Assesment the economic value of

6 GHz spectrum band in Australia

August 2024

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TELECOM ADVISORY SERVICES
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This study was commissioned by the Dynamic Spectrum Alliance and was conducted between July and August of 2024; the authors are solely responsible for its contents.

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EXECUTIVE SUMMARY

In 2021, the Australian Communications and Media Authority (ACMA) decided to allow the use of radio local area networks (RLANs) in the lower part of the 6 GHz band (5625-6425). In addition, on June 4, 2024, ACMA opened a consultation on planning options to introduce radio local area networks (RLANs) and/or wide-area broadband (WBB) services into the upper 6 GHz band (6425-7125). In particular, ACMA requested industry views on the services proposed to be delivered using the upper 6 GHz band, how the proposed services will benefit users, and their expected demand.

In this context, the purpose of this study is to provide an assessment of the economic value of the 6 GHz band according to two alternatives. The first alternative estimates the value of opening the entire 6 GHz band for RLANs[1]. While the ongoing consultation by ACMA is focused only on the upper part of the 6 GHz band, this assessment considers two economic value areas: (i) the contribution of unlicensed spectrum in the 2.4 and 5 GHz bands (the "baseline" estimate), and (ii) the value of allocating the entire 1200 MHz of the 6 GHz band for RLANs use. The second analysis estimates the economic value if the 6 GHz band were to be split between Wi-Fi and International Mobile Telecommunication (IMT), allocating the lower 500 MHz of the 6 GHz band to RLANs, as is currently the case, and the upper 700 MHz of the band for use by telecommunication service providers. In other words, this alternative represents the option of maintaining the existing arrangement of allocating the upper part of the band to IMT service providers. In comparison with the first alternative, this option values: (i) the contribution of unlicensed spectrum in the 2.4 and 5 GHz bands (the "baseline"), and (ii) the value of allocating 500 MHz of the 6 GHz band for RLANs use. In addition, to allow an "apples to apples" comparison, this analysis includes an assessment of the value to be captured through an auction of the upper part of the 6 GHz band to be used in 5G and 6G.

The methodology used to develop estimates for the two alternatives is similar to the one used in prior studies conducted by the authors, whereby the different sources of economic value were estimated independently and then aggregated within a single value (this allows cumulating GDP impact, with consumer and producer surplus[2]) (see table A).

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[1] In February 2021, the authors of this study published a global study developed for the Wi-Fi Alliance estimating the economic value of Wi-Fi both to consumers and producers and predicting Wi-Fi's direct contribution to Gross Domestic Product (GDP) between 2021 and 2025 ("the 2021 Report"). The report included Australia as one of the in-depth country analyses. In the years since 2021, demand, technology development and use of Wi-Fi and its ecosystem of devices and service offerings have exploded. This report seeks to update the economic value set forth in the 2021 Report to reflect that significant growth and impact. Building on the results of the 2021 Report, the current study estimates Wi-Fi's economic value between 2024 and 2034.

[2] We consider that combining GDP effect and producer surplus on equipment sales is reasonable given that the impact on GDP is fundamentally attributed in our models based on historical data to speed increase and not to produce surplus driven by equipment sales triggered by new unlicensed spectrum allocation. On the other hand, CAPEX savings incurred by wireless carriers incurred by offloading traffic to Wi-Fi has been occurring for a while and could also be included in the GDP model estimates.

Table A. Sources of economic value of Wi-Fi to be assessed

Source	Effects	Consumer Surplus	Producer surplus	GDP contribution
1. Free Wi-Fi	1.1. Savings incurred by consumers by accessing free Wi-Fi in public sites	X		
	1.2. Free Wi-Fi service supporting the needs of the broadband unserved population			X
	1.3. Benefit to consumers enjoying higher speed from free Wi-Fi under Wi-Fi 6E, and Wi-Fi 7	X		
	1.4. Benefit to consumers relying on Wi-Fi in educational institutions	X		
	1.5. Use of Wi-Fi in highly dense heterogeneous environments	X		
2. Residential Wi-Fi	2.1. Home internet access for devices that lack an Ethernet port	X		
	2.2. Avoidance of inside wiring investment	X		
	2.3. Consumer benefit derived from faster broadband speed	X		
	2.4. Consumer benefit generated by use of residential Wi-Fi devices and equipment	X		
	2.5. Bridging the digital divide: use of Wi-Fi to increase coverage in rural and isolated areas			X
3. Enterprise Wi-Fi	3.1. Savings in business Internet traffic transmitted through Wi-Fi		X	
	3.2. Avoidance of enterprise building inside wiring		X	
	3.3. Benefits derived from an increase in average speed			X
	3.4. Benefits derived from reduced latency			X
	3.5. Enhanced IoT deployment			X
	3.6. Deployment of Augmented Reality/Virtual Reality solutions			X
4. ISPs	4.1. Cellular networks CAPEX savings by off-loading traffic to Wi-Fi		X	
	4.2. Revenues of Wi-Fi based Public Internet Service Providers			X
	4.3. Revenues of Wi-Fi based Wireless Internet service Providers			X
5. Wi-Fi ecosystem	5.1. Manufacturing of Wi-Fi devices and equipment for residential use		X	
	5.2. Manufacturing of enterprise Wi-Fi devices and equipment		X	
	5.3. Benefits of Firms in the IoT ecosystem		X	
	5.4. Benefits of firms in the AR/VR ecosystem		X	

Source: Telecom Advisory Services analysis

The economic contribution of each of the two alternatives for Australia is presented below.

Economic value of allocating the full 6 GHz band for RLANs

The cumulative economic value between 2024 and 2034 for the first alternative (baseline scenario plus allocating the full 6 GHz band for unlicensed use) amounts to US$ 1,685.9 billion[3], comprising US$ 1,219.2 billion in GDP contribution, US$ 189.1 billion in producer surplus and US$ 277.6 billion in consumer surplus (see table B).

[3] All value estimates and calculations in this report are presented in United States dollars.

Table B. Australia: Economic value of Wi-Fi in case of full allocation of 6 GHz band for RLANs (2024-2034) (in US$ millions)

Source	Effects	Consumer Surplus	Producer surplus	GDP contribution
1. Free Wi-Fi	1.1. Savings incurred by consumers by accessing free Wi-Fi in public sites	$ 3,373		
	1.2. Free Wi-Fi service supporting the needs of the broadband unserved population			$ 201,741
	1.3. Benefit to consumers enjoying higher speed from free Wi-Fi under Wi-Fi 6E, and Wi-Fi 7	$ 949		
	1.4. Benefit to consumers relying on Wi-Fi in educational institutions	$ 1,901		
	1.5. Use of Wi-Fi in highly dense heterogeneous environments	$ 31		
2. Residential Wi-Fi	2.1. Home internet access for devices that lack an Ethernet port	$ 214,791		
	2.2. Avoidance of inside wiring investment	$ 999		
	2.3. Consumer benefit derived from faster broadband speed	$ 6,903		
	2.4. Consumer benefit generated by use of residential Wi-Fi devices and equipment	$ 48,698		
	2.5. Bridging the digital divide: use of Wi-Fi to increase coverage in rural and isolated areas			$ 340,440
3. Enterprise Wi-Fi	3.1. Savings in business Internet traffic transmitted through Wi-Fi		$ 119,982	
	3.2. Avoidance of enterprise building inside wiring		$ 2,594	
	3.3. Benefits derived from an increase in average speed			$ 192,673
	3.4. Benefits derived from reduced latency			$ 332,253
	3.5. Enhanced IoT deployment			$ 126,265
	3.6. Deployment of Augmented Reality/Virtual Reality solutions			$ 13,974
4. ISPs	4.1. Cellular networks CAPEX savings by off-loading traffic to Wi-Fi		$ 1,610	
	4.2. Revenues of Wi-Fi based Public Internet Service Providers			$ 267
	4.3. Revenues of Wi-Fi based Wireless Internet service Providers			$ 11,558
5. Wi-Fi ecosystem	5.1. Manufacturing of Wi-Fi devices and equipment for residential use		$ 6,083	
	5.2. Manufacturing of enterprise Wi-Fi devices and equipment		$ 0	
	5.3. Benefits of Firms in the IoT ecosystem		$ 53,473	
	5.4. Benefits of firms in the AR/VR ecosystem		$ 5,329	
TOTAL (in US$ billion)		$ 277.6	$ 189.1	$ 1,219.2

Source: Telecom Advisory Services analysis

Economic value of Wi-Fi if the lower 500 MHz is allocated for RLANs and the upper 700 MHz for use by IMT

The allocation of only 500 MHz rather than 1200 MHz of the 6 GHz band has significant implications on RLAN performance and, consequently, its economic value. As an example:

- The total number of devices that a Wi-Fi hotspot site can support simultaneously depends on the allocated bandwidth, the usage and traffic demand profile of the average user and the simultaneity factor which depends on the number of devices connected at the same time. Considering wireless internet usage statistics for Australia, the number of users that can be handled by a free hotspot under 500 MHz frequency allocation will be reduced by 41.18% relative to 1200 MHz.[4]
- Within a residential use, if the frequencies allocated for unlicensed use in the 6 GHz band are reduced from 1200 MHz to 500 MHz, this has an impact on the number of resource units assigned for transmission, and consequently the maximum speed at the device level. We estimate the reduction of speed at the device to be of 50%.
- The increase in subscribers that can be handled by Wireless ISPs relying on RLAN technology depends on the number of outdoor channels. Considering that a 500 MHz alternative supports 25 20 MHz channels, compared to 42 under the full 6 GHz band, the maximum number of users with 242 Resource Units decreases by 40.48%.
- An allocation of 500 MHz of the 6 GHz band rather than 1200 MHz would decrease the number of IoT sensors that can be connected by 58.33%.
- A simulation of AR/VR use in a school setting indicates that when considering a 1200 MHz allocation of the 6 GHz band, RLANs can support 22 headsets; the number of headsets diminishes to 4 if only 500 MHz spectrum is allocated in the same band. The reduction in the number of handsets under 500 MHz is also confirmed by a degradation of latency, as indicated in a health care trial currently taking place in Thailand.

The effects discussed above, and other ones analyzed in this study have a significant effect on RLAN economic value under 500 MHz allocation. The cumulative economic value of the second alternative (baseline scenario plus allocating 500 MHz for unlicensed use) for the 2024-2034 period amounts to US$ 1,391.7 billion, composed of US$ 963.4 billion in GDP contribution, US$ 155.4 billion in producer surplus and US$ 272.9 billion in consumer surplus (see table C).

[4] All engineering calculations are presented in Appendices B and C.

Table C. Australia: Economic value of Wi-Fi in case of allocating 500 MHz for RLANs (2024-2034) (in US$ millions)

Source	Effects	Consumer Surplus	Producer surplus	GDP contribution
1. Free Wi-Fi	1.1. Savings incurred by consumers by accessing free Wi-Fi in public sites	$ 3,373		
	1.2. Free Wi-Fi service supporting the needs of the broadband unserved population			$ 164,516
	1.3. Benefit to consumers enjoying higher speed from free Wi-Fi under Wi-Fi 6E, and Wi-Fi 7	$ 558		
	1.4. Benefit to consumers relying on Wi-Fi in educational institutions	$ 1,901		
	1.5. Use of Wi-Fi in highly dense heterogeneous environments	$ 31		
2. Residential Wi-Fi	2.1. Home internet access for devices that lack an Ethernet port	$ 214,791		
	2.2. Avoidance of inside wiring investment	$ 999		
	2.3. Consumer benefit derived from faster broadband speed	$ 4,295		
	2.4. Consumer benefit generated by use of residential Wi-Fi devices and equipment	$ 46,924		
	2.5. Bridging the digital divide: use of Wi-Fi to increase coverage in rural and isolated areas			$ 320,842
3. Enterprise Wi-Fi	3.1. Savings in business Internet traffic transmitted through Wi-Fi		$ 118,877	
	3.2. Avoidance of enterprise building inside wiring		$ 2,594	
	3.3. Benefits derived from an increase in average speed			$ 102,081
	3.4. Benefits derived from reduced latency			$ 297,761
	3.5. Enhanced IoT deployment			$ 61,916
	3.6. Deployment of Augmented Reality/Virtual Reality solutions			$ 4,847
4. ISPs	4.1. Cellular networks CAPEX savings by off-loading traffic to Wi-Fi		$ 292	
	4.2. Revenues of Wi-Fi based Public Internet Service Providers			$ 225
	4.3. Revenues of Wi-Fi based Wireless Internet service Providers			$ 11,210
5. Wi-Fi ecosystem	5.1. Manufacturing of Wi-Fi devices and equipment for residential use		$ 5,730	
	5.2. Manufacturing of enterprise Wi-Fi devices and equipment		$ 0	
	5.3. Benefits of Firms in the IoT ecosystem		$ 25,530	
	5.4. Benefits of firms in the AR/VR ecosystem		$ 2,383	
TOTAL (in US$ billion)		$ 272.9	$ 155.4	$ 963.4

Source: Telecom Advisory Services analysis

The decrease in economic value from the first alternative (amounting to US$ 294.2 billion) is due to the following effects:

- 40.48% of Wi-Fi outdoor accessibility provided by WISPs is limited due to their restricted access in the 6GHz band.
- Wi-Fi indoor speed is restricted by 50%, which means that residential broadband access undergoes a bottleneck for lines in excess of 600 Mbps.
- Under a constant speed assumption, latency would increase under frequency allocation scenarios: in other words, the 500 MHz alternative would result in 40% less reduction of latency relative to the 1200 MHz option.
- More than half of IoT devices undergoes a limit in their indoor and outdoor access.
- 81.82% of the AR/VR devices supported in indoor environments is restricted by limits in terms of their ability to operate.

Part of the negative economic impact of limiting access of the 6 GHz band for RLANs is mitigated by the benefits resulting from allocating 700 MHz to be auctioned for use by IMT. Revenues to be collected amount to US$ 77.6 billion.

- The GSMA estimates that the allocation of mid bands to IMT in East Asia and Pacific would generate a GDP contribution of US$ 218 billion in 2030, from where U$S 12 billion can be interpolated for Australia.[5] Prorating this value to the 700 MHz in the 6 GHz band yields a total GDP contribution between 2024 and 2034 of US$ 33.7 billion.
- Additionally, by gaining access to 700 MHz, wireless service providers could generate US$ 19.6 in producer surplus (primarily driven by IoT and AR/VR deployment) and US$ 19.2 billion in consumer surplus.
- Finally, it is estimated that auction proceeds for 700 MHz in the 6 GHz band could generate US$ 5.2 billion.

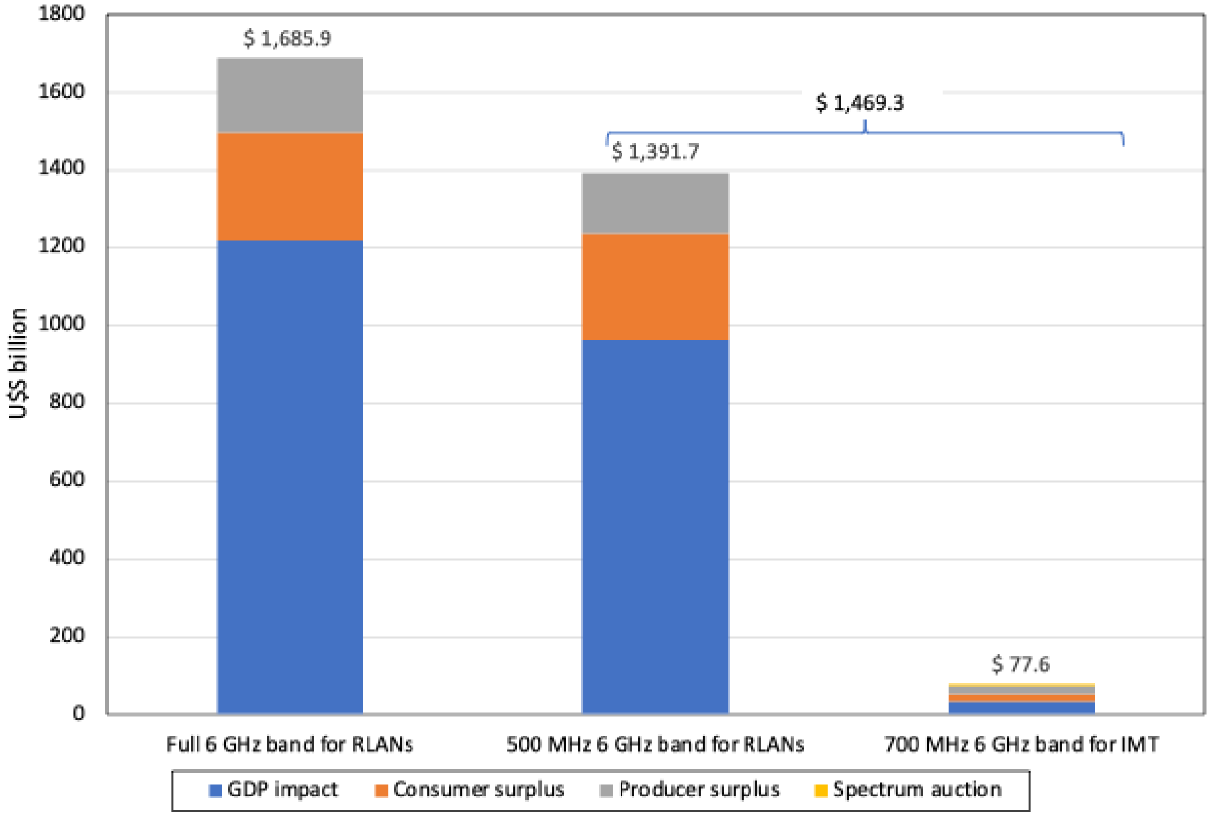
Considering the economic value associated with the 6 GHz band only (excluding the "baseline" value), the total economic benefits between 2024 and 2034 of allocating the lower 500 MHz for unlicensed use and the upper 700 MHz band for use by IMT is US$ 604.2 billion, of which US$ 526.6 billion is generated by the spectrum received for unlicensed use and US$ 77.6 billion would be generated by IMT.

Conclusion and implications

A comparison of the two regulatory alternatives indicates that the highest economic impact is associated with the full allocation of the 6 GHz band for use by RLANs (see Graphic A).

[5] Source: GSMA, "The Socio-Economic Benefits of Mid-Band 5G Services" (February 2022)

Graphic A. Comparative economic value of RLANs under the two regulatory alternatives (*)



(*) Options include the economic value of RLAN generated by the 2.4 GHz and 5 GHz bands
Source: Telecom Advisory Services analysis

As indicated in graphic A, the full allocation to RLANs is US$ 216.6 billion than the second alternative. This advantage occurs, even considering revenues collected from spectrum auctions, and without contemplating the costs to IMT generated by spectrum refarming. In summary, the allocation of the 1200 MHz of the 6 GHz will generate the highest economic value for Australia, which becomes the most attractive alternative of the two under consideration.

1. INTRODUCTION

In 2021, the Australian Communications and Media Authority (ACMA) decided to allow the use of radio local area networks (RLANs) in the lower part of the 6 GHz band (5625-6425). Furthermore, on June 4, 2024, ACMA opened a consultation on planning options to introduce radio local area networks (RLANs) and/or wide-area broadband (WBB) services into the upper 6 GHz band (6425-7125). In particular, ACMA requested industry views on the services proposed to be delivered using the upper 6 GHz band, how the proposed services will benefit users, and their expected demand.

In this context, the purpose of this study is to provide an assessment of the economic value of the 6 GHz band. The study focuses on the estimation of two alternatives:

- An assessment of the value of opening the entire 6 GHz band for RLANs[6]. While the ongoing consultation is focused only on the upper part of the 6 GHz band, this assessment considers two economic value areas: (i) the contribution of unlicensed spectrum in the 2.4 and 5 GHz bands (the "baseline"), and (ii) the value of allocating the entire 1200 MHz of the 6 GHz band for RLANs use.
- An estimation of the economic value if the 6 GHz band were to be split between Wi-Fi and International Mobile Telecommunication (IMT), allocating the lower 500 MHz for RLANs, as is currently the case, and the upper 700 MHz band for use by telecommunication service providers. In other words, this alternative represents the option of maintaining the existing arrangement of allocating the upper part of the band to IMT service providers. In comparison with the first alternative, this option values: (i) the contribution of unlicensed spectrum in the 2.4 and 5 GHz bands (the "baseline"), and (ii) the value of allocating 500 MHz of the 6 GHz band for RLANs use. In addition, to allow an "apples to apples" comparison, this option includes an assessment of the value to be captured through an auction of the upper part of the 6 GHz band to be used in 5G and 6G.

The time horizon for quantifying economic value of the three alternatives is 2024-2034. At the aggregate level, the methodology relied upon in this study is exactly the same as the one used in our prior study, whereby the different sources of economic value are estimated independently and then aggregated within a single value (this allows cumulating GDP impact, with consumer and producer surplus).

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[6] In February 2021, the authors of this study published a global study estimating the economic value of Wi-Fi[6] in order to measure its value, both to consumers and producers[6], and to predict Wi-Fi's direct contribution to Gross Domestic Product (GDP) between 2021 and 2025 ("the 2021 Report"). The report included Australia as one of the in-depth country analyses. In the years since 2021, demand, technology development and use of Wi-Fi and its ecosystem of devices and service offerings have exploded. This report seeks to update the economic value set forth in the 2021 Report to reflect that significant growth and impact. Building on the results of the 2021 Report, the current study estimates Wi-Fi's economic value between 2024 and 2034.

Chapter 2 presents the theoretical framework to be used in the assessment of the three allocation alternatives described above. Chapter 3 details changes that have taken place since 2021 in the Australian wireless and broadband sectors that have an impact on the assessment of economic value of the 6 GHz band. Chapter 4 estimates the economic benefits of allocating the 1,200 MHz for its use by RLANs. Chapter 5 shifts the focus to the economic implications of dedicating the lower 500 MHz of the band to RLANs use, reiterating similar benefits as discussed in Chapter 4 but within the context of this narrower allocation. In addition, it quantifies the economic value of allocating the upper 700 MHz to the IMT players. Finally, Chapter 6 concludes by summarizing the total economic value generated by the two 6 GHz allocation alternatives and drawing the policy implications.

2. STUDY THEORETICAL FRAMEWORK AND METHODOLOGIES FOR ESTIMATING THE ECONOMIC VALUE OF THE 6 GHz BAND

The allocation of the 6 GHz band for unlicensed use by Radio Local Area Network (RLAN) devices yields economic value by complementing wireline and cellular wideband technologies, thereby enabling the development of products and services that enlarge consumer choice, support the creation of innovative business models, and expand access to communications. The following chapter begins by defining the intrinsic value of the unlicensed use of the 6 GHz band, both as a complementary to the telecommunications ecosystem, by enhancing the performance of networks, and providing a platform for developing innovative applications. Following this, we put forward the concept of economic value, calculated as gains to consumer and producer surplus, and a contribution to GDP. Having formalized these sources of value, we then move to categorize the five economic agents that benefit from them: (i) individual consumers benefitting from access to free Wi-Fi service, (ii) individual consumer residences, (iii) enterprises, (iv) Internet Service Providers, and (v) manufacturers of communications equipment and consumer electronics. This categorization provides the framework for defining spectrum allocation assumptions and methodologies to assessing different alternatives.

2.1. The intrinsic value of unlicensed spectrum

Considered as a factor of production, a complementary technology is a resource that, due to its intrinsic strengths, compensates for the limitations of another resource. Complementarity has been initially studied as the interdependencies supporting the stimulation of demand of capital goods. This effect operates in the technology sector at two levels: (i) a given technology enables the production of another one by lowering manufacturing and distribution costs (Dosi et al., 1990; Schmookler, 1966), and/or (ii) one technology addresses bottlenecks in the diffusion and adoption of a second one (Rosenberg, 1976). The first level focusses on reducing the cost of intermediate inputs, while the second one addresses user needs.

The study of technology interdependencies has been extended to address the complementarity within value chains (Mäkitie et al., 2022). The authors analyze three mechanisms by which complementarity emerges: (i) **synchronization**, which depicts "the simultaneous and mutually supporting development between the input and user sectors in a technology value chain"; (ii) **amplification**, where a technology accelerates the adoption of another one; and (iii) **integration,** whereby technological advances in one sector spill in accelerating the development and adoption of technology in another one. In particular, the principle of "amplification" is defined as follows:

> *"Diffusion of a novel technology in a user sector creates demand for products and services in the input sectors of the [technology value chain], making it imperative that input sectors are scalable enough to ensure a balance between supply and demand. Thus, economies of scale may emerge, driving further development and deployment in the user sector*

due to reduced costs, network effects, and increased availability of necessary services and products." (p.9)

The complementarity between devices and technologies, relying on unlicensed spectrum and wideband networks, appears to be a clear example of amplification. Each technology was developed independently, although their combination acts as a multiplier of demand and impact. For example, RLAN can enhance the effectiveness of devices, such as smartphones, which typically rely on licensed spectrum. RLAN access points can enhance the value of cellular networks by allowing wireless devices to switch to Wi-Fi hotspots, thereby relieving the burden on the mobile wireless network, - reducing the cost of broadband access and increasing the access speed rate. Consumers accessing the Internet within the reach of a Wi-Fi access point can also reduce their access costs by turning off their cellular service. They can also gain additional access speed as the transfer data rate of RLAN sites is generally faster than that offered by current cellular technology.[7] Likewise, many wireless operators reduce their capital spending by complementing their cellular networks with carrier-grade Wi-Fi access points, which are considerably less expensive than cellular network equipment with similar capacity.[8] In addition to reducing capital expenditures, wireless carriers can offer fast access to service without a base station congestion challenge.

Furthermore, Wi-Fi can provide the required environment to enable the development and introduction of innovations such as RLAN-enabled communications devices, wireless security systems and household appliances, thereby providing consumers with a larger set of choices. By limiting transmission power and relying on spectrum with low propagation, RLAN avoids interference, rendering irrelevant any barriers to innovation caused by the need to use licensed spectrum. In fact, some of the most important technological innovations in communications are intimately linked to Wi-Fi for gaining access. Numerous products and services, such as the multi-AP/mesh networking systems and smart speakers launched in the past were developed leveraging Wi-Fi. By providing consumers with service choices in addition to those offered through cellular services, RLAN also supports the development of innovative business models. Firms developing new applications that rely on Wi-Fi do not need approval from cellular operators, do not incur time-to-market penalties, and do not face financial disincentives derived from costly revenue splits with cellular service providers.

In addition to innovative applications, technologies relying on unlicensed spectrum used by RLAN technology can help address the digital divide in broadband coverage. A portion of the population that has not adopted broadband access is located in rural and isolated areas. Many of them can gain access to the Internet through free Wi-Fi service offered by anchor

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[7] For example, at the end of 2023 the average mobile connection speed in the United States is estimated by Ookla at 208 Mbps while the average Wi-Fi speed is 289 Mbps (Source: data extracted from Ookla Speedtest.net).

[8] The CAPEX savings resulting from Wi-Fi offloading for a cellular carrier in 1.5 million population cities is approximately 30 percent (Source: LCC Wireless). See also Spirent. *Wi-Fi Offload: Is your gateway ready?* Retrieved in: https://assets.ctfassets.net/wcxs9ap8i19s/0CmCW0buQpAINDJKN2z9NJ/b860733ac8cc6b724a55080b89f1cc60/WiFi_Offload_Whitepaper.pdf; ENEA. The drivers for Wi-Fi offloading. Retrieved in: https://www.enea.com/insights/the-drivers-for-wifi-offloading/

public institutions such as libraries, municipalities or supplied for a fee by Wireless Internet Service Providers (WISPs), which typically provide end-connectivity to consumer devices through Wi-Fi.

2.2. The derived value of unlicensed spectrum

There is a significant amount of research-based evidence demonstrating that unlicensed spectrum technology has very high social and economic value. At a highest level, contrary to licensed bands where economic value can equate to whatever is paid at auction, the economic value of unlicensed spectrum, such as Wi-Fi, needs to be measured based on the concept of economic surplus.[9]

The concept of economic surplus is based on the difference between the value of units consumed and produced up to the equilibrium price and quantity, allowing for the estimation of consumer surplus and producer surplus.[10] Consumer surplus measures the total amount consumers would be willing to pay to have the service, compared to what they actually pay. Producer surplus measures the analogous quantity for producers, which is essentially the economic profit they earn from providing the service. Consumer and producer surplus together yield an economic surplus. Adding GDP contribution results in a total economic value estimate.

Consistent with the concept presented above, this study measures the economic value of the 6 GHz band by focusing first on the economic surplus generated after its adoption.[11] The underlying assumption is that unlicensed spectrum technologies such as Wi-Fi generate a shift both in the demand and supply curves, resulting from changes in how services are produced, as well as the corresponding willingness-to-pay for such services. On the supply side, the approach measures changes in the value of inputs in the production of wireless communications. The most obvious example is, as mentioned above, whether Wi-Fi represents a positive contribution to wireless carriers' capital expenditures (CAPEX) and operating expenses (OPEX) insofar as they can control their spending, while meeting demand for increased wireless traffic. From an economic theory standpoint, the telecommunications industry can then increase its output, yielding a marginal benefit exceeding the marginal cost. This results in a shift in the supply curve by a modification in the production costs. The shift in the supply curve yields a new equilibrium price and

[9] Thanki, R. (2009); Thanki, R. (2012). *The Economic Significance of License- Exempt Spectrum to the Future of the Internet.* London; Perspective Associates; Milgrom, P., et al. (2011); Katz, R. (2014).

[10] Following Alston (1990), we acknowledge that this approach ignores effects of changes in other product and factor markets; for example, Wi-Fi also increases the economic value of technologies operating in licensed bands (Alston, J.M. and Wohlgenant, M.K. (1990). "Measuring Research Benefits Using Linear Elasticity Equilibrium Displacement Models". John D. Mullen and Julian M. Alston, *The Returns to Australian Wool Industry from Investment in R&D*, Sydney, Australia: New South Wales Department of Agriculture and Fisheries, Division of Rural and Resource Economics).

[11] See a similar approach used by Mensah and Wohlgenant (2010) to estimate the economic surplus of adoption of soybean technology (Mensah, E., and Wohlgenant, M. (2010). "A market impact analysis of Soybean Technology Adoption", *Research in Business and Economics Journal*).

quantity. Additionally, since the demand curve is derived from the utility function[12], the consumer surplus from stable Wi-Fi prices, yields an increase in the willingness-to-pay, and consequently a drives shift in the demand curve. Under these conditions, total economic value is now represented by both changes in the consumer and producer surplus.

To quantify the incremental surplus derived from RLAN technology adoption, we need to itemize all the effects linked to this technology. In addition, we complement the concept of economic surplus with an assessment of the direct contribution of the technologies and applications relying on RLAN, such as Wi-Fi service providers, to national GDP. By including the GDP contribution measurement, we follow Greenstein et al. (2010) and prior research literature measuring the economic gains of new goods.[13] We focus on consumer and producer surplus, but also consider the new economic growth enabled by Wi-Fi. In measuring the direct contribution to GDP, we strictly consider the revenues added "above and beyond" what would have occurred had the Wi-Fi spectrum been licensed. After quantifying Wi-Fi's contribution to GDP, the impact on job creation can also be ascertained not only within the telecommunications industry but also in terms of the spillovers through the rest of the economy.

