 15 blocks of 20MHz and auctioned between three operators • A spectrum cap of 120MHz was applied • The three operators received 120MHz, 100MHz and 80MHz
UK	2018 and 2021	Yes	• In 2018, 150MHz (3410–3480MHz and 3500–3580MHz) was auctioned in 5MHz blocks between four operators • After the auction, no operator could hold more than 37% of all currently licensed spectrum (i.e. including all other mobile bands), this restricted the largest operator in the UK market to obtaining 85MHz of spectrum in the mid-band • In 2021, 120MHz (3680–3800MHz) was auctioned in blocks of 5MHz • The same 37% spectrum cap was placed on the auction; in practice this limited the largest operator in the UK market to obtaining a maximum 120MHz of spectrum out of a total 200MHz assigned through this auction (the auction assigned 120MHz in the mid-band and 80MHz in the 700MHz band, the cap went across both bands). If this was all acquired in the 3680–3800MHz range, then this would mean an effective cap of 160MHz in this band for the most restricted operators • Following the two auctions, Three holds the most mid-band spectrum with 150MHz, O2 and EE hold 80MHz, and Vodafone holds 90MHz • 3800–4200MHz is available for local licensing for private network use on a first-come, first-served basis
USA	2020, 2021 and 2022	Yes	• In 2020, 70MHz of spectrum between 3550MHz and 3650MHz) was auctioned across 3233 areas (the precise frequencies making up the 70MHz differed between areas) • The spectrum was available in blocks of 10MHz • In each area an operator was limited by a cap of 40MHz

Country	Year of spectrum award	Spectrum cap used	Nature of the mid-band auction, and details of caps applied
			• In 2021, 280MHz (3700–3980MHz) was auctioned in 14 blocks of 20MHz over 406 areas • There was no spectrum cap for the 2021 auction • An auction of 100MHz (3450–3550MHz) occurred in early 2022 • The spectrum was split into ten blocks of 10MHz • The auction used the same 3233 areas used in 2020 • A spectrum aggregation limit was imposed that allowed any individual entity to hold a maximum of 40MHz in any licensed area, for four years post-auction with AT&T acquiring this cap in all countries