Australian Government

acma

Australian
Communications
and Media Authority

Future use of the 3.6 GHz band

Highest value use assessment—Quantitative analysis

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Executive summary

Following consultation to the *Future use of the 1.5 and 3.6 GHz bands* discussion paper, the 3.6 GHz band (3575–3700 MHz) has progressed through to the preliminary re-planning stage of the process undertaken by the Australian Communications and Media Authority (the ACMA) for the consideration of additional spectrum for mobile broadband services. As part of its considerations at the preliminary re-planning stage, the ACMA has committed to undertaking a comprehensive assessment of the highest value use of the band.

This paper represents the comprehensive assessment of the highest value use of the 3.6 GHz band. The quantitative findings from this paper are further considered, along with any qualitative considerations, in the Options paper released parallel to this paper. The ACMA uses the comprehensive highest value use assessment as an input to the Options paper, in which a range of options for future arrangements in the 3.6 GHz band are identified. Stakeholder input to this public consultation process will be used to help determine the most appropriate option and whether the 3.6 GHz band should progress to the re-farming stage of the ACMA process for consideration of additional spectrum for mobile broadband.

The 3.6 GHz band is part of a larger band that has been identified by various countries for mobile broadband (MBB) network capabilities, including the early deployment of 5G. To determine whether MBB is a higher value use than the incumbent use(s), the re-farming benefits of MBB need to exceed the incremental costs of displacing incumbent users. If this occurs, overall economic welfare—which includes producer surplus, consumer surplus and associated broader social net benefits—will increase by moving the 3.6 GHz band to its new use.

In this context, this highest value use assessment is provided in three separate but interlinked parts. 'Re-farming benefits' represent the potential increases in economic welfare that may result from using the band for a new service under area-wide licensing (that is, expected to be MBB services). 'Incremental costs' represent the potential costs to economic welfare resulting from displacing incumbent users. 'Net benefit' ties these two parts and all of their related uncertainties together to help form a view of whether the 3.6 GHz band should be re-farmed.

Re-farming benefits

While the broader benefits of deploying mobile broadband services are understood, itemising the benefits associated with deploying networks in a particular band requires the use of proxies. The proxy used for the economic welfare benefits of re-farming in this highest value use assessment is potential operators' potential valuations of 3.6 GHz band spectrum. These valuations are used as they indicate the economic welfare increase that the spectrum can provide to potential users, primarily by lowering network deployment costs and/or providing new or improved services.

Total valuations of spectrum are built up from potential operators' $/MHz/pop valuations (that is, assuming a licence duration of 15 years for unencumbered spectrum), available bandwidth and population size. The context of the 3.6 GHz band being an early implementation band for 5G and premium 5G spectrum means that valuations are likely to be relatively high. However, the ACMA does not have access to the individual operators' valuations of the 3.6 GHz band. As proxies for these valuations, the ACMA has used the prices set for the re-issue of spectrum licences as the lower and upper bounds.

Recent re-issue and auction prices indicate that $0.03/MHz/pop represents a lower bound of valuations for the 3.6 GHz band, while expressions of demand and comments from industry inform a view that 3.6 GHz band spectrum is valued much higher than the lower bound. For instance, Vodafone Hutchison Australia (VHA) has indicated its expectation that the entire 3400–3700 MHz band will be worth 'several billion dollars at auction'.[1] The re-issue price for 2 GHz band spectrum of $0.625/MHz/pop has been used as the upper bound as it represents the highest re-issue price applied for spectrum above 1 GHz.

There are uncertainties about how industry's valuations relate to the geographic area options that may be selected for re-farming, along with the bandwidth available for a new use. Four area options are available, spanning from only metropolitan areas (that is, Area 1) to Australia-wide. Wider geographic areas would allow for mobile network operators (MNOs) to use the 3.6 GHz band to serve more of the population, which would typically result in a greater willingness to pay for the spectrum. However, wider geographic areas also result in greater incremental costs as more incumbent licences are displaced.

The available bandwidth is assumed to be 125 MHz, provided there are no hybrid approaches implemented. When this amount of bandwidth is coupled with the $/MHz/pop valuation and the population served in the geographic area option selected, the economic welfare benefits of re-farming (represented by potential users' overall valuations) can be estimated.

Table 1: Expected benefit for each area if the 3.6 GHz band is re-farmed

	Area 1	Area 2	Area 3	Australia-wide
Population	16.1 million	19.1 million	22.8 million	23.3 million
$/MHz/pop value				
$0.03	$60 million	$72 million	$86 million	$87 million
$0.05	$101 million	$119 million	$143 million	$146 million
$0.10	$201 million	$239 million	$285 million	$291 million
$0.25	$503 million	$597 million	$713 million	$728 million
$0.50	$1.0 billion	$1.2 billion	$1.4 billion	$1.5 billion
$0.625	$1.3 billion	$1.5 billion	$1.8 billion	$1.8 billion

Note: Area 1 refers to metropolitan areas of all capital cities except for Hobart and Darwin; Area 2 includes Area 1 and adds buffer zones around the applicable cities; Area 3 includes Areas 1–2 and most regional and some remote areas within Australia; while Australia-wide includes all of Australia (except external territories). Further information can be found in Geographic area options in this paper and in Appendix 6 to the Options paper.

Incremental costs

The incremental costs associated with re-farming the 3.6 GHz band can be split between 'constant output' and 'variable output' cases. Constant output cases assume no change in final output, but result in a reduction in producer surplus due to the costs involved in continuing service through using another band or another technology. In contrast, variable output cases result in a change in final output that has economic implications for producer surplus, consumer surplus and broader social net benefits, especially if incumbents are unable to continue their service at all. These costs, particularly in variable output cases, may not be possible to quantify.

Constant output and variable output cases can affect any individual incumbent licence, although the ability to find alternative spectrum or communications technologies varies between types of licensed services, making constant or variable output cases more

[1] Vodafone Hutchison Australia's submission to the Joint Standing Committee on the NBN.

likely for particular services. The primary differentiating characteristic for incumbent licences is therefore the type of licensed service—point-to-multipoint, FSS earth receive and point-to-point:

> **Point-to-multipoint licences.** While there may be some variability in different types of cases, point-to-multipoint licensees are likely to be constant output cases if they find an appropriate substitute for 3.6 GHz band spectrum. The increase in supply costs from changing to a substitute band represents the incremental costs. Point-to-multipoint licensees unable to find an appropriate substitute band are more likely to be variable output cases, with incremental costs affecting producer surplus, consumer surplus and broader social net benefits. The likelihood of variable output cases is expected to be greater for point-to-multipoint licensees that are wireless internet service providers (WISPs), as they use the spectrum to provide a direct service to consumers, and there may be limited alternative spectrum options if the 5.6 GHz band is unavailable.

> **FSS earth receive licences.** These are likely to have the highest incremental costs of any incumbent type of licensed service if they are displaced from the 3.6 GHz band. The cost of relocating C-band licences to a new facility is substantial (that is, between $20 million and $50 million per facility), and there are seven facilities hosting 19 FSS earth receive licences across Australia. Assuming that entire C-band relocation costs are applicable to the specific licences potentially being displaced from the 3.6 GHz band can lead to a large cumulative impact on producer surplus.[2]

> **Point-to-point licences.** The majority of point-to-point licences are expected to represent constant output cases, as they are typically in regional and remote areas with multiple substitute band options. For the purposes of this analysis, all point-to-point licences are considered constant output cases. The incremental costs associated with displacing point-to-point licences will therefore be the resulting increase in supply costs—either replacing existing equipment for equipment that is compatible with a different band, or re-tuning equipment where possible.

[2] There may be ways to protect the locations of these facilities from interference, which would reduce incremental costs, although this would also reduce the re-farming benefits of moving to spectrum licensing in these areas (i.e. 5G MBB services provided via the 3.6 GHz band would not be available). Refer to Appendix A for further detail.

Table 2: Incremental costs of displacing all incumbent licences from the 3.6 GHz band

		Area 1	Area 2	Area 3	Australia-wide
Quantifiable costs	**Point-to-multipoint**	$0	$6 million–$27 million	$11 million–$59 million	$12 million–$74 million
	FSS earth receive	$105 million–$230 million	$105 million–$230 million	$125 million–$280 million	$125 million–$280 million
	Point-to-point	$101,000–$200,000	$705,000–$1 million	$2 million–$5 million	$2 million–$5 million
	Total	$105 million–$230 million	$112 million–$259 million	$139 million–$344 million	$139 million–$359 million
Unquantifiable costs	**Point-to-multipoint licences**	Licensees unable to find a substitute band or technology for 3.6 GHz band spectrum may experience a change in output (which may include ceasing delivering services altogether). The unquantifiable costs are the change in overall economic welfare in consumers having to move from the incumbent service to a substitute service.			
	FSS earth receive licences	**Areas 1–3.** Some of the 17 licences in Areas 1–3 may represent variable output cases if it is not viable to relocate them. **Remote areas.** Atwood Oceanics Pacific is not expected to be able to relocate its offshore remote licences—the costs of discontinuing service for this FSS earth receive licence are unquantifiable.			

The unquantifiable costs associated with displacing incumbent licences can be either a substitute for quantifiable costs (for example, WISPs having to discontinue operations rather than moving to a different band) or in addition to quantifiable costs (for example, Atwood Oceanics Pacific discontinuing use of its offshore FSS earth receive licences). As such, there is no clear quantifiable figure that can be deduced from the range of applicable incremental costs and used to objectively determine the net benefit.

Net benefit

There will be a net economic benefit if the re-farming benefits of the spectrum being available for area-wide licensing arrangements are greater than the incremental costs of displacing incumbent licences. This will ultimately mean that the new use following re-farming would be the highest value use of the spectrum.

The forecast outcomes for re-farming benefits and incremental costs in this paper indicate that re-farming the 3.6 GHz band will be net beneficial and increase overall economic welfare. The welfare maximising option is for re-farming for area-wide licensing to occur across Area 3, which includes metropolitan and regional areas, as the potential re-farming benefits from selecting this geographic area option are significantly greater than the incremental costs that would be incurred.

There are also hybrid approaches that can be applied, including setting aside some bandwidth for site-based apparatus licensing or protecting particular geographic areas and frequencies for some incumbent licensees. These approaches are Option 4a and Option 4b in the Options paper. The economic analysis outlined in this paper indicates that these hybrid approaches are unlikely to be welfare maximising.

The analysis suggests that re-farming of the spectrum will be net beneficial. However in coming to a preferred option, the ACMA recognises that it has relied on estimates and assumptions. The preferred option is discussed in the accompanying Options paper.

Issues for comment

The ACMA invites comments on the issues set out in this paper.

Specific questions are featured in the relevant sections of this paper and collated below. Details on making a submission can be found in the *Invitation to comment* section in the accompanying Options paper.

1. Are there any general economic impacts that should be included but are not currently included in the method to determine highest value use?

2. Are there any other spectrum valuations (for example, domestic or international auction prices or re-issue prices) that should be considered as a guide to the value of the 3.6 GHz band?

3. Is the range of $/MHz/pop values suitable for this analysis, or is there a case to narrow or broaden the range?

4. Would there be a change in the quality of services that could be provided by WISPs with the 5.6 GHz band compared with the incumbent 3.6 GHz band services?

5. What alternative internet services could regional consumers access (excluding NBN Sky Muster services) if WISPs are unable to provide their fixed wireless broadband services?

6. How could the loss of point-to-multipoint licences in the 3.6 GHz band affect regular business operations for non-WISP licensees?

7. Are the applicable costs for equipment replacement and re-tuning for point-to-multipoint licences suitable? If not, what cost ranges should be applied?

8. Are there any additional costs (applicable under a Total Welfare Standard) that have not been considered in this analysis?

9. If the 3.6 GHz band is re-farmed, what is the extent to which a longer re-allocation period would reduce incremental costs under a TWS?

10. Is the cost range for the relocation of all C-band licences from an FSS earth station facility suitable for this analysis?

11. Are the applicable costs for equipment replacement and re-tuning for point-to-point licences suitable? If not, what cost ranges should be applied?

Introduction

Background

The ACMA published its Mobile broadband strategy in February 2016, along with the *Mobile broadband work program—February 2016 update*. The work program was subsequently updated in September 2016 as part of the ACMA's *Five-year spectrum outlook 2016–20*. As part of the work program, the 1427–1518 MHz band (the 1.5 GHz band) and the 3575–3700 MHz band (the 3.6 GHz band) were included under the *initial investigation* stage of the process for consideration of additional spectrum for mobile broadband (MBB) services.

The *Future use of the 1.5 and 3.6 GHz bands* discussion paper (the October 2016 discussion paper) was released on 20 October 2016, with consultation closing on 9 December 2016. Following this consultation and consideration of public submissions, the ACMA has prioritised the 3.6 GHz band and progressed the band from the initial investigation stage to the preliminary re-planning stage. The ACMA notes that there is significant interest both domestically and internationally for the use of 3.6 GHz band spectrum for the deployment of 5G MBB technologies.

In forming a judgement as to whether a band should progress from the preliminary re-planning stage to the re-farming stage, the ACMA's decision will be informed by the results of a comprehensive assessment of highest value use. The purpose of this report is to provide that highest value use assessment, determining whether re-farming the 3.6 GHz band for area-wide licensing (for example, to support the deployment of dense wide-area 5G MBB networks) is a higher value use of the band than the current arrangements. This will ultimately determine whether the 3.6 GHz band should progress to the re-farming stage.

Determining highest value use

The Total Welfare Standard (TWS) is one of the tools used by the ACMA when considering whether or not to proceed with spectrum re-farming.[3] Under a TWS, the impact that a regulatory proposal has on the public interest is measured as the sum of the effects on consumers, producers and government, as well as the broader social impacts on the community. The decision to re-farm a particular spectrum band is therefore informed by evidence that there are alternative uses that increase the total value derived from using the spectrum.

Spectrum re-farming decisions typically involve an incremental increase or reduction in spectrum for different services, which results in an incremental change in the total value derived by consumers and citizens from the services. The highest value use of a portion of spectrum is therefore the use that enables the highest incremental increase in the total value of that spectrum, rather than the use for which the services on offer have the highest total absolute value.

In many cases, spectrum re-farming decisions will affect only the cost of delivering a given service. In these cases, the outputs of the affected parties—both those parties losing spectrum and those parties gaining spectrum—are unlikely to significantly change. These are referred to as 'constant output' cases. It is important to note that these cases do not always depend upon the availability of equivalent spectrum; the same or very similar output may be achieved through the use of options that do not

[3] See *Regulating in the public interest*, speech by Rebecca Burdon, Principal Economist, ACMA ACE Telecommunications Summit, 27–28 August 2008, Sydney.

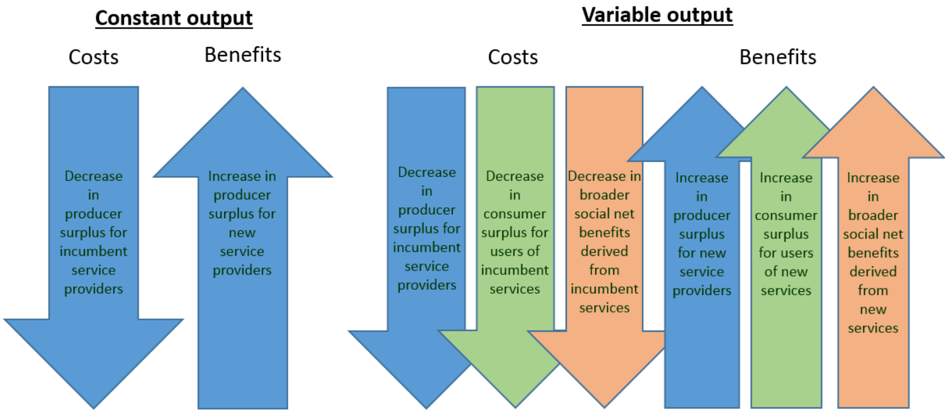
require alternative spectrum (for example, fibre options) or that use spectrum already available (that is, class-licensed spectrum).

Where outputs do not substantially change, the private benefits (that is, consumer surplus) and broader social net benefits will not change. In these cases, it will be sufficient to only evaluate the cost implications of the reform. This means that the incremental cost of the change is the increase in the supply cost of the existing service (for example, higher costs of relocating to a different spectrum band), and the incremental benefit is equal to the reduction in the supply cost of the new service.

Spectrum re-farming can also result in ‘variable output’ cases, in which the incremental costs and benefits of re-farming extend beyond supply cost changes. In addition to estimating changes in producer surplus, it is necessary in these cases to estimate the effect that consumer benefits have on consumer surplus, along with broader social net benefits. With regard to incremental costs, this occurs when an incumbent user is unable to continue providing the same or similar services. The incremental costs associated with this change in spectrum allocation will typically refer to the discrepancy in economic welfare between the existing service and either a substitute service—if one exists—or no service.

The ability that the new users have to provide new and/or improved services with the re-farmed spectrum (for example, 5G networks) can generate incremental benefits under a TWS. Consumers are likely to place a higher value on these new services, which would be likely to result in an increase in consumer surplus, while providing the providers of these services with the opportunity to increase producer surplus through price rises. This is also an example of a ‘variable output’ case.

Figure 1: The different types of analysis required under constant and variable output cases



If the 3.6 GHz band is re-farmed for area-wide licensing arrangements, the value placed on the spectrum by potential users will be considered a proxy for the increase in economic welfare under a TWS. This is because they are not expected to value the spectrum higher than the economic welfare increase they would obtain. However, it should be noted that discussion of spectrum valuations in this paper is not equivalent to an expected revenue in a price-based allocation. Spectrum valuations reflect the amount a potential user would be willing to pay. If potential users are able to pay less than their full valuation, this does not mean that the economic welfare benefits of the spectrum are diminished, but rather that they are able to retain more of this benefit by transferring less of the benefit to the government.

Furthermore, it is important to note that the impacts of a potential change in spectrum use can be assessed qualitatively and/or quantitatively. Some benefits or detriments may not be amenable to quantification, such as changes in the value placed on services by consumers, and broader social impacts (externalities). Notwithstanding this, they should be evaluated and supported with evidence to the extent possible.

1. Are there any general economic impacts that should be included but are not currently included in the method to determine highest value use?

The role of this analysis

This work on highest value use is not intended to directly inform which individual party or particular user is to be allocated spectrum—rather, it is to indicate whether change of spectrum use is likely to be welfare maximising. These findings will then be used as an input to the Options paper, in which a decision will be proposed on the preferred option for potential re-farming of the 3.6 GHz band.

Technology flexibility

Re-farming the band for area-wide licensing would afford the potential new highest value user the flexibility to deploy whichever technology they choose as long as they remain within the boundaries of the technical framework. This technology flexibility not only provides scope for the use of a broad range of technologies, but also, ideally, the opportunity to migrate to newer technologies without regulatory intervention. As such, while much of the discussion in this paper refers to potential use of the 3.6 GHz band for 5G MBB services, other potential highest value uses are not ruled out.

Area-wide licensing

The role of this analysis is to determine whether re-farming the band for area-wide licensing and displacing incumbent licensees will represent the highest value use. In the context of this paper and in view of the available options in the Options paper, the general use of the term 'area-wide licensing' is typically referring to spectrum licensing in its current form under the *Radiocommunications Act 1992*.

Option 2a has not been considered as it extends site-based apparatus licensing to inside of Area 1, while the purpose of this analysis is to determine the relative benefits of area-wide licensing. The relative inefficiencies of site-based apparatus licensing in high demand areas are outlined in the Options paper.

Option 2b involves area-wide apparatus licensing in Area 1. It is basically equivalent to a combination of Option 3a (that is, spectrum licensing in Area 1) and Option 4b (that is, if protection of incumbent licensees was confined to Area 1). Due to spectrum licensing typically being considered optimal in high demand areas, it is expected that a combination of Options 3a and 4b would be more likely than Option 2b to result in a welfare maximising use of the spectrum.

Due to the above reasoning, Options 2a and 2b are disregarded in this analysis. This ultimately means that the analysis is largely attempting to determine whether Options 3a–d (spectrum licensing across different geographic area options) are a higher value use of the 3.6 GHz band than Option 1 (no change).

This paper assumes that the subsequent spectrum licence valuations are based on 15-year licences for unencumbered spectrum, as the purpose of this analysis is to determine whether a new spectrum use is of higher value than the existing use or uses. Potential implementation options if the band is re-farmed (for example, extended transition periods) are not considered in spectrum valuation estimates, as their purpose will ultimately be to mitigate costs and maximise welfare after the highest value use is determined.

Hybrid approaches

While the role of this overall analysis is to determine whether a change of spectrum use is likely to be welfare maximising, there may be the ability to implement hybrid approaches. These solutions are outlined in parts throughout this paper, and would help limit the incremental costs of displacing incumbent licensees while retaining most of the benefits of re-farming. In essence, an isolated highest value use assessment is performed in these cases to determine whether such a solution may be welfare maximising in comparison with complete spectrum re-farming.