2.3. Sources and economic agents driving value of unlicensed spectrum

The economic value of unlicensed spectrum is generated from multiple sources of value, including (i) the capability to deliver traffic at faster speed and lower latency than other networking technologies, (ii) provide Internet access, and (iii) interconnect devices. These sources of economic value are then channeled into economic gains for five economic agents:

- Individual consumers accessing free Wi-Fi sites.
- Residential consumers.
- Enterprises.
- Internet service Providers (ISPs); and
- Companies that provide Wi-Fi products and services or manufacture products enabled by Wi-Fi (participants in the Wi-Fi ecosystem).

For each economic agent, the above-mentioned sources of value translate into cost savings, productivity gains, and expanded economic activity:

- **Free Wi-Fi:** The providers of free Wi-Fi service (i.e., coffee shops, retailers, municipalities, public libraries) allow consumers to connect to the Internet without paying for access, creating a surplus to consumers.[14] Additionally, free Wi-Fi hotspots could also provide Internet access to those consumers that lack broadband service,

[12] A utility function measures the consumer preference for a service beyond the explicit monetary value paid for it.
[13] Greenstein, S. and McDevitt, R. (2009). *The broadband bonus: accounting for broadband Internet's impact on U.S. GDP.* National Bureau of Economic Research Working Paper 14758. Cambridge, MA.
[14] This category does not include providers of paid Wi-Fi access such as those operating in airports or hotels; this type of agent is included in the Internet Systems Providers category below.

thereby partially bridging the "digital divide". While less important in metropolitan areas, this effect could be critical to increasing broadband adoption in some less developed geographies, and hence, convey impact on GDP.[15]

- Residential Wi-Fi: As calculated in our 2021 study, residential Wi-Fi also drives consumer surplus. Routers installed in home dwellings provide Internet access for devices that lack a wired port (i.e., tablets, smartphones, netbooks), allowing consumers to avoid the investment in Ethernet wiring.[16] Wi-Fi routers also support easy networking between devices (printers, storage devices, computers), allow for sharing and streaming media content (sound systems, home theaters, etc.), represent a network hub to handle home automation, and may interface with a smart grid. Additional surplus is generated as a Wi-Fi connection for last mile of fixed broadband is typically faster than that of a cellular network.[17] Finally, consumer surplus is generated if the willingness-to-pay exceeds the price paid for purchasing residential Wi-Fi devices and equipment. All of these effects can be aggregated in terms of the residential consumer surplus.

- **Enterprise Wi-Fi:** Wi-Fi in office buildings and industrial campuses allows for voice and data communications without incurring the cost of "capped" connectivity and avoids the limited in-building coverage of cellular networks, as well as the cost of enterprise wiring. Additionally, Wi-Fi supports communication between enterprises and their customers (i.e., customer/client access in financial services, employee/guest connections in the hospitality industry), while also improving internal production efficiencies (product/inventory tracking, remote control equipment, and POS ordering in the retail industry). This equates to a producer surplus, composed of the cost savings enjoyed by enterprises that rely on Wi-Fi

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[15] See Katz, R., & Jung, J. (2021). *The economic impact of broadband and digitization through the COVID-19 pandemic – Econometric modelling* (ITU report). International Telecommunication Union. Available at: https://www.itu.int/pub/D-PREF-EF.COV_ECO_IMPACT_B-2021. Barrero, J. M., Bloom, N., & Davis, S. J. (2021a). Internet access and its implications for productivity, inequality, and resilience. In M. S. Kearney & A. Ganz (Eds.), *Rebuilding the post-pandemic economy*. Aspen Institute Press. Retrieved in: https://www.economicstrategygroup.org/publication/barrero-bloom-davis/
Bertschek, I., Briglauer, W., Hüschelrath, K., Kauf, B., & Niebel, T. (2015). "The Economic Impacts of Broadband Internet: A Survey." *Review of Network Economics*, 14(4), 201–227. Retrieved in: https://doi.org/10.1515/rne-2016-0032; De Clercq, M., D'Haese, M., & Buysse, J. (2023). "Economic growth and broadband access: The European urban-rural digital divide." *Telecommunications Policy*, 47(6), Article 102579. https://doi.org/10.1016/j.telpol.2023.102579; Isley, C., & Low, S. A. (2022). "Broadband adoption and availability: Impacts on rural employment during Covid-19." *Telecommunications Policy*, 46(7), Article 102310. https://doi.org/10.1016/j.telpol.2022.102310
; Katz, R., & Jung, J. (2022a). *The contribution of fixed broadband to the economic growth of the United States between 2010 and 2020*. Telecom Advisory Services LLC.; Katz, R.; Jung, J. (2022b). "The Role of Broadband Infrastructure in Building Economic Resiliency in the United States during the COVID-19 Pandemic." *Mathematics* 10, 2988. https://doi.org/10.3390/math10162988.
[16] This effect is not total since users can potentially purchase adapters for smartphones and tablets, although the most popular connectors (such as micro-USB to Ethernet) cannot deliver comparable speeds and require some consumer inputs to be activated.
[17] This effect is particularly important in 4G networks but could also be relevant in relation to indoor reception.

technology, rather than wideband cellular service. In addition, Wi-Fi allows faster access to the Internet than cellular networks do. These faster speeds have a positive contribution to the economy in terms of increased overall productivity, efficiency, and innovation. Finally, Wi-Fi technology facilitates the expansion of Internet of Things (IoT) platforms and Augmented Reality and Virtual Reality (AR/VR) applications. Those developments generate productivity spillovers on the economy, thereby contributing to the growth of GDP.

- **Internet Service Providers (ISPs):** Due to the explosive growth in data traffic, wireless carriers operating in licensed bands deploy Wi-Fi access points to reduce both capital and operating expenses and reduce congestion challenges. Since ISPs monetize the Wi-Fi access they provide, the producer surplus measures the difference in capital and operating expenses for the traffic that is off-loaded. This model is critical to understanding Wi-Fi's contribution to 5G deployment, yielding economic value generated for wireless carriers who offload 5G traffic on to Wi-Fi in the home/business. Wi-Fi allows service providers to launch paid Internet access in public places (such as venues, stadiums, airports, airlines, hotels, etc.). These access points generate new revenues that would not exist if Wi-Fi were not available. Similarly, Wireless Internet Service Providers (WISPs) rely on Wi-Fi to offer broadband connectivity in areas typically not served by wireline carriers, yielding additional revenues to be accounted for as part of the GDP. Since the technology allows for increasing broadband penetration, it becomes a key factor in driving service coverage and, consequently, GDP growth. This could have multiple positive effects, such as job creation, enhancing the productivity of rural businesses, and increasing access to public services.[18]

- **Wi-Fi ecosystem**: Locally manufactured Wi-Fi devices generate revenues. The difference between the market price of these Wi-Fi enabled devices and the cost to manufacture them represents the manufacturer's profit margin (producer surplus). Such products include home networking devices, Wi-Fi enabled wireless speakers, routers, and security systems on the consumer side, and access points and controllers on the enterprise side. Similarly, as Wi-Fi facilitates the expansion of IoT, developing firms within the IoT ecosystem (hardware, software, and services), it generates a producer surplus. Finally, the economic effect of AR/VR is driven in part by an ecosystem that includes firms ranging from software development to hardware production and applications development. The profit margins of firms involved in this endeavor represent again producer surplus.

2.4. Methodologies for estimating the economic value of unlicensed spectrum

Measuring the economic value of Wi-Fi requires a formal approach that can integrate the various economic gains, whether consumer or producer surplus, as well as their net direct

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[18] Katz, R. and Beltran, F. (2015). *Socio-economic impact of alternative spectrum assignment approaches.* Presentation to the International Telecommunications Society Regional Conference, Los Angeles, CA.

contributions to the GDP.[19] The methodology used in this study is structured around the surplus captured by each of the five economic agents reviewed above (individuals benefitting from free Wi-Fi service, residential Wi-Fi, enterprise Wi-Fi, Internet Service Providers, and Wi-Fi ecosystem companies). As outlined above, the economic value for each agent will be measured based on three potential economic dimensions: consumer surplus, producer surplus, and GDP growth.

The assessment of economic value will be conducted according to two allocation alternatives described in the introduction:

1. Full allocation of the 1200 MHz of the 6 GHz band for unlicensed use, which allows the aggregation in channels of 160 MHz, leading to doubling the maximum channel bandwidth from its predecessor technology and improving the maximum speed.

2. An estimation of the economic value if the 6 GHz band were to be split between unlicensed spectrum and IMT, allocating the lower 500 MHz for RLANs and the upper 700 MHz band for use by telecommunication service providers. This option would enable an auction of 700 MHz for development of 5G and 6G.

Total economic value will result from adding the estimates of the five scenarios. Table 2-1 formalizes each source of value creation by economic agent and Wi-Fi scenarios.

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[19] See the prior research in Thanki, R. (2009); Milgrom, et al. (2011); Cooper, M. (2011); Katz, R. (2014a); Katz, R (2014b); and Katz, R. (2018).

Table 2-1. Sources of economic value of Wi-Fi by economic agent

Agents	Sources	GDP contribution	Producer surplus	Consumer surplus
1. Free Wi-Fi	1.1. Savings incurred by consumers by accessing free Wi-Fi in public sites			Savings for consumers due to using free Wi-Fi
	1.2. Free Wi-Fi service supporting the needs of the broadband unserved population	Increase in GDP due to enhanced broadband adoption		
	1.3. Benefit to consumers enjoying higher speed from free Wi-Fi under Wi-Fi 6E			Consumer surplus from faster data download rate as enabled by faster broadband
	1.4. Benefit to consumers relying on Wi-Fi in educational institutions			Savings for students due to using Wi-Fi in educational institutions
	1.5. Use of Wi-Fi in highly dense heterogeneous environments			Savings for attendees using Wi-Fi in sports stadiums
2. Residential Wi-Fi	2.1. Home internet access for devices that lack an Ethernet port			Consumer surplus from avoiding paying data due to using Wi-Fi
	2.2. Avoidance of inside wiring investment			Savings for consumers due to avoiding investing in internal wiring
	2.3. Consumer benefit derived from faster broadband speed			Consumer surplus from increasing speed
	2.4. Consumer benefit generated by use of residential Wi-Fi devices and equipment			Consumer surplus derived from additional sales of residential Wi-Fi devices and equipment
	2.5. Bridging the digital divide: use of Wi-Fi to increase coverage in rural and isolated areas	Improved affordability associated with broadband provision in the WISP sector		
3. Enterprise Wi-Fi	3.1. Savings in business Internet traffic transmitted through Wi-Fi		Cost reduction of enterprise use of wireless communications	
	3.2. Avoidance of enterprise building inside wiring		Savings for enterprises due to avoiding investing in internal wiring	
	3.3. Benefits derived from an increase in average speed	Increased economic impact due to faster internet speed		
	3.4. Benefits derived from reduced latency	Increased economic impact due to reduced latency		
	2.5. Enhanced IoT deployment	Spillovers of IoT deployment on productivity on key sectors of the Australian economy (e.g., automotive, food processing, logistics, etc.)		
	3.6. Deployment of Augmented Reality/Virtual Reality solutions	Spillovers of AR/VR deployment on the Australian economy		
4. ISPs	4.1. Cellular networks CAPEX savings by off-loading traffic to Wi-Fi		Cost reduction derived from offloading wideband wireless traffic to carrier grade Wi-Fi hot spots	
	4.2. Revenues of Wi-Fi based Public Internet Service Providers	Revenues of service providers offering paid Wi-Fi due to increase in connected devices		
	4.3. Revenues of Wi-Fi based Wireless Internet service Providers	Revenues of WISP providers due to new subscribers		
5. Wi-Fi ecosystem	5.1. Manufacturing of residential Wi-Fi devices and equipment		Producer surplus derived from additional sales of residential Wi-Fi devices and equipment	
	5.2. Manufacturing of Wi-Fi enterprise equipment		Producer surplus derived from additional sales of enterprise Wi-Fi devices and equipment	

	5.3. Benefits of firms of Internet of Things ecosystem	[redacted]	Margins of ecosystem firms (Hardware, software, services) involved in IoT deployment	[redacted]
	5.4. Benefits of firms of AR/VR solutions ecosystem		Margins of ecosystem firms involved in AR/VR deployment	

Source: Telecom Advisory Services

The above table presents an overview of the different sources of Wi-Fi economic value channeled to each economic agent under different Wi-Fi standards operating in different frequency bands.

2. CHANGES IN THE AUSTRALIAN BROADBAND SECTOR SINCE 2021

The 2021 Report by Telecommunications Advisory Services[20] concluded that Wi-Fi technology had become a critical component in Australia's telecommunications infrastructure. Before considering the additional effect of Wi-Fi 6 and the potential 6 GHz spectrum band for unlicensed use, the baseline economic value of Wi-Fi in Australia in 2021 amounted to US$34.1 billion. Likewise, the 2025 baseline forecast of economic value was projected to reach US$36.3 billion. In addition to the value generated from the unlicensed use of the 2.4 GHz and 5 GHz bands, the allocation of the 6 GHz spectrum band for Wi-Fi and the deployment of Wi-Fi 6 and Wi-Fi 6E devices would trigger a boost in economic value, reaching US$5.4 billion in 2025. Considering our forecast that by 2025 only 40 percent of Wi-Fi traffic would rely on the 6 GHz channels, the accelerating effect of the new spectrum allocation and latest Wi-Fi technologies would still be far from reaching its maximum potential at this time. By combining the baseline and the Wi-Fi 6 and 6 GHz scenarios, the overall economic value of Wi-Fi for Australia would yield $41.7 billion in 2025.

Since the publication of Telecom Advisory Services 2021 report, the Australian telecommunications market has undergone significant changes in terms of three key variables:

- Improvement in fixed broadband download speed
- Increase in the number of fixed broadband lines in excess of 150 Mbps
- Decrease of prices in mobile broadband service

These three changes have important implications for assessing the economic value of opening the full value of the 6 GHz band.

3.1. Increase in fixed broadband download speed

In the 2021 study, based on CISCO data and projections, we estimated that 2021 fixed broadband average download speed was 40.26 Mbps, and forecast that it would reach 53.20 Mbps by 2023. However, driven by an accelerated natural growth of demand and the additional boost of the pandemic, actual speeds departed from the original forecast. More importantly, the deployment of FTTx and cable modem technology enabled broadband suppliers to deliver enhanced service at lower prices, therefore acting as an additional demand accelerator (see table 2-1).

[20] Telecom Advisory Services (2021). *The economic value of Wi-Fi: a global view (2021-2025): Report developed for Wi-Fi Alliance*. Retrieved in: https://www.wi-fi.org/system/files/The_Economic_Value_of_Wi-Fi-A_Global_View_2021-2025_202109.pdf

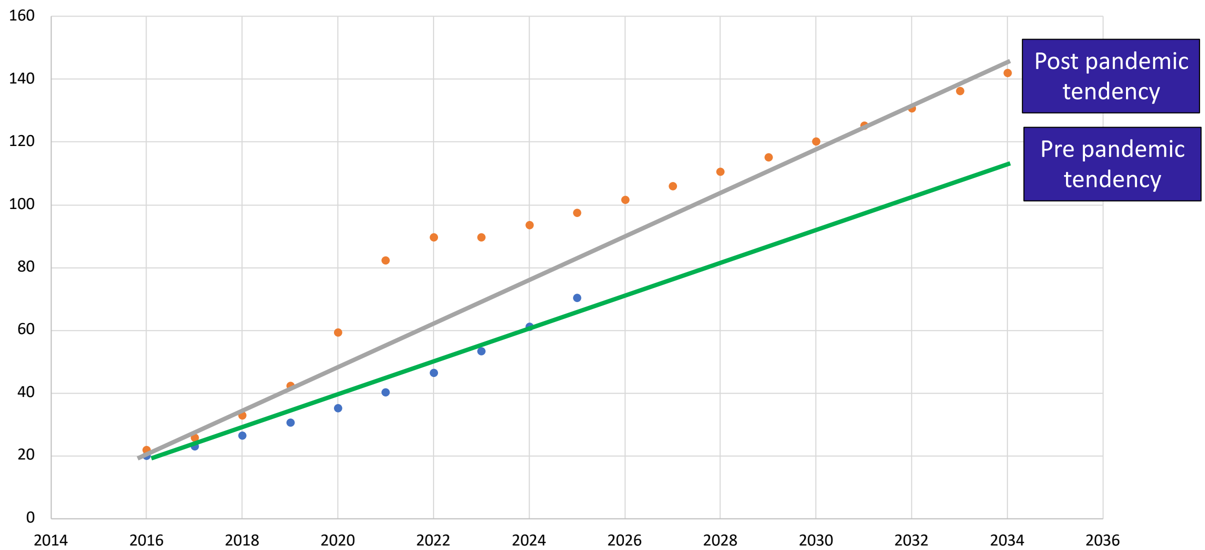
Table 2-1. Fixed broadband average download speed: Original forecast versus actual (Mbps) (2020-2023)

		2019	2020	2021	2022	2023
Original forecast in 2021 study (*)		30.46	35.02	40.26	46.28	53.20
Actual data	Sell (**)	43.89	45.03	49.31	54.05	56.41
	Real (***)	42.14	59.30	82.32	89.53	89.53

Sources: (*) CISCO
(**) Australian Competition & Consumer Commission
(***) Ookla

Actual data in table 2-1 depicts a variance between advertised broadband speeds and crowdsourced data from user tests. An extrapolation of growth vectors between the original study data and the actual data is illustrative of the acceleration of fixed broadband speed, which, as our study will show, has an impact on Wi-Fi economic value (see Graphic 2-1).

Graphic 2-1. Average fixed broadband download speed (2016-34) (in Mbps)



Source: Telecom Advisory Services analysis based on Australian Competition & Consumer Commission and Ookla

As a consequence of the increase in average download speed, the number of lines in excess of 150 Mbps, a threshold driving a potential bottleneck if Wi-Fi routers do not gain access to the 6 GHz spectrum, has also increased dramatically.

3.2. Increase in the number of fixed broadband lines in excess of 150 Mbps

In the 2021 study we estimated based on OECD and Cisco data that the percent of lines with speeds higher than 150 Mbps in Australia was 2.81% and forecast that it would reach 3.66% by 2023. In fact, using recently published Australian Competition & Consumer Commission data of average download speed, distribution of connections by download speed allowed us to estimate the percentage in 2020 to be 5.21%[21] and in 2023 5.60%. As indicated in table 2-2, the 2023 value is close to two times higher than the projection for 2023 study.

Table 2-2. Australia: Percent of fixed broadband connections>150 Mbps: Original forecast versus actual (Mbps) (2020-2023)

	2021	2022	2023
Original forecast in 2020 study (*)	2.81%	3.20%	3.66 %
Actual data (**)	5.21%	5.33%	5.60%

Sources: (*) TAS estimation based on OECD and CISCO
(**) Australian Competition & Consumer Commission

As it will be shown later, the increase in the percentage of lines with speeds higher than 150 Mbps is expected to reach 24.14% by 2030 and 45.14% in 2034. As our analysis will show, this increase has a significant impact in the value of addressing the residential Wi-Fi bottleneck by allocating the full 6 GHz band for RLAN use.

3.3. Slower decrease of prices in mobile broadband service

Our 2021 study predicted a gradual decrease in mobile broadband prices over the years, estimating a drop from $0.54 per GB in 2021 to $0.35 per GB by 2025. This forecast was based on a survey of pricing data in the UIT database and a projection of the industry historical price evolution. Actual data revealed a less pronounced decline than forecasted. Table 2-3 presents a comparative analysis of the price per GB of mobile data between 2021 and a 2025 forecast.

Table 2-3. Price per GB of mobile data (2021-2025)

	2021	2022	2023	2024	2025
Original forecast in 2020 study (*)	$ 0.54	$ 0.49	$ 0.44	$ 0.39	$ 0.35
Actual data (**)	$ 0.48	$ 0.47	$0.45	$ 0.43	$ 0.41

Sources: (*) UIT data for a basket with 10 GB of mobile data and extrapolation
(**) Plan review & average growth rate of low use mobile basket for Australia (ITU)

The slower than forecast decline in mobile broadband prices accentuates the cross-elastic advantage of re-routing wireless traffic to Wi-Fi from wideband cellular.

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To sum up, changes in the Australian broadband and wireless markets dynamics that took place since our 2021 report will increase the original value of Wi-Fi and the allocation of the 6 GHz band for unlicensed use:

- The average download speed of fixed broadband has increased faster than forecast, partly driven by resilient pandemic use behavior. This trend has an impact on the

[21] The estimation was based as follows: The percentage of connections exceeding 150 Mbps is estimated as the median speed (Source: Ookla), divided by the calculation speed of 150 Mbps, and further divided by 2, considering the median divides the connections into halves - one above and the other below the threshold speed.

value to be derived by Wi-Fi use in the 6 GHz band to fulfill speed requirements at the device level.
- The percent of fixed broadband lines in excess of 150 Mbps has increased faster than forecast which will augment the value of the 6 GHz spectrum in addressing the speed bottleneck at the router level in residences.
- A slower than forecast decrease in mobile broadband prices will emphasize the cross-elasticity benefit of relying on Wi-Fi for wireless broadband use.

These trends will have an impact on the economic value of allocating the 6 GHz band for RLANs to be addressed in the next chapters.

4. ECONOMIC VALUE OF ALLOCATING THE FULL 6 GHz BAND FOR RLANs

The allocation of the 1200 MHz of the 6 GHz for unlicensed use would yield economic value across five main effects:

- Increase in GDP and consumer surplus resulting from providing free Internet access to consumers that lack residential broadband.
- Faster Internet access in residences as a result of eliminating router bottleneck in high-speed connections.
- Cost reduction for enterprise wireless use.
- Revenues for service providers offering paid Wi-Fi service.
- Development of an ecosystem of Wi-Fi enabled products and services.

Each effect will be assessed in terms of its economic contribution, differentiating between GDP, consumer and producer surplus.

4.1. Free Wi-Fi service

According to Wi-Fi Map (2024)[22], there are 40,039 free Wi-Fi sites in Australia, which enable individual consumers to access the internet for limited time. They include hotspots deployed in retail outlets (stores, coffee shops, etc.), transportation hubs, and points of delivery of public services (hospitals, doctors offices, public libraries, etc.) among others.

The economic value of free Wi-Fi service originates from five contribution sources:

- Savings incurred by consumers by accessing free Wi-Fi in public sites rather than incurring cellular costs
- Free Wi-Fi service supporting the needs of the broadband unserved population
- Benefit to consumers enjoying higher speed from free Wi-Fi under Wi-Fi 6E
- Benefit to consumers relying on Wi-Fi in educational institutions: avoidance of the purchase of mobile data services in educational institutions
- Use of Wi-Fi in highly dense heterogeneous environments

Each source will be described and assessed in terms of economic value. While data in this chapter is presented in tables between 2023 and 2030, the overall value is assessed for 2024-2034.

4.1.1. Wireless data savings for consumers from accessing free Wi-Fi in public sites

Free Wi-Fi offered in retail shops, coffee shops, city halls, and corporate guest accounts allows consumers to save money that would otherwise be spent purchasing cellular service. In addition, free hotspots provide access to the Internet for consumers that cannot afford to

[22] *Free Wi-Fi in Australia*. Retrieved in: https://www.wifimap.io/14-australia in May 2024.

purchase broadband service. This last effect was particularly important during the coronavirus pandemic, allowing broadband unserved households to access the Internet for telecommuting, telemedicine, and remote education, among other applications.

To estimate the amount consumers can save by use free public Wi-Fi, we start by quantifying the Internet traffic by wireless data-enabled devices (smartphones, tablets, PCs).

The increased adoption of devices combined with an increase in usage has driven overall Internet traffic growth. Forecasts of the installed base of these devices in Australia shows a steady rise from 2023 to 2030 for smartphones and tablets, and a reduction in the case of laptops. (see Table 4-1).

Table 4-1. Australia: Device Installed Base and Penetration (2023-2030)

Device	Metrics	2023	2024	2025	2026	2027	2028	2029	2030	CAGR
Smartphones	Units (in million)	28.41	29.05	29.70	30.36	31.04	31.73	32.44	33.16	2.23%
	Penetration (%)	107.10%	107.71%	108.41%	109.19%	110.06%	111.01%	112.06%	113.19%	0.79%
Tablets	Units (in million)	9.55	9.69	9.85	10.00	10.16	10.31	10.48	10,64	1.56%
	Penetration (%)	35.98%	35.95%	35.94%	35.97%	36.01%	36.09%	36.19%	36.32%	0.13%
Laptops	Units (in million)	17.98	17.86	17.75	17.63	17.52	17.40	17.29	17.18	-0.65%
	Penetration (%)	67.77%	66.24%	64.79%	63.42%	62.12%	60.90%	59.74%	58.64%	-2.04%
Devices per user		2.11	2.10	2.09	2.09	2.08	2.08	2.08	2.08	-0.18%

Sources: Cisco Annual Internet Report Highlights Tool 2018-2023; GSMA Intelligence; Telecom Advisory Services analysis

Adding to the proliferation of devices, traffic per device is also estimated to increase significantly. The average monthly traffic per device in Australia is projected to rise considerably from 2023 to 2030 (see Table 4-2).

Table 4-2. Australia: Average Traffic Per Device (gigabytes per month) (2023-2030)

Device	2023	2024	2025	2026	2027	2028	2029	2030	CAGR
Smartphones	62.8	89.5	127.4	163.2	209.1	267.9	343.3	439.9	32.05%
Tablets	8.4	9.6	10.9	11.1	11.4	11.6	11.9	12.2	5.43%
Laptops	5.0	5.4	5.8	5.7	5.5	5.4	5.2	5.1	0.37%

Sources: Cisco Annual Internet Report Highlights Tool 2018-2023; Telecom Advisory Services analysis

The installed base of devices times traffic per device drives overall traffic growth (see Table 4-3).

Table 4-3. Australia: Internet Traffic (2023-2030) (exabytes[23] per month)

Device	2023	2024	2025	2026	2027	2028	2029	2030	CAGR
Smartphones	1.66	2.42	3.52	4.61	6.04	7.92	10.37	13.58	35.02%
Tablets	0.30	0.36	0.43	0.46	0.49	0.52	0.56	0.60	10.41%
Laptops	1.04	1.18	1.34	1.36	1.38	1.41	1.44	1.46	4.97%

Sources: Cisco Annual Internet Report Highlights Tool 2018-2023; Telecom Advisory Services analysis

This growth has and will continue to put pressure on the public networks of all wireless service providers to accommodate the traffic without incurring congestion. Based on the premise that cellular off-loading varies by device, and assuming that off-loading will increase over time with the deployment of more Wi-Fi sites, we estimate the portion of overall mobile traffic by device transmitted through Wi-Fi (see Table 4-4).

Table 4-4. Australia: Wireless Device Off-Loading Factors (2023-2030)

Device	2023	2024	2025	2026	2027	2028	2029	2030
Smartphones[24]	48%	48%	48%	48%	48%	48%	48%	48%
Tablets	63%	63%	63%	63%	63%	63%	63%	63%
Laptops	63%	63%	63%	63%	63%	63%	63%	63%

Sources: Cisco Annual Internet Report Highlights Tool 2018-2023; Opensignal; Telecom Advisory Services analysis

By applying these off-loading factors to the total data traffic generated by each type of device, we estimate that total Wi-Fi traffic in Australia is currently 2.12 Exabytes per month in 2024 and will reach 7.78 by 2030 (see Table 4-5).

Table 4-5. Australia: Total Wi-Fi Traffic (2023-2030) (exabytes per month)

Device	2023	2024	2025	2026	2027	2028	2029	2030	CAGR
Smartphones	0.79	1.16	1.68	2.20	2.89	3.78	4.95	6.49	35.10%
Tablets	0.19	0.23	0.27	0.29	0.31	0.33	0.35	0.38	10.41%
Laptops	0.66	0.74	0.84	0.86	0.87	0.89	0.90	0.92	4.86%
Total	1.64	2.12	2.79	3.35	4.07	5.00	6.21	7.78	24.91%

Sources: Cisco Annual Internet Report Highlights Tool 2018-2023; Telecom Advisory Services analysis

The estimation of consumer surplus proceeds, then, by multiplying the total Wi-Fi traffic from Table 4-5 by 4.32%, our estimate of the amount of traffic using free Wi-Fi access points[25] (Table 4-6).

Table 4-6. Australia: Total Public Wi-Fi Traffic (2023-2030)

Variable	2023	2024	2025	2026	2027	2028	2029	2030
Total Wi-Fi traffic (exabytes per month)	1.64	2.12	2.79	3.35	4.07	5.00	6.21	7.78
Total Public Wi-Fi traffic (exabytes per month)	0.07	0.09	0.12	0.14	0.18	0.22	0.27	0.34
Total Public Wi-Fi traffic (exabytes per year)	0.85	1.10	1.45	1.74	2.11	2.59	3.22	4.04
Total Public Wi-Fi traffic (million GB per year)	914	1,183	1,555	1,864	2,264	2,783	3,457	4,334

Sources: Cisco; Telecom Advisory Services analysis

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[24] In 2023, the smartphone offloading factor grew to an average of 50%, which would imply an increase in economic value. We prefer to continue estimating 48% for conservative purposes, because we lack data as to whether that increase will be permanent.

[25] We assume a constant number for 4.32% of total Wi-Fi going through public sites. Considering that 52% of this amount in 2024 goes through free hot spots, at 2.25% remains a conservative assumption. This has been used as a constant number for past reports although recent qualitative data indicates that this percent has been growing.

The consumer surplus generated by free Wi-Fi sites is composed of two sources: the benefit originated by unlicensed spectrum operating in the 2.4 GH and 5 GHz bands and that derived from allocating the entire 6 GHz band for Wi-Fi use. To isolate the effect from the increased capacity derived from the 6 GHz allocation, we calculate the portion of free Wi-Fi traffic attributed to current spectrum bands. For this, we relied on the assumption than current traffic levels are already producing congestion in most free Wi-Fi hotspots at times of peak demand. Thus, we assume that traffic per hotspot beyond 2021 has remained at the average 2020 levels (15,328 GB per year, per hotspot) (See Table 4-7).

Table 4-7. Australia: Total free Wi-Fi Traffic projection (2023-2030)

Variable	2023	2024	2025	2026	2027	2028	2029	2030
Free Wi-Fi traffic (million GB per year) - considering current trends	914	1,183	1,555	1,864	2,264	2,783	3,457	4,334
Free Wi-Fi hotspots (million)	0.04	0.04	0.04	0.05	0.05	0.05	0.06	0.06
Annual traffic per hotspot - considering current trends (GB)	24,634	29,555	35,970	39,950	44,948	51,175	58,884	68,383
Annual traffic per hotspot - capped due to congestion (GB)	15,328	15,328	15,328	15,328	15,328	15,328	15,328	15,328
Total traffic (not attributed to 6 GHz allocation) (million GB)	569	614	663	715	772	834	900	972

Sources: Cisco; Wi-Fi Map; Telecom Advisory Services analysis

We calculate consumer benefit by multiplying the total free traffic (not attributed to 6 GHz) by the difference between what the consumer would have to pay if she/he were to rely on a wireless carrier and the cost of offering free Wi-Fi (incurred by the retailer or public site). To do so, we need an estimate of the average price per GB of wireless data transmitted by wideband networks, which we calculated by averaging the most economic "US dollar per GB" plan of Australian wireless carriers (US$ 0.43).[26] Starting from this previous estimate of a price per GB in 2024 of $3.77, we expect the average price per GB will reach an estimated US$ 0.324 in 2030.

