Assessing the economic value of unlicensed use of the 6 GHz band in Indonesia

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EXECUTIVE SUMMARY

The objective of the following study is to provide an assessment of the economic value to be derived through opening the 6 GHz spectrum band to unlicensed use in Indonesia. The analysis focuses on the impact on service quality, coverage, affordability, as well as the introduction of specific applications and use cases in the enterprise and consumer markets supported by three classes of 6 GHz devices[1] and favorable technical rules[2]. The study does not address the cost of clearance of the 6 GHz band.

The methodology relied upon in this study identifies the different sources of economic value, calculates them independently, and then aggregates them within a single estimate (table A).[3]

Table A. Sources of Value of 6 GHz Band in Indonesia

Source of Value	GDP contribution	Producer surplus	Consumer surplus
Enhanced coverage and improved affordability	Improve affordability associated with broadband provision and increase access sharing in the Wireless ISP sector		Faster speed of access for Wireless ISP subscribers
Increased broadband speed by reducing Wi-Fi congestion	Benefits of eliminating router bottleneck in high-speed connections by increasing speed of residential Wi-Fi		Consumer surplus from increasing speed
Wide deployment of Internet of Things	Spillovers of IoT deployment on productivity of key sectors of the Indonesian economy (e.g. automotive, food processing, logistics, etc.)	Margins of ecosystem firms (Hardware, software, services) involved in IoT deployment in Indonesia	
Reduction of enterprise wireless costs		Cost reduction of enterprise use of wireless communications	
Deployment of AR/VR solutions	Spillovers of AR/VR deployment on the Indonesian economy	Margins of ecosystem firms involved in AR/VR deployment in Indonesia	
Enhanced deployment of municipal Wi-Fi	Increase in GDP due to enhanced broadband adoption		Consumer surplus from faster data download rate as enabled by faster broadband

[1] The three classes of 6 GHz Restricted Radiation Radiocommunications Equipment are low power indoor devices, standard power devices, and very low power devices.
[2] Technical rules such as the amount of spectrum permitted for shared use, radiated power limit, radiated power spectral density limit, and the out-of-band-emissions limit for each class of devices will determine whether the 6 GHz band spectrum can be used to its fullest economic potential.
[3] All estimates in this report are provided in US dollars.

Source of Value	GDP contribution	Producer surplus	Consumer surplus
Deployment of Free Wi-Fi Hot Spots	Increase in GDP due to enhanced broadband adoption		Consumer surplus from faster data download rate as enabled by faster broadband
Aligning spectrum decision with that of other advanced economies	Potential opportunity of creating a Wi-Fi equipment manufacturing sector	Benefits of economies of scale of aligning Indonesia with the regions of lower equipment prices	
Enhancing the capability for cellular off-loading		CAPEX reduction derived from offloading wideband wireless traffic to carrier grade Wi-Fi hot spots	
Increasing production of residential Wi-Fi devices and equipment		Margins of ecosystem firms involved in manufacturing Wi-Fi enabled equipment in Indonesia	Consumer surplus from using Wi-Fi enabled residential devices and equipment

Source: Telecom Advisory Services analysis

The following study provides an estimate for making the full 6 GHz band available to unlicensed use, a model adopted in many countries around the world.[4] The cumulative economic value between 2022 and 2031 associated with allocating the 1200 MHz in the 6 GHz band in Indonesia amounts to US$ 187.63 billion, broken down by US$ 126.44 billion in GDP contribution, US$ 37.73 billion in producer surplus to Indonesian enterprises, and US$ 23.47 billion in consumer surplus to the Indonesian population (see table B).

Table B. Indonesia: Economic Value of Allocating 1200 MHz in 6 GHz Band (2022-2031) (in US$ billions)

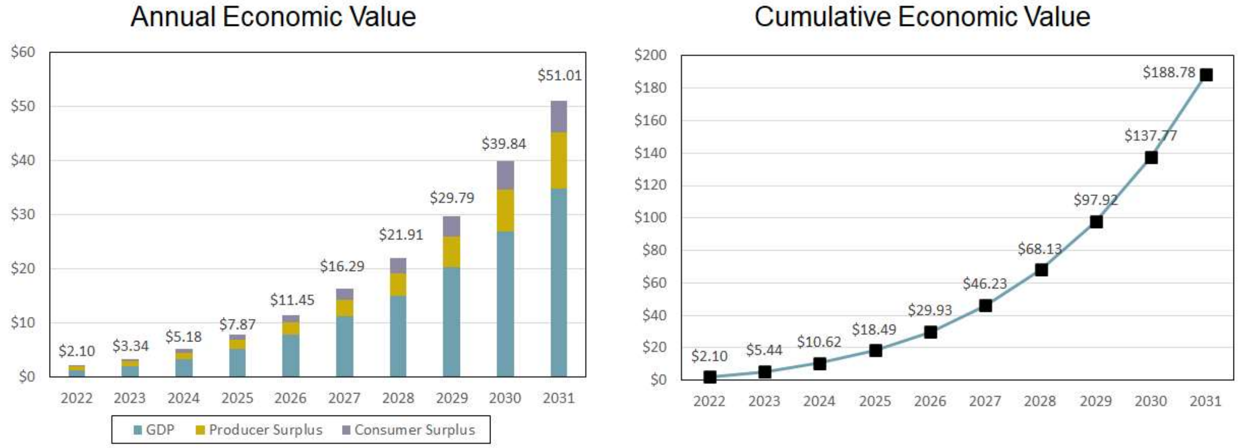
Source of Value	GDP contribution	Producer surplus	Consumer surplus
Enhanced coverage and improved affordability	**$ 5.16**		**$ 0.05**
Increased broadband speed by reducing Wi-Fi congestion	**$ 29.99**		**$ 3.62**
Wide deployment of Internet of Things	**$ 14. 09**	**$ 21.24**	
Reduction of enterprise wireless costs		**$ 0.92**	
Deployment of AR/VR solutions	**$ 36.57**	**$ 7.24**	
Enhanced deployment of municipal Wi-Fi	**$ 6.61**		**$ 0.04**
Deployment of Free Wi-Fi Hot Spots	**$ 34.03**		**$ 1.88**
Aligning spectrum decision with other advanced economies		**$0.38**	
Enhancing the capability for cellular off-loading		**$ 2.96**	
Increasing production of residential Wi-Fi devices and equipment		**$ 4.99**	**$ 17.88**
TOTAL	**$ 126.44**	**$ 37.73**	**$ 23.47**

Source: Telecom Advisory Services analysis

[4] The United States, South Korea, Brazil, Saudi Arabia, and Canada, among many other countries.

The total economic value increases over time with significant acceleration towards the end of the period due to the value leverage capability of 6 GHz (see graphic C).