It should be noted that area-wide licensing arrangements would be technology-flexible, so incumbent licensees protected by these hybrid approaches would still have the opportunity to demonstrate that they are the highest value use of the band. However, area-wide licensing arrangements may not be as suitable to the business requirements of incumbents as they are for prospective new users of the 3.6 GHz band, such as MNOs. These hybrid approaches may therefore be a welfare maximising outcome for the 3.6 GHz band even if incumbents do not express a willingness to pay for area-wide spectrum or apparatus licences that would indicate that they represent the highest value use of the spectrum.

Option 4a

This hybrid approach involves re-allocating only a portion of the band for area-wide licensing. The analysis throughout this highest value use assessment assumes that if only part of the band is re-allocated, there will be a minimum of 25 MHz of bandwidth set aside for site-based apparatus licensing arrangements, and that this set-aside will apply in all newly spectrum-licensed areas outside of Area 1.

A 25 MHz set-aside is analysed as the ACMA considers that 20 MHz of spectrum is the minimum bandwidth required to deploy a viable wireless broadband service in most instances. A further 5 MHz guard band would also be reasonable to help manage a majority of adjacent channel interference issues between time division duplex (TDD) services, if and when required. While the spectrum would also be available to other point-to-multipoint users, it would not be available for point-to-point links and satellite services as larger bandwidths would generally be required to support their continued operation (Option 4b is considered a more viable option for such services).

The set-aside will not include Area 1 in this analysis as there are no point-to-multipoint licences within this area option. This means in Area 1, the highest value use of this 25 MHz of bandwidth hinges on whether area-wide licensing (suitable for the deployment of dense wide-area MBB networks) or site-based apparatus licensing (suitable for point-to-multipoint) maximises economic welfare. Geographic areas with high demand for spectrum are typically better suited to area-wide licensing. Site-based apparatus licensing has therefore not been considered for Area 1 in this analysis.

The analysis ultimately aims to determine whether the lost economic benefits from not being able to re-allocate the 25 MHz for area-wide licensing are greater or lesser than the reduction in incremental costs resulting from incumbent point-to-multipoint licensees either moving to a different band or having to discontinue their operations. If the incremental cost savings exceed the lost economic benefits, applying a set-aside is considered to be welfare maximising, as the net benefit under a TWS would increase.

Higher bandwidth amounts for a spectrum set-aside have not been considered in this analysis. If setting aside the minimum 25 MHz is not welfare maximising, any higher bandwidth amount would also not be welfare maximising, as the incremental costs avoided would remain the same, while the re-farming benefits forgone would increase as more spectrum would be unavailable for area-wide licensing.

Option 4b

Option 4b defines frequencies and areas around incumbent apparatus-licensed services that would not be re-allocated for area-wide licensing. In this highest value use assessment, the defined frequencies and areas will be those of the major FSS facilities that host incumbent 3.6 GHz band earth receive licences. The major metropolitan FSS facilities are located in Sydney and Perth.

If the 3.6 GHz licences at these facilities are displaced, the relocation of licences (which will include relocating all C-band licences) is expected to incur significant incremental costs. There may be the ability to allow FSS earth receive licences to remain in their locations by protecting them from interference. However, this is expected to cause potential users to place a lower value on the spectrum, as such protections would reduce the population that the re-farmed spectrum could reach and may reduce the utility of the spectrum.

There are multiple options that would allow for the protection of FSS earth receive licence locations. For each option, the analysis aims to identify whether the incremental cost savings from preventing widespread C-band licence relocations exceed the lost economic benefits from not fully re-farming the spectrum. If this is the case, it is likely that protecting FSS earth receive licence locations is welfare maximising as the net benefit under a TWS would increase.

Further detail on how this hybrid approach relates to the highest value use assessment is available in Appendix A: Protection of FSS earth receive licence locations, while further detail on the technical aspects of this hybrid approach is available in Appendix 5 of the Options paper.

Re-farming benefits

There are two types of potential benefits that result from the re-farming of spectrum:

1. Additional revenues or lowering of costs for producers providing new services using the re-farmed spectrum (that is, an increase in producer surplus).
2. Reduction in price of services, or new or increased quality of services being rolled out (that is, an increase in consumer surplus).[4]

Producer surplus is the revenue earned from the sale of a product that is in excess of the costs to produce and sell the product. Using the example of a MNO, if an MNO obtains a marginal unit of spectrum, they would not need to erect as many base stations (and other inputs) nor increase the spectral efficiency of their network technologies in order to deliver the same services to consumers. In this way, additional spectrum enables a reduction in network deployment costs (that is, an increase in producer surplus). This cost reduction partially informs the amount an MNO would be willing to pay for that marginal unit of spectrum.

It is possible that when purchasing spectrum, new users will factor in aspects of value in addition to these ‘cost saving’ values. For example, producers may anticipate the ability to capture consumer benefits (higher quality or new services) when bidding for spectrum. In this case, consumers placing a higher value on new services has the potential to result in consumer surplus gains, while the ability to charge higher prices due to this value gain can result in producer surplus gains. The magnitude of producer surplus versus consumer surplus gains is a function of the ability of producers to capture the value increase placed by consumers on services provided via area-wide licences (for example, MBB) through price rises.

Calculating re-farming benefits

Throughout this highest value use assessment, the value placed on the applicable spectrum by potential new users is used as a proxy for the economic welfare benefits of re-farming the spectrum. Potential users are assumed to only invest in spectrum if it is a profitable exercise. This means that the economic welfare benefits they attain—such as cost reductions and the ability to charge higher prices—should be equal to or greater than the amount they pay for the spectrum. Valuations should therefore be equal to or less than the economic benefits that accrue from re-farming, particularly once consumer surplus gains and broader social net benefits are taken into account.

Estimates of the overall valuations for 3.6 GHz band spectrum are built up from $/MHz/pop valuations in this analysis (that is, for a 15-year licence for unencumbered spectrum). The $/MHz/pop value allows for comparisons with expressed valuations in previous price-based allocations, as it is a standardised value that reflects the economic welfare benefits that potential users can gain from the spectrum for a given bandwidth and population size. More accurate comparisons with past price-based allocations can therefore be drawn from $/MHz/pop values than with the overall amount paid in an allocation. These comparisons will still be imperfect as each allocation features unique market characteristics.

The $/MHz/pop value that would be placed on 3.6 GHz band spectrum is uncertain, so a range of valuations have been provided in this analysis. This range is guided by the previous expiring spectrum licence process, which provides some potential spectrum

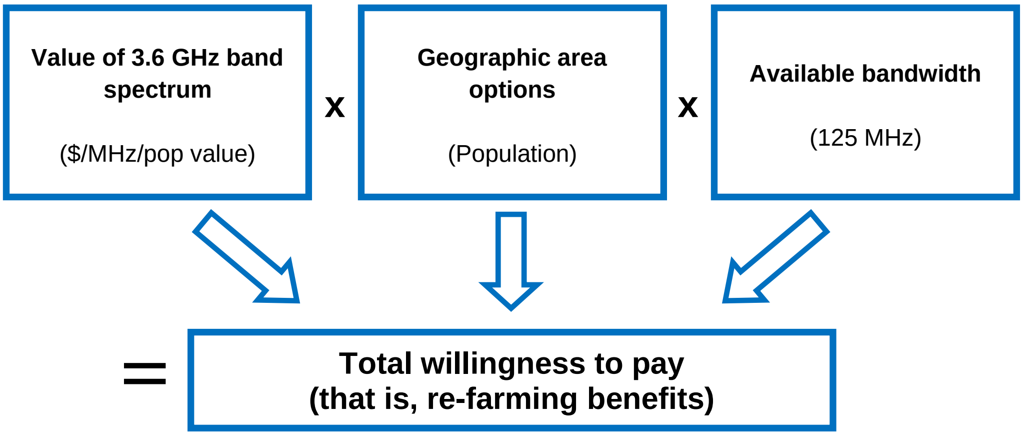
[4] It should be noted that a reduction in price might be captured in lower costs. The interaction between these elements will be considered if required.

valuations. The $/MHz/pop values can be multiplied by the available bandwidth and population size to determine the total value of the 3.6 GHz band, which is ultimately used as a proxy for re-farming benefits.

Re-farming benefits—analysis structure

An analysis of the potential benefits of re-farming the 3.6 GHz band is subject to many variables and assumptions, which means that the final estimated outcomes can be highly uncertain. The purpose of this analysis is to tie together these variables and forecast a range of outcomes for the potential economic welfare benefits associated with re-farming the 3.6 GHz band. To calculate the economic welfare benefit, estimated $/MHz/pop values are multiplied by the population affected by and the bandwidth available for re-farming. The following analytical structure is used to allow all of the relevant uncertainties involved in re-farming to form part of the overall assessment of highest value use.

Figure 2: Diagram of re-farming benefits analysis structure



> **Value of 3.6 GHz spectrum.** This analysis of the value of 3.6 GHz spectrum (for a 15-year licence to unencumbered spectrum) aims to demonstrate that the minimum $/MHz/pop value of the band would be $0.03/MHz/pop, and that the actual valuation is likely to be significantly higher—an upper bound of $0.625/MHz/pop is used. The $/MHz/pop valuation estimates are based on similarities with past spectrum allocations and the 5G context of 3.6 GHz band spectrum.

> **Geographic area options.** There are multiple geographic area options that could be selected for re-farming, and the area option chosen will ultimately determine the population affected by re-farming the spectrum. These area options are outlined in Appendix 6 to the Options paper. A larger population affected by spectrum re-farming is therefore likely to increase potential users' overall valuations, as the services for which they use spectrum can reach more people.

> **Available bandwidth.** There is assumed to be 125 MHz available for the 3.6 GHz band, as the band refers to 3575–3700 MHz. There is the potential for the available bandwidth to fall under Option 4a (for example, if 25 MHz is set aside for site-based apparatus licensing arrangements).

> **Overall economic welfare benefits.** This section ties together the variables to determine the economic welfare benefits of re-farming the 3.6 GHz band. The geographic area options and available bandwidth analyses are combined with multiple $/MHz/pop valuations (between $0.03/MHz/pop and $0.625/MHz/pop) to demonstrate the variability of potential outcomes. These can be compared with incremental costs to determine whether re-farming is net beneficial, and ultimately whether a new use via area-wide licensing arrangements is of higher value than incumbent uses.

- **Option 4a.** The effects of setting some of the spectrum in an area aside for site based apparatus licensing on the economic welfare benefits of re-farming are analysed, although these effects should be viewed in conjunction with the set-aside causing a reduction in the incremental costs of re-farming.
- **Option 4b.** The effects of not re-farming specific areas to enable incumbent services to continue operating, and therefore not being able to realise the full economic welfare benefits (or any benefits at all) of the 3.6 GHz band being re-allocated for area-wide licences, are analysed here. This should also be compared with a corresponding reduction in incremental costs.

Value of 3.6 GHz spectrum

The $/MHz/pop value applied to 3.6 GHz band spectrum by potential users will reflect the standardised value of the spectrum (that is, for a 15-year licence for unencumbered spectrum). This $/MHz/pop valuation can then be coupled with both the bandwidth available and the population served within the geographic boundaries of area-wide licence areas to determine a lower bound for potential users' overall willingness to pay, which reflects the economic welfare benefit of spectrum re-farming under a TWS.

This analysis outlines several factors that help determine an estimated minimum valuation for the 3.6 GHz band of $0.03/MHz/pop, along with an upper bound that is expected to be at least $0.625/MHz/pop. The analysis includes:

- Detail of the 5G context of the 3.6 GHz band. High demand from MNOs for the 3.6 GHz band is anticipated as the band is considered to contain premium spectrum for 5G network deployments.
- Comparisons with recent re-issue prices for spectrum with relatively similar characteristics. These comparisons indicate that potential users would value 3.6 GHz spectrum higher than $0.03/MHz/pop, with particular comparisons indicating valuations as high as $0.625/MHz/pop.

It should be noted that this section refers to the valuations placed on the spectrum by potential users rather than the amount that may be paid for the spectrum in a price-based allocation (for example, a spectrum auction). This is because the economic benefits provided by the spectrum are a function of the value of the spectrum—potentially paying more for the spectrum does not increase or decrease its value.

5G context

With the successful establishment and relatively high take-up of 4G technologies, industry stakeholders are now looking towards the development of 5G services in the next progression of wireless technologies. Domestically, submissions to the October 2016 discussion paper indicate that the 3.6 GHz band is being looked at for 5G. The 3.6 GHz band is also being looked at internationally as an early band for 5G.[5]

The 5G ecosystem is developing and definitions are still fluid. However, there appear to be a number of defining objectives for 5G that distinguish it from previous developments, including massive system capacity, very low latency, high reliability and availability as well as very high data rates (greater than 10 Gbps likely to be supported).[6] From a spectrum perspective, it appears that MNOs want to obtain

[5] Policy Tracker, 'Ofcom provides an update on its 5G spectrum plans', 2017, viewed 15 February 2017.
[6] Ericsson, '5G radio access—capabilities and technologies', 2016, viewed 18 May 2017.

access to large contiguous bandwidths (up to 100 MHz) in order to deploy 5G services in the 3.6 GHz band.

Statements made by MNOs in submissions to the October 2016 discussion paper also underline the importance of the band for 5G deployment plans. Telstra's submission, for example, outlines the heightened and pressing demand for available 3.6 GHz band spectrum, which would support the introduction of 5G services:

> There is urgent demand for MBB services to use the 3600 MHz band coinciding with global launches of 5G services using the band, and work is urgently required to progress this band… We envisage the benefits from MBB will be continuation of benefits realised from mobile and MBB services today, as outlined in the body of our submission.

While this urgent demand for the 3.6 GHz band is primarily driven by MNOs wanting the spectrum to enable network planning and deployments to commence in earnest, the properties of the spectrum compared with other potential 5G bands means that it is not just its position as the *first* 5G band that is attractive to potential users. The 3.6 GHz band is considered the optimal spectrum for the technologies to be used for 5G networks, finding the 'sweet spot' between competing technological objectives. Specifically, this relates to technologies such as beamforming and massive MIMO, where the benefits are best achieved at higher frequencies, versus cell coverage and in-building penetration, where the benefits are best achieved in lower frequencies.[7]

In its submission to the October 2016 discussion paper, Vodafone Hutchison Australia (VHA) outlines the qualitative benefits of such spectrum for 5G services, although its submission does not drill down to a particular band:

> The requirements of capacity (shortest possible wavelength) and best coverage (longest possible wavelength) are therefore in tension, and in principle the wavelength must be short enough to allow the use of beam-forming and MIMO but long enough to reach most users from macro sites. In VHA's studies undertaken with industry partners, the range of bands between 3 GHz and 6 GHz represent the best compromise. Below this range, whilst still serving a valuable purpose, the frequency is too low to support the key future features in both networks and devices. Above this frequency range they become progressively more suited only to short range scenarios like those that could be served by small cells or smaller 'street furniture' macro sites.

While VHA did not outline the 3.6 GHz band specifically in the above comments, they have provided value indications for the entirety of the 3.4–3.7 GHz spectrum bands. In a submission to the Joint Standing Committee on the National Broadband Network (NBN), VHA indicated that '5G spectrum' within the 3.4–3.7 GHz bands should be made available for MBB as 'the spectrum is likely to be worth several billion dollars at auction'.[8] Using a conservative assumption based on these comments of $3 billion for the full 300 MHz of spectrum, servicing an Australia-wide population of 23.3 million (refer to Table 3 in this document), the implied valuation is $0.43/MHz/pop.

The aforementioned properties of 5G services outline the potential economic benefits that would accrue to consumers and citizens, which are ultimately the reasons why potential users would value the 3.6 GHz band highly. When coupled with the demand already expressed for the band and the large contiguous bandwidths (for example, 100 MHz) required to enable the full benefits of 5G technology, it is expected that the value of 3.6 GHz band spectrum is likely to be closer to the upper bound of

[7] Massive beamforming in 5G radio access, Ericsson Research Blog

[8] Vodafone Hutchison Australia's submission to the Joint Standing Committee on the NBN

$0.625/MHz/pop than it is to the conservative lower bound value estimate of $0.03/MHz/pop.

Past spectrum valuations

Spectrum valuations (measured on a $/MHz/pop basis) are difficult to estimate. The actual valuations of potential users are unknown as they are private information. Past domestic and international spectrum allocations with similar characteristics can be used as a general guide to estimate spectrum value, but there will remain a wide range of potential valuations for the 3.6 GHz band.

Past spectrum prices are guiding a value estimate of between $0.03/MHz/pop and $0.625/MHz/pop for the 3.6 GHz band. These prices represent re-issue prices for the 3.4 GHz and 2 GHz bands respectively (in '[Direction to ACMA under the *Radiocommunications Act 1992*]'), as part of the [expiring spectrum licences process]. The re-issue price of $0.03/MHz/pop for the 3.4 GHz band is used as the lower bound valuation in this analysis as it represents the minimum willingness to pay for spectrum in an adjacent band, which occurred without the 5G context. The re-issue price of $0.625/MHz/pop for the 2 GHz band is used as the corresponding upper bound as it is the highest expressed willingness to pay for spectrum above 1 GHz.

3.4 GHz re-issue price (2012)

The $0.03/MHz/pop re-issue price for 3.4 GHz band spectrum licences was implemented in 2012, with 15-year licences re-issued in December 2015. The willingness to pay the re-issue price for 3.4 GHz band spectrum indicates that the valuation for spectrum adjacent to the 3.6 GHz band was higher than the $0.03/MHz/pop in 2012.

The value of the 3.4 GHz band is likely to have increased since its re-issue price was set, due to the recent mobile industry identification of the importance of the broader 3300-3800 MHz band (which encompasses the 3.6 GHz band) for providing a network coverage layer for 5G technologies.

In taking into account the incumbents' willingness to pay the renewal price prior to the technological and market demand changes driven by 5G developments, the ACMA considers $0.03/MHz/pop to represent the minimum valuation that potential users would place on the 3.6 GHz band.

2 GHz re-issue price (2012)

The $0.625/MHz/pop re-issue price for 2 GHz band spectrum licences was implemented in 2012, with 15-year licences to be re-issued in October 2017. While the 2 GHz band is not adjacent to the 3.6 GHz band, there are similarities with the 3.6 GHz band. The 2 GHz band is currently being used to deploy wide-area MBB services, and it is assumed that improvements to cell sizes in the 3.6 GHz band, due to advanced antenna techniques, would approach existing cell sizes in the 2 GHz band. There is also the 5G context that is expected to cause the value of the 3.6 GHz band to appreciate compared with similar bands.

Relevant comparisons with the value of the 2 GHz band can therefore be drawn for the purpose of finding an applicable upper bound for 3.6 GHz band valuations. Users' willingness to pay a re-issue price of $0.625/MHz/pop indicates that the value of 2 GHz band spectrum is no lower than this price. As this is the highest recently expressed valuation of spectrum similar to the 3.6 GHz band, $0.625/MHz/pop will be considered the upper bound of spectrum valuations in this analysis.

2. Are there any other spectrum valuations (for example, domestic or international auction prices or re-issue prices) that should be considered as a guide to the value of the 3.6 GHz band?

Geographic area options

There are four different geographic area options that could be selected as part of re-farming the 3.6 GHz band. These area options are outlined in further detail in Appendix 6 to the Options paper. Expanded area options include the smaller area option within their boundaries. Each geographic area option is detailed below:

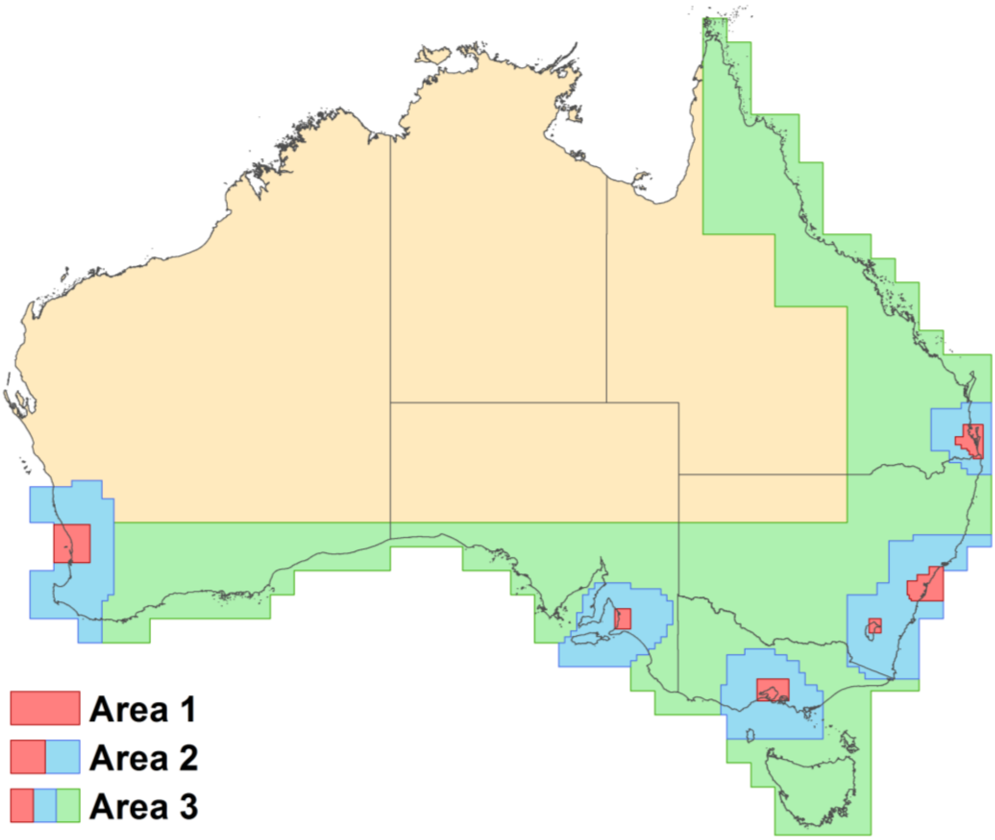
> **Area 1.** This includes the metropolitan areas of Sydney, Melbourne, Brisbane, Canberra, Adelaide and Perth.