As to the cost of offering the free Wi-Fi service, the counterfactual option, this would include an additional router and bandwidth for the provider of free service.[27] We assume those costs to be prorated at $2.50 per gigabyte in 2020, which was what some Wi-Fi services in public sites charge per 2-hour service (assuming this to be costs passed through to the customer)[28]. By relying on the total free Wi-Fi traffic not attributed to 6 GHz allocation shown in Table 4-7 and the average price per cellular gigabyte minus the cost of provisioning Wi-Fi service, we calculated the consumer surplus of free Wi-Fi traffic relying on the 2.4 GHz and 5 GHz bands (see Table 4-8).

[26] The US dollar per GB is calculated by prorating by market share the least expensive plans for Telstra, Optus and Vodafone Hutchinson. This calculation yields 0.66 Australian cents, which is converted to US$ 0.43.
[27] The cost of provisioning fixed broadband is not accounted since those are already part of the existing infrastructure of the location where the user of free service is.
[28] This is assumed to decline to $1.34 per gigabyte by 2025, assuming the same decline rate as the price per GB for mobile broadband.

Table 4-8. Australia: Consumer surplus of free Wi-Fi traffic in the 2.4 and 5 GHz bands (2023-2030)

Variable	2023	2024	2025	2026	2027	2028	2029	2030
Total Free Traffic (not attributed to 6 GHz) (million GB)	569	614	663	715	772	834	900	972
Price per cellular gigabyte (US$)	$ 0.45	$ 0.43	$ 0.41	$ 0.39	$ 0.37	$ 0.36	$ 0.34	$ 0.32
Cost per Wi-Fi provisioning (US$)	$ 0.20	$ 0.19	$ 0.18	$ 0.17	$ 0.17	$ 0.16	$ 0.15	$ 0.14
Consumer benefit per gigabyte (US$)	$ 0.25	$ 0.24	$ 0.23	$ 0.22	$ 0.21	$ 0.20	$ 0.19	$ 0.18
Total Consumer surplus (US$ million)	$ 141	$ 146	$ 151	$ 155	$ 160	$ 165	$ 170	$ 175

Sources: Websites of cellular operators; Telecom Advisory Services analysis

As indicated in Table 4-8, consumer surplus of free Wi-Fi traffic in the 2.4 GHz and 5 GHz bands 2023 was an estimated US$141 million, increasing to US$175 million to 2030.

The allocation of the 6 GHz spectrum band for unlicensed use and the technological advancements provided by the Wi-Fi 6E standard would alleviate some of the previously mentioned bottlenecks causing congestion. Consequently, the traffic per hotspot will continue to grow at its natural rate, as determined by the extrapolation of recent trends. Based on these projections, the total traffic attributable to use of the 6 GHz band will grow from 98 million GB in 2023, to 854million GB in 2030 (See Table 4-9).

Table 4-9. Australia: Free Wi-Fi Traffic generated due to allocation of the 6 GHz band (2023-2030)

Variable	2023	2024	2025	2026	2027	2028	2029	2030
Traffic per hotspot (capped due to congestion Wi-Fi 6E) (GB)	24,634	29,555	29,555	29,555	29,555	29,555	29,555	29,555
Free Wi-Fi hotspots (million)	0.04	0.04	0.04	0.05	0.05	0.05	0.06	0.06
Total traffic (million GB)	914	1,183	1,277	1,379	1,489	1,607	1,735	1,873
Additional traffic through the 6 GHz band (million GB)	345	570	615	664	717	774	835	902
Traffic through the 6 GHz band (%)	28%	51%	66%	77%	84%	89%	92%	95%
Total Free traffic (attributable to the 6 GHz band) (million GB)	98	288	405	508	601	687	771	854

Sources: Cisco; Wi-Fi Map; Telecom Advisory Services analysis

Once we compute the additional traffic due to the 6 GHz band, we follow a similar approach to calculate the consumer surplus, by multiplying it by the difference between what the consumer would have to pay if he were to utilize a wireless carrier and the cost of offering free Wi-Fi (Table 4-10). As a result, we project an additional consumer benefit of $153 million from free Wi-Fi traffic attributed to the 6 GHz in 2030.

Table 4-10. Australia: consumer benefit of free Wi-Fi traffic due to allocation of the 6 GHz band (2023-2030)

Variable	2023	2024	2025	2026	2027	2028	2029	2030
Total Free traffic (attributable to the 6 GHz band) (million GB)	98	288	405	508	601	687	771	854
Price per cellular gigabyte (US$)	$ 0.45	$ 0.43	$ 0.41	$ 0.39	$ 0.37	$ 0.36	$ 0.34	$ 0.32
Cost per Wi-Fi provisioning (US$)	$ 0.20	$ 0.19	$ 0.18	$ 0.17	$ 0.17	$ 0.16	$ 0.15	$ 0.14
Consumer benefit per gigabyte (US$)	$ 0.25	$ 0.24	$ 0.23	$ 0.22	$ 0.21	$ 0.20	$ 0.19	$ 0.18
Total Consumer benefit (US$ Million)	$ 24	$ 68	$ 92	$ 110	$ 124	$ 136	$ 145	$ 153

Sources: Websites of cellular operators; Telecom Advisory Services analysis

In sum, the consumer surplus for accessing internet access in free Wi-Fi sites amounts to US$ 214 million in 2024, reaching US$ 366 million in 2034 (see table 4-11).

Table 4-11. Australia: Consumer surplus of free Wi-Fi access (million US$) (2024-2034)

Variable	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
2.4 GHz and 5 GHz bands	$ 146	$ 151	$ 155	$ 160	$ 165	$ 170	$ 175	$ 180	$ 185	$ 191	$ 191
6 GHz band	$ 68	$ 92	$ 110	$ 124	$ 136	$ 145	$ 153	$ 161	$ 168	$ 174	$ 175
Total	$214	$243	$265	$284	$301	$315	$328	$341	$353	$365	$366

Sources: Websites of cellular operators; Telecom Advisory Services analysis

4.1.2. Free Wi-Fi service supporting the needs of the broadband unserved population

Deployment of free Wi-Fi provides Internet access to the unserved population. Consumers that do not have broadband at home because they lack the economic means to acquire services can rely on free Wi-Fi to gain Internet access. As a result, more people can be connected, which in turn enhances the economic contribution of broadband.

The calculation of this economic impact starts by calculating which portion of Australian households that lack broadband service are already accessing the Internet through free hotspots. Statista reported that by the end of 2023 there were 6,480,000 households with internet access in Australia. The estimation of non-connected households is based on the number of households (10,376,842[29]), which results in a total non-connected as of 2023 of 3,769,842 million. We follow a conservative approach and assume that only 5% of unconnected households rely on free hotspots for accessing the Internet. After calculating the increase in broadband penetration due to households relying on free Wi-Fi, we rely on the broadband impact coefficient from Katz and Callorda (2024), that estimates for the Asia Pacific region a 1.62% increase in GDP for every 10% increase in penetration. As a result, the GDP contribution of this effect is expected to amount to US$ 8.21 million in 2023, increasing to $10.5 billion in 2030 (see table 4-12).

[29] Australian Institute of Family Studies (2024). Population, households and families. Retrieved in: https://aifs.gov.au/research/facts-and-figures/population-households-and-families#:~:text=According%20to%20the%202021%20Census,9.275%20million%20households%20in%20Australia.

Table 4-12. Australia: GDP contribution due to households relying on free Wi-Fi in the 2.4 GHz and 5 GHz bands (2023-2030)

Variable	2023	2024	2025	2026	2027	2028	2029	2030
Households without Internet (million)	3.77	3.76	3.76	3.77	3.85	3.93	4.00	4.07
Households that don't buy because access the Internet via free hotspots (%)	5%	5%	5%	5%	5%	5%	5%	5%
Households served by free Wi-Fi hot spots	188,478	187,992	188,089	188,769	192,534	196,386	199,824	203,316
Households with Fixed Broadband (million)	6.48	6.62	6.75	6.87	6.93	6.99	7.06	7.13
Increase in national broadband penetration	2.91%	2.84%	2.79%	2.75%	2.78%	2.81%	2.83%	2.85%
Impact of fixed broadband adoption in GDP	16.20%	16.20%	16.20%	16.20%	16.20%	16.20%	16.20%	16.20%
Increase in the GDP due to the new broadband adoption (% GDP)	0.47%	0.46%	0.45%	0.45%	0.45%	0.46%	0.46%	0.46%
GDP (US$ billion)	$ 1,742	$ 1,790	$ 1,863	$ 1,940	$ 2,017	$ 2,096	$ 2,179	$ 2,265
Total impact in GDP (US$ billion)	$ 8.21	$ 8.24	$ 8.41	$ 8.64	$ 9.08	$ 9.54	$ 9.99	$ 10.46

Sources: ITU; STATISTA; IMF; Katz cand Callorda (2024); Telecom Advisory Services analysis

Moving on to the use of the 6 GHz band, Wi-Fi 6E technology supports a high number of devices on a single access point. Accordingly, the improved throughput of free Wi-Fi hotspots under the 6 GHz allocation will allow for the possibility of serving additional unconnected households. We follow again a conservative approach and assume that a further 5% of unconnected households are served through free hotspots with the technological advantages of Wi-Fi 6E. We have also considered that the expansion of traffic through the new band, with Wi-Fi 6E will take place gradually, reaching 52% in 2025.[30] All in all, we estimate that additional 115,934 households will be served in 2025 due to free hotspots operating under 6 GHz spectrum, yielding an additional GDP contribution of approximately US$ 2,208 million in 2023, reaching US$ 9,168 in 2030 (Table 4-13).

[30] See Graphic 3-2 for detail reference.

Table 4-13. Australia: GDP contribution due to households relying on Free Wi-Fi in the 6 GHz band (2023-2030)

Variable	2023	2024	2025	2026	2027	2028	2029	2030
Households without Internet (not served by free Wi-Fi and not new adopters of WISP) (million)	3.58	3.55	3.52	3.51	3.58	3.64	3.70	3.76
Potential households that could be served through free Wi-Fi hotspots under increased capacity (% of those not connected)	5%	5%	5%	5%	5%	5%	5%	5%
Traffic through Wi-Fi 6E (%)	28%	51%	66%	77%	84%	89%	92%	95%
Additional households served by free Wi-Fi hot spots with Wi-Fi 6E	50,707	89,761	115,934	134,424	149,955	161,822	170,857	178,188
Increase in national broadband penetration	0.78%	1.36%	1.72%	1.96%	2.16%	2.32%	2.42%	2.50%
Increase in the GDP due to the new broadband adoption (% GDP)	0.13%	0.22%	0.28%	0.32%	0.35%	0.38%	0.39%	0.40%
Total impact in GDP (US$ million)	$ 2,208	$ 3,933	$ 5,184	$ 6,151	$ 7,070	$ 7,862	$ 8,542	$ 9,168

Sources: ITU; STATISTA; IMF; Katz cand Callorda (2024); Telecom Advisory Services analysis

In sum, the GDP contribution for providing internet access in free Wi-Fi sites to consumers lacking residential service amounts to US$ 12.2 billion in 2024, reaching US$ 24.1 billion in 2034 (see table 4-14).

Table 4-14. Australia: GDP contribution of free Wi-Fi access (billion US$) (2024-2034)

Variable	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
2.4 GHz and 5 GHz bands	$ 8.2	$ 8.4	$ 8.6	$ 9.1	$ 9.5	$ 10.0	$ 10.5	$ 11.0	$ 11.5	$ 12.0	$ 12.6
6 GHz band	$ 3.9	$ 5.2	$ 6.2	$ 7.1	$ 7.9	$ 8.6	$ 9.2	$ 9.8	$ 10.3	$ 10.9	$ 11.5
Total	$ 12.2	$ 13.6	$ 14.8	$ 16.1	$ 17.4	$ 18.5	$ 19.6	$ 20.7	$ 21.8	$ 22.9	$ 24.1

Sources: Websites of cellular operators; Telecom Advisory Services analysis

4.1.3. Benefit to consumers enjoying higher speed from free Wi-Fi operating in the 6 GHz band

In addition to providing increased access to consumers lacking residential broadband, when the 6 GHz band is adopted by free Wi-Fi access points, it delivers service at faster broadband speeds. We estimate that public Wi-Fi hotspots in 2023 averaged 30 Mbps of download speed[31]. Thus, the expanded capabilities due to the allocation of 6 GHz spectrum band will enhance free Wi-Fi speed using Wi-Fi 6E, and as a result, will increase consumer benefit. We assume that relying on the 6 GHz allocation, speed from free hotspots will be similar as one third of the average download speed in households (Assuming that the number of devices connected to a mobile hotspot at the same time is on average three times less than the

[31] Telecom Advisory Services estimation, using as reference the WISP average download speed based on Broadband Now Research (https://broadbandnow.com/research/wisp-speed-performance-up-250-percent-2019)

devices connected at home[32]). After calculating the average speed by considering the expected share of traffic through Wi-Fi 6E, we follow Nevo et al. (2016) and calculate the additional consumer benefit per household relying on free Wi-Fi. We expect the benefit resulting from faster speed in free Wi-Fi sites to reach US$95.86 million in 2030 due to Wi-Fi 6E in the 6 GHz band (see table 4-15).

Table 4-15. Australia: consumer benefit for enjoying higher speed from free Wi-Fi with Wi-Fi 6E (2023-2030)

Variable	2023	2024	2025	2026	2027	2028	2029	2030
Free Wi-Fi mean speed with no Wi-Fi 6E (Mbps)	11	12	13	13	14	15	16	17
Free Wi-Fi mean speed with Wi-Fi 6E (Mbps)	30	31	32	34	35	37	38	40
Traffic through Wi-Fi 6E (%)	28.36%	50.60%	65.93%	76.51%	83.80%	88.83%	92.30%	94.69%
Average Free Wi-Fi mean speed with Wi-Fi 6E (Mbps)	16.57	21.67	25.73	29.06	31.90	34.39	36.67	38.81
Demand for average download speed	86.01	87.50	89.00	90.49	91.98	93.48	94.97	96.46
New Demand for average download speed	95.72	102.56	106.94	110.04	112.40	114.32	115.96	117.40
Additional Monthly Consumer Benefit	9.71	15.06	17.94	19.55	20.42	20.85	20.99	20.94
Additional Yearly Consumer Benefit	116.56	180.73	215.27	234.56	245.05	250.16	251.83	251.27
Households that rely on Free Wi-Fi	239,185	277,754	304,023	323,193	342,490	358,208	370,681	381,503
Impact (US$ million)	$27.88	$50.20	$65.45	$75.81	$83.93	$89.61	$93.35	$95.86

Sources: Nevo et al. (2016); Telecom Advisory Services analysis

These estimates should be considered conservative since the launch of Wi-Fi 7 operating in the 6 GHz band would be increasing speeds resulting from higher spectral efficiency of the new standard.

4.1.4. Benefit to consumers relying on Wi-Fi in educational institutions

This analysis is based on a detailed financial analysis of the cost of Wi-Fi in educational institutions, focusing on capital expenditures (CAPEX) and operational expenditures (OPEX) for 19,000 students, as a case study constructed for a particular US school.[33] The CAPEX,

[32] Our starting point is the speed that we get from a single device when connected through Wi-Fi at home, which is reported by Ookla (289 Mbps) in 2023. Now, since we do not have the speed data in free Wi-Fi connections, we thought that this being a shared connection, the speed should be lower. Our assumption of a third of speed is qualitatively confirmed by interviews that the upgrade of free sites to higher standards is proceeding very slowly.
[33] The original estimate was developed in Katz, R. (2022). *The "to and through" opportunity: An economic analysis of options to extend affordable broadband to students and households via anchor institutions: Economic analysis,*

which is a one-time investment, is amortized at US$128,571 per year from 2023 to 2027, reaching a total investment of US$900,000 over seven years. The OPEX, representing the annual operational costs, remains steady at $742,000 per year. Consequently, the yearly cost per student is calculated at $45.62, derived by dividing the sum of CAPEX and OPEX by the total number of students, which is 19,000.

Enrollment data from the Australia Bureau of Statistics is used to determine the total number of students at various educational levels: higher education, secondary school, and elementary school (grades 5 to 8), resulting in a consistent total population of 4,890,298 students in 2021. The analysis assumes no increase in enrollment numbers for conservative purposes. Additionally, the share of time spent on homework is estimated for different education levels: 25% for higher education, 20% for secondary school, and 15% for elementary school. The weighted average share of time spent on homework, across all levels, is 20.2% in 2024, marginally increasing to 22.3% in 2034.

The analysis also examines the counterfactual expenses associated with using Mobile Broadband (MBB) for educational purposes, considering it as an alternative to Wi-Fi. The total cost of using MBB is projected to decrease annually from US$ 486 in 2023 to US$ 349.81 in 2030.[34] This reduction is calculated using the same rate applied to the price of one gigabyte of mobile broadband. Additionally, it is important to note that only 20.4% of this cost is relevant, as it represents the proportion of time spent using data for homework. Consequently, the adjusted cost ranges from US$ 97.03 in 2023 to US$ 74.88 in 2030.

The yearly benefit per student, calculated as the difference between the adjusted cost using MBB and the yearly cost per student to have Wi-Fi in schools, decreases from $53.18 in 2023 to $16.40 in 2027 (reflecting the declining cost of mobile broadband). Finally, the total consumer benefit, determined by multiplying the yearly benefit per student by the number of students, declines from $2,955 million in 2023 to $911 million in 2027 (see Table 4-16).

Cost Calculation Toolkit and Public Policy Implications. New York: Telecom Advisory Services and is based on the case study of a US High School District.

[34] Average based on the assessment reported above.

Table 4-16. Australia: Benefit to consumers relying on Wi-Fi in educational institutions (2023-2030)

Variable	2023	2024	2025	2026	2027	2028	2029	2030
Yearly cost per student (US$)	$ 43	$ 43	$ 43	$ 43	$ 43	$ 43	$ 43	$ 43
Higher education enrollment (million)	1.19	1.20	1.20	1.21	1.22	1.22	1.23	1.23
Secondary school enrollment (million)	1.80	1.84	1.85	1.90	1.94	1.97	2.01	2.04
Elementary school enrollment (Grades 5 to 8)	2.11	2.12	2.14	2.15	2.16	2.18	2.19	2.20
Total enrollment (million)	5.11	5.16	5.21	5.26	5.31	5.37	5.42	5.48
Share of time to do homework (Higher School)	25%	25%	25%	25%	25%	25%	25%	25%
Share of time to do homework (Secondary School	20%	20%	20%	20%	20%	20%	20%	20%
Share of time to do homework (Elementary School)	15%	15%	15%	15%	15%	15%	15%	15%
Share of time in education	19.96%	20.16%	20.36%	20.57%	20.77%	20.98%	21.19%	21.41%
Total Cost using MBB (US$)	$ 486.00	$ 463.70	$ 442.42	$ 422.12	$ 402.75	$ 384.27	$ 366.64	$ 349.81
Real Cost using MBB (US$)	$ 97.03	$ 93.49	$ 90.09	$ 86.81	$ 83.66	$ 80.62	$ 77.70	$ 74.88
Yearly benefit by student (US$)	$ 54.13	$ 50.59	$ 47.19	$ 43.91	$ 40.76	$ 37.72	$ 34.80	$ 31.98
Consumer surplus	$ 265	$ 247	$ 231	$ 215	$ 199	$ 184	$ 170	$ 156

Sources: Verizon website; US Census; Telecom Advisory Services analysis

Despite the decline in mobile broadband costs, the benefit of Wi-Fi in supporting educational needs is clear.

4.1.5. Use of Wi-Fi in highly dense heterogeneous environments

By leveraging the 6 GHz band, Wi-Fi 6E can offer faster speeds and greater capacity, ensuring that attendees in highly dense environments such as at professional sporting events can enjoy seamless connectivity for activities such as streaming video, accessing social media, and utilizing various data-intensive applications. Sports venues have already started deploying these facilities.[35]

Attendance at these events is expected to grow steadily[36], with mobile data usage per user increasing significantly each year[37]. The adoption rate of Wi-Fi 6E is estimated at 28.36% in 2023 and reaches 94.69% in 2030. Yearly traffic handled by Wi-Fi 6E is projected to reach 17,825,434 GB in 2030.

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[35] See for example: https://www.sportsvideo.org/2024/04/24/san-francisco-giants-oracle-park-byus-lavell-edwards-stadium-tap-6-ghz-wi-fi-connectivity/

[36] Analysis based on number of teams and and average assistance in major Australian sports leagues (Australian Football League, Rugby League, A-League, BBL and WBBL for cricket, and National Basketball League) using information from https://www.statscore.com/market-research/what-are-the-5-most-popular-sports-in-australia/

[37] Based on average data use per match in Qatar Soccer World Cup

In the calculation, we also consider the capital expenditure for Wi-Fi 6E infrastructure, that remains constant at US$ 3 million per year[38]. Finally, the consumer benefit is calculated by comparing the savings from using Wi-Fi 6E to the costs of mobile data. The consumer surplus is projected to gradually increase reflecting slow adoption in sport venues (see Table 4-17).

Table 4-17. Australia: Use of Wi-Fi in highly dense heterogeneous environments using the 6 GHz band (2023-2030)

Variable	2023	2024	2025	2026	2027	2028	2029	2030
Attendance to professional sporting events (yearly) (million)	8.47	8.70	8.93	9.18	9.42	9.68	9.94	10.21
Mobile data usage per user, per match (GB)	0.47	0.57	0.69	0.84	1.02	1.25	1.52	1.84
Traffic through Wi-Fi 6E (%)	28.36%	50.60%	65.93%	76.51%	83.80%	88.83%	92.30%	94.69%
Yearly traffic using Wi-Fi 6E (million GB)	1.12	2.51	4.01	5.92	8.09	10.72	13.91	17.83
Cost of the traffic using mobile network	$ 0.45	$ 0.43	$ 0.41	$ 0.39	$ 0.37	$ 0.36	$ 0.34	$ 0.32
CAPEX (in price of sporting event)	$ 3	$ 3	$ 3	$ 3	$ 3	$ 3	$ 3	$ 3
Consumer surplus (US$ million)	$ 0	$ 0	$ 0	$ 0	$ 0	$ 1	$ 2	$ 3

Sources: Telecom Advisory Services analysis

As stated above, this estimate should be conservative considered additional boost in 6 GHz use derived from the launch of Wi-Fi 7.

* * * * *

In sum, the use of Wi-Fi technology in sites accessed for free represents an important source of economic value:

- Free Wi-Fi offered in retail shops, coffee shops, city halls, and corporate guest accounts allows consumers to save money that would otherwise be spent purchasing cellular service: this amounts to US$ 214 million in 2024, reaching US$ 365 million in 2034.
- Free Wi-Fi service supporting the needs of the broadband unserved population: assuming conservatively that only 5% of 3.769 million unconnected households rely on free Wi-fi sites to support their connectivity needs and considering the contribution of broadband lines to the GDP, Wi-Fi will increase GDP by US$ 12.17 billion in 2024 and US$ 24.05 billion in 2034.
- Benefit to consumers enjoying higher speed from free Wi-Fi under Wi-Fi 6E operating in the 6GHz band which amounts to US$ 50.20 million in 2024 and US$ 99.36 million in 2034.
- Benefit to consumers relying on Wi-Fi rather than purchasing mobile data services in educational institutions, which ranges between US$ 247 million in 2024 and US$ 106 million in 2034.

[38] $49 million estimated cost of deployment, over 5 years

- Use of Wi-Fi in highly dense heterogeneous environments: consumer benefit in settings, such as stadiums where large numbers of users are accessing the network simultaneously, reaching US$ 9 million in 2034.

4.2. Residential use

Wi-Fi is a critical component of a home's infrastructure. It is an enabler of wireless communication between the point of access of fixed broadband and among multiple devices, such as data processing equipment, sound systems, home security, appliances, and the like. As a consequence, RLAN is becoming not only a support fixed broadband wireless interface, but also a critical inter-device connectivity device, which is the reason why Wi-Fi routers are becoming pervasive: as of 2024, 94% of Australian households are equipped with Wi-Fi networks.

This level of adoption drives economic contribution at multiple levels:

- Due to the technology features, Wi-Fi, especially Wi-Fi 6E operating in the 6 GHz band is faster than mobile broadband.
- Wi-Fi represents an infrastructure that supports in-home device connectivity avoiding the need to deploy Ethernet cable in each room, an expensive proposition.
- In the absence of Wi-Fi, the traffic of devices lacking an Ethernet port, such as smartphones and tablets, would have to depend on the cellular networks to gain Internet access (although we acknowledge that adaptors exist that allow hooking up these devices to the wired Ethernet).
- RLAN enables the adoption of a multiplicity of devices that propel consumer benefit (such as alarm systems).
- Wi-Fi is an integral component of wireless ISPs (called WISPs) that provide broadband connectivity for unserved communities. The contribution to GDP of wireless broadband access materializes through multiple effects: creation of new businesses, increasing productivity of existing enterprises, and growth of average income per household
- The growing integration of digital technologies in the automotive industry is driving increased adoption of Wi-Fi in new use cases yielding consumer benefit.
- Wi-Fi is an integral component of wireless ISPs (called WISPs) that provide broadband connectivity for unserved communities.

4.2.1. Consumer surplus derived from faster broadband speed

Consumer benefit increases if users enjoy faster Internet speeds, which is why they expect to pay more for faster broadband. Therefore, residential Wi-Fi customers are expected to benefit from faster services than those provided by cellular networks, as a counterfactual alternative (see appendix A). It is important to note that this consumer surplus only benefits households with Wi-Fi 6E and those with Internet and Wi-Fi. For example, in 2023, 28.36% of traffic went through Wi-Fi 6E, and there were 5,961,000 households with Internet and Wi-Fi. The impact is calculated by multiplying the additional consumer benefit, the percentage of traffic through Wi-Fi 6E, and the number of households. This results in an impact of $24 million in 2023, increasing to $504 million in 2034 (see Table 4-18).

Table 4-18. Australia: Consumer benefit from faster speed in households with 6 GHz (2023-2027)

Variable	2023	2024	2025	2026	2027	2028	2029	2030
Households that have connections over 150 Mbps (%)	5.60%	6.90%	8.50%	10.47%	12.91%	15.90%	19.59%	24.14%
Percentage of household traffic that goes through Wi-Fi	5.60%	6.90%	8.50%	10.47%	12.91%	15.90%	19.59%	24.14%
Share of traffic affected	5.60%	6.90%	8.50%	10.47%	12.91%	15.90%	19.59%	24.14%
Avg Fixed broadband Speed (Mbps) - connections >150 Mbps (sell)	354	394	439	488	544	605	673	750
Max Download speed using Wi-Fi 6E	1,186	1,186	1,186	1,186	1,186	1,186	1,186	1,186
CAP Avg Fixed broadband Speed (Mbps) - connections >150 Mbps	162	183	205	227	247	266	282	295
Mean speed with no Wi-Fi 6E (Mbps)	162	183	205	227	247	266	282	295
Mean speed with Wi-Fi 6E (Mbps)	169	194	220	247	271	293	313	331
Demand for average download speed (Nevo Curve) (US$)	153.75	156.97	159.86	162.40	164.59	166.43	167.92	169.04
New Demand for average download speed (Nevo Curve) ($)	154.93	158.38	161.57	164.53	167.31	169.97	172.58	175.26
Additional Consumer Benefit with Wi-Fi 6E Yearly ($)	14.18	16.88	20.56	25.63	32.64	42.40	55.95	74.69
Traffic through Wi-Fi 6E (%)	28.36%	50.60%	65.93%	76.51%	83.80%	88.83%	92.30%	94.69%
Households with internet and Wi-Fi (million)	5.96	6.22	6.48	6.73	6.93	6.99	7.06	7.13
Impact (US$ billion)	$24	$53	$88	$132	$190	$263	$365	$504

Sources: FCC; Cisco; Ookla; Nevo et al. (2016); Telecom Advisory Services analysis

As explained above, this benefit could be higher if considering the introduction of Wi-Fi 7 operating under the 6 GHz band.

4.2.2. Home Internet access for devices that lack an Ethernet port

The underlying premise of this analysis is that in the absence of Wi-Fi, users of devices lacking an Ethernet port would have to depend on the cellular network to gain Internet access. For this reason, estimating value would first measure the traffic generated by these devices at home, and then multiply it by the average price charged by cellular carriers. In calculating this benefit, it is important to consider that it is feasible to connect phones and tablets to the Ethernet through adapters. However, three limits should be considered in assessing the remaining number of devices that cannot be hooked up to the Ethernet:

- Most Android devices and newer iPad models will need a USB-C-to-Ethernet adapter, while older Android phones and tablets should require a micro USB-to-Ethernet adapter. In fact, micro USB to Ethernet cannot deliver speeds as fast as USB-C to Ethernet.
- Furthermore, since USB-C adapters are relatively new to be introduced, one has to reduce a portion of the likely universe out of the potential connectivity universe of users.

- Operationally, the user needs to purchase an Ethernet cable, turnoff the Wi-Fi, refresh the Internet page and then access the Internet.

To estimate the traffic of smartphones and tablets, we relied on Cisco and GSMA estimates and extrapolated those growth rates to 2027 considering both the increase in units and the increase in traffic. According to Cisco IBSG (2012), 43.12% of use time of devices that lack an Ethernet port occurs at home.[39] After that, we estimate that 75% of the traffic generated from smartphones and tablets is relying on Wi-Fi connectivity. Accordingly, the portion of Wi-Fi traffic generated at home will reach 249,415 million gigabytes in 2027 (see Table 4-19).

Table 4-19. Australia: Total Wi-Fi Traffic at home from mobile devices (2023-2030)

Variable	2023	2024	2025	2026	2027	2028	2029	2030
Total Annual traffic – Smartphones (billion GB)	21.43	31.19	45.39	59.46	77.88	102.01	133.62	175.03
Total Annual traffic – Tablets (billion GB)	4.84	5.73	6.77	7.20	7.66	8.15	8.67	9,23
Share of traffic at Home (%)	43.12%	43.12%	43.12%	43.12%	43.12%	43.12%	43.12%	43.12%
Share of traffic at Home using Wi-Fi (%)	75.00%	75.00%	75.00%	75.00%	75.00%	75.00%	75.00%	75.00%
Total Traffic at Home – Smartphones (billion GB)	6.93	10.08	14.68	19.23	25.18	32.99	43.21	56.60
Total Traffic at Home – Tablets (billion GB)	1.57	1.85	2.19	2.33	2.48	2.64	2.80	2,98
Total Traffic at Home (billion GB)	8.50	11.94	16.87	21.56	27.66	35.62	46.02	59.59
Average Price per Gb (US$)	$0.45	$0.43	$0.41	$0.39	$0.37	$0.36	$0.34	$0.32
Price per home traffic (US$ million)	$ 3,829	$ 5,133	$ 6,921	$ 8,439	$ 10,332	$ 12,696	$ 15,647	$ 19,331

Sources: Cisco; GSMA Intelligence; Websites of cellular operators; Telecom Advisory Services analysis

If this traffic had to be transported by cellular networks, at the average price per GB estimated previously, it would result in costs of US$3.83 billion in 2023, reaching US$19.33 billion in 2030. That is computed as a benefit to consumers.

4.2.3. Avoidance of inside wiring investment

Residential Wi-Fi allows consumers to avoid paying for wiring to connect all home devices (printers, laptops, storage units, etc.). The average cost of deploying inside wiring in a U.S. residence is approximately US$684 per household[40]. Considering that we estimate 92% of Australian connected households have Wi-Fi in 2023, the avoidance costs of inside wiring for 6.48 million households yields a total savings of US$ 121 million in 2023. To estimate the forward-looking benefit, we only consider the additional value for each year of incremental

[39] While this study is not up to date, our reliance for the analysis indicates a conservative assumption. If one were to adjust this value for the tendency to hybrid work patterns, the share of Wi-Fi traffic at home could be significantly higher. Furthermore, even if the time at home has not changed, the use cases from home have become heavier (e.g., streaming, etc.). Under Wi-Fi, one would assume that the percent of traffic being originated at home has increased.
[40] National average for wiring a 2-room residence with CAT 6. Prices for the US adjusted for the PPP.

households that avoid deploying Ethernet wiring.[41] The net result is a saving of US$ 48 millions in 2030 (See Table 4-20).

Table 4-20. Australia: Consumer surplus from avoidance of investment in in-house wiring (2023-2030)

Variable	2023	2024	2025	2026	2027	2028	2029	2030
Total Wiring Cost	$684.91	$684.91	$684.91	$684.91	$684.91	$684.91	$684.91	$684.91
Households with internet (million)	6.48	6.62	6.75	6.87	6.93	6.99	7.06	7.13
Households with internet and Wi-Fi (%)	92%	94%	96%	98%	100%	100%	100%	100%
Households with internet and Wi-Fi (million)	5.96	6.22	6.48	6.73	6.93	6.99	7.06	7.13
Inside Wiring Costs ($ million) yearly	$4,083	$4,262	$4,438	$4,611	$4,746	$4,788	$4,835	$4,884
Inside Wiring Costs ($ million)	$121	$179	$176	$173	$135	$41	$48	$48

Sources: ACMA; Telecom Advisory Services analysis

4.2.4. Consumer surplus generated by use of residential Wi-Fi devices and equipment

Consumers receive an economic surplus from acquiring Wi-Fi devices at a lower price than their willingness-to-pay for them. The absence of willingness-to-pay data for each piece of equipment makes it very difficult to reliably estimate consumer benefit. To overcome that limitation, a possible approximation is to assume that consumer benefit would equal the producer surplus (see Milgrom et al., 2011). Therefore, we calculate the producer's margin, and attribute that value to the consumer benefit.

The consumer surplus derived from the adoption of residential Wi-Fi devices and equipment focuses on seven consumers products which are intrinsically linked to Wi-Fi: smart home devices and systems such as Wi-Fi speakers and home security systems, home networking systems, Wi-Fi tablets, access points, external adapters, routers, and gateways. Assuming that consumer surplus is roughly equal to producer surplus in six of the seven products (excluding tablets), we estimated local sales in the six product categories in Australia[42]. After computing the sales in Australia, we applied the prorated margin estimated by CSI markets (44.59%) which yields an estimated producer surplus for these products of US$ 1.92 billion in 2023, of which US$ 358 million are linked to the 6 GHz band (802.11ax standard). As anticipated, we assume these to be of the same magnitude as consumer surplus (see Table 4-21).

[41] In the 2021 study, following Tanki (2009) and Milgrom et 1l. (2011), we assumed that the savings in inside wiring were calculated for all Wi-Fi residences **every year**. We decided, based on feedback, to calculate only the benefit of incremental Wi-Fi households, which, obviously, reduces the benefit. This is important to consider in the context of comparability of the 2021 and 2024 studies.

[42] Calculated by prorating data for the United States based on GDP.

Table 4-21. Australia: Economic Value of Wi-Fi enabled consumer products (2023-2030)

Variable	2023	2024	2025	2026	2027	2028	2029	2030
Total sales (US$ million)	5,128	5,294	5,465	5,642	5,824	6,012	6,207	6,407
Gross margin	44.59%	44.59%	44.59%	44.59%	44.59%	44.59%	44.59%	44.59%
Producer surplus ($ million US$)	$ 2,287	$ 2,360	$ 2,437	$ 2,516	$ 2,597	$ 2,681	$ 2,768	$ 2,857
Total Consumer Benefit (US$ million)	$ 2,287	$ 2,360	$ 2,437	$ 2,516	$ 2,597	$ 2,681	$ 2,768	$ 2,857

Sources: Consumer Technology Association; CSI Insight; Telecom Advisory Services analysis

Finally, we must consider that part of those sales corresponds to devices in the 2.4 GHz and 5 GHz bands and the share of equipment in the 6 GHz band. According to IDC, global shipments of consumer devices linked to 6 GHz (802.11ax standard) will represent 39.59% of the shipments from previous generations in 2027. Therefore, the consumer benefit generated by products operating in 2.4 GHz and 5 GHz bands is US$ 1.928 billion in 2023 and US$ 1.137 billion in 2027 (see table 4-9).

Table 4-22. Australia: Economic Value of Wi-Fi enabled consumer products operating in 2.4 GHz and 5 GHz bands (2023-2030)

Variable	2023	2024	2025	2026	2027	2028	2029	2030
Global - Total Wi-Fi 6E or more shipments	15.67%	22.39%	28.72%	34.42%	39.59%	45.52%	52.35%	60.20%
Total Consumer Benefit (US$ million)	$ 2,287	$ 2,360	$ 2,437	$ 2,516	$ 2,597	$ 2,681	$ 2,768	$ 2,857
Total Consumer Benefit (US$ million) 2.4 GHz and 5 GHz	$ 1,928	$ 1,832	$ 1,737	$ 1,650	$ 1,569	$ 1,460	$ 1,319	$ 1,137
Total Consumer Benefit (US$ million) 6 GHz	$ 358	$ 529	$ 700	$ 866	$ 1,028	$ 1,220	$ 1,449	$ 1,720

Sources: Consumer Technology Association; IDC; Telecom Advisory Services analysis

Conversely, the consumer surplus associated to the 6 GHz band increases from US$ 358 million in 2023 and reaches US$ 1,720 in 2030. This estimate is conservative since it does not include the adoption of Wi-Fi 7 devices relying on the 6 GHz band, expected to start launch in 2025.

4.2.5. Bridging the digital divide: use of Wi-Fi to increase coverage in rural and isolated areas

Wi-Fi is an appropriate technology to offer Internet access in rural and isolated areas. The increase in WISP connections is directly related to the growth of connections according to the scenarios differentiating the use of 2.4 and 5 GHz bands versus the 6 GHz band. In this regard, in order to analyze the impact of the standard upgrade on the increase of connections in homes in rural and isolated areas, two main aspects must be established: (i) the number of maximum outdoor channels driving the amount of connections that could be deployed (160MHz for Wi-Fi 6E); and, (ii) the number of connections for the allocation of resource units with which similar speeds can be achieved in both standards (8 connections with 242 RU for Wi-Fi 6E to reach 1,186.27 Mbps).

The calculation of the contribution of unlicensed spectrum to the reduction of the digital divide must subtract the direct impact of WISPs detailed below to avoid double counting. On the other hand, we assume that 70-90% of WISP potential connections may be theoretically served by other technologies (i.e. satellite) covering the same isolated footprint. Thus, we can conservatively expect 10%-30% of broadband subscriptions in remote locations exclusively attributed to WISPs. Once this is done, we calculate the impact on GDP by relying on the coefficient estimated by Katz and Callorda (2024) through regression models that links increase in broadband penetration to economic growth.

The contribution to GDP materializes through two effects: creation of new businesses, and growth of average income per household. ACMA estimates that in 2023 there were 861,914 WISP connections which we project to reach 1,113,000 in 2030. Considering that, WISP generates an increase in the number of broadband connections between 8.4% in 2023 to 9.9% in 2030. If we apply to that growth in the number of connections the coefficient of impact on GDP from Katz and Callorda (2024), we have a total economic impact of WISP from US$ 38 billion in 2023 to US$ 57 billion in 2030. To that number we have to subtract the direct impact (revenues) and also consider that a fraction of those connections would also exist with other technologies. For the 2.4 GHz and 5 GHz band we assume that share of these technologies is 50%, and consequently 50% would be met by WISPs. All in all, we expect a GDP contribution of $18.43 billion in 2023, increasing to $28.11 billion in 2027 (see Table 4-23).

Table 4-23. Australia: Estimation of GDP Contribution derived from reducing the digital divide (2023-2030)

Variable	2023	2024	2025	2026	2027	2028	2029	2030
WISP subscribers (000)	862	924	984	1,035	1,072	1,096	1,108	1,113
Households with Fixed Broadband (000)	6,480	6,620	6,750	6,870	6,930	6,990	7,060	7,131
Households (000)	10,250	10,380	10,512	10,645	10,781	10,918	11,056	11,197
Adoption WISP	8.4%	8.9%	9.4%	9.7%	9.9%	10.0%	10.0%	9.9%
Adoption broadband	63.22%	63.78%	64.21%	64.54%	64.28%	64.02%	63.85%	63.68%
WISP additional	13.30%	13.96%	14.58%	15.06%	15.48%	15.68%	15.69%	15.60%
Impact of fixed broadband adoption in GDP	16.20%	16.20%	16.20%	16.20%	16.20%	16.20%	16.20%	16.20%
GDP (US$ billion)	$ 1,742	$ 1,790	$ 1,863	$ 1,940	$ 2,017	$ 2,096	$ 2,179	$ 2,265
WISP Total impact (US$ billion)	$ 38	$ 40	$ 44	$ 47	$ 51	$ 53	$ 55	$ 57
WISP Revenues (US$ billion)	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1
Share that exist because WISP	50.00%	50.00%	50.00%	50.00%	50.00%	50.00%	50.00%	50.00%
WISP spillovers on GDP (US$ million)	$ 18,431	$ 19,861	$ 21,549	$ 23,205	$ 24,793	$ 26,119	$ 27,186	$ 28,113

Sources: WISPA; IMF; Telecom Advisory Services analysis

The allocation of the full 6 GHz band to unlicensed use would allow WISPs to increase their subscriber base within their same coverage footprint. We follow a conservative approach and consider that the expanded coverage yielded an additional 2%, adjusted by the share of the households that adopt Wi-Fi 6E. In addition, an increase of the user base would allow service providers to lower their operating costs. Thus, by assuming stability in prices, affordability would increase as GDP per capita grows. For conservative purposes we only consider 50% of those affected, given that the other 50% of households could also be connected using an alternative technology, such as satellite. All in all, we estimate an overall increase in WISP connections due to use of the entire 6 GHz of 20,568 connections in 2024 growing to 111,770 connections in 2030, contributing to an increase of approximately 0.90% of the national broadband penetration. Considering the impact coefficient of broadband on the economy, this increase will yield US$ 5.11 billion of GDP contribution in 2030 (See Table 4-24).

Table 4-24. Australia: GDP Contribution derived from reducing the digital divide due to 6 GHz (2023-2030)

Variable	2023	2024	2025	2026	2027	2028	2029	2030
New subscribers due to expanded coverage (%)	2%	2%	2%	2%	2%	2%	2%	2%
New subscribers due to expanded coverage	4,888	9,350	12,974	15,836	17,975	19,469	20,449	21,070
GDP per capita	$ 65,644	$ 66,379	$ 68,014	$ 69,787	$ 71,518	$ 73,345	$ 75,271	$ 77,303
Growth in GDP per capita	0.00%	1.12%	2.46%	2.61%	2.48%	2.55%	2.63%	2.70%
New WISP adoption after price decrease (% households)	8%	9%	10%	11%	11%	11%	11%	11%
Traffic through Wi-Fi 6E (%)	28.36%	50.60%	65.93%	76.51%	83.80%	88.83%	92.30%	94.69%
Increase in WISP connections due to lower prices (households that buy the service)	0	20,568	62,798	81,120	87,570	97,705	105,509	111,770
Share that exist because WISP	70%	70%	70%	70%	70%	70%	70%	70%
Total Increase in WISP connections	4,888	23,748	56,933	72,620	79,274	87,862	94,305	99,309
Increase in national broadband penetration	0.05%	0.23%	0.54%	0.68%	0.74%	0.80%	0.85%	0.89%
Impact of fixed broadband adoption in GDP	16.20%	16.20%	16.20%	16.20%	16.20%	16.20%	16.20%	16.20%
Increase in the GDP due to the new broadband adoption (% GDP)	0.01%	0.06%	0.14%	0.17%	0.19%	0.20%	0.22%	0.23%
Total impact in GDP (US$ million)	$ 213	$ 1,040	$ 2,546	$ 3,323	$ 3,738	$ 4,269	$ 4,715	$ 5,109

Sources: World Bank; ACMA; Katz and Callorda (2024); Telecom Advisory Services analysis

While not included in the assessment of 6 GHz economic value, it is estimated that the impact on coverage of Wi Fi 7 operating in the 6 GHz band will be 37.50% higher than in the previous case.

* * * * *

To sum up, as a key component of residential infrastructure, Wi-Fi drives economic contribution at multiples levels:

- Wi-Fi devices operating in the 6 GHz band, provide faster than mobile broadband device interfacing, driving a total consumer surplus of $130.10 million in 2024 increasing to $658.33 million in 2034.
- In the absence of Wi-Fi, users of devices lacking an Ethernet port, such as smartphones and tablets, would have to depend on the cellular network to gain Internet access (although we acknowledge that adaptors exist that allow hooking up these devices to the wired Ethernet). If this traffic had to be transported by cellular networks, it would result in a consumer saving of $5.13 billion in 2024, reaching US$45.82 billion in 2034.
- Wi-Fi represents an infrastructure that supports in-home device connectivity avoiding the need to deploy Ethernet cable in each room, an expensive proposition. Considering the additional annual value of incremental households that avoid deploying Ethernet wiring, results in consumer savings of US$ 179 million in 2024.
- Wi-Fi enables the adoption of a multiplicity of devices that propel consumer benefit (such as alarm systems). The consumer benefit associated with the adoption of devices operating in all Wi-Fi standards in 2.4 GHz, 5 GHz, and 6 GHz bands yields a consumer surplus equivalent to US$ 2.36 billion in 2024 and US$ 3.24 billion in 2034.
- Wi-Fi is an integral component of wireless ISPs (called WISPs) that provide broadband connectivity for unserved communities. The contribution to GDP of wireless broadband access materializes through multiple effects: creation of new businesses, increasing productivity of existing enterprises, and growth of average income per household, reaching US$ 20.90 billion in 2024 and US$ 37.97 billion in 2034.

4.3. Enterprise Wi-Fi

Beyond the impact on consumers, Wi-Fi also contributes significant economic value in the Australian enterprise segment. This section provides estimates in seven areas:

- Benefits derived from an increase in average speed: the improvements of average download speed for enterprises as a result of using Wi-Fi within in-building connectivity.
- Benefits derived from reduced latency: The total improvements of latency from Wi-Fi, principally from Wi-Fi 6E, for enterprises.
- Savings in business Internet traffic transmitted through Wi-Fi: Total Wi-Fi enterprise savings results from wireless traffic that is routed through Wi-Fi access points.
- Avoidance of campus and enterprise facilities inside wiring.
- Enhanced IoT deployment: the spillover impact of Wi-Fi enabled IoT terminals.
- Deployment of Augmented Reality/Virtual Reality solutions: the adoption of AR/VR among Australian business has a spillover effect on productivity, thereby contributing to the growth of GDP.
- Energy productivity: the total energy consumption reduction from Wi-Fi is projected to escalate dramatically.
- Deployment of Augmented Reality/Virtual Reality solutions.

4.3.1. Benefits derived from an increase in average speed

Since Wi-Fi accessibility allows, in general, faster access to the Internet than cellular networks do, higher speeds have a positive contribution on the economy in terms of increased overall efficiency and innovation. This contribution is measured in terms of economic growth.

As described in the area of consumer benefit of Wi-Fi impact operating in the 2.4 GHz and 5 GHz bands, we assume, for conservative purpose, no impact, given Wi-Fi technological limitations. These constraints create a discrepancy between the fixed broadband purchased speed and the actual speed delivered at the device level. As a result, while the theoretical maximum speeds of Wi-Fi might be high, real-world factors such as network congestion, signal interference, and device capabilities mean that the actual speeds experienced by users are often lower, thereby affecting the overall performance and reliability of Wi-Fi connections.

On the other hand, household residences benefit from Wi-Fi 6E additional speeds if the fixed line acquired is higher than 150 Mbps and the router is based on that standard. In the present section we utilize the speeds estimates in section 4.1.2 to analyze the benefit on GDP. The economic benefit of higher internet speeds is addressed in the enterprise section because we assume that the economic impact primarily stems from increased labor productivity and overall efficiency in business locations. Enhanced internet speeds facilitate more efficient remote work, reduced downtime, and more efficient communication and collaboration. As a result, the productivity gains experienced by workers translate into broader economic benefits, which are then reflected in the enterprise sector's performance and growth.

To translate the increase in speed with Wi-Fi 6E into GDP growth, we rely on the results of the econometric model explained in Appendix B. This model quantifies the relationship between quality improvement in fixed broadband with its economic effect. In this way, after calculating the difference in average download speed attributed to Wi-Fi 6E, the additional contribution to the Australian GDP will yield $11.609 billion in 2030 (see table 4-20).

Table 4-20. Australia: Estimation of speed differential due to Wi-Fi 6E (2023-2030)

Variable	2023	2024	2025	2026	2027	2028	2029	2030
Mean speed with no Wi-Fi 6E (Mbps)	162	183	205	227	247	266	282	295
Mean speed with Wi-Fi 6E (Mbps)	169	194	220	247	275	306	339	376
Speed increase due to Wi-Fi 6E (%)	5%	6%	7%	9%	11%	15%	20%	28%
Impact speed on GDP	1.96%	1.96%	1.96%	1.96%	1.96%	1.96%	1.96%	1.96%
Increase in GDP	0.09%	0.11%	0.14%	0.17%	0.22%	0.29%	0.39%	0.54%
Traffic through Wi-Fi 6E (%)	28.36%	50.60%	65.93%	76.51%	83.80%	88.83%	92.30%	94.69%
GDP increase ($ million)	$459	$1,006	$1,672	$2,540	$3,726	$5,419	$7,900	$11,609

Sources: Ookla Speedtest; Telecom Advisory Services analysis

4.3.2. Benefits derived from reduced latency

Reducing latency enhances the efficiency and responsiveness of various applications and services. Lower latency improves the performance of real-time applications such as telemedicine, online education, and remote work, facilitating better access to essential services and reducing disparities caused by geographical barriers. In the economic sector, reduced latency boosts productivity by enabling faster and more reliable data transmission, critical for industries like finance, manufacturing, and logistics. Overall, minimizing latency fosters greater innovation, economic growth, and social inclusion by ensuring that technology can meet the demands of an increasingly digital and interconnected world. In the present section we estimate that impact.

In this section, we measure the latency gains from using Wi-Fi rather than relying on mobile broadband. We estimate, using historical Ookla Speedtest data, that in Australia average Wi-Fi latency decreased from 11.00 Ms in 2023 to 10.00 Ms in 2024 and is projected to decline to 9.16 ms by 2030. On the other hand, mobile networks latency also dropped from 22.00 Ms to 21.00 Ms between 2023 and 2024 and is projected to reach 17.51 Ms in 2030. Considering that the percentage of household traffic going through Wi-Fi will increase from 71% in 2023 to 74% in 20230, we forecast a latency reduction due to Wi-Fi ranging from -38% to -35%.

To estimate the economic impact of latency reduction, we developed an econometric model linking the improvement in speed and latency to GDP (see details in Appendix D). According to the model, we estimate that the increase in GDP due to reduced latency is 4.50%. Considering that the traffic through in the 2.4 GHz and 5 GHz bands decreases over the years, the resulting GDP contribution due to latency reduction is US$20,016 million in 2023, declining to US$1,918 million in 2027 (see table 4-21).

Table 4-21. Australia Estimation of latency reduction due 2.4 GHz and 5 GHz bands (2023-2030)

Variable	2023	2024	2025	2026	2027	2028	2029	2030
Average Latency using Wi-Fi (Ms)	11.00	10.00	9.86	9.71	9.57	9.43	9.30	9.16
Average Latency using mobile network (Ms)	22.00	21.00	20.37	19.77	19.18	18.60	18.05	17.51
Percentage of household traffic that goes through Wi-Fi	71%	72%	72%	73%	73%	73%	74%	74%
Average Latency with no Wi-Fi (Ms)	22	21	20	20	19	19	18	18
Average Latency using Wi-Fi (Ms)	14	13	13	12	12	12	12	11
Latency reduction (%)	-36%	-38%	-37%	-37%	-37%	-36%	-36%	-35%
Impact of latency in GDP	4.50%	4.50%	4.50%	4.50%	4.50%	4.50%	4.50%	4.50%
Increase in GDP	1.60%	1.69%	1.68%	1.66%	1.65%	1.63%	1.61%	1.59%
GDP (US$ billion)	$ 1,742	$ 1,790	$ 1,863	$ 1,940	$ 2,017	$ 2,096	$ 2,179	$ 2,265
Traffic through Wi-Fi 6 or less	72%	49%	34%	23%	16%	11%	8%	5%
GDP increase (US$ million)	$ 20,016	$ 14,956	$ 10,643	$ 7,576	$ 5,379	$ 3,816	$ 2,706	$ 1,918

Sources: OOkla Speedtest; IMF; Telecom Advisory Services analysis

When comparing Wi-Fi in the 6 GHz band versus 2.4 GHz and 5 GHz, latency diminishes by 40% (see detail calculation in Appendix C). This significant reduction translates to enhanced performance and user experience across various applications and services. Table 4-21 analyzes the economic impact of this latency reduction from 2023 to 2030. The analysis begins by estimating the share of traffic that could be affected by that improvement (i.e., the traffic through the 6 GHz band, considering the share of household traffic that goes through Wi-Fi). When considering all connections, the overall latency reduction due to Wi-Fi 6E varies, starting at 6% in 2023, increasing to 12% in 2025, and then reducing to 8% by 2027 (due to the substitution from Wi-Fi 6E to Wi-Fi 7). By relying on the same methodology as in the previous section, we obtain that the corresponding increase is US$ 6,338 million in 2023, rising to $28,685 million in 2030 (see table 4-22).

Table 4-22. Australia: Estimation of latency differential due to the 6 GHz band (2023-2030)

Variable	2023	2024	2025	2026	2027	2028	2029	2030
Percentage of household traffic that goes through Wi-Fi	71.24%	71.68%	72.12%	72.56%	72.99%	73.42%	73.84%	74.26%
Traffic through Wi-Fi 6E	28.36%	50.60%	65.93%	76.51%	83.80%	88.83%	92.30%	94.69%
Latency reduction due to Wi-Fi 6E	40.00%	40.00%	40.00%	40.00%	40.00%	40.00%	40.00%	40.00%
Latency reduction due to Wi-Fi 6E (Considering all connections)	8%	15%	19%	22%	24%	26%	27%	28%
Impact latency on GDP	4.50%	4.50%	4.50%	4.50%	4.50%	4.50%	4.50%	4.50%
Increase in GDP	0.36%	0.65%	0.86%	1.00%	1.10%	1.17%	1.23%	1.27%
GDP increase ($ million)	$6,338	$11,697	$15,960	$19,404	$22,222	$24,627	$26,750	$28,685

Sources: Ookla Speedtest; IMF; Telecom Advisory Services analysis

As a side note, we should mention that Wi-Fi 7 operating in the 6 GHz band offers substantial improvements in latency compared to Wi-Fi 6E, creating even greater economic potential.

4.3.3. Savings in business Internet traffic transmitted through Wi-Fi

As expected, Australian corporations generate substantial wireless Internet traffic. Using the last Cisco estimate we project 14,258 million GB of internet traffic for 2023. Wi-Fi enterprise savings results from wireless traffic that is routed through Wi-Fi access points rather than cellular networks. Considering Cisco projections, we estimate that total business Internet traffic will reach 56,148 million GB in 2030, of which 34,162 million GB will be transported through Wi-Fi access points. Considering the average price per GB transported by cellular carriers, savings from Wi-Fi will reach US$ 11.08 billion, assuming the amount of data consumed would stay constant[43] (see table 4-23).

Table 4-23. Australia: Savings in business wireless traffic (2023-2030)

Variable	2023	2024	2025	2026	2027	2028	2029	2030
Share of Business Internet Traffic by Wi-Fi	59.40%	59.61%	59.81%	60.02%	60.22%	60.43%	60.64%	60.84%
Total Business Internet Traffic (billion GB)	14.256	17.342	21.093	25.655	31.204	37.954	46.163	56.148
Total GB Wi-Fi enterprise traffic (billion GB)	8,470	10,337	12,616	15,398	18,792	22,935	27,991	34,162
Average Price per GB	$0.45	$0.43	$0.41	$0.39	$0.37	$0.36	$0.34	$0.32
Economic Impact (US$ billion)	$ 3,818	$ 4,445	$ 5,177	$ 6,028	$ 7,019	$ 8,174	$ 9,518	$ 11,083

Sources: Cisco; Websites of cellular operators; Telecom Advisory Services analysis

[43] We acknowledge that enterprises are likely to negotiate wireless rates lower than those offered in the consumer market; however, data in this area is not available.

The deployment of the latest enterprise applications will generate an exponential growth in data traffic that will be handled by devices operating in unlicensed spectrum, through the combination of the existing bands and the 6 GHz band using Wi-Fi 6E. In 2019, an updated Cisco traffic forecast based on the explosion of IoT and AR/VR applications, among other factors, increased the estimates of future total business Internet traffic. We assume that part of the growth was driven by "natural" growth (that is to say, the extrapolation of historical growth rate by averaging the growth rate between 2018 and 2019 and between 2017 and 2018), and another portion was triggered by Wi-Fi traffic stimulated by changes in 6 GHz using Wi-Fi 6E. The sum of the difference due to broader Wi-Fi traffic between will reach US$ 248 million in 2030 (see Table 4-24).

Table 4-24. Australia: Savings in business wireless traffic due to 6 GHz band (2023-2030)

Variable	2023	2024	2025	2026	2027	2028	2029	2030
Share of Business Internet Traffic by Wi-Fi	63.00%	63.00%	63.00%	63.00%	63.00%	63.00%	63.00%	63.00%
Total Business Internet Traffic (billion GB)	14.747	18.246	22.575	27.932	34.560	42.761	52.907	65.461
Total GB Wi-Fi enterprise traffic (billion GB)	9.290	11.495	14.222	17.597	21.773	26.939	33.331	41.241
Total (US$ billion)	$4.187	$4.943	$5.836	$6.889	$8.133	$9.601	$11.334	$13.379
Difference between the 2 estimations (US$ million)	$369.77	$497.81	$659.03	$861.10	$1,113.30	$1,426.95	$1,815.74	$2,296.30
Difference because natural growth (US$ million)	$329.91	$444.14	$587.99	$768.27	$993.29	$1,273.12	$1,620.00	$2,048.75
Difference due to Wi-Fi 6E (US$ million)	$39,86	$53.66	$71.04	$92.83	$120.02	$153.83	$195.74	$247.54

Sources: Cisco; Telecom Advisory Services analysis

Wi-Fi 7 is expected to achieve even greater improvement in efficiency and quality of business internet traffic compared to its predecessors. Based on our technical analysis (see Appendix C), we estimate an incremental benefit of 60% over the existing benefits of Wi-Fi 6E. This substantial enhancement in traffic management and efficiency is projected to result in significant economic impacts.

4.3.4. Avoidance of enterprise building inside wiring

Similar to residential Wi-Fi savings due to capital investment avoidance in inside wiring, we take the total number of business establishments are equipped with Wi-Fi access points and multiply this value by a standard cost of deploying a CAT 6 network (US$2,200 per building). We only consider the savings due to the yearly increase in the number of connections, so we estimate a producer surplus of US$114 million in 2023, and US$242 million in 2030 (See Table 4-25).

Table 4-25. Australia: Savings in business wiring CAPEX (2023-2030)

Variable	2023	2024	2025	2026	2027	2028	2029	2030
Total Wiring Cost (*)	$2,283	$2,283	$2,283	$2,283	$2,283	$2,283	$2,283	$2,283
Number of establishments (million)	2.590	2.677	2.767	2.860	2.956	3,056	3.158	3,264
Establishments with Wi-Fi (%)	100%	100%	100%	100%	100%	100%	100%	100%
Establishments with Wi-Fi (million)	2.590	2.677	2.767	2.860	2.956	3,056	3.158	3,264
Inside Wiring Costs (US$ million)	$5,913	$6,112	$6,317	$6,529	$6,749	$6,976	$7,210	$7,453
Inside Wiring Costs, Yearly increase (US$ million)	$114	$199	$205	$212	$220	$227	$235	$242

(*) Wiring costs assumed to be stable in the future based on the trend between the 2018 and 2020.
Sources: Australia Bureau of Statistics; Telecom Advisory Services analysis

4.3.5. Enhanced IoT Deployment

IoT adoption has a contribution to GDP growth through the multiplicity of use cases that improve efficiency in processes such as preventive maintenance, production monitoring and the like. To estimate this, we rely on a coefficient of GDP impact calculated through an aggregate simple production function which estimates that a 10% rise in M2M connections results in annual increases in GDP of 0.7%[44].

The key methodological objective to apply the impact coefficient is to determine what is the increase year-on year in Wi-Fi enabled IoT connections. Unfortunately, we lack this indicator, although we have three related ones:

- The difference between two forecasts of M2M connections from the same source (GSMA Intelligence, 2024)
- The difference in yearly forecasts of M2M connections (GSMA Intelligence)
- The percent of IoT installed base that is supported by Wi-Fi, which is 31% (IoT Analytics (2023)). In addition, this source indicates that the CAGR for the Wi-Fi IoT connected devices is expected to be 16% between 2022 and 2027.[45]

The number of M2M is an adequate proxy for the level of development of the IoT market. M2M terminals are often isolated, stand-alone networked equipment. IoT systems take M2M to the next level, bringing together disparate systems into one large, connected ecosystem. While not totally equivalent, the M2M variable provides a fairly good quantitative indicator.

Starting with a 2023 installed base of 12,881,293M2M connections, we estimated that higher Wi-Fi speeds explain the growth from 10,968,619 connections based on previous M2M estimations for 2023 (a 17.43% increase). According to this metric, we are assuming that the percentage change in Wi-Fi enabled IoT (or in this case M2M) devices is related to the difference between both forecasts. A second approach may be to consider the yearly difference between the number of M2M connections for Australia, considering the growth rate between the 12,895,652 million M2M connections projected for 2024 against the 15,144,356 million from the 2023 forecast. A third alternative approach is available, relying on IoT Analytics projections of a worldwide CAGR for Wi-Fi M2M devices of 16%. That

[44] See Frontier Economics (2018)
[45] Retrieved in: https://iot-analytics.com/number-connected-iot-devices/

alternative has several problems: First, it is a global rather than US value. Second, we lack the base of total IoT terminals against which we can calculate the number of terminals that are Wi-Fi enabled. We decided to rely on the first approach, although, cognizant of its limitations, we will provide the results of the second and the third approximation to demonstrate that the first one provides a more conservative Wi-Fi value estimate.

Regarding the first approach, we calculate the incremental number of devices between both estimates from GSMA Intelligence, apply the coefficient of GDP impact of 0.7%. In this way, the impact on GDP, expressed as a percentage, grows from 0.29% in 2023 to 0.75% in 2027. The annual economic impact, calculated as a product of GDP impact and GDP itself, ranges from $77.99 billion in 2023 to $234.70 billion in 2027 (see table 4-26).

Table 4-26. Australia: GDP Contribution of IoT Deployment due to Wi-Fi (2023-2030)

Variable	2023	2024	2025	2026	2027	2028	2029	2030
Connections, M2M (2021 est.) (million)	10.97	12.90	14.40	15.30	16.10	16.77	17.25	17.50
Connections, M2M (2024 est.) (million)	12.88	15.14	16.91	17.97	18.91	19.69	20.25	20.55
Incremental	17.44%	17.44%	17.44%	17.44%	17.44%	17.44%	17.44%	17.44%
Impact of 100% M2M Growth on GDP	3.00%	3.00%	3.00%	3.00%	3.00%	3.00%	3.00%	3.00%
Impact on GDP (%)	0.52%	0.52%	0.52%	0.52%	0.52%	0.52%	0.52%	0.52%
GDP (US$ billion)	$1,742	$1,790	$1,863	$1,940	$2,017	$2,096	$2,179	$2,265
Annual Impact (US$ billion)	$9,112	$9,366	$9,747	$10,151	$10,551	$10,966	$11,398	$11,847

Sources: GSMA Intelligence; Frontier Economics; IMF; Telecom Advisory Services analysis

In tale 4-26, we estimated the total impact of M2M connections, considering all categories of Wi-Fi. Now, we break down the effect for Wi-Fi operating in the 2.4 GHz and 5 GHz bands. To account for the differential impact by frequency bands, we considered a decline in traffic as a result of diminishing impact of Wi-Fi 6 or lower standards. This results in a decrease in GDP contribution from US$ 6.528 billion in 2023 to US$ 0.629 billion in 2030 (See Table 4-27).

Table 4-27. Australia: GDP Contribution of IoT Deployment in 2.4 GHz and 5 GHz bands (2023-2030)

Variable	2023	2024	2025	2026	2027	2028	2029	2030
Connections, M2M (2021 est.)	10.97	12.90	14.40	15.30	16.10	16.77	17.25	17.50
Connections, M2M (2024 est.)	12.88	15.14	16.91	17.97	18.91	19.69	20.25	20.55
Incremental	17.44%	17.44%	17.44%	17.44%	17.44%	17.44%	17.44%	17.44%
Impact of 1% M2M Growth on GDP	3.00%	3.00%	3.00%	3.00%	3.00%	3.00%	3.00%	3.00%
Impact on GDP (%)	0.52%	0.52%	0.52%	0.52%	0.52%	0.52%	0.52%	0.52%
GDP ($ billion)	$1,742	$1,790	$1,863	$1,940	$2,017	$2,096	$2,179	$2,265
Annual Impact (US$ billion)	$9,112	$9,366	$9,747	$10,151	$10,551	$10,966	$11,398	$11,847
Traffic through Wi-Fi 6 or lower	71.64%	49.40%	34.07%	23.49%	16.20%	11.17%	7.70%	5.31%
Impact (US$ billion)	$6,528	$4,627	$3,321	$2,385	$1,709	$1,225	$878	$629

Sources: GSMA Intelligence; Frontier Economics; IMF; Telecom Advisory Services analysis

For estimating the effect in the 6 GHz band, we first break down the effect for Wi-Fi 6E using the 6 GHz band. We estimate that the use of Wi-Fi 6E along all Wi-Fi categories varies from 28.36% in 2023 to 94.69% in 2030, with its impact ranging from US$ 2.58 million in 2023 to US$11.22 million in 2030 (see Table 4-28).

Table 4-28. Australia: GDP Contribution of IoT Deployment Boost caused by 6 GHz (2023-2030)

Variable	2023	2024	2025	2026	2027	2028	2029	2030
Wi-Fi 6E share (%)	28.36%	50.60%	65.93%	76.51%	83.80%	88.83%	92.30%	94.69%
Impact (US$ million)	$2,584	$4,739	$6,427	$7,766	$8,842	$9,741	$10,520	$11,217

Sources: GSMA Intelligence; Frontier Economics; IMF; Telecom Advisory Services analysis

4.3.6. Deployment of Augmented Reality/Virtual Reality solutions

The adoption of AR/VR among Australian businesses has a spillover effect on productivity, thereby contributing to the growth of GDP. Estimating spillover effects of AR/VR is not a trivial exercise considering the embryonic adoption of some of these use cases. Since the objective is to estimate the spillover effect of AR/VR sales by Australian firms in the domestic market, we will take as points of departure the estimate by PwC of the total GDP contribution of AR/VR, and the sales of AR/VR components as estimated by Statista. These two parameters allow estimating the indirect (spillover) contribution of AR/VR to the Australian economy for the period under analysis. Starting with the total estimated impact for AR/VR provided by PwC, we then subtract the portion attributable to Wi-Fi 6 or lower technologies. Next, we deduct the direct impact of AR/VR, which yields the total indirect impact figure.

To maintain a conservative approach, we assume that the indirect impact does not exceed the direct impact. If we do not consider this restriction, the indirect impact of AR/VR is projected to be $423.7 million in 2023, to $2,547.2 million in 2030[46]. But if we apply the restriction, the indirect impact could as high be the same as the direct impact, the contribution in million US dollars is projected to be $366.2 million in 2023, to $442.07 million in 2030 (See Table 4-29).

Table 4-29. Australia: GDP contribution resulting from AR/VR spillovers (2023-2030)

Variable	2023	2024	2025	2026	2027	2028	2029	2030
Spending in AR/VR - Hardware ($ billion)	$0.27	$0.45	$0.56	$0.62	$0.67	$0.71	$0.76	$0.81
Spending in AR/VR - Software, Contents, Services ($ billion)	$0.87	$0.80	$0.80	$0.87	$0.96	$1.07	$1.19	$1.26
Total Spending in AR/VR ($ billion)	$1.14	$1.25	$1.36	$1.49	$1.63	$1.78	$1.95	$2.08

[46] Considering the latest available applications of AR/VR and their projections up to 2027, such as immersive educational tools, advanced virtual training environments, and enhanced remote collaboration platforms, we believe that the restriction preventing the indirect effect from exceeding the direct effect should not be applied. However, to maintain comparability with the previous study and to generate conservative results, we will adhere to this restriction.

Share attributable to Wi-Fi (Wi-Fi 6 or less)	32.18%	30.88%	29.32%	27.76%	26.21%	24.61%	22.97%	21.28%
Direct Impact Wi-Fi 6 or less ($ billion), spending	$0.37	$0.38	$0.40	$0.41	$0.43	$0.44	$0.45	$0.44
Total Impact on GDP ($ billion)	$2.46	$3.62	$5.34	$7.08	$9.39	$12.46	$13.23	$14.04
Share attributable to Wi-Fi (Wi-Fi 6 or less)	32.18%	30.88%	29.32%	27.76%	26.21%	24.61%	22.97%	21.28%
Total Impact (Wi-Fi 6 or less)	$0.79	$1.12	$1.56	$1.97	$2.46	$3.07	$3.04	$2.99
Indirect impact ($ million)	$424	$733	$1,165	$1,552	$2,035	$2,629	$2,591	$2,547
Indirect / direct impact	1.16	1.91	2.92	3.75	4.77	6.00	5.79	5.76
Max indirect/direct	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Annual Indirect Impact ($ million)	$366	$384	$399	$414	$427	$438	$448	$442

Sources: Statista; PwC; Telecom Advisory Services analysis

Higher throughput enabled by the allocation of the 6 GHz band is expected to spur further adoption and use of AR/VR among enterprises, hence increasing the associated spillover effects. By relying on the ratio built from 5 GHz and 6 GHz AR/VR related products, we were able to isolate the specific economic contribution of the new spectrum allocation.

Following a similar procedure as the one described in the section above, spillovers from AR/VR attributed to the 6 GHz band will account for US$ 392 million in 2023 and are expected to increase by 2030 to US$ 3.76 billion (see Table 4-30).

Table 4-30. Australia: GDP contribution resulting from AR/VR spillovers due to the 6 GHz band (2023-2030)

Variable	2023	2024	2025	2026	2027	2028	2029	2030
Impact on the 2.4 GHz and 5 GHz bands	106.97%	115.66%	127.12%	139.86%	154.12%	170.62%	189.95%	212.88%
Impact of the 6 GHz band (US$ billion)	$392	$445	$508	$578	$658	$748	$850	$941

Sources: Statista; PwC; Telecom Advisory Services analysis

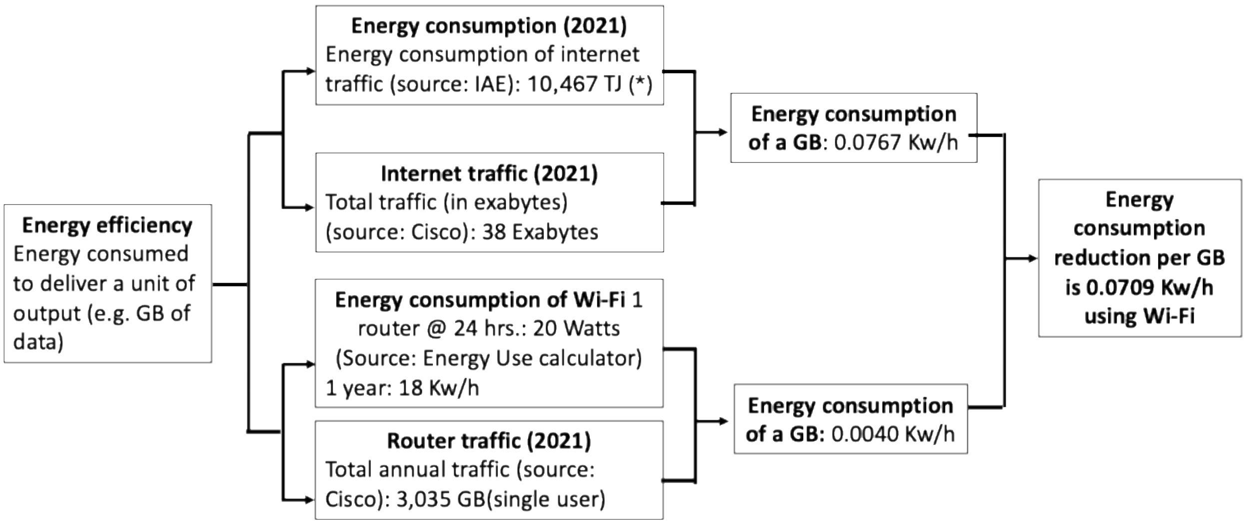
4.3.7. Wi-Fi and energy efficiency

Wi-Fi technology offers a significant advantage over alternative technologies in terms of energy efficiency.[47] Unlike other technologies that may consume more energy for data transmission, Wi-Fi is designed to provide high-speed internet access while minimizing energy usage. This efficiency is crucial in an era where the volume of internet traffic is exponentially increasing, necessitating solutions that can handle large data loads without proportional increases in energy consumption.

[47] See Kroon, P., Godlovitch, I. and Plückebaum, Th. (2023). *Sustainability benefits of 6 GHz Spectrum Policy*. Bad Honnef: WIK Consult.

The present analysis demonstrates the energy savings achieved through the use of Wi-Fi (see figure 5-1).

Figure 5-1. Comparative analysis of energy consumption per GB



(*) 1 Terajoule = 277778 Kw/h
Sources: International Energy Agency; Cisco; Telecom Advisory Services analysis

In 2023, the total energy consumption of internet traffic in Australia is estimated at 10,467 TJ, translating to 2,907,533,357 kW/h. With a total internet traffic of 38 Exabytes, or 37,910,000,000 GB, the energy consumption per GB stands at 0.0767 kW/h. When considering Wi-Fi, the annual energy consumption is significantly lower, at 18 kW/h, resulting in an energy consumption per GB of just 0.0040 kW/h in 2023, decreasing further to 0.0013 kW/h by 2030 (due to the increase in data usage).

The cost reduction per GB, calculated as the difference between the energy consumption per GB of internet traffic and Wi-Fi, indicates substantial savings, increasing from 0.0727 kW/h in 2023 to 0.0754 kW/h in 2030. With the number of households using internet and Wi-Fi expected to grow from 5,961,600 in 2023 to 7,130,701 in 2030, the total energy consumption reduction is projected to escalate dramatically, from 1,908,396,159 kW/h in 2023 to 8,703,509,131 kW/h in 2027. This reduction underscores the critical role of Wi-Fi in enhancing energy productivity and highlights the significant economic and environmental benefits of adopting energy-efficient internet technologies (see Table 4-31).

Table 4-31. Australia: Wi-Fi energy saving (2023-2030)

Variable	2023	2024	2025	2026	2027	2028	2029	2030
Energy consumption of internet traffic (TJ)	10,467	10,467	10,467	10,467	10,467	10,467	10,467	10,467
Energy consumption of internet traffic (million Kw/h)	2,908	2,908	2,908	2,908	2,908	2,908	2,908	2,908
Total traffic (Exabytes)	38	38	38	38	38	38	38	38
Total traffic (million GB)	37,910	37,910	37,910	37,910	37,910	37,910	37,910	37,910
Energy consumption of a GB (Kw/h)	0.0767	0.0767	0.0767	0.0767	0.0767	0.0767	0.0767	0.0767
Energy consumption of Wi-Fi (1 year) Kw/h	18	18	18	18	18	19	20	21
Total annual traffic (GB per user)	4,402	5,302	6,386	7,691	9,263	11,156	13,436	16,182
Energy consumption of a GB (Kw/h) with Wi-Fi	0.0040	0.0033	0.0027	0.0023	0.0019	0.0017	0.0015	0.0013
Cost Reduction per GB	0.0727	0.0734	0.0740	0.0744	0.0748	0.0750	0.0752	0.0754
Households with internet and Wi-Fi (000)	5,962	6,223	6,480	6,733	6,930	6,990	7,060	7,131
Energy consumption reduction (million Kw/h)	1,908	2,421	3,060	3,853	4,802	5,851	7,137	8,704

Sources: IAE; CISCO; Telecom Advisory Services analysis

* * * * *

In summary, Wi-Fi also contributes significant economic value in the US enterprise segment:

- Benefits derived from an increase in average speed. The improvements of average download speed for enterprises as a result of using Wi-Fi within in-building connectivity are estimated at US$ 1,006 million in 2024 and projected to reach US$ 50.12 billion in 2034.
- Benefits derived from reduced latency. The total improvements of latency from Wi-Fi for enterprises are estimated at US$ 26.65 billion in 2024, reaching US$ 36.18 billion in 2034.
- Savings in business Internet traffic transmitted through Wi-Fi. Total Wi-Fi enterprise savings results from wireless traffic that is routed through Wi-Fi access points is estimated to have reached US$ 4.50 billion in 2024 and will amount to US$ 20.98 billion in 2034.
- Avoidance of campus and enterprise facilities inside wiring: Similar to residential Wi-Fi savings due to capital investment avoidance in inside wiring, we assume that the total number of business establishments are equipped with Wi-Fi access points and consider only the savings due to the yearly increase in the number of connections, yielding a producer surplus of US$199 million in 2024, and US$277 million in 2034.
- Enhanced IoT deployment. It is conservatively estimated that the spillover impact of Wi-Fi enabled IoT terminals is estimated at US$ 9.37 billion in 2024 and will grow to reach US$ 13.83 billion in 2034.
- Deployment of Augmented Reality/Virtual Reality solutions: the adoption of AR/VR among U.S. business has a spillover effect on productivity, thereby contributing to the growth of GDP. Total spillovers driven by successive generation of Wi-Fi standards are estimated to reach US$ 13.29 billion in 2034.

- Wi-Fi technology offers a significant advantage over alternative technologies in terms of energy efficiency. Considering the number of Australian households accessing the internet and Wi-Fi residences expected to grow from 6,222,800 in 2024 to 7,420,600 in 2034, the total energy consumption reduction is projected to escalate dramatically, from 2,421 million kW/h in 2024 to 19,196 kW/h in 2034.

4.4. Unlicensed spectrum and Internet Service Providers

In addition to the economic value generated by the sources analyzed above, RLANs will also contribute to either producer surplus or GDP of Internet Service Providers. This section will assess the economic value within three sources:

- Producer surplus of cellular operators resulting from CAPEX savings incurred in network deployment and operations
- Revenues of Wi-Fi carriers offering service in public spaces
- Revenues of Wireless ISPs (this effect differs from the GDP impact of WISPs as a result of their deployment in rural and isolated areas, assessed in section 4.5)

4.4.1. Cellular network CAPEX savings from off-loading traffic to RLANs

The value of cellular off-loading decreases the total cost of ownership by using RLANs to complement cellular networks, thereby limiting the need for future capacity increases. While the economic advantage of off-loading varies substantially by topography and size of the urban environment, carrier-grade RLAN sites are considerably less expensive than cellular network equipment with similar capacity.

Based on interviews, we estimate that cellular networks CAPEX savings by relying on Wi-Fi for off-loading traffic is 8.07% in 2023, growing to 8.44% in 2030[48] by relying on the 6 GHz band. This amounts to savings ranging from $ 3,768 million in 2023, to $ 3,527 million in 2030 (See Table 4-32).

Table 4-32. Australia: Cellular network CAPEX savings by off-loading traffic to Wi-Fi using Wi-Fi 6E (2023-2030)

Variable	2023	2024	2025	2026	2027	2028	2029	2030
Total mobile CAPEX (US$ billion)	$1,860	$1,687	$1,692	$1,716	$1,739	$1,743	$1,727	$1,712
Share of traffic off-load	8.07%	8.10%	8.13%	8.18%	8.24%	8.31%	8.38%	8.44%
Total CAPEX savings by traffic off-loading (US$ billion)	$150	$137	$138	$140	$143	$145	$145	$145

Sources: GSMA Intelligence; Telecom Advisory Services analysis

We consider these benefits to be conservative since the introduction of Wi-Fi 7 operating in the 6 GHz band significantly enhances data transmission efficiency compared to previous technologies.

[48] We estimate that traditional MNOs off-load 8% of their traffic and cable operators off-load 10% of their traffic, with the overall off-load a weighted average of these two percentages with weights based on the connection shares of these two segments of the industry.

4.4.2. Revenues of Wi-Fi based Public Internet Service Providers

The economic value generated by Wi-Fi carriers is calculated from the sum of revenues collected by public Wi-Fi-based service providers operating within transit hubs and other public venues. These revenues are being considered as contributions to the Australian GDP.

To estimate the total revenues of these providers, we start by calculating the number of commercial Wi-Fi hotspots in Australia. According to WIMAN, in 2023 there were approximately 60,000 commercial Wi-Fi hotspots, which are estimated to decrease to 30,000 in 2030 as a consequence of substitution from either free sites or mobile broadband. Based on revenue figures from financial statements and the number of hotspots deployed by a publicly traded company in the U.S., we estimate an average revenue figure per hotspot. By extrapolating that amount to the overall number of paid Wi-Fi hotspots in the country, we estimate total revenues generated by this sector in Australia to be US$ 39 million in 2023, gradually decreasing to US$ 15 million in 2030 (Table 4-33).

Table 4-33. Australia: Revenues of Wi-Fi carriers (2023-2030)

Variable	2023	2024	2025	2026	2027	2028	2029	2030
Pay Wi-Fi hotspots (million)	0.06	0.06	0.05	0.05	0.04	0.04	0.03	0.03
Revenue per hotspot	$617	$612	$607	$602	$597	$592	$587	$582
Revenue (million US$)	$39	$36	$33	$29	$26	$23	$19	$15

Sources: Cisco, Wi-Fi Map; Boingo; Telecom Advisory Services analysis

The allocation of the 6 GHz spectrum band offers an opportunity for commercial Wi-Fi carriers to enhance their business. As Wi-Fi 6E developments will allow up to 1,500 connected devices per access point, Wi-Fi carriers will have the possibility of adding more customers without quality limitations due to congestion. By considering a conservative potential increase of 40% in the number of connected devices in public venues and weighting that figure by the gradual expansion of the latest technology, we expect commercial Wi-Fi carriers using Wi-Fi 6E to increase their user base from 11% in 2023 to 38% in 2030. If the revenue per hotspot increases in the same amount, that will yield an increase in overall revenues for the sector of an additional US$ 5.8 million by 2030 (Table 6-4).

Table 4-34. Australia: Revenues of Wi-Fi carriers due to Wi-Fi 6E in 6 GHz (2023-2030)

Variable	2023	2024	2025	2026	2027	2028	2029	2030
Potential increase in connected devices in public venues	40%	40%	40%	40%	40%	40%	40%	40%
Traffic through Wi-Fi 6E (%)	28%	51%	66%	77%	84%	89%	92%	95%
Increase in connected devices due to Wi-Fi 6E	11%	20%	26%	31%	34%	36%	37%	38%
Revenue per hotspot if 6 GHz allocated	$ 687	$ 735	$ 767	$ 786	$ 797	$ 802	$ 804	$ 803
Revenue if Wi-Fi 6E allocated (million US$)	$4.4	$7.2	$8.6	$9.0	$8.7	$8.0	$7.0	$5.8

Sources: Boingo; Telecom Advisory Services analysis

This estimate is conservative since Wi-Fi 7 operating in the 6 GHz is expected to also enhance the potential for paid hotspots due to its technological advancements.

4.4.3. Revenues of Wi-Fi based Wireless Internet Service Providers (WISPs)

WISPs rely primarily on unlicensed spectrum to offer broadband accessibility in rural areas of the country. ACMA estimates that Australian WISPs serve 862,000 subscribers in 2023. Based on industry growth trends, we expect the subscriber base to reach 1,113,000 by 2030. Assuming a monthly ARPU of US$ 65, 2023 revenues are estimated at US$ 671.92 million (see table 4-35).

Table 4-35. Australia: WISP revenues (2023-2030)

Variable	2023	2024	2025	2026	2027	2028	2029	2030
Subscribers (million)	0.86	0.92	0.98	1.03	1.07	1.10	1.11	1.11
Revenues (US$ million)	$671.92	$759.58	$900.03	$946.71	$981.08	$1,002.45	$1,013.37	$1,017.78

Sources: ACMA; Telecom Advisory Services analysis

As described, the allocation of 6 GHz spectrum band using Wi-Fi 6E will potentially increase the WISP user base by 99,310 million subscribers in 2030, due to expanded coverage and better affordability. Assuming the same ARPU values as described above, the new subscriptions will account for an additional US$ 90.84 million in revenues in 2030 (Table 4-36).

Table 4-36. Australia: WISP revenues due to 6 GHz (2023-2030)

Variable	2023	2024	2025	2026	2027	2028	2029	2030
WISP annual ARPU ($)	$779.57	$822.05	$914.76	$914.76	$914.76	$914.76	$914.76	$914.76
New subscribers with 6 GHz (million)	0.00	0.02375	0.06	0.07	0.08	0.09	0.09	0.099309
New revenue (US$ million)	$3.81	$19.52	$52.08	$66.43	$72.52	$80.37	$86.27	$90.84

Sources: ACMA; Telecom Advisory Services analysis

* * * * *

Wi-Fi will also contribute to either producer surplus or GDP of Internet Service Providers. This section has assessed the economic value within three sources:

- Producer surplus of cellular operators resulting from CAPEX savings incurred in network deployment and operations. The value of cellular off-loading relates to the total cost of ownership required to accommodate future capacity requirements using Wi-Fi to complement cellular networks. Estimated at 8.10% of total CAPEX in 2024, it amounts to US$ 137 million, increasing to US$ 149 million in 2034.
- Revenues of Wi-Fi carriers offering service in public spaces. Based on the revenues per site of Wi-Fi service providers, total revenues have reached US$ 42.9 million in 2024, diminishing to US$ 0.66 million in 2034.
- Revenues of Wireless ISPs: The WISPs relying on unlicensed bands to deliver service to their customers generate revenues totaling US$ 779.10 million in 2024, increasing to $1.12 billion in 2034.

4.5. Development of the Wi-Fi Ecosystem

The economic value generated by Wi-Fi within the Wi-Fi ecosystem companies is calculated based on the following five sources:

- The producer surplus (i.e., margins) of residential Wi-Fi devices and equipment manufactured in the United States
- The producer surplus (i.e., margins) of enterprise Wi-Fi equipment manufactured in the United States
- The producer surplus of local firms providing products and services in the IoT ecosystem (hardware, software and systems integration) in the United States
- The producer surplus of local firms providing products and services in the AR/VR ecosystem (hardware, software and content) in the United States; and
- Benefits of firms developing vehicular technologies

4.5.1. Manufacturing of Wi-Fi devices and equipment for residential use

In section 4.4 we calculated the producer surplus attributed to residential Wi-Fi devices and equipment, relying on the Milgrom et al. (2011) assumption that consumer surplus could be approximated by producer surplus. In this section we estimate the producer surplus, which differs from the previous analysis in two areas: (i) we only consider the residential Wi-Fi devices and equipment manufactured by local firms, and (ii) we also consider the overseas revenues generated by local residential Wi-Fi devices and equipment manufacturers.

Since our focus is estimating producer surplus, the estimation begins by compiling revenues of local manufacturers for each Wi-Fi enabled product.[49] Considering only the share of revenues generated by local manufacturers of Wi-Fi-enabled products, sales amount to US$ 1,502 million in 2023, decreasing to $ 1,274 million in 2030, due to 6 GHz enabled products. After computing the global sales of U.S. manufacturers, we applied the prorated margin estimated by CSI markets (44.6%) which yields an estimated producer surplus for these products of US$ 383 million in 2023 decreasing to US$ 226 million in 2030 (see table 4-37)

Table 4-37. Australia: producer surplus from locally manufactured residential Wi-Fi devices and equipment (2023-2030)

Variable	2023	2024	2025	2026	2027	2028	2029	2030
Total sales (US$ billion)	$ 1,019	$ 1,052	$ 1,086	$ 1,122	$ 1,158	$ 1,195	$ 1,234	$ 1,274
Gross margin	44.59%	44.59%	44.59%	44.59%	44.59%	44.59%	44.59%	44.59%
Producer surplus (US$ billion)	$ 455	$ 469	$ 484	$ 500	$ 516	$ 533	$ 550	$ 568

Sources: Consumer Technology Association; Telecom Advisory Services analysis

We must consider that a portion of the revenues estimated above corresponds to devices operating within the Wi-Fi 6E standard operating in the 6 GHz band. According to IDC, global shipments of consumer devices linked to Wi-Fi 6E or more will represent 39.59% of the shipments from previous generations in 2027. So, the producer surplus generated by

[49] Calculated by prorating data for the United States based on GDP.

products with 2.4 GHz and 5 GHz bands was US$ 383 million in 2023 and forecast to attain US$ 226 billion in 2027 (see table 4-38).

Table 4-38. Australia: producer surplus from locally manufactured residential Wi-Fi devices and equipment operating in the 2.4 GHz and 5 GHz bands (2023-2030)

Variable	2023	2024	2025	2026	2027	2028	2029	2030
Global - Total Wi-Fi 6E or more shipments	15.67%	22.39%	28.72%	34.42%	39.59%	45.52%	52.35%	60.20%
Total Producer Surplus (US$ million)	$ 455	$ 469	$ 484	$ 500	$ 516	$ 533	$ 550	$ 568
Total Producer Surplus (US$ million) Wi-Fi 6 or less	$ 383	$ 364	$ 345	$ 328	$ 312	$ 290	$ 262	$ 226

Sources: Consumer Technology Association; IDC; Telecom Advisory Services analysis

The declining trend is the result of gradual replacement of legacy equipment with Wi-Fi 6E enabled. For this reason, we need to break down revenues between devices and equipment for Wi-Fi 6E based on the breakdown of traffic projections. On this basis, we estimate that the producer surplus generated by products operating with Wi-Fi 6E was US$ 71 million in 2023 and will increase to US$ 342 million in 2030 (see table 4-39).

Table 4-39. Australia: Economic Value of Wi-Fi enabled consumer products operating in the 6 GHz band (2023-2030)

Variable	2023	2024	2025	2026	2027	2028	2029	2030
Global - Total Wi-Fi 6E shipments	15.67%	22.39%	28.72%	34.42%	39.59%	45.52%	52.35%	60.20%
Total Producer Surplus (US$ million)	$ 455	$ 469	$ 484	$ 500	$ 516	$ 533	$ 550	$ 568
Wi-Fi 6E Adoption	28.36%	50.60%	65.93%	76.51%	83.80%	88.83%	92.30%	94.69%
Producer Surplus Wi-Fi 6E Devices (US$ million)	$ 71	$ 105	$ 139	$ 172	$ 204	$ 243	$ 288	$ 342

Sources: Consumer Technology Association; IDC; Telecom Advisory Services analysis

4.5.2. Manufacturing of enterprise Wi-Fi devices and equipment

Our starting assumption in this domain is that Australia does not hold a market position in the world market of enterprise RLAN equipment in the 2.4 GHz and 5 GHz band. For example, analysts reported that U.S. manufacturers control the largest share of the enterprise access points and controller's world market. For example, in 2020 Cisco controlled 45.7% of the enterprise wireless local area network market share worldwide[50].

4.5.3. Benefits of Firms in the IoT ecosystem

According to estimates from Statista and Bain & Co, we expect total industrial 2023 IoT revenue in Australia to amount US$ 13.1 billion in 2023. By relying on the percentage of hardware connectivity spending in IoT in Asia-Pacific, we were able to split that figure into

[50] Source: IDC (2020). *Worldwide Enterprise WLAN Market Declines Moderately in the Second Quarter of 2020, according to IDC* (September 2). Retrieved in: https://www.idc.com/getdoc.jsp?containerId=prUS46826820

the two main segments: (i) hardware; and (ii) software, contents, and services. By weighting those amounts by the share of local production (20% for hardware, 74% for software and services) and the margins (44.6% and 77.5%, respectively), we estimated the overall producer surplus. However, the share attributed to 6 GHz should be subtracted from the total economic value. To do so, we estimated a natural growth rate, by subtracting the corresponding share attributed to 6 GHz spectrum according to the growth rates indicated above. Thus, we estimate a producer surplus not attributed to 6 GHz (see table 4-40).

Table 4-40. Australia: IoT ecosystem direct contribution (2023-2030)

Variable	2023	2024	2025	2026	2027	2028	2029	2030
IoT revenue - Hardware ($ billions)	$1	$1	$1	$1	$1	$1	$1	$1
IoT revenue - Software, Contents, Services ($ billions)	$13.1	$15	$17	$20	$22	$25	$28	$31
Total Industrial IoT revenue in (billions)	$14	$16	$18	$20	$23	$26	$29	$32
Local production (%) - Hardware	20%	20%	20%	20%	20%	20%	20%	20%
Local production (%) - Software & Services	74%	74%	74%	74%	74%	74%	74%	74%
Margins (%) - Hardware	44.6%	45%	45%	45%	45%	45%	45%	45%
Margins (%) - Software & Services	77.5%	77%	77%	77%	77%	77%	77%	77%
Margins - IoT Hardware revenue	$0	$0	$0	$0	$0	$0	$0	$0
Margins - Software, contents and services IoT revenue	$7	$9	$10	$11	$13	$14	$16	$17
Producer surplus (US$ million)	$7,564	$8,641	$9,854	$11,232	$12,799	$14,580	$16,010	$17,575

Sources: Statista, CSI, Telecom Advisory Services analysis

On this basis, we must limit the estimates developed in the previous analysis to the share of sales that are generated due to Wi-Fi: we estimate that value to be 31% based on IoT Analytics data.[51] Additionally, we should subtract the share attributed to the Wi-Fi 6 E standard. To do so, we relied on our analysis of the shares by Wi-Fi category presented in section 5.5. Thus, we estimate a producer surplus attributed to the 2.4 GHz and 5 GHz of US$ 1.68 billion in 2023, decreasing to US$ 0.29 billion in 2030 (Table 4-41).

Table 4-41. Australia: IoT ecosystem direct contribution due to 2.4 GHz and 5 GHz bands (2023-2030)

Variable	2023	2024	2025	2026	2027	2028	2029	2030
Producer surplus ($ billion)	$7,564	$8,641	$9,854	$11,232	$12,799	$14,580	$16,010	$17,575
Share Due to Wi-Fi	31%	31%	31%	31%	31%	31%	31%	31%
Share Due to Wi-Fi 6 or less	71.64%	49.40%	34.07%	23.49%	16.20%	11.17%	7.70%	5.31%
Producer surplus attributable to Wi-Fi 6 or less ($ billion)	$1,680	$1,323	$1,041	$818	$643	$505	$382	$289

Sources: Statista, CSI, Telecom Advisory Services analysis

[51] IoT Analytics (2023). "State of IoT 2023: Number of connected IoT devices growing 16% to16.7 billion globally", retrieved from: https://iot-analytics.com/number-connected-iot-devices/

Following the previous analysis, we were able to estimate which portion of IoT producer surplus growth can be attributed to the 6 GHz band. As Table 5-32 indicates, we expect the additional IoT surplus to account for US$ 665 million in 2023 (see table 4-42).

Table 4-42. Australia: IoT ecosystem direct contribution due to 6 GHz (2023-2030)

Variable	2023	2024	2025	2026	2027	2028	2029	2030
Share Due to 6 GHz	28.36%	50.60%	65.93%	76.51%	83.80%	88.83%	92.30%	94.69%
Additional surplus due to 6 GHz	$665	$1,355	$2,014	$2,664	$3,325	$4,015	$4,581	$5,159

Sources: Statista Market Insights; CSI; Telecom Advisory Services analysis

4.5.4. Benefits of firms in the AR/VR ecosystem

Following an approach similar to the one used for estimating the IoT contribution, we can calculate the direct contribution of the AR/VR ecosystem to the Australian economy. Starting with the local spending in AR/VR by category (hardware, software, and contents), and weighting those figures by the respective shares of local production and margins, we were able to estimate the total producer surplus (see Table 4-43).

Table 4-43. Australia: AR/VR ecosystem direct contribution (2023-2030)

Variable	2023	2024	2025	2026	2027	2028	2029	2030
Spending in AR/VR - Hardware (US$ billion)	$0.27	$0.45	$0.56	$0.62	$0.67	$0.71	$0.76	$0.81
Spending in AR/VR - Software, Contents, Services (US$ billion)	$0.87	$0.80	$0.80	$0.87	$0.96	$1.07	$1.19	$1.26
Total Spending in AV/VR (US$ billion)	$1.14	$1.25	$1.36	$1.49	$1.63	$1.78	$1.95	$2.08
Share of local production - Hardware	19.88%	19.88%	19.88%	19.88%	19.88%	19.88%	19.88%	19.88%
Share of local production - Software, Contents, Services	73.82%	73.82%	73.82%	73.82%	73.82%	73.82%	73.82%	73.82%
Local production for local consumption - Hardware (US$ billion)	$0.05	$0.09	$0.11	$0.12	$0.13	$0.14	$0.15	$0.16
Local production for local consumption - Software, Contents, Services (US$ billion)	$0.64	$0.59	$0.59	$0.64	$0.71	$0.79	$0.88	$0.93
Total Local production for local consumption	$0.69	$0.68	$0.70	$0.77	$0.84	$0.93	$1.03	$1.10
Local Producer Surplus - Hardware (US$ billion)	$0.02	$0.04	$0.05	$0.05	$0.06	$0.06	$0.07	$0.07
Local Producer Surplus - Software, Contents, Services (US$ billion)	$0.50	$0.46	$0.46	$0.50	$0.55	$0.61	$0.68	$0.72
Total Producer Surplus ($ billion)	$0.52	$0.50	$0.51	$0.55	$0.61	$0.67	$0.75	$0.80

Sources: Statista Market Insights; Telecom Advisory Services analysis

By relying on a ratio estimated for 5 GHz and 6 GHz, AR/VR related products based on the estimations of indirect impact made above, we were able to isolate the specific economic contribution of the 6 GHz band. Following a similar procedure as that described above for

IoT, the direct contribution from the AR/VR ecosystem in Australia attributed to 2.4 GHz and 5 GHz bands is estimated at US$ 167 billion in 2023 (see Table 4-44).

Table 4-44. Australia: AR/VR ecosystem direct contribution due to 2.4 GHz and 5 GHz bands (2023-2030)

Variable	2023	2024	2025	2026	2027	2028	2029	2030
Total Producer Surplus (US$ billion)	$0.52	$0.50	$0.51	$0.55	$0.61	$0.67	$0.75	$0.80
Share Due to Wi-Fi 6 or less (includes a discount for Wi-Fi usage)	32.18%	30.88%	29.32%	27.76%	26.21%	24.61%	22.97%	21.28%
Producer surplus attributable to Wi-Fi 6 or less (US$ million)	$167	$153	$149	$154	$160	$166	$171	$169

Sources: Statista Market Insights; Telecom Advisory Services analysis

Following the previous analysis, we were able to estimate which portion of AR/VR producer surplus growth that can be attributed to the 6 GHz band. As Table 4-45 indicates, we expect the additional AR/VR surplus generated by the 6 GHz band to account for US$ 179 million in 2023 (see table 4-45).

Table 4-45. Australia: AR/VR ecosystem direct contribution due to the 6 GHz band (2023-2030)

Variable	2023	2024	2025	2026	2027	2028	2029	2030
Total Producer Surplus (US$ billion)	$167	$153	$149	$154	$160	$166	$171	$169
Attributable Wi-Fi to the 6 GHz band	34.42%	35.72%	37.27%	38.83%	40.39%	41.99%	43.63%	45.31%
Attributable to Wi-Fi	66.6%	66.6%	66.6%	66.6%	66.6%	66.6%	66.6%	66.6%
Share due to Wi-Fi 6E	100%	100%	100%	100%	100%	100%	100%	100%
Impact of Wi-Fi 6E	$179	$177	$190	$215	$246	$283	$326	$360

Sources: Statista Market Insights; Telecom Advisory Services analysis

* * * * *

Wi-Fi will also generate economic value equivalent to the producer surplus of Australian firms that are part of the Wi-Fi ecosystem:

- The producer surplus of residential Wi-Fi devices and equipment manufactured in Australia across Wi-Fi standards amounts to US$ 469 million in 2024 and US$ 645 billion in 2034.
- The producer surplus of US firms providing products and services in the IoT ecosystem (connectivity, apps, platforms, and related professional services) in Australia amounts to US$ 2.68 billion in 2024 and forecast to reach US$ 6.78 billion in 2034.
- The total producer surplus of local firms providing products and services in the AR/VR ecosystem (hardware, software and content) across Wi-Fi standards in Australia is estimated at US$ 331 million in 2024 and US$ 636 million in 2027.

4.6. Total economic value of allocating the full 6 GHz band for RLANs

The cumulative economic value between 2024 and 2034 for the first alternative (baseline scenario plus allocating the full 6 GHz band for unlicensed use) amounts to US$ 1,685.9 billion, comprising US$ 1,219.2 billion in GDP contribution, US$ 189.1 billion in producer surplus and US$ 277.6 billion in consumer surplus (see table 4-46).

Table 4-46. Australia: Economic value of Wi-Fi in case of full allocation of 6 GHz band for RLANs (2024-2034) (in US$ millions)

Source	Effects	Consumer Benefit	Producer surplus	GDP contribution
2. Free Wi-Fi	1.1. Savings incurred by consumers by accessing free Wi-Fi in public sites	$ 3,373		
	1.2. Free Wi-Fi service supporting the needs of the broadband unserved population			$ 201,741
	1.3. Benefit to consumers enjoying higher speed from free Wi-Fi under Wi-Fi 6E, and Wi-Fi 7	$ 949		
	1.4. Benefit to consumers relying on Wi-Fi in educational institutions	$ 1,901		
	1.5. Use of Wi-Fi in highly dense heterogeneous environments	$ 31		
2. Residential Wi-Fi	2.1. Home internet access for devices that lack an Ethernet port	$ 214,791		
	2.2. Avoidance of inside wiring investment	$ 999		
	2.3. Consumer benefit derived from faster broadband speed	$ 6,903		
	2.4. Consumer benefit generated by use of residential Wi-Fi devices and equipment	$ 48,698		
	2.5. Bridging the digital divide: use of Wi-Fi to increase coverage in rural and isolated areas			$ 340,440
3. Enterprise Wi-Fi	3.1. Savings in business Internet traffic transmitted through Wi-Fi		$ 119,982	
	3.2. Avoidance of enterprise building inside wiring		$ 2,594	
	3.3. Benefits derived from an increase in average speed			$ 192,673
	3.4. Benefits derived from reduced latency			$ 332,253
	3.5. Enhanced IoT deployment			$ 126,265
	3.6. Deployment of Augmented Reality/Virtual Reality solutions			$ 13,974
4. ISPs	4.1. Cellular networks CAPEX savings by off-loading traffic to Wi-Fi		$ 1,610	
	4.2. Revenues of Wi-Fi based Public Internet Service Providers			$ 267
	4.3. Revenues of Wi-Fi based Wireless Internet service Providers			$ 11,558
5. Wi-Fi ecosystem	5.1. Manufacturing of Wi-Fi devices and equipment for residential use		$ 6,083	
	5.2. Manufacturing of enterprise Wi-Fi devices and equipment		$ 0	
	5.3. Benefits of Firms in the IoT ecosystem		$ 53,473	
	5.4. Benefits of firms in the AR/VR ecosystem		$ 5,329	
TOTAL		$277,645	$189,071	$1,219,170

Source: Telecom Advisory Services analysis

5. ECONOMIC VALUE OF ALLOCATING 500 MHZ FOR UNLICENSED USE AND 700 MHZ FOR IMT

The second allocation alternative of the 6 GHz band to be evaluated consists of splitting the band between RLANs and IMT, allocating the lower 500 MHz for RLANs, as is currently the case, and the upper 700 MHz band for use by telecommunication service providers. In comparison with the first alternative assessed in chapter 4, this option values (i) the contribution of unlicensed spectrum in the 2.4 and 5 GHz bands (the "baseline", which is exactly the same as the one assessed in chapter 4), and (ii) the value of allocating only 500 MHz of the 6 GHz band for RLANs use. In addition, to allow for an "apples to apples" comparison, this option includes an assessment of the value to be captured through an auction of the upper part of the 6 GHz band to be used in 5G and 6G.

This chapter begins by estimating the technical implications of allocating only 500 MHz rather than 1200 MHz to RLANs. On this basis, it presents its economic implications. The final section presents the estimation of proceeds to be generated by a potential auction of the 700 MHz to be allocated to IMT.

6.1. Technical implications of allocating 500 MHz in the 6 GHz band

Our overarching objective is to assess RLAN performance, operating under two scenarios (1200 MHz and 500 MHz of the 6 GHz band), in terms of the **number of potential devices to be served simultaneously and the speed and latency received by each device**. The impact on speed, latency and number of devices are critical inputs in estimating Wi-Fi economic contribution. The estimation of number of devices, speed and latency is based on the following parameters:

- The **number of channels** available in different frequency bands defines the total bandwidth available in a frequency band.

- **Bandwidth allocated by channel** determines the number of devices to be supported by each standard and frequency band.

- The **spatial streams** available by device: Wi-Fi spatial streaming is a MIMO (Multiple Input Multiple Output) transmission technique used in wireless communications to transmit or receive independent and separately coded data signals. Spatial streams allow a single device to transmit and receive at the same time simultaneously. The number of spatial streams (defined by the number of antennas) in the router and devices allows a reduction in the time required to receive the information flow.

- The **number of resource units** available by channel. A Resource Unit is a subdivision of the primary channel that allows the transmission of information required by a device, following specific Wi-Fi modulation techniques.[52] Each standard stipulates the type and number of resource units that can accommodate the maximum number of devices by channel.

- The **modulation technique** allows compressing information to allow the transmission of packets in bits per symbol (BPS) within a fixed time interval (TT). RLAN relies on different digital modulation characteristics by standard (see table 5-1). Each modulation adds bits for redundancy (Error Correction codes) that allow the recovery of information in case errors occur during the transmission.

The use of Wi-Fi 6E standard within the entire 6 GHz band can drive several advantages (see table 5-1).

Table 5-1. Wi-Fi 6E under a full 6 GHz band

Total available bandwidth (MHz)		1760
Possible channelization		20MHz, 40 MHz, 80MHz, 160MHz
Maximum number of channels	20 MHz	88
	40 MHz	43
	80 MHz	21
	160 MHz	9
	320 MHz	
Maximum allowed modulation (QAM)		1024
Maximum speed (Mbps) 1SS		1,200.98
Maximum medium access		OFDMA
Type of transmission		MU-MIMO
Maximum spatial streams (SS)		8
Maximum speed (Mbps) under maximum spatial streams		9,607.84
Improvement relative to Wi-Fi 6		Increase of bandwidth to accommodate a larger number of users with similar speeds as the prior standard; in addition, channel aggregation allows increasing the speed in a dynamic fashion according to device requirements

Source: Telecom Advisory Services compilation

A restriction in the amount of spectrum available for RLAN introduces a limitation in the band performance and consequently in its economic value (see detailed analysis by effect in Appendix C). An analysis was conducted for each source of economic value as presented in chapter 2 and assessed for a full band allocation in chapter 4 (see table 5-2).

[52] In technical terms, (RU) is a unit in OFDMA terminology used in 802.11ax WLAN to denote a group of 78.125 kHz bandwidth subcarriers (tones) used in both DownLink (DL) and UpLink (UL) transmissions. With OFDMA, different transmit powers may be applied to different Resource Units.

Table 5-2. Impact of 500 MHz limitation on economic impact of the 6 GHz band

Sources	Effects	Reduction of economic impact from 1200 MHz	Key limitation drivers
1. Free Wi-Fi	1.1. Savings incurred by consumers by accessing free Wi-Fi in public sites	No reduction effect assumed	
	1.2. Free Wi-Fi service supporting the needs of the broadband unserved population	41.18 %	• Speed of access to content • Number of simultaneous users • Available bandwidth
	1.3. Benefit to consumers enjoying higher speed from free Wi-Fi under 6 GHz	41.18 %	• Available bandwidth
	1.4. Benefit to consumers relying on Wi-Fi in educational institutions	N/A	
	1.5. Use of Wi-Fi in highly dense heterogeneous environments	No reduction effect assumed	
2. Residential Wi-Fi	2.1. Home internet access for devices that lack an Ethernet port	N/A	
	2.2. Avoidance of inside wiring investment	N/A	
	23. Consumer benefit derived from faster broadband speed	Speed for connections above 150 Mbps is capped at 600 Mbps	• Available bandwidth Number of Resource Units available
	2.4. Consumer benefit generated by use of residential Wi-Fi devices and equipment	Sales reduction from 3.04% in 2028 to 15.52% in 2034, according to speed cap	• Speed maximum of connections • Number of devices using 6 GHz band for residential use
	2.5. Bridging the digital divide: use of Wi-Fi to increase coverage in rural and isolated areas	40.48 %	• Number of 20 MHz channels
3. Enterprise Wi-Fi	3.1. Savings in business Internet traffic transmitted through Wi-Fi	Savings adjusted in same proportion as speed	• Internet traffic by WiFi • Speed maximum of connections
	3.2. Avoidance of enterprise building inside wiring	N/A	
	3.3. Benefits derived from an increase in average speed	Speed for connections above 150 Mbps is capped at 600 Mbps	• Available bandwidth • Number of Resource Units available
	3.4. Benefits derived from reduced latency	Latency improvements adjusted in the same proportions as speed	• Available bandwidth • Connection speed
	3.5. Enhanced IoT deployment	58.33 %	• Available bandwidth
	3.6. Deployment of Augmented Reality/Virtual Reality solutions	81.82 %	• Available bandwidth • Less users
4. ISPs	4.1. Cellular networks CAPEX savings by off-loading traffic to Wi-Fi	83.33 %	• Number of 320 MHz available channels • Connection speed
	4.2. Revenues of Wi-Fi based Public Internet Service Providers	66.67 %	• Available 320 MHz channels • Number of Resource Units available
	4.3. Revenues of Wi-Fi based Wireless Internet service Providers	40.48%	• Number of 20 MHz channels

5. Wi-Fi ecosystem	5.1. Manufacturing of Wi-Fi devices and equipment for residential use	Sales reduction from 3.04% in 2028 to 15.52% in 2034, according to speed cap	• Speed maximum of connections • Number of devices using 6 GHz band for residential use
	5.2. Manufacturing of enterprise Wi-Fi devices and equipment	Sales reduction from 3.04% in 2028 to 15.52% in 2034, according to speed cap	• Speed maximum of connections • Number of devices using 6 GHz band for industrial use
	5.3. Benefits of Firms in the IoT ecosystem	58.33 %	• Available bandwidth
	5.4. Benefits of firms in the AR/VR ecosystem	81.82 %	• Available bandwidth • Less users

The reduction from the 1200 MHz alternative was factored in the assessment of RLAN economic value of the 500 MHz alternative.

6.2. Economic implications for RLAN of allocating 500 MHz in the 6 GHz band

The cumulative economic value of RLAN by allocating only the lower 500 MHz of the 6 GHz band for RLAN devices is composed of two areas: (i) the value generated by RLAN in the 2.4 GHz and 5 GHz bands (the "baseline" value); and (ii) the additional value derived by relying on 500 MHz in the 6 GHz band. Both areas have been estimated for the 2024-2034 period.

The "baseline" economic value (use of 2.4 GHz and 5 GHz bands) amounts to US$ 865.0 billion and is composed of U$S 485.2 billion in GDP contribution, U$S 250.2 billion in consumer surplus, and U$S 129.7 billion in producer surplus (see table 5-3).

Table 5-3. Australia: Economic value of Wi-Fi in the baseline scenario (2024-2034) (in US$ millions)

Source	Effects	Consumer Benefit	Producer surplus	GDP contribution
2. Free Wi-Fi	1.1. Savings incurred by consumers by accessing free Wi-Fi in public sites	$ 1,867		
	1.2. Free Wi-Fi service supporting the needs of the broadband unserved population			$ 111,346
	1.3. Benefit to consumers enjoying higher speed from free Wi-Fi under Wi-Fi 6E	$ 0		
	1.4. Benefit to consumers relying on Wi-Fi in educational institutions	$ 1,901		
	1.5. Use of Wi-Fi in highly dense heterogeneous environments	$ 0		
2. Residential Wi-Fi	2.1. Home internet access for devices that lack an Ethernet port	$ 214,791		
	2.2. Avoidance of inside wiring investment	$ 999		
	2.3. Consumer benefit derived from faster broadband speed	$ 0		
	2.4. Consumer benefit generated by use of residential Wi-Fi devices and equipment	$ 30,598		
	2.5. Bridging the digital divide: use of Wi-Fi to increase coverage in rural and isolated areas			$ 292,027

Source	Effects	Consumer Benefit	Producer surplus	GDP contribution
3. Enterprise Wi-Fi	3.1. Savings in business Internet traffic transmitted through Wi-Fi		$ 117,255	
	3.2. Avoidance of enterprise building inside wiring		$ 2,594	
	3.3. Benefits derived from an increase in average speed			$ 0
	3.4. Benefits derived from reduced latency			$ 50,473
	3.5. Enhanced IoT deployment			$ 15,946
	3.6. Deployment of Augmented Reality/Virtual Reality solutions			$ 4,535
4. ISPs	4.1. Cellular networks CAPEX savings by off-loading traffic to Wi-Fi		$ 28	
	4.2. Revenues of Wi-Fi based Public Internet Service Providers			$ 203
	4.3. Revenues of Wi-Fi based Wireless Internet service Providers			$ 10,698
5. Wi-Fi ecosystem	5.1. Manufacturing of Wi-Fi devices and equipment for residential use		$ 2,485	
	5.2. Manufacturing of enterprise Wi-Fi devices and equipment		$ 0	
	5.3. Benefits of Firms in the IoT ecosystem		$ 5,567	
	5.4. Benefits of firms in the AR/VR ecosystem		$ 1,729	
TOTAL		$ 250.2	$ 129.7	$ 485.2

Source: Telecom Advisory Services analysis

Beyond the "baseline" value, the economic implication derived from allocating 500 MHz of the 6 GHz band amounts to US$ 526.6 billion and is composed of U$S 478.2 billion in GDP contribution, U$S 22.7 billion in consumer surplus, and U$S 25.7 billion in producer surplus (see table 5-4).

Table 5-4. Australia: Economic value of the 6 GHz band in case of allocating 500 MHz for RLANs (2024-2034) (in US$ millions)

Source	Effects	Consumer Benefit	Producer surplus	GDP contribution
1. Free Wi-Fi	1.1. Savings incurred by consumers by accessing free Wi-Fi in public sites	$ 1,507		
	1.2. Free Wi-Fi service supporting the needs of the broadband unserved population			$ 53,171
	1.3. Benefit to consumers enjoying higher speed from free Wi-Fi under Wi-Fi 6E	$ 558		
	1.4. Benefit to consumers relying on Wi-Fi in educational institutions	$ 0		
	1.5. Use of Wi-Fi in highly dense heterogeneous environments	$ 31		
2. Residential Wi-Fi	2.1. Home internet access for devices that lack an Ethernet port	$ 0		
	2.2. Avoidance of inside wiring investment	$ 0		
	2.3. Consumer benefit derived from faster broadband speed	$ 4,295		
	2.4. Consumer benefit generated by use of residential Wi-Fi devices and equipment	$ 16,327		

Source	Effects	Consumer Benefit	Producer surplus	GDP contribution
	2.5. Bridging the digital divide: use of Wi-Fi to increase coverage in rural and isolated areas			$ 28,816
3. Enterprise Wi-Fi	3.1. Savings in business Internet traffic transmitted through Wi-Fi		$ 1,622	
	3.2. Avoidance of enterprise building inside wiring		$ 0	
	3.3. Benefits derived from an increase in average speed			$ 102,081
	3.4. Benefits derived from reduced latency			$ 247,288
	3.5. Enhanced IoT deployment			$ 45,970
	3.6. Deployment of Augmented Reality/Virtual Reality solutions			$ 312
4. ISPs	4.1. Cellular networks CAPEX savings by off-loading traffic to Wi-Fi		$ 264	
	4.2. Revenues of Wi-Fi based Public Internet Service Providers			$ 21
	4.3. Revenues of Wi-Fi based Wireless Internet service Providers			$ 512
5. Wi-Fi ecosystem	5.1. Manufacturing of Wi-Fi devices and equipment for residential use		$ 3,246	
	5.2. Manufacturing of enterprise Wi-Fi devices and equipment		$ 0	
	5.3. Benefits of Firms in the IoT ecosystem		$ 19,962	
	5.4. Benefits of firms in the AR/VR ecosystem		$ 655	
TOTAL		$ 22.7	$ 25.7	$ 478.2

Source: Telecom Advisory Services analysis

The combined value of both areas, encompassing the baseline (2.4 GHz and 5 GHz) and the 500 MHz of the 6 GHz band amounts to US$ 1,391.7 billion, composed of US$ 963.4 billion in GDP contribution, U$S 155.4 billion in producer surplus and US$ 272.9 billion in consumer surplus. This amount is, strictly speaking, the economic value attached to ACMA's current allocation (see table 5-5).

Table 5-5. Australia: Total economic value of Wi-Fi in case of allocating 500 MHz for RLANs (2024-2034) (in US$ millions)

Source	Effects	Consumer Benefit	Producer surplus	GDP contribution
2. Free Wi-Fi	1.1. Savings incurred by consumers by accessing free Wi-Fi in public sites	$ 3,373		
	1.2. Free Wi-Fi service supporting the needs of the broadband unserved population			$ 164,516
	1.3. Benefit to consumers enjoying higher speed from free Wi-Fi under Wi-Fi 6E	$ 558		
	1.4. Benefit to consumers relying on Wi-Fi in educational institutions	$ 1,901		
	1.5. Use of Wi-Fi in highly dense heterogeneous environments	$ 31		
2. Resi	2.1. Home internet access for devices that lack an Ethernet port	$ 214,791		

Source	Effects	Consumer Benefit	Producer surplus	GDP contribution
	2.2. Avoidance of inside wiring investment	$ 999		
	2.3. Consumer benefit derived from faster broadband speed	$ 4,295		
	2.4. Consumer benefit generated by use of residential Wi-Fi devices and equipment	$ 46,924		
	2.5. Bridging the digital divide: use of Wi-Fi to increase coverage in rural and isolated areas			$ 320,842
3. Enterprise Wi-Fi	3.1. Savings in business Internet traffic transmitted through Wi-Fi		$ 118,877	
	3.2. Avoidance of enterprise building inside wiring		$ 2,594	
	3.3. Benefits derived from an increase in average speed			$ 102,081
	3.4. Benefits derived from reduced latency			$ 297,761
	3.5. Enhanced IoT deployment			$ 61,916
	3.6. Deployment of Augmented Reality/Virtual Reality solutions			$ 4,847
4. ISPs	4.1. Cellular networks CAPEX savings by off-loading traffic to Wi-Fi		$ 292	
	4.2. Revenues of Wi-Fi based Public Internet Service Providers			$ 225
	4.3. Revenues of Wi-Fi based Wireless Internet service Providers			$ 11,210
5. Wi-Fi ecosystem	5.1. Manufacturing of Wi-Fi devices and equipment for residential use		$ 5,730	
	5.2. Manufacturing of enterprise Wi-Fi devices and equipment		$ 0	
	5.3. Benefits of Firms in the IoT ecosystem		$ 25,530	
	5.4. Benefits of firms in the AR/VR ecosystem		$ 2,383	
TOTAL		$ 272.9	$ 155.4	$ 963.4

Source: Telecom Advisory Services analysis

The decrease in economic value from the first alternative of 1200 MHz allocation (US$ 294.2 billion) is due to the following effects:

- 40.48% of Wi-Fi outdoor accessibility provided by WISPs is limited due to their restricted access in the 6GHz band.
- Wi-Fi indoor speed is restricted by 50%, which means that residential broadband access undergoes a bottleneck for lines in excess of 600 Mbps.
- Under a constant speed assumption, latency would increase under frequency allocation scenarios: in other words, the 500 MHz alternative would result in 40% less reduction of latency relative to the 1200 MHz option.
- More than half of IoT devices undergoes a limit in their indoor and outdoor access.
- 81.82% of the AR/VR devices supported in indoor environments is restricted by limits in terms of their ability to operate.

6.3. Potential auction proceeds of 700 MHz of the 6 GHz band

Part of the negative economic impact of limiting access of the 6 GHz band for RLANs is mitigated by the benefits resulting from allocating 700 MHz to be auctioned for use by IMT. Revenues to be collected amount to US$ 77.6 billion. The GSMA estimates that the allocation of mid bands to IMT in East Asia and Pacific would generate a GDP contribution of US$ 218 billion in 2030, from where U$S 12 billion can be interpolated for Australia.[53] Prorating this value to the 700 MHz in the 6 GHz band yields a total GDP contribution between 2024 and 2034 of US$ 33.7 billion. Additionally, by gaining access to 700 MHz, wireless service providers could generate US$ 19.6 in producer surplus (primarily driven by IoT and AR/VR deployment) and US$ 19.2 billion in consumer surplus. Finally, it is estimated that auction proceeds for 700 MHz in the 6 GHz band could generate US$ 5.2 billion.

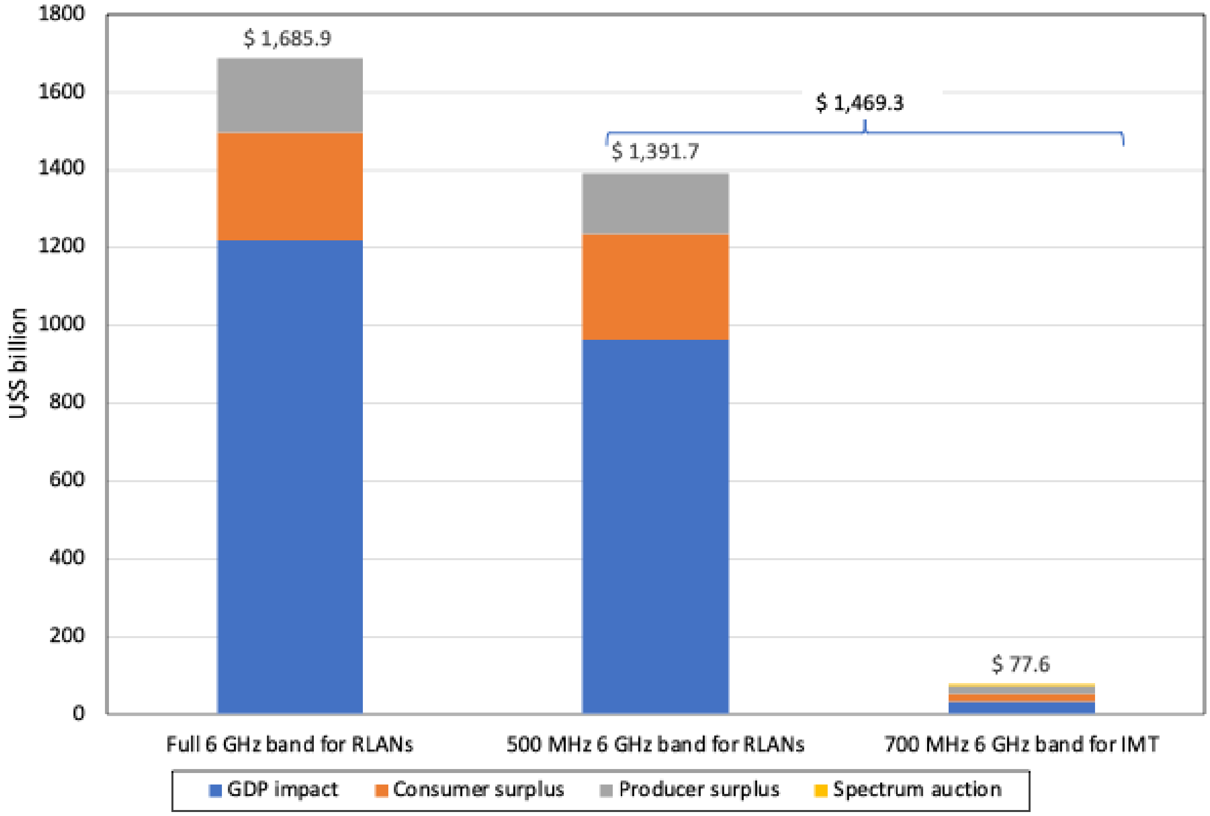
Considering the economic value associated with the 6 GHz band only, the total economic benefits between 2024 and 2034 of allocating the lower 500 MHz for unlicensed use and the upper 700 MHz band for use by IMT is US$ 604.2 billion, of which US$ 526.6 billion is generated by the spectrum received for unlicensed use and US$ 77.6 billion would be generated by IMT.

[53] Source: GSMA, "The Socio-Economic Benefits of Mid-Band 5G Services" (February, 2022)

6. COMPARISON OF ECONOMIC VALUE OF THE TWO ALTERNATIVES AND POLICY IMPLICATIONS

A comparison of the two regulatory alternatives indicates that the highest economic impact is associated with the full allocation of the 6 GHz band for use by RLANs (see Graphic 6-1).

Graphic 6-1. Comparative economic value of the two regulatory alternatives



(*) All three options include the economic value of RLAN generated by the 2.4 GHz and 5 GHz bands
Source: Telecom Advisory Services analysis

As indicated in graphic 6-1, the full allocation to RLANs is US$ 216.6 billion than the second alternative. This advantage occurs, even considering revenues collected from spectrum auctions, and without contemplating the costs to IMT generated by spectrum refarming. In summary, the allocation of the 1200 MHz of the 6 GHz will generate the highest economic value for Australia, which becomes the most attractive alternative of the two under consideration.

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APPENDIX A. Methodology for calculating the impact of speed on consumer benefit

According to Quotient Associates (Wi-Fi Alliance, 2017), Wi-Fi 4 (802.11n) and Wi-Fi 5 (802.11ac) standards rely on 2.4 GHz and 5 GHz spectrum bands. Typical channel deployment and theoretical maximum speeds within those standards indicate that 80% of the traffic is generated by devices operating in the 2.4 GHz band[54] (See Table A-1).

Table A-1. Relationship between speed and bandwidth in the most widely used Wi-Fi standards

Spatial streams	Technology	Band	Typical piping			
			20MHz	40MHz	80MHz	160MHz
1x1	802.11n	2.4 and 5 GHz	72 Mbps	150 Mbps		
	802.11ac	5 GHz	87 Mbps	200 Mbps	433 Mbps	867 Mbps

Source: Adapted from Wi-Fi Alliance (2017). [55]

As indicated in table A-1, the 802.11n standard with a typical 20 MHz configuration results in an average device speed of 72 Mbps. Additionally, real-world factors such as network congestion, signal interference, and device capabilities mean that the actual speeds experienced by users are often lower, thereby affecting the overall performance and reliability of Wi-Fi connections. For example, a household with 26 devices, equipped with a router operating in Wi-Fi 6 in the frequencies of 2.4 GHz and 5 GHz can accommodate 28 channels of 20 MHz, under the largest number of resource units by channel (242 RU), can handle a maximum of 28 of 1 spatial stream users, with a maximum speed of 103.79 Mbps.

Considering that mobile broadband speeds are 208 Mbps (see table 4-1 above), we assume an impact of zero consumer benefit. It is, therefore, implied that the **consumer benefit derived from Wi-Fi speed materializes only under Wi-Fi 6E operating on the 6 GHz band.**

A.1. Consumer benefit derived from Wi-Fi speed increase under Wi-Fi 6E, and Wi-Fi 7 operating in the 6 GHz and in the 7 GHz bands

As mentioned above, Wi-Fi speed to be delivered within the household is a function of the amount of bandwidth assigned by frequency bands (consequently the number of enabled channels), the Wi-Fi standard, and the number of devices to be interconnected.

If a household is equipped with 21 devices and migrates to a Wi-Fi 6E router relying on the 6 GHz band, the assumptions to determine the theoretical maximum speed are four: (i) the maximum channelization of 80 MHz, (ii) the maximum number of resource units would be 980 (RU) in that bandwidth, (iii) the maximum modulation would be 1024-QAM with a transmission rate (BPS) of 10 bits per symbol and error correction rate (EC) of 5/6; and, (iv) the transmission time (TT) per symbol is considered to be 12. 8μs and its guard interval in

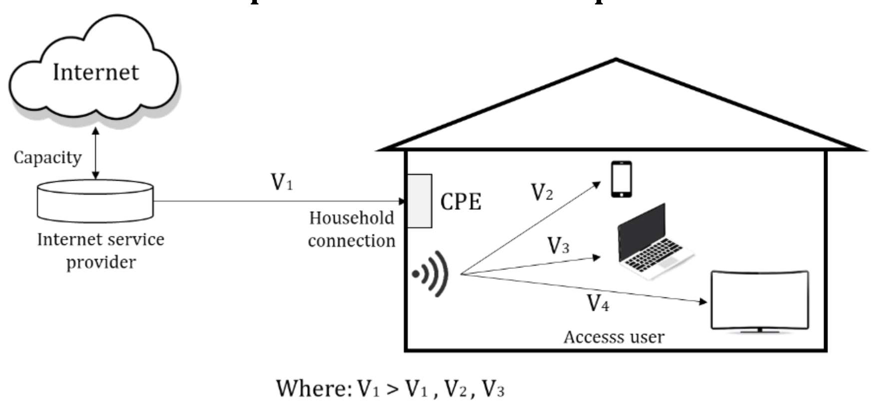
[54] Source: Gehlhaus, D et. al (2018) www.rand.org/t/RR2720
[55] Source: WiFi Alliance (2017), "Wi-Fi Spectrum Needs Study." Table 2-1.

0.8μs. Thus, applying equation 1, the maximum speed reached in this scenario can be 1200.98 Mbps for 2 spatial streams (SS). However, this speed is a theoretical one; in reality, the feasible speed would be 840.68 Mbps. This estimate only considers an average signal degradation rate of 30% for interference (which according to research can reach up to 50%) and does account for distance between the router and the devices.

$$V_{max} = \frac{BPS.CE}{TT} * RU * SS = \frac{10\ bps.\frac{5}{6}}{13.6x10^{-6}\ seg} * (980) * 2 = 1{,}200.98\ Mbps\ (840.68\ Mbps)$$

That being said, the speed delivered at the device level is not only dependent on Wi-Fi's capability. In addition to Wi-Fi, the fixed broadband plan contracted with the Internet Service Provider (ISP) is also a key determinant. In general terms, the access speed within the home can never be higher than the effective speed of the connection (see Figure A-1).

Figure A-1. Relationship between connection speed and user access



Source: Telecom Advisory Services.

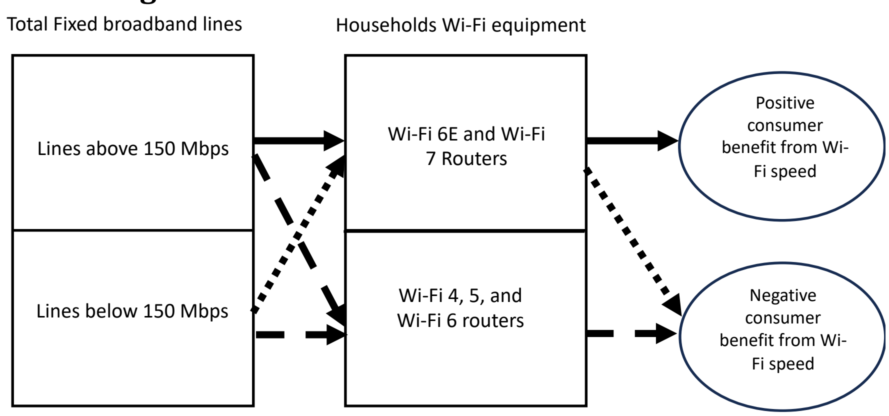
Access to the fixed broadband connection through Wi-Fi technology determines the maximum speed that can be accessed by a user device. Going back to the examples presented above, if the household acquires a broadband plan of 30 Mbps but is equipped with a Wi-Fi router operating with Wi-Fi 6E standard, the speed delivered at the device level cannot exceed 30 Mbps. Conversely, if the household acquires a service plan of 1 Gbps but is equipped with a Wi-Fi 6 router operating in the 2.4 GHz and 5 GHz frequencies, the speeds delivered at the device level will be constrained by the router's capability. The reliance on the two frequencies represents an implicit threshold in speed capability. For example, if the household has 26 devices, the assumptions to determine the theoretical maximum speed at the device level with a Wi-Fi 6 router operating in 2.4 GHz and 5 GHz bands are four: (i) the minimum channelization is 20 MHz, (ii) the maximum number of resource units would be 242 (RU) in each channel, (iii) the maximum modulation would be 1024-QAM with a transmission rate (BPS) of 10 bits per symbol and error correction rate (EC) of 5/6; and, (iv) the transmission time (TT) per symbol is considered to be 12.8μs and its guard interval 0.8μs. Thus, the maximum theoretical speed reached in this scenario can be 148.28 Mbps for

1 spatial stream (SS), which has to be discounted by 30% due to signal degradation, thus reaching:

$$V_{max} = \frac{BPS.CE}{TT} * RU * SS = \frac{10\ bps.\frac{5}{6}}{13.6x10^{-6}\ seg} * (242) * 1 = 148.28\ Mbps\ (103.20\ Mbps)$$

On this basis, the estimation of consumer benefit derived from Wi-Fi speed under Wi-Fi 6E, operating in the 6 GHz band needs to exclude all fixed broadband lines in household equipped with a Wi-Fi router under the Wi-Fi threshold. We define such threshold to be 150 Mbps (which is conservative given the speed limits demonstrated above).

Figure 4-2. Wi-Fi Residential Benefit Conditions

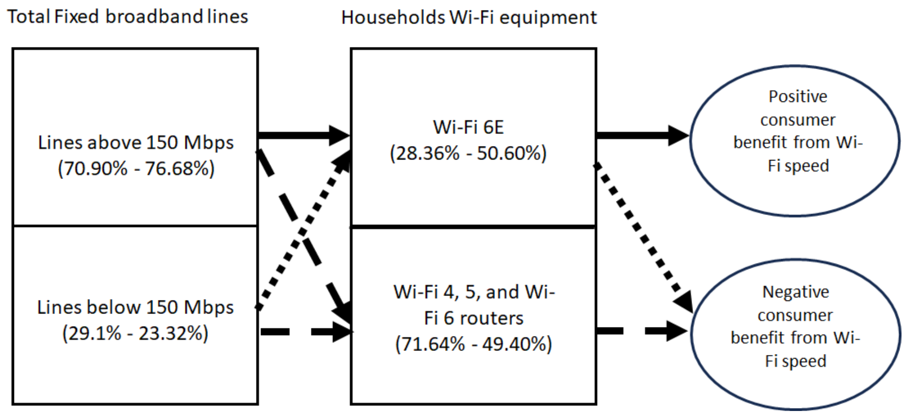


Note: Broadband households can also address connectivity needs through wired Ethernet (see section 4.3)
Source: Telecom Advisory Services.

How do we reconcile the 150 Mbps threshold at the router level with the average download speed reported by Ookla at the time with practically no Wi-Fi 6E deployment (174 Mbps in 2020 and 211 Mbps in 2021)? Two factors are at play: (i) a portion of residences rely on Ethernet wiring, and consequently do not encounter a Wi-Fi bottleneck, (ii) overall speed is a function of channels and resource units, which can be driven by the number of devices. Following on the example cited above, if the residence has a significantly smaller number of devices than 26, speeds will necessarily improve.

In other words, household residences benefit from Wi-Fi 6E additional speeds if the fixed line acquired is higher than 150 Mbps. As described above, the households acquiring a 150 Mbps (or faster) fixed broadband line will be affected due to router bottlenecks in the counterfactual scenario with no Wi-Fi 6E. Based on the percentage of graphic 4-2, we can provide a first estimate of households that benefit from Wi-Fi 6E (see figure 4-3).

Figure A-2. Wi-Fi Residential Benefit Conditions (2023-24)



Source: Telecom Advisory Services.

The first step in the analysis is to account for the households affected, specifically those purchasing a download speed of more than 150 Mbps (70.9% of households in 2023 to 87.9% of households in 2027). It is crucial to consider that not all the traffic from these households goes through Wi-Fi networks. Thus, the percentage of traffic that uses Wi-Fi must be deducted. Taking these two factors into account, we determine the percentage of traffic affected. For instance, in 2023, 70.90% of households had connections over 150 Mbps, but only 53.86% of their traffic went through Wi-Fi, resulting in a 38.19% share of traffic affected.

In terms of speeds, it is noted that the purchased speeds (within the subgroup of over 150 Mbps) are increasing over time (in average from 721 Mbps in 2023 to 1,245 Mbps in 2027). However, these Wi-Fi 6E speeds are capped at 1,186 Mbps due to the router bottleneck. Since previous average speeds include speeds above 1,186 Mbps, we must recalculate the average considering this cap, resulting in average speeds ranging from 721 Mbps in 2023 to 869 Mbps in 2027. Considering both factors, we arrive at the speeds with Wi-Fi 6E in comparison to the world without Wi-Fi 6E (using the mobile broadband download speed). By comparing these speeds and using the Nevo curve, we can estimate the willingness to pay for both speeds, thereby deriving the additional consumer benefit.

APPENDIX B. TECHNICAL ANALYSIS OF PERFORMANCE OF UNLICENSED SPECTRUM

The assessment of economic value of unlicensed spectrum is contingent upon a technical analysis of performance under different scenarios combining the standards and alternate frequency band allocations – i.e. 2.4 GHz and 5 GHz for Wi-Fi 4, Wi-Fi 5, and Wi-Fi 6, and 6 GHz for Wi-Fi 6E. Appendix B and C explain the assumptions, methodology and calculations used to estimate the economic impact according to technical performance of each scenario. It has been conducted for three scenarios:

- Wi-Fi 4, Wi-Fi 5, Wi-Fi 6 and Wi-Fi 6E relying on the 2.4 GHz and 5 GHz bands: under this scenario, beyond the legacy standards the Wi-Fi 6E standard operating in 2.4 GHz and 5 GHz bands already represents an improvement in signal modulation vis-a-vis Wi-Fi 6 when operating in the same bands.

- Wi-Fi 6E operating in the 1200 MHz of the 6 GHz band, which by allowing the aggregation in channels of 160 MHz, represents a significant performance improvement. This feature allows doubling the maximum channel bandwidth and improving the maximum speed.

- Wi-Fi 6E operating in the 500 MHz of the 6 GHz band

This Appendix is structured in three sections. Section B.1 presents the variables and equations used to estimate Wi-Fi performance under different bands and standards. Section B.2 presents calculations to support the performance of Wi-Fi standards operating in the 2.4, and 5 GHz bands. Section B.3 presents the calculations supporting the added benefit in performance when using Wi-Fi 6E operating in the 6 GHz bands. Appendix C draws the implications of the technical analysis in the assessment of economic value of each source and effect studied in the main report.

B.1. Theoretical framework for assessing Wi-Fi performance

Each Wi-Fi standard can be used in different spectrum bands. The operations of Wi-Fi4 (802.11n), Wi-Fi5 (802.11ac) and Wi-Fi 6 (802.11ax) rely on the 2.4 GHz and 5 GHz bands. Wi-Fi 6E (802.11ax) operates within the 2.4 GHz, 5 GHz and 6 GHz bands. Our overarching objective is to assess Wi-Fi performance, operating under different frequency band allocations and standard scenarios, in terms of the **number of potential devices to be served simultaneously and the speed and latency received by each device**. The impact on speed, latency and number of devices are critical inputs in estimating Wi-Fi economic contribution. The estimation of number of devices, speed and latency is based on the following parameters:

- The **number of channels** available in different frequency bands defines the total bandwidth available in a frequency band, following the Unlicensed National Information Infrastructure (UNII) scheme.

- The **bandwidth allocated by channel** determines the number of devices to be supported by each standard.

- The **spatial streams** available by device determine Wi-Fi spatial streaming is a MIMO (Multiple Input Multiple Output) transmission technique used in wireless communications to transmit or receive independent and separately coded data signals. Spatial streams allow a single device to transmit and receive at the same time simultaneously. The number of spatial streams (defined by the number of antennas) in the router and receiving device allows a reduction in the time required to receive the information flow.

- The **number of resource units** available by channel. A Resource Unit is a subdivision of the primary channel that allows the transmission of information required by a device, following specific Wi-Fi modulation techniques.[56] Each standard stipulates the type and number of resource units that can accommodate the maximum number of devices by channel.

- The **modulation technique** allows compressing information to allow the transmission of packets in **bits per symbol** (BPS) within a **fixed time interval** (TT). Modulation techniques are roughly divided into four types: Analog modulation, Digital modulation, Pulse modulation, and Spread spectrum method. Wi-Fi relies on different digital modulation characteristics by standard (see table B-1). Each modulation adds bits for redundancy (Error Correction codes) that allow the recovery of information in case errors occur during the transmission.

Table B-1. Wi-Fi standards transmission characteristics

Standard	Modulation	Bits per symbol (BPS)	Error correction (EC)	Transmission time (TT)
Wi-Fi5	256 QAM	8	5/6	3.6 us
Wi-Fi 6	1024 QAM	10	5/6	13.6 us
Wi-Fi 6E	1024 QAM	10	5/6	13.6 us

Source: IEEE Computer Society, (2021). "Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications" https://ieeexplore.ieee.org/document/9442429

The speed delivered by a particular Wi-Fi standard is calculated as follows:

$$Speed = \frac{Bits\ per\ symbol.Error\ Correction}{Transmission\ Time} * Resource\ Units * Spatial\ Steams \qquad (Eq.1)$$

[56] In technical terms, (RU) is a unit in OFDMA terminology used in 802.11ax WLAN to denote a group of 78.125 kHz bandwidth subcarriers (tones) used in both DownLink (DL) and UpLink (UL) transmissions. With OFDMA, different transmit powers may be applied to different Resource Units.

Source: National Instruments. "Introduction to Wireless LAN Measurements from 802.11a to 802.11ac" Reference to IEEE. (2016), "Performance comparison of IEEE 802.11n and IEEE 802.11ac" https://download.ni.com/evaluation/rf/Introduction_to_WLAN_Testing.pdf

Having specified the equation to calculate the number of devices and speed we can estimate the performance of Wi-Fi under different frequency bands and standards.

B.2. Wi-Fi 6 performance operating under 2.4 and 5 GHz bands

Taking into consideration that the Wi-Fi4 and 5 standards have been presenting challenges in terms of saturation due to the large amount of equipment and devices deployed, as well as the restriction of the maximum available bandwidth, 802.11ax technology, known as Wi-Fi 6, offered a solution. The main features of Wi-Fi 6 can be summarized in five areas according to the following reference[57]: (i) increased channel aggregation[58] due to increased bandwidth at the 6 GHz frequency, (ii) channel splitting by multiple access of multiple users by orthogonal frequency division[59] (OFDMA), (iii) transmission link adaptation through maximum 1024-QAM modulation[60] , (iv) guard or guard interval to avoid information overlap[61] ; and, (v) transmission of multiple simultaneous information streams over the same channel to increase bandwidth[62] .

In this context, if we consider a saturation scenario for a single user per channel, occupying 802.11ax technology (Wi-Fi 6), the assumptions to determine the theoretical maximum speed would be four: (i) the technology could be executed from a minimum channelization of 20 MHz (both in the 2.4 GHz or 5 GHz band), (ii) the maximum number of subchannels occupied by such user would be 242 resource units (RU) in such bandwidth (see Figure B-1), (iii) the maximum modulation would be 1024-QAM with a transmission rate (BPS) of 10 bits per symbol and error correction rate (EC) of 5/6; and, (iv) the transmission time (TT) per symbol is considered to be 12.8μs and its guard interval 0.8μs.

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[57] IEEE Computer Society, (2021). "Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications" https://ieeexplore.ieee.org/document/9442429

[58] The maximum bandwidth for Wi-Fi 6 operation in the 2.4 GHz band corresponds to 3 channels of 20 MHz or 1 channel of 40 MHz in the 5 GHz band, it corresponds to 25 channels of 20 MHz, 6 channels of 80 MHz or 2 channels of 160 MHz The 6 GHz band corresponds to 59 20 MHz channels, 14 80 MHz channels or 7 160 MHz channels.

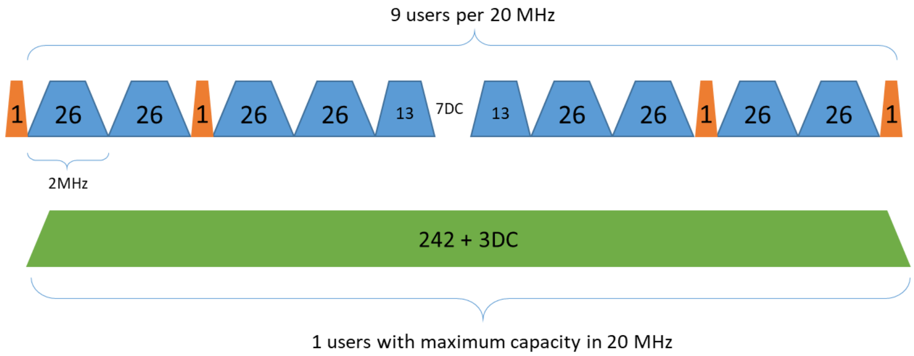
[59] This allows the generation of smaller sub-channels, called Resource Units (RU), to carry information from multiple users at the same time over the entire channel. Depending on the bandwidth of the channel where the data is transmitted, up to 26 (2MHz), 52 (4MHz), 102 (8MHz), 242 (20MHz), 484 (40MHz), 980 (80MHz) or 1960 (160MHz) subchannels or RU's can be accommodated.

[60] Wi-Fi 6 uses modulations ranging from BPSK to 1024-QAM. The difference is the number of bits per symbol that are transmitted to adapt the speed to changes in distance, antenna position and interference. Thus, BPSK can transmit up to 1 bit per symbol, whereas 1024-QAM transmits up to 10 bits per symbol. The time that each symbol lasts is defined in the protocol, and the shorter the symbol is, the more information can be sent per second, but it is easier to have errors. In 1024-QAM it is possible to have an error correction rate of 5/6, i.e. 5 bits of information and 1 bit of error correction.

[61] This means that there is a waiting time before sending the next symbol to make the link more robust and avoid loss of information as the data takes different paths and the information frame is assembled at the receiver. The transmission time in 1024-QAM, for example, is 12.8us, and its guard interval corresponds to 0.8us, i.e. a total of 13.6us.

[62] This is achieved by the implementation of MU-MIMO technology which allows up to 8 simultaneous data *streams* or *spatial streams to* be transmitted to achieve higher transmission speeds. However, this feature also depends on the receiving equipment being able to support this technology.

Figure B-1. Channelization for Wi-Fi 6 in a 20 MHz wide channel



Source: Telecom Advisory Services adapted from CISCO[63]

Table B-2 presents all parameters driving Wi-Fi 6 performance under 2.4 GHz and 5 GHz bands.

Table B-2. Wi-Fi 6 parameters

Commercial denomination		Wi-Fi 6
IEEE standard		802.11 ax
Frequency bands		2.4 GHz, 5 GHz
ISM (Industrial Scientific and Medical band)		(B1) 2412-2472: 60MHz (ISM)
UNII (Unlicensed National Information Infrastructure)		(B2i) 5170-5330: 160MHz (UNII-1-2) (B3) 5490-5730: 240MHz (UNII-2Ex) (B4) 5735-5835: 100MHz (UNII-3)
Total available bandwidth (MHz)		560
Possible channelization		20MHz, 40 MHz, 80MHz, 160MHz
Maximum number of channels by channelization	20 MHz	28
	40 MHz	14
	80 MHz	7
	160 MHz	3
	320 MHz	[redacted]
Maximum allowed modulation (QAM)		1024
Maximum speed (Mbps) 1SS		1,200.98
Maximum medium access		OFDMA
Type of transmission		MU-MIMO
Maximum spatial streams (SS)		8
Maximum speed (Mbps) under maximum spatial streams		9,607.84
Improvement relative to Wi-Fi5		Improvement technique to simultaneously transmit information at faster speed and larger bandwidth to accommodate more devices

Source: Telecom Advisory Services compilation

By relying on the parameters of table 2 and equation 1, we calculate the maximum speed for channels of 20 MHz with 242 resource units of one spatial stream (which means one user per channel). As the equation indicates, under the Wi-Fi 6 standard operating within the 2.4

[63] Source: CISCO. https://blogs.cisco.com/networking/wi-fi-6-ofdma-resource-unit-ru-allocations-and-mappings

and 5 GHz frequencies, we can **theoretically** accommodate 28 devices with speeds of up 148.28 Mbps.

$$Speed = \frac{BPS.CE}{TT} * RU * SS = \frac{10bps.\frac{5}{6}}{13.6\ us} * (242) * 1 = 148.28\ Mbps$$

According to this, it could be estimated that the **maximum theoretical value** that can be reached **by a user in a high traffic environment,** with a **minimum operating channel, can** be determined at **150 Mbps.** In this case, Wi-Fi 6 solves both performance and coverage challenges of Wi-Fi5. In addition, the technology introduces a combination of features including OFDMA and 1024-QAM peak modulation which improve spectral efficiency, thereby increasing speed while supporting many devices in a congested area.

In the similar way as the case above, we calculate the theoretical performance levels for different scenarios (see table B-3).

Table B-3. Performance of Wi-Fi 6 operating in the 2.4 GHz and 5 GHz bands

Scenarios	Number of channels (A)	Bandwidth by channel (B)	Spatial Streams (C)	Resource units (D)	Maximum devices per resource unit (E)	BPS	CE	TT (µs)	Total number of devices (A*E)	Channel speed (V=C*D*CE/T) (Mbps)
1	28	20	1	26 (2MHz)	9	10	5/6	13.6	252	15.93
2	28	20	2	26 (2MHz)	9	10	5/6	13.6	252	31.86
3	28	20	1	242 (20MHz)	1	10	5/6	13.6	28	148.28
4	12	40	1	484 (20MHz)	1	10	5/6	13.6	12	296.57
5	12	40	2	484 (20MHz)	1	10	5/6	13.6	12	593.14

Source: Telecom Advisory Services analysis

This table allows estimating several theoretical scenarios of Wi-Fi performance under Wi-Fi 6:

- Scenario 1 (theoretical): this scenario allows 28 channels of 20 MHz. Under the largest number of resource units by channel (26 RU), Wi-Fi 6 can handle a maximum of 252 of 1 spatial streams users, at a maximum speed of 15.93 Mbps.

- Scenario 2 (theoretical): this scenario allows 28 channels of 20 MHz. Under the largest number of resource units by channel (26 RU), Wi-Fi 6 can handle a maximum of 252 of 2 spatial streams users, with a maximum speed of 31.86 Mbps.

- Scenario 3 (theoretical): this scenario allows 28 channels of 20 MHz. Under the largest number of resource units by channel (242 RU), Wi-Fi 6 can handle a maximum of 28 of 1 spatial stream users, with a maximum speed of 148.28 Mbps.

- Scenario 4 (theoretical): this scenario allows 12 channels of 40 MHz. Under the largest number of resource units by channel (484 RU), Wi-Fi 6 can handle a maximum of 12 of 1 spatial stream users, with a maximum speed of 296.57 Mbps.

- Scenario 5 (theoretical): this scenario allows 12 channels of 40 MHz. Under the largest number of resource units by channel (484 RU), Wi-Fi 6 can handle a maximum of 12 of 2 spatial stream users, with a maximum speed of 593.14 Mbps.

It is important to consider these results to be valid only theoretically. The following factors come into play to significantly reduce the estimated speed. While the theoretical maximum speed for a user in a saturation scenario can reach 150 Mbps, this could be affected by a greater number of users making use of the channel. In fact, as described in Figure C-1, the 802.11ax standard could distribute the bandwidth to up to 9 users; and if this number increases, the user experience will be degraded due to a reduction in speed, generally in applications with high resource requirements. Considering the interference in bands allocated for indoor use, more likely feasible scenarios[64] are as follows:

- Scenario 1 (feasible): this scenario allows 28 channels of 20 MHz. Under the largest number of resource units by channel (26 RU), Wi-Fi 6 can handle a maximum of 252 of 1 spatial streams users, at a maximum speed of 11.15 Mbps.

- Scenario 2 (feasible): this scenario allows 28 channels of 20 MHz. Under the largest number of resource units by channel (26 RU), Wi-Fi 6 can handle a maximum of 252 of 2 spatial streams users, with a maximum speed of 22.30 Mbps.

- Scenario 3 (feasible): this scenario allows 28 channels of 20 MHz. Under the largest number of resource units by channel (242 RU), Wi-Fi 6 can handle a maximum of 28 of 1 spatial stream users, with a maximum speed of 103.79 Mbps.

- Scenario 4 (feasible): this scenario allows 12 channels of 40 MHz. Under the largest number of resource units by channel (484 RU), Wi-Fi 6 can handle a maximum of 12 of 1 spatial stream users, with a maximum speed of 207.59 Mbps.

- Scenario 5 (feasible): this scenario allows 12 channels of 40 MHz. Under the largest number of resource units by channel (484 RU), Wi-Fi 6 can handle a maximum of 12

[64] In this regard, it is important to consider that the performance of Wi-Fi is compromised by environmental factors such as congestion, noise and interference. The signal degradation from theoretical speed is between 9% and 49%. See Ivan Forenbacher, Siniša Husnjak, Ivan Jovović, and Mislav Bobić, Raffaele Bruno. "Throughput of an IEEE 802.11 Wireless Network in the Presence of Wireless Audio Transmission: A Laboratory Analysis", *Sensors* DOI: 10.3390/s21082620. For purposes of this analysis, we use the midpoint of 30% of signal degradation. This value does not include the additional degradation taking place by the distance between the router and the device.

of 2 spatial stream users, with a maximum speed of 415.19 Mbps (again, as stipulated in footnote 8, the degradation of speed does not include the distance factor).

In sum, under the 2.4 and 5 GHz frequency bands, 12 devices in 40 MHz channels can reach a feasible maximum speed at the device level of 207.59 Mbps. This speed would increase to 415.19 Mbps if the number of spatial streams is increased from 1 to 2 for the router and all receiving devices. However, an additional problem to consider is that deployment of routers with spatial streams >1 is not totally common (note: for a spatial stream configuration to be feasible, they have to be available at the router and all receiving devices). While it is difficult to quantify the number of spatial streams existing at each device level, we have estimations at the router level. An estimated market share of spatial streams of routers is as follows: 1 and 2 streams (30%-40%), 3 and 4 (40%-50%), 5 and 8 (10%-20%, mostly in enterprise installations) (Sources: Mordor Intelligence. *Global Wi-Fi router market (2024 – 2029)*).

B.3. Wi-Fi 6E performance under the 6 GHz band and below

The key improvement of Wi-Fi 6E relative to Wi-Fi 6 is that by accessing the 6 GHz band, the number of users can be increased with a similar number of resource units. Wi-Fi 6E is used in the 2.4 GHz, 5 GHz, and 6 GHz bands according to the following performance features (see table B-4).

Table B-4. Wi-Fi 6E parameters

Commercial denomination		Wi-Fi 6E
IEEE standard		802.11 ax
Frequency bands		2.4GHz, 5 GHz y 6GHz
Industrial, Scientific and Medical (ISM) band		(B1) 2412-2472: 60MHz (ISM)
UNII (Unlicensed National Information Infrastructure)		(B2i) 5170-5330: 160MHz (UNII-1-2) (B3) 5490-5730: 240MHz (UNII-2Ex) (B4) 5735-5835: 100MHz (UNII-3) (B5) 5925-6425: 500MHz (UNII-5) (B6i) 6425-6525: 100MHz (UNII-6) (B7) 6525-6875: 350MHz (UNII-7) (B8i) 6875-7125: 250MHz (UNII-8)
Total available bandwidth (MHz)		1760
Possible channelization		20MHz, 40 MHz, 80MHz, 160MHz
Maximum number of channels	20 MHz	88
	40 MHz	43
	80 MHz	21
	160 MHz	9
	320 MHz	[redacted]
Maximum allowed modulation (QAM)		1024
Maximum speed (Mbps) 1SS		1,200.98
Maximum medium access		OFDMA
Type of transmission		MU-MIMO
Maximum spatial streams (SS)		8

Maximum speed (Mbps) under maximum spatial streams	9,607.84
Improvement relative to Wi-Fi 6	Increase of bandwidth to accommodate a larger number of users with similar speeds as the prior standard; in addition, channel aggregation allows increasing the speed in a dynamic fashion according to device requirements

Source: Telecom Advisory Services compilation

Relying on equation 1 and based on the Wi-Fi 6E characteristics, we can estimate the maximum speed for 40 MHz bandwidth with 484 resource units (one user per channel) and 1 spatial stream.

$$Speed = \frac{BPS.CE}{TT} * RU * SS = \frac{10bps.\frac{5}{6}}{13.6\ us} * (484) * 1 = 296.57\ Mbps$$

In a similar way as the case above, we calculate the theoretical performance levels for different scenarios (see table B-5).

Table B-5. Performance of Wi-Fi 6E operating in the 6 GHz band and below

Scenarios	Number of channels (A)	Bandwidth by channel (B)	Spatial Streams (C)	Resource units (D)	Maximum devices per resource unit (E)	BPS	CE	TT (µs)	Total number of devices (A*E)	Channel speed (V=C*D*CE/T) (Mbps)
1	88	20	1	26 (2MHz)	9	10	5/6	13.6	792	15.93
2	88	20	2	26 (2MHz)	9	10	5/6	13.6	792	31.86
3	88	20	1	242 (20MHz)	1	10	5/6	13.6	88	148.28
4	43	40	1	484 (40MHz)	1	10	5/6	13.6	43	296.57
5	43	40	2	484 (40MHz)	1	10	5/6	13.6	43	593.14
6	18	160	2	980	1	10	5/6	13.6	18	1,200.98

Under this case, the **feasible** performance of scenarios discounted from the theoretical case, are estimated as follows:

- Scenario 1 (feasible): this scenario allows 88 channels of 20 MHz. Under the largest number of resource units by channel (26 RU), Wi-Fi 6E can handle a maximum of 792 of 1 spatial streams users, at a maximum speed of 11.15 Mbps.

- Scenario 2 (feasible): this scenario allows 88 channels of 20 MHz. Under the largest number of resource units by channel (26 RU), Wi-Fi 6E can handle a maximum of 792 of 2 spatial streams users, with a maximum speed of 22.30 Mbps.

- Scenario 3 (feasible): this scenario allows 88 channels of 20 MHz. Under the largest number of resource units by channel (242 RU), Wi-Fi 6E can handle a maximum of 88 of 1 spatial stream users, with a maximum speed of 103.79 Mbps.

- Scenario 4 (feasible): this scenario allows 43 channels of 40 MHz. Under the largest number of resource units by channel (484 RU), Wi-Fi 6E can handle a maximum of 43 of 1 spatial stream users, with a maximum speed of 207.59 Mbps.

- Scenario 5 (feasible): this scenario allows 43 channels of 40 MHz. Under the largest number of resource units by channel (484 RU), Wi-Fi 6E can handle a maximum of 43 of 2 spatial stream users, with a maximum speed of 415.19 Mbps.

B.4.3. Latency

The demand for new high-performance, low-latency services, such as AR/VR, remote offices, cloud computing, and gaming, is increasing rapidly. These applications, which are intended for use in a variety of environments, including homes, enterprises and industrial plants, require improved performance and reliability, reduced latency (e.g., latency of less than 5 Ms for real-time gaming) and jitter, and improved energy efficiency in Wi-Fi networks. Advanced AR/VR applications require 4K-8K video, minimum throughput of 400-2350 Mbps and maximum transmission/interactivity latency on the order of 10 ms (see Table B-7).

Table B-7. Summary of latency and throughput requirements for industrial application use cases

Applications and requirements	Class A	Class B	Class C
Applications	Interactive video, real time software control, mobile robotics, automated guided vehicles (AGV)	AR/VR, remote HMI, real time cyclic control, machine control, production line control	Real-time asynchronous control, motion control, printing, packaging
Synchronization time	10-1µs	~1 µs	~1 µs
latency limit	50 -10 ms	10 - 1 ms	1ms - 250 µs
Reliability	99% - 99.9%	99.9% - 99.99%	> 99.999%
Performance	High (Video) Low (Control, robotics, AGV)	High (VR) Moderate-Low (control, automation, AR)	Moderate-Low

Source: INTEL (2023), "Next Generation Wi-Fi: Spectrum Needs of Wi-Fi 7".

Initially, a comparison of the technical aspects on latency for Wi-Fi 6, a Wi-Fi Alliance analysis[65] refers to field tests conducted by Qualcomm Technologies in three environments: home, office and classrooms, where the response of sending information is reduced by 40%, 53% and 93%, respectively (see Table B-8).

[65] Source: Wi-Fi Alliance, "The Beacon" https://www.wi-fi.org/beacon/rolf-de-vegt/reduced-latency-benefits-of-wi-fi-6-ofdma

Table B-8. Latency scenarios in use cases for Wi-Fi 6 environments.

Environments	Latency (ms) Download (DL)	% DL Latency Reduction	Latency (ms) Upload (UL)	% Latency Reduction UL
Home (Normal)	15	40	76	63
Home (Wi-Fi 6)	9		28	
Office (Normal)	53	53	70	23
Office (Wi-Fi 6)	25		54	
Classroom (Normal)	452	93	5,875	99
Classroom (Wi-Fi 6)	31		66	

Source: Wi-Fi Alliance

APPENDIX C. IMPACT OF TECHNICAL ANALYSIS ON ASSESSMENT OF RLAN ECONOMIC VALUE

Based on the analyses of performance of unlicensed spectrum bands presented in Appendix C, this appendix details the implications for assessing its economic value. Each area of analysis is assessed independently following the sources of value outlined in the study methodology. The objective is to calculate the performance improvement from unlicensed spectrum operating in the 1200 MHz, and 500 MHz of the 6 GHz band and the consequent impact on the variables driving economic value (speed, latency, number of users). The effects analyzed are only the ones where the allocation of frequencies is expected to have an impact on economic value (see table C-1).

Table C-1. Sources of Wi-Fi economic value

Sources	Effects
2. Free Wi-Fi	1.1. Savings incurred by consumers by accessing free Wi-Fi in public sites
	1.2. Free Wi-Fi service supporting the needs of the broadband unserved population
	1.3. Benefit to consumers enjoying higher speed from free Wi-Fi under Wi-Fi 6E
	1.4. Benefit to consumers relying on Wi-Fi in educational institutions
	1.5. Use of Wi-Fi in highly dense heterogeneous environments
3. Residential Wi-Fi	2.1. Home internet access for devices that lack an Ethernet port
	2.2. Avoidance of inside wiring investment
	2.3. Consumer benefit derived from faster broadband speed
	2.4. Consumer benefit generated by use of residential Wi-Fi devices and equipment
	2.5. Bridging the digital divide: use of Wi-Fi to increase coverage in rural and isolated areas
3. Enterprise Wi-Fi	3.1. Savings in business internet traffic transmitted through Wi-Fi
	3.2. Avoidance of enterprise building inside wiring
	3.3. Benefits derived from an increase in average speed
	3.4. Benefits derived from reduced latency
	3.5. Enhanced IoT deployment
	3.6. Deployment of Augmented Reality/Virtual Reality solutions
4. ISPs	4.1. Cellular networks CAPEX savings by off-loading traffic to Wi-Fi
	4.2. Revenues of Wi-Fi based Public Internet Service Providers (WISPs)
	4.3. Revenues of Wi-Fi based Wireless Internet Service Providers
5. Wi-Fi ecosystem	5.1. Manufacturing of Wi-Fi devices and equipment for residential use
	5.2. Manufacturing of enterprise Wi-Fi devices and equipment
	5.3. Benefits of Firms in the IoT ecosystem
	5.4. Benefits of firms in the AR/VR ecosystem

	Effects where the different allocation of frequencies has an impact on economic value

C.1. Free Wi-Fi service supporting the needs of the broadband unserved population (effect 1.2)

One of the main benefits of using the 6 GHz band is the reduction of latency, and, therefore, an increase in traffic in public places, which depends on the number of connected devices that a Wi-Fi site can host simultaneously. The total number of devices (US) that a hotspot site can host depends on the allocated bandwidth (AB), the usage factor (FU), the traffic demand profile of the average user (CM) and the simultaneity factor that depends on the number of devices connected at the same time (FS). Equation 1 specifies their relationship as follows:

$$(Eq. 1) \qquad US = \frac{AB}{FS. \sum_{i=1}^{n} CM_i . FU_i}$$

Where "n" represents the total number of users that are hosted in the Wi-Fi site and "i" corresponds to the individual demand profile of the users that are connected.

The following sections explain the considerations and calculations of each of the components that influence the number of users that a Wi-Fi site can handle.

Demand Profile (DC)

The demand profile represents the maximum download capacity for four types of user requirements (web pages, email, social networking, calls, video, etc.). For calculation purpose, we compile the traffic of an average Australian user: (i) web page browsing, (ii) video conferencing, (iii) music or video streaming, and (iv) calls and social networks. Traffic by service allows calculating download capacity. For example, when a user is accessing the Internet, if it is considered that a user accesses every 20 seconds one type of the most visited web content, whose average size is around 1,226.93 KB. Consequently, the maximum capacity assigned to the device is 490.77 Kbps (see Table C-2).

Table C-2. Size and capacity of most visited pages in Australia

Type	Most visited pages	Size (T) KB	Capacity (CM) Kbps
Navegation	Google	616	$CM = \frac{\bar{T}}{t} . \frac{8\ bits}{1\ byte}$ $= \frac{1{,}226.93KB}{20s} . \frac{8\ bits}{1\ byte}$ $= 490.77\ \boldsymbol{Kbps}$
	YouTube	171	
	Facebook	348.4	
	Reddit	197.7	
	News	3.3	
	Wikipedia	78.5	
	Instagram	2,764.8	
	Oz Bargain	1,433.6	
	ABC	4,710.4	
	Netflix	1,945.6	
Average size and capacity		**1,226.93**	**490.77**

Source: We Are Social. https://wearesocial.com/au/blog/2023/02/digital-2023-australia-1-in-3-australians-use-social-networks-for-brand-research/; Telecom Advisory Services analysis

In the case of other applications such as video streaming or videoconferencing, the average maximum capacity assigned to the device is around 2,666.51 Kbps (2.60 Mbps) (see Table C-3).

Table C-3. Application capacity

Applications	Capacity(CM) Kbps	Percent use
Videoconferencing (e.g., Skype)	3,000	5.6%
Video streaming (e.g., YouTube)	4,800	35.8%
Phone calls / Social networks (e.g., WhatsApp)	12.33	11.0%

Source: Webpage size: PINGDOM

By adding all usage traffic, the average capacity of a device connected to a Wi-Fi site reaches 2,122.57 Kbps (2.07 Mbps) (see Table C-4).

Table C-4. Capacity of web pages and applications
Applications and Web pages

Applications and webpages	Capacity (CM) Kbps
Internet browsing	490.77
Broadcast and Streaming (Video)	3,000
Social networks (calling)	4,800
Podcast (Videoconference)	12.33
Average total capacity	**2,122.57**

Source: Telecom Advisory Services analysis

Usage Factor (UF)

The usage factor corresponds to the percentage of content accessed by a single device. This value depends on the time or amount of information that the average user collects from the Internet via the Wi-Fi site. The usage factor is calculated by the daily time spent by an average user which, for the most part, is linked to Internet browsing (5h 51m - 31.1%, see Table C-5).

Table C-5. Common time spent using Internet applications in the US

Internet browsing	Hours	Minutes	Total (h)	% Use
Broadcast and Streaming (Video)	5	104	6.73	35.8%
Social networks (calling)	2	4	2.07	11.0%
Podcast (Videoconference)	1	3	1.05	5.6%
Internet browsing	5	51	5.85	31.1%

Source: We Are Social; Telecom Advisory Services analysis

Simultaneity Factor

The simultaneity factor assumes that the capacity calculated above decreases by half due to the number of simultaneous users occupying a channel. In a scenario where the number of users increases by 100%, this factor is assumed to be 0.5, i.e., capacity could be reduced due to the duplication of connected devices.

Bandwidth

Considering that a Wi-Fi site uses the outdoor spectrum portions, the useful bandwidth in the 6 GHz band varies by allocation alternative (see table C-6).

Table C-6. Bandwidth scenarios

UNII	Starting frequency	Final frequency	Bandwidth (MHz)	Standard Power	Low Power	Very low Power
UNII-5	5,925	6,425	500	Outdoor/Indoor	Indoor	Indoor
UNII-6	6,425	6,525	100		Indoor	Indoor
UNII-7	6,525	6,875	350	Outdoor/Indoor	Indoor	Indoor
UNII-8	6,875	7,125	250		Indoor	Indoor

Source: DSA. Unlicensed spectrum access in the 6 GHz band

Based on the usage pattern in Australia and bandwidth availability the number of users and, consequently the discount factor of alternative allocation scenarios were defined (see table C-7).

Table C-7. Number of users by frequency allocation scenarios

	UNII-5	UNII-5 + UNII-7
	500 MHz	1200MHz
Average capacity (from table D-4)	2,086.05	2,086.05
Simultaneity factor	0.5	0.5
AB (KHz)	500,000	850,000
Number of users	479.37	814.94

Source: Telecom Advisory Services analysis

Based on this, the number of users that can be handled by a free hotspot can be estimated under frequency band allocation of 500 MHz. While the number of users under 1200 MHz is 814.94, the reduction is estimated through the following equation 2:

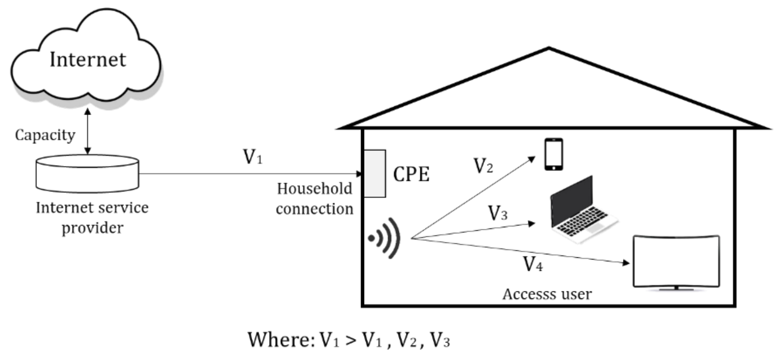
$$(Eq.2)\ Impact_{500MHz} = \frac{Users_{1200} - Users_{500}}{Users_{1200}} = \frac{814.94 - 479.37}{814.94} = 41.18\%$$

C.2. Consumer benefit derived from faster broadband speed within the residence (effect 2.3)

The network elements that play a crucial role in residential speed are the fixed broadband plan contracted with the Internet Service Provider (ISP) and the access mechanism (wired or wireless) by which a user connects[66] to the service. In general terms, the access speed within the home can never be higher than the effective speed of the connection (see Figure C-1).

[66] We will call a **user** the internal customer of a household who can access the Internet through a wired or wireless medium.

Figure C-1. Relationship between connection speed and user access



Source: Telecom Advisory Services.

Access to the fixed broadband connection through Wi-Fi technology determines the maximum speed that can be accessed by a user device. According to Quotient Associates (Wi-Fi Alliance, 2017), Wi-Fi4 (802.11n) and Wi-Fi5 (802.11ac) standards rely on 2.4 GHz and 5 GHz spectrum bands. Typical channel deployment and theoretical maximum speeds within those standards indicate that 80% of the traffic is generated by devices operating in the 2.4 GHz band[67] (See Table C-8).

Table C-8. Relationship between speed and bandwidth in the most widely used Wi-Fi standards

Spatial streams	Technology	Band	Typical piping			
			20MHz	40MHz	80MHz	160MHz
1x1	802.11n	2.4 and 5 GHz	72 Mbps	150 Mbps		
	802.11ac	5 GHz	87 Mbps	200 Mbps	433 Mbps	867 Mbps

Source: Adapted from Wi-Fi Alliance (2017).[68]

In this context, if the household has 26 devices, the assumptions to determine the theoretical maximum speed at the device level are four: (i) the minimum channelization is 20 MHz, (ii) the maximum number of resource units would be 242 (RU) in each channel, (iii) the maximum modulation would be 1024-QAM with a transmission rate (BPS) of 10 bits per symbol and error correction rate (EC) of 5/6; and, (iv) the transmission time (TT) per symbol is considered to be 12.8µs and its guard interval 0.8µs. Thus, applying equation 3, the maximum theoretical speed reached in this scenario can be 148.28 Mbps for 1 spatial stream (SS), which has to be discounted by 30% due to signal degradation, thus reaching.

$$(Eq.3)\ V_{max} = \frac{BPS.CE}{TT} * RU * SS = \frac{10\ bps.\frac{5}{6}}{13.6x10^{-6}\ seg} * (242) * 1 = 148.28\ Mbps\ (103.20\ Mbps)$$

If a household has 13 devices, the assumptions to determine the theoretical maximum speed at the device level are four: (i) the minimum channelization is 40 MHz, (ii) the maximum number of resource units would be 484 (RU) in each channel, (iii) the maximum modulation

[67] Source: Gehlhaus, D et. al (2018) www.rand.org/t/RR2720
[68] Source: Wi-Fi Alliance (2017), "Wi-Fi Spectrum Needs Study." Wi-Fi Alliance, Table 2-1.

would be 1024-QAM with a transmission rate (BPS) of 10 bits per symbol and error correction rate (EC) of 5/6; and, (iv) the transmission time (TT) per symbol is considered to be 12.8μs and its guard interval 0.8μs. In this case, applying equation 1, the maximum theoretical speed reached in this scenario can be 296.57 Mbps for 1 spatial stream (SS), which has to be discounted by 30% due to signal degradation, thus reaching 207.59 Mbps.

If the household is equipped with 21 devices and migrates to a Wi-Fi 6E router relying on 1200 MHz of the 6 GHz band, the assumptions to determine the theoretical maximum speed are four: (i) the maximum channelization of 80 MHz, (ii) the maximum number of resource units would be 980 (RU) in that bandwidth, (iii) the maximum modulation would be 1024-QAM with a transmission rate (BPS) of 10 bits per symbol and error correction rate (EC) of 5/6; and, (iv) the transmission time (TT) per symbol is considered to be 12. 8μs and its guard interval in 0.8μs. Thus, applying equation 4, the maximum speed reached in this scenario can be 1200.98 Mbps for 2 spatial streams (SS).

$$(Eq.4)\ V_{max} = \frac{BPS.CE}{TT} * RU * SS = \frac{10\ bps.\frac{5}{6}}{13.6x10^{-6}\ seg} * (980) * 2 = 1{,}200.98\ Mbps$$

If the frequencies allocated for unlicensed use in the 6 GHz band are reduced from 1200 MHz, this has an impact on the number of resource units assigned for transmission, and consequently the maximum speed at the device level (see table C-9).

Table C-9. Number of resource units by frequency allocation

Allocation alternatives	Resource Units	Maximum speed[69]
1200 MHz	1960 (7 channels of 160 MHz)	1200.98
500 MHz	980 (6 channels of 80 MHz)	600.49

Source: Telecom Advisory Services analysis

From these estimates, the impact of device speed under different frequency allocation scenario under 500 MHz can be calculated:

$$(Eq.5)\ Impact_{500MHz} = \frac{Speed_{1200} - Speed_{500}}{Speed_{1200}} = \frac{1200.98 - 600.49}{1200.98} = 50\%$$

C.3. Bridging the digital divide: use of Wi-Fi to increase coverage in rural and isolated areas (effect 2.5)

The increase in WISP connections is directly related to the growth of connections according to the allocation scenarios of the 6 GHz band.

In this regard, in order to analyze the impact of the standard upgrade on the increase of connections in homes in rural and isolated areas, two main aspects must be established: (i)

[69] Calculated as 10 BTS (Bits per Symbol) * 0.83 (error correction) * (Resource units/0.000136 sec)/100000

the number of maximum outdoor channels influences the number of connections that could be deployed; and (ii) the number of connections for the allocation of resource units (see Table C-10).

Table C-10. Maximum number of users per 6 GHz band allocation scenarios

	1200 MHz	500 MHz
Available bandwidth	1,200	500
Available bandwidth outdoors (UNII-5 and UNII-7)	850	500
Number of 20 MHz channels	42	25
Maximum number users with 242 RUs	42	25

Source: Telecom Advisory Services analysis

Along these lines, the impact of different frequency allocation scenarios is related to the reduction of the number of connections to be handled under 500 MHz alternative relative to 1200 MHz:

$$(Eq. 6)\ Impact_{500MHz} = \frac{Connections_{1200} - Connections_{500}}{Connections_{1200}} = \frac{42 - 25}{42} = 40.48\%$$

C.4. Benefits derived from reduced latency (effect 3.4)

As a starting point, in a comparison of the technical performance regarding latency for Wi-Fi 6, a Wi-Fi Alliance analysis refers to field tests conducted by Qualcomm in a home environment where the data delivery response is reduced by 40% (see Table C-11 and Equation 7).

Table C-11. Latency scenarios in use cases for Wi-Fi 6 environments

Environments	Latency (ms) Download (DL)	% Latency reduction
Household Wi-Fi5	15	**40%**
Household Wi-Fi 6	9	

Source: WiFi Alliance, "The Beacon" https://www.wi-fi.org/beacon/rolf-de-vegt/reduced-latency-benefits-of-wi-fi-6-ofdma

$$(Eq. 7)\quad \Delta L = \frac{L_{WiFi} - L_{WiFi6}}{L_{WiFi}} = \frac{15 - 9}{15} = \frac{6}{15} = 40\%$$

Although the Wi-Fi Alliance refers to the latency of office environments with Wi-Fi 6, it is assumed that in relation to the Wi-Fi 6E standard there is a similar variation in latency, since it has the same channelization characteristics, although with greater bandwidth, which achieves the same theoretical speeds with an increase in the number of users. In this sense, the usage ratio between Wi-Fi 6 and Wi-Fi 6E could establish at most a latency similar to Wi-Fi 6 considering the use of the same channel width in the most used bands, currently, such as 2.4 GHz and 5 GHz.

Considering the lack of available information of tests differentiating between frequency bands in terms of their latency impact, we had to assume regarding the impact scenarios. In that sense, we rely on the reduction of latency data from Wi-Fi 6 (40%) and assume that use of the 6 GHz band will remain at constant speed and therefore the variable changing as a result of the different frequency allocation scenarios would be for the same number of users. Under the constant speed assumption, latency would change under frequency allocation scenarios: in other words, the 40% reduction would be the same under the two-frequency allocation alternative of 500 MHz.

C.5. Enhanced IoT deployment (effect 3.5)

Considering that the number of M2M connections is the main variable in this case, the ratio of total IoT equipment is linked to the amount of assigned spectrum ($\Delta Spectrum$).

For the scenario of occupying the 6GHz band (1,200MHz) there would be no increase since Wi-Fi 6E under the 6 GHz band would occupy the same amount of spectrum. However, for the scenario of reduced allocation of 500 MHz, the reduction of M2M connections would amount to 58.33% (see Equation 8).

$$(Eq.8) \quad \Delta Spectrum = \frac{S_{1200\ MHz} - S_{500MHz}}{S_{1200\ MHz}} = \frac{1{,}200 - 500}{1{,}200} = \frac{700}{1{,}200} = 58.33\%$$

C.6. Deployment of Augmented Reality/Virtual Reality solutions (effect 3.6)

The impact of different frequency allocation alternatives is assessed on the basis of Mehrnoush, M., Hu, C. and Aldana, C. (2022) “AR/VR spectrum requirement for Wi-Fi 6E and beyond” paper[70], which estimate the maximum number of AR/VR devices supported in a classroom of a given school, depending on whether 500 MHz or 1200 MHz are available for unlicensed use cases. This paper estimates, under a set of parameters of speed (50 Mbps) and latency (20 ms), through a simulation the maximum simultaneous number of headsets that can be used under both frequency allocation alternatives, keeping at a minimum the signal degradation.

According to the paper results, under 500 MHz allocation, the RLAN can only handle four students in a school composed of four classrooms per floor. Under 1200 MHz, the RLAN can handle up to 22 students within 14 classrooms per floor (or the whole school). The number of connected users diminishes by 81.82% from 1200 MHz to 500 MHz scenario. (see table C-12).

[70] Mehrnoush, M., Hu, C. and Aldana, C. (2022) “AR/VR spectrum requirement for Wi-Fi 6E and beyond”, *IEEE Access* (December)

Table C-12. Reduction of AR/VR users under different frequency allocation alternatives

Available spectrum (MHz)	500	1200
Connected users	4	22
Impact	81.82%	

Source: Telecom Advisory Services analysis

This simulation estimates were validated in a 6 GHz pilot project testing the impact of 6 GHz in Ramathibodi Hospital in the outskirts of Bangkok (Thailand). While the complete pilot was not finished, the test of AR/VR use cases for 10-12 users under the 500 MHz indicated a serious degradation of latency reaching between 200 ms and 260 ms due to code channel interference. When use cases were moved to 160 MHz channel (a feature facilitated by 1200 MHz allocation that can handle seven such channels) latency dropped to 30 ms.

DC.7. Cellular networks CAPEX savings by off-loading traffic to Wi-Fi (effect 4.1)

The increase in traffic due to the amount of spectrum assigned in the 6 GHz band has a direct influence on the reduction of CAPEX due to the overflow of mobile traffic to Wi-Fi networks. It is possible to relate the average speed variation with this indicator to establish a relationship between CAPEX and Wi-Fi traffic (see example of equation 13 below).

Table C-13 presents the impact of alternative scenarios of frequency allocation.

Table C-13. Difference between frequency allocation scenario of the 6 GHz band

Frequency allocation scenario	Speed	3200 maximum channels	Speed per connection	Difference with 1200 MHz
1200 MHz	1,200.98	3	3,602.94	0%
500 MHz	600.49	1	600.49	83.33%

Source: Telecom Advisory Services analysis

That is, under 500 MHz alternative, speed is the variable that allows us to establish an impact relationship between Wi-Fi network overflow traffic and the mobile network of 83.33%.

C.8. Revenues of Wi-Fi based Public Internet Service Providers (effect 4.2)

The main variable driving economic value of the 6 GHz band for WISPs is related to the number of public Wi-Fi access points. From a technical point of view, the 6 GHz band for outdoor use is defined through the power characteristic of the equipment (*standard power*) occupying the UNII-5 (5925-6425: 500MHz) and UNII-7 (6525-6875: 350MHz) band classification. To determine the impact of the technological upgrade on the increase of connections, two variables must be taken into consideration: (i) the maximum number of outdoor channels and (ii) the number of connections by resource units and bandwidth (see Table C-14).

Table C-14. Number of connections by resource units and bandwidth

Resource Units \ MHz	20	40	80	160	320
26	9	18	36	72	144
52	4	8	16	32	64
102	2	4	8	16	32
242	1	2	4	8	16
484	-	1	2	4	8
980	-	-	1	2	4
1960	-	-	-	1	2
3920	-	-	-	-	1

Source: Telecom Advisory services analysis

In a 1200 MHz allocation scenario, the implied 102 resource units and three 320 MHz channels could serve a maximum of 96 connections. A reduction in the amount of allocated frequency has a negative impact in the number of connections, according to the values of table C-15.

Table C-15. Impact of decreasing frequency scenarios on the number of connections

	500 MHz	1200 MHz
Maximum number of 320 MHz channels	1	3
Connections with 242 resource units	32	96

Source: Telecom Advisory services analysis

In light of this, the reduction in the number of connections under the 500 MHz alternative relative to the 1200 MHz alternative is 66.67% (see Eq. 14) (Eq. 9).

$$(Eq. 9) \quad Connections_{500} = \frac{C_{1200} - C_{500}}{C_{1200}} = \frac{96 - 32}{96} = 66.67\%$$

C.9. Manufacturing of Wi-Fi devices and equipment for residential use (effect 5.1)

It is possible that, in the ratio of total sales of locally manufactured residential equipment, only the sales of Access Points are linked to the number of indoor users. However, it would be necessary to validate whether only part of the percentage increase in users is applicable to this case. In that sense, while leaving the values that increase indoor users, it would be important to look for a market-related value rather than a technical one.

Under the 500 MHz frequency allocation alternative, the reduction on the number of devices manufactured would be 58.33% (see Eq. 10).

$$(Eq. 10) \quad \Delta Spectrum = \frac{S_{1200\ MHz} - S_{MHz}}{S_{1200\ MHz}} = \frac{1{,}200 - 500}{1{,}200} = \frac{700}{1{,}200} = 58.33\%$$

In this sense, the percentage increase in indoor users is linked to the estimated traffic generated and bandwidth by the adoption of each standard, which has a direct impact on the manufacturing of equipment for residential use (see Table C-16).

Table C-16. Impact of decreasing frequency scenarios on the number of devices

	Bandwidth (MHz)	Reduction relative to 1200 MHz
Full Band 6 GHz	1200	0 %
500 MHz	500	58.33%

Source: Telecom Advisory services analysis

C.10. Benefits of firms in the AR/VR ecosystem (effect 5.4)

Similar to the C.6 item, the number of AR/VR devices that can be simultaneously connected depends on the amount of unlicensed spectrum in the 6 GHz band (see table C-17).

Table C-17. Reduction of AR/VR users under different frequency allocation alternatives

Available spectrum (MHz)	500	1200
Connected users	4	22
Impact	81.82%	

Source: Telecom Advisory Services analysis

C.11. Compilation of improvement ratios by source of economic value

The impact of the 500 MHz RLAN allocation options has been compiled in relation to the reduction in either broadband speed, latency, number of users, or spectrum capability.

Table C-18. Decrease of 500 MHz RLAN allocation alternative relative to 1200 MHz (in percentage)

Sources	Effects	500 MHz decrease over 1200 MHz			
		Speed (Mbps)	Latency (Ms)	# Users	Spectrum
1. Free Wi-Fi	1.1. Savings incurred by consumers by accessing free Wi-Fi in public sites				
	1.2. Free Wi-Fi service supporting the needs of the broadband unserved population			41.18%	
	1.3. Benefit to consumers enjoying higher speed from free Wi-Fi under Wi-Fi 6E, and Wi-Fi 7			41.18%	
	1.4. Benefit to consumers relying on Wi-Fi in educational institutions				
	1.5. Use of Wi-Fi in highly dense heterogeneous environments				
2. Res	2.1. Home internet access for devices that lack an Ethernet port				

	2.2. Avoidance of inside wiring investment				
	2.3. Consumer benefit derived from faster broadband speed	50%			
	2.4. Consumer benefit generated by use of residential Wi-Fi devices and equipment				
	2.5. Bridging the digital divide: use of Wi-Fi to increase coverage in rural and isolated areas			40.48%	
3. Enterprise Wi-Fi	3.1. Savings in business Internet traffic transmitted through Wi-Fi				
	3.2. Avoidance of enterprise building inside wiring				
	3.3. Benefits derived from an increase in average speed				
	3.4. Benefits derived from reduced latency		40%		
	3.5. Enhanced IoT deployment				58.33%
	3.6. Deployment of Augmented Reality/Virtual Reality solutions			81.82%	
4. ISPs	4.1. Cellular networks CAPEX savings by off-loading traffic to Wi-Fi	83.33%			
	4.2. Revenues of Wi-Fi based Public Internet Service Providers			66.67%	
	4.3. Revenues of Wi-Fi based Wireless Internet service Providers			40.48%	
5. Wi-Fi ecosystem	5.1. Manufacturing of Wi-Fi devices and equipment for residential use				58.33%
	5.2. Manufacturing of enterprise Wi-Fi devices and equipment				
	5.3. Benefits of Firms in the IoT ecosystem				58.33%
	5.4. Benefits of firms in the AR/VR ecosystem			81.82%	