Setting Prices for Expiring Spectrum Licences in Australia

A report prepared by NERA and Aetha Consulting

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Executive Summary

The Australian Communications and Media Authority (ACMA) recently concluded its Stage 2 consultation on Expiring Spectrum Licences (ESL). A crucial next step in the process for the ACMA, having considered stakeholder submissions, will be to develop a methodology for pricing spectrum for renewal. Although the ACMA has not yet consulted on pricing, this issue was addressed in several stakeholder submissions, notably by Optus and TPG which submitted papers prepared by independent consultants.

Our recommendations, summarised in this section, are based on experience advising both regulators and mobile operators around the world on pricing of mobile spectrum licences and analysis of the situation in Australia.

When setting ESL fees, the ACMA should consider low industry profitability and declining global prices for spectrum

Decisions on spectrum pricing matter. Spectrum is the essential input enabling mobile network operators (MNOs) to build and upgrade networks and provide mobile broadband, which constitutes critical infrastructure and enables critical services for consumers and the economy. The service is used by all Australians and has become essential to our everyday lives and the way we do business. According to the GSMA, in 2023, mobile technologies and services generated 5.4% of global GDP and supported around 35 million jobs. In Australia, a 2022 report by Deloitte identified scope for the industry to add a further $90bn to Australian GDP by 2030 if local MNOs are amongst the global leaders in 5G deployment.

A serious challenge to future success, including ongoing 5G rollout and future 6G rollout, is the industry's difficult financial condition. MNOs worldwide and in Australia are experiencing low profitability and a higher cost of financing debt, with no expectation of an upturn in the near term. Consequently, Australian operators would struggle to afford high spectrum fees, indicating that a conservative approach to ESL fee setting is necessary.

In the 5G award era, the global average unit value of mobile spectrum has declined sharply, owing to a combination of factors, including increased spectrum supply, a slowdown in data growth, technological advances, and higher cost of capital. Therefore, if ESL fees are set with reference to historic award prices in Australia or elsewhere, a significant discount to prior benchmarks is appropriate given the reasonable expectation that these prices overstate current market value and may do so even more by the time that ESL licences reach expiry from 2028.

Benchmarking and valuation modelling are the primary tools available to the ACMA to estimate the full market value of mobile spectrum

Two principal methodologies are available to estimate the full market value of mobile spectrum:

1. **Benchmarking.** The market value of spectrum is estimated by analysing prices paid for comparable spectrum in similar countries.
2. **Valuation modelling.** A discounted cash flow model is developed to estimate MNOs' valuations for marginal spectrum based primarily on the avoided network costs to realise equivalent capacity.

The most robust approach is to undertake both methodologies, as each can be used to cross-check the other. However, if the ACMA decides to focus only on one approach, then we recommend benchmarking over valuation modelling. Benchmarking draws on actual market transactions across multiple awards in comparable countries, providing a good indicator of spectrum value that is reasonably robust to individual distortions. In contrast, valuation modelling requires access to private industry data and many subjective assumptions about operator behaviour. It is challenging to do without close cooperation with actual operators. Benchmarking results are also easier for stakeholders to understand and scrutinise, enhancing credibility.

However, benchmarking is inherently backward looking. Given the current downward trend in spectrum prices, unadjusted benchmarks may overstate current value. And, even if the downward trend is factored into an estimate of prices in 2025 (using techniques we describe below), this may overstate prices in the years of renewal, starting 2028. A good valuation exercise may be informative in anticipating how future industry trends may further erode average spectrum values.

Regardless of approach, ESL renewal prices should be set at a significant discount to estimated market value

We identify an 'effective pricing zone' within which the ACMA could plausibly set prices, being an amount between low, nominal pricing, as Optus has proposed, up to a modest discount on full market value. We strongly recommend against setting prices at or near full market value. High prices come with a material risk of market failure in spectrum allocation. Even if prices are set within the effective pricing zone now, they may become too high in later years of the licence term, as spectrum prices have been falling. Furthermore, the financial burden on the industry at a time of low profitability would be high and this may be reflected in lower investment and weakened price competition. This would negatively impact all Australian MNOs and the broader economy.

A middle ground would be to set fees at a conservative level relative to full market price. All available techniques for valuing spectrum, including both benchmarking and valuation modelling, are inherently imprecise. The harm to industry and society from setting spectrum prices above market value is significant, whereas there may be little, if any harm (only distributional effects), from setting prices at lower levels. Given this asymmetric risk, it is appropriate for regulators to at least take a conservative approach when setting renewal prices.

A fee level up to one-half of estimated full market value may be considered conservative. Modelling conducted by Aetha illustrates that four recent industry trends – the introduction of massive MIMO antennas, lower traffic forecasts, higher cost of capital and the anticipated release of future spectrum bands (600 MHz, 1500 MHz, Upper 6 GHz) – have reduced the market value of spectrum by potentially five- to nine-fold (although other factors may have tempered these trends to an extent). This reduction is likely to continue, as technology further improves and new spectrum bands are identified for IMT. A reduction of at least 50% compared to estimated full market value is roughly in line with the observed global decline in spectrum prices between 2018 and 2024. Put differently, if this exercise had been conducted in 2018 and no conservative discount had been applied, the licence price would now be double the market value! A reduction of at least 50% is also reflective of the large error bounds associated with benchmarking and valuation modelling, with a difference of well over 100% between the upper and lower quartiles of spectrum benchmark datasets common.

The choice between nominal and conservative pricing is ultimately a policy decision, and the ACMA should adopt a price level that aligns with its objectives.

We make a series of recommendations regarding how ACMA might conduct a benchmarking exercise to support price setting

International benchmarking requires a series of decisions about sampling, adjustment factors necessary to allow comparison across countries, and statistical techniques used to average across observations. We explore each step in a benchmarking process and make detailed recommendations on methodology in Section 4 of our report.

A summary of our recommended approach to benchmarking for the ESL process is as follows:

1. Construct a sample of awards from higher income countries globally across a period of 2017 to the present day, using nationwide prices (including annual fees) and treating each band sold within an award as a unique observation.

   Higher income countries are most comparable to Australia. Income also serves as a proxy for a range of factors that should impact spectrum value, so other more complicated cross-country adjustments are not required. Pre-2017 awards are associated with 4G era allocations, when market circumstances were very different and average price levels paid for spectrum generally much higher, so are unlikely to be informative about value in 2025, let alone the 2026-2032 ESL renewal period.

2. Convert all prices to Australian dollars using FX exchange rates and adjust all benchmarks to a common 20-year licence term.

If the sample is restricted to higher income countries, this limits scope for price distortions between countries, which eliminates the advantage of purchasing power parity (PPP) over FX exchange rates. FX exchange rate data is also more reliable and up to date than PPP rates. A 20-year licence term is typically used in Australia, so this is the appropriate duration for renewal.

3. Categorise bands into groups for benchmarking purposes: low band (sub-1 GHz), lower mid band (1800 MHz & 2100 MHz) and upper mid band (2300 MHz & 2600 MHz, with 3500 MHz either included or as a separate subcategory), and explore two options for statistical analysis:

   - Simple: Strip out extreme outliers and calculate the median value. No adjustment for inflation.

   - Sophisticated (preferred): Calculate an Exponentially Weighted Moving Average (EWMA) with extreme outliers removed and use the value for the final (current) year. In this case, values may be adjusted for inflation.

   Bands that play similar roles within a modern 5G network may be grouped together to improve sample size. The resulting samples are still noisy and can be distorted by a limited number of high price outliers which are associated with local spectrum scarcity. These values contribute to an upward bias when using a simple mean. This can be addressed by stripping out extreme outliers and calculating the median value.

   A further adjustment is necessary to account for the downward trend in prices. In the simple case, this may be approximated by using nominal price for historic awards rather than real values that take account of general price inflation (as general prices have moved in the opposite direction to spectrum prices over the relevant period). A more sophisticated approach is to use a EWMA which places greater weights on more recent awards over older ones. In this case, the weighting addresses the bias associated with using a mean, so real, inflation adjusted prices may be used.

4. Further quantitative and qualitative analysis may be used to make (modest) differentiations in estimated values for individual bands within each group.

   The first three steps will produce three reference valuations, one each for low band, lower mid band and upper mid band. Sample size is generally insufficient to estimate value differences within these groups but inferences may be made from past awards and technical analysis.

We also make recommendations regarding how ACMA might build a valuation model to identify the marginal value of spectrum in each band

Valuation modelling can be used to estimate spectrum value to a specific operator by forecasting and discounting the incremental cash flows generated from gaining access to spectrum. Full market value can then be estimated using the following process:

1. In each band in the ESL process, consider scenarios where each operator acquires a different number of spectrum blocks (e.g. 2×5MHz), and value each incremental block. Owing to the number of bands in the ESL process, each band should be considered separately – assuming existing holdings in other bands are retained.

2. Order the block valuations from highest to lowest value – to any operator.

3. In each band, if there are "n" blocks available, Take the $(n+1)^{th}$ highest value that any operator has for an incremental block. This is the market value for this band, as it is the highest value which is denied to any operator. Put differently, it is the bid value that would set the price for all blocks in a fully competitive auction.

Spectrum primarily provides value by reducing site build and equipment deployment requirements, and thereby decreasing network costs (technical or network cost avoidance value). The ESL process involves incremental spectrum with incremental benefits, and therefore value will primarily be driven by network cost avoidance. Therefore, to be conservative, we recommend modelling technical value only.

Valuation modelling involves forecasting many inputs over the licence duration – i.e. out to the 2050s. To reduce uncertainty, forecasts should be conservative and only include trends that can be predicted with confidence. In Section 5.3, we detail our recommendations for several valuation model inputs. The key ones include:

- **Future spectrum awards.** The ACMA has plans to award various new spectrum bands for mobile use. This will increase the supply of spectrum to the market. It is important to include these bands in the model, as not doing so would overstate the value of the spectrum already in use. We recommend including the awards of 600MHz, 1500MHz, and the upper 6GHz bands (splitting the spectrum between the MNOs based on market share). It is likely that there will be further mobile spectrum awards in the 2035+ timeframe. However, without a clear roadmap for their award, it is difficult to account for this in the model.

- **New technologies.** Future technology developments will significantly improve the spectral efficiency, and therefore capacity, of mobile networks. Where these can be forecast with reasonable confidence, they should be included in the model. Not doing so would overstate the value of the spectrum. In particular, transitions to active antenna systems for mid-band FDD bands and for sub-1GHz FDD bands should be anticipated (with spectral efficiency improvement of 1.5-2× over passive antennas). Also, higher-order MIMO equipment will likely be available in the upper 6GHz band (e.g. 256T 256R – which may provide a 2× improvement in spectral efficiency over 64T 64R). It is likely that there will be additional not currently foreseeable technology improvements in the 2035+ timeframe. It is not possible to model these specifically – instead we recommend modelling a generic year-on-year improvement in spectral efficiency.

- **Data traffic forecast.** Globally, data usage growth rates have fallen and are predicted to continue falling, with the following implications for modelling:
    - Traffic growth in the short term should reflect this trend – we suggest a CAGR of ~12-18% over the period 2024-2035.
    - Over the long-term (2035+), use a conservative traffic forecast. It is not reasonable to forecast long-term future traffic growth without also including the spectrum and technology that will emerge to serve this traffic. This would significantly overvalue spectrum. We recommend using a long-term traffic growth in the mid-single digit range.
    - FWA traffic should not be included. Operators apply traffic management techniques to ensure that FWA traffic does not significantly contribute to network congestion.
- **Weighted average cost of capital (WACC).** Selection of an appropriate WACC should reflect substantial increases to the cost of debt in recent years. We recommend using a post-tax nominal WACC of 7-8% or, if tax is not modelled, a pre-tax nominal WACC of 10-11%.

Further adjustments are required to translate an estimate of full market value to actual fees paid by operators

Using a benchmarking exercise and/or valuation model, the ACMA will be able to estimate full market value. It may then apply either conservative pricing (50%+ reduction) or nominal pricing to arrive at a final lump sum value per MHz in each band. As we describe in the final section of our report, various studies have suggested that mobile markets where operators have enjoyed lower fees have tended to outperform markets with higher fees. These findings reinforce the case for the ACMA to adopt a conservative approach or consider nominal prices when setting ESL fees.

We recommend two further steps to arrive at actual fees

- **Conversion of lump sum fees to annual payments.** There is a strong case for applying ESL fees as annual payments to defer and reduce the financial burden on mobile operators. We explore possible methodologies to do this, including a simple, industry-friendly approach based on the payment terms adopted for Australian 26 GHz licences.
- **Setting prices for regional licences.** A formula is required for breaking down national prices to regional licenses. We identify two options based on population weighting and differences in spectrum value across urban, rural and remote. Overpricing risks associated with these approaches can be mitigated by the ACMA adopting a sufficiently conservative approach to setting national spectrum renewal fees.

Unless the ACMA opts for nominal pricing, the ESL process will generate significant revenues. Historically, such revenues have flowed to the Government, thereby leaving the industry. Alternatively, a share of fees could be repurposed to support initiatives that promote connectivity for marginal areas and peoples within Australia. We provide some examples from other countries where spectrum revenues have been reinvested in the industry.

1. Context: an industry in pain

Decisions on spectrum pricing matter. Spectrum is the essential input enabling mobile network operators (MNOs) to build and upgrade networks and provide mobile broadband. The service is used by all Australians and has become essential to our everyday lives and the way we do business. According to the GSMA, in 2023, mobile technologies and services generated 5.4% of global GDP and supported around 35 million jobs.[1] In Australia, a 2022 report by Deloitte identified scope for the industry to add a further $90bn to Australian GDP by 2030 if local MNOs are amongst the global leaders in 5G deployment.[2]

When approaching the topic of spectrum renewal pricing, it is important to consider the industry context. Two major industry trends that must be considered are:

1. Low industry profitability; and
2. Declining value of mobile spectrum.

These are structural, global trends that are relevant to every country with a competitive mobile sector including Australia. These trends are expected to continue for the foreseeable future. We briefly describe each trend here and explain why they are relevant to ESL pricing, and more generally to the future economic strength and competitiveness of the Australian economy.

In summary, the key implications are that:

- MNOs in Australia face fiscal constraints that would make steep spectrum fees untenable, so a conservative approach to ESL fee setting is required; and
- If ESL fees are set with reference to historic award prices in Australia or elsewhere, then they should be set at a significant discount to those benchmarks given the reasonable expectation that historic prices significantly overstate current market value and may do so even more by the time that ESL pricing begins from 2028.

1.1. Low industry profitability

In countries worldwide, mobile network operators (MNOs) are struggling with low profitability. In the mobile sector, profitability has long been constrained by effective downstream competition, associated with the presence of multiple MNOs with differentiated infrastructure. However, over the last decade, margins have been further squeezed by a combination of increasing costs and stagnating revenues. The

1 GSMA (2024), The Mobile Economy 2024, p2.

2 Deloitte (2022), 5G Unleashed: Realising the potential of the next generation of mobile technology, p.14.

high cost of acquiring the greater quantity of spectrum necessary to support a next generation network is an important component in this story.

Australian operators are amongst the many companies worldwide under intense pressure from shareholders to improve margins. For example, in their response to the ESL consultation, Optus states that its Return on Invested Capital (ROIC) is "*below 2% and well below our cost of capital*"; and cites equity research from Barrenjoey that shows that "*[Australian mobile] industry ROIC has halved since 2017, and sits well below costs of capital*."[3] Meanwhile, TPG states in its response that "*[t]he industry is not making adequate returns relative to the level of investment.*"[4]

The reasons for the poor returns experienced by MNOs are many. Firstly, for many years now, MNOs worldwide have experienced flat or declining revenues owing to:

- **Intense price competition.** Infrastructure-based competition in mobile markets is a long-run success story. Despite huge growth in data traffic, prices for mobile service have been falling, as MNOs compete vigorously for market share. For example, Accenture reports that fixed and mobile average revenue per user (ARPU) globally has declined 27% in the past ten years[5], whereas global mobile subscriptions have increased only modestly, as markets approach saturation. This trend is evident in Australia. For example, Coleago (in their ESL submission for Optus) cites data from the ACCC Communications Market Reports that shows a 79% decline in mobile services retail prices in real terms in Australia between 2014 and 2022.[6]
- **Absence of new revenue streams.** In the 4G era, there was considerable optimism that that growth in data traffic would be accompanied by the emergence of new revenue streams for mobile operators. However, significant new revenue streams have not materialised. Most of the benefits of exploding data use have flowed to consumers and to social media and over-the-top (OTT) providers whose traffic is carried over mobile networks. Meanwhile, there has been a convergence of fixed and mobile communication business cases and commoditisation of data, as former revenue streams, such as voice and text, have disappeared. One bright spot for operators in some countries, such as New Zealand, has been growing demand for fixed wireless access (FWA) via mobile, but this is less a new market than a cannibalisation of the fixed market.

And MNOs have also faced increasing costs owing to:

- **High network build costs.** MNOs are under intense government and competitive pressure to maintain investments in next generation networks. However, 5G is expensive. Notably, the

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3 Optus (2024a), Submission in response to the ACMA Consultation Paper: Expiring spectrum licences: Stage 2, p.43.

4 TPG (2024), Expiring spectrum licences: TPG submission to the ACMA, p.9.

5 Accenture (2023), 'Pathways to profitability for CSPs', https://www.accenture.com/content/dam/accenture/final/accenture-com/document/Accenture-Comms-Narrative-POV-final.pdf.

6 Coleago (2024), ESL Pricing Paper (submitted by Optus to the ACMA), p.34.

active antenna systems (AAS), which enable the step change in network speeds that consumer expect from 5G, are much more expensive than their passive predecessors. The cost of electric power – a substantial component to network operational costs – has increased substantially over recent years, and operators are experiencing increased costs driven by resilience requirements for critical infrastructure and services

- **Regulator-imposed costs.** The mobile market is a heavily regulated sector, with mobile operators subject to oversight from dedicated communications industry regulators. They must adhere to a range of regulations, including those pertaining to security, resiliency obligations, and consumer protection, which impose additional costs on the operators. In contrast, adjacent sectors, such as OTT operators, which drive traffic on mobile networks, are lightly regulated.
- **Spectrum burden increase.** To expand capacity to support high traffic growth and deploy 5G networks, operators worldwide have needed to buy more and more spectrum. Between 2017 and 2023, the ACMA increased sub-4 GHz spectrum for mobile operators by 82%, an increase comparable to other major economies such as Germany (80%), UK (90%) and USA (98%).[7] As we discuss in Section 1.2, rising supply has contributed to a decline in spectrum prices on a per MHz-pop basis, but the overall spectrum burden (i.e. the absolute amount invested in spectrum) has continued to increase.
- **A higher cost of capital.** To finance investments in network and spectrum, operators have taken on substantial debts. The cost of financing these debts has risen owing to significant increases in interest rates that followed the post-Covid surge in general inflation. Given the industry's other challenges, MNOs also face less favourable borrowing terms.

In response to these challenges, MNOs in Australia and elsewhere have, for many years, been cutting costs. For example, Telstra recently announced that it was cutting 2,800 jobs, about 9% of its workforce, with the aim of freeing up capital for "*investments needed to support the ever-increasing growth in data volumes on its networks and deliver improved connectivity for customers across the country*."[8] This follows previous headcount reductions announced in 2017, 2018 and 2019. Optus and TPG have also shed workers in recent years. Other efforts to reduce costs through mergers or network sharing have often been rebuffed on competition grounds. For example, in Australia: TPG and Telstra's proposal to share regional infrastructure was denied by the Australian Competition Tribunal; and a subsequent sharing deal between TPG and Optus is now under review; in Europe, competition authorities blocked four to three MNO mergers in Denmark and the United Kingdom; and in Portugal, Vodafone's acquisition of a smaller rival, Nowo, was blocked on competition grounds.

Given these constraints in Australia and similar challenges in other mobile markets worldwide, the era of low industry profitability is expected to continue for the foreseeable future and certainly through at

7 Marsden, Richard (2024), Round-Round: Learnings from the First 35 Years of Spectrum Auctions", Figure 34 on p.113.

8 https://www.itnews.com.au/news/telstra-to-cut-up-to-2800-roles-by-year-end-608129

least 2030. For example, GSMA Intelligence (2023) projects an average worldwide mobile industry revenue growth rate of only 1% per annum.[9]

A pessimistic summary of this situation is provided by Professor William Webb in his provocatively titled new book, "The End of Telecoms history":

> "*In essence, the MNOs have little room to adapt to such forces. Regulators aim to avoid any one of them gaining an advantage, reducing the incentive to innovate. They all use the same technology, conforming to the same global standard and delivered from the same two to three suppliers. And they deliver services that are commodities where differentiation is very hard. As a result, innovation does not lead to greater efficiencies, and instead the status quo is maintained at low levels of operator profitability*."[10]

More immediately, as TPG and Optus warn in their submissions, it may not be sustainable for Australian MNOs to continue to invest at current rates unless their financial situation improves.

In this context, Government intervention in spectrum fees could be an attractive way to assist the industry during this challenging period. By setting prices conservatively, the ACMA could reduce the cost burden on MNOs, freeing up capital for investment and making it easier for operators to secure financing to invest in network infrastructure. And lower unit spectrum fees benefit all operators without distorting downstream competition.

1.2. Declining value of mobile spectrum

Spectrum prices (i.e. the cost of spectrum on a per MHz basis) have been trending downwards throughout the 5G award era, in large part owing to increased supply and lower scarcity. Nevertheless, the 'spectrum burden' – the absolute amount that operators spend on spectrum has increased because a modern mobile network requires far more spectrum to support the huge growth in mobile data traffic. Put simply, mobile operators worldwide have needed to buy a lot more spectrum, so their total spend has increased despite the fall in prices.