> **Area 2.** This area option includes all of Area 1 and adds a buffer zone around each of the areas in Area 1.

> **Area 3.** This area option includes all of Area 2 and adds regional areas along Australia's south and east coasts.

> **Australia-wide.** This area option includes all hierarchical cell identification scheme (HCIS) cells within the Australian spectrum map grid (ASMG). Geographic areas outside of Areas 1-3 are referred to as remote areas throughout this paper, although some more populated areas (for example, Darwin and Hobart) fall into this category. There may also be population differences between this area option and a typical count of the Australian population, as the ASMG does not include some external territories (for example, Christmas Island).

Figure 3: Pictorial depictions of Area 1, Area 2 and Area 3



The area option selected has implications for both incremental costs and re-farming benefits. Incremental costs would generally be assumed to be higher if a larger geographic area option is selected, as there would be a greater number of displaced incumbent licensees. However, the selection of a larger geographic area option could also be assumed to result in greater re-farming benefits, as the new use of the spectrum would extend to a greater population.

While the available bandwidth is likely to be fixed irrespective of the area option selected, the $/MHz/pop valuation has the potential to vary depending on the area option selected. For instance, spectrum is likely to be valued differently in regional and remote areas than it is in metropolitan areas, particularly due to cost disparities in different areas to deploy network infrastructure for given populations. However, due to the uncertain nature of both the $/MHz/pop valuation and subsequent discrepancies across different areas, the average $/MHz/pop valuation is considered to be uniform across each geographic area option for the purposes of this analysis.

Population estimates

Population figures for these options have been forecast to April 2017:

> Population figures for each HCIS cell, as per the Australian Bureau of Statistics (ABS) 2011 census, provide the starting point for these forecasts.[9] This is used as the starting point as 2016 census data is not yet available, while more recent ABS data does not drill down to the specific HCIS cells that make up the different geographic area options in this scenario.

> An estimated population growth rate from 9 August 2011 (census night) through to April 2017 is used to estimate population figures in April 2017. This growth rate is based on the growth of Australia's estimated resident population from the June 2011 quarter to the December 2016 quarter (ABS data is currently available to the September 2016 quarter, so an average quarterly growth estimate has been applied for the December 2016 quarter), which is equal to 8.81 per cent.[10]

The estimated population growth rate of 8.81 per cent has been uniformly applied to all geographic area options, although there are likely to be discrepancies between different area options. For example, it is likely that increasing urbanisation has led to faster population growth in Area 1 than Australia-wide. However, there is a lack of population growth figures detailing specific areas, while discrepancies between these estimates and actual figures are likely to be too minor to have a material impact on overall economic welfare benefit estimates.

Table 3: Population estimates for each area (April 2017)

	Area 1	Area 2	Area 3	Australia-wide
Population (2011 census)	14.8 million	17.6 million	20.9 million	21.5 million
Estimated population (April 2017)	16.1 million	19.1 million	22.8 million	23.3 million
% of Australia-wide population (April 2017)	69.1	82.0	97.9	100.0

[9] See 'Hierarchical Cell Identification Scheme (HCIS) – List of Population Data' on the ACMA website.

[10] *ABS 3101.0 – Australian Demographic Statistics, Sep 2016*. From Series ID A2060842F in Table 4 (Estimated Resident Population, State and Territories (Number)), the September 2016 quarterly population figure of 24,220,192 is pushed forward to December 2016 (using the average quarterly growth rate of the past four quarters, equal to 0.3632 per cent) to find 24,308,163. This population figure is 8.81 per cent greater than the population figure of 22,340,024 for the June 2011 quarter in the same series. It should be noted that there are discrepancies between the population numbers in the ABS time series used for the growth rate and the population numbers in the 2011 census—as such, the time series should only be used for the growth rate.

It should be noted at this point in the analysis that determining the geographic area option to be selected requires viewing re-farming benefits and incremental costs together, along with taking technical considerations into account.

Available bandwidth

The 3.6 GHz band refers to the 125 MHz of spectrum between 3575 and 3700 MHz. For the purposes of this analysis it is assumed that the full 125 MHz of bandwidth would be available for area-wide licensing. Detail on current arrangements in and adjacent to the 3.6 GHz band can be found in the *Coexistence and sharing with incumbent services* section of the October 2016 discussion paper.

Option 4a

There is the potential for part of the 3.6 GHz band to be re-allocated for area-wide licensing, while another part would remain available for site-based apparatus licensing arrangements in some or all areas (for example, 25 MHz set aside for fixed wireless broadband). Consideration of the set-aside option is derived from feedback to the October 2016 discussion paper, as several submissions—particularly from WISPs—proposed leaving 25 MHz available for fixed wireless broadband.

The purpose of a 25 MHz set-aside would be to reduce incremental costs. Costs resulting from point-to-multipoint licensees either relocating to a different band or discontinuing operations would potentially be avoided, while there would be options available for the provision of new services and the expansion of incumbent users' existing services. However, despite these opportunities, a 25 MHz set-aside would also be expected to reduce re-farming benefits, as there would be less bandwidth available for a potential new use (for example, MBB).

There are no point-to-multipoint licences in Area 1. For the purposes of this analysis, the set-aside option would therefore only apply to geographic areas subject to re-farming that are located outside of Area 1. This would reduce the size of the population affected by the set-aside and consequently limit the reduction in re-farming benefits.

Overall economic welfare benefits

To measure the economic welfare benefits of a new use of the 3.6 GHz band, the potential spectrum valuations of new users are used as a proxy. These valuations are a function of an estimated $/MHz/pop valuation, the bandwidth available and population size. These three factors are multiplied by one another to determine overall valuations of the 3.6 GHz band, and therefore the economic welfare gains generated through re-farming the band.

Spectrum is assumed to only be valued by potential users to the extent that it is profitable to acquire—there would be no case for the investment if spectrum cost more than the economic welfare gains it generated. Potential users are therefore expected to value spectrum less than or equal to the economic welfare gains that they can generate, such as cost reductions for network deployment and the ability to charge higher prices for new or improved services.

There may also be additional economic welfare gains resulting from the positive effects that re-farming the 3.6 GHz band could have for consumers and citizens. The potential increases in consumer surplus—largely stemming from consumers placing greater value on new or improved services—and broader social net benefits may not be reflected in potential users' spectrum valuations. However, they should be considered equally with the producer surplus gains that are likely to shape the valuations of potential users.

The table below therefore represents the minimum economic welfare gains for given fixed characteristics, including particular $/MHz/pop valuations, population sizes (for different geographic area options) and bandwidth (125 MHz). Potential users are expected to value 3.6 GHz band spectrum higher than $0.03/MHz/pop, so the re-farming benefits that would result from a range of $/MHz/pop valuations up to $0.625/MHz/pop have been outlined. The table below assumes that spectrum value is uniform across the different area options, but this is unlikely to occur in practice.

Table 4: Expected benefit for each area if the 3.6 GHz band is re-farmed

	Area 1	Area 2	Area 3	Australia-wide
Population	16.1 million	19.1 million	22.8 million	23.3 million
$/MHz/pop value				
$0.03	$60 million	$72 million	$86 million	$87 million
$0.05	$101 million	$119 million	$143 million	$146 million
$0.10	$201 million	$239 million	$285 million	$291 million
$0.25	$503 million	$597 million	$713 million	$728 million
$0.50	$1.0 billion	$1.2 billion	$1.4 billion	$1.5 billion
$0.625	$1.3 billion	$1.5 billion	$1.8 billion	$1.8 billion

While selecting a more expansive geographic area option can be expected to increase the economic benefits gained due to the greater population being served by the new use of the spectrum, it can also be expected to result in increased incremental costs due to a greater number of incumbent licences being affected. An increase in the expected economic welfare benefit is therefore not necessarily representative of an economically net beneficial outcome under a TWS.

3. Is the range of $/MHz/pop values suitable for this analysis, or is there a case to narrow or broaden the range?

Option 4a

If Option 4a is applied, part of the 3.6 GHz band would remain available for site-based apparatus point-to-multipoint apparatus licensing arrangements. The following example is used for illustrative purposes: 25 MHz is set aside (which is considered the minimum bandwidth for this option to be viable) for site-based apparatus licensing outside Area 1 and 100 MHz is re-farmed for area-wide licensing. For the purposes of this analysis, Area 1 is completely re-farmed.

Applying Option 4a would help reduce incremental costs, but it would also result in a corresponding reduction in re-farming benefits. Option 4a should only be considered a preferred option if it is welfare maximising. That is, where the reduction in incremental costs is greater than the fall in re-farming benefits from the spectrum not being available for area-wide licensing uses.

The table below outlines the loss of economic welfare benefits that may occur due to 25 MHz not being re-allocated for area-wide licensing outside of Area 1. In this case, all other variables remain constant (that is, factors that influence the $/MHz/pop valuation and population), with the only change being a reduction in bandwidth.

Table 5: Expected benefit for each area with 25 MHz set aside

	Area 2	Area 3	Australia-wide
Population	19.1 million	22.8 million	23.3 million
Population (excluding Area 1)	3.0 million	6.7 million	7.2 million
Effect of 25 MHz set-aside on economic welfare benefit per $/MHz/pop value			
$0.03	–$2 million	–$5 million	–$5 million
$0.05	–$4 million	–$8 million	–$9 million
$0.10	–$8 million	–$17 million	–$18 million
$0.25	–$19 million	–$42 million	–$45 million
$0.50	–$38 million	–$84 million	–$90 million
$0.625	–$47 million	–$105 million	–$113 million
New expected economic welfare benefit per $/MHz/pop value (incl. Area 1)			
$0.03	$69 million	$80 million	$82 million
$0.05	$116 million	$134 million	$137 million
$0.10	$231 million	$268 million	$273 million
$0.25	$578 million	$671 million	$683 million
$0.50	$1.2 billion	$1.3 billion	$1.4 billion
$0.625	$1.4 billion	$1.7 billion	$1.7 billion

The negative effect of a 25 MHz set-aside on the potential economic welfare benefit is greater as the $/MHz/pop value of the spectrum increases. It should be noted that potential users are likely to place a lower value on spectrum in the metropolitan fringe, regional and remote areas that a set-aside would apply to when compared with the metropolitan areas of Area 1. However, irrespective of spectrum valuations, these figures should be viewed alongside the associated incremental cost savings to get the full picture as to whether applying a set-aside is welfare maximising.

Option 4b

There may be a case to create arrangements that support some or all incumbent apparatus licensees to continue operating in the 3.6 GHz band indefinitely. This would enable a reduction in the incremental costs of relocating such services. However, it would also result in a reduction in re-farming benefits. The effect on re-farming benefits would be greatest when this option is applied to incumbent service located in and near populated areas (for example, FSS earth receive licences). The degree to which this affects benefits depends on the incumbent service and the protection criteria implemented. The finer details of these methods and the potential reduction in re-farming benefits resulting from protecting these locations are outlined in Appendix A.

For illustrative purposes, the effect of applying Option 4b to incumbent FSS earth receive licences is used. To simplify the assessment, only FSS earth receive licences operated in capital cities have been considered. The table below provides a summary of the re-farming benefit reductions associated with protecting FSS earth receive licence locations in Sydney and Perth. This is based on the results of the FSS and mobile broadband sharing study at Appendix 4 of the Options paper.

In summary, the mobile broadband sharing study shows the areas and associated populations where the deployment of different MBB systems (base stations and user terminals) would likely be restricted without further mitigation techniques being employed (if available). In this case, the reduction in re-farming benefits is estimated as being equal to potential users' full valuation of the spectrum being denied. This valuation comprises the population affected by the FSS earth receive licence remaining at its current location, the bandwidth affected, and potential users' $/MHz/pop valuations of the spectrum.

It is noted that the study shows that MNOs could reduce the area and population affected by spectrum denial by deploying small (including micro) cells in areas where macro-cell deployments are restricted. However, this comes at a greater cost to achieve similar coverage as a macro station. This is likely to result in a significant devaluation of the spectrum by prospective licensees, as the spectrum has reduced utility. The analysis in the following table does not take these increased costs or the affect this might have on an operator's business model into account.

In this case, there are two separate reductions in re-farming benefits. For the areas where the spectrum is completely unable to be utilised for area-wide licensing, the reduction in re-farming benefits is equal to potential users' full valuations for the spectrum if it were available. However, in areas where small cell coverage is able to be deployed, the reduction in re-farming benefits is equal to the difference between potential users' valuations of this limited-use spectrum and the valuation they would place on unrestricted spectrum in that area. This difference in valuation is unquantifiable, but further qualitative analysis is available in Appendix A.

Table 6: Analysis of re-farming benefit reductions due to the implementation of Option 4b for FSS earth receive licence locations in metropolitan areas in the 3.6 GHz band

		Reduction in re-farming benefits	
		Macro cell case	**Small cell case**
Quantifiable benefits reduced	**Sydney**	$8 million–168 million	$0.2 million–5 million
	Perth	$8 million–161 million	$3 million–67 million
	Total	$16 million–329 million	$3 million–72 million
Unquantifiable benefits reduced	**Total**	N/A	In addition to quantifiable reduction in benefits, a significant reduction in benefits may occur due to small cell use spectrum receiving a lower value from potential users than unrestricted spectrum.

Note: The range of quantifiable benefits reduced represents the outcomes of a lower bound of $0.03/MHz/pop and an upper bound of $0.625/MHz/pop.

Key points

> The calculation of the economic welfare benefit associated with spectrum re-farming uses potential users' predicted valuations of 3.6 GHz band spectrum as a proxy. Economic welfare benefit outcomes have been built up from a range of $/MHz/pop value estimates, population estimates for the different geographic area options of re-farming, and the bandwidth (expected to be 125 MHz) that potentially could be re-farmed.

> The 3.6 GHz band is considered to be premium spectrum for deploying 5G networks, and there is projected to be significant excess demand as large contiguous bandwidths are required for 5G. Past re-issue prices indicate a lower bound valuation of $0.03/MHz/pop and an upper bound of $0.625/MHz/pop, although there is the potential for valuations to be higher than the upper bound.

> The geographic area option selected for re-farming will play a major part in determining the economic welfare benefits of re-farming, as this determines the size of the population affected by re-farming. The economic welfare benefits of selecting different area options need to be coupled with incremental costs to find a clearer picture of which area option maximises economic welfare.

> The overall economic benefits of spectrum re-farming vary widely depending on the potential users' spectrum valuations and the geographic area option selected. For instance, at the lower bound of $0.03/MHz/pop for Area 2, the economic benefit is equal to $72 million. In contrast, the economic benefit at $0.625/MHz/pop for Area 3 is equal to $1.8 billion.

> Further uncertainties can be generated by implementation decision possibilities, such as setting aside a portion of the 3.6 GHz band for site based apparatus licensing arrangements, or protecting FSS earth receive locations from spectrum interference. These possibilities have the potential to either make less spectrum available to potential users or alter their valuations substantially, although these potential benefit reductions should be viewed in conjunction with their associated cost reductions.

Incremental costs

In many cases, spectrum re-farming decisions will affect only the relative cost of delivering certain services or the price at which the services are supplied. In these cases, the outputs of all affected parties—both those parties losing spectrum and those parties gaining spectrum—do not change. It is for this reason that these cases are referred in the literature as 'constant output cases'.[11] It should be noted that it is not expected that output changes will be exactly equal to zero in constant output cases, but rather that the change in output will be near-zero—that is, there will be no material impact on output.

In constant output cases, the provider of the existing service is able to fully mitigate the impact of the change in spectrum use, albeit at an increased cost of supply. They do this by using some combination of different spectrum, additional network investment, and/or increased use of other inputs and methods of supply. This is a crucial point—constant output cases do not always depend upon the availability of equivalent spectrum. The same or very similar output may be able to be achieved using alternative communications technologies.

In these cases, given the services continue to be provided to consumers, there is no need to estimate the impact of the proposed change in allocation on the benefits to consumers and citizens, and hence there is no need to consider changes in private value or broader social value for either service. As such, it will be sufficient to only evaluate the cost implications of the reform for constant output cases, and it will not be necessary or appropriate to determine how much society values the service.

In contrast, there may be cases where spectrum re-farming will prevent the incumbent service (at risk of losing spectrum) from being able to continue at all, or to significantly alter the output or quality of the service being offered. For this to be the case, there has to be no close substitute to the spectrum available (that is, either other spectrum or other communications platforms). Such cases are referred to as 'variable output cases'. In these cases, the analysis is more complex, in that it is necessary to consider the impacts on consumer surplus and externalities, in addition to the usual cost and producer surplus impacts.

For variable output cases, if no substitute service is available, the loss of all producer surplus, consumer surplus and broader net social benefits will be considered to be the incremental costs. However, if a substitute service is available, incremental costs will be incurred due to the discrepancy in value placed by consumers on the substitute service compared with the existing service, along with pricing changes. In either scenario, the consumer surplus and social benefit reductions are highly difficult to quantify, and therefore more suited to a qualitative analysis.

3.6 GHz band context

Incumbent services in the 3.6 GHz band are likely to represent a variety of constant output and variable output cases. Many licensees would be able to fully mitigate the impact of the loss of 3.6 GHz spectrum assets, and therefore be considered constant output cases as the level of service to end users remains the same. However, there is also likely to be a number of variable output cases, where end users (that is, consumers, business users and public sector users) may no longer have access to services provided by incumbent licensees, who are either unable to provide services

[11] The broad constant- and variable-output methodology outlined in this section is derived from: Martin Cave et al. Incorporating Social Value into Spectrum Allocation Decisions. p 22.

or have to change their services significantly in the absence of their 3.6 GHz holdings. This will have subsequent impacts on consumer surplus and broader social net benefits.

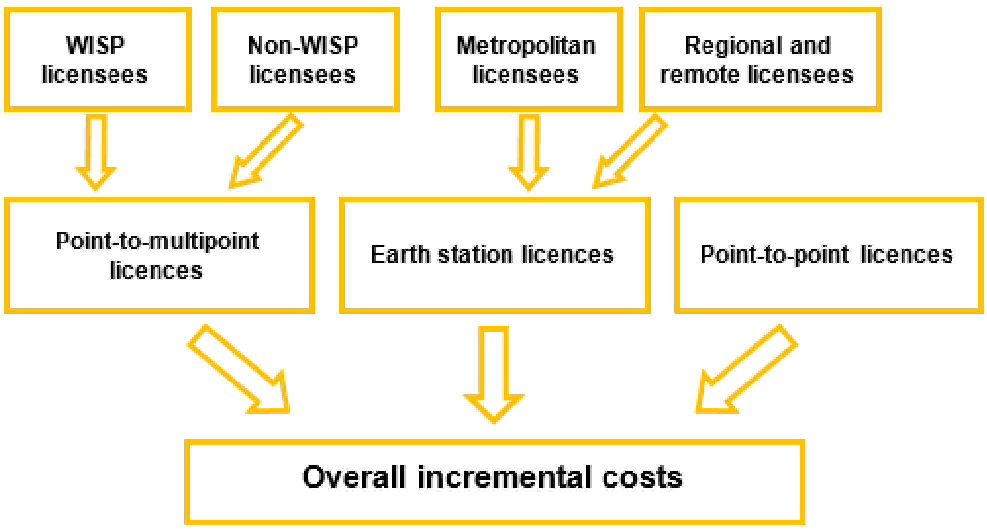
For the constant output cases in the 3.6 GHz band, the incremental costs involve either relocating geographically, or re-tuning or replacing equipment such that their network will rely on alternative spectrum bands. While costs will increase, the final output available to end users will remain constant in these cases. In contrast, determining the incremental costs for variable output cases is more difficult. Due to the final output changing and end users either completely losing access to the service or having to substitute a replacement service, variable output cases require additional analysis of the effects on consumer surplus and broader social net benefits.

Whether output is constant or variable primarily depends on the type of licensed service provided by the licensee, along with their ability to use substitute bands in their geographic area and the availability of equipment compatible with those available substitute bands. The type of licensed service is therefore the primary factor that determines whether output is constant or variable, although there is some variability within each type. As such, the incremental cost analysis is broken down by the different incumbent licensed service types: point-to-multipoint, FSS earth receive and point-to-point licences.[12]

Incremental costs—analysis structure

An analysis of the incremental costs associated with displacing incumbent licensees from the 3.6 GHz band is subject to various uncertainties. Similar licensed service types (or sub-groups within these types) are expected to encounter similar outcomes with regard to being constant or variable output cases. The analysis of incremental costs is therefore built up from the costs associated with different types of licensed services, and is outlined as per the structure detailed below.

Figure 4: Diagram of incremental costs analysis structure



[12] There are also two amateur repeater licences in the 3.6 GHz band, which are located in Sydney and Adelaide. Due to their use being on a secondary basis, which means that they operate on a 'no interference and no protection' basis, the incremental costs of displacing these licences have not been considered in this highest value use assessment.

- **Point-to-multipoint licences.** Whether these licences represent constant or variable output cases depends on the ability to find substitute spectrum or an alternative technology to use, as geographic relocation is typically not a feasible option. These licences can be broken down into those held by WISPs and those that are not held by WISPs; they are broken down further into the different types of constant output and variable output cases that could arise if they are displaced. Licensees are considered to be WISPs if their product offerings include fixed wireless internet services—even if these services constitute a small portion of their overall product offerings, it is highly likely that their licences have been obtained specifically to provide such services.
- **FSS earth receive licences.** There are relatively few FSS earth receive licensees, so all licensees can be analysed individually. The analysis is broken down by the geographic area in which licences are located, as this plays a significant part in determining incremental costs. The incremental costs associated with displacing FSS earth receive licences primarily involves geographic relocation of all C-band licences at incumbents' FSS earth station facilities, with some potential variable output cases causing further unquantifiable costs.
- **Point-to-point licences.** These licences are expected to have several frequency relocation opportunities, particularly in comparison with other types of licensed services, and are therefore likely to be constant output cases. The analysis of incremental costs for point-to-point licences primarily involves an analysis of the equipment replacement costs associated with moving to a different spectrum band, with consideration given to equipment potentially being able to be re-tuned rather than replaced.
- **Overall incremental costs.** This section ties together the range of incremental cost outcomes for the affected types of licensed services, and includes both quantitative data points and qualitative cost assessments. The analyses of different types of licensed services leads to a range of potential overall incremental costs being determined. These cost ranges can subsequently be compared with incremental re-farming benefits to determine the net benefit of different scenarios—and ultimately the highest value use of the 3.6 GHz band.

Point-to-multipoint licences

The entities that hold point-to-multipoint licences in the 3.6 GHz band are generally public sector entities (councils and state government departments), mining operators or fixed wireless internet service providers (WISPs). Whether a point-to-multipoint licensee is considered a constant output case or a variable output case largely depends on their location, as this will determine whether there are substitute bands available that enables them to continue providing the same service. Licences located in remote areas (those counted in 'Australia-wide' but not located in Areas 1–3) typically have greater opportunities for frequency relocation.

Table 7: Incumbent point-to-multipoint licences by licensee type in different areas across the 3.6 GHz band (based on 1 May 2017 RRL data)

Client type	Area 1	Area 2	Area 3	Australia-wide
WISPs	0	87	167	174
Mining	0	1	53	162
Public	0	12	47	51
Other	0	22	26	26
Total	**0**	**122**	**293**	**413**

Collectively, WISPs are the most likely group of entities to represent variable output cases if the 3.6 GHz band is re-allocated for area-wide licensing. The consumer-facing aspect of the point-to-multipoint equipment held by WISPs makes them different to the majority of other point-to-multipoint licensees in the 3.6 GHz band. While others use point-to-multipoint devices for support in the provision of an unrelated good or service, WISPs use point-to-multipoint devices to deliver services directly to consumers. Consequently, the analysis of incumbent point-to-multipoint licensees can be separated by WISP licensees and non-WISP licensees, such as those in the mining or public sectors.

Wireless Internet Service Providers (WISPs)

WISPs (17 unique licensees) held 174 of the 413 point-to-multipoint licences in the 3.6 GHz band as at 1 May 2017.[13] Many submissions from WISPs to the October 2016 discussion paper detailed the potential negative effects of being displaced from the 3.6 GHz band, with the most extreme cases resulting in WISPs being unable to continue providing their services.

Licensees that are unable to continue providing services are considered to be variable output cases. The incremental costs related to these variable output cases are not equal to the entire economic welfare contribution of WISPs under a TWS, as it is not expected that consumers will lose all internet access. Rather, consumers are expected to be able to find substitute internet services (for example, satellite internet services). The producer surplus loss to incumbent WISP licensees (that is, consumers' current ISP) would therefore be offset under a TWS by the producer surplus gain to the substitute internet service providers (consumers' new ISPs).

With a substitute internet service available for consumers, the primary causes of variable output are expected to be the difference in price and the difference in value that consumers place on the existing service (provided by WISPs) compared with the substitute service. Higher prices and consumers placing a lower value on the substitute service would cause a consumer surplus reduction. While consumers will not necessarily be paying higher prices for internet services, they are generally expected to undergo a consumer surplus reduction. This is because consumers are anticipated to have been using the existing WISP services due to these services providing the greatest value (that is, consumer surplus) of all currently available options—they would have already chosen to forgo the substitute service.

There are two alternative processes that could prevent WISPs from representing variable output cases. WISPs would be able to continue providing their services if they get the opportunity to relocate from the 3.6 GHz band to the 5600–5650 MHz band (5.6 GHz band). This would be subject to the availability of the 5.6 GHz band in the particular area of the WISP service due to existing usage by the Bureau of Meteorology (BoM) (further detail can be found in Appendix B). WISPs would also be able to continue providing services if spectrum is set aside for site-based apparatus licensing arrangements in the 3.6 GHz band under Option 4a. In these cases, WISPs are expected to be constant output cases, with relocation costs (either within the 3.6 GHz band or to the 5.6 GHz band) acting to reduce producer surplus.

Variable output cases—WISPs unable to relocate

If the 3.6 GHz band is re-farmed, WISPs may be unable to continue operating in the affected areas and frequencies. If it is not possible for licensees to move into a

[13] The count of 17 unique WISPs includes all licensees that provide fixed wireless internet services. While fixed wireless internet services may only constitute a small portion of their business models (e.g. they could resell NBN services or provide their own wired services), it is likely that these point-to-multipoint licences are used specifically for the provision of these services.

different band or gain third-party access to the spectrum, spectrum-based relocation solutions would be exhausted. Generally, additional options to continue service include geographic relocation or the use of alternative technologies, but these can largely be ruled out for WISPs.

> The primary purpose of the majority of WISPs is to provide internet or other data related services to clients in a specific area, which requires equipment to be located in these areas—geographic relocation is therefore not an option.

> The equipment that WISPs use to provide fixed wireless broadband services is generally only available for a limited set of bands that are either already allocated for spectrum licensing or are in the early stages of consideration for wireless broadband services in Australia. If potential substitute bands (for example, the 5.6 GHz band, which is not an IMT band[14]) are unavailable and no spectrum is set aside in the 3.6 GHz band for WISPs, the only other compatible bands would only represent temporary solutions, as they may be proposed for re-farming in the near future.

> WISPs are largely constrained to fixed wireless broadband technology. It is unlikely that WISPs could use alternative technologies to replace their fixed wireless services in the event of no spectrum being available. For example, it would not be economical to deploy fixed line services in regional areas that have low population density and require substantial capital investment.

If WISPs are unable to continue operating, the loss in economic welfare from losing these services will not be the only economic impact. In this highest value use assessment, the use of a TWS means that the total economic welfare of a society is measured without positively or negatively discriminating against particular actors. The loss of producer surplus for an entity that is unable to continue operating is therefore not considered more or less important than the increase to producer surplus for the entity that fills the gap in the market vacated by the discontinuing entity.

In the case of WISPs potentially going out of business, customers are assumed to continue receiving internet services, but from different providers. While producer surplus for WISPs would fall as they discontinue operations, producer surplus for alternative providers would increase as their substitute services expand their customer base. To this extent, the effect on producer surplus under a TWS is net-neutral, although that producer surplus is transferred to a different producer.

The 'variable output' nature of these cases occurs due to the differences between the new service and the previous incumbent service. These differences are largely unquantifiable, and can affect producer surplus and consumer surplus, while creating further positive or negative externalities. The broader social value of externalities is not calculated under a TWS as it is not part of producer surplus or consumer surplus, although it is considered qualitatively as part of the highest value use assessment.

If consumers are forced to replace their use of an incumbent service with a new service, there is likely to be a decline in consumer surplus. This is because rational consumers are assumed to be already aiming to maximise their consumer surplus by using the incumbent service—if the new service provided additional consumer surplus compared with the incumbent service, they would have already been using the new

[14] IMT band refers to frequency bands identified for International Mobile Telecommunications (IMT) in the footnotes to the Table of Frequency Allocations in the International Telecommunications Union (ITU) Radio Regulations.

service. Such changes to economic welfare lead to these cases being considered variable output cases.

These consumer surplus effects on economic welfare under a TWS can often be compounded by a reduction in producer surplus as well, as prices have to be lower to account for the lower value placed on the new services by consumers. There may also be a loss of positive externalities that were the result of the incumbent service, such as improved productivity for regional businesses due to having internet connections with faster latency.

In submissions to the October 2016 discussion paper, some consumers (and WISPs) indicated that the services provided by WISPs are considered superior to their potential alternatives. Based on submissions, this is largely because WISPs are considered to be more flexible operators that can tailor products specific to their regional customers—particularly regional business clients. They are not subject to the type of nationwide product and pricing strategies that can constrain larger providers when dealing with regional customers.

WISPs have largely located their services in areas where historically there were limited to no alternative broadband services on offer. These areas are now being targeted for coverage by NBN terrestrial fixed wireless broadband and satellite (Sky Muster) services, but presently are primarily situated outside of the NBN's fixed wireless footprint. For existing customers of WISPs, NBN satellite services are consequently the primary substitute service if required.

Feedback from end users to the October 2016 discussion paper indicated that some consumers place a lower value on the satellite component of the NBN compared with services provided by WISPs. It is assumed that consumers continuing to use the services of WISPs rather than switching over to NBN satellite services when they become available are likely to already be making a rational, economically welfare maximising product choice. For these consumers, if WISPs are unable to continue providing their services, there is an expected—but unquantifiable—decline in consumer surplus, and therefore total economic welfare. These potential unquantifiable reductions in economic welfare will be considered alongside the quantifiable changes to economic welfare that would occur if the 3.6 GHz band is re-farmed.

Constant output cases—WISPs able to relocate to a different band

WISPs may have the opportunity to continue providing their services by relocating to a different band. The *Options for incumbent services* section of the Options paper identifies and discusses the options available to WISPs. This includes identifying the 5.6 GHz band for the relocation of existing and deployment of new fixed wireless broadband services.

Further technical detail on the 5.6 GHz band is outlined in Appendix 3 to the Options paper. The availability of the 5.6 GHz band will also depend on its own highest value use, which is considered in further detail in Appendix B to this paper. It should be noted that even with the 5.6 GHz band being available, there may be scenarios where one or more licensee could not relocate to the new band, so these options cannot be uniformly applied to all incumbent licences:

> WISPs could move directly to the 5.6 GHz band if it is made available for site-based apparatus licensing arrangements. They would be considered constant output cases, as services could continue being provided without varying output. The costs that licensees incur in moving to the 5.6 GHz band would result in a decline in producer surplus, which translates into a decline in the net benefit measured under a TWS. For WISPs, relocation costs are expected to primarily

comprise equipment replacement costs for base stations and user terminals. The focus on equipment replacement is due to the following factors:

> Existing equipment compatible with the 3.6 GHz band is expected to be unable to be re-tuned for the 5.6 GHz band. Therefore, radio equipment would have to be replaced rather than re-tuned in order to continue service.

> Equipment replacement at the existing site means that there will be no additional site rental costs or site acquisition costs resulting from displacement from the 3.6 GHz band. Spectrum band changes are unlikely to cause site rental costs to change, while a new site will not need to be acquired if the existing site can remains in use with new equipment.

Cost estimates based on stakeholder feedback, desktop research and ACMA staff assumptions can be applied to WISPs potentially moving to the 5.6 GHz band and needing to replace equipment. These estimated costs include $90,000 to add a new frequency to an existing macro site and $365,000 to establish a new macro site (this includes new ACMA frequency assignment charges of $606 on the issue of new point-to-multipoint licences, administered under the Radiocommunications (Charges) Determination 2017). The cost of adding a new frequency to an existing macro site can be inferred as the cost of replacing equipment to move to a different frequency, while the cost of establishing a new macro site is the cost of investing in a new tower.

For the most part, it is expected that equipment replacement will be equivalent to adding a new frequency to an existing site. It is unclear to what extent new towers will be necessary using the 5.6 GHz band. For example, what affect any coordination requirements or other deployment restrictions have on the service coverage area and therefor whether there is a need for additional base stations need to be assessed by operators on a case-by-case basis. Many incumbents have already innovatively avoided tower construction by utilising existing standing infrastructure for their equipment rather than building new towers. The estimated $365,000 cost of establishing new towers is therefore not going to be considered as a quantifiable cost across all incumbent WISP licences, but will be considered as an unquantifiable cost that may be incurred in addition to regular equipment replacement costs.

The base stations (or macro sites) used by point-to-multipoint licensees are used to connect with multiple user terminals. User terminals are expected to need to be replaced in order to use the 5.6 GHz band. Stakeholder feedback, desktop research and ACMA staff assumptions have guided estimates of 240 user terminals per site and a cost of $750 for each user terminal upgrade. The ACMA acknowledges that while a greenfield install for user terminal costs could be higher, it is expected that part of each existing installation can be re-used (e.g. cabling, antenna mounts, power supply, etc.) when migrating to a another band. These costs need to be considered when determining the overall incremental costs—and loss of producer surplus—involved in displacing WISPs from the 3.6 GHz band.

Table 8: Estimated costs of replacing equipment for WISPs

	Cost/quantity
Base station equipment replacement and frequency assignment (per licence)	$90,000
Estimated number of user terminals (per site)	240
Estimated cost of upgrading individual user terminals	$750
Estimated total cost of upgrading user terminals (per site)	$180,000
Total cost per licence	**$270,000**

The estimated cost of replacing equipment for WISPs is projected to be $270,000. To determine the overall quantifiable incremental costs (and reduction in net benefit under a TWS) of WISPs moving from the 3.6 GHz band to the 5.6 GHz band, these costs need to be applied to all displaced licences. When averaging these costs across all incumbent licences, the total effect of these quantifiable costs on the net benefit under a TWS will depend on the geographic area option selected.

There is also the potential for unquantifiable incremental costs to be incurred. If the 5.6 GHz band requires the construction of new towers, there will be additional costs of approximately $365,000 for each site, with these costs unable to be quantified across all incumbent licences as the extent to which new towers will be needed is currently unclear. Furthermore, some incumbent licensees may decide to discontinue their operations and will therefore represent variable output cases. The incremental costs associated with these variable output cases will be the same as those for if the 5.6 GHz band is unavailable—that is, the difference in total economic welfare between the existing WISP service and the replacement service that their customers use.

Table 9: Summary of incremental costs if WISP licences migrate to the 5.6 GHz band

		Area 1	Area 2	Area 3	Australia-wide
Quantifiable costs	**WISP licences**	0	87	167	174
	Total cost ($270,000 per licence)	$0	$23 million	$45 million	$47 million
Unquantifiable costs	Some licences may require new towers to be constructed to continue providing similar quality of service. This will cost an estimated $365,000 per site. However, the total cost across all incumbent WISP licences is unclear, as the extent to which new towers will be required is also unclear. Some incumbent licensees may discontinue service. The incremental costs will be the difference in economic welfare between the existing WISP service and the substitute internet service that customers use.				

Constant output cases—under Option 4a

A hybrid approach as per Option 4a of the Options paper, where a portion of the 3.6 GHz band is set aside for site-based apparatus licensing arrangements, would increase the number of constant output cases and reduce incremental costs. It should be noted that while incremental costs would be likely to fall, the cost reduction would come at the expense of not being able to realise the area-wide licensing benefits for the portion of the 3.6 GHz band that has been set aside for site-based apparatus licensing.

Quantifiable incremental costs would be lower in this scenario than if WISPs had to move to a different band. Remaining in the same band allows for a higher share of equipment needing to be re-tuned rather than replaced, as existing equipment is more likely to be compatible with a new frequency within the same band. Furthermore, some licences may already be located in the set-aside spectrum, which would enable them to incur no loss of producer surplus as they avoid equipment replacement or re-tuning costs, as well as frequency assignment costs.

> **Replacement costs.** While it is expected that most WISPs would be able to re-tune their equipment in this case, there are likely to be some licensees that are

unable to use their existing equipment in the new available bandwidth. These licensees will therefore have to incur the costs associated with investing in new equipment. This scenario, with frequency assignment changes resulting in equipment replacement, is expected to result in licensees incurring the same costs as they would if they moved into the 5.6 GHz band. The estimated cost per licence (and reduction to net benefit under a TWS) is therefore $270,000, although there would be no unquantifiable threat of having to invest in new towers.

> **Re-tuning costs.** Moving to any set-aside spectrum within the 3.6 GHz band will represent only a small frequency shift for many WISP licensees, which means there is a greater chance that the new frequency will be within the tuning range of the equipment. While some equipment can be re-tuned remotely, for the purposes of this analysis, it has been assumed that all equipment needing to be re-tuned will require labour being sent to the site. Based on stakeholder feedback, desktop research and ACMA staff assumptions, the labour cost of re-tuning is estimated at $232, with ACMA frequency assignment charges of $606 per assignment also applicable. This leads to a total cost of $838 per licence—substantially less than equipment replacement costs.

> **No change.** WISP licensees already located within a 25 MHz set-aside would incur zero incremental costs. Licences that require no change have not been considered in this set-aside analysis, as the number of licences affected is highly uncertain and the cost differential between no change and re-tuning is relatively minor.

Total incremental costs incurred by incumbent WISPs are likely to primarily be shaped by the composition of replacement, re-tuning and unchanged scenarios. If the number of licences that only require equipment re-tuning—or no change at all—is higher, the magnitude of incremental costs is expected to fall. In this case, all licensees are assumed to continue service; if some licensees decide to discontinue service, the unquantifiable incremental costs incurred will be the same as those outlined for WISP variable output cases.

Table 10: Cost of replacing or re-tuning WISP point-to-multipoint licences in the 3.6 GHz band with a spectrum set-aside under Option 4a

	Area 1	Area 2	Area 3	Australia-wide
WISP licences	0	87	167	174
Total cost	$0	$6 million–12 million	$11 million–23 million	$12 million–24 million

Note: Replacement costs are $270,000 per licence, while re-tuning costs are $838 per licence. The data in this table outlines ranges from 25 per cent replacement (75 per cent re-tuning) to 50 per cent replacement (50 per cent re-tuning).

While the reduction in incremental costs translates into an increase in net benefit under a TWS, a potentially greater increase in net benefit under a TWS—due to increased producer surplus and consumer surplus derived from the spectrum's ability to support MBB services—would not be realised. Therefore, for a more accurate comparison between the different alternatives for WISPs, the reduction in incremental costs under Option 4a has to take into account the lost economic benefits that would have occurred for any set-aside spectrum not re-allocated for area-wide licensing. This is considered in more detail in the *Net benefit* section of this paper.

4. Would there be a change in the quality of services that could be provided by WISPs with the 5.6 GHz band compared with the incumbent 3.6 GHz band services?

5. What alternative internet services could regional consumers access (excluding NBN Sky Muster services) if WISPs are unable to provide their fixed wireless broadband services?

Non-WISP licensees

Non-WISP 3.6 GHz point-to-multipoint licensees primarily comprise public sector (for example, councils and state government departments) and mining sector entities. The ACMA considers it unlikely that the end outputs from these types of users are going to be affected by loss of access to 3.6 GHz band spectrum. It is unlikely, for example, that a mining entity's overall mining output will be subject to a major negative effect resulting from changes to the 3.6 GHz band.

Whether licensees are able to move to a different spectrum band will largely depend on the geographic location of licences. The same options for relocation to alternative spectrum apply to non-WISPs, this includes relocating to the 1800 MHz, 2 GHz or 5.6 GHz band where available. The options become increasingly viable the further away from metropolitan areas the service is located.