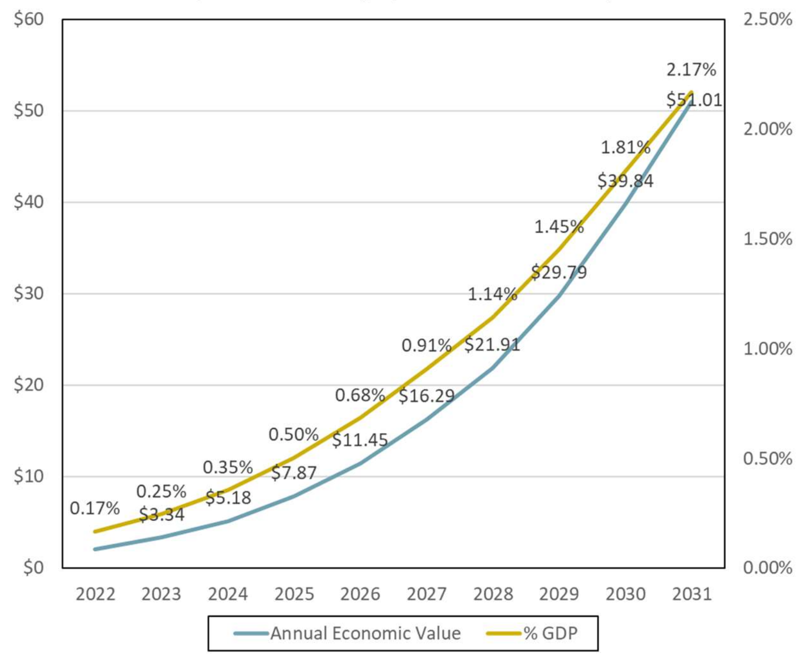
Graphic C. Indonesia: Economic value of allocating 1200 MHz in the 6 GHz band (2022-2031) (in US$ billions)



Source: Telecom Advisory Services analysis

The total cumulative impact of $ 188.78 billion equates to 1.07 % of the country's cumulative GDP between 2022 and 2031. Furthermore, the economic impact of the allocation of the entire 6 GHz band to unlicensed use will be increasing over time, reaching in 2031 over 2.2 % of the country's GDP (see Graphic D).

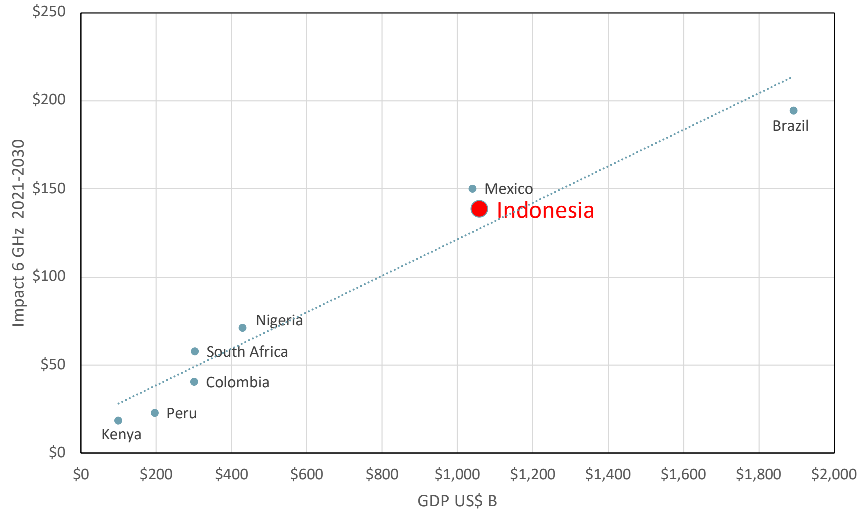
Graphic D. Indonesia: Annual GDP Impact of Allocating 1200 MHz of the 6 GHz Band (2022-2031) (in US$ billions)



Source: Telecom Advisory Services analysis

The economic impact of the 1200 MHz spectrum allocation of Indonesia is in line with the country's economy (see Graphic E).

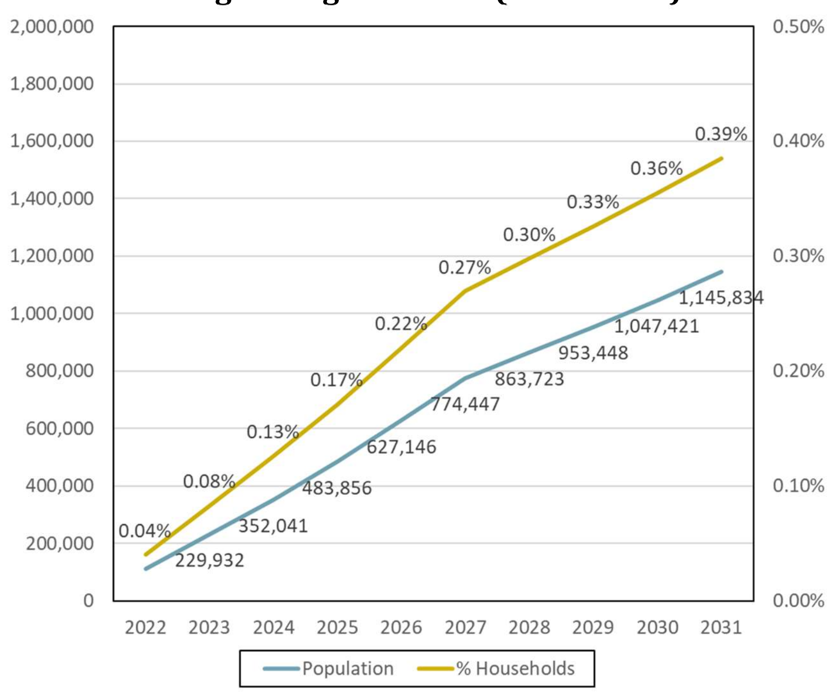
Graphic E. Cumulative Economic impact of 1200 MHz and GDP



Source: Telecom Advisory Services analysis

In addition, the allocation of the entire band to unlicensed use will result in a significant contribution to a reduction of Indonesia´s digital divide. By providing affordable paid service and free access over hot spots because of allocating the full 6 GHz band to Wi-Fi, an incremental 1,145,834 Indonesians will be able to gain access to the Internet by 2031 (see Graphic E).

Graphic E. Indonesia: Contribution of Allocating 1200 MHz of the 6 GHz Band to closing the digital divide (2022-2031)



Source: Telecom Advisory Services analysis

In conclusion, the allocation of the full 1200 MHz of the 6 GHz band is an advantageous approach from an economic impact and digital divide reduction standpoints. Based on the decisions made by regulators around the world, equipment capable of using the new band is starting to be approved.[5]

[5] For example, the FCC already approved a transmitter chipset capable of operating in the 1200 MHz of the 6 GHz band produced by Broadcom, and a Tri-band system on a chip manufactured by NXP Semiconductors.

1. INTRODUCTION

The objective of this study is to provide an assessment of the economic value to be derived by opening the 6 GHz band to unlicensed use in Indonesia by assessing the impact on service quality, coverage, and affordability, as well as focusing on specific applications and use cases likely to be introduced in the enterprise and consumer markets. At the aggregate level, the methodology relied upon in this study is like the one used in our studies in support of the 6 GHz decision in the United States[6], Brazil[7], Colombia[8], Mexico[9], and Peru[10], whereby the different sources of economic value were calculated independently and then aggregated within a single estimate (this allows cumulating GDP impact, with consumer and producer surplus).

Chapter 2 provides the background and theoretical framework in support of the analyses. Chapter 3 presents the methodologies implemented to quantify the economic value to be generated by the proposal under consideration. Following that, Chapters 4 through 13 detail the analyses and results of each source of value. Chapter 14 concludes by providing an aggregate estimate of economic value.

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[6] See Katz, R. (2020). *Assessing the economic value of unlicensed use in the 5.9 GHz and 6 GHz bands*. Washington, DC: Wi-Fi Forward.

[7] See Katz, R. and Callorda, F. (2020). *Avaliação do valor econômico do uso não licenciado na faixa de 6 GHz no Brasil.* New York: Telecom Advisory Services (Agosto).

[8] See Katz, R. and Callorda, F. (2021). *Estimación del valor económico del uso no licenciado de la banda de 6 GHz en Colombia*. New York: Telecom Advisory Services (Enero).

[9] See Katz, R. and Callorda, F. (2021). *Estimación del valor económico del uso no licenciado de la banda de 6 GHz en México*. New York: Telecom Advisory Services (Enero).

[10] See Katz, R. and Jung, J. (2021). *Estimación del valor económico del uso no licenciado de la banda de 6 GHz en Perú*. New York: Telecom Advisory Services (Marzo).

2. THEORETICAL FRAMEWORK AND BACKGROUND

Indonesia has so far allocated some license-exempt frequency bands for Wi-Fi use: the 2400-2483.5 MHz band plus the following frequency ranges: 5150 – 5250 MHz, 5250 – 5350 MHz, and 5725 – 5825 MHz.[11] The main objective of allocating unlicensed spectrum has been to promote rapid expansion of services and to increase use of Internet services, relying on Wi-Fi technologies.

The following study provides an estimate for expanding the frequencies available for unlicensed use, by considering the potential allocation for this purpose of the full 6 GHz, a model adopted in many countries around the world. The recent decisions adopted by several countries on this subject reflects the growing importance that Wi-Fi technology represents in the fixed wireless ecosystem. It raises the need to evaluate the impact of such a move in terms of its contribution to economic growth, enterprise surplus, and consumer welfare. The following chapter presents the theoretical framework within which such contributions will be estimated.

2.1. The intrinsic value of unlicensed spectrum

Unlicensed spectrum (that is to say, spectrum not owned by a license holder) existed since the 1930s. However, recognizing its importance, the United States Federal Communications Commission (FCC) opened new spectrum for unlicensed use in the 902-928 MHz, 2400-2483.5 MHz, and 5725-5850 MHz bands in 1985. This initiative led to the introduction of protocols such as Bluetooth and Wi-Fi devices. In 2003, recognizing the growing value of the technology, the International Telecommunications Union World Radio-communication Conference recommended to open more bands to Wi-Fi use around the world. Ever since then, Wi-Fi technology has taken a prominent position in the wireless ecosystem.[12]

The debate over the most effective way of allocating frequency spectrum has been carried on over the past fifty years, especially since the publication of Coase's seminal paper (1959) on spectrum management. A key issue of the policy debate relates to the management of unlicensed spectrum. Key policy questions range from whether granting exclusive licenses would deter innovation to if setting spectrum for unlicensed uses would be costly in terms of reduced government revenues to be derived from auctioning frequency rights. Along these lines, research to date has produced several very important theoretical and empirical studies in support of unlicensed use (Milgrom et al, 2011; Carter, 2003; Cooper, 2011; Marcus et al, 2013; Crawford, 2011; Benkler, 2012; Calabrese, 2013). That said, while the debate has highlighted the diverse beneficial effects of unlicensed spectrum - such as triggering

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[11] https://www.cetecom.com/en/news/sdppi-regulates-use-of-products-with-radio-technologies-in-indonesia/

[12] The success of both standards led to the assignment in the United States of other bands to unlicensed use. By the end of 2008, approximately 955 MHz were allocated to unlicensed use below 6 GHz (the most used bands included 900 MHz, 2.4 GHz, 5.2/5.3/5.8 GHz, and above 60 GHz). In 2014, the FCC assigned the 5.8 GHz band to unlicensed application and is presently considering supplementing this band by making the bottom 45 MHz of the 5.9 GHz band available to unlicensed use. Finally, in 2020, the FCC allocated 1200 MHz in the 6 GHz band to unlicensed use.

technological innovation, complementing cellular networks, and the like - research has only recently focused on assessing unlicensed spectrum's economic value, particularly the producer and consumer surplus derived from keeping a portion of the spectrum unassigned as well as its GDP contribution[13]. Part of the difficulty in assessing the value of unlicensed spectrum resides on the fact that, unlike licensed spectrum that is used for a few, homogeneous services, unlicensed bands provide the environment for the provision of several heterogeneous services and devices. Furthermore, given the complementarity between applications relying on unlicensed and licensed spectrum, value estimation of the unlicensed portion is non-trivial. Nevertheless, an evidence-based policy debate requires the rigorous quantification of economic value of the unlicensed spectrum.

In 2009, Richard Thanki produced the first paper to determine the economic value of unlicensed spectrum. He estimated that three major applications (residential Wi-Fi, hospital Wi-Fi, and retail clothing RFID) in the United States generated value in the range of $16 billion to $36.8 billion. At the time, the author acknowledged that these estimates covered only a fraction of the economic value[14] and, consequently, were too conservative. Two years later, Milgrom et al. (2011) supported Thanki's estimates, but also provided additional values for other applications. For example, the authors estimated the economic value of Apple's iPad, a device intimately linked to the use of Wi-Fi, at $15 billion. Additionally, the authors quantified other benefits in the United States alone, such as Wi-Fi supported cellular off-loading ($25 billion) and the value of Wi-Fi faster data rates of mobile phones ($ 12 billion). Finally, they referenced other non-quantified benefits, such as the usage of Wi-Fi only devices and future applications such as Super Wi-Fi[15] and Advanced Meter Infrastructure. A year later, Thanki (2012) produced a new piece of research, refining his residential Wi-Fi estimate and quantifying other benefits of unlicensed spectrum. He estimated the annual consumer surplus of residential Wi-Fi to be between $118 and $225 per household (a total of $15.5 billion for the United States). Additionally, enlarging the original scope of benefits, he assessed the producer surplus derived from carrier savings resulting from Wi-Fi off-loading ($8.5 billion for the United States). Finally, he estimated the value generated by enhanced affordability (an assessment mainly focused on emerging markets) and mentioned potential innovation related benefits related to deployment by Wireless Internet Service Providers (WISPs). In the same year, Cooper (2012) calculated the economic value by estimating the number of cell sites that the wireless industry would avoid investing in as a result of traffic off-loading to Wi-Fi carrier grade hot spots (130,000), which would result in annual savings of $26 billion. In a similar vein, the author of this paper has developed numerous studies assessing the economic value of unlicensed spectrum for different bands in the United States (Katz, 2014a, 2014b, 2018, 2020) and other advanced economies (Katz et al., 2018).

[13] This is contrary to research on the valuation of consumer welfare derived from the use of licensed spectrum which has been a standard research practice given the availability of auction data and consumption series (see Hazlett (2005): Hausman, 1997).

[14] Thanki estimated that the three applications represented 15% of the unlicensed wireless chipsets to be shipped in the US in 2014.