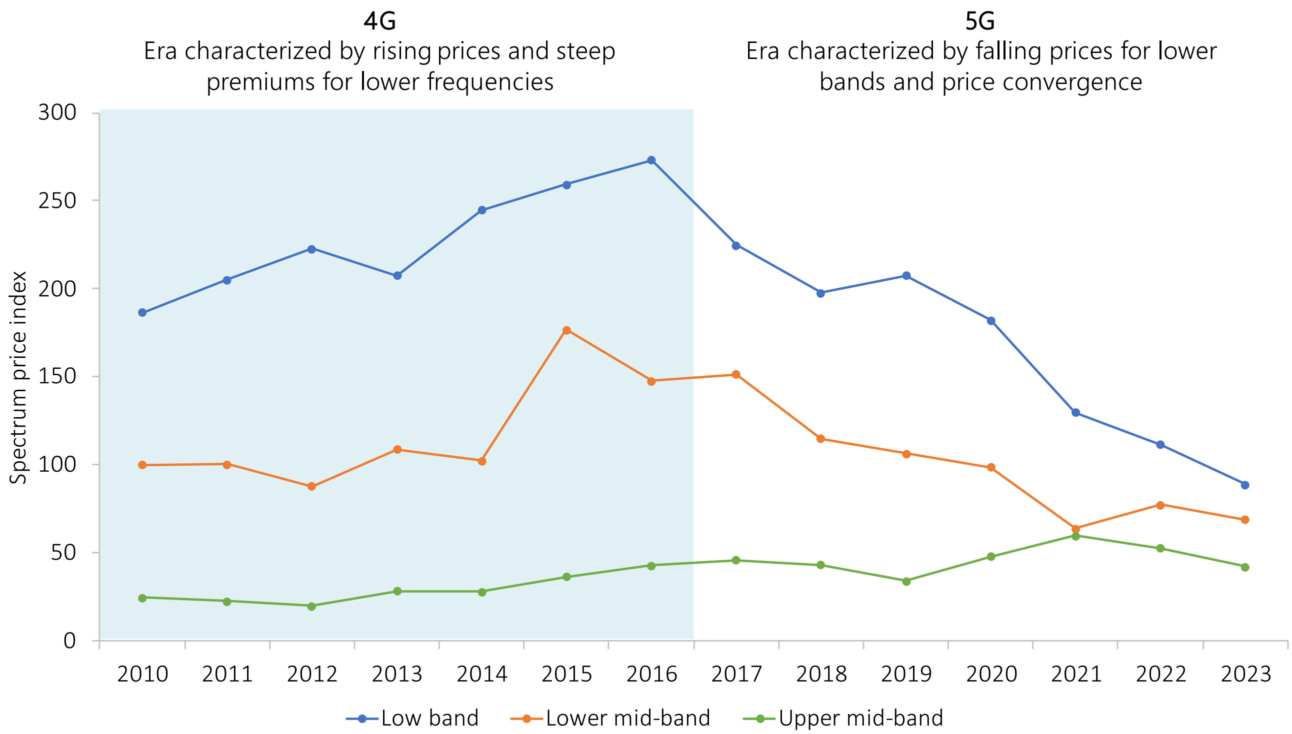
Figure 1 plots a relative spectrum price index for three categories of spectrum between 2010 and 2023. The index is constructed by normalising the three-year moving average price for each category of spectrum in each year relative to the price of lower mid band spectrum in 2010. It is based on data from 334 awards of spectrum between 600 MHz and 4 GHz across 51 developed countries from 2008 to

9 GSMA. "The Mobile Economy 2023," 2023, available at: https://www.gsma.com/mobileeconomy/wp-content/uploads/2023/03/270223-The-Mobile-Economy-2023.pdf.

10 Webb, William (2024), The End of Telecoms History, p.97.

2023.[11] The figure shows that prices paid for mobile spectrum peaked in around 2015-2016, towards the end of the 4G era. Since then, the average prices paid for low band (sub-1 GHz) and lower mid band (1700-2200 MHz) spectrum have more than halved. Only the upper-mid band (2300-4000 MHz) spectrum has maintained its value in recent years, although it too has seen a decline since 2021. The stronger price performance of upper mid band likely reflects its low starting value and the potential for operators to acquire larger contiguous blocks of spectrum in these bands suitable for delivering higher capacities and network speeds over 5G networks.

Figure 1: Spectrum Price Index for Three Categories of Mobile Spectrum, 2010-2023



Notes: Figure 1 shows an index of the three-year moving average price for each category of spectrum in each year normalized relative to the price of lower mid band spectrum in 2010.
Source: Adapted from Figure 31 in Marsden (2024), Round-by-Round: Learnings from the First 35 Years of Spectrum Auctions

As part of the Optus's ESL submission, a paper from Coleago argued to the contrary that average global spectrum prices have not changed meaningfully over the last 15 years.[12] In our opinion, there are deficiencies in Coleago's approach that led to this mistaken conclusion. Firstly, they appear to have

[11] This is the same samples as used in Marsden, Richard (2024), Round-by-Round: Learnings from the first 35 years of spectrum auctions, Chapter 10, Fig. 31., p.100.

[12] Coleago (2024), Appendix F.

adjusted for differences in GDP per capita, which is an unconventional approach to dealing with value differences across countries and tends to exaggerate values for low-income countries relative to higher-income ones. Secondly, they rely on a smaller sample of awards than the Marsden (2024) study, so have missed relevant data points. Thirdly, Coleago attempt to fit a linear trend line to price data between 2007-2023, but this approach will obviously fail to identify the non-linear trend mapped out in Figure 1, with average prices generally rising from 2010-2016, and falling significantly thereafter.

The observation that prices paid for low band and lower mid band spectrum have fallen significantly in recent years also makes intuitive sense, explained by the following factors:

- **Supply increase.** Like any market, prices paid for spectrum should be linked to the level of supply. In the 5G era, there has been a huge increase in the supply of mobile spectrum below 4 GHz to keep up with the ongoing demand growth. For example, in Australia, supply increased 82% from 610 MHz to 1,113 MHz. Further, the release of more mobile spectrum is expected in the future, including but not limited to the 600 MHz, 1500 MHz and Upper 6 GHz bands. Operators typically include this future increase in supply when valuing spectrum.
- **Technological advances and network densification.** Figure 1 reveals a marked convergence in the value of all mobile spectrum bands below 4 GHz, with the premium paid for lower frequencies that propagate more now quite modest, at least at a national level. Value convergence can be linked to network densification and technological change. With denser networks in urban areas, the premium value of lower frequencies is reduced, as the advantage of signals that propagate further is diminished. In recent years, this trend has been accentuated by improvements in antenna technology (specifically massive MIMO) which has increased spectral efficiency as well as the coverage of upper mid bands.
- **Slowdown in data growth.** For many years, growth in data use on mobile networks was exponential and some industry forecasts anticipated that this would continue indefinitely; however, in recent years, growth in traffic has slowed.[13] As operators have become more confident about the limits of future capacity requirements, and in particular that high case growth forecasts are unlikely to materialise, it follows that their incremental value for spectrum will fall. We review this trend in more detail in Section 5.2.
- **Industry weakness.** As described in Section 1.1, the industry is struggling with low profitability and commentators have become increasingly pessimistic about the potential for MNOs to grow revenues. The associated increase in cost of capital for MNOs also directly decreases operator

[13] See Ihle, Marsden & Frizlen (2024), Evolution of Prices for Mobile Spectrum and Possible Explanations (available at: https://www.nera.com/insights/publications/2024/evolution-of-prices-for-mobile-spectrum-and-possible-explanation), for an analysis of recent forecast data and review of sources.

valuations as these are typically developed using discounted cash flow (DCF) modelling. These trends tend to make spectrum auctions less competitive, as incumbents reduce their valuations or factor in budget constraints, and potential entrants are deterred from participation.

Figure 2 and Figure 3 below illustrate the impact of these factors on the market value of spectrum. They show the results of modelling conducted by Aetha Consulting to estimate how the market value of the 700MHz and 1800MHz bands (as illustrative low- and mid-bands) is impacted by the above trends. Specifically, they estimate how much higher the market value would be if:

- **Future spectrum awards are excluded from the modelling.** This sensitivity is to illustrate the impact on spectrum value of increased supply. In the sensitivities, the introduction of the 600 MHz, 1500 MHz and Upper 6 GHz band (all of which are assumed to be in 2030) are excluded.

- **Massive MIMO antennas had not been introduced.** Massive MIMO antennas were deployed from ~2019, mainly in the 3600MHz and 2300MHz bands, substantially increasing the capacity provided by these bands. The modelled sensitivity assumes the capacity provided by these two bands is reduced by 25%, reflecting a hypothetical situation where passive antennas had instead been used (this is a conservative assumption as capacity reduction of using passive antennas would likely be larger). Note that this sensitivity still assumes the coverage benefits from massive MIMO antennas, so it should be considered a conservative estimate of the impact of massive MIMO.

- **A higher traffic forecast is assumed.** This sensitivity increases the forecast annual growth rate from 16% to 22% for 2024-2030 and from 9% to 11% for 2030-2040, as an illustration of the impact if recent reduced expectations of future traffic levels had not occurred.

- **The cost of capital is decreased.** This sensitivity decreases the WACC (post-tax, nominal) from 7.5% to 5.5% to broadly reflect the impact if the recent increase in the cost of capital had not occurred.

Making these assumption changes – i.e. reversing trends that have broadly occurred in the market in recent years – is estimated to increase the market value of 700 MHz five-fold. Similar results are seen for other low-bands (e.g. 850 MHz). The impact is greater for the 1800 MHz band – the reversal of the trends increases the market value nine-fold. Similar results are seen for other mid-bands (e.g. 2500 MHz).

Figure 2: Impact of industry trends on market value of 700MHz spectrum

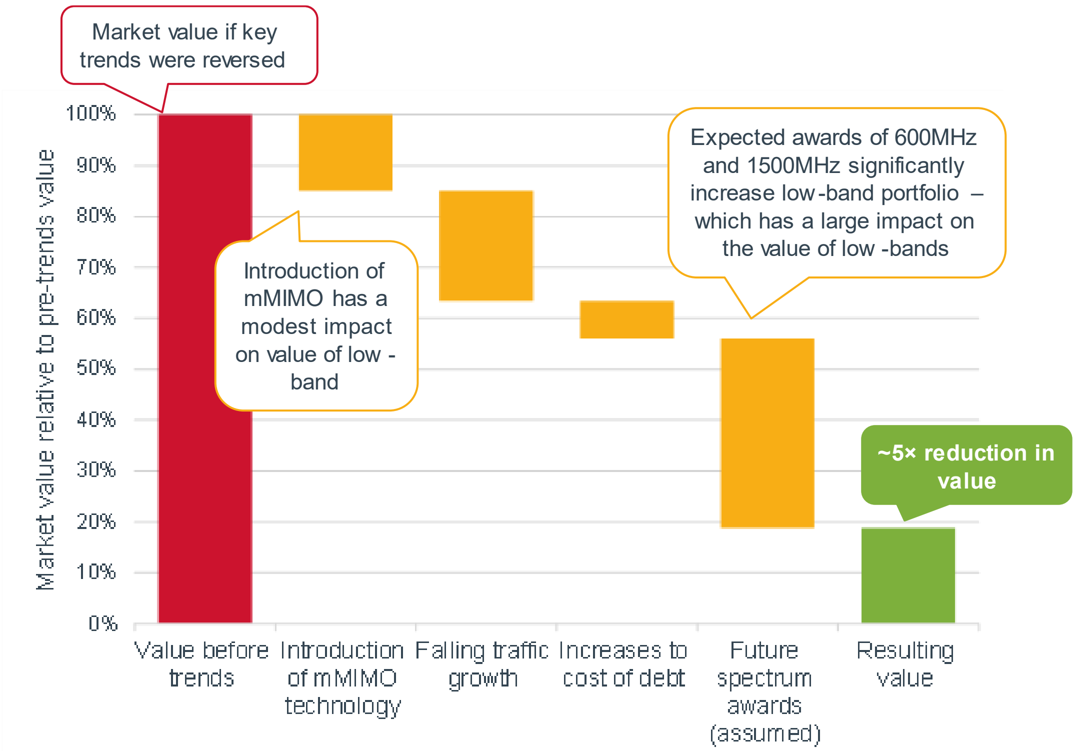
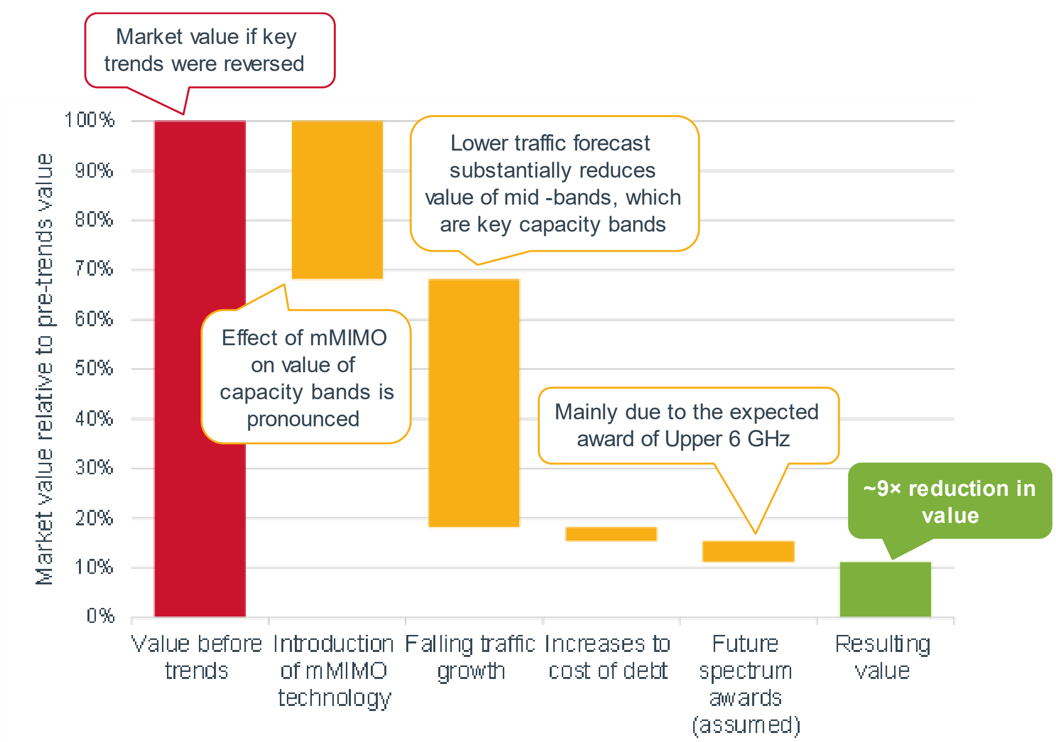


Figure 3: Impact of industry trends on market value of 1800MHz spectrum



For clarity, these results do not suggest that the value of 700 MHz and 1800 MHz spectrum has fallen five-to-nine-fold in recent years. Other factors have impacted spectrum values, some in an upwards direction. However, they illustrate the scale of influence of just these four factors, which largely explain why spectrum values have fallen in recent years.

Notwithstanding the declining prices paid per unit of spectrum, the absolute "spectrum burden" on operators remains high and has risen in many countries. This is because to keep up with traffic growth and demand, the total volume of spectrum held by each MNO has increased hugely in recent years, especially with acquisition of 3500 MHz spectrum necessary to deploy wide bandwidth 5G; this increase in volume offsets price declines for other spectrum.

Figure 4 shows how Australian MNO annualised spend on spectrum has increased since 2014, both in absolute terms and as a percentage of mobile service revenue. From 2024 through 2025, absolute spend has more than doubled to over A$750M per year. The requirement for MNOs to spend ever more on spectrum at a time when mobile service revenues are not increasing is a contributing factor to the industry's low profitability and difficulties attracting capital investment in networks.

Figure 4: Australian MNO Total Spectrum Spend, FY2014-2025

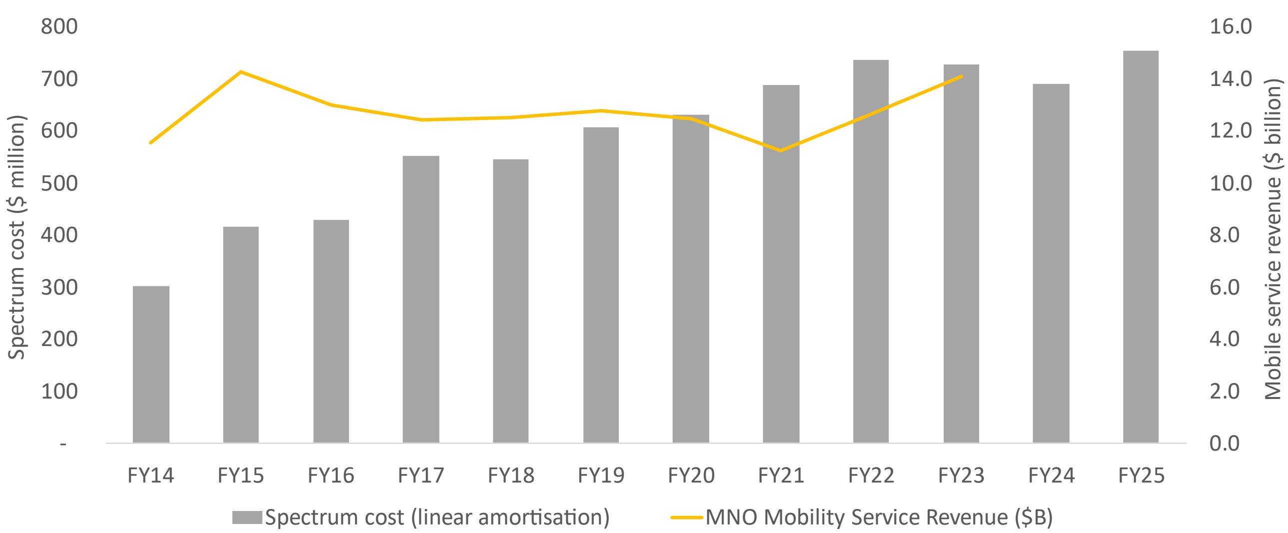


Figure 2 Notes: Spectrum costs have been annualised across the lifetime of each licence. Bar chart shows annual spend in A$ per financial year (FY) and line graph shows annual spend as a % of mobile service revenues. Sources: Revenue data from Globalcomms. Spectrum spend data collated by Telstra from public domain sources, including ACMA and annual reports of Australian mobile operators.

Other mobile operators worldwide are experiencing a similar challenge. For example, in Figure 5, we plot aggregate annualised spend on mobile spectrum in auctions and renewals for all MNOs in each of

France, Germany and the UK, the three largest economies in Europe. Similar to Telstra, their spectrum burden has steadily increased over the last 15 years.

Figure 5: Spectrum burden (annualised spend) for leading European economies, 2010-23

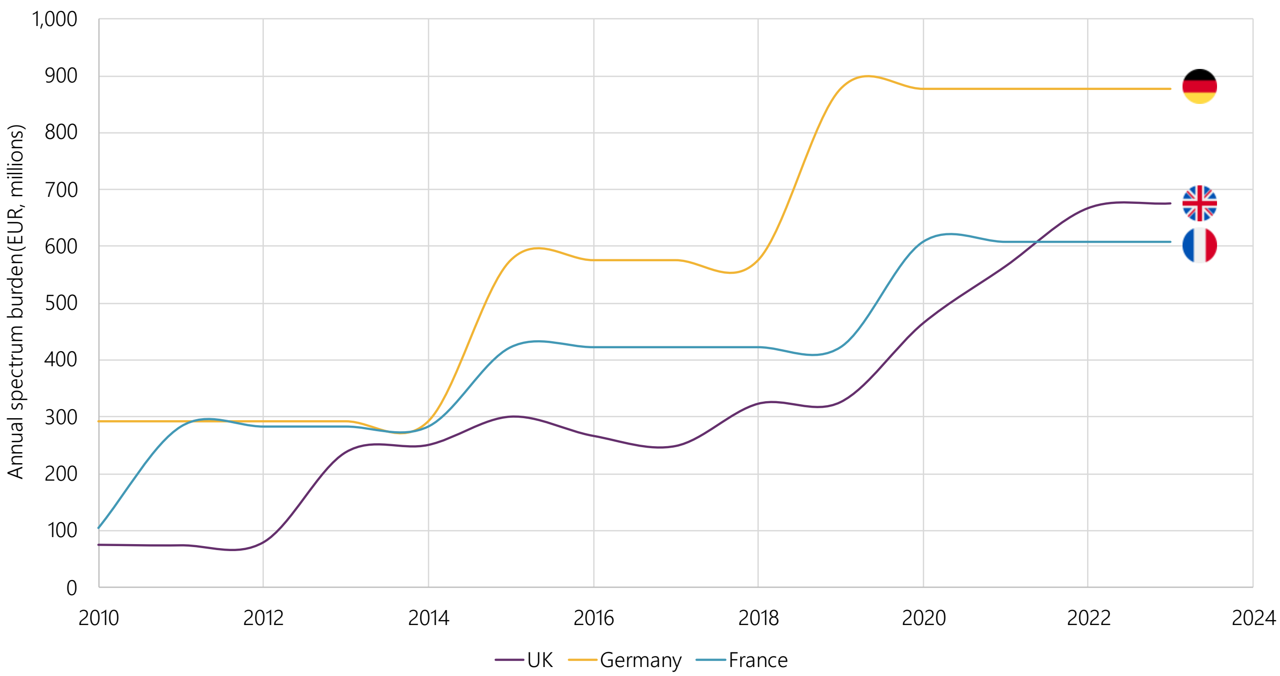


Figure 3 Notes: The spectrum burden in each year is calculated as the sum of annual licence fees payable in that year and the prorated upfront fee (upfront fee divided by licence duration) over the licence period. The spectrum burden for the UK is converted to EUR in the given year. The chart only shows spectrum burden in relation to mobile spectrum acquired or renewed in the 4G and 5G award eras; costs associated with spectrum acquired before 2010 (including the 3G auctions) are not included.
Source: NERA

Looking forward, further releases of spectrum are expected in anticipation of the 6G mobile era. Expected new bands relevant to Australia include 600 MHz (already allocated in Canada and the USA), 1500 MHz (already allocated in some European countries) and upper 6 GHz (proposed for IMT in Europe). Accordingly, the spectrum burden is set to jump again within the next decade, unless new spend is offset by lower prices for legacy renewals.

In summary, there has been a significant decline in mobile spectrum prices across the 5G era, with values for low band and lower mid band spectrum falling significantly, and more recent evidence that values for upper mid band spectrum have peaked and are also now falling. This decline needs to be factored into any exercise to set renewal fees for expiring spectrum licences, as otherwise use of historic prices could hugely overstate current values. At the same time, the overall price burden of acquiring spectrum for mobile networks has increased, notwithstanding price declines. This is a factor in the industry's poor financial performance. Looking forward, in Australia, given the significant proportion of spectrum subject to renewal, ESL pricing will be the main determinant of whether there is any easing of this burden.

2. Tools to estimate the value of spectrum

When considering how to set prices for spectrum that is scarce (i.e. demand exceeds supply), it is relevant to consider its 'full market value'. By full market value, we mean the price that would arise in an auction if MNOs were competing for spectrum lots and submitted bids based on their full set of marginal values (based on technical cost and savings and commercial benefits, excluding strategic or anti-competitive effects). For avoidance of doubt, we are not recommending setting fees at full market value; as we explain in Section 3, there are strong arguments to support the ACMA setting fees at a significantly lower level.

Here, we discuss methodologies commonly used to estimate market value. We begin with a discussion of **next best alternative use pricing**. The basic principle here is that the cost should reflect the opportunity cost of denying the next best alternative use for the spectrum. This could be set by more spectrum being allocated to an existing operator, a new operator with the same use case, an alternative use case, or, if there were no alternative use, the opportunity cost of the regulator's cost in allocating the spectrum.

The alternative use approach is not typically considered further for mobile. This is because it is usually obvious that the next best use case will be more mobile, so a mobile industry valuation method can be deployed. Nevertheless, the conceptual approach discussed below may have some merit when considering ESL pricing. In the current mobile market, the market value of spectrum is likely to be set by existing MNOs denying spectrum to each other. But pricing at this level imposes high costs on the industry. Setting spectrum prices at levels that reflect the (lower) value that the industry is denying to others could provide a fairer, more sustainable approach for pricing renewals.

We next consider the two methodologies used for valuing spectrum to mobile operators:

1. **Benchmarking.** The market value of spectrum is estimated by analysing prices paid for comparable spectrum in similar countries.
2. **Valuation modelling.** A discounted cash flow model is developed to estimate the MNO valuations for marginal spectrum based primarily on the avoided cost of not having to densify networks to realise equivalent capacity.

These approaches, when executed correctly, are designed to estimate the full market value of spectrum in a frequency band. We briefly introduce each of these approaches below and discuss their pros and cons.

2.1. Next best alternative use

Next best alternative use pricing is a method that estimates what the value of spectrum would be in a hypothetical case were it to be allocated in a market context to alternative users or use cases. For the purposes of administrative pricing, this approach is designed to ensure that users at least pay a price consistent with the opportunity cost of denying alternative uses.

The approach was developed in the United Kingdom and applied as a tool for setting prices for certain commercial or government bands, such as fixed links, some satellite uses and non-essential military uses, where the spectrum itself was not necessarily congested, but interference management requires rules that actually or de facto preclude alternative use cases. It is not generally used to value mobile spectrum, where opportunity cost is often set by existing or potential new mobile operators denying spectrum to each other.

In the context of the ESL, it may be a useful thought exercise for the ACMA to explore pricing from a next best alternative use perspective. Conceptually, there are four potential sources of opportunity cost:

1. Denying rival MNOs from having more spectrum;
2. Denying spectrum to an entrant MNO;
3. Denying spectrum to an alternative use; and
4. The regulator’s costs associated with managing and allocating the spectrum.

Prices in spectrum auctions are often set by competition between incumbent MNOs for incremental spectrum. This is true, for example, for many spectrum lots in recent Australian auctions of mobile spectrum, where Optus, Telstra and TPG/VHA have set prices for each other. This is the maximum opportunity cost or “full market value” of the spectrum. Pricing at this level may have been necessary at the time to identify the highest value outcome and promote efficient allocation. However, in hindsight, the same efficient outcome might have been achieved at lower prices if operators had had better information about their relative strengths and moderated demand accordingly. Such an alternative outcome would involve lower revenues but, in the case where all three MNOs won spectrum, it would have left all operators in stronger financial positions.

A valuation model, as described below, models maximum opportunity cost (i.e. full market value) because it de facto assumes unmoderated competition between MNOs for spectrum. To the extent that a benchmarking exercise is based on observations of fully competitive awards, it too will tend towards modelling full market value. In a renewal process where spectrum allocation is pre-determined, and an auction is not required to distinguish between rival MNO demand, there is no efficiency requirement to set a price at this high level.

What lower price may be appropriate? When managing spectrum and running licensing processes, a regulator incurs costs, so this might be considered a low-end floor on prices. MNO use of spectrum also denies spectrum to other users. Unsurprisingly, given the current state of the industry, there appears to be no interest in new national MNO entry (we note, for example, that no aspiring entrants responded to the ESL consultation). However, there has been participation in auctions by niche regional mobile operators, such as Pivotel. Other alternative uses might include fixed wireless access, satellite uses, broadcasting, or industrial private networks. The value that these users might attach to the spectrum may provide a higher floor for the pricing of ESL spectrum, based on the principle that the industry should pay at least the opportunity cost of denying alternative use cases.

2.2. Benchmarking

Benchmarking is the most common methodology deployed to value spectrum licences. It is a comparative approach that looks at prices paid for spectrum in equivalent completed spectrum awards and uses them to estimate the price for spectrum subject to a new award or renewal. It is widely used by operators, consultants and regulators to value mobile spectrum, ether instead of or alongside valuation modelling. For example, UK communications regulator Ofcom has used benchmarking to set renewal fees for expiring spectrum licences in the 900 MHz, 1800 MHz and 2100 MHz bands.[14]

A high-quality benchmarking exercise involves multiple steps. First, a sample of relevant prior awards must be identified, requiring decisions based on relevant frequency bands, types of country and award process, and timeframe. Second, adjustments to the observed prices to facilitate fair comparison across awards are made, considering factors such as exchange rate conversion, licence duration and inflation. Third, the regulator must adopt a statistical technique for arriving at a value point estimate or value range for the relevant licenses, requiring decisions on the type of averaging and designation of outlying observations. In Section 4, we discuss best practice approaches to benchmarking in the context of ESL renewals.

For a regulator attempting to value spectrum for renewal, an international benchmarking methodology offers a number of attractive characteristics:

- *Real world observations*. The raw data consists of actual prices paid by operators for equivalent spectrum observed in comparable marketplaces. Owing to the international mobile ecosystem, countries around the world use the same (or equivalent) spectrum bands as Australia, meaning there is a large pool of potential relevant observations. The circumstances of each award are often well documented, giving a regulator great scope to explore the relevance of each award.

[14] Ofcom (2018), Annual licence fees for 900 MHz and 1800 MHz frequency bands. Ofcom (2021), Annual licence fees for 2100 MHz spectrum.

The factual nature of the observations may be contrasted with a valuation model that rests on forward-looking assumptions, so is unavoidably speculative.

- *Accessibility*. The data is relatively accessible. It is practical to collate and audit data on spectrum prices from many countries worldwide. Although there are multiple steps in a sophisticated benchmarking exercise, the process is not unduly difficult to execute, meaning that a benchmarking exercise can be conducted quickly and cost effectively, and can be replicated by stakeholders. In contrast, valuation models require many more assumptions and ideally require information about local mobile deployments that are private to competing operators.
- *Transparent, generic results*. International benchmarking produces transparent, generic benchmarks that can be applied to all spectrum in a band, providing a common reference point for pricing that spectrum for all operators. Each benchmark is an estimate of a market price. In contrast, valuation models are more suited to estimate the value to individual operators, with further steps required to arrive at a market price (see discussion in Section 2.3).

Notwithstanding these advantages, benchmarking has its challenges and is imprecise. It relies on observed prices from other countries and time periods to attempt to value spectrum in a different award. The circumstances of each award vary, and differences can have a big impact on prices. Methodological choices (see Section 4) can also impact resulting values. Accordingly, benchmarked prices should be interpreted with caution.

Not all auctions realise prices at full market value because MNOs may make informed compromises on demand to moderate prices. Such compromises may have little or no impact on the efficiency of allocation, as incumbent MNOs will not normally compromise on spectrum when they anticipate having the highest value.[15] Auctions can also overstate full market value, for example if supply is artificially constrained or there is strategic bidding. Benchmarking may therefore over- or under-estimate full market value, but in general is usually considered to be a measure of full market value.

In Optus's Stage 2 ESL submission, the report prepared by Coleago Consulting is highly critical of the use of benchmarking to estimate the value of spectrum.[16] Coleago argues that benchmarking is ineffective for valuing spectrum, owing to the noisiness of country and award specific data. We strongly disagree with their position. We recognise that spectrum price data is noisy but there are established techniques for controlling for this noise. These include: using broad data samples to discern spectrum price trends over time; and identifying specific benchmarks of particular relevance and controlling for known differences in local conditions, such as local supply constraints and differences in the intensity of competition. Applying these techniques may not be easy and may require applying qualitative

15 Marsden (2024), p.38.

16 Coleago (2024), Appendix F.

judgement alongside quantitative analysis, but ultimately the available data does provide some of the best available evidence for the market value of spectrum. In our opinion, it would be foolish to disregard such obviously relevant data when considering the potential value of ESL frequencies subject to renewal.

2.3. Valuation modelling

Valuation modelling is the approach typically used by operators to value spectrum prior to spectrum awards. Regulators may also use this approach to estimate the value of mobile spectrum, typically in conjunction with benchmarking, with the modelling results being used to sense check the benchmarking results (and vice versa).

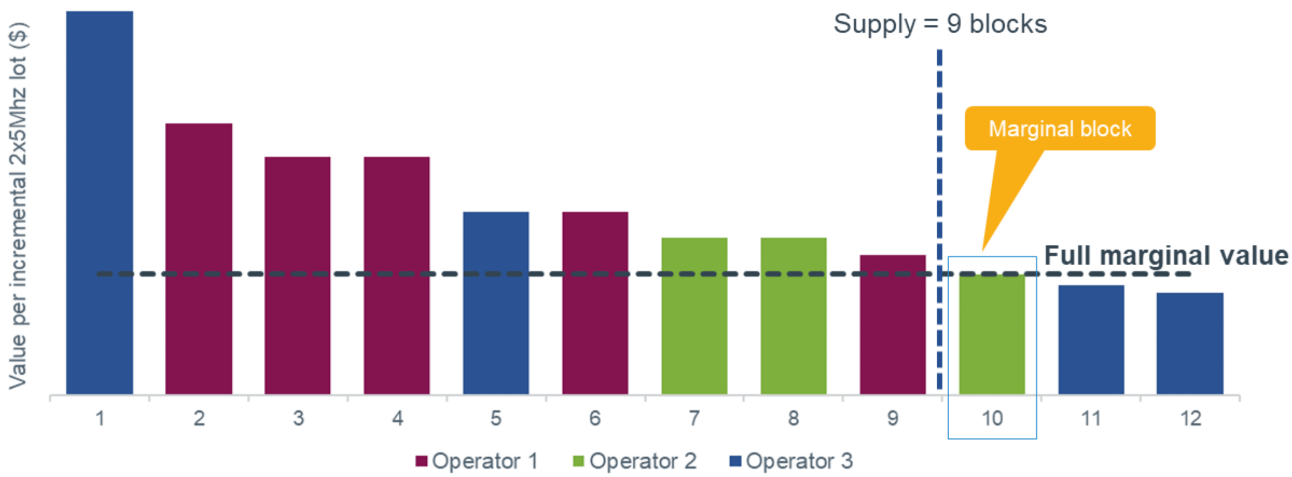
The objective of valuation modelling is to quantify the value that potential users place on acquiring various amounts of spectrum, identify how the available supply of spectrum should be allocated to each user in an efficient outcome, and then identify the highest value that any user places on any additional spectrum. This is often referred to as the highest losing value, the opportunity cost or the 'full marginal value'.

In theory, the opportunity cost for mobile spectrum could be set by an entrant operator or even an alternative use. However, as discussed above, in the context of the ESLs, it is highly likely to be set by one of the three existing mobile operators (Telstra, Optus and TPG) wishing to acquire additional spectrum. Therefore, we recommend that if the ACMA undertakes a valuation modelling exercise, it need only consider the three existing mobile operators.

Spectrum valuation modelling involves the development of a DCF model that calculates the incremental cash flows that an operator would enjoy over the full licence period (e.g. 20 years) from gaining access to additional spectrum. These incremental cash flows are then discounted to produce a Net Present Value (NPV) using an appropriate Weighted Average Cost of Capital (WACC).

Considering just a single spectrum band, to determine the full marginal value, it is necessary to consider each operator acquiring various quantities of spectrum in the band. These valuations can then be ordered highest to lowest. As illustrated in Figure 6, if there are for example nine 2×5MHz lots available in a band (such as in the 700MHz band), the full marginal value is the value of the 10th highest value block. This could be associated with any of the operators – for example, it could be the strongest operator's fifth block or the weakest operator's first block – depending on the distribution of the first nine blocks between the operators. Note that the average value of the blocks that each bidder 'wins' is necessarily higher than the full marginal value.

Figure 6: Identification of the full margin value – illustrative example for 700MHz band



Source: Aetha

In the context of the ESLs, the spectrum valuation exercise is potentially more complex, as licences in seven spectrum bands are due to expire between 2029-2032. In theory, one should consider all permutations for the distribution of spectrum between the three operators simultaneously in order to a) identify the efficient allocation across all seven bands, and b) the highest losing value in each band. However, such an approach would be very complex. Therefore, we suggest that the ACMA considers each band individually, assuming the operators retain their current holdings in each of the other ESL bands. Whilst this simplified approach is reasonable given the complexities of considering all bands simultaneously, it will produce a slightly higher estimate of the full market value.

The advantages of using valuation modelling to estimate the full marginal value of spectrum include the following:

1. *Market specificities can be captured* – valuation modelling can provide a context-specific estimate of spectrum value that is directly tied to its use in mobile networks in Australia.
2. *It is possible to investigate the robustness of the results* – through:
    - observing the 'depth' of the market (e.g. if there are nine lots available in a band, how much does the value of the tenth lot vary from the ninth and eleventh?); and
    - conducting sensitivity analysis (e.g. how much does the resulting full market value change when key input assumptions are changed?).

3. *Trend ana*lysis can be incorporated – By 'playing' with the inputs, it is possible to use valuation modelling to investigate trends in spectrum valuations (e.g. why are lower frequencies typically more valuable than higher frequencies? Why are spectrum prices falling?).

The main disadvantages of valuation modelling are that:

1. *Results typically have large error margins* – It is necessary to forecast an extensive range of inputs for the full duration of the spectrum licence period (e.g. 20 years). Inevitably, there are wide error bounds in each input forecast, which when combined, produce even higher error margins in the results. However, these large error margins are an inherent aspect of valuing spectrum – it is an uncertain exercise. This uncertainty should be reflected in the choice of the discount rate and/or by being conservative when setting renewal fees.

2. *Modelling ideally requires access to commercially sensitive input data* – Many of the inputs required for valuation modelling reside within the mobile operators and are commercially sensitive; for example, traffic forecasts and unit costs. Regulators typically do not have access to these inputs and therefore must estimate them. This adds to the error margins.

Owing to concern about large error margins, regulators typically avoid estimating the value of spectrum to a mobile operator by valuation modelling alone. Instead, it is often used to corroborate or supplement benchmarking.

Plum's approach to valuation modelling in 2011

In 2011, the ACMA commissioned Plum Consulting to consider the value of expiring spectrum licences in the 800 MHz, 1800 MHz, 2100 MHz, 2300 MHz and 3400 MHz bands. As part of this, Plum modelled the value of an incremental 2x5 MHz of 800 MHz and 2x10 MHz of 1800 MHz to a hypothetical operator with: (i) the lowest market share of the incumbent operators (at the time, VHA with a 27% share); (ii) one third of the available spectrum; and (iii) the minimum site count of any incumbent operator in each area type (i.e., urban, suburban, and rural).

Plum modelled two sources of value:

- *Technical value* – stemming from network cost avoidance of having an incremental block of spectrum – this is an estimation of the 'full market value'.

- *Enterprise value* – calculated as the proportion of the total cash flows associated with the operator's LTE / 3G offering. This is an estimate of weakest operator's aggregate value for <u>all</u> its spectrum in each band. This is very different, and inherently higher, than full market value, which is the value of the marginal block of spectrum (i.e. the highest losing value).

Along with international benchmarking of spectrum auction prices, the results of the valuation model were then used to inform the setting the renewal fees for 800 MHz and 1800 MHz licences.

We believe there were shortcomings in the approach taken by Plum:

- No operator like the one being modelled existed, so it is unclear that a true market value is being modelled.
- The methodology used is highly sensitive to the assumptions made. Many of Plum's assumptions are difficult to validate, and some of them have large impacts on the results obtained. Plum alleviates this concern to some extent by modelling various scenarios, but the range of scenarios modelled do not cover the scenario that actually unfolded over 2011-2023. Mobile data consumption for example, grew much faster than predicted, while 2G shutdown was earlier than anticipated.
- Plum assumes that the price operators would be willing to pay would be higher than the technical value, but less than the full enterprise value. Consequently, it argued that the appropriate renewal cost should be between these two values. This amount is above the full market value and therefore carried a risk that the spectrum would not be renewed.

  For example, for the 800MHz band, Plum estimated the technical value to be $1.15/MHz/pop and the full enterprise value to be $3.12/MHz/pop. Plum suggest that the renewal price should be set between these two values, despite the lower technical value ($1.15/MHz/pop) being Plum's estimate of the full market value.

Plum justified the uplift above the technical value (i.e. above the full market value) on the fact that a renewal of the licences would mean that the operators would avoid the costs or risks associated with an auction. This is inappropriate, given that the baseline is an estimation of full market price, as opposed to (say) a discounted auction reserve price. Also, the costs of participating in a spectrum auction are typically insignificant compared to the value of the spectrum, so are not relevant consideration.

Notwithstanding Plum's use of a methodology that potentially priced the spectrum above full marginal value, all of the spectrum was renewed. This may be explained by the fact that the renewal process took place during a period when spectrum prices were rising. In contrast, were the same approach to be used today, at a time when prices are falling, there would be a significant risk that operators inefficiently returned spectrum to reduce their costs. The 2011 process effectively extracted expected profits from the mobile operators. Whilst the operators may have been able to bear this then (given the lower spectrum burden and higher sector profitability at the time), they are in a much worse financial position today (as discussed in Section 1.1), and therefore more likely to refuse over-priced spectrum.

2.4. Recommendations on tools for estimating spectrum value

Both benchmarking and valuation models are recognised techniques for estimating full market value for mobile spectrum. If the ACMA decides to focus only on only one approach, then we strongly recommend benchmarking over valuation modelling. Benchmarking draws on actual market transactions across multiple awards in comparable countries, providing a good indicator of spectrum value that is reasonably robust to individual distortions. In contrast, valuation modelling requires access to private industry data and many subjective assumptions about operator behaviour. It is challenging to do without close cooperation with actual operators. Benchmarking results are also easier for stakeholders to understand and scrutinise, enhancing credibility.

For the 2011 renewal, the ACMA opted for a combination of benchmarking and valuation model. At the time, the dataset of international benchmarks was more limited than today, as only a few countries had released 4G spectrum. Therefore, there was as stronger rationale than today to also rely on a valuation model. However, for the reasons explained, we do not think the 2011 value model exercise was aligned with best practice. If valuation modelling is used again, the ACMA would need to take a more sophisticated approach, as we describe in Section 5. The effort required to do this would be much greater than a benchmarking exercise. The ACMA may note that many peer regulators in Europe and North America rely to some extent on benchmarking when setting reserve prices or pricing spectrum renewals, but few make any effort to build valuation models.

In their Stage 2 ESL reply comments, Optus disagree with Telstra's position that international benchmarking may be used to estimate the value of spectrum in Australia.[17] Optus also says that nominal pricing rather than benchmarking is the optimal methodology for pricing renewed ESL spectrum in Australia. However, our understanding of Telstra's submission is different to Optus. Telstra is not saying that ESL spectrum should be priced at benchmark levels (in fact, Telstra tell us that they believe that prices should be set a significant discount to full market value). Rather, Telstra is making a more mainstream point that it is reasonable for a regulator charged with pricing spectrum for renewal to explore the underlying value of the spectrum, and that benchmarking is a good tool to do this.

All available techniques for valuing spectrum, including benchmarking, are imprecise. The harm to industry and society from setting spectrum prices above market value can be significant, whereas there may be little, if any harm (only distributional effects), from setting prices at lower levels. Given this asymmetric risk, it is appropriate for regulators to take a conservative approach when setting renewal prices, considering evidence of market value from benchmarking and the broader opportunity cost of denying alternative use cases.

[17] Optus (2024b), Expiring Spectrum Licences – Stage 2 'Reply to Comment', paras 62-64.

3. Methodologies for pricing spectrum renewals

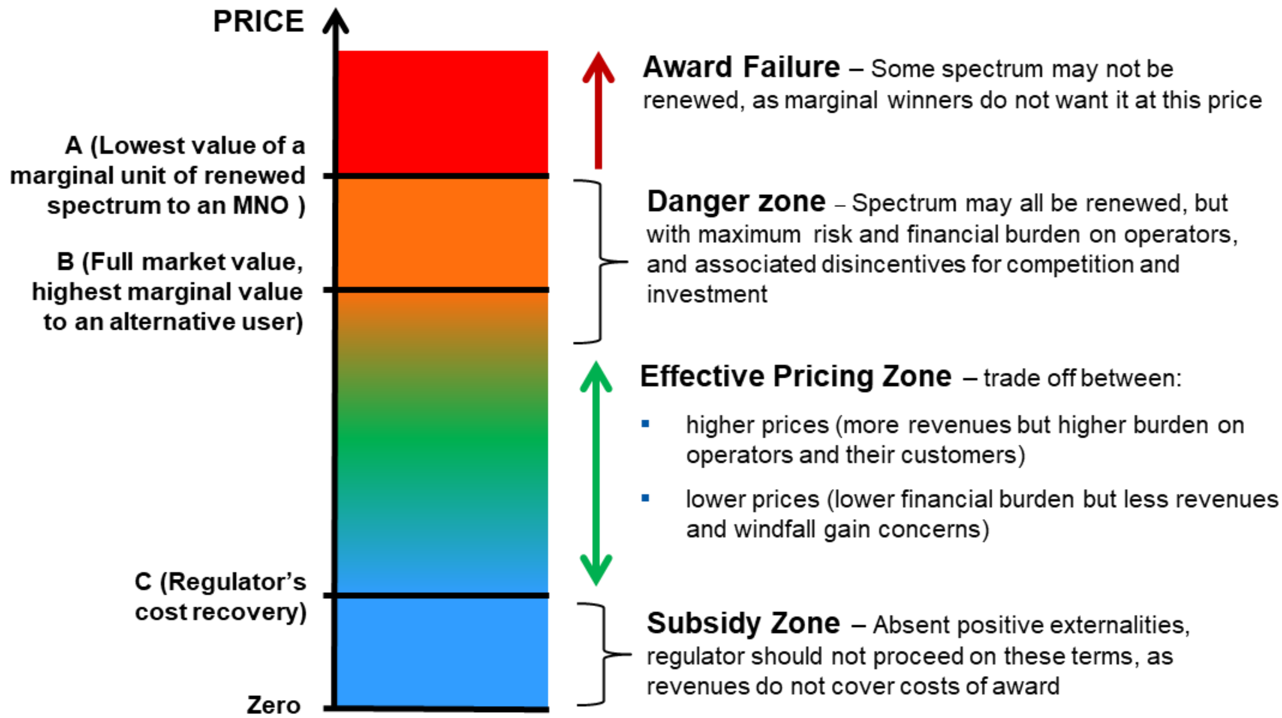
In Section 2, we discussed approaches to valuing mobile spectrum. We now turn to the question of where to set prices relative to those valuations. We begin by introducing the concept of an 'effective pricing zone', the range in which prices could be set without compromising allocative efficiency. At the high end of the range is the full market value, as may be identified using benchmarking or valuation modelling, and at the bottom end is a nominal price, which might be set in relation to the regulator's costs of managing the spectrum. We then explore the pros and cons of setting prices at different levels within this range. A concluding section argues that a conservative approach to price setting is appropriate, given the asymmetric risk associated with higher prices over lower ones.

3.1. The effective pricing zone

The concept of an "effective pricing zone" was introduced in a 2017 report written by NERA and published by the GSMA, which addresses best practice in pricing mobile spectrum.[18] This is illustrated in Figure 7. The basic premise is that mobile spectrum should not be priced above full market value, as this could lead to inefficiency in spectrum use, and should not be priced below a level that covers the government's costs of managing spectrum, as this would be an unjustified subsidy. In principle, an efficient allocation is possible at any price level between these extremes, but there are policy trade-offs, with higher prices favouring government revenues and lower prices favouring mobile consumers and operators. There is also a question of fairness: setting prices below the willingness to pay of an alternative use case that has no spectrum is arguably unfair and may be perceived as an unreasonable windfall gain for operators.

[18] GSMA (2017), Effective Spectrum Pricing: Supporting better quality and more affordable mobile services, Section 1.3.

Figure 7: Mapping the effective pricing zone



Source: Adapted from GSMA (2017), Figure 2, p. 12.

As discussed in Section 2, for awards of mobile spectrum, full market value is typically set by one MNO denying another MNO from winning marginal spectrum. This is the value revealed through a benchmarking or valuation model. It may be significantly higher than the value of the spectrum to an alternative use case or entrant MNO.

It is worth noting that the previous methodology developed by Plum to set renewal prices in Australia led to a value that was in the red zone of Figure 7. This is because Plum calculated full market value and then added a premium on the basis that the operators had a higher total enterprise value and benefitted from avoiding the uncertainty associated with an auction. However, in our opinion, attempting to extract enterprise value is inappropriate, and a (modest) premium for easing uncertainty should only be considered in situations where a renewal price is being set relative to a conservative price for equivalent spectrum being made available in an action. Fortunately, the renewal process did not fail, possibly because Plum's values ultimately turned out to be sufficiently conservative in the context of a then rising market price for spectrum.

3.2. Approaches to setting prices

There are three approaches to setting prices within the effective pricing zone that the ACMA could in principle adopt:

1. It could attempt to set a price at or close to "full market value";
2. It could set a much lower price that contributes to spectrum management costs – we call this "cost recovery" or "nominal pricing"; or
3. It could set an intermediate price, based on a substantial discount to market value – we call this the "conservative approach"

We describe each approach below and address their pros and cons.

For avoidance of doubt, all methods described would produce a common price per MHz for each mobile spectrum band, applicable to all users. In their ESL submission, TPG proposed asymmetric pricing with smaller operators paying lower fees, but this was strongly opposed by Optus and Telstra. We do not consider the TPG proposal because it is contrary to efficient pricing principles, and we are not aware of any finding that Australia's three-player market is uncompetitive. A price linked to market share would have the perverse effect of penalising operators that grow market share and subsidising operators that lose share. At the margins, it may encourage successful operators to decline spectrum when they would be the most efficient user, and underperforming operators to hold on to spectrum that they should sell.

3.2.1. Full market value

With the full market value approach, the regulator uses benchmarking and/or valuation modelling to estimate full market value and set prices at or close to this level. In effect, the regulator is using an administrative process to proxy the outcome of a hypothetical fully competitive auction. The approach maximises fees payable to the government but is associated with significant disadvantages. For obvious reasons, it is unpopular with MNOs.

From a government perspective, the advantage of this approach is that it maximises revenues without breaching a price level that would manifestly risk unsold spectrum and inefficient allocation. In situations where the full price is paid upfront, full market value pricing has been justified on the basis that the cost is "sunk" and should therefore not impact future investment decisions. However, as discussed further in Section 6.1, this argument – which was popular in the 2000s – has been undermined by both theoretical and empirical evidence that mobile operators do in fact consider the level of these costs when making pricing and investment decisions, for example because it impacts their financial health and credit ratings.[19] The sunk cost argument does not apply if the full market value is spread over the licence term in the form of annual fees, as bidders may have an option to return licences and save on fees.

Full value pricing has been further justified, notably by Ofcom, on the basis that the annual fees act as an incentive for inefficient operators to sell spectrum to rivals who could use it better. However, this argument is controversial. Economists have countered that pricing is not required to promote efficiency if the trading regime is functional. Notably, Professor Martin Cave, who played a key role in designing Ofcom's spectrum pricing regime, writing with Analysys Mason, said "*that pricing is not needed as an extra incentive to support economic or technical efficiency in mobile spectrum*".[20] As Australia, like the UK, has a functioning secondary market, it is our opinion that that Professor Cave's position holds for ESL renewal.

The full market value approach has three potentially significant disadvantages:

1. *Risk of inefficient allocation.* It carries a non-trivial risk of market failure with spectrum inefficiently going unsold because the methodologies for calculating full market value have inherent wide error margins (including both benchmarking and valuation modelling), and the regulator could easily unintentionally set too high a price. This risk is accentuated in a period when spectrum prices are trending downward, given that historic market assumptions or benchmarks are likely to overstate value. Even if the price is initially set at what is perceived as a fair level, markets conditions may change resulting in annual fees (or the debt burden associated with a lump sum payment) being too high in later years of the licence term.

2. *Barrier to efficient trades*. High fees may act as a deterrent to trading spectrum. If fees are set at or close to full market value, the secondary market price of spectrum is de facto zero. Buyers will only bid for spectrum if they can develop a use case that justifies taking on the risk of the high fee, whereas licensees may be reluctant to surrender the spectrum given the hope that it could appreciate in value later. Lower renewal fees create room for negotiation in secondary market trades, just as modest reserve prices in an auction create space for competition between bidders.

3. *High financial burden, and disincentive for price competition and investment*. This approach would result in high total renewal fees for MNOs and, in a period of low industry profitability, this would be challenging for operators. It also potentially bad for consumers and for the broader economy, as high spectrum costs feed into challenging financial circumstances which

19 GSMA (2017), p13-15.

20 Analysys Mason and Professor Martin Cave (2022), Review of market mechanisms as applied to mobile spectrum in the UK, final report for UK Policy Forum.

in turn limit scope for innovation in price and service competition, constrain access to capital markets and limit flexibility to fund network investments.

Both benchmarking and valuation modelling are approximate tools with wide error margins. Therefore, even when attempting to estimate full market value, it is prudent for a regulator to be cautious with respect to setting input assumptions into valuation or benchmark models. For example, Ofcom, which was directed by the UK government in the mid-2010s to set annual licence fees (ALF) for renewed 900 MHz and 1800 MHz spectrum "*to reflect the full market value of those frequencies*",[21] declined to discount its benchmark value estimates but did recognise "*that we should exercise any necessary regulatory judgement by adopting a conservative approach when interpreting the evidence*".[22] Adopting cautious assumptions is not the same as adopting a conservative approach (as described below), as this only reduces rather than eliminates the risk of market failure and still places the full fee burden on the industry. We note that Ofcom recently announced a review of ALFs for the 900, 1800 and 2100 MHz mobile bands, following a request from an MNO to revisit pricing levels; that operator had presented evidence that owing to market changes, the 1800 MHz price may now be too high.[23]

3.2.2. Cost recovery / nominal pricing

Cost recovery pricing is an established mechanism used for spectrum bands where there is no congestion. Fees are gathered from licensees that in aggregate cover the regulator's costs of awarding and managing the spectrum.

As discussed, there is likely to be contention for the expiring mobile spectrum licenses between the exiting MNOs. Therefore, in this context, nominal pricing involves setting prices at a level that is deliberately very low relative to full market value, based on public interest considerations. Nominal prices are not necessarily linked to a regulator's costs, but the revenues may be used for the same purpose and the two approaches may lead to similar low prices.

To implement cost recovery properly, the regulator first needs to estimate and project its own costs over the licence term. This should include both the regulator's specific costs in managing the relevant bands and a contribution to its broader fixed costs. In practice, as this exercise is not straightforward, the regulator may alternatively simply set a modest price level that it is confident is sufficient to cover its costs without actually undertaking any calculations. Thus, in practice, there may be little difference between an exercise labelled as cost recovery or one described as nominal pricing. In either case, as prices are not being set with reference to full market value, benchmarking or valuation modelling is not

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[21] Ofcom (2015), Annual licence fees for 900 MHz and 1800 MHz spectrum, Provisional decision and further consultation, p.2 (About this document).

[22] Ibid, para. 1.41.

[23] https://www.ofcom.org.uk/spectrum/innovative-use-of-spectrum/ofcom-launches-review-of-spectrum-licence-fees.

required. A regulator might still benchmark its price against other countries perceived to have adopted modest fees or reserve price for similar spectrum.

The Coleago (2024) report advocates for nominal pricing for ESL spectrum. They argue that low spectrum charges would enable greater mobile network investment, citing evidence from studies on linkages between low fees and higher investments, and presenting the example of Finland, which has low fees and high network investment. They also point out that while low fees would help all operators, they would disproportionately improve the financial situation of Optus and TPG, given their smaller scale. They further say that the ACMA's proposal for low fees for railway safety spectrum provides a precedent for nominal pricing for sectors where there is a "*broader public benefit to the community through the economic and social value generated from high quality, affordable services*."[24]

These are all reasonable arguments. Any approach that sets renewal prices at low levels relative to full market value would provide welcome relief to the industry. However, we recognise that the ACMA must weigh the benefits associated with nominal pricing against potential downsides. Low pricing means lower direct revenues for the state, albeit with the potential for offsetting this revenue through higher tax proceeds if the industry is more successful and contributes more to the broader economy. Nominal prices may also be below the value of an alternative use case, which is contrary to the principle of opportunity cost pricing and arguably unfair. If nominal fees are converted to annual fees, there may also be concern that low fees may encourage operators to 'warehouse' spectrum that they are not using. Also, if an operator ultimately elected to sell spectrum that has nominal fees, it would be positioned to secure windfall profits.

3.2.3. Conservative approach

With a conservative approach, prices are set at a substantial discount to full market value. The regulator begins by estimating full market value using benchmarking and/or valuation modelling. It then determines a substantial discount to this value estimate to set the price. This discount could be tied to an anchor, such as a rough estimate of value to an alternative use case, or simply a sufficiently large percentage discount – say around one-half of estimated value – to substantially mitigate the disadvantages associated with pricing at full market value.

This approach offers several possible advantages relative to the alternatives. If the discount is substantial, the immediate risk of inadvertently over-estimating full market value, resulting in market failure, should be eliminated. Importantly, such a discount creates headroom in case spectrum values continue to decline over time. There is also headroom for profitable trading, and the overall financial burden on the

24 Coleago (2024), p.2.

mobile industry is reduced. At the same time, relative to cost recovery, the revenues are substantial and scope for windfall gains constrained.

The approach also has two conflicting downsides. On the one hand, relative to pricing at full market value, the government is foregoing potential revenues which might otherwise be used to support other policy goals. On the other hand, the financial burden on the industry is still large relative to a cost recovery / nominal pricing approach. The ACMA would need to consider these trade-offs when deciding on the size of discount.

A further advantage of the conservative approach is transparency. Unlike nominal pricing, there is a public estimate of the benefit being accorded to the industry from renewal at these prices relative to holding a hypothetical auction. There would be an expectation that much of this concession would then be passed through to consumers through enhanced price competition and higher rates of investment, although one may also expect that operators may benefit from improved rates of return.

3.3. Recommendations on ESL price setting methodology

We strongly recommend against the full market value approach. High prices come with a material risk of market failure in spectrum allocation. Even if prices are set within the effective pricing zone now, they may become too high in later years of the licence term, as spectrum prices have been falling. Furthermore, the financial burden on the industry at a time of low profitability would be high and this may be reflected in lower investment and weakened price competition. This would negatively impact all Australian MNOs and the broader economy.

The choice between nominal and conservative pricing is ultimately a policy decision, and the ACMA should adopt a price level that aligns with its objectives. In our opinion, a price level set at about one-half of estimated full market value might be considered conservative.

4. Best practice in international benchmarking

In Section 2, we identified international benchmarking as the best available approach for estimating the market value of the spectrum subject to renewal. And in Section 3, we identified an approach of setting renewal fees conservatively relative to market value as a viable option for pricing that spectrum. If the ACMA instead opts for a nominal pricing approach, then a benchmarking exercise is not necessarily required to set prices but may still be a useful exercise, as it provides an indicative estimate of the implicit subsidy to the industry. In this section, we consider how the ACMA might conduct a benchmarking exercise.

When benchmarking the value of spectrum, practitioners face a trade-off between identifying broader samples of countries and awards, which is helpful for statistical analysis, and a smaller sample of highly relevant benchmarks, drawn from countries and time periods most similar to spectrum being analysed.

At a high level, our general recommendation is to:

- Use large samples of awards across groups of similar spectrum bands, disparate countries and long time periods to discern trends in spectrum prices over time. This approach is valuable to understand how spectrum prices have changed worldwide over time and is relevant for identifying shorter time ranges that may be more relevant for benchmarking specific values.
- Identify a 'relevant' subset of the larger sample to develop benchmarks for the value of spectrum in a specific country. As we will explain, we think the most important characteristics for determining relevance to the ESL process are choice of bands, the time period, and national income levels.
- Use qualitative analysis of specific 'highly relevant' awards as a cross check on findings and to make adjustments to value estimates for specific bands. For the ESL process, a designation of high relevance would require comparison to Australia across multiple criteria, for example, but not limited to income levels, competitive conditions and absence of other factors, such as licence obligations, which might have distorted prices.

International benchmarking requires a series of decisions about sampling, adjustment factors necessary to allow comparison across countries, statistical techniques used to average across observations; and final adjustments to arrive at the fees actually applied to operators. In the following paragraphs, we set out our thoughts on best practice for benchmarking of spectrum prices in each of these areas.

4.1. Sample selection

The first step is to identify the relevant sample of observations. This requires identification of relevant countries, relevant awards and bands for those countries, relevant price points within those awards, and the applicable time period. We discuss each of these choices below in the context of Australia's ESL process. For reference, Figure 8 provides a summary of sampling approaches used in a selection of international benchmarking exercises that are in the public domain. Each study had a different goal, so one should be cautious in drawing inferences for the ESL exercise. Nevertheless, they provide a useful comparison point when discussing best practice and whether it may or may not be appropriate to deviate from past practice in Australia.

Figure 8: Approaches to sampling used in selected benchmarking exercises

Event	UK annual licence fees	Global spectrum pricing study	Mexico study of spectrum prices	Irish 5G auction preparation	Australia 600 MHz valuation
For	*Ofcom*	*GSMA*	*IFT*	*ComReg*	*Free TV*
By	*DotEcon*	*NERA*	*Aetha*	*DotEcon*	*CEG*
Year	*2013*	*2017*	*2018*	*2019*	*2021*
Countries	Mainly EU, some other major economies	Separate categories for lower, middle and upper income	OECD + 6 Latin American countries + Romania	Wide sample but weighted towards EU / OECD economies	16 OCED countries with "similar" income levels to Australia
Bands	Each band within award is a single price point				
Price pts	All five studies used award price plus annual fees				
Time period	Prior 17 years, but greater weight given to recent awards	16 years of data, but with focus on last 9 years	Prior 10 years	Two periods: full sample from 1994; and limited sample of last 10 years	Prior 11 years

Sources: Collated by NERA. See footnotes for references: UK[25]; Global[26]; Mexico[27]; Ireland[28]; and Australia[29].

25 DotEcon (2013), "International benchmarking of 900MHz and 1800MHz spectrum value. Final Report for Ofcom", available at: https://www.dotecon.com/wp-content/uploads/2023/08/benchmarking-ofcom2013.pdf.

26 GSMA (2017), "Effective Spectrum Pricing: Supporting Better Quality and More Affordable Mobile Services", available at: https://www.gsma.com/spectrum/wpcontent/uploads/2017/02/Effective-Spectrum-Pricing-Full-Web.pdf.

27 Aetha (2018), "Estudio sobre la valuación y determinación de derechos para bandas IMR en México. Informe para el Instituto Federal de Telecomunicaciones (IFT) de México", available at https://www.ift.org.mx/sites/default/files/contenidogeneral/espectro-radioelectrico/07-informeaethaparaift-preciosespectroimt20dic2018v21pdftestado.pdf.

28 DotEcon (2019), "Proposed Award process for rights of use in the 700 MHz, 2.1 GHz, 2.3 GHz and 2.6 GHz bands: Benchmarking and minimum prices. Prepared for ComReg", available at: https://www.comreg.ie/publication/dotecon-report-proposed-award-process-for-rights-of-use-in-the-700-mhz-2-1-ghz-2-3-ghz-and-2-6-ghz-bands-benchmarking-and-minimum-prices/.

29 Competition Economist Group (CEG) (2021), "Value of the 600 MHz spectrum band. Report for Free TV", available at: https://www.freetv.com.au/wp-content/uploads/2021/05/CEG-report-Value-of-600MHz-spectrum-band.pdf.

Country selection

When identifying sets of countries for the purposes of conducting benchmarks, the primary factor used to define those sets is income levels, based on GDP per capita. This metric is a good proxy not just for the relative wealth of countries but is also closely correlated with other factors that should drive the value of spectrum for mobile use, including average revenues per user (ARPU), mobile penetration and progress in rolling out latest generation networks. Australia is a wealthy country with a mature mobile market, so it follows that countries with similar profiles should provide the best benchmarks.

Other factors that are sometimes considered for defining sets include geographic location and population size. We reject geographic location in the case of Australia owing to its relatively remote location and the fact that many of its neighbours in the broader Asia Pacific region have much less developed economies. Accordingly, it is appropriate to draw on an international country set. We also do not recommend attempting to differentiate between countries based on population size. The standard metric for pricing spectrum – price / MHz / pop – already adjusts for population size. We are not aware of any evidence systematically linking population size to spectrum value, so in principle both much smaller and much larger countries could provide benchmarks for Australia and its ~27 million population.

Consistent with our position, we observe that all the studies in Figure 8 adopted international samples and differentiated based on income. While the exact composition of countries used varies in each case, a common approach for benchmarking for a developed economy, such as Australia, is to use a sample incorporating OECD countries and other economies with comparable income levels. As we discuss under adjustments below, a significant advantage of limiting the sample to higher income countries is that because income serves as a proxy for a range of factors that should impact spectrum value, other more complicated cross-country adjustments may not be necessary.

Recommendation for ESL:

Identify a broad international sample of higher income countries for purposes of benchmarking value of spectrum in Australia.

Observations by award and band

A standard approach to benchmarking is to treat each band within an eligible award as a single benchmark. For example, on this basis, the 2022 Belgian 5G auction for 700, 1800, 2100 and 3600 MHz would provide four separate benchmark observations, one for each band. If a country sells spectrum from the same band in more than one auction, these observations may be combined if the awards take place at a similar time (e.g. within a few months) or treated as separate observations of the same value if there is a meaningful time gap.

Where bands were sold on a regional basis, we recommend aggregating regional values to identify a single national benchmark. This is because most countries sell spectrum at a national level and if we treated each regional price as a separate observation, our sample would be overly weighted towards countries that sell many regional licences, such as Canada and the United States.

Most higher income countries use auctions for most of their spectrum awards.[30] However, some have used direct awards at fixed prices for all awards (e.g. Japan) or for selected awards (e.g. New Zealand 3500 MHz). There are pros and cons associated with including these awards in the benchmark sample. On the pro side, including them provides a larger sample that represents the broad range of international pricing practices, On the con side, these prices have been determined administratively, not by the market, and may or may not have been set with reference to market value. Accordingly, the ACMA may consider exploring both options. Our experience is that the price difference between the two approaches is small.

Our recommendations here are consistent with observed practice in all the benchmarking studies described in Figure 8.

Recommendation for ESL:

Treat each band within an eligible award as a single benchmark.

In countries that sell spectrum on a regional basis, aggregate prices to identify a national price.

Compare benchmarks with and without prices for non-auction awards.

Observed price points

Depending on the spectrum packaging and auction rules, spectrum within the same band and same award may sell for different prices. A standard approach is to aggregate all prices associated with spectrum in the same band and then divide by the nationwide MHz and population associated with the relevant licences. For regional or sub-national licences, MHz are weighted by the population covered.

When benchmarking spectrum prices, it is important to consider the entire cost of the licence, including not only the headline auction price but also any annual fees associated with the underlying spectrum. The level of such fees can vary hugely across countries, so failure to incorporate them could lead to

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gross distortions in benchmarks. All the studies highlighted in Figure 8 incorporated annual fees. We also need to consider the impact of payments terms, which may allow for payment of auction fees by instalment. Our recommended approach is to calculate the NPV of the flow of annual fees and/or instalment fees across the licence term, applying an appropriate discount rate, and add these to the upfront payment.

Some licences may be associated with onerous obligations that are hard to value, for example coverage targets, or costs that are not proportionate to the MHz acquired, such as an obligation to contribute to a universal service triggered by the acquisition of any amount of spectrum. Ideally, benchmark prices should be adjusted to account for such costs, with licence specific costs applied to the relevant observation and general costs averaged across relevant observations. In practice, the data to do this is rarely available, so these costs are generally ignored in quantitative analysis, and may only be considered as a qualitative overlay. This must be assessed on a case-by-case basis.

In multi-band auctions that use combinatorial bidding (such as a CCA), each winning bidder may have only one price for a package of licences containing multiple bands. In many of these auctions, it is possible to infer a band-specific price from the results of certain bidders that only won in single bands, or by analysing the bid data. If the full bid data is available, then a technique known as linear reference pricing (LRP)[31] may be applied to estimate band specific prices. Again, the relevance of such adjustments should be assessed on a case-by-case basis.

Recommendation for ESL:

For each award, aggregate all prices associated with spectrum in the same band and then divide by the nationwide MHz pops associated with the relevant licences. Use the total price associated with each band, including the NPV of the flow of instalment payments and annual fees.

On a case-by-case basis, consider deviations from this default methodology to (a) account for the cost of onerous obligations; or (b) to break down package prices by band.

Time period selection

Another critical decision when benchmarking is the relevant time period. Here, there is a trade-off between limiting the sample to recent years, such that observed awards were conducted under reasonably similar conditions with respect to mobile ecosystem development, and using longer periods,

31 The application of the LRP methodology to package bid prices was developed for Ofcom in the context of a benchmarking exercise used to inform the setting of annual licence fees for 900 MHz and 1800 MHz spectrum. For a description, see: DotEcon (2013), 800MHz and 2.6GHz linear reference prices and additional spectrum methodology,, Report prepared for Ofcom.

which may significantly increase the number of observations. As discussed at the start of this section, we favour using long periods to identify broad trends in global spectrum prices and then to use this analysis to assist in identifying a shorter, relevant period for ESL benchmarking purposes. As already observed in Section 1.2, there is strong evidence that spectrum prices trended upwards during the 4G awards era but have declined significant over the 5G awards era starting about 2017. From this, we may reasonably conclude that awards before 2017 are unlikely to provide good information about the value of ESL spectrum today.

The issue of time period duration has been considered in each of the reference studies. Several of the studies limit the time period to around 10 years, based on relevancy. For example, for their study for Mexico's IFT, Aetha – writing in 2018 – say that "T*he value of the spectrum evolves over time, and in particular the relative value of spectrum bands. Therefore, including results prior to 2008 may introduce errors or biases into the results*.' [32] And although the Ofcom, DotEcon, GSMA/NERA and DotEcon/ComReg all consider data from a longer period, they all place greater weight on observations from the last ten years, which in each case roughly corresponds to the start of the 4G awards era. Accordingly, if the ACMA were to align a new exercise with the 5G era starting 2017, this approach would be consistent with the spirit of the reference studies.

Even limiting the sample period to 2017-2024, we face the complication that the global value of spectrum has fallen significantly in this period. The ACMA could attempt to address this by further reducing the time period, but this may lead to concerns about sample size and some relevant countries being omitted. At the same time, the period 2017-2024 has seen relatively high general inflation. As these two factors work in opposite directions, a possible solution discussed below is to ignore inflation but not make any adjustment for deflation in spectrum values.

Recommendation for ESL:

Limit the sample to 5G era awards, starting the sample period no earlier than 2017.

4.2. Adjustment factors

To allow comparison across countries, spectrum prices must be converted into a common currency, usually USD or Euro for global comparisons, or local currency for a specific benchmark country. For the ESL analysis, the appropriate currency is Australian dollars. A decision is required over the type of exchange rate data to be used and whether to make any additional adjustments, for example to account for differences in local mobile market conditions or inflation levels. It is also necessary to adjust for a

[32] Google translation from original Spanish. See Aetha (2018), p.59.

common licence duration and to set a WACC for valuing the NPV of any instalment payments and annual fees.

For reference, Figure 9 provides a summary of adjustment approaches in our sample of international benchmarking exercises.

Figure 9: Approaches to adjustment factors used in selected benchmarking exercises

Event	UK annual licence fees	Global spectrum pricing study	Mexico spectrum price study	Irish 5G auction preparation	Australia 600 MHz valuation
Year	*2013*	*2017*	*2018*	*2019*	*2021*
Currency adjustment	PPP	PPP	FX and GDP per capita PPP	PPP	PPP
Other adjustments	None	None	Also explored GDP per capita and PPP separately	None	None
Inflation adjustment	Yes	Yes	Yes	Yes	Yes
Licence duration	20 years	15 years	20 years	15 years	15 years
Cost of capital	8.86% pre-tax nominal	5%	10% pre-tax nominal	7.13% pre-tax real	4.7% post-tax real

Source: Collated by NERA from same studies as described in Figure 8.

Currency adjustment

For benchmarking studies, all observations must be converted into a common currency, and this is typically done using either prevailing financial exchange rates (FX) or purchasing power parity (PPP) rates that adjust exchange rates to take account of differences in prevailing price levels. An advantage of PPP rates is that they are less vulnerable to distortions owing to currency market fluctuations. They also provide a tool for comparing across countries with very different income levels. However, PPP rates are calculated based on a basket of general goods, which may be rather unrepresentative of the costs faced by a mobile operator.

If FX rates are observed, we recommend adopting the average annual exchange rates rather than the rate at the time of the award, as this should dampen the impact of currency fluctuations. If PPP rates are adopted, we recommend using World Bank data, as this provides a single cross-country source. However, a challenge with this approach is that some countries are slow reporting data for recent years, so the data set may be incomplete.

Although most of the reference benchmark sets used PPP rates (the Mexico study is an exception), the ACMA may prefer FX rates for the ESL work for several reasons. Firstly, we recommend that the ACMA use a sample of higher income countries, which limits scope for price distortions between countries that PPP is designed to address. Secondly, as the ACMA will be benchmarking for the purposes of setting prices several years in the future, it is important to incorporate new data points, such as 2024 spectrum awards, as soon as they are available, so the delay in availability of latest PPP rates is problematic.

Recommendation for ESL:

Convert all benchmarks to Australian dollars based on the average FX exchange rate for the year of award.

Other cross-country adjustments

To adjust for differences in local economic conditions and mobile markets, a further option is to make additional adjustments to licence prices, based on differences in selected metrics, such as GDP per capita and average revenue per user (ARPU). For example, the Mexico study considered a modified version of PPP adjusted for differences in GDP per capita and compared this to simple FX rate conversion. None of the other references studies considered such adjustments.

We do not think such additional adjustments are appropriate for a quantitative analysis of the value of the ESL spectrum. If, as we recommend, the sample is limited to high income countries, such factors should be less important. And, methodologically, they are challenging to implement. To the extent there is concern that sampling and FX adjustment is not sufficiently accounting for heterogeneity between countries, we recommend considering such factors as a qualitative overlay.

Recommendation for ESL:

Consider any further adjustments as a qualitative overlay only.

General inflation vs spectrum price deflation

Our preferred time period is one in which there has been significant inflation in general prices (from 2022-24), but also one in which the cost of mobile services has been broadly flat, and the value of mobile spectrum has declined significantly. These contrarian trends present a significant challenge when using awards from earlier in the sample period to estimate the value of spectrum today.

The typical approach when observing country X to produce a benchmark for country Y is to derive a benchmark in the year of award and then adjust it for inflation in country Y through to the current year, such that all benchmarks reported are expressed in current year prices. This approach was used for all the reference studies, but all were completed before the jump in inflation observed in 2022 and 2023, and the older studies predate definitive evidence of declining spectrum values. A problem with applying the standard approach in 2024 is that application of inflation will tend to significantly inflate benchmarks for earlier years when in fact we should expect that they are significant over-estimates of values in 2024.

One approach to this problem could be to use nominal prices with no adjustment for inflation, on the assumption that doing so offsets the downward trend in spectrum values. This approach would be simple to implement but rather arbitrary. De facto it is the approach adopted by Coleago (2024) in their paper for Optus, as their analysis of spectrum prices over time appears to ignore inflation. In our view, such an approach would likely overestimate values for low band and lower mid band spectrum, given evidence their value has declined significantly. However, if the ACMA adopted an approach of setting prices conservatively relative to estimated valuations, it could adjust for the likelihood of overestimate at this final stage.

A more sophisticated statistical approach would be to adopt an Exponentially Weighted Moving Average (EWMA), which places higher weights on recent observations and progressively lower weights on older observations. We discuss how this might be done in Section 4.3. An EWMA approach would provide an established methodology for undertaking a current benchmark valuation based on historic data and is compatible with adjusting for inflation.

On balance, we prefer the EWMA method, on the basis that it provides a mechanisms to specifically address the trend of declining mobile prices, but we think it would be reasonable for the ACMA to explore both options. In contrast, the standard approach used in the reference studies of only adjusting for general inflation is clearly inappropriate, given the significant downward trend in spectrum prices across the sample period at a time when general inflation has moved strongly in the opposite direction.

Recommendation for ESL:

A new approach is required to adjust for historic price levels, to address the general decline in spectrum prices in the 5G awards era. An EWMA approach, which places higher weights on recent observations and progressively lower weights on older observations, offers the advantage that it can address the trend of declining mobile prices.

Licence duration

The duration of a licence is an important determinant of licence value, with longer durations offering greater value. Countries almost invariably sell licences on a fixed term basis, with expiring licences either reclaimed and re-auctioned or renewed for a fee. Licence terms vary, but most awards are for durations of between 15 and 25 years, with the most common in the 5G era being 20 years. In recent years, licence duration has trended upward, as regulators recognise the importance of longer terms in providing certainty for investment in deploying new network technology. For Australia, we recommend modelling a 20-year term, in line with recent policy for releasing new bands (850 MHz may be an exception, as a 16-year term would align expiry with the recently auctioned 850 spectrum).

A number of approaches can be taken to convert prices from licences of varying terms to reflect the price of an equivalent 20-year licence. Our preferred approach is based on the assumption that a spectrum licence yields a stream of equal annual profits, such that the NPV of the profit streams generated by two licences of different durations can be compared:

- An N-year licence yielding R profit each year discounted using a WACC of i has NPV equal to:

$$\mathrm{NPV}(i, N, R) = \mathrm{R} \cdot \left(\frac{1 - \left(\frac{1}{1+i}\right)^{N+1}}{1 - \left(\frac{1}{1+i}\right)} \right)$$

- The value of an N-year licence can therefore be adjusted to a 20-year licence by multiplying the price of the N-year licence by the ratio of the NPVs of the profit streams generated by each licence:

$$Licence\ duration\ adjustment\ factor = \frac{NPV(i,20)}{NPV(i,N)} = \left(\frac{1 - \left(\frac{1}{1+i}\right)^{21}}{1 - \left(\frac{1}{1+i}\right)^{N+1}} \right)$$

When considering individual benchmarks, it is appropriate to consider certainty over renewal and expected renewal prices. Where either renewal or price are uncertain, it is reasonable to consider observed prices to be limited to the licence duration. However, where renewal is predictable at a nominal price, it may be more appropriate to consider that the licences have long duration. For example, US mobile licences are subject to renewal every 10 years, but as the conditions for renewal are usually easy to meet and renewal fees are nominal, the licences may be treated as de facto indefinite.

Recommendation for ESL:

Adjust the value of all benchmarks to align on a 20-year term

Cost of capital

We use a weighted cost of capital (WACC) to adjust for annual fees and payment terms to arrive at lump sum values, and also to adjust for differences in licence terms. Ideally, benchmarks would be adjusted using operator- and country-specific WACCs, to better reflect difference in the value and risk that an operator in a given country would place on the cash flows spent on and generated by the acquisition of a spectrum licence. However, given that precise historical WACC data is generally not available, we recommend simplifying the approach by selecting a suitable universal WACC for the analysis of benchmarks. Reference studies have adopted a WACC of around 7-8% nominal post-tax or 9-11% nominal pre-tax. The choice of WACC is generally informed by regulatory studies of the telecommunications market in the country being benchmarked. A default level of 10% is widely used in situations where there is uncertainty over the specific rate to be used.[33]

Although there is some variance in the data, there is also significant commonality in the approaches that regulators have adopted on payment terms and licence duration. Therefore, in our experience, the choice of WACC tends not to have a major impact on the results of a benchmarking exercise. To understand this, consider that doubling the chosen WACC from say 10% to 20% only results in an 8.0% difference in the value of the licence duration adjustment factor for converting a 15-year licence to an equivalent 20-year licence.

For avoidance of doubt, the WACC proposed here is only for benchmarking, and not for any subsequent conversion of lump sum values to annual payments. We discuss the methodology for setting annual fees in Section 6.2.

Recommendation for ESL:

Adopt a universal industry WACC rate (e.g. 10-11% nominal pre-tax) for purposes of adjusting international benchmarks consistent with reference studies.

4.3. Statistical techniques

The sampling and adjustment factors described above will provide a series of individual country benchmark observations. As a final step, statistical techniques must be applied to aggregate the observations to produce a preferred benchmark for a band or group of bands.

We identify here three decisions on statistics relevant to an ESL benchmarking exercise:

1. Whether and how to group spectrum bands;
2. Approach to averaging across benchmarks; and
3. Treatment of outliers amongst the benchmark observations.

[33] For example, this is the default rate used in the oil industry, as described in: https://www.investopedia.com/terms/p/pv10.asp

For reference, Figure 10 provides a summary of statistical approaches adopted in similar international benchmarking exercises.

Figure 10: Approaches to statistical techniques used in selected benchmarking exercises

Event	UK annual licence fees	Global spectrum pricing study	Mexico spectrum price study	Irish 5G auction preparation	Australia 600 MHz valuation
Year	*2013*	*2017*	*2018*	*2019*	*2021*
Spectrum band groups	All sub-1 GHz for 900 MHz 1800, 2100 & 2600 MHz for 1800 MHz	Separate categories for sub-1 GHz and mid band spectrum	Band specific comparisons	All sub-1 GHz for 700 MHz Mix of band specific and combined for mid bands	All sub-1 GHz for 600 MHz
Average	Arithmetic mean used as reference point	Unweighted moving average (mean & median)	Median	Geometric mean used as reference point	Median
Outliers	Excluded *Box plot, standard and absolute deviation methods*	Included	Included	Excluded *Box plot & standard deviation methods*	Included

Source: Collated by NERA from same studies as described in Figure 8.

Grouping spectrum bands

From a usage perspective, certain mobile spectrum bands have similar attributes, and therefore may be expected to have similar value. In such cases, it may be appropriate to combine benchmarks across similar bands. Aggregation increases sample size, so may provide more reliable statistical averages. It also produces a common price for bands of similar use (i.e. substitutable bands), so it is appropriate only if the ACMA anticipates levying similar renewal fees for those bands. Notwithstanding this point, prices for individual bands within a group could be adjusted subsequently based on further quantitative and qualitative analysis, as appropriate.

As networks evolve, the differences between bands at similar frequencies have diminished. Early mobile devices and network equipment treated each band individually and needed to be customised to a market, so even bands with similar frequencies often had very different values. For example, the 850 MHz band is associated with legacy 2G and 3G deployment, so historically was valued very differently from the APT 700 MHz band, which was a 4G band. However, today, new devices have wide band RF capabilities that can group like bands into a single RF chain and then use tuning techniques to optimise the performance for the band being used. Accordingly, looking forward, there is arguably little value difference between 700 MHz and 850 MHz (or any sub-1 GHz paired band established in global mobile ecosystems).

The major device vendors serving the Australian market classify the bands below 6 GHz in up to five groups, enabling devices that work worldwide:

- Low band 600 MHz to 1 GHz
- Mid Low band 1.4 GHz to 1.6 GHz
- Mid band 1.7 GHz – 2.2 GHz
- High band 2.3 GHz to 2.7 GHz (some vendors combine this group with Mid band)
- Ultra High band 3.3 GHz to 5 GHz.

Other factors that may impact spectrum value include:

- *Ecosystem maturity*. Some bands, such as the 700 MHz SDL and 1500 MHz SDL bands have only been released in a few countries and lack mature ecosystems. As these bands have not been released in Australia, we suggest excluding them from the benchmark exercise.

- *Technology and ratio of uplink and downlink*. Mainstream mobile bands work with either FDD or TDD technology. Historically, FDD bands – which provide equal uplink and downlink capacity – were preferred owing to their more mature ecosystems. However, as data traffic has become dominant and new technologies have matured, TDD bands have become increasingly preferred because they can support a higher ratio of downlink in line with actual traffic loads.

- *Availability of larger carriers*. Some bands have larger bandwidth, creating room for individual operators to acquire the larger carriers which support more efficient deployment of 4G (blocks up to 20 MHz) and 5G (blocks up to 100 MHz), and these bands may attract a premium. For example, despite having a much higher bandwidth than other mainstream mobile bands, 3.5 GHz has become increasingly popular, as it is the only band below 4 GHz that can support multiple operators with up to 100 MHz (or more) blocks each.

We recommend that the ACMA categorise all bands into either three or four categories for benchmarking purposes:

1. Low band (700 MHz, 800 MHz, 850 MHz, 900 MHz);

2. Lower mid band (1800 MHz, 2100 MHz, PCS, AWS); and

3. Upper mid band, either:

    a. one category: (2300 MHz, 2500 MHz, 3500 MHz); or

    b. two categories: (2300 MHz, 2500 MHz) and (3500 MHz)

An advantage of the three-category approach is the increase in sample size. For example, there are relatively few recent observations for 2300 MHz and 2500 MHz, so grouping them with 3500 MHz is insightful. However, as a secondary step, the ACMA may want to look at differences within categories, especially upper mid band, where the variation in frequency level and propagation performance is wide. If the quantitative evidence for differentiation is not robust, this might be handled at a qualitative level when setting prices conservatively relative to benchmarks for full value.

For other benchmarking work, NERA has applied a Wilcoxon rank-sum test[34] to explore whether there is statistical evidence that the prices of certain bands are related.[35] NERA found all pairs of bands within our recommended three groups passed the Wilcoxon rank-sum test, with one exception: 700 MHz (FDD) and 900 MHz bands within the low band group. The 900 MHz band has historically been used for 2G networks, unlike other sub-1 GHz bands, and allocations of the 900 MHz band may therefore systematically differ from allocations of other sub-1 GHz bands. With 2G network shutdowns however, we expect that the 900 MHz band will in future resemble other sub-1 GHz spectrum more closely. To assess this hypothesis, we applied the Wilcoxon test on a restricted sample of 900 MHz awards held in the 5G-era, from 2017 onwards. The test results suggest that 900 MHz spectrum has similar value to other sub-1 GHz bands in 5G era awards.

Recommendation for ESL:

We recommend that the ACMA group Australian mobile bands into either three or four categories for benchmarking purposes: low band (all sub-1 GHz); lower mid band (1800 MHz, 2100 MHz, PCS, AWS); and upper mid band (2300 MHz, 2500 MHz and 3500 MHz, with possibility of 3500 MHz being its own category). Any perceived value differences between bands within these groups can be addressed in follow-up analysis.

34 A Wilcoxon rank-sum test is a non-parametric test that determines whether two sets of prices are likely to have been drawn from the same underlying distribution. A non-parametric test like this one is more robust, as it avoids making potentially incorrect assumptions about the specific underlying distribution of licence prices. The null hypothesis is that prices for a pair of bands prices belong to the same underlying distribution. We use a 5% significance level.

35 The supporting statistical data is not public domain but we anticipate that we would find the same results if the work was replicated in the context of the ESL process.

Average: mean, median or weighted average?

With respect to averaging, there are three decisions to be made:

- Whether to use a mean or median?
- If a mean is used, whether to use:
  - a straight mean across the sample period but with outliers excluded; or
  - a weighted average that favours more recent observations over older ones?

When considering 5G award era benchmark sets, the distribution of spectrum prices is positively skewed, with a number of high price outliers. Given that samples consist of tens of observations rather than hundreds, high price outliers have a disproportionate impact on the mean but have much less impact on the median. Accordingly, if a mean is applied to the full sample, it is important that there is a method for weeding out outliers (see next sub-section). The median may therefore be preferred on the grounds that it is less vulnerable to distortion.

Alternatively, the ACMA could proceed with a mean, but adopt an Exponentially Weighted Moving Average (EWMA) that weights recent observations more heavily than older ones. In this case, the observed benchmark value for current market value is the value of the moving average in the final year of the sample period (i.e. 2023-24 for currently available data). The primary rationale for this approach is that more recent observations should provide higher quality benchmarks than older ones, especially given evidence that prices for spectrum have fallen significantly since 2017. As high price outliers are disproportionately weighted towards the earlier part of the 5G award era, i.e. 2017-20 rather than 2021-24, the weighting has also the effect of dampening the impact of outliers.

Our surveyed benchmark studies used both means and medians. The NERA/GSMA global pricing study used an unweighted moving average, based on both metrics, but that is not comparable to the ESL process as the purpose was to show trends in pricing over time, not to produce a single benchmark value. The UK and Irish studies focused on the mean, but the result was used as an input into price setting rather than a definitive value. The Mexico and Australia studies used the median. Although none adopted an EWMA, this may be explained by timing: all were completed between 2013-2021, when the downward prices were either not applicable or not yet established.

Recommendation for ESL:

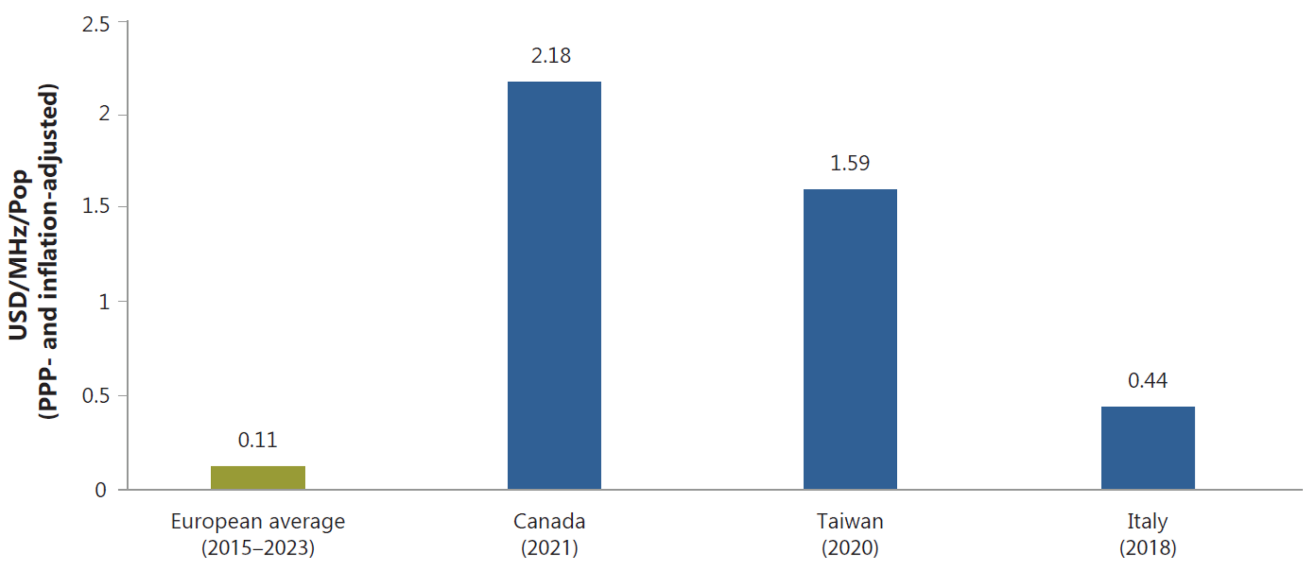
For each benchmark group, we recommend that the ACMA identify both a median value and a weighted moving average. A simple mean should be avoided as it is likely to overstate value.

Treatment of outliers

Spectrum benchmark samples are ‘noisy’, often including observations that are significantly above and below the mean. Samples tend to be skewed positive, owing to the presence of a significant minority of very high price benchmarks. Further, these higher priced auctions are more prominent in the 4G era and in the earlier part of the 5G era. Most examples of very high prices can be linked to situations of local scarcity in spectrum supply; accordingly, they are likely to significantly overstate market value in a situation of full supply of the relevant mobile band, which is the relevant situation for ESL modelling. Further, prices paid may incorporate a significant element of enterprise value because, when spectrum supply is constrained, MNOs may be concerned that they are vulnerable to network inadequacy and massive market share loss. In such situations, MNOs may be willing to pay an inflated price for spectrum. In our opinion, it is therefore essential to adopt a statistical technique that either lessens the impact of these outliers or strips them out of the benchmark sample.

Marsden (2024) addresses the sensitivity of spectrum prices to the level and structure of supply in key spectrum bands. As illustrated in Figure 11, the average value of 3500 MHz spectrum in Europe is compared against much higher prices seen in Canada (2021), Taiwan (220) and Italy (2018). The authors explain how supply constraints in each of these three countries led to aggressive bidding and high prices.

Figure 11: Inflated prices paid for 3500 MHz spectrum in countries with exceptional local spectrum scarcity vs European average price

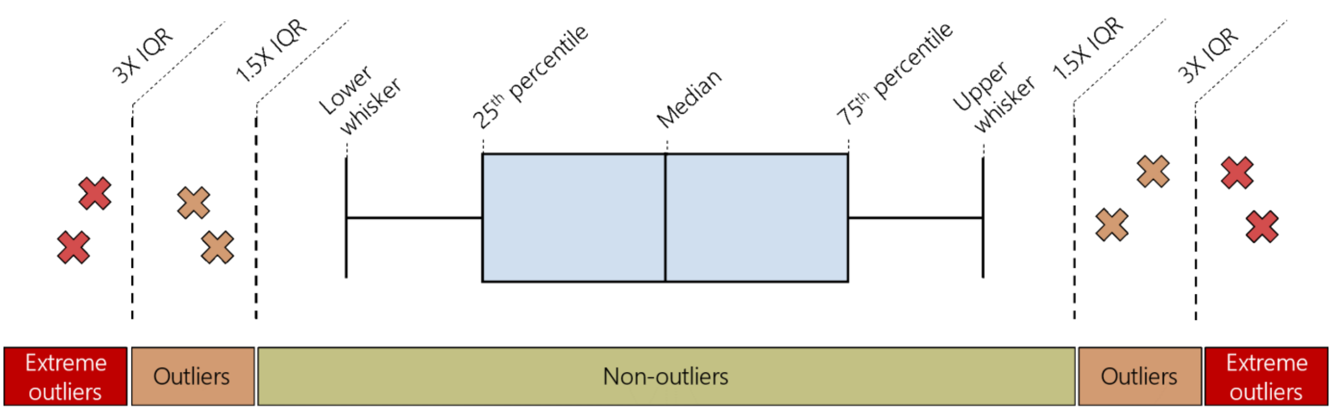


Source: Marsden (2024), Fig. 35, p. 114.

The requirement to exclude outliers when using a mean for benchmark specific valuations is well established. For example, both the UK and Irish reference studies when calculating mean averages excluded outliers. These studies used box plots, which is an established methodology for removing outlying variables.[36] A box plot is a statistical method used to visualise the distribution of data based on quartiles.

An illustration of the box plot approach is provided in Figure 12. The box represents the interquartile range (IQR), with the line within the box representing the median value. The 'whiskers' show the extent of the highest and lowest observed data points that lie within 1.5 times (1.5X) the IQR from the edges of the box. The fences – selected by the statistician – determine the observations identified as outliers. Here, we illustrate an 'inner fence', set at 1.5X IQR, identifying outliers, and an 'outer fence', set at 3X IQR, identifying extreme outliers. According to the US Dept of Commerce, "A *point beyond an inner fence [1.5X IQR] on either side is considered a mild outlier. A point beyond an outer fence [3X IQR] is considered an extreme outlier*." [37]

Figure 12: Box-plot methodology illustration



Both the 1.5X and 3X fences for defining outliers are in common usage, with the choice depending on context. Given that the mean is very sensitive to outliers, we recommend excluding any data points further than 1.5X IQR from the edge of the box. The case for excluding outliers is weaker if either a median or weighted moving average are used, as these approaches by design already lessen the impact of outlying data points. Nevertheless, extreme outliers should still be excluded if there is concern that they have been distorted by local factors to the point where they are not perceived to be plausible benchmarks for Australia. There are a few examples of very high price auctions, such as Canada (2021) shown in Figure 11, where prices may be linked to exceptional local scarcity issues. We recommend that

[36] See John Tukey, 1977, Exploratory Data Analysis, for a description of the box plot methodology.

[37] US Dept of Commerce at https://www.itl.nist.gov/div898/handbook/prc/section1/prc16.htm.

the ACMA consider removing these outliers. Extreme outliers could be removed manually or using the box plot with a 3X IQR fence.

Recommendation for ESL:

We recommend a box plot methodology to strip out outliers from the benchmark sample. If a mean is used, we propose applying a 1.5X IQR fence for the mean to strip out outliers. If a median or weighted moving average is adopted, we recommend a 3X IQR that eliminates extreme outliers.

4.4. Further adjustments to benchmarks

Applying the above three steps will produce a 'lump sum' estimate of the full market value of spectrum in each group of mobile frequency. Further quantitative and qualitative analysis may be used to make (modest) differentiations in estimated values for individual bands within each group. For national licences, the resulting lump sum values can then be divided by the volume of MHz in the band and multiplied by the MHz associated with specific licences to arrive at an estimate of the market value of each MNO's spectrum. Additional adjustments may be required if certain spectrum blocks within bands are regional or sub-national, or subject to special usage restrictions, for example owing to coordination requirements with other use cases.

These are estimates of the full market value of the nationwide spectrum in the current year, not fee levels. Several further steps may be required to arrive at the prices to be applied to operators for renewing spectrum. We discuss four of these here:

1. Adjustments for the year of renewal;
2. Implementation of the conservative approach to spectrum pricing;
3. Converting lump sum values to annual fees; and
4. Calculating fees for regional and sub-national licences.

Renewal year

We anticipate that the ACMA will develop benchmarks in 2025, but the licence terms associated with renewed licences will not actually commence until 2028-2032. In this period, prices can be expected to evolve further, so a price set in 2025 may no longer be appropriate at the time of renewal.

In principle, this issue could be addressed by forecasting prices into the future. However, forecasting spectrum prices is challenging. It is plausible that the current downward price trend will continue but at what rate? A possible approach could be to extrapolate from current prices using a compound annual growth rate (CAGR). However, if we extrapolate prices shown in Figure 1, we would quickly reach a point where the value of low band spectrum falls below upper mid band, which seems rather unlikely. One could apply a common CAGR to all bands but this would lock in existing value differences between the bands, which may not be correct.

Another approach would be to revisit the benchmarking in the year before each renewal, so the value estimate is more up to date. This approach has merit but is relatively onerous. One concern with this approach is that whereas the period 2017 through 2023 has seen many awards worldwide every year, the next few years could see a smaller number of awards, as many regulators in developing countries have completed their 5G era awards and neither regulators nor industry are yet ready for 6G era awards. This may raise concerns about sample size.

Rather than attempt to project prices forward or repeatedly revisit benchmarks, it may be easier for the ACMA to factor expectations of continued downward prices into the rationale for setting fees conservatively relative to estimated current value. As discussed below, if prices are set sufficiently conservatively relative to full market value, the risk that 2025 values overstate values at the point of renewal falls away.

Recommendation for ESL:
The ACMA could address concerns that a 2025 benchmark may overstate value for 2028-2032 renewal start dates by taking a sufficiently conservative approach when setting fees relative to full market value.

Conservative approach

If the ACMA decides to use market values as a reference point for calculating fees, we recommend it sets prices conservatively. As discussed in Section 3.2.3 and Section 6.1, this approach mitigates risk and is pro-competitive and pro-investment. In addition, this approach addresses above concerns that prices may continue to decline between a 2025 benchmarking exercise and the beginning of actual renewals from 2028.

A fee level at least one-half of estimated full market value may be considered conservative. As discussed in Section 1.2, modelling conducted by Aetha illustrates that four recent industry trends – the introduction of massive MIMO antennas, lower traffic forecasts, higher cost of capital and the anticipated release of future spectrum bands (600 MHz, 1500 MHz, Upper 6 GHz) – have reduced the market value of spectrum by potentially five- to nine-fold (although other factors may have tempered these trends to an extent). Further, a reduction of at least 50% compared to estimated full market value is roughly in line with the observed global decline in spectrum prices between 2018 and 2024, as illustrated in Figure 1. Put differently, if this exercise had been conducted in 2018 and no conservative discount had been applied, the licence price would now be double the market value!

When setting the discount, the ACMA should also consider the significant uncertainties associated with benchmarking and valuation modelling. These models are subject to large confidence intervals, with a difference of well over 100% between the upper and lower quartiles of the benchmark datasets typical. As UK regulator Ofcom has recognised, there is also asymmetric risk when setting fees, meaning that there is a significant downside associated with pricing spectrum "too high" and limited concerns with pricing "too low". Accordingly, in our view, it is appropriate to set prices at the bottom end of plausible value ranges. If fees are set above market value, then spectrum can go unused inefficiently and mobile operators that do take on spectrum may struggle with the financial burden. In contrast, there is little risk associate with pricing below market value, as efficient use is not impacted, and revenues forgone by the state may be offset by benefits to consumers and MNOs. See Section 6.1 for further discussion of what can go wrong for the economy and society when spectrum prices are set too high.

Recommendation for ESL:

If implementing a conservative approach to setting spectrum prices, the ACMA should consider a discount of at least 50% to an estimate of full market value.

Annual fees

The above adjustments calculate an upfront lump sum value for spectrum renewal. However, given the large amount of spectrum coming up for renewal with a few years, requiring MNOs to pay all renewal fees upfront would be exceptionally onerous, especially given the context of low industry profitability. This can be addressed by converting lump sum values into a flow of annual payments spread across the licence term. We discuss how this could be done in Section 6.2, drawing on the precedent set by Ofcom for the UK ALF process.

Recommendation for ESL:

Renewal fees should be levied as annual fees, not upfront payments.

Regional licences

Thus far, we have assumed that the process for pricing ESL is conducted at a national level. However, a complication in Australia is that many mobile spectrum licences are sub-national (with certain rural and remote areas excluded) or regional. A process will therefore by required to calculate prices not only for national area licences but also for these smaller area licences. As discussed in Section 6.4, we propose this be done by disaggregating fees for national licences based on a formula related to population size. We discuss two ways of doing these, noting that both are imprecise and give risk to a risk that fees for certain regions may be set too high. As with concerns about the renewal year above, this risk can be mitigated by adopting a sufficiently large conservative adjustment when setting nationwide fees.

Recommendation for ESL:

A formula is required for breaking down national prices to regional licenses. Risks associated with this approach can be mitigated by the ACMA adopting a sufficiently conservative approach to setting national spectrum renewal fees.

4.5. Recommendations on benchmarking ESL renewal prices

In summary, our recommended approach to benchmarking for the ESL process is as follows:

1. Construct a sample of awards from higher income countries globally across a period of 2017 to the present day, using nationwide prices (including annual fees) and treating each band sold within an award as a unique observation;
2. Convert all prices to Australian dollars using FX exchange rates, and adjust the value over a common 20-year term; and
3. Categorise bands into three groups – low band, lower mid band and upper mid band – for benchmarking purposes, and explore two options for statistical analysis:
   - Simple: Strip out extreme outliers and calculate the median value. No adjustment for inflation.
   - Sophisticated (preferred): Calculate a weighted moving average with extreme outliers removed and use the value for the final (current) year. In this case, values may be adjusted for inflation.

This approach will produce three reference valuations, one each for low band, lower mid band and upper mid band. Further quantitative and qualitative analysis may be used to make (modest) differentiations in estimated values for individual bands within each group.

Three further adjustments are then required to arrive at final renewal prices:

- Application of either conservative pricing or nominal pricing to arrive at a final lump sum value per MHz in each band;

- Conversion of lump sum values to annual fees;
- Adjustments to the value of regional and sub-national licences to account for differences in population.

5. Best practice in valuation modelling

In Section 2, we discussed the high-level approach that a regulator might take to estimate spectrum value using modelling, and in Section 3 we identified an approach of setting renewal fees conservatively relative to market value as a viable option for pricing that spectrum. In this section, we discuss best practice with respect to undertaking a valuation exercise to estimate full market value for spectrum in a mobile frequency band.

Specifically, we discuss:

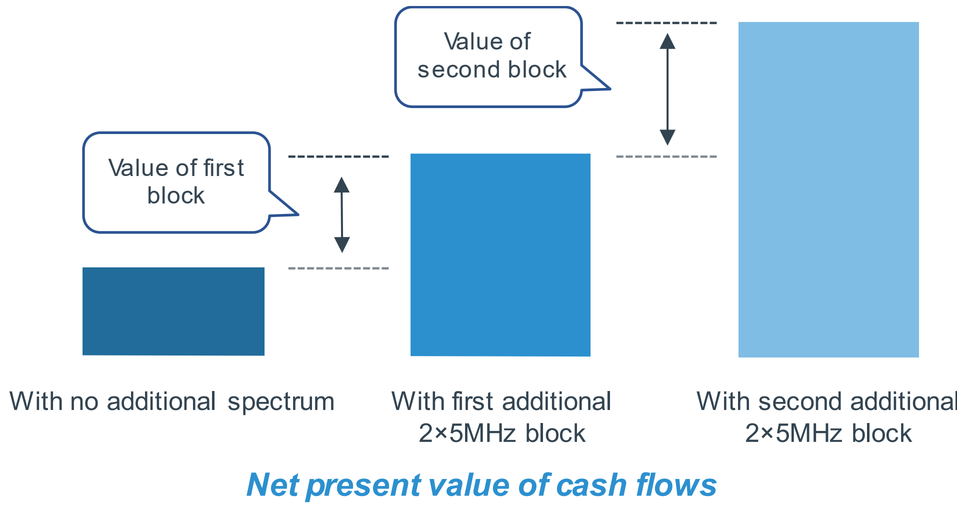
- the key principles of valuation modelling, including how best to use valuation modelling to arrive at an estimate of full market value, rather than value to a single operator, and how to manage the topic of variable spectrum supply across Australia.
- the sources of value that should be considered, i.e. technical and commercial value, and the relative importance of including each in the modelling.
- appropriate approaches for applying key inputs into the modelling, including recommendations for data traffic forecasting, modelling operator spectrum holdings, and including future technology developments.

5.1. Key principles of valuation modelling

As discussed in Section 2, valuation modelling is typically used by operators ahead of spectrum awards to obtain an estimate of spectrum value. In this section, we outline the principles of valuation modelling. We will also discuss how valuation models may be used to obtain an estimate of full market value.

Spectrum is valuable to operators because it enables them to either reduce costs or increase revenues. The standard approach to valuation modelling is to develop a DCF model, which involves forecasting the incremental cash flows that an operator can generate from gaining access to the spectrum (through either increasing revenues or reducing costs) over the licence duration. These are then discounted using an appropriate WACC to produce a NPV of the incremental cash flows. An illustration of the outcome of such an exercise is provided in Figure 13.

Figure 13: Spectrum value depends on the difference in NPV of cash flows between spectrum scenarios



Source: Aetha Consulting

Value to operators vs full market value

Valuation modelling is commonly used to estimate the value of a spectrum licence to a specific operator – for example, ahead of a spectrum award. However, it may also be used to arrive at an estimate for the full market value of the spectrum, as is the objective when considering renewal prices for ESL spectrum.

The full market value of a block of spectrum is the highest losing value, or the opportunity cost. In Section 2, we discussed sources of opportunity cost, including denying spectrum to other MNOs, denying spectrum to entrant MNOs, and denying spectrum to an alternative use. In the ESL process, the opportunity cost is likely to be set by the existing MNOs. Therefore, by modelling the value of ESL spectrum to each of the three MNOs – Telstra, Optus and TPG – and identifying the 'highest losing value', i.e. opportunity cost, an estimate of the market value can be obtained.

Approach to finding market value

There are seven bands in the ESL process. To obtain an estimate of the market value of spectrum in each band, each of the three MNOs must be modelled with a variety of spectrum holdings.

The value of spectrum in one band to an operator is dependent on that operators' holdings in other bands. For example, with all else equal, an operator with access to a large spectrum portfolio will have lower value for incremental spectrum than an operator with a limited spectrum portfolio. Therefore, the full market value of spectrum in each band in the ESL process is dependent on the assumptions made about the operators' holdings in other bands.

The operators' existing holdings in bands not included in the ESL process should be accurately reflected in the model. Many of these bands will expire during the renewed licence duration. A reasonable assumption is that these bands are renewed, and the holdings remain unchanged.

For bands included in the ESL process, the situation is more complex. In principle, the value of every possible spectrum package to each operator should be modelled. This would identify the most efficient allocation of spectrum across all seven bands. However, this would be a very complex undertaking – requiring millions of spectrum permutations to be modelled.

An alternative approach is to value spectrum in each ESL band individually, assuming that operators retain their current holdings in each of the other bands. Although a reasonable simplification, this introduces a constraint, in that the operators' existing holdings are 'baked in' – and therefore this approach will overstate the market value of the spectrum band being considered. This presents a further reason to set renewal prices conservatively relative to the results of any valuation modelling.

Using this approach, the first step is to consider scenarios in which each operator acquires a different number of blocks. For example, the 850MHz band will have 2×20MHz available. Assuming a block size of 2×5MHz, this are four blocks. The next step is to calculate the value of each operator obtaining up to four blocks, and then order these values. The operator with the fifth highest value for a block will set the opportunity cost, and therefore the full market value.

Figure 14: Illustrative value of different quantities of spectrum in hypothetical three-player market

Spectrum acquisition	Value to Operator A (AUD million)	Value to Operator B (AUD million)	Value to Operator C (AUD million)
Zero --> One blocks	10	13	9
One --> Two blocks	8	5	6
Two --> Three blocks	7	4	3
Three --> Four blocks	4	3	2

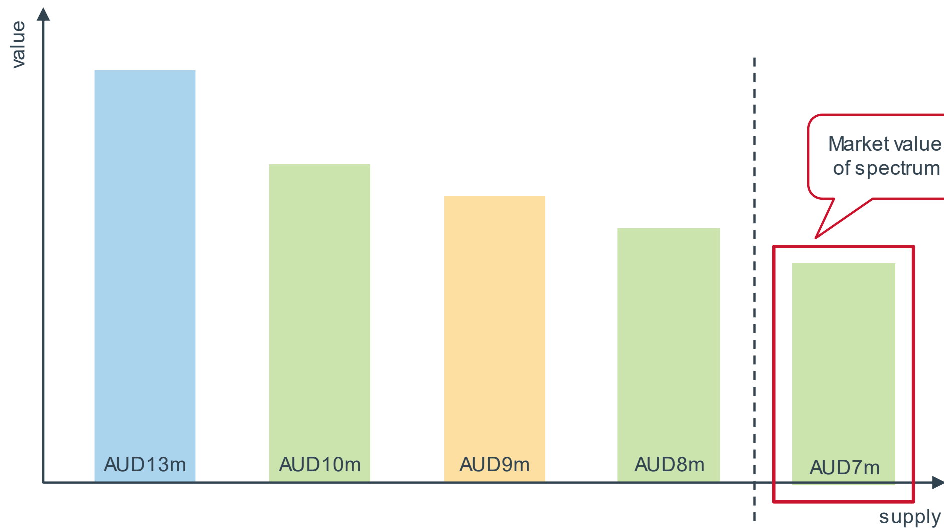
Source: Aetha Consulting

If there are three operators, A, B and C, with illustrative values as in Figure 14, the order of blocks is:

- Highest: Operator B goes from zero blocks to one block, with a value of AUD13m
- Second highest: Operator A goes from zero blocks to one block, with a value of AUD10m
- Third highest: Operator C goes from zero blocks to one block, with a value of AUD9m
- Fourth highest: Operator A goes from one block to two blocks, with a value of AUD8m
- Fifth highest: Operator A goes from two blocks to three blocks, with a value of AUD7m.

Therefore, Operator A sets the full market value as it has the 'highest losing value' for an additional block. The market value for spectrum in this band would be AUD7m, as illustrated in Figure 15.

Figure 15: The market value in this band is the value of the 5th block, where there are 4 blocks in the supply, and the values are ordered



Source: Aetha Consulting

Generalising this approach, the full market value is set by the value (to any operator) of the (n+1)th block in each band, where there are n blocks in the band, and the block values are ordered.

However, it is not uncommon for 'earlier' spectrum blocks to have lower value to an operator than 'later' blocks. For example, consider a band in which one operator does not have holdings. The value of that operator's first block of spectrum in the band will be low, as acquiring this spectrum will incur a cost to roll out equipment which supports this spectrum. The second block will have a higher value, as the rollout cost will only be incurred once. Even if there is no rollout cost associated with the initial block, later blocks may be more valuable as they create a larger, more efficient carrier in that band.

Nevertheless, operators must acquire lower-value early blocks to access the value of later blocks – and should be willing to do so, provided the total value of the package is above zero. To reflect this, the value of the blocks should be adjusted in such circumstances by averaging the valuations across blocks.

Substitutable bands

Several of the bands included in the ESL process are substitutable – for example, the 1800 MHz and 2100 MHz bands, or the 700 MHz and 850 MHz bands. Substitutable bands have similar propagation characteristics, and in many cases may be supported simultaneously by the same piece of equipment. The market value of substitutable bands should be similar. For example, the market value of the 1800 MHz band should be similar to the market value of the 2100 MHz band.

There may be minor differences between the value of these bands owing to existing equipment asymmetries, for example where an operator already has more single band 1800MHz equipment than 2100 MHz equipment deployed.

To reflect the similar value of substitutable bands, and offset the impact of historical equipment asymmetries, we recommend that the ACMA consider grouping substitutable bands together and averaging over the modelled value, as discussed for benchmarking in Section 4.1.

Spectrum supply

The methodology presented above involves defining the supply of spectrum in each band (i.e. n blocks) such that the (n+1)th block can be identified. In several of the bands, where the whole of the band is currently licensed to the three MNOs, this is straightforward. For example, the supply in the 700 MHz band is clearly 2×45MHz.

However, the situation is more complex in some ESL bands, where not all of the band is licensed to the existing MNOs in all regions. For example, 2×10/15MHz of spectrum in the 1800 MHz band is used by the state railways in major cities, and the 3400-3800 MHz band has the nbn urban excise spectrum and spectrum owned by nbn. Limiting the spectrum supply available to MNOs – making "n" smaller – will inflate the value of the (n+1)th block. The theoretically correct approach, where spectrum is held by other users, would be to include these users in the modelling but then include all the spectrum in the band as the supply (i.e. when determining 'n').

In the 1800 MHz band, this would mean modelling the value of spectrum to the state railways. However, this poses a challenge – the business case of the railway operators for access to spectrum is very different to that of the MNOs, and the value of the spectrum to these operators has not recently been tested in an auction. Assuming that the licences held by the railways are renewed, this already deprives the MNOs of 2×10/15MHz in metro areas, increasing network costs. Reducing the supply in the model would inflate the full market value, thereby penalising the operators twice for not having access to this spectrum. Therefore, even if it not possible to include the railways in the modelling, our recommendation is to include their spectrum in the modelled supply.

The situation in the 3400-3800 MHz range is more complicated. Again, the theoretically correct approach would be to include all spectrum in the band and model the value of spectrum to nbn. As with the railway operators, this presents a challenge, as nbn has a materially different business case for access to spectrum than the MNOs. Unlike the situation in the 1800MHz band, nbn holds a substantial quantity of spectrum, therefore excluding nbn from the modelling but including its spectrum in the supply appears unreasonable. The alternative approach is to exclude nbn from the model, and exclude nbn's holdings from the modelled supply. We note that the market value for 3400MHz spectrum was recently tested in the 3.7GHz auction. The ACMA may wish to place more weight on this benchmark in its assessment than on the modelling, given the above complexities.

Spectrum increment

It is necessary to select an increment for each band – i.e. size of blocks of spectrum considered in the modelling. This increment should represent the minimum useful quantity of spectrum. When 3G and 4G were the dominant technologies, increments were typically set (for FDD bands) at 2×5MHz. However, given that 5G will lend itself to larger carrier sizes, there is an argument for using a larger increment, especially for the larger, higher frequency bands. We suggest using increments of:

- Low band: 2×5MHz
- FDD mid band: 2×5MHz or 2×10MHz
- TDD mid band: 10MHz or 20MHz.

5.2. Sources of value

As discussed in Section 2, spectrum is valuable because operators can use it to reduce costs or increase revenues. Spectrum value can be categorised into two broad sources: technical value (network cost avoidance) and commercial value. In this section, we will explain each source of value and provide a brief overview of how they should be treated in the context of the ESLs.

Technical value (network cost avoidance)

An operator's spectrum portfolio is a key component in its network deployment strategy, impacting the number and density of sites in the network, and the equipment deployed to those sites. Therefore, changes to an operator's spectrum portfolio will affect its network costs – both capex and opex.

Typically, gaining access to additional spectrum will reduce site build and equipment deployment requirements. Acquiring spectrum therefore leads to a reduction in network costs, and confers **technical value**, or network cost avoidance value, to the operator.

To estimate technical value, a valuation model must contain dimensioning rules to forecast the network deployments that would be necessary under a specified spectrum scenario. By applying the dimensioning rules to two different spectrum scenarios, the difference in forecasted network costs can be obtained. For example, consider an operator who builds 200 fewer sites over a 20-year period owing to the added capacity of an additional spectrum block. The technical value of the additional block is the network capex and opex avoided (expressed in discounted terms) from *not* having built the 200 sites.

Commercial value

If an operator acquired less spectrum, it may not be possible, practical, or economically viable to fully compensate for this via increased network investment. In this case, its commercial offer will be impacted. This can manifest in several ways, such as lower market share, higher churn, or higher subscriber acquisition and retention costs. This will negatively impact the operator's cash flows in the scenario where it acquired more spectrum. Therefore, acquiring spectrum may avoid a negative cash flow impact, and confer **commercial value** onto the operator.

To estimate commercial value, it is important to consider the ways that a change to commercial offering may impact an operator's cash flows – whether that be via lower market share, higher churn, higher subscriber acquisition and retention costs, etc. The commercial value of a spectrum block is the avoided cash flow impact (expressed in discounted terms).

Sources of value to include in setting renewal price

In Aetha's experience of conducting over 100 spectrum valuation exercises, in most instances, technical value contributes a significant majority of the spectrum value. This is particularly relevant in the ESL process, as operators have spectrum holdings in other bands. Therefore, ESL spectrum represents incremental spectrum with incremental benefits. In such circumstances, technical value is likely to dominate over commercial value.

A further advantage of only modelling technical value is that it is based on objective dimensioning rules – although there are uncertainties arising from inputs and forecasts. Commercial value requires estimating the links between acquiring an incremental block of spectrum, improved service quality and then improved commercial performance This inevitably carries larger error margins.

As discussed in Sections 2 and 4, the risks of setting spectrum prices above market value are significant, whereas there is little harm to setting prices below market value. Given the significant uncertainties involved in modelling commercial value and given that technical value makes up the majority of spectrum value, our recommendation is that any valuation modelling used to estimate market value includes technical value only. This aligns with a conservative approach.

There are scenarios where commercial value may meaningfully contribute to spectrum value. As an example, consider an operator which loses access to its low-band holdings. To meet its previous level of coverage, significant densification would be required. However, for an existing operator, such a densification would be extremely expensive and would not be economically viable. Therefore, instead of making large network investments, the operator would likely reduce the quality of its service offering and accept a commercial penalty (e.g. lower market share, higher churn). As this penalty could be avoided by acquiring low-band spectrum, it therefore has a large commercial value.

Choosing to model the above scenario using a technical value approach – i.e. by assuming that the MNO would compensate for the lack of spectrum through network investment – would overstate the value of the spectrum, as the alternative commercial value approach would produce a lower valuation.

However, if the modelling exercise focuses on the valuation of the marginal (‘n+1’) block using the approach described above, only taking a technical valuation approach (and not commercial) should not be problematic. Any overestimates of value – i.e. scenarios where a commercial approach would produce a lower value – are likely to be focussed in the first few blocks within any band. The value of the marginal block should be largely unaffected and is typically dominated by technical value.

5.3. Key modelling inputs

In this section, we discuss several key inputs that are typically required in a spectrum valuation model and consider how the ACMA might approach them in the context of valuing ESL spectrum:

- Modelling period
- Existing spectrum holdings
- Future spectrum awards
- New technologies and spectrum efficiency improvements
- Data traffic forecast
- Fixed Wireless Access (FWA) traffic
- Frequency zones
- Financial inputs

Modelling period

Valuation modelling should cover an appropriate timeframe or modelling period to reflect the value of spectrum over the full duration of the licence.

Cash flows should be discounted over the full licence period. In some instances, it may be relevant to also include cash flows generated after the end of the licence period or a terminal value; however, we recommend not doing so in this instance. It is likely that at the end of the renewed licence period, there will be a further renewal process for the 2050+ timeline, which will incur an additional renewal fee. Any cash flows incurred after the licence period should be reflected in the 2050 renewal fee; including these cash flows in the modelling would overvaluing the spectrum. For the same reasons, terminal value should not be included.

The ESL bands expire between 2028 and 2032 and are expected to be renewed for 20 years (with the potential exception of 850 MHz, which may be 16 years to align expiry with other spectrum in the same band). For an ESL market value modelling exercise, the ACMA may wish to simplify this and assume a common start date of 2030 for all ESL bands. This enables ease of comparison between bands, particularly substitutable bands, and better comparison against benchmarks.

The cash flows in the model should be discounted to 2030, if a common ESL licence start date of 2030 is assumed. Otherwise, the cash flows for scenarios in each band should be discounted to the start date for the renewed licence in that band.

Recommendation for ESL:

Modelling should cover the full licence period, with cash flows from the licence period discounted to the start of the licence. No terminal value or post-licence cash flows should be included.

Existing spectrum holdings

The market value of spectrum in the ESL bands will be heavily dependent on the operators' existing holdings. All else being equal, an operator with a larger spectrum portfolio will not require additional capacity until later in the licence period. An incremental spectrum block therefore has lower value than if it were needed earlier in the licence period.

Historically, spectrum has been awarded in Australia both nationally and on a region-by-region basis, with the award regions changing between awards. For example, the 700 MHz band was awarded on a national basis, the 850 MHz band is split between Major Metro Areas and Rest of Australia, and the recent "leftover lot" auction in the 3700 MHz band included spectrum in twenty regions across Australia.

Therefore, valuation modelling should be on a site-by-site basis where possible, to ensure that existing spectrum holdings are accurately modelled. Alternatively, sites should be aggregated into spectrum regions where an operator's holdings are the same on each site in the region.

This will involve an in-depth mapping exercise. The operators' sites will need to be mapped against the spectrum regions of each historic award for which the licences have not yet expired.

Recommendation for ESL:

Modelling should consider "spectrum regions" for each operator where all sites have access to the same existing spectrum holdings.

Future spectrum awards

As demand for mobile services has increased, the ACMA has regularly awarded new spectrum for mobile use to enable operators to keep up with demand. This process will continue, with the current five-year spectrum outlook[38] identifying the 1500 MHz band as a focus area. Bands such as the 600 MHz and 4.0 GHz are under ongoing monitoring for domestic and international developments, and the 6 GHz band is under initial investigation.

It is important to include new spectrum bands in any spectrum valuation exercise, as not doing so would overstate the value of spectrum in the ESL bands. However, modelling should only include future bands if there is a reasonable confidence that they will be awarded, and in what quantity. We believe that it would be appropriate to include future awards in the 600 MHz, 1500 MHz, and upper 6 GHz bands. These are likely to be awarded in the 2030-2035 timeframe. Spectrum in these bands will need to be split between the three MNOs – we suggest using market share to do this (as a broad proxy for valuation).

The inclusion of future spectrum awards may materially impact the value of ESL spectrum. Therefore, it is important to consider how this should be modelled. The interplay between acquisition of additional ESL spectrum and the likely outcome of a future spectrum award is complex. For example, if an operator were to acquire less 700 MHz spectrum, it may choose to acquire more 600 MHz in a future award. Including these dependencies in the modelling would require making assumptions about future scenarios which carry a high level of uncertainty. We recommend that a more pragmatic approach is taken, in which each operator is assumed to acquire the same quantity of spectrum in future awards, and that the cost of the spectrum in these future awards is assumed to be zero.

To illustrate why this is a reasonable approach, consider a scenario where an operator wins an additional block of 700 MHz spectrum and later buys a package of 2×10MHz of 600 MHz spectrum. To determine

38 The ACMA (2024), "FYSO 2023-28: Annual progress report", available at: https://www.acma.gov.au/publications/2023-10/five-year-spectrum-outlook-2023-28.

the value of the 700 MHz block, the scenario where the operator does not win 700 MHz must be modelled.

If we first consider the scenario that, despite not winning the 700 MHz spectrum, the operator again acquires 2×10MHz of 600 MHz spectrum, and that the price per block is unchanged (although this operator's valuation for 600 MHz spectrum may have increased due to not buying 700 MHz, another operator will have won more 700 MHz, thus reducing is valuation for 600 MHz. The net effect from this is difficult to predict). Consequently, the cash flows associated with the 600 MHz award (fees and subsequent impact on network costs) are broadly the same to the 700 MHz acquisition scenario, and so "net out". Hence, it is reasonable to assume zero cost for the 600 MHz award.

Of course, the operator may choose to acquire more 600 MHz spectrum to compensate for not winning 700 MHz spectrum. In such circumstances, the cash flows associated with the additional 600 MHz spectrum (including the licence fee) must represent a net gain for the operator, or it would not make the purchase. Therefore, network cost cash flows (including the licence fee) associated with this scenario decrease, and so does the value of the 700 MHz.

In summary, assuming that the outcome of future spectrum awards is unaffected by the quantity of ESL spectrum won and that the cost of future spectrum awards is zero is a pragmatic but reasonable approach, which, if anything, may overstate the value of ESL spectrum.

Finally, in addition to the 600 MHz, 1500 MHz, and upper 6 GHz bands, it is likely that further bands will be awarded in the 2035+ timeframe. If these bands are not included in the model, spectrum may be overvalued. However, the visibility of these awards is low, and including them will add uncertainty into the model outputs. We recommend that any further bands are not included in the modelling. However, to offset this effect, it is important to use a conservative traffic forecast in the long-term. We discuss this further in a later subsection.

Recommendation for ESL:

The ACMA should include future spectrum awards in the model where there is reasonable certainty they will be awarded in the next circa 10 years – such as the 600 MHz, 1500 MHz, and upper 6 GHz bands. In the longer term, the model should include a conservative traffic forecast to offset the impact of not including future awards in the 2035+ timeframe which cannot be accurately forecasted.

New technologies and spectrum efficiency improvements

Inputs to the model should reflect observed trends in technology development, particularly regarding the spectral efficiency that can be achieved. The spectral efficiency that can be achieved in each band is dependent on the equipment used to deploy it. Today, most spectrum bands are predominantly deployed on passive antennas. However, the 2300 MHz and 3400-3800 MHz bands are predominantly deployed on active antennas (AAS), which utilise beamforming techniques and improved modulation schemes to achieve higher spectral efficiency than is possible on passive antennas.

While the 2300 MHz and 3400-3800 MHz bands already have widespread AAS deployments, it is likely that it will be economically viable to support mid band FDD spectrum with AAS technology in the coming circa five years. The ACMA has modified the technical frameworks for licences in the 850 MHz, 900 MHz[39], 1800 MHz[40], and 2100 MHz[41] bands to enable deployment of AAS, and Aetha already has experience with operators deploying mid band FDD AAS. For example, Ericsson's "AIR 3284" 32T32R FDD MIMO supports the 1800MHz, 2100MHz, and 2600MHz bands, with a downlink capacity (and thus spectral efficiency) 2× higher than a comparable 4T4R radio[42]

At a later date, AAS deployments in the sub-1GHz bands may also become available and economically viable, although this carries a higher level of uncertainty. Low bands are likely to experience a lower spectral efficiency uplift than the mid band FDD bands due to the longer wavelength of sub-1GHz frequencies. Spectral efficiency uplifts from upgrading to FDD active antenna systems may be in the order of 1.5× compared to passive antennas.

When the upper 6 GHz band is awarded to IMT, along with any other >3 GHz bands such as the 8 GHz or 10 GHz bands, it is likely that higher-order MIMO will be available. Nokia have reported successful 128TRX mMIMO trials in the upper 6GHz band[43]. Samsung have reported that they expect their proposed "X-MIMO" 256T256R radio tuned to the 8 GHz band to see spectral efficiency improvements

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39 The ACMA (2021), "Development of the 850MHz expansion and 900MHz bands spectrum licensing technical framework", available at: https://www.acma.gov.au/sites/default/files/2021-09/Development%20of%20the%20850-900%20MHz%20band%20technical%20framework_Summary%20of%20submissions.docx.

40 The ACMA (2021), "Review of the 1800 MHz band spectrum licence technical framework", available at: https://www.acma.gov.au/consultations/2021-10/review-1800-mhz-spectrum-licencing-technical-framework-consultation-352021.

41 The ACMA (2022), "Review of the 2 GHz band spectrum licence technical framework", available at: https://www.acma.gov.au/consultations/2022-11/review-2-ghz-spectrum-licensing-technical-framework-consultation-382022.

42 Ericsson (2023), "Massive MIMO handbook, extended third edition", available at: https://www.ericsson.com/en/ran/massive-mimo

43 Nokia (2024), "Nokia and Telia complete successful outdoor trial in 6GHz range with Massive MIMO radio", available at: https://www.nokia.com/about-us/news/releases/2024/06/04/nokia-and-telia-complete-successful-outdoor-trial-in-6-ghz-range-with-massive-mimo-radio/

of 2× over 3700 MHz 64T64R mMIMO[44]. It would be reasonable to assume that the equipment available for the upper 6 GHz band will enable a similar spectral efficiency improvement.

On top of the 'step-change' improvements owing to new technologies, spectral efficiency can be expected to undergo a modest year-on-year increase of between 2-4%. This reflects better network optimisation and radio resource management, and improved user equipment.

Increasingly, operators can deploy multiple bands using a single piece of equipment (radio and base band units). For example, the sub-1GHz bands (700 MHz, 850 MHz, and 900 MHz), and the FDD mid bands (1800 MHz, 2100 MHz, and 2600 MHz) may each be deployed simultaneously on multi-band equipment. Including this in the model is important as, owing to natural technology replacement cycles, multi-band equipment will lower the cost to deploy new bands. For example, Telstra or TPG may incur a lower cost to roll out the 2300 MHz owing to 2300 MHz / 3400 MHz / 3700 MHz multi-band equipment coming available than if only 2300 MHz and 3400 MHz / 3700 MHz antennas were available. Similarly, sub-1GHz multi-band equipment would lower the deployment cost of 850 MHz to Optus.

It is likely that further improvements to equipment will be available in the long-term (e.g. 2035+ timeframe). If these developments are not included in the model, spectrum will be overvalued. However, the visibility of these developments is low, and including them will add uncertainty into the model outputs. We recommend that any further developments are not included in the modelling. Therefore, to offset this effect, it is important to use a conservative traffic forecast in the long-term. We discuss this further in a later subsection.

Recommendation for ESL:

Model inputs should include technology developments which have been forecast with reasonable confidence. We recommend including transitions to active antenna systems in the 2027-2030 timeframe for mid-band FDD bands, with a spectral efficiency uplift of ~2× over passive antennas, and in the 2035+ timeframe for sub-1GHz FDD bands, with a spectral efficiency uplift of ~1.5× over passive antennas. We also recommend modelling higher-order mMIMO equipment for the upper 6GHz band with spectral efficiency uplift over 3400-3800MHz mMIMO of ~2×. In the longer term, the model should include a conservative traffic forecast to offset the impact of not including technology developments which cannot be forecasted.

[44] Samsung (2024), "Upper Mid-Band Spectrum for 6G: Opportunities and Key Enablers", available at: https://research.samsung.com/blog/Upper-Mid-Band-Spectrum-for-6G-Opportunities-and-Key-Enablers

Fixed Wireless Access (FWA) traffic

A significant driver of current traffic growth is fixed wireless access (FWA) usage. FWA usage is much higher than traditional mobile usage, with an average usage in Australia in 2023 of 315 GB/HH/month[45]. However, growth in FWA traffic is not likely to continue at these rates, given expected increases in fibre adoption. Fibre provides improved speed and reliability, making it a more attractive option than FWA in regions where it is available.

FWA traffic is both distributed and handled differently to other mobile network traffic. Operators tend to deploy FWA only in regions where there is spare network capacity. They also apply a variety of traffic management techniques to ensure that FWA traffic does not significantly contribute to network congestion.

Therefore, FWA traffic contributes much less than traditional mobile traffic to dimensioning traffic – that is, the traffic that triggers capacity upgrades in the network. Consequently, there is a strong case for FWA traffic to be excluded from the traffic forecast in a spectrum valuation model.

Recommendation for ESL:

FWA traffic should not be included in valuation modelling as it does not materially contribute to dimensioning traffic.

Data traffic forecast

Data traffic growth rates have fallen in recent years, both domestically and internationally.

The OECD Data Kitchen[46] reports that average monthly mobile broadband data usage growth in Australia fell from a two-year rolling average of 90% in 2019 to 12% in 2022 (see Figure 16). Over the same period, the rolling average across all OECD countries fell from 31% to 22%. Other reporting, such as that done by Tefficient[47] and Analysys Mason[48] highlights the decrease in the growth of reported data usage.

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45 ACCC (2023), “Internet activity report – June 2023”, available at: https://www.accc.gov.au/by-industry/telecommunications-and-internet/telecommunications-industry-record-keeping-and-reporting-rules/internet-activity-record-keeping-rule/june-2023-report.

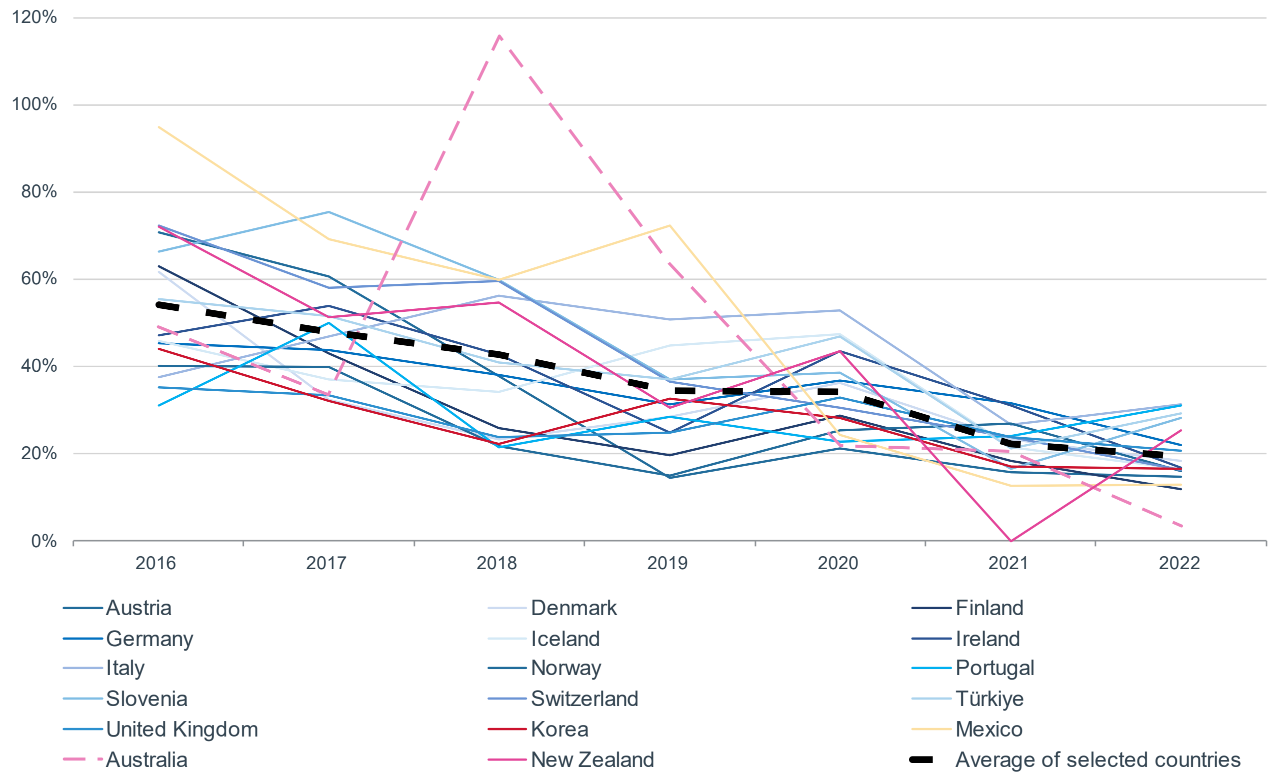
46 OECD Going Digital Toolkit (accessed August 2024), “Average monthly mobile data usage per mobile broadband subscription”, available at: https://goingdigital.oecd.org/en/indicator/15.

47 Tefficient (2023), ”Data-only drives traffic. The same can’t be said for 5G.”, available at: https://tefficient.com/data-only-drives-traffic-the-same-cant-be-said-for-5g/.

48 Analysys Mason (2023), “Operators and vendors need to plan for more conservative mobile data growth in the near future”, available at: https://www.analysysmason.com/research/content/articles/cellular-data-traffic-rdnt0/.

Telstra have reported traffic growth of 30% over recent years, which is partially driven by the growth of FWA[49]. This figure would be expected to fall when FWA is removed, and when it is projected into the future.

Figure 16: Falling data traffic growth rates in selected OECD countries



Source: Organised by Aetha Consulting; originally reported by the OECD Data Kitchen (see footnotes).

The trend of slowing data usage growth has been noted by Ericsson and Nokia, among other vendors. Ericsson's June 2024 Mobility Report[50] reports the decrease in growth of global mobile network data traffic, from ~70% in 2017 to ~20% in 2024. It predicts that this trend will continue, with data per active smartphone growing from 2023-2029 with a CAGR of 16% globally (16% in SEA and Oceania); the corresponding report from June 2014[51] predicted a 2013-2029 CAGR of 45% globally (51% in Asia

49 Telstra (2024), "What's next for Australia's best, largest and most reliable mobile network", available at: https://www.telstra.com.au/exchange/what-s-next-for-australia-s-best--largest-and-most-reliable-mobi

50 Ericsson (2024), "Ericsson Mobility Report – June 2024", available at: https://www.ericsson.com/en/reports-and-papers/mobility-report/reports/june-2024.

51 Ericsson (2014), "Ericsson Mobility Report – June 2014", available at: https://www.ericsson.com/en/reports-and-papers/mobility-report/reports.

Pacific). Nokia's Global Network Traffic 2030 report[52] supports this trend, forecasting global monthly usage per subscriber to grow from 2022-2030 with a CAGR of ~19% in the "moderate" case.

Whilst traffic will inevitably continue to grow throughout the ESL licence period, necessitating the need for more spectrum, the traffic inputs for a model that considers the period 2024-2035 should reflect the trend of falling data traffic growth. A traffic forecast that grows too quickly will overvalue spectrum.

As discussed above, it is only possible to forecast future technology developments and new mobile spectrum awards for the early part of the modelling period – perhaps up to 2035. Beyond this, technology developments and new spectrum awards are too uncertain. Therefore, it is important to be conservative when forecasting traffic growth over the long-term. This promotes consistency between the spectrum inputs, technology inputs, and traffic inputs.

As an example of this effect, consider a (hypothetical) valuation model conducted in 2000, designed to value a spectrum licence from 2004-2023. It would not have been reasonable for this model to forecast the impact of massive MIMO technologies on spectral efficiency, or the allocation of 3400-3800 MHz for mobile use. Therefore, if this model had used a traffic forecast which correctly predicted data traffic rising to 10 GB/SIM/month, the spectrum bands in the model would have been significantly over-valued. In the same way, we cannot predict technology and spectrum developments that will occur 10-20 years from now. In valuation modelling, the appropriate way to handle this is to use a conservative traffic forecast, as set out in Figure 17 below.

The assumptions made about future spectrum awards, achievable spectral efficiency, and traffic forecast in the 2035+ timeframe must be consistent with each other. It is not reasonable to include long-term future traffic in the modelling if the spectrum and technology that will emerge to serve that traffic are not included. A simple method to check the consistency of the traffic, spectral efficiency, and spectrum inputs is to look at the long-term network capex and opex forecasts. Network capex and opex should be kept at a reasonably flat proportion of revenue. If the networks costs increase over the course of the modelling period, due to an optimistic traffic forecast without corresponding optimistic assumptions regarding future spectrum awards and improvements in spectral efficiency, the model will overvalue the ESL spectrum. As discussed, the exact long-term traffic forecast chosen will depend on the future spectrum award and spectral efficiency assumptions. However, as broad guidance, we suggest beyond 2035 annual traffic grow should be in the mid-single digit range.

52 Nokia (2023), "Global Network Traffic 2030 Report", available at: https://www.nokia.com/about-us/news/releases/2023/10/31/nokia-technology-strategy-2030-emerging-technology-trends-and-their-impact-on-networks/.

Figure 17: Recommended approach to forecasting traffic growth

	Short-term (2024-2035)	Long-term (2035+)
Traffic forecast (usage per subscription)	CAGR between 12% and 18% to reflect the current trend of falling traffic growth	Conservative traffic in the 'mid-single digit range' offsets non-inclusion of spectrum bands and technology developments which cannot be reliably forecast

Source: Aetha Consulting

Recommendation for ESL:

Data usage growth rates have fallen and are predicted to continue to fall. Traffic growth in the short term (2023-2035) should reflect this trend with a CAGR of ~12-18%. Over the long-term (2035+), a conservative traffic forecast 'mid-single digit range' should be used to offset the capacity gains associated with future technology developments and spectrum awards that cannot be modelled today.

Frequency zones

In any valuation modelling exercise, it is important to consider the propagation characteristics of the different spectrum bands being considered. Low bands propagate further than mid bands and penetrate better through wall. This extends coverage further from the site, aids coverage in rural areas as well as in-building. Therefore, for each site, there is a proportion of traffic that must be served by low band spectrum only. This area may be called the low band frequency zone.

This concept can be extended to mid bands and high bands. As band frequency increases, its coverage decreases. Therefore, each band in the operators' spectrum portfolios can be organised into a frequency zone.

Frequency zones typically vary by geography. Low band spectrum is more critical in rural areas, where the site grid is less dense, and users are typically situated further away from sites. Rural areas are also more likely to have geographical features which limit the propagation of higher-frequency bands. In metro areas, sites are more densely spaces, and users are more likely to be close to the site – increasing the proportion of traffic which can be served by higher-frequency bands.

In Figure 18, we show a suggested grouping of bands along with approximate cumulative frequency zones. For example, we suggest that in metro areas, 10% of traffic must be served by low bands only. Approximately 15% of traffic must be served by either low bands or lower mid bands.

Figure 18: Estimate of cumulative share of traffic only supported by lower frequency zones as each higher zone is added

Frequency zone	Bands included	Approximate frequency zone – metro	Approximate frequency zone - rural
Low band / sub-1GHz	700MHz, 850MHz, 900MHz, 600MHz and 1500MHz if awarded	10%	40%
Lower mid band	1800MHz, 2100MHz, 2300MHz	15%	50%
2600MHz	2600MHz	20%	50%
3500MHz	3400MHz, 3700MHz	100%	100%

Source: Aetha Consulting

If it is included in modelling, an assumption will need to be made about the relative coverage of the upper 6GHz band.

Including frequency zones is important in valuation modelling to account for differences in value between bands. The superior propagation characteristics of sub-1GHz bands increase their value as they play a stronger role in avoiding network densification than spectrum in any other band.

Recommendation for ESL:

Modelling should include frequency zones to reflect that the propagation characteristics of the different band types mean that not all traffic can be served by all bands.

Financial inputs

Cash flows in any DCF model are discounted using an assumed weighted average cost of capital (WACC). A lower WACC means that future cash flows are discounted by a smaller factor, and therefore increases spectrum valuation, compared to a higher WACC. A WACC that is too low will overvalue spectrum. Therefore, it is important to be conservative when selecting the WACC.

Due to higher cost of debt, operators' WACCs have increased substantially in recent years. This needs to be taken account in any spectrum valuation model to inform ESL renewal fees. As an indication, Damodaran[53] estimate an appropriate post-tax WACC for companies in the telecoms wireless and service sectors globally to be 7-8% (nominal), based on a cost of equity of 9-10% and a cost of debt of

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53 Aswath Damodaran, NYU Stern School of Business (accessed January 2024), "Costs of capital by Industry Sector – Global", available at: https://pages.stern.nyu.edu/~adamodar/New_Home_Page/datacurrent.html.

6-7%, and KPMG's 2023 "Cost of Capital" Study[54] supports this by reporting that the Media and Telecommunications industry 2023 post-tax WACC is 7.6%.

Modelling tax and using a post-tax WACC is the most accurate approach. However, if tax is not modelled, a pre-tax WACC can be used. A post-tax WACC of 7-8% and a marginal tax rate of 28% corresponds to a pre-tax WACC of approximately 10-11%.

Recommendation for ESL:

Selection of an appropriate WACC should reflect substantial increases to the cost of debt in recent years. We recommend using a post-tax nominal WACC of 7-8% or, if tax is not modelled, a pre-tax nominal WACC of 10-11%.

54 KPMG (2023), "Cost of Capital Study 2023", available at https://kpmg.com/de/en/home/insights/2023/10/cost-of-capital-study-2023.html

6. Other considerations when setting ESL fees

In this section, we highlight four further issues that are relevant to the process of setting ESL fees:

1. **Linkages with downstream competition and lower investment.** Various studies have suggested that mobile markets where operators have enjoyed lower fees have tended to outperform markets with higher fees. These findings reinforce the case for the ACMA to adopt a conservative approach or consider nominal fees when setting ESL fees.

2. **Conversion of lump sum fees to annual payments.** There is a strong case for applying ESL fees as annual payments to defer and reduce the financial burden on mobile operators. The ACMA may consider a simple industry-friendly approach, for example inspired by the payment terms adopted for Australian 26 GHz licences or a more sophisticated methodology, such as that developed by Ofcom to convert UK lump sum values to annual payments.

3. **Setting prices for regional licences.** A formula is required for breaking down national prices to regional licenses. We identify two options based on population weighting and differences in spectrum value across urban, rural and remote. Risks associated with these approaches can be mitigated by the ACMA adopting a sufficiently conservative approach to setting national spectrum renewal fees.

4. **Using the revenues generated from licence renewals to improve connectivity.** Unless the ACMA opts for nominal pricing, the ESL process will generate significant revenues. Historically, such revenues have flowed to the Government, thereby leaving the industry. Alternatively, a share of fees could be repurposed to support initiatives that promote connectivity for marginal areas and peoples within Australia.

6.1. Linkages with downstream competition and investment

Perhaps the most significant downside associated with setting high renewal fees for mobile spectrum is the potential for this to weaken price competition in the downstream market and deter investment in network infrastructure. In the early 3G era, there was a school of thought that high license fees for spectrum were akin to a distortion-free tax because mobile operators would treat them as sunk costs,[55] and would therefore make pricing and investment decisions independent of their spectrum spend. However, the reality has been very different. Multiple studies have found a relationship between high

[55] See, for example, Kwerel, E (2000), Federal Communications Commission, Spectrum Auctions Do Not Raise the Price of Wireless Services: Theory and Evidence; and Wolfstetter, E (2001), The Swiss UMITS Spectrum Auction Flop: Bad Luck or Bad Design?

costs and weaker price competition and investment. And more advanced economic theory explains why that MNOs do not in fact behave as if spectrum costs are sunk.

In the build-up to 3G-era auctions, the concept that spectrum fees would be treated as sunk costs seemed plausible, given the huge enthusiasm for the fast-growing mobile industry. However, the optimism regarding the industry's performance that underpinned this thinking has not endured. The 3G auctions left operators in some countries, such as the UK and Germany, with huge debts at a time when they also faced huge financial commitments to build third generation networks. Subsequently, investor sentiment soured and did not recover until the late 2000s. Broadly speaking, the 4G era was a period of greater optimism, with MNOs investing heavily in both new spectrum and new networks. However, while network quality has improved hugely and the traffic carried has increased exponentially, MNOs have not been able to significantly expand revenues. Accordingly, while MNOs have been compelled by competitive pressure to keep investing in spectrum and new (5G) network technology, they have generally seen their financial positions weaken.

As explained in GSMA (2016), there are three distinct and complementary explanations why firms do not behave as if upfront spectrum costs are fully sunk.

1. **Hold-up problem.** Spectrum awards are recurring transactions, not one-off events. If firms perceive that their expected returns will be extracted in successive auctions, a rational response is that they should moderate their investment behaviour.

2. **Internal financing constraints.** High spectrum prices may exhaust access to scarce lower cost internal funds, displacing other investment activity. And access to capital from multinational parents or external sources may be rationed in response to low profitability.

3. **Observed pricing decisions.** Empirical evidence from behavioural economics academic research suggests that in sectors with naturally constrained competition, firms with high sunk costs are more reluctant to engage in price competition. High spectrum fees may act as a signal for market participants to resist incentives to engage in more vigorous downstream price competition.

In recent years, many MNOs have struggled with profitability and interest rates in many countries have increased, so it is reasonable to expect that internal financing constraints have come to the fore. We note that both Optus and TPG focus on financial constraints in their ESL responses.

Many industry studies in recent years have highlighted the link between high spectrum prices and lower investment and weaker downstream price competition:

- The GSMA have published multiple studies that have identified relationships between higher spectrum prices and lower quality networks and reduced take-up of mobile data services owing to reduced incentives for investment, and between high spectrum prices and weaker downstream price competition for mobile broadband data. GSMA (2016), authored by NERA,, which looked at mobile sectors worldwide estimated lost consumer welfare with a purchasing power of US$250bn across a group of countries where spectrum was priced above the global median.[56] Further studies by NERA for the GSMA looking at European countries (2017) and Latin American countries (2018) made similar observations.[57] And a study by GSMA Intelligence (2019) presents further evidence that "*high spectrum prices can cause negative consumer outcomes, including lower coverage levels and slower data speeds*".[58]

- Several publications have specifically criticised the UK policy of setting spectrum renewal prices based on an estimate of full market value, on the basis that such charges are not necessary to promote efficient use, have extracted too much money from an industry, and have diverted funds from infrastructure investment. Analysys Mason (2023), writing with Professor Martin Cave, found that the basic philosophy articulated in the Cave report[59] did not support the continued use of spectrum pricing (ALFs) in its current form.[60] And Temple and Webb (2024) say that, for the UK mobile sector, "*Pricing should have been a transitory tool, used as markets were becoming established and then removed. Instead, it became a permanent feature, likely inhibiting economic gains. There is no evidence that it has or could incentivise more efficient use of the mobile spectrum in use today, although very different versions of pricing may have roles in other areas*."[61]

- Various studies have also provided case study examples of mobile market success stories where spectrum prices were low and setbacks where prices were high. While this evidence is more anecdotal, it is often compelling. For example, Coleago (2024) highlights the relative success of the mobile sector in Finland, where consumer prices are low, usage is high and investment is strong, and link this to government policies that have resulted in very low mobile spectrum fees.[62] In contrast, Myers (2013), a former chief economist at Ofcom, highlights examples of

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56 GSMA (2016), p.1.

57 GSMA (2017), Effective Spectrum Pricing in Europe: Policies to support better quality and more affordable mobile services; and GSMA (2018), Effective Spectrum Pricing in Latin America: Policies to support better quality and more affordable mobile services.

58 GSMA (2019), The impact of spectrum prices on consumers, p2.

59 The Cave Report was a report commissioned by the UK government entitled Review of radio spectrum management, led by Professor Martin Cave, which played a key role in shaping the market mechanisms, including spectrum pricing, that the government and Ofcom have defined for managing access to licensed mobile spectrum in the UK.

60 Analysys Mason (2023), p.4.

61 Temple, S & Webb, W (2024), Emperor Ofcom's New Clothes, p54.

62 Coleago (2024), p.14-15.

auctions in India and Australia where excessive reserve prices caused "*valuable spectrum*" to be "*left unsold and not brought into productive use to benefit the public and the economy*."[63]

These many studies all point to a strong case for the ACMA to set modest prices to ESL renewals.

6.2. Conversion of lump sum fees to annual payments

In their ESL consultation responses, TPG, Optus and Telstra all advocated for spreading renewal fees over the lifetime of the spectrum licences.[64] Given the huge volume of mobile spectrum in Australia coming up for renewal and the industry's low profitability, having to pay upfront for all renewals would be challenging for the MNOs, who would likely struggle to obtain good financing terms. Upfront fees, imposed in the mid-late 2020s, would further erode industry profitability and divert funds from network investment, which could be highly detrimental to the Australian economy. Accordingly, in our opinion, the case for the ACMA to adopt annual fees for ESL is very strong.

Whatever the methodology that the ACMA adopts for setting ESL fees, it is likely that it will initially derive an upfront lump sum fee estimate for each band. Accordingly, it will require a mechanism for converting lump sum fees to annual payments.

Given the current financial challenges in the mobile industry and expectations that spectrum values are likely to fall further in coming years. The ACMA may consider an approach to setting annual fees that allows them to gently fall in real terms over time. We note that this was the de facto approach when setting payment terms for Australian 26 GHz spectrum, where operators had the option to make five successive annual payments of 20.32% of the licence fee instead of a 100% upfront fee.[65] Such an approach would lessen the likelihood that fees would need to be reviewed because they become too high, as is now the case in the United Kingdom.

An alternative precedent is the approach developed by Ofcom for setting UK annual licence fees (ALF) for 900 MHz and 1800 MHz, based on converting a lump sum value to a stream of payments over twenty years. This process has subsequently been re-used by Ofcom to set ALF for licence renewals in the 3.4 GHz and 2100 MHz bands.

Ofcom has summarised the approach as follows:

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63 Myers, G (2023), Spectrum Auctions, p.5. He refers to six of the last seven auctions in India between 2010 and 2021, and to the 2013 Australian 4G auction, where the responsible minister intervened to increase reserve prices.

64 TPG (2024),, p.1; Optus (2024b), p.17; and Telstra (2024b), Expiring Spectrum Licences: Stage 2 Consultation – Telstra's reply to submission, Section 3.6.

65 Australia Minister for Communications, Radiocommunications (Spectrum Access Charges – 26 GHz Band) Direction 2020, Section 5 (3), p.4.

> "*To convert the lump-sum value into an equivalent annual payment, we apply an annualisation rate, derived from a post-tax discount rate (which takes into account the degree of risk-sharing between licensees and the Government) and a tax adjustment factor (reflecting the more favourable tax treatment of annual fees compared to lumpsum auction payments)*."[66]

A fuller description of the annualisation process can be found in Annex 4 of Ofcom's 2021 statement on setting ALFs for 2100 MHz.[67] The discussion indicates that the overall methodology for annualisation has been broadly accepted by UK stakeholders. However, debate continues regarding the setting of specific parameters. For example, all four UK MNOs considered that Ofcom overstated the annualisation rate when setting ALFs for 2100 MHz.[68]

One controversial aspect of Ofcom's approach to setting ALFs is that annual fees are increased each year in line with the Consumer Price Index. This approach was adopted during a period of very low inflation, so was not initially a concern. However, in recent years, with higher inflation, fees have been increasing more rapidly even though evidence suggests that the market value of the relevant spectrum bands has been falling (see discussion in Section 1.2). This inconsistency may be a factor in Ofcom's recent announcement that it will conduct a review of ALFs at 900, 1800 and 2100 MHz.

6.3. Setting prices for regional licences

As we described in Section 4.4, the ACMA will need to develop a methodology to calculate prices not only for national area licences but also for sub-national and regional licences.

In our opinion, it would be unduly burdensome to attempt individually to model spectrum values for each regional licence. This would add significant complexity to a valuation model which, as we have explained, is complex and inevitably has wide error margins. And international benchmarking may not deliver sufficiently robust samples for statistical analysis given that only a small subset of countries regularly award mobile spectrum at a regional level.

Instead, we recommend that the ACMA adopt a process of breaking down national level fees based on population size, which is the primary driver of licence value. We identify here two possible ways this could be done:

1. **Actual pops.** Licence values could be determined by the proportion of the national population associated with each licence. This approach is very simple. However, it takes no account of the differences in value between urban and rural licences

66 Ofcom (2021), Annual licence fees for 2100 MHz spectrum, Statement 13 December 2021, p.13.

67 Ofcom (2021), Annex 4.

68 Ofcom (2021), p.35.

2. **Weighted pops.** Licences values could be determined by weighted population, with weights based on the location of the pops classified by, say, ABS geotype. This would make it possible weigh urban, rural and remote area pops differently. Weightings could be further adjusted based on the frequency band group, for example so that the value for rural pops is weighted progressively lower for higher frequencies with weaker propagation. The value of each licence would then reflect the composition of the different categories of population located within the licence area. As this process would necessarily be novel and Australia-specific, stakeholder consultation on weightings and category definition would be required. It is more complex that the actual pops approach but should be more accurate.

An advantage of using actual or weighted pops is that the same formula can be applied to calculate the value of all licences subject to renewal and can also be used to recalculate fees in the event that licences are later partitioned or aggregated, e.g. owing to trading or (if applicable) use-it-or-lose-it (UIOLI) conditions. This would be more challenging if licences were instead being valued individually. There could also be a process for periodically reviewing regional fee partitions based on census updates that may reveal regional population shifts.

A critical risk when portioning a national licence value on a regional basis is that the process may lead to some areas being over-valued. This risk is present under either pops approach but more acute with the simpler actual pops approach. If fees were then set on this basis, then over-priced regions may be uneconomic, and operators would be inefficiently incentivised to return spectrum. Furthermore, if licence partition is allowed, operators might even try to return geographic parts of licences so as reduce their costs, leading to some areas being underserved with deployed spectrum. Fortunately, this risk can be mitigated by the ACMA either adopting nominal or conservative pricing (as described in Section 3.2). Under either approach, because prices are set well below the regulator's estimate of full market review, there is enough headroom to allow for error in regional pricing, thereby diminishing the risk that local area prices are inadvertently set too high.

6.4. Using the revenues generated from licence renewals

In Australia, as in many countries, revenues raised through auctions and renewals of spectrum licences flow to the Government. Over time, this has resulted in a large amount of capital exiting the industry. For example, as illustrated in Figure 4, Australian MNOs are in aggregate spending the equivalent of $700M-$750M on spectrum every year. At the same time, operators face a huge investment bill to rollout 5G networks and are under political pressure to extend coverage. This challenging financial equation has left many commentators to consider whether there are ways that more money could be kept in the industry. The ESL process provides an opportunity to explore this question in Australia.

The concept of “cashless auctions” or “cashless renewals” for radio spectrum has recently received significant attention. In the United Kingdom, the Analysis Mason / Martin Cave (2023) report for the UK Spectrum Policy Forum advocated “*considering whether societal benefits from greater access to mobile services through <u>a “non-cash” approach</u> for currently licensed mobile bands, in which, for example, ALFs are replaced by MNO coverage/investment commitments that can contribute to economic growth and increased spectrum utilisation*” [emphasis added].[69] In Europe, Internal Market Commissioner Thierry Breton recently suggested that EU member states should prioritize coverage obligations over cash commitments.[70] And New Zealand – the country that pioneered spectrum auctions, recently awarded 5G spectrum directly in return for funds to support the country’s Rural Connectivity Group.[71]

A literal definition of “cashless auctions” would involve competitive bidding based on criteria other than money, such as coverage rollout. However, unless the bid criteria are objective and fairly weighted, an auction may end up looking more like a beauty contest, a form of award that long lost favour amongst regulators averse to controversy and legal challenge. It is hard to imagine this approach gaining much traction. A more plausible future is that spectrum auctions and renewals will continue to require mobile operators to pay (or commit to pay) cash for frequencies, but that there will be mechanisms that return that cash to the industry in return for fulfilling obligations.

Approaches that keep the money in the industry can deliver on the intent of cashless auction. Many mobile operators are struggling to make adequate profits right now, a situation unlikely to change anytime soon. Therefore, if governments want to achieve their ambitious connectivity goals, they must find new tools to support coverage of marginal areas and communities. The New Zealand award is an example of this, as the money spent should come back to the operators in the form of grants to support rollout in uneconomic areas. Another example is Austria which ran a conventional auction to award 5G spectrum in 2020, but then conducted – within the same process – a reverse auction that discounted fees payable in return for commitments to roll out services to specific unserviced rural locations.[72]

This concept could be applied to the ESL process in Australia. The ACMA could use the money generated to fund connectivity schemes, such as the Government’s Mobile Blackspots program and Regional Connectivity Plan. One of the major barriers to funding connectivity that is socially valuable but uneconomic for private deployment is a lack of dedicated government funding. A way round this could be to link subsidy programmes to the renewal process, using the revenues generated from annual fees to provide the funding. As Marsden (2004) sets out, “*this is potentially a win-win for regulators, who can*

69 Analysys Mason (2023), p.4.

70 PolicyTracker, 28 February 2024, European Commission endorses cashless spectrum auctions.

71 https://www.mbie.govt.nz/about/news/accelerated-5g-roll-out-to-benefit-rural-new-zealanders

72 See Marsden (2024, p130-31, for a case study description of the Austrian 5G award.

progress their objectives to improve connectivity, and for mobile operators, who will see less money extracted from the industry."[73]

[73] Marsden (2024), p.134.

QUALIFICATIONS, ASSUMPTIONS, AND LIMITING CONDITIONS

This report was prepared by NERA and Aetha Consulting on behalf of Telstra for submission to the ACMA. This report is intended to contribute to the public debate regarding the ACMA's approach to pricing expiring spectrum licences (ESL). It was not prepared for use outside this process. There are no third-party beneficiaries with respect to this report, and neither NERA nor Aetha accept any liability to any third party.

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