Given, a majority of no-WISP use is in the outskirts of Area 3 and remote areas, there is therefore a greater chance that these licences will be constant output cases. Licensees unable to migrate to a different band would need to either consider third-party authorisation options or other (non-wireless, such as fibre) means to provide their service if possible. If licensees are unable to find an alternative solution after exhausting all options, they could remain constant output cases if their final output is not materially affected; otherwise, they would be variable output cases.

Overall, there is expected to be a combination of constant output and variable output cases. However, the composition of such cases is unquantifiable, as determining whether a particular licence represents a constant output or variable output case depends on the circumstances of that licence.

Constant output cases—non-WISP licensees

There are two types of constant output cases for non-WISP licensees:

1. Licensees that are not dependent on the 3.6 GHz band may be able to migrate to alternative spectrum options. This includes moving to set-aside spectrum if Option 4a was to be implemented (the incremental cost range for non-WISP licensees under this option falls within the broader cost range for non-WISP constant output cases). In these cases, they are likely to only incur frequency relocation costs, with no resulting change in output—these are therefore constant output cases.
2. Licensees dependent on the 3.6 GHz band may be unable to continue their own licensed spectrum use, or will have to find alternative technologies (for example, fibre, MBB). These cases have the potential to be constant output or variable output cases. Spectrum for wireless broadband applications is often an indirect input into an unrelated final output (for example, spectrum represents an auxiliary input into the extraction of minerals by miners). Cases where there is no material change in final output are considered to be constant output cases.

For all constant output cases, the incremental costs (that is, the negative effect on producer surplus and reduction in net benefit under a TWS) are the increased supply costs resulting from either relocating to a different spectrum band or finding different inputs to help achieve the same end output (meeting data needs in a way that does not involve the use of apparatus-licensed spectrum).

Table 11: Estimated costs of replacing equipment for non-WISP licensees

	Cost/quantity
Base station equipment replacement and frequency assignment (per licence)	$90,000
Estimated number of user terminals (per site)	30
Estimated cost of upgrading individual user terminals	$750
Estimated total cost of upgrading user terminals (per site)	$22,500
Total cost per licence	**$112,500**

The circumstances for cases where alternative spectrum is available are largely similar to constant output cases for WISPs, in that the costs for some licences will primarily represent the cost of replacing equipment. Non-WISP licensees' point-to-multipoint sites are assumed to service a lower number of user terminals as they are not providing a consumer broadband service. The replacement cost for non-WISP licensees' equipment is therefore considered to be $112,500 per licence, while re-tuning costs are considered to be $838 per licence.

Cases where alternative spectrum is not available are unable to be quantified, as there is no common alternative input with cost data that can be averaged across these types of constant output cases. These costs are also likely to be determined by the individual circumstances of each licence, such as the alternative input used, the location of the site of use, and so forth. As such, these cases are subject to unquantifiable costs that act as a substitute for quantifiable costs.

Table 12: Incremental costs for non-WISP constant output cases

<table>
<tr><th></th><th></th><th>Area 1</th><th>Area 2</th><th>Area 3</th><th>Australia-wide</th></tr>
<tr><td rowspan="2">Quantifiable costs</td><td>Non-WISP licences</td><td>0</td><td>35</td><td>126</td><td>239</td></tr>
<tr><td>Total cost ($112,500 per licence)</td><td>$0</td><td>$0–4 million</td><td>$0–14 million</td><td>$0–27 million</td></tr>
<tr><td>Unquantifiable costs</td><td colspan="5">Constant output cases assume no material change in end output—unquantifiable costs are therefore equal to the increase in supply cost of producing the end output in a difference way (for example, replacing spectrum inputs with alternative technologies like fibre if practical).</td></tr>
</table>

The overall incremental costs for constant output cases among non-WISP point-to-multipoint licences are unclear due to the uncertain composition of different types of constant output cases. Furthermore, the composition of constant output and variable output cases is also unclear, as some of the licences that are unable to be moved to a different spectrum band could cause a change in output. As such, there are further unquantifiable costs among non-WISP licences that require analysis.

Variable output cases—non-WISP licensees

It is possible that some incumbent non-WISP licensees that are unable to migrate to alternative spectrum may be variable output cases—this will occur if licensees experience a material change in output due to the 3.6 GHz band being unavailable as an input. In addition to the producer surplus reduction that would result if output was unchanged, reductions in consumer surplus and broader social net benefits are likely due to the change in output.

While the majority of cases are expected to be constant output cases, as outlined above, there are several ways in which non-WISP licensees may be variable output cases. Some brief examples include the following:

> Local councils that hold point-to-multipoint licences may be the licence-holder but are ultimately providing a wireless internet service, which makes their cases more akin to the variable output effect on WISPs.

> Miners that hold point-to-multipoint licences may use these licences to assist in the automation or remote control of equipment to improve safety and productivity. The loss of wireless communications means to provide these services may result in a reduction in productivity due to reversion to older (or other alternative) methods to manage safety and productivity.

In these and other similar cases, incremental costs are unquantifiable. While the effect on producer surplus could potentially be measured, there is no way to quantify the combined effects on consumer surplus and broader social net benefits resulting from non-WISP licensees no longer being able to use the 3.6 GHz band.

6. How could the loss of point-to-multipoint licences in the 3.6 GHz band affect regular business operations for non-WISP licensees?

Overall incremental costs for point-to-multipoint licences

The overall incremental costs for point-to-multipoint licences depend on a variety of uncertainties across the different industries in which incumbent licensees operate, along with whether the 5.6 GHz band is an available spectrum substitute for incumbents. The applicable incremental costs are made up of a variety of quantifiable and unquantifiable costs—in some cases, unquantifiable costs will be a substitute for quantifiable costs, but in other cases they will be additional costs.

Table 13: Incremental costs of displacing point-to-multipoint licences from the 3.6 GHz band

<table>
<tr><th></th><th></th><th>Area 1</th><th>Area 2</th><th>Area 3</th><th>Australia-wide</th></tr>
<tr><td rowspan="3">Quantifiable costs</td><td>WISPs</td><td>$0</td><td>$6 million–23 million</td><td>$11 million–45 million</td><td>$12 million–47 million</td></tr>
<tr><td>Non-WISP licensees</td><td>$0</td><td>$0–4 million</td><td>$0–14 million</td><td>$0–27 million</td></tr>
<tr><td>Total costs</td><td>$0</td><td>$6 million–27 million</td><td>$11 million–59 million</td><td>$12 million–74 million</td></tr>
<tr><td>Unquantifiable costs (includes WISPs and non-WISP licensees)</td><td colspan="5">Licensees that are unable to move to a different spectrum band are likely to incur unquantifiable costs. These would be a substitute for the quantifiable costs that would be incurred if licensees are able to move to a different spectrum band.
> Where licensees can maintain the same level of end output, they will be considered constant output cases—the incremental costs incurred will be the reduction in producer surplus resulting from increased supply costs.
> Where licensees are unable to maintain the same level of output, they will be considered variable output cases. In addition to a reduction in producer surplus resulting from increased supply costs, there are also likely to be unquantifiable effects on consumer surplus and broader social net benefits that influence economic welfare (for example, the difference in welfare between an existing and replacement internet service).
There may be a difference in costs between equipment in an alternative band and 3.6 GHz band equipment if the replacement of equipment occurs as a regular business cost (that is, part of a regular equipment replacement cycle).
If a set-aside is applied under Option 4a: a number of licences may be subject to no change by already being within the set-aside, which will cause uncertain lower quantifiable costs of displacement.</td></tr>
</table>

It should be noted that it is unlikely that the quantifiable incremental costs of displacing WISPs from the 3.6 GHz band will be equal to zero. This value is only considered the lower bound of the range of incremental costs because there is the potential for WISPs to be unable to continue operating in their current form, which could mean that all licences are variable output cases. This situation would result in zero quantifiable costs for WISPs, but it would also result in maximum unquantifiable costs.

7. Are the applicable costs for equipment replacement and re-tuning for point-to-multipoint licences suitable? If not, what cost ranges should be applied?
8. Are there any additional costs (applicable under a Total Welfare Standard) that have not been considered in this analysis?
9. If the 3.6 GHz band is re-farmed, what is the extent to which a longer re-allocation period would reduce incremental costs under a TWS?

FSS earth receive licences

There are only five individual licensees with FSS earth receive licences in the 3.6 GHz band—Telstra, Inmarsat, Optus, Lockheed Martin and Atwood Oceanics Pacific. While the location of existing FSS earth receive facilities will pose varying relocation challenges, the low number of licensees enables each licensee's circumstances to be viewed on an individual basis.

Licensees are expected to encounter varying relocation costs, as there are multiple geographic relocation options. Advice from licensees is that they have the potential to either:

> relocate only their 3.6 GHz band licences

> relocate all of their C-band (3.4–7.25 GHz) licences.

Based on stakeholder feedback, the most cost-effective option is to relocate all C-band licences to a new facility. Any analysis of FSS earth receive licence relocation in this paper therefore refers to a licensee relocating all C-band licences from an existing facility. The ACMA notes that re-farming the 3.6 GHz band could potentially act as the trigger for licensees to relocate their entire FSS earth receive facilities over time to consolidate operations at one location.

All licence number data is based on the Register of Radiocommunications Licences (RRL) as at 1 May 2017.

Table 14: Number of incumbent earth receive licences in the 3.6 GHz band (based on 1 May 2017 RRL)

Licensee	Area 1	Area 2	Area 3	Australia-wide
Telstra	9	9	9	9
Inmarsat	4	4	4	4
Optus	2	2	2	2
Lockheed Martin	0	0	2	2
Atwood Oceanics Pacific	0	0	0	2
Total	**15**	**15**	**17**	**19**

Metropolitan licences

Metropolitan licences refer to all FSS earth receive licences in Area 1—there are no licences in Area 2 that are not in Area 1. The incumbent Area 1 licensees are Telstra, Inmarsat and Optus.

Telstra

Telstra holds nine FSS earth receive licences in the 3.6 GHz band. Six are in the Perth suburb of Landsdale and three are in the Sydney suburb of Belrose. Telstra holds 196 licences across the Landsdale and Belrose facilities, with further details as follows:

> Landsdale—a total of 126 FSS earth station licences (112 located in C-band), which includes 65 earth receive and 61 fixed earth licences.

> Belrose—a total of 70 FSS earth station licences (67 located in C-band), which includes 35 earth receive and 35 fixed earth licences.

Telstra has not provided an indication of its potential relocation costs. However, the company has outlined its preference for some form of spectrum=sharing in their submission to the October 2016 discussion paper, along with a preference for the 3.6 GHz band to be re-farmed for MBB.

Inmarsat
Inmarsat holds four FSS earth receive licences in the 3.6 GHz band. These licences are all at the same Landsdale (Perth) location where Telstra holds licences. In its submission to the October 2016 discussion paper, Inmarsat referenced its submission to a prior consultation in 2011, in which it outlined costs of between $25 million and $30 million to relocate its Perth facilities.[15]

The four FSS earth receive licences in the 3.6 GHz band contribute to 116 FSS licences held by Inmarsat at the Landsdale facility. This licence count includes 38 earth receive licences and 73 fixed earth licences. The relocation costs of $25–30 million are assumed to be spread across the 67 licences located in C-band, with licences located in other satellite bands (for example, Ku-band and Ka-band) expected to remain in Landsdale.

Optus
Optus holds two FSS earth receive licences in the 3.6 GHz band. These include one licence in Sydney (Oxford Falls) and one licence in Perth (Lockridge). Further details about licence holdings at these facilities include:

> Oxford Falls—a total of 31 FSS earth station licences (all 31 located in C-band), which includes 17 earth receive and 14 fixed earth licences.

> Lockridge—a total of 50 FSS earth station licences (24 located in C-band), which includes 20 earth receive and 30 fixed earth licences.

Optus has submitted that the costs involved in establishing new facilities in more remote areas ‘would be in the tens of millions of dollars’.[16] It is further assumed that this figure refers only to Optus’s C-band licence holdings (55 licences) at a single facility.

Regional and remote licences

Regional and remote licences refer to licences in Area 3 and in remote areas (counted in ‘Australia-wide’). There is one licensee in each area—Lockheed Martin in Area 3 and Atwood Oceanics Pacific in a remote area.

Lockheed Martin
Lockheed Martin holds two licences in Area 3, which are both located in Uralla, New South Wales. Lockheed Martin holds a total of 33 FSS earth station licences at this location (10 in C-band), including 15 earth receive and 18 fixed earth licences. The company did not provide a submission to the October 2016 discussion paper, so there are no cost data points outlining how expensive it could potentially be to relocate this facility.

Atwood Oceanics Pacific
Atwood Oceanics Pacific, an offshore drilling company, holds two FSS earth receive licences located offshore in a remote area in the 3.6 GHz band. These are the only two FSS earth station licences located at this facility. These licences are not going to have their incremental costs assessed quantitatively—they are located offshore and will not be a constant output case, as there will be no potential substitute service (for example, fibre) that could replace spectrum in this case. It will therefore be considered a variable output case with unquantifiable incremental costs. The company did not provide a submission to the October 2016 discussion paper.

[15] Inmarsat and Stratos submission to Earth station siting consultation, October 2011

[16] Optus submission to the October 2016 discussion paper, December 2016

General incremental costs for FSS earth receive licences

The majority of incumbent FSS earth receive licences are considered to be constant output cases. There is not expected to be any material decline in output due to frequency relocation or geographic relocation, which means the only effect on the net benefit is anticipated to be a decline in producer surplus related to relocation costs. However, there are challenges associated with each type of relocation. For instance, these challenges can include that frequency relocation requires that there are alternative spectrum options available, and that the offshore position of Atwood Oceanics Pacific's licences means they are not expected to be able to relocate.

Frequency relocation

In some cases, it may be possible for licensees to relocate their services to a different band, including the adjacent 3700–4200 MHz band. However, this may not necessarily be a simple or practical option in many circumstances. This is because there are numerous factors that affect the frequency a satellite service operates on, which are not always easily controlled by the FSS earth receive licensee. In addition to this, many of the services already operate across large portions of C-band from a single antenna, so there may be limited opportunity to move to other portions of the band. Licensees located in Area 1 are not expected to be able to relocate their licences to a different spectrum band, while it is unknown whether licensees in regional and remote areas could do so.

Geographic relocation

FSS earth receive licensees could potentially take the opportunity provided by re-farming the 3.6 GHz band to relocate either their entire facility or at least all of the facility's C-band licences from metropolitan areas to less populated areas. This would enable mobile broadband to make use of the 3.6 GHz band in highly populated areas while also supporting ongoing access of the band by satellite services. The ACMA has indicated a long-term intention to consider the development of an earth station siting policy that supports similar actions for many years.

Such a change could be supported by the identification of specific areas on the east and west coasts of Australia with defined protection and coordination zones, longer term certainty provided to earth station licensees and lower licence fees. While the ACMA has already created such an area on the west coast of Australia, an east coast solution would also need to be found for this option to be viable.[17] It is further understood that the geographic relocation of either part or all of existing earth station facilities from metropolitan areas would require a suitable timeframe to implement. This is discussed further in the Options paper.

In this analysis, the ACMA assumes that geographic relocation refers to the relocation of all C-band licences, rather than entire FSS earth station facilities or individual licences. This is based on stakeholder feedback, desktop research and assumptions made by the ACMA.

Attribution of relocation costs to the 3.6 GHz band

It is unclear as to how the welfare cost of a C-band relocation should be attributed specifically to the 3.6 GHz band. While a decline in producer surplus resulting from relocation costs is expected, these costs could potentially be apportioned to the 3.6 GHz band in their entirety or on a proportional basis.

For the purposes of this analysis, the entire costs of a C-band geographic relocation are attributed to the 3.6 GHz band despite C-band spanning 3.4–7.25 GHz. Licensees have indicated they would relocate just the licences in the 3.6 GHz band, because

[17] Refer to Embargo 49

otherwise it is an unviable business solution. Displacing licensees from the band therefore forces them to either incur the costs of geographically relocating all C-band licences or cease supporting services operating in the 3.6 GHz band. As such, it would be inappropriate to apportion part of these costs towards potential benefits in the future when these future events are uncertain (that is, it may prevent future relocation costs if another band within C-band was re-farmed, but there is no certainty that another band within C-band be re-farmed).

Overall incremental costs of FSS earth receive licence displacement

The incremental costs associated with geographically relocating an FSS earth station facility will refer to relocating all C-band licences. There are multiple costs associated with relocating C-band licences for any particular facility:

> There would be costs involved in acquiring and constructing a new facility located in a regional or remote area. These costs include land acquisition, construction of building facilities (materials and labour), labour accommodation costs (due to it being in a regional or remote area), and power and fibre interconnection for the new facility.

> Costs would be involved in either relocating existing C-band antennas and radio equipment from existing sites or, if these are unable to be relocated, investment in new equipment.

> There may be additional costs involved in operating a new facility from a regional or remote location that would not be incurred with existing facilities. Only costs that are over and above the costs involved in operating existing facilities are considered to be incremental costs associated with re-farming the 3.6 GHz band.

The cost of relocating all C-band licences for a single FSS earth station facility is expected to range between $20 million and $50 million, as per stakeholder feedback to consultation, desktop research and ACMA staff assumptions. This range of potential incremental costs will therefore be applied to all facilities that are expected to be constant output cases and for which relocation costs are unknown. This includes all facilities operated by Telstra, Optus and Lockheed Martin.

These costs ranges are not applied to Inmarsat or Atwood Oceanics Pacific. Inmarsat has already indicated that relocating its Landsdale facility would cost between $25 million and $30 million, while it is not expected that Atwood Oceanics Pacific would be able to effectively geographically relocate its offshore licences—as such, they are considered a variable output case with incremental costs that are unable to be subject to quantification.

Each of the FSS earth receive licences that are considered constant output cases (all except the Atwood Oceanics Pacific licence) may actually be variable output cases, depending on the course of action taken by each licensee. This will be the case if licensees consider discontinuing service to be a more profitable exercise than relocating to a new facility. The costs in these cases are unquantifiable and would be a substitute to quantifiable costs.

Table 15: Incremental costs of displacing FSS earth receive licences from the 3.6 GHz band

<table>
<tr><th></th><th></th><th>Area 1</th><th>Area 2</th><th>Area 3</th><th>Australia-wide</th></tr>
<tr><td rowspan="2">Quantifiable costs</td><td>No. of licences</td><td>15</td><td>15</td><td>17</td><td>17</td></tr>
<tr><td>Incremental costs</td><td>$105 million–230 million</td><td>$105 million–230 million</td><td>$125 million–280 million</td><td>$125 million–280 million</td></tr>
<tr><td rowspan="2">Unquantifiable costs</td><td>No. of licences</td><td>0</td><td>0</td><td>0</td><td>2</td></tr>
<tr><td colspan="5">Areas 1–3: While they are not included in the number of licences here, some of the 17 licences in Areas 1–3 may represent variable output cases if it is not viable to relocate them.

Remote areas: Atwood Oceanics Pacific is not expected to be able to relocate its offshore remote licences—the costs of discontinuing service for these FSS earth receive licences are unquantifiable.</td></tr>
</table>

These ranges are the potential incremental costs of displacing FSS earth receive licensees from their current location. In the event coexistence arrangements are developed and they are not required to change location, some incremental costs will be avoided. Further detail on the potential outcomes that would result from the protection FSS earth receive licence locations is outlined in Appendix A.

10. Is the cost range for the relocation of all C-band licences from an FSS earth station facility suitable for this analysis?

Point-to-point licences

Point-to-point licensees have multiple options for frequency relocation as defined in RALI FX3.[18] In a number of cases, alternative delivery options such as gaining access to an existing fibre run in an area may also be viable. These licences will therefore all be considered constant output cases.

The incremental costs associated with relocating point-to-point licences will depend on how many licences require equipment replacement, as opposed to licences with equipment that can be re-tuned to another channel in the 3.8 GHz fixed link band. The cost of replacing devices far exceeds the cost of re-tuning. Therefore, the analysis of point-to-point devices will focus on replacement costs, re-tuning costs, and the potential share of devices that are replaced versus those that are re-tuned.

Replacement costs

There were no data points provided for the 3.6 GHz band in response to the October 2016 discussion paper. Data points for the 1.5 GHz band and the 1800 MHz band (received prior to the 1800 MHz regional auction in 2016) have therefore been used as an approximation for the replacement costs of point-to-point licences. These data

[18] RALI FX3 is available from the ACMA website

points are considered to give a reasonable indication of costs due to the similarity in frequencies and the fact that costs are similarly based on the relocation of services to higher frequency point-to-point bands:

> In response to the October 2016 discussion paper, the NSW Telco Authority outlined that: 'NSW Government agencies currently own and operate 59 links using the 1.5 GHz band … The cost associated with moving the links to alternative spectrum bands will be significant, with initial estimates by the NSW Telco Authority suggesting costs could be in the order of up to $5M.' This calculates to a figure of approximately $85,000 per fixed link.

> There was one public submission for the 1800 MHz band in 2016 that contained data points. AirServices Australia outlined that it would cost approximately $370,000 to relocate its four fixed links. The average cost per fixed link was therefore estimated to be $92,500.

Table 16: Incremental costs of replacing equipment for point-to-point licences in the 3.6 GHz band

	Area 1	Area 2	Area 3	Australia-wide
No. of licences	2	14	47	47
Equipment replacement cost per licence				
$85,000	$170,000	$1.2 million	$4.0 million	$4.0 million
$92,500	$185,000	$1.3 million	$4.3 million	$4.3 million
$100,000	$200,000	$1.4 million	$4.7 million	$4.7 million

The ACMA expects that these per-licence costs are likely to be reflected across the majority of point-to-point licences. For the purposes of this analysis, the NSW Telco Authority figure of $85,000 represents the lower bound; the AirServices Australia figure of $92,500 represents the mid-point; and an additional buffer has been applied to determine an upper bound of $100,000, which would be a worst-case scenario. These costs are also assumed to include ACMA frequency assignment charges of $505 for each point-to-point licence issued, which are administered under the Radiocommunications (Charges) Determination 2017.

Re-tuning costs

The cost of re-tuning equipment is significantly lower than the cost of replacing equipment. The ability of equipment to be re-tuned largely depends on the availability of another channel in the 3.8 GHz fixed link plan in the incumbent licence's geographic area, along with agility of incumbent user's equipment with regard to switching channels (which will largely depend on the age of equipment).

This analysis assumes the cost of re-tuning equipment will require a technician to re-tune equipment on-site, although the ACMA notes some equipment could potentially be re-tuned remotely at less cost. Based on stakeholder feedback, desktop research and ACMA staff assumptions, the labour cost of re-tuning equipment for an individual licence is an estimated $232, with ACMA frequency assignment charges of $505 per assignment also applicable. This leads to a total cost of $737 per licence.

Table 17: Incremental costs of re-tuning point-to-point licences in the 3.6 GHz band

	Area 1	Area 2	Area 3	Australia-wide
No. of licences	2	14	47	47
Equipment re-tuning cost per licence				
$737	$1,474	$10,318	$34,639	$34,639

Replacing versus re-tuning

The percentage of point-to-point licences that are replaced rather than re-tuned will have a bearing on incremental costs and the associated reduction in producer surplus for point-to-point licensees. Replacement costs are higher than re-tuning costs. Therefore, a higher proportion of licences that need to be replaced rather than re-tuned will result in much higher incremental costs (that is, a greater decline in producer surplus and net benefit under a TWS).

Licensees will determine whether their individual licences will be subject to equipment replacement or equipment re-tuning. This will largely depend on both the spectrum relocation options for each licence and the frequency agility of existing equipment. The ACMA has limited ability to determine the percentage shares of licences that would be subject to either equipment replacement or equipment re-tuning. As such, overall incremental costs derived from a range of percentage shares have been outlined to illustrate the variety of incremental cost outcomes that could occur.

Table 18: Cost of variable shares of replacing or re-tuning point-to-point licences in the 3.6 GHz band

	Area 1	Area 2	Area 3	Australia-wide
No. of licences	2	14	47	47
Incremental costs	$101,000–$200,000	$705,000–$1.4 million	$2.4 million–$4.7 million	$2.4 million–$4.7 million

Note: Replacement costs are $100,000 per licence and re-tuning costs are $737 per licence. The minimum cost for each area assumes that 50 per cent of licences require equipment replacement and 50 per cent require re-tuning; the maximum cost for each area assumes 100 per cent of licences require equipment replacement. Figures below $1 million are rounded to the nearest $1,000; figures above $1 million are rounded to the nearest $100,000.

It should be noted that there may be some variable output cases among incumbent point-to-point licences. While there is expected to be available spectrum to move into for point-to-point licences, some licensees may determine that the cost of relocating into a different band is unviable. These will be variable output cases and the incremental costs involved will be unquantifiable. These cases have not been considered in detail due to their expected low likelihood and lack of materiality on the overall outcome of this net benefit analysis.

11. Are the applicable costs for equipment replacement and re-tuning for point-to-point licences suitable? If not, what cost ranges should be applied?

Overall incremental costs

The incremental costs associated with re-farming the 3.6 GHz band are subject to multiple uncertainties for each incumbent licensed service type, which will have variable effects on producer and consumer surplus. To determine a range for the overall incremental costs of re-farming the 3.6 GHz band, both the quantifiable and unquantifiable costs of displacing each incumbent licensed service type need to be analysed and collated. These costs can then be compared with expected re-farming benefits to help find the potential re-farming scenario that maximises economic welfare under a TWS. There are some considerations to take into account for each type of licensed service:

> **Point-to-multipoint licences.** The range of quantifiable incremental costs for point-to-multipoint licences refers to the range between the minimum and maximum costs of all licences being constant output cases; that is, the range of costs involved in either replacing or re-tuning equipment. It is likely that the maximum quantifiable costs will not be reached; rather, some licences will be variable output cases for whom incremental costs are unquantifiable. As such, both quantifiable and unquantifiable costs should be considered.

> **FSS earth receive licences.** The majority of FSS earth receive licences are held by Telstra, Optus and Inmarsat—including all in metropolitan areas. For the purposes of this analysis, relocation of earth station facilities refers to the relocation of all C-band licences when considering the incremental costs (and subsequent reduction in producer surplus) in constant output cases. If any of the metropolitan or regional licensees discontinue service, they will be a variable output case, incurring unquantifiable costs rather than quantifiable relocation costs. The Atwood Oceanics Pacific licences are also expected to represent a variable output case if they are not protected, as it is unlikely that geographic relocation or the use of an alternative technology will be possible due to their offshore position.

> **Point-to-point licences.** A similar method to that which was used for point-to-multipoint licences can be used to determine maximum incremental costs for point-to-point licences. Incumbent point-to-point licences are each considered to be constant output cases, with relocation costs representing a loss of producer surplus. Incremental costs for each licence will depend on whether equipment is able to be re-tuned or if it has to be replaced, as replacement is more costly.

The combined incremental costs across all incumbent types of licensed services spans a broad range of potential outcomes, as the path forward for each type of licensed service—and certain groups falling under each type—is uncertain. The uncertainties surrounding these costs mean that they should be viewed with a subjective lens, with all potential variables taken into account to determine what the most realistic outcomes may be.

Table 19: Incremental costs of displacing all incumbent licences from the 3.6 GHz band

<table>
<tr><th></th><th></th><th>Area 1</th><th>Area 2</th><th>Area 3</th><th>Australia-wide</th></tr>
<tr><td rowspan="4">Quantifiable costs</td><td>Point-to-multipoint licences</td><td>$0</td><td>$6 million–27 million</td><td>$11 million–59 million</td><td>$12 million–74 million</td></tr>
<tr><td>FSS earth receive licences</td><td>$105 million–230 million</td><td>$105 million–230 million</td><td>$125 million–280 million</td><td>$125 million–280 million</td></tr>
<tr><td>Point-to-point licences</td><td>$101,000–200,000</td><td>$705,000–1 million</td><td>$2 million–5 million</td><td>$2 million–5 million</td></tr>
<tr><td>Total</td><td>$105 million–230 million</td><td>$112 million–259 million</td><td>$139 million–344 million</td><td>$139 million–359 million</td></tr>
<tr><td rowspan="2">Unquantifiable costs</td><td>Point-to-multipoint licences</td><td colspan="4">If point-to-multipoint licensees are unable to move to a different band or deem the costs of moving to a new band to be too high, some unquantifiable incremental costs will be incurred.

Some point-to-multipoint licensees may be unable to relocate to a different spectrum band. If they can maintain the same level of output, they will incur unquantifiable incremental costs through a reduction in producer surplus; if output falls, there will be further unquantifiable incremental costs through decreases in consumer surplus and broader social net benefits.</td></tr>
<tr><td>FSS earth receive licences</td><td colspan="4">Areas 1-3. Some of the 17 licences in Areas 1-3 may represent variable output cases if it is not viable to relocate them.

Remote areas. Atwood Oceanics Pacific is not expected to be able to relocate its offshore remote licences—the costs of discontinuing service for this FSS earth receive licence are unquantifiable.</td></tr>
</table>

Table 19 summarises the quantifiable and unquantifiable incremental costs associated with displacing incumbent licensees. It should be noted that unquantifiable costs may be a replacement for quantifiable costs in some cases, and in addition to quantifiable costs in other cases. An example for unquantifiable costs as a replacement is if WISPs are unable to move to a different band, as the increase in unquantifiable costs will occur with a related decrease in quantifiable costs. In contrast, there are no quantifiable costs associated with displacing the Atwood Oceanics Pacific FSS earth receive licence, so displacement of this licence would result in an increase in unquantifiable costs without any related reduction in quantifiable costs.

The displacement of FSS earth receive licences is expected to cause the most significant quantifiable incremental costs of potentially re-farming the 3.6 GHz band. These costs also are unable to be avoided through selecting particular geographic areas, as the majority of these licences are in populous cities in Area 1. The implementation of Option 4b would be valid if the reduction in re-farming benefits is not greater than the cost of relocating FSS earth receive licences. In particular, Option 4b may be an appropriate approach to the FSS earth receive licences located at Uralla.

This is because these are already located in a relatively low population density area which means the re-farming benefits are already low compared to incremental costs.

The quantifiable incremental costs of displacing point-to-multipoint licences ramps up when the geographic area option expands to either Area 3 or Australia-wide. The magnitude of these quantifiable costs is not expected to be the sole factor that would cause incremental costs to potentially outweigh re-farming benefits. However, there is also the potential that point-to-multipoint licensees will be unable to move to a different band, which could lead to substantial, but unquantifiable, incremental costs. As such, Option 4a may be appropriate unless suitable spectrum alternatives are identified.

Key points

> In constant output cases, incumbent licences have to relocate (provided no relevant hybrid approach is implemented), but output is largely unaffected. The incremental costs of spectrum re-farming in these cases are the necessary relocation costs to continue providing services, which represent a reduction in producer surplus. In variable output cases, the change in output (with no substitute service or a substitute service that is valued differently) can lead to changes in producer surplus, consumer surplus and broader net social benefits. There is likely to be a mix of constant output cases and variable output cases in the 3.6 GHz band.

> Point-to-multipoint licensees can primarily be categorised as WISPs and non-WISP licensees. While most non-WISP licensees are expected to have a range of options to relocate and therefore represent constant output cases, WISPs are more likely to represent variable output cases if they are displaced from the 3.6 GHz band and a viable relocation solution is not available. These potential variable output cases are unable to be subject to quantification, leading to some numerical uncertainty regarding overall incremental costs.

> FSS earth receive licences are likely to contribute the largest portion of incremental costs among the different types of licensed services. The relocation costs associated with FSS earth receive licences are expected to be based on the singular characteristics of each individual licensee, but they share the common trait of being highly costly due to the capital expenditure required as part of relocating geographically. However, there may be the ability to implement co-existence arrangements that would enable them to continue operating in the 3.6 GHz band at their current location. This would significantly reduce their incremental costs. Provided the reduction in re-farming benefits does not exceed this cost reduction, implementing Option 4b may be a valid approach so FSS earth receive licences in metropolitan areas can continue operating unaffected by any re-farming activities.

> Point-to-point licences are expected to be the least costly incumbent licensed service type, with the majority to be constant output cases as relocation options are largely readily available. Point-to-point licences' contribution to incremental costs will primarily be determined by the composition of incumbent licensees' equipment that undergoes less costly re-tuning as opposed to more costly replacement.

> The overall incremental costs include a range of quantifiable costs and a range of unquantifiable costs. The quantifiable costs stem from the constant output cases across different licenced services, while the unquantifiable costs are primarily the result of variable output cases for point-to-multipoint licences. FSS earth receive relocation costs are the largest incremental costs, although the unquantifiable costs of point-to-multipoint variable output cases can also be significant.

Net benefit

The net benefit of re-farming the 3.6 GHz band is the difference between the:

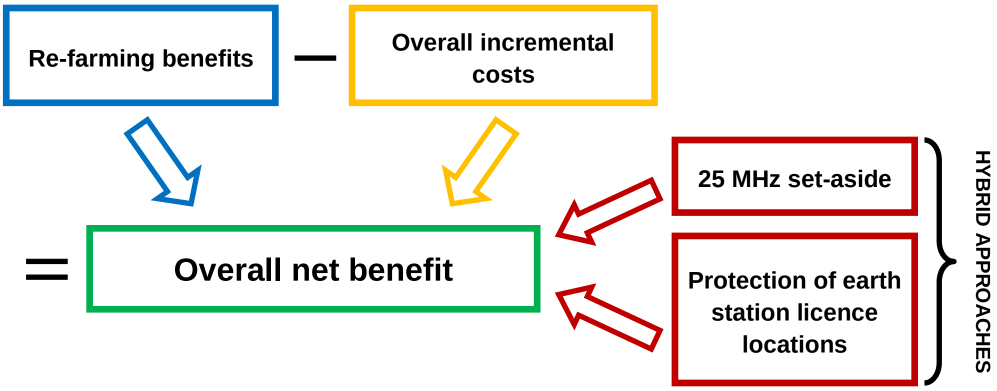
> economic welfare benefits of re-farming (which is estimated using the total willingness to pay for the spectrum by potential users as a proxy)

> incremental costs of displacing incumbent licensees from the band.

A range of potential cost-benefit outcomes have been analysed, with a view of what the probable outcomes are (rather than just the absolute worst outcome for net benefit), to determine the ultimate highest value use of the 3.6 GHz band.

This section performs a general net benefit analysis, attempting to determine whether re-farming benefits exceed incremental costs. An analysis of whether hybrid approaches are net beneficial in their own right follows, as these have the potential to significantly improve the economic outcome of the net benefit analysis.

Figure 5: Diagram of overall net benefit determination



Overall net benefit analysis

The economic welfare impact of re-farming the 3.6 GHz band is subject to a range of uncertainties on both the benefit side and the cost side. On the benefits side, in area-wide licensing arrangements, the potential population served and bandwidth available are likely to be pre-determined. The primary uncertainty with re-farming benefits is therefore the value placed on 3.6 GHz band spectrum by potential users.

The re-issue price of $0.03/MHz/pop for 3.4 GHz band spectrum in 2012 provides the principal basis for this being the lower bound valuation for the 3.6 GHz band, as it indicates a similar valuation for adjacent spectrum with similar characteristics. The value placed on such spectrum is only likely to have increased since this re-issue, as new technologies such as massive MIMO and beamforming are currently considered viable technologies for the 3.6 GHz band, but were not at this stage of development when the 3.4 GHz spectrum re-issue price was developed in 2012.

The re-issue price of $0.625/MHz/pop for 2 GHz band spectrum, set at the same time as the 3.4 GHz band re-issue price, is used as the corresponding upper bound in this analysis. This is because it is the highest expressed willingness to pay for spectrum above 1 GHz.

A range of potential spectrum valuations between $0.03/MHz/pop and $0.625/MHz/pop have been outlined. These are categorised by the different geographic area options, as different population figures lead to different overall benefits when multiplying by a $/MHz/pop value and the available bandwidth (125 MHz).

It should be noted that the spectrum valuations in the table below do not equate to the amount that would be paid in a potential price-based allocation. For instance, if a potential user valued 3.6 GHz band spectrum at $0.50/MHz/pop but only had to pay $0.03/MHz/pop to secure a licence, the economic welfare benefits of re-farming would be the overall valuation that is equivalent to $0.50/MHz/pop.

Table 20: Expected economic welfare benefit for each area if the 3.6 GHz band is re-farmed

Benefit ($/MHz/pop)	Area 1	Area 2	Area 3	Australia-wide
$0.03	$60 million	$72 million	$86 million	$87 million
$0.05	$101 million	$119 million	$143 million	$146 million
$0.10	$201 million	$239 million	$285 million	$291 million
$0.25	$503 million	$597 million	$713 million	$728 million
$0.50	$1.0 billion	$1.2 billion	$1.4 billion	$1.5 billion
$0.625	$1.3 billion	$1.5 billion	$1.8 billion	$1.8 billion

While there are uncertainties surrounding the expected benefits of re-farming, there are more variables that can influence the incremental costs of re-farming the 3.6 GHz band. Incremental costs for three different incumbent types of licensed services are considered: point-to-multipoint (388 licences), FSS earth receive (20) and point-to-point (47). Two amateur repeater licences have not been considered in this analysis. The licences considered in the analysis can all potentially be constant output cases (that is, incremental costs are relocation costs, which reduce producer surplus) or variable output cases (that is, incremental costs result from a change in output, affecting consumer surplus, producer surplus and broader social net benefits).

Whether point-to-multipoint licences are constant output or variable output cases largely depends on the availability of alternative spectrum to continue providing services—particularly for WISPs. There may be opportunities for point-to-multipoint licences to be relocated to a different band or to a specific part of the 3.6 GHz band, which would cause incremental costs to be confined to relocation costs. If these opportunities are unavailable, they are likely to be variable output cases, for which the incremental costs will be unquantifiable effects on producer surplus, consumer surplus and broader social net benefits.

The displacement of FSS earth receive licensees adds further uncertainties. While FSS earth receive licences are only held by a small number of licensees in the 3.6 GHz band, relocation of these licences would require the relocation of all C-band licences (i.e. 3.4–7.25 GHz), which is estimated to cost anywhere between $20 million and $50 million. FSS earth receive licences therefore represent the highest quantifiable incremental costs of all incumbent licensed service types. Alternatively, coexistence arrangements could be developed under Option 4b so one or more of these facilities would not have to relocate, which would reduce incremental costs but also reduce re-farming benefits. This potential solution is outlined in Appendix A.

Point-to-point licences demonstrate lesser uncertainties than the other incumbent types of licensed services. These licences are generally expected to be entirely constant output cases, with the main uncertainty stemming from whether equipment would be re-tuned or replaced, as re-tuning is considerably less costly than replacing equipment. There may also be variable output cases if relocation costs are considered too great for some incumbent licensees, but the economic impact of such cases—if they are present at all—is likely to be very minimal.

Table 21: Incremental costs of displacing all incumbent licences from the 3.6 GHz band

<table>
<tr><th></th><th></th><th>Area 1</th><th>Area 2</th><th>Area 3</th><th>Australia-wide</th></tr>
<tr><td rowspan="4">Quantifiable costs</td><td>Point-to-multipoint licences</td><td>$0</td><td>$6 million–27 million</td><td>$11 million–59 million</td><td>$12 million–74 million</td></tr>
<tr><td>FSS earth receive licences</td><td>$105 million–230 million</td><td>$105 million–230 million</td><td>$125 million–280 million</td><td>$125 million–280 million</td></tr>
<tr><td>Point-to-point licences</td><td>$101,000–200,000</td><td>$705,000–1 million</td><td>$2 million–5 million</td><td>$2 million–5 million</td></tr>
<tr><td>Total</td><td>$105 million–230 million</td><td>$112 million–259 million</td><td>$139 million–344 million</td><td>$139 million–359 million</td></tr>
<tr><td rowspan="2">Unquantifiable costs</td><td>Point-to-multipoint licences</td><td colspan="4">If WISPs are unable to move to a different band or deem the costs of moving to a new band to be too high, some unquantifiable incremental costs will be incurred.
Some non-WISP licensees may undergo an output reduction if displaced from the 3.6 GHz band.</td></tr>
<tr><td>FSS earth receive licences</td><td colspan="4">Areas 1–3. Some of the 17 licences in Areas 1–3 may represent variable output cases if it is not viable to relocate them.
Remote areas. Atwood Oceanics Pacific is not expected to be able to relocate its offshore remote licences—the costs of discontinuing service for this FSS earth receive licence are unquantifiable.</td></tr>
</table>

The overall net benefit of re-farming the 3.6 GHz band is subject to a range of factors that lead to an uncertain conclusion. A subjective lens is required when analysing the broad range of quantifiable and unquantifiable benefits and costs. The following summary table aims to support a subjective view of the economic net benefit of re-farming by providing a snapshot of the potential re-farming benefits and incremental costs involved. The table has been arranged in such a way as to be able to view the benefits and costs side-by-side and compare them effectively.

The range of re-farming benefits for each geographic area option uses a lower bound valuation of $0.03/MHz/pop, and an upper bound valuation of $0.625/MHz/pop. There may be some further unquantifiable economic benefits associated with re-farming the 3.6 GHz band. The primary factors for spectrum valuations are expected to be potential users' ability to reduce network deployment costs and charge higher prices for new or improved services, such as 5G capabilities. Some consumer surplus and broader social net benefit gains may not be captured in these valuations, which means re-farming the 3.6 GHz band is likely to result in some unquantifiable economic benefits being realised.

The incremental costs involved in the summary table do not defer from more detailed incremental cost ranges outlined earlier in this paper. The majority of quantifiable costs can be attributed to displacing point-to-multipoint and FSS earth receive licences. Unquantifiable costs for these licensed service types are also included, although the potential for variable output cases among point-to-point licences is not considered. It should be noted that some of the unquantifiable costs in the summary table act as a substitute for quantifiable costs, while others are in addition to quantifiable costs.

Table 22: Summary of economic benefits and incremental costs of re-farming the 3.6 GHz band

		Re-farming benefits ($0.03–$0.625/MHz/pop)	Incremental costs
Quantifiable	**Area 1**	$60 million–1.3 billion	$105 million–230 million
	Area 2	$72 million–1.5 billion	$112 million–259 million
	Area 3	$86 million–1.8 billion	$139 million–344 million
	Australia-wide	$87 million–1.8 billion	$139 million–359 million
Unquantifiable	**Addition to quantifiable**	Some additional consumer and broader social net benefits are likely to result from the availability of 5G services via the 3.6 GHz band, which could increase economic welfare.	Atwood Oceanics Pacific is not expected to be able to relocate its offshore remote licences—the costs of discontinuing service for these FSS earth receive licences are unquantifiable.
	Substitute to quantifiable	N/A	WISP point-to-multipoint: if WISPs are unable to move to a different band or deem the costs of moving to a new band to be too high, some unquantifiable incremental costs will be incurred. Non-WISP point-to-multipoint: some licensees may incur increased supply costs through using alternative technologies, or may undergo an end-output reduction if displaced from the 3.6 GHz band, also reducing consumer surplus and broader social net benefits. FSS earth receive (Areas 1–3): Some of the 17 licences in Areas 1–3 may represent variable output cases if it is not viable to relocate them.

The ACMA considers it likely that MBB services represent the highest value use of the 3.6 GHz band, and that re-allocating the band for area-wide licensing arrangements would therefore be economically net beneficial. While it would not be net beneficial at a valuation of $0.03/MHz/pop, this is a worst-case scenario—the value of the 3.6 GHz band is expected to be significantly higher.

Based on the analysis in this paper, either Area 2 or Area 3 are the geographic area options that are most economically beneficial if the 3.6 GHz band is re-farmed for area-wide licensing arrangements. This is due to the following:

> The incremental costs in Area 1, which are associated with FSS earth receive licence relocation, may be substantial and cause re-farming not to be net beneficial if it was confined to this area. However, the marginal growth in potential re-farming benefits in Area 2 and Area 3 significantly outweighs incremental cost growth, although this gap could be narrowed if the 5.6 GHz band is unavailable and WISPs discontinue operations, causing significant unquantifiable costs.

> While uniform $/MHz/pop values have been applied to the different geographic area options in this analysis, it is likely that MNOs would place a lower value on remote spectrum than metropolitan or regional spectrum. When standardised for population, it is typically more costly to deploy a mobile network for a highly dispersed population in regional areas than it is for a dense population in urban areas. Consistent spectrum valuations are therefore unlikely to extend into remote areas, which significantly reduces the chance that it is economically net beneficial to re-farm the entire Australia-wide geographic area option.

This comprehensive highest value use assessment ultimately indicates that re-farming the 3.6 GHz band for area-wide licensing across Area 3 (Option 3c) is likely to maximise economic welfare under a TWS. Area 2 and Area 3 are relatively similar in the magnitude to which they are expected to be net beneficial, so extending the re-farming geographic area to the larger of these two options is considered optimal.

The potential re-farming benefits of re-farming the band across Area 3 are expected to significantly outweigh the potential incremental costs. For example, a conservative valuation of $0.15/MHz/pop would generate re-farming benefits of $428 million. This would be likely to significantly exceed the upper bound of all quantifiable and unquantifiable incremental costs, and ultimately maximise the economic welfare derived from the spectrum. A decision on the preferred option, using this highest value use assessment as an input, is proposed in the accompanying Options paper.

Hybrid approaches

Option 4a

Setting-aside a portion of the 3.6 GHz band for site-based apparatus licensing would enable a number of point-to-multipoint licensees to remain in the band rather than moving to the 5.6 GHz band (if available) or having to discontinue operations. A set-aside of 25 MHz (that is, expected minimum bandwidth required for viable services to be provided via point-to-multipoint licences) would only apply to the part of the geographic area selected for re-farming that is outside of Area 1. There are no point-to-multipoint licences located in Area 1, and area-wide licensing is considered to be a higher value new use within these high demand areas than site-based apparatus licensing. However, there are multiple licences in Areas 2–3 and in remote areas for which the incremental costs of band displacement would be reduced.

If a set-aside is applied, the reduction in incremental costs is equal to the difference between the costs of applying a set-aside or not applying a set-aside. For instance, if the incremental costs of displacing point-to-multipoint licences when a set-aside is not applied are $10 million, and the costs when a set-aside is applied are $5 million, the reduction in incremental costs for WISPs will be $5 million (that is, an increase in net benefit of $5 million). In order for a set-aside to ultimately be net beneficial, this incremental cost reduction would then need to be greater than the economic welfare benefits forgone from not being able to re-farm the amount of bandwidth set-aside in the applicable geographic area.

The application of a set-aside is expected to reduce incremental costs, as most equipment is likely to just need to be re-tuned. This would be less costly than the equipment replacement that would have to occur with a move to another band such as the 5.6 GHz band, and likely to be less costly than the unquantifiable costs in a variable output case where incumbent licensees are unable to continue operations. Some licensees may not have to incur any costs if they are already located within the set-aside spectrum.

The following table outlines the costs involved in a set-aside, along with the costs that could be avoided if a set-aside is in place. The reduction in incremental costs can be determined as the incremental costs of a set-aside not being applied minus the incremental costs of a set-aside being applied. There is significant uncertainty surrounding the costs involved if there is no set-aside, particularly with regard to unquantifiable costs in variable output cases. As such, no quantifiable analysis of net difference is provided in the table, as the potential quantifiable costs cannot be separated out from the unquantifiable costs.

Table 23: Summary of incremental costs of displacing point-to-multipoint licences from the 3.6 GHz band that may be avoided through the use of a 25 MHz set-aside

		Area 2	Area 3	Australia-wide
25 MHz set-aside applied				
WISPs		$6 million–12 million	$11 million–23 million	$12 million–24 million
Non-WISP licensees		$1 million–2 million	$4 million–7 million	$7 million–14 million
Total		$7 million–14 million	$15 million–30 million	$19 million–37 million
25 MHz set-aside not applied				
Quantifiable costs	**Alternative spectrum unavailable (discontinue operations)**	$0	$0	$0
	Alternative spectrum available (all licences move)	$0–27 million	$0–59 million	$0–74 million
Unquantifiable costs	**Alternative spectrum unavailable (discontinue operations)**	Licensees that have to discontinue operations will cause incremental costs to economic welfare (that is, difference in welfare between existing and new internet service). This will be a substitute for the $0 quantifiable cost.		
	Alternative spectrum available (all licences move)	Difference in costs between alternative band equipment and 3.6 GHz band equipment if the replacement of equipment occurs as a regular business cost. This will be in addition to quantifiable costs.		

Note 1: The incremental cost ranges for a 25 MHz set-aside being applied (for both WISPs and non-WISP licensees) assume a lower bound with re-tuning costs being applied to 75 per cent of licences, and an upper bound of re-tuning costs being applied to 50 per cent of licences.

Note 2: The change to the overall net benefit is the difference between applying a set-aside and not applying a set-aside. For instance, if Area 3 is selected, an alternative spectrum option is available and there are no unquantifiable costs, the increase in net benefit is equal to the costs avoided from not having to move bands (for example, $59 million) minus the costs of a set-aside (for example, $30 million). Using these examples, a set-aside would equal an increase in net benefit of $29 million.

While incremental costs would be reduced by an undetermined amount through reserving a portion of the 3.6 GHz band for point-to-multipoint licensees, there would be an associated reduction in re-farming benefits, as there would be less bandwidth re-allocated for area-wide licensing arrangements (for example, for MBB services). The following table outlines the potential change (that is, a reduction) in re-farming benefits resulting from using a set-aside of 25 MHz.

Table 24: Estimated re-farming benefits with and without 25 MHz set-aside, assuming valuation range of $0.03/MHz/pop to $0.625/MHz/pop

	Area 2	Area 3	Australia-wide
Estimated re-farming benefit	$72 million–1.5 billion	$86 million–1.8 billion	$87 million–1.8 billion
Estimated re-farming benefit with set-aside	$69 million–1.4 billion	$80 million–1.7 billion	$82 million–1.7 billion
Difference in re-farming benefit	–$2 million to –47 million	–$5 million to –105 million	–$5 million to –113 million

When taking into consideration the possible reduction in both incremental costs and re-farming benefits, the potential gain in net benefit derived from setting aside spectrum will depend on the availability of other bands for the deployment of wireless broadband services. If the 5.6 GHz band is made available for site-based apparatus licensing of wireless broadband services, the reduction in incremental costs resulting from a set-aside would be relatively minor, rendering the use of a set-aside less likely to be welfare maximising. This will particularly be the case the longer the period of time point-to-multipoint licensees are given to relocate their services in to another band. The Options paper proposes a seven-year period for this to occur.

The 5.6 GHz band will not be available for site based apparatus licensing if class licensing arrangements (to facilitate the provision of wireless services) are deemed a higher value use (refer to Appendix B for further information). In this case, the validity of a set-aside, assuming no other bands are available, depends on the difference in net benefit between a set-aside and point-to-multipoint licensees having to shut down their services. These costs are not quantifiable and depend on the loss of economic welfare associated with operators employing alternative means to deliver the desired service, and consumers having to switch service providers if this is a viable option.

The net benefit outcome is not quantifiable regardless of whether the 5.6 GHz band becomes available for site-based apparatus licensing. When taking into account both quantifiable and unquantifiable costs, there is only a relatively minor difference in the incremental costs between having a set-aside and not having a set-aside. The potential re-farming benefits forgone if a set-aside is applied to Area 3 (the preferred geographic area option) are far greater than the potential cost reductions. As such, this economic analysis indicates that Option 4a would not maximise economic welfare under a TWS. These findings will feed into the Options paper, where there will be discussion of a proposed decision on this option.

Option 4b

Employing Option 4b so FSS earth receive licences can continue operating at their current locations (that is, licences in capital cities) depends on whether or not the incremental costs avoided from incumbent licences not being displaced are greater than the economic benefits that would be realised if these geographic areas were re-farmed. This will ultimately determine whether protecting FSS earth receive licence locations is welfare maximising under a TWS. Further detail on the protection of FSS earth receive licence locations can be found in Appendix A.

Table 25: Analysis of re-farming benefits and incremental costs protecting FSS earth receive licence locations in the 3.6 GHz band

		Reduction in re-farming benefits		Reduction in incremental costs
		Macro-cell case	Small cell case	
Quantifiable	Sydney	$8 million–168 million	$0.2 million–5 million	$40 million–100 million
	Perth	$8 million–161 million	$3 million–67 million	$65 million–130 million
	Total	$16 million–329 million	$3 million–72 million	$105 million–230 million
Unquantifiable	Total	Additional consumer surplus and broader social net benefits would be forgone if the band is not re-farmed.	Additional consumer surplus and broader social net benefits would be forgone if the band is not re-farmed. The difference in the value of spectrum with use restricted to small cells versus that of the same spectrum with unrestricted use.	Potentially replacing quantifiable reduction in incremental costs: some facility operators may not see relocation of licences as a viable business plan.

Note 1: Quantifiable ranges refer to the reduction in re-farming benefits based on $/MHz/pop valuations between a lower bound of $0.03/MHz/pop and an upper bound of $0.625/MHz/pop for 15-year licences.

Note 2: The maximum reduction in re-farming benefits in the small cell case, including both quantifiable and unquantifiable costs, is equal to the maximum reduction in re-farming benefits in the macro-cell case.

The ACMA notes that the preferred option for each city is subject to uncertain variables and is not indisputable. For both Sydney and Perth, the difference between the reduction in re-farming benefits and the reduction in incremental costs is largely subject to spectrum valuations. However, the additional economic benefits that could stem from re-farming the 3.6 GHz band in each city on top of spectrum valuations (that is, consumer surplus and broader social net benefits) indicate that re-farming is likely to maximise economic welfare.

12. To what extent would 3.6 GHz band spectrum be less valuable if it was restricted to small cell use only?
13. What kind of differences in value would there be for 3.6 GHz band spectrum in regional or remote areas when compared with metropolitan areas?

Conclusion

The overall economic net benefit can be calculated as the economic welfare benefits of re-farming for a new use under area-wide licensing arrangements (that is, expected to be used for MBB services), minus the incremental costs of displacing incumbent licensees. The potential benefits and costs are each surrounded by multiple uncertainties that make an unequivocal net benefit determination unachievable. The various factors affecting re-farming benefits and incremental costs therefore need to be viewed together to determine whether re-farming would be net beneficial.

On balance, this highest value use assessment indicates that re-farming the 3.6 GHz band in Area 3 (Option 3c) is likely to maximise the economic welfare derived from the band, therefore enabling the band to find its highest value use. There is expected to be high demand for the spectrum to provide 5G services in metropolitan and regional areas, with spectrum valuations anticipated to outweigh the incremental costs of displacing incumbent users in the band in these geographic areas. This highest value use assessment will be used to inform the proposed decision on the preferred option, which is discussed in more detail in the Options paper.

Hybrid approaches that could help maximise welfare on top of this and help alleviate the concerns of incumbent licensees have been considered. These are Options 4a and 4b. Option 4a is not considered to maximise economic welfare, as the loss of economic benefits from the spectrum not being re-farmed is projected to be greater than the benefits to incremental costs. Option 4b is also not considered to be welfare maximising. The outcomes for hybrid approaches are quite uncertain, however, and will be subject to further consultation and stakeholder feedback.

Glossary

Term	Definition
Apparatus licence	An apparatus licence issued under the *Radiocommunications Act 1992*, that authorises the use of a radiocommunications device to provide a particular service type, in a particular frequency range and at a particular geographic location for a period of up to five years.
Constant output case	This occurs when re-farming spectrum causes the supply cost of the existing or new service using the band to be changed, but output remains unchanged. The resulting economic effect is therefore only an increase or decrease in producer surplus.
Consumer surplus	The difference between the value a consumer places on a product and the lower (or equal) price they pay for the product. This amount for each consumer can be totalled across all consumers and contribute to economic welfare.
Externalities	Economic effects that are not accounted for in the market price and output (for example, pollution emitted from a factory is a negative externality). These make up broader social net benefits.
MNO	Mobile network operator
Mobile broadband (MBB)	The variety of ways an internet service is delivered via a mobile network, typically comprising mobile wireless internet services provided via a dongle, USB modem or data card service, or mobile phone handset internet services.
Producer surplus	The difference between the value a producer is willing to sell a product for and the higher (or equal) price paid they receive for the product. This amount for each producer can be totalled across all producers and contribute to economic welfare.
RALI	A Radiocommunications Assignment and Licensing Instruction (RALI) is a technical document made by the ACMA that outlines frequency assignment and information pertaining to coordination and interference management.
Register of Radiocommunications Licences (RRL)	Comprehensive online database of licensed radiocommunications services in Australia.
Spectrum licence	A spectrum licence issued under the *Radiocommunications Act 1992* authorises the use of a particular frequency band within a particular geographic area for a period of up to 15 years. The geographic area can vary in size, up to and including the entire country.
Total Welfare Standard (TWS)	The ACMA uses the TWS to determine the highest value use of a spectrum band. The TWS assumes that the highest value use maximises the overall economic welfare to consumers and citizens, without prioritising any particular economic actor.

Term	Definition
Variable output case	This occurs when re-farming spectrum causes a change in final output for either the existing service or the new service using the band. The resulting effect on economic welfare is a combination of changes to producer surplus, consumer surplus and broader social net benefits.

Appendix A: Protection of FSS earth receive licence locations

There are 17 incumbent fixed satellite service (FSS) earth receive licences operated from four facilities located in the metropolitan areas that make up Area 1, including 13 in Perth and four in Sydney. These licences have the potential to be very costly to relocate, which may make it economically net beneficial to allow the locations of the facilities that house these licences to remain available for FSS earth receive licences in the 3.6 GHz band. This would avoid the high relocation costs of FSS earth receive licences and disruption to important services, but would have the potential to significantly reduce the economic welfare benefits of the 3.6 GHz band being re-farmed for area-wide licensing (that is, potentially available for MBB services) in these particular areas.

This appendix aims to provide detail for the calculations behind the reduction in re-farming benefits that may result from protecting FSS earth receive licence locations. These benefit reductions can then be compared with the incremental costs of displacing FSS earth receive licences, which would be avoided through protection. Determining the magnitude of the benefit reduction compared with the incremental costs avoided will ultimately help determine whether protecting FSS earth receive licence locations is net beneficial (that is, if the re-farming benefits forgone are greater than the incremental costs that have been avoided, then FSS earth receive licence locations should not be protected).

Reduction in re-farming benefits

The ACMA has investigated the potential areas of spectrum denial that would be caused to MBB deployments if FSS earth receive licences remain at their current location. Details of this study are provided at Appendix 5 of the Options paper.

In summary, this study determined the areas and associated population where the deployment of MBB stations would likely be restricted by the need to protect incumbent FSS earth receive licences in Sydney and Perth. Two types of MBB base station deployments where modelled, macro-cells and small cells. These can be considered as the two bookend cases for outdoor base station deployments. While it is acknowledged that a range of other in-between cases exist and that there may be different mitigation techniques that can be employed to facilitate coexistence, in most cases it is expected that the spectrum denial caused will fall somewhere within the range identified for the macro and small cell cases. The use of detailed clutter information may also assist in reducing the size of spectrum denial areas.

The macro-cell case represents the worst-case scenario and has the largest areas of potential spectrum denial. While the macro-cell spectrum denial areas do encompass the Perth and Sydney CBD, a majority of the areas affected are in suburban and outer-metro areas. The study shows that in these areas where macro-cell deployments are restricted, a MBB operator could still make use of large portions of the spectrum by deploying micro-cells, small cells and/or employing other mitigation techniques such increasing antenna down tilt, reducing antenna height or only deploying sectors that point away from the FSS earth receive licence locations. However, such deployments come at a greater cost to achieve similar coverage as a macro-cell and may result in an operator not providing the same coverage as would otherwise be achieved. This is likely to cause a devaluing of the spectrum by prospective licensees.

While creating arrangements so FSS earth receive licences can continue operating from their current locations would prevent some significant incremental costs, it would create restrictions and likely increase the cost of deploying MBB services in the surrounding area. MNOs will therefore be unable to extract producer surplus gains from providing MBB services to large portions of the population of both Perth and Sydney, resulting in an economic net benefit reduction under a TWS.

Small cell basis protection is based on the area required to protect incumbent FSS earth receive licences from low power or 'small cell' MBB base stations based on the results of sharing studies in the Options paper. The same geographic area affected under macro basis protection would also be affected under small cell basis protection and restricted for use for macro base stations. However, part of this area would be available for use for small cell base stations, while there would still be no re-farming of the spectrum for that part of this area where small cell base stations are shown in sharing studies to cause interference to incumbent FSS earth receive licences. Spectrum limited to small cell use is expected to have a lower value to MNOs than if the spectrum was available for macro cell use, as the benefits of 5G are anticipated to largely be realised through macro cell coverage. However, allowing use of small cell base stations will enable some of the potential economic net benefit to be recouped when compared to the macro basis protection case.

To determine the overall reduction in re-farming benefits, the affected populations of Sydney and Perth for each scenario need to be determined. Estimates of each city's affected population under both the macro basis and small cell basis methods have been found using Geocoded National Address File (GNAF) data, which relates to the population in 2011 (as per the 2011 census). Further information can be found in Appendix 5 of the Options paper. The 2011 population figures have been brought forward to the current period by applying the overall population growth rate of 8.81 per cent.

Table 26: Population estimates for Sydney and Perth areas affected by the protection of FSS earth receive licence locations

	Sydney	Perth	Total
Population affected (2011)			
Macro basis	1,980,000	1,890,000	3,870,000
Small cell basis (no use)	50,000	790,000	840,000
Population affected (April 2017)			
Macro basis	2,150,000	2,060,000	4,210,000
Small cell basis (no use)	60,000	860,000	920,000

Note: All population numbers have been rounded to the nearest 10,000, but the 8.81 per cent increases were applied to unrounded numbers.

The calculation of the forgone economic benefits from protecting these areas involves determining the reduction in potential users' spectrum valuations. The calculation method differs depending on whether the macro basis or small cell basis is used.

For the macro basis calculation, the forgone economic benefit is equal to what potential users would have been willing to pay for the spectrum if it was available. This is equal to the affected population for Sydney and/or Perth, multiplied by 125 for the amount of bandwidth that is now unavailable (125 MHz), then multiplied by a uniform $/MHz/pop valuation (a range between $0.03/MHz/pop and $0.625/MHz/pop).

Table 27: Expected forgone benefit for Sydney and Perth within Area 1 boundaries for macro basis protection of FSS earth receive locations

	Sydney	Perth	Total
Affected population	2,150,000	2,060,000	4,210,000
Economic benefit forgone (per $/MHz/pop value)			
$0.03	$8 million	$8 million	$16 million
$0.10	$27 million	$26 million	$53 million
$0.25	$67 million	$64 million	$132 million
$0.50	$134 million	$129 million	$263 million
$0.625	$168 million	$161 million	$329 million

There are two separate parts to the small cell basis calculation—one is quantifiable, while the other is unquantifiable. For the affected population completely unable to access the spectrum for MBB, the same quantifiable method as the calculation for the macro basis can be applied, as the forgone economic benefit is equal to potential users' valuations for the spectrum in these geographic areas.

Spectrum for the rest of the population of the affected area (that is, part of the macro basis population but not part of the small cell basis population) will be restricted to small cell coverage. The forgone economic benefit for this area and its associated population will be equal to the difference between potential users' valuations for unrestricted spectrum and spectrum that is only available for small cell coverage.

The ACMA is not in a position to assess the potential discrepancies in value that potential users may place on limited-use spectrum as opposed to full-use spectrum, particularly as estimates of absolute valuations are already highly uncertain. This difference is therefore not quantifiable and is limited to a qualitative analysis.

While it is not quantifiable, it is likely that the value of spectrum only available for micro and small cell use will be considerably lower than that for unrestricted spectrum. In their submission to the October 2016 discussion paper, VHA made the following comments on the importance of macro cells deployments in particular areas:

> Small cells are only applicable to very specific places with extremely high user geographic density … Given the high prominence of suburban morphologies in MBB data trends, macro sites will continue to play the key role in network capacity and their inherent density limitations call for the use of frequency bands that can reach the most possible number of users.[19]

Macro-cells are generally preferred to provide area-wide coverage since fewer base stations are required. Small cells are generally used to provide additional capacity in hot spots. Micro-cells provide an in-between case and are generally used to provide limited coverage in busy areas. While it is expected each of the aforementioned cases will apply in the 3.6 GHz band, it is clear there is particular interest in using this band as a base 5G coverage layer. The most practical and cost effective way to do this in suburban and regional areas is by deploying macro-cells. Achieving the same coverage via micro and small cell deployments may be impractical and too costly due to the larger number of sites required.

Therefore, restricting the 3.6 GHz band to micro and small cell use will reduce some of the producer surplus benefits of the spectrum. Furthermore, the ability to provide improved services to consumers would be limited when compared with providing

[19] Vodafone Hutchison Australia's submission to the October 2016 discussion paper

macro cell coverage, which would result in a reduction in consumer benefits (affecting producer surplus and consumer surplus) and broader social net benefits.

Table 28: Expected forgone benefit for Sydney and Perth within Area 1 boundaries for small cell basis protection of FSS earth receive locations

	Sydney	Perth	Total
No use—affected areas			
Affected population	60,000	860,000	920,000
Economic benefit forgone per $/MHz/pop value (quantifiable)			
$0.03	$0.2 million	$3 million	$3 million
$0.10	$0.8 million	$11 million	$12 million
$0.25	$2 million	$27 million	$29 million
$0.50	$4 million	$54 million	$58 million
$0.625	$5 million	$67 million	$72 million
Limited use—affected areas			
Affected population	2,090,000	1,200,000	3,290,000
Economic benefit forgone (unquantifiable)			
The reduction in re-farming benefits can range from anywhere between the full willingness to pay for unrestricted spectrum for these populations (that is, if users value small cell use spectrum at zero) and zero (if users placed equal value on small cell use spectrum as they would for unrestricted spectrum). It is likely that the reduction in re-farming benefits would fall somewhere between these two extremes.			

Note: The affected population for limited use areas is equal to the difference between the macro basis affected population and the small cell basis (no use) affected population.

There is likely to be considerable economic benefit forgone from restricting spectrum servicing a relatively large portion of both Perth and Sydney populations to small cell use. However, the economic benefit forgone is expected to be lower than that for the macro basis, as some value could still be extracted from the spectrum through such small cell use, albeit to a smaller magnitude than if the spectrum was unrestricted.

Reduction in incremental costs

The FSS earth receive licences referred to in this section are those located in Perth and Sydney in Area 1. If arrangements are created so FSS earth receive licences continue operating at their current locations, the incremental costs attached to these licences will be equal to zero. The reduction in incremental costs associated with this protection will therefore be equal to the full incremental costs if there is no protection.

In the analysis of FSS earth receive licence incremental costs, the range of potential costs spans from a minimum of $75 million to a maximum of $160 million. This refers to the cost of relocating all C-band licences at each facility in Area 1—Telstra and Optus each have two facilities, while Inmarsat has one facility—to a regional or remote location. There may also be some unquantifiable costs stemming from variable output cases if a licensee or multiple licensees determine that relocating some of their 3.6 GHz band FSS earth receive licences is an unviable business proposition.

Economic net benefit of protecting metropolitan FSS earth receive licence locations

Determining whether protecting FSS earth receive licence locations is economically net beneficial requires comparing the reduction in re-farming benefits with the reduction in incremental costs.

> If the reduction in re-farming benefits is greater than the reduction in incremental costs, FSS earth receive licence locations should not be protected. In this case, the use of the spectrum for other services (for example, MBB) would cause economic welfare under a TWS to increase despite the incremental costs incurred due to the relocation of incumbent FSS earth receive licences.

> If the reduction in re-farming benefits is less than the reduction in incremental costs, FSS earth receive licence locations should be protected. In this case, the incremental costs incurred through displacing FSS earth receive licences would cause economic welfare under a TWS to be lower even after accounting for the economic benefits associated with MBB services.

Table 29: Analysis of re-farming benefits and incremental costs protecting FSS earth receive licence locations in the 3.6 GHz band

		Reduction in re-farming benefits		Reduction in incremental costs
		Macro-cell case	Small cell case	
Quantifiable	Sydney	$8 million–168 million	$0.2 million–5 million	$40 million–100 million
Quantifiable	Perth	$8 million–161 million	$3 million–67 million	$65 million–130 million
Quantifiable	Total	$16 million–329 million	$3 million–72 million	$105 million–230 million
Unquantifiable	Total	Additional consumer surplus and broader social net benefits would be forgone if the band is not re-farmed.	Additional consumer surplus and broader social net benefits would be forgone if the band is not re-farmed. The difference in the value of spectrum with use restricted to small cells versus that of the same spectrum with unrestricted use.	Potentially replacing quantifiable reduction in incremental costs: some facility operators may not see relocation of licences as a viable business plan.

Note: Quantifiable ranges refer to the reduction in re-farming benefits based on $/MHz/pop valuations between a lower bound of $0.03/MHz/pop and an upper bound of $0.625/MHz/pop.

Due to the presence of some unquantifiable benefits and costs, there is no objective answer as to whether FSS earth receive licence locations should be protected from interference. For example, if the actual reduction in re-farming basis was on the lower end of the estimated quanta at $16 million for the macro case, it would be net beneficial to protect FSS earth receive licences in their existing locations. However, if the actual reduction in re-farming basis was on the higher end of the estimated quanta at $263 million for the macro case, it would not be net beneficial to protect FSS earth receive licences in their existing locations at a maximum incremental cost of

$230 million. Determinations may be made easier by separating the two cities from one another, as the characteristics of each city differ.

Furthermore, the quantifiable and unquantifiable benefits and costs are interlinked. In these cases, the presence of unquantifiable costs can lead to a reduction in quantifiable costs and so forth. As such, a subjective view of all of the benefit and cost reductions associated with the available options is required to help determine which solution is most likely to be welfare-maximising. Determinations on the suitability of applying Option 4b in a potential re-farming process are outlined in the 'Net benefit' section of the main analysis.

FSS earth receive licences in regional and remote locations

There may also be a case to protect regional and remote FSS earth receive licence locations—these include Lockheed Martin's Area 3 facility in Uralla and Atwood Oceanics Pacific's remote offshore facility. Protecting these locations will be economically net beneficial if the incremental costs saved by preventing a geographic relocation or shutdown of services are greater than the re-farming benefits lost from spectrum not being available for MBB in these areas.

Lockheed Martin—Area 3 licences

The actual area that would be zoned off and protected for Lockheed Martin's Area 3 licence, along with the potential population affected, is currently unknown. However, it is likely that a coordination zone in the order of 150 km would be planned around Lockheed Martin's Uralla facility in order to provide interference protection which, in the worst case, could restrict the deployment of other services to approximately 100,000 people (though it is likely to be far less than this). The potential for Uralla to be a long-term earth station protection zone is outlined in the 'Example assessment of sites' section in Appendix 5 to the Options paper.

An incremental cost range of between $20 million and $50 million has been applied to Lockheed Martin's facility based on feedback from other stakeholders, desktop research and ACMA staff assumptions. If these costs are conclusively in excess of $20 million, the reduction in re-farming benefits from the spectrum being unable to service the protected area would have to reach over $20 million in order for protection of this licence location to not be viewed as the welfare maximising solution.

In the geographic areas that would be affected by protecting Uralla for FSS earth station facilities, the economic welfare benefits of spectrum re-farming are unlikely to exceed the lower bound cost reduction of $20 million. Economic welfare benefits of $20 million for 125 MHz of bandwidth and a population of 100,000 (that is, a rudimentary estimate of the population of such a protection zone, which would include Armidale and Tamworth) reflect an implied valuation of $1.60/MHz/pop. This is considerably above any estimated upper bound value of the spectrum, making it likely that it would be net beneficial to protect Lockheed Martin's FSS earth receive licences.

Atwood Oceanics Pacific—remote licence

Similar to the Lockheed Martin licence in Uralla, the incremental cost range for the Atwood Oceanics Pacific facility is likely to be in excess of the reduction in re-farming benefits from the spectrum being unable to service the protected area given the low population of this area.

Appendix B: Highest value use of the 5.6 GHz band

Introduction

The 5600–5650 MHz band is currently used by Bureau of Meteorology (BoM) weather radars. Due to technology developments, the ACMA is reviewing the band under the expectation that it could also be used by wireless broadband services (such as WiFi) under either site-based apparatus licensing or class licensing arrangements.

As with to the 3.6 GHz band, the highest value use of the 5.6 GHz band can be analysed by comparing whether the incremental benefits of a new service exceed the incremental costs of displacing the incumbent service. In this case, the respective incremental benefits of class-licensed versus apparatus licensed use need to be compared. Use of the band by wireless broadband services would be on a ‘no interference basis’—thus there will be no incremental costs relating to the displacement of existing BoM radars.

Demand for 5.6 GHz

The 5600–5650 GHz band is being slated for allocation for class-licensed use, and is used elsewhere by Wi-Fi and LTE-U/LAA (LTE in unlicensed bands) technologies. This technology can be used in the same spectrum as weather radars when a mechanism known as ‘dynamic frequency selection’ is implemented.

The availability of spectrum suitable for Wi-Fi (and LTE-U/LAA) is of great interest to policymakers worldwide. WRC-15 Agenda Item 1.16 is looking at identifying more spectrum for these uses. Wi-Fi Alliance provided a submission to the ACMA’s Five-year spectrum outlook on the issue of spectrum access in the 5.6 GHz band for class licensing:[20]

> Deployment of wide channel bandwidths with higher data rates in the 5 GHz band can help meet the challenges posed by the rapidly growing number of applications that use class-licensed spectrum. Further, the International Table of Allocations contains, in all regions, a mobile allocation in the 5470-5725 MHz and 5850-5925 MHz bands, which includes the 5470-5630 MHz band in which class-licensed operations are not permitted in Australia. At a minimum, the ACMA should permit class-licensed operations in those bands, which would add an additional 255 megahertz and 75 megahertz of contiguous spectrum to class-licensed use, respectively. Expanded use of the 5 GHz band is consistent with actions already taken in the U.S. and work being done in the United Kingdom and in India.

However, the ACMA considers that the 5.6 GHz band to be a reasonable substitute for 3.6 GHz point-to-multipoint licences, due to the availability of hardware suitable for the deployment of wireless broadband services. It may also be possible to coordinate point-to-multipoint licences in the same spectrum as weather radars in order to manage interference.

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[20] See Wi-Fi Alliance’s submission to the ACMA’s Five-year spectrum outlook, p. 4.

As outlined in the main document, there are two types of potential benefits that result from the re-farming of spectrum:

1. Additional revenues or lowering costs for producers providing new services using the re-farmed spectrum (that is, an increase producer surplus).
2. Reduction in price of services, or new or increased quality of services being rolled out (that is, an increase in consumer surplus).[21]

There are also two types of potential costs that result from the re-farming of spectrum:

1. An increase in costs for incumbent providers (that is, a reduction in producer surplus).
2. An increase in the prices of services provided by incumbent spectrum users, or a degradation in quality of services (that is, a reduction in consumer surplus).[22]

Benefit comparison

Class-licensed use of 5.6 GHz

Class licensing is used by the ACMA to manage spectrum used by services which employ a limited set of common frequencies using equipment under a common set of conditions. One of the most widely used technologies that employ class-licensed spectrum is WiFi.

Due to its commons use, the incremental benefits of allocations of class-licensed use of spectrum are not represented in the same framework (outlined above) as those associated with licensed use (outlined above). The incremental value of additional spectrum allocated to class-licensed use is the value attached to the reduction in the risk of congestion that the additional spectrum will provide. If a class-licensed band becomes congested, users of class-licensed devices will experience a reduction in the quality of services resulting from interference. In effect, additional increments of class-licensed spectrum mitigate the risk of this reduction in quality.

In addition, it is argued that class-licensed spectrum facilitates new and innovative technology and business models.[23] As such, it is possible that additional increments of class-licensed spectrum will enable additional benefits in innovation. However, given that this portion of spectrum is a relatively minor allocation of class-licensed spectrum overall, the ACMA considers that this benefit will be negligible in the context of the 5.6 GHz band.

While potentially significant in quantum, it is not feasible to quantify the benefits associated with allocating additional increments of spectrum for class-licensed use such as WiFi and LTE-U/LAA. There has been no research conducted on the extent of congestion in WiFi bands in Australia, nor has there been any research into the extent to which an additional allocation of class-licensed spectrum would reduce any forecast congestion, and what this reduction in congestion is worth.

It is possible to say that demand for WiFi could be very strong. According to Cisco, fixed/WiFi was 55.2 per cent of total internet traffic in 2015, and will be 59.1 per cent of

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[21] It should be noted that a reduction in price might be captured in lower costs. The interaction between these elements will be considered if required.

[22] It should be noted that an increase in price might be the result of increasing costs. The interaction between these elements will be considered if required.

[23] See, for example, *Licensed or unlicensed: The economic considerations in incremental spectrum allocations*

total internet traffic in 2020.[24] These projections combined with the projected growth in overall traffic (predicted by Cisco to increase three-fold between 2015 and 2020 globally) suggest significantly increased demand for WiFi. Given the limited availability of class-licensed spectrum it is not possible to say definitively whether there is widespread congestion in the relevant bands.

However, based on submissions from WISPs to the October 2016 discussion paper, as well as other anecdotal evidence provided to the ACMA, wireless broadband providers are increasingly seeking access to apparatus-licensed spectrum. This is because it is possible to deliver a carrier-grade service in an interference-managed environment. While class-licensed spectrum is seen as a valuable resource for wireless broadband services, the uncontrolled interference environment means it is difficult (or impossible) for an operator to guarantee quality service.

Site-based apparatus licence arrangements in the 5.6 GHz band

It is possible for site-based apparatus licence arrangements to be implemented in the 5.6 GHz band. These arrangements could be implemented to support the relocation of incumbent point-to-multipoint licences in the 3.6 GHz band as well as supporting new services.

The 5.6 GHz band is considered a reasonable substitute for 3.6 GHz band spectrum, due to the availability of hardware suitable for the deployment of wireless broadband services. As outlined in the *Incremental costs* section of this paper, there were 413 point-to-multipoint licences in the 3.6 GHz band as at 1 May 2017, including 174 licences held by WISPs. If point-to-multipoint licensees lose access to the 3.6 GHz band, they may either discontinue operations or find another spectrum band. If point-to-multipoint licensees—particularly WISPs as these licences are a more direct input into their services—cannot obtain alternative spectrum, they are likely to represent ‘variable output cases’.

As such, the incremental benefit of enabling 5.6 GHz be used for site-based apparatus licences supporting wireless broadband services is that a larger portion of 3.6 GHz point-to-multipoint licensees will be able to continue providing their services. In effect, this benefit is the prevention of a loss in consumer welfare that would occur if these licensees weren’t able to offer their services. This loss in consumer welfare is the difference in economic welfare consumers derive from the existing service compared with the substitute service. For example, in the absence of WISP services, consumers may only be able to access internet services from satellite providers (that is, NBN).

However, it should be noted that in order for consumers to be able to derive the discussed benefits associated with the availability of existing services, 3.6 GHz point-to-multipoint licensees will need to incur costs associated with infrastructure upgrades. These costs are detailed in the *Point-to-multipoint licences* section of the main report.

[24] www.cisco.com/c/m/en_us/solutions/service-provider/vni-forecast-highlights.html

Table 30: Summary of incremental costs for the relocation of 3.6 GHz point-to-multipoint licences to the 5.6 GHz band

		Area 1	Area 2	Area 3	Australia-wide
Quantifiable costs	**Point-to-multipoint licences**	0	122	293	413
	Total cost	$0	$27 million	$59 million	$74 million
Unquantifiable costs	Some licences may require new towers to be constructed to continue providing a similar service. This will cost an estimated $365,000 per site. However, the total cost across all incumbent WISP licences is unclear, as the extent to which new towers will be required is also unclear. Some incumbent licensees may discontinue service. The incremental costs will be the difference in economic welfare between the existing WISP service and the substitute internet service that customers use.				

Note: The total cost is calculated by applying equipment replacement costs of $270,000 to each licence held by a WISP licensee and $112,500 to each licence held by a non-WISP licensee.

It is not feasible to estimate the quantum of the prevention of a loss in consumer welfare. Generally, without undertaking complex research that is subject to some uncertainty, changes in consumer surplus such as these are not amenable to quantification. However, one key indicator of the materiality of this prevention of a loss in consumer welfare is understanding the extent to which WISP consumers consider alternatives to be of lower quality.

Incremental costs

The 5600–5650 GHz band is currently used by BoM weather radars. BoM weather radars generally fulfil a crucial safety-of-life role, and also provide timely information to the Australian people and industry on weather developments. Interference with current radar deployments may reduce the quality of the services deployed through use of the 5.6 GHz band.

It is not feasible to quantify any potential incremental reduction in the value of services that may result from introduction of new services into the band. Indeed, the ACMA notes the importance and general value of weather radars, and aims to only introduce new services if they do not result in a degradation in BoM services. The implication is that the incremental value of these radars is greater than that of competing services, as the benefits provided by radars and costs of interference may be sufficiently high as to outweigh the potential economic benefits of a competing service.

The ACMA understands that due to developments in technology, it is possible to deploy WiFi in this band using radar detection and avoidance capability. Where this technology is deployed, it is understood that incumbent services will not be affected. As a result, the ACMA understands that the potential costs that result from the sharing of this spectrum are likely to be negligible.

It is also possible to create site-based apparatus licence arrangements for wireless broadband services in the 5.6 GHz band that would be required to coordinate with BoM radars. This would ensure existing BoM radars could continue operating in the band with negligible costs resulting from the sharing of this spectrum.

It is possible that the introduction of site-based apparatus licence arrangements into the 5600–5650 GHz band may limit future weather radar deployments in this band. However, the arrangements proposed by the ACMA, as described in the Options paper, are intended to reduce the likelihood of this occurring.

In addition, if the 5.6 GHz band is made available for the site-based apparatus licensing of wireless broadband services, licensees may seek a level of certainty regarding the minimum amount of time these arrangements would remain in place. Under the Act, the ACMA is not able to provide such certainty but may issue policy statements around the minimum amount of time these arrangements are intended to remain in place. This would help point-to-multipoint licensees in making investment decisions in their network infrastructure. Such a representation might make it more difficult for the ACMA's ability to re-farm this spectrum during that period, which may be problematic in the event that there is strong demand from another spectrum user.

Conclusion

Due to the lack of data points informing the relative sizes of costs and benefits, it is not possible to say conclusively which use is the highest value use at this point in time. In essence, it is a comparison between the values associated with the following:

> The incremental reduction in the risk of WiFi congestion associated with allocating additional class-licensed spectrum.

> Reducing the incremental costs of displacing point-to-multipoint licensees from the 3.6 GHz band, such as the additional value of consumers of WISPs retaining access to fixed wireless broadband services, rather than a substitute that they consider of lower value. There is also the additional value derived from new potential point-to-multipoint services.

This band will only be made available to alternative uses should they not impose risk of undue interference on the BoM weather radars.