[15] Super Wi-Fi refers to IEEE 802.11g/n/ac/ax implementations over unlicensed 2.4 and 5 GHz Wi-Fi channels but with performance enhancements for antenna control, multiple path beam selection, advance control for best path, and applied intelligence for load balancing.

In all, the evidence is quite compelling about unlicensed spectrum capacity to enable numerous applications, services, and devices (see table 2-1):

Table 2-1. Unlicensed Spectrum: Standards and enabled complementary technologies

Standards	Frequency bands	Geographic Range	Data rate	Devices and applications
Wi-Fi (802.11b, 802.11ax)	• 2.4 GHz • 5 GHz • 6 GHz	• indoor: 38 meters • outdoor: 125 meters	• Up to 1200 Mbps	• Computers, Printers, scanners, tablets • Mobile phones, scanners • AR/VR devices
Bluetooth (802.15.1)	• 2.4 GHz	• Short range indoors	• 1-3 Mbps	• Phone headsets, PC networks • Barcode scanners • Credit card payment machines
ZigBee (802.15.4)	• 915 MHz	• 75 meters	• 250 Kbps	• Wireless light switches • Electrical meters with in-home-displays • Traffic management systems
Wireless HART (802.15.4)	• 2.4 GHz	• indoor: 60 -100 meters • outdoor: 250 meters	• 250 Kbps	• Equipment and process monitoring • Environmental monitoring, energy management • Asset management, predictive maintenance, advanced diagnostics
Wireless HD	• 60 GHz	• 30 feet	• 28 Gbps	• High Definition consumer electronic devices
WiGig (802.11ad)	• 60 GHz	• 5 -10 meters	• 6 Gbps	• Smartphones, Tablets, Docking stations • PCs & Peripherals, TV & Peripherals • Digital Cameras, Camcorders
RFID	• 50-500 KHz • 13.56 MHz • 0.9 to 2.5 GHz	• Up to 29 inches	• Read-only: 8.75 kbps • Active Read - Write: 3 kbps	• Asset tracking • Livestock tracking, credit card payments • Highway toll payments • Supply chain management

Source: Compiled by Telecom Advisory Services

The economic value generated by the use of unlicensed spectrum can be categorized across four dimensions:

- **Complementing wireline and cellular technologies:** A complementary technology is a resource that, due to its intrinsic strengths, compensates for the limitations of another. In the case of spectrum management, unlicensed frequency bands can enhance the effectiveness of devices that use licensed spectrum. For example, Wi-Fi base stations operating in unlicensed bands can enhance the value of cellular networks by allowing wireless devices to switch to Wi-Fi access points, thereby reducing the cost of wireless broadband access and increasing the access speed rate. Consumers accessing the Internet within the reach of a Wi-Fi site can reduce their costs of access by turning off their wideband service. They can also gain additional access speed because the transfer rate of Wi-Fi sites is generally faster than that offered by cellular technology (although 5G is narrowing down the difference).

Wireless operators can also 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. In addition to reducing spending, wireless carriers can offer fast access service without a base station congestion challenge. Finally, cellular carriers derive benefits from avoiding CAPEX because a portion of traffic is off-loaded to residential Wi-Fi or business networks.

- **Developing alternative technologies, thus expanding consumer choice**: In addition to complementing cellular networks, unlicensed spectrum can provide the environment needed for operating technologies that are substitutes to licensed uses, thereby providing consumers with a larger set of choices. By limiting power and relying on spectrum with low propagation, unlicensed bands avoid interference, rendering the need for property rights irrelevant. In fact, some of the most important innovations in wireless communications are intimately linked to Wi-Fi for gaining access. This is particularly relevant in the 6 GHz band for the development of Very Low Power devices.

- **Supporting innovative business models:** By providing consumers with additional service choices, unlicensed spectrum also supports the development of innovative business models. The causality between unlicensed spectrum and innovation occurs at multiple levels. First, firms developing new applications in an unlicensed spectrum environment do not need approval from the operators of cellular networks. On the other hand, a firm that attempts to develop a product running on spectrum licensed to a set of exclusive holders faces a "coordination failure" barrier (Milgrom et al., 2011). Along those lines, if the product requires the acceptance and coordination of multiple license holders (say, multiple cellular network operators), the innovator must negotiate with every one of them (unless it is willing to face the problem of restricting its market reach).[16]

- **Expanding access to communications services**: In addition to the applications discussed above, technologies operating in unlicensed spectrum can bridge the broadband coverage digital divide. Further developments in the areas of spectrum sensing, dynamic spectrum access, and geolocation techniques (Stevenson et al., 2009) have improved the quality of wireless service based on unlicensed spectrum technologies, substantially extending the geographic range of conventional 802.11 standard and providing cost-efficient access in rural settings.

[16] This is a very common phenomenon existing in the development of wireless devices, whereby manufacturers need to face not only type approval certification from regulatory agencies but also the need to sign distribution agreements with wireless operators. Witness the experience of Apple at the time of iPhone launch.

2.2. Alternative models for allocating the 6 GHz band for unlicensed use

Ever since October 2018, when the Federal Communications Commission in the United States presented a Notice of Proposed Rulemaking (NPRM) that recommended opening the 6 GHz band to unlicensed operations, countries around the world have either launched public consultations or made allocation decisions. At the highest level, countries have been following two approaches – allocating the entire band or just its lower portion – although differences exist in terms of the authorization to use the band for specific devices. For example, the United States regulator permitted standard power and low power indoor devices to operate in the 6 GHz band but proposed a third category of 6 GHz RRRC Equipment -- Very Low Power devices (VLP), that should be permitted to be used indoors or outdoors in certain sub-bands.[17] In a more radical move, Canada became the world's first country to allow all three (LPI, VLP, and standard power) device classes to operate in 6 GHz.[18]

Other countries have followed or are considering an approach to allocate the lower band – 5925-6425 MHz – which is adjacent to the currently used 5 GHz band, has similar mid-range propagation characteristics, and offers, wide, non-overlapping channels. The underlying rationale for considering only the 5,925-6,425 MHz band is that some countries (especially in Europe) have critical services in the upper part of the 6 GHz band (e.g., large amounts of point-to-point fixed services, earth to space communications, road intelligent traffic systems and communication-based train control, and some radio astronomy sites). That said, those countries that have adopted the allocation of only the lower portion of the 6 GHz band, recognize that this can change in the future. For example, OFCOM in the United Kingdom made its final decision to allocate 500 MHz for unlicensed use low power indoor and very low power outdoor use as an initial matter[19]. The purpose in limiting the allocation to 500 MHz is to initially show Wi-Fi can benefit from the lower part of the band and investigate the upper part I the future[20]. In the words of OFCOM, "we will continue to review use of the upper 6 GHz band to determine what the optimal use may be".[21]

The current state of the process in the allocation of the 6 GHz around the world can be summarized at the time of closing of this study as follows (see table 2-2).

Table 2-2. Countries that have either approved or are considering allocating the 6 GHz band for unlicensed use (September 2021)

[17] Very Low Power devices (VLP), authorized to power levels 160 times lower than standard-power Wi-Fi, and permitted to be used indoors or outdoors in certain sub-bands, and not requiring frequency coordination because they would operate with 60 times less power than standard-power Wi-Fi. These VLP devices would be capable of operating using multiple extremely wide channels (160 MHz) with sub-millisecond latency performance. The category includes AR/VR headsets, Ultra High-Definition Video Streaming, high-speed[17] tethering (watches, ear pods) or entertainment devices in the automobile.

[18] Government of Canada (2021). *Government of Canada to make more spectrum available to support high-quality wireless service,* Ottawa, May 21.

[19] OFCOM (2020). *Statement: improving spectrum access for wi-fi – spectrum use in the 5 and 6 GHz bands* (July 24).

[20] Ebbecke, Ph. (2019). *Road to 6 GHz in Europe*. Presentation to WLPC Prague 2019

[21] OFCOM (2020). *Improving spectrum access for Wi-Fi*. London, p.21.

Continent	Lower part (5925-6425 MHz)		Full band (5925-7125 MHz)	
	Adopted	Under consideration	Adopted	Under consideration
Americas		Argentina	Brazil, Canada, Chile, Costa Rica, Guatemala, Honduras, Peru, United States	Colombia, Mexico
Europe	European Union, Norway, United Kingdom	Switzerland, Turkey		
Arab States	United Arab Emirates	Oman	Saudi Arabia	Jordan, Qatar
Asia Pacific		New Zealand	South Korea	Australia, Japan, Malaysia
Africa	Morocco	Egypt, Tunisia		Kenya

Source: Compiled by Telecom Advisory Services from regulatory agency websites.

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Based on the background and theoretical bases presented in this chapter, this study provides an assessment of the value resulting from allocating 1200 MHz. The following chapter presents the different methodologies and assumptions that will be relied upon to estimate the economic value of designating the full 6 GHz band for unlicensed use in Indonesia.

3. METHODOLOGIES FOR ASSESSING THE VALUE OF ALLOWING UNLICENSED USE OF THE 6 GHz BAND IN INDONESIA

The objective of the study is to provide an assessment of the economic value to be derived by allowing unlicensed use in the 6 GHz band in Indonesia. Our approach to measuring economic value of unlicensed spectrum focuses first on the new economic growth in Gross Domestic Product (GDP) enabled by the additional unlicensed spectrum channels in the 6 GHz band. By including the GDP contribution measurement, we follow Greenstein et al. (2010) and prior research literature measuring the economic gains of new goods. In measuring the GDP direct contribution, we strictly consider the revenues added "above and beyond" what would have occurred had the spectrum under consideration been licensed.

Beyond GDP contribution, we add to this analysis by measuring the economic surplus triggered by the adoption of the technologies operating in the unlicensed network bands. The underlying assumption of this approach is that the unlicensed spectrum resource generates a shift both in the demand and supply curves resulting from changes in the production function of services as well as the corresponding willingness to pay. On the supply side, the approach measures changes in the value of inputs in the production of wireless communications. The most obvious example is whether Wi-Fi, enabled by unlicensed spectrum, represents a positive contribution to wireless carriers' CAPEX and OPEX insofar as they can control their capital spending while meeting demand for increased wireless traffic. From an economic theory standpoint, the wireless 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. To quantify incremental surplus derived from the adoption of technologies operating in the 6 GHz band, we itemize the number of technologies and applications intricately linked to this environment. We complement the concept of producer surplus with an assessment of the consumer surplus, a measure of user benefit.

At the aggregate level, the methodology relied upon in this study is like the one used in prior studies by the author[22], 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[23]). The area of impact of each source of value varies (see table 3-1).

[22] Katz, R. (2014a). *Assessment of the economic value of unlicensed spectrum in the United States*. New York: Telecom Advisory Services. Katz, R. (2014b). *Assessment of the future economic value of unlicensed spectrum in the United States*. New York: Telecom Advisory Services. Katz, R. (2018). A 2017 assessment of the current and future economic value of unlicensed spectrum. Washington, DC: Wi-Fi Forward. Katz, R. (2018*). The global economic value of Wi-Fi 2018-2023*. New York: Telecom Advisory Services. Katz, R. (2020). *Assessing the economic value of unlicensed use in the 5.9 GHz and 6 GHz bands*. Washington, DC: Wi-Fi Forward.

[23] We consider that cumulating 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 producer surplus driven by equipment sales triggered by new unlicensed spectrum allocation. On the other hand, CAPEX savings incurred by wireless carriers offloading traffic to Wi-Fi has been occurring for a while and could then be included in the GDP model estimates.

Table 3-1. Sources of Value of 6 GHz Band in Indonesia

Source of Value	GDP contribution	Producer surplus	Consumer surplus
Enhanced coverage and improved affordability	Improve affordability associated with broadband provision and increasing access sharing in the Wireless ISP sector		Faster speed of access for Wireless ISP subscribers
Increased broadband speed by reducing Wi-Fi congestion	Benefits of eliminating router bottleneck in high-speed connections by increasing speed of in-door Wi-Fi		Consumer surplus from increasing speed
Wide deployment of Internet of Things	Spillovers of IoT deployment on productivity on key sectors of the Indonesian economy (e.g. automotive, food processing, logistics, etc.)	Margins of ecosystem firms (Hardware, software, services) involved in IoT deployment in Indonesia	
Reduction of enterprise wireless costs		Cost reduction of enterprise use of wireless communications	
Deployment of AR/VR solutions	Spillovers of AR/VR deployment on the Indonesian economy	Margins of ecosystem firms involved in AR/VR deployment in Indonesia	
Enhanced deployment of municipal Wi-Fi	Increase in GDP due to enhanced broadband adoption		Consumer surplus from faster data download rate as enabled by faster broadband
Deployment of Free Wi-Fi Hot Spots	Increase in GDP due to enhanced broadband adoption		Consumer surplus from faster data download rate as enabled by faster broadband
Aligning spectrum decision with that of other advanced economies	Potential opportunity of creating a Wi-Fi equipment manufacturing sector	Benefits of economies of scale of aligning Indonesia with countries producing equipment at lower prices	
Enhancing the capability for cellular off-loading		CAPEX reduction derived from offloading wideband wireless traffic to carrier grade Wi-Fi hot spots	
Increasing production of residential Wi-Fi devices and equipment		Margins of ecosystem firms involved in manufacturing Wi-Fi enabled equipment in Indonesia	Consumer surplus from using Wi-Fi enabled residential devices and equipment

Source: Telecom Advisory Services analysis

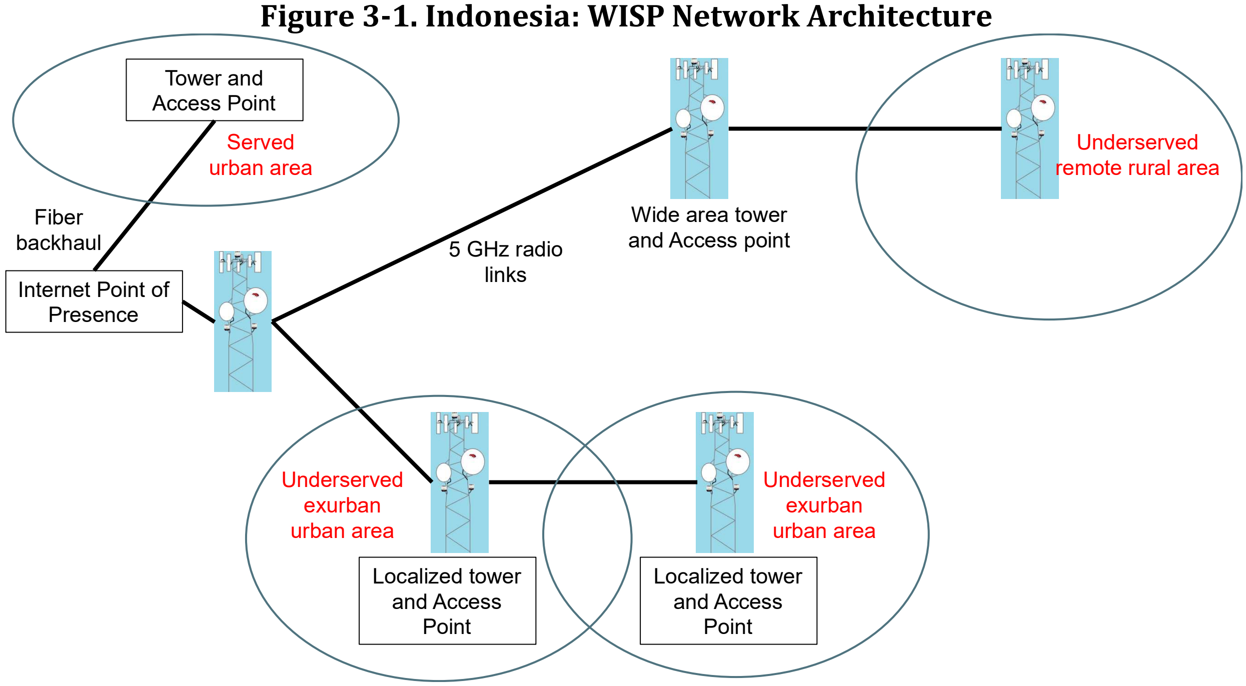
The assessments of economic value have been estimated for the years 2022 to 2031.

3.1. Enhanced broadband coverage and improved affordability

One of the most important areas of economic impact of the 6 GHz decision must be the improvement of coverage and affordability of broadband service. This analysis will focus on estimating the impact of the 6 GHz decision on the wireless ISP (WISP) industry and community networks in Indonesia. According to different data sources,[24] we estimate that an approximate 100,000 internet subscribers are served by WISPs (or 1% of the total number of fixed-broadband subscribers) although a large portion may be served by unregistered service providers. Broadband non-adopters are, as expected, concentrated on the lower income population in small urban areas and rural geographies. Wireless ISPs tend to have a primary focus on the vulnerable population and part of their deployment is in rural municipalities. In that sense, it is critical to understand how these players could benefit from the 6 GHz allocation.

For reference, the network architecture of a WISP or a community network is composed of a backhaul network linking the internet point of presence to local access points. Each access point relies in turn on Wi-Fi technology operating in the 2.4 GHz spectrum, to provide last mile broadband service to consumers (see figure 3-1).

Figure 3-1. Indonesia: WISP Network Architecture



Source: Telecom Advisory Services

In this context, the growth of WISPs has been constrained by technology and infrastructure factors, of which spectrum access is one, affecting both backhaul links and access points. Access to the 6 GHz spectrum band could have an impact on the WISP business at four levels:

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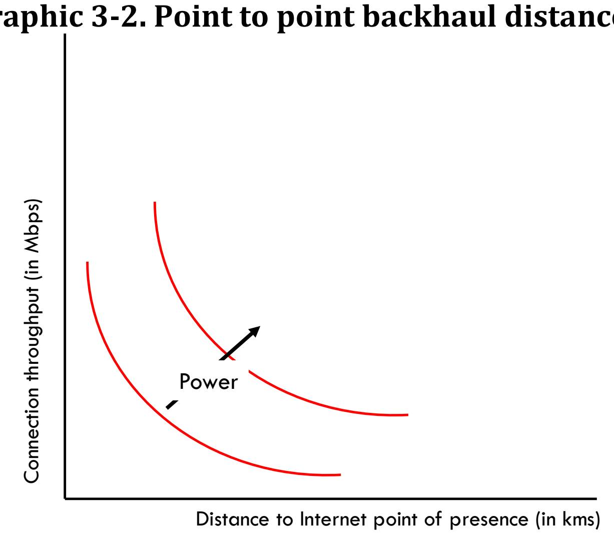
[24] Global Data estimates (2020) and Katz (2017).

- **Enhanced point to point back-haul capacity which allows WISPs to increase coverage**: as mentioned above, the link between access points is generally handled by 5 GHz radios. Under current spectrum use, the 5 GHz band is very crowded, depicting high interference. Scaling of last mile coverage is fulfilled by deploying additional access points which operate in the 2.4 GHz band. An access point relying on a single backhaul link provides access in the 10-20 Mbps bandwidth and serves 30-40 subscribers. In this context, growth of subscribers is limited by the capacity of the backhaul. While there is no limit in increasing the number of access points to serve additional users, when this occurs, service quality diminishes, and interference becomes very high because the backhaul becomes the primary bottleneck.[25]

  Access to the 6 GHz unlicensed spectrum band would allow the WISP to increase the number of access points with no backhaul constraint, since based on this decision the bandwidth available increases to 100 Mbps. A critical benefit of this move will be that WISPs could further penetrate rural areas, thereby addressing part of the digital divide. As of 2020, 4G coverage reaches 85% of the Indonesian population, which leaves 40,000,000 citizens unserved by cellular broadband. As expected, the distance that WISPs could enhance their backhaul coverage is a function of path loss and has an impact on available speed to be delivered to the consumer. Along those lines, the higher the power to be available, the lower the path loss (see conceptual graphic 3-2).

Graphic 3-2. Point to point backhaul distance



Note: This relationship assumes free space path loss with no obstructions.
Source: Telecom Advisory Services

Beyond extending their point to point backhaul links, by having the large spectrum in 6 GHz available, different WISPs could operate in similar areas with little risk of interference or serve specific communities.

[25] This effect is commonly experienced by WISPs operating in urban areas, but less so by providers serving rural areas.

- **Increase in speed to existing subscribers**: The consumer welfare of WISP customers is expected to benefit from the 6 GHz allocation and the consequent increase in access point performance, which will yield faster broadband service. Beyond the benefit of the speed increase to the existing subscriber base, the growth in throughput provides a more efficient use of infrastructure for sharing lines across subscribers, a feature that could be beneficial among low-income WISP subscribers in Indonesia.

- **Increase coverage per access point:** under use of the 2.4 GHz spectrum, WISP served areas range between 3.5 kms in urban settings to 12 kms in rural areas. Coverage is a function of spectrum frequency and power (the higher the frequency the higher the path loss, which is compensated by an increase in power). To grow coverage under standard power allowance, increased coverage could be gained by bonding channels (a technology not yet used by WISPs), available by the 6 GHz allocation. A caveat should be raised in this point: given the type of vulnerable population served by WISPs, their ability to gain access to high end devices powered with 6 GHz chips would be limited in the very near future.

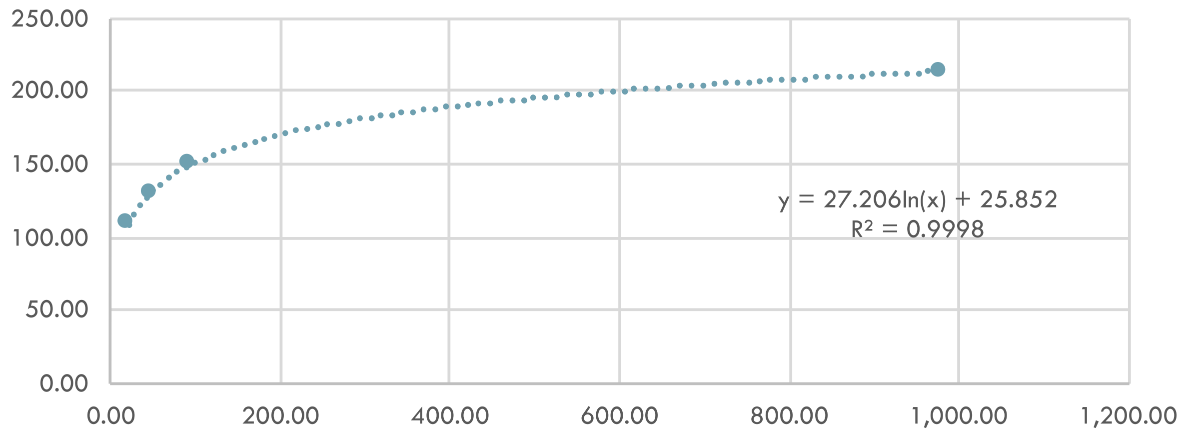
- **Higher capacity per access point**: The use of the lower part of the 6 GHz channel would allow the WISPs to increase the number of subscribers to be handled by access point, particularly in the closer areas. OFCOM estimates that the cumulation of 2.4 GHz, 5.8 GHz and 6 GHz could increase the number of subscribers per access point to at least 200. This positive effect might be limited by the caveat raised above regarding the availability of devices powered by 6 GHz chips.

Contribution to consumer surplus as a result of increasing broadband speed

Consumer surplus is defined as the value that consumers receive from purchasing a product for a price that is less than what they would be willing to pay. Early on, Rosston et al. (2010) noted that, in addition to the benefits that consumers receive from broadband adoption (quick access to large amounts of information for health-related services, access to distance learning, access to the world's largest portal for social and entertainment services and the potential for savings from online shopping), one must also consider consumer preferences and benefits received from the nature of the service, which include speed of access and reliability.

Most studies of consumer surplus derived from faster broadband speed are based on primary research, where users stipulate the amount, they would be willing to pay for broadband service (Savage et al. (2004); Greenstein and McDewitt (2011); Liu et al. (2017). All studies on consumer surplus focus the assessment of how US consumers react to variations in price according to their data usage. For example, Nevo et al. (2015) studied hour-by-hour Internet usage for 55,000 US subscribers in the United States facing different price schedules. They concluded that consumer surplus for speed is heterogeneous. Consumers will pay between $0 to $5 per month for a 1 Mbps increase in connection speed, with an average of $2.[26] In addition, they stipulated that, with the availability of more content and applications, consumers will likely increase their usage, implying greater time savings and a higher willingness to pay for speed. At the time of the study cited above, the increase in willingness to pay at high speeds dropped by approximately $0.11 per Mbps. This is confirmed by a more recent study. Liu et al. (2017) administered two national, discrete choice surveys of US consumers to measure households' willingness-to-pay for changes in price, data caps, and speed. The authors found that the valuation of bandwidth is highly concave, with lesser added value beyond 100 Mbps (see Graphic 3-3).

Graphic 3-3. Log Curve of relationship between broadband speed and consumer surplus (based on Nevo et al., 2016)



Sources: Liu et al. (2018); Telecom Advisory Services analysis

As reported in this study, households are willing to pay about US$2.34 per Mbps (US$14 total) monthly to increase bandwidth from 4 Mbps to 10 Mbps, US$1.57 per Mbps (US$24) to increase from 10 to 25 Mbps, and US$0.02 per Mbps (US $19) for an increase from 100 Mbps to 1000 Mbps. To adapt the curve in Graphic 3-3 to Indonesia, we multiplied it by country's purchasing power parity of 0.32, as estimated by the World Bank.

Increase coverage per access point would allow to stabilize real prices and increase affordability

The allocation of the 6 GHz band to unlicensed use would allow the Indonesian WISPs to potentially increase their subscriber base within their same coverage footprint[27]. As mentioned above, the allocation of the 6 GHz band to unlicensed use would allow WISPs to sign up new devices and increase download speed, which would trigger several simultaneous positive effects. As an example, the temporary assignment of spectrum by the FCC to deal with the COVID-19 pandemic allowed WISPs in the United States to immediately increase their subscriber base between 20% and 30%.

[26] Heterogeneity in willingness to pay for broadband was also highlighted by Rosston et al. (2010).

[27] Based on the assumption that the technical rules for standard power access points operated by WISPs in the 6 GHz are similar to the technical rules (e.g., radiated power limit, radiated power spectral density, etc.) established for access point operated by WISPs in the 2.4 GHz and 5 GHz bands.

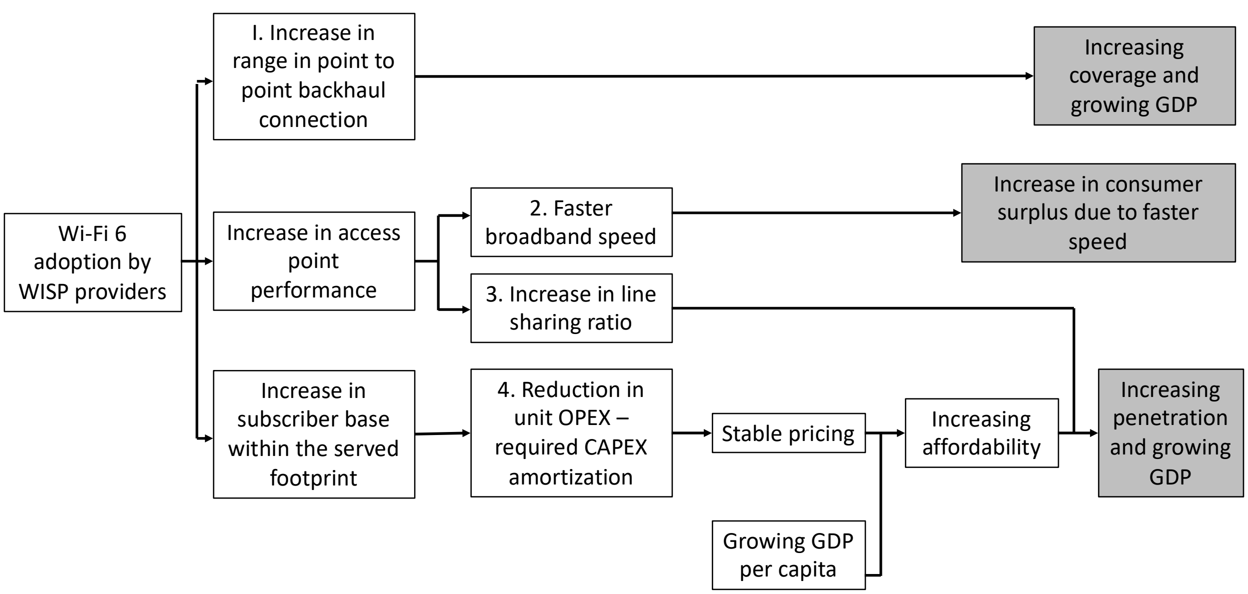
Recognizing the economies of scale in telecommunications services, an increase of the user base would allow service providers to lower their operating costs. Under a conservative scenario assumed within our study, prices will remain stable in a context of increasing GDP per capita. As a consequence, affordability would increase for those potential subscribers that indicate that they do not purchase broadband service because of its cost. With an increase in affordability, the penetration of broadband will grow.

Higher capacity per access point

As mentioned above, a second-order effect on broadband adoption from WISP providers relates to an increase in household sharing ratio as result of increased access point performance. As a result of lower income population concentration, WISP Wi-Fi lines can be shared across neighbors. According to the last survey conducted by the Indonesia Internet Service Provider Association (APJII) in 2020 there were over 200,000 households that used internet from neighbors. Therefore, we can estimate a sharing rate of 100%.

The increase in affordability combined with an enhancement of the capability to share lines will result in the growth of broadband connections. According to econometric models developed by the authors for the International Telecommunication Union, an increase of 1 percent in fixed broadband in Asia-Pacific countries yields a growth of 0.16 percent in the GDP.[28] The sum of all these convergent effects on WISP performance is displayed in figure 3-2.

Figure 3-2. Economic Impact of 6 GHz on WISP performance



Source: Telecom Advisory Services

[28] Katz, R. and Jung, J. (2021). *The economic impact of broadband and digitization through the COVID-19 pandemic. Econometric modelling* Geneva: International Telecommunications Union.

At a theoretical level, the sum of economic impact of the 6 GHz allocation on the WISP performance could be specified as follows:

Economic effect of 6 GHz in WISPs = $a_1 + a_2 + a_3 + a_4$

Where,

a_1 Extended coverage due to longer P2P backhaul (impact on GDP)
a_2 Added consumer surplus due to faster speed (impact on consumer surplus)
a_3 Better coverage per access point (impact on GDP)
a_4 Higher sharing ratio per access point (impact on GDP)

3.2. Increased broadband speed by reducing Wi-Fi congestion

The economic value of allocating the 6 GHz band to unlicensed use reduces router congestion, increases Wi-Fi throughput, and has a net effect of accelerating broadband speed. This result does not affect all fixed broadband connections, although its impact among high-speed broadband users has a net effect increasing average broadband speed at the customer premise and device level for the country. The increase in average speed results into two types of economic contribution: a growth in GDP (also called the "return to speed"), and an increase in consumer surplus. This transitive causal chain can be disaggregated into three effects:

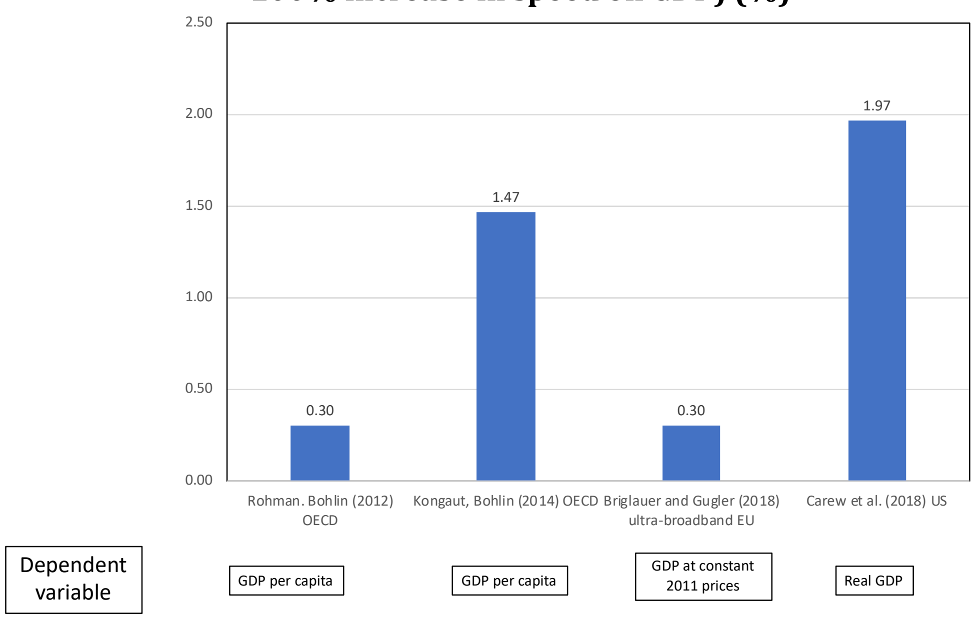
- A removal of Wi-Fi congestion has an impact on broadband speed at the device level in the customer premise;
- An increase in broadband speed for high-speed users in turn drives a contribution to the Indonesian GDP;
- An increase in broadband speed increases the willingness to pay of users of high-speed broadband access because they can gain access to a larger number of applications.

Each effect is explained in turn. When a consumer accesses the Internet, the speed of access at the device level is a function of the performance of the fixed and/or wireless network and the router's throughput. The net result differs from the speed of the purchased broadband connection. For example, if a user acquires a 20 Mbps fixed broadband line, it is highly unlikely that the Wi-Fi router will become a performance bottleneck. A dual band router can deliver peak speeds of 1.2 Gbps on 2.4 GHz, 4.8 Gbps on one 5 GHz radio, and 4.8 Gbps on the other 5 GHz radio. Using multiple bands and spatial streams, routers commonly today have total throughput capabilities well in excess of the speeds they can deliver to individual devices. Based on the current 2.4 GHz and 5 GHz allocation, dual router performance is estimated to be 266.50 Mbps (which results from assuming an even split of traffic between the 2.4 GHz band (at 173 Mbps) and the 5GHz band (at 360 Mbps)).

This does not mean, however, that each user is receiving the total speed when a faster fixed broadband line is purchased. Under this situation, if a household of establishment acquires a 150 Mbps fixed broadband line, the router becomes a "choke" point in the network, and the speed experienced by a consumer will not be equivalent to that delivered by the fixed network. For example, a high-end 802.11ax device can, in theory, handle total throughput of 4.8 Gbps, but each user will receive a throughput well under 200 Mbps.[29] The allocation of the 6 GHz band, with the capability of providing up to eight 160 channels can deliver speeds of up to 2000 Mbps to each device.

Research on the economic contribution of broadband speeds uniformly concludes that faster Internet access has a positive impact on GDP growth. Three types of effects explain this relationship. First, faster broadband contributes to an improvement of labor productivity resulting from the adoption of more efficient business processes. Marketing of excess inventories and optimization of the supply chain are two of the economic benefits that might be generated. Second, faster connectivity yields an acceleration of the rate of introduction of new products, services, and the launch of innovative business models. Third, the acceleration of broadband speeds drives a set of network externalities resulting in a restructuring of industry value chains (in other words, faster communications allow enterprises to either outsource operations without any disruption risk or relocate functions to areas with more advantageous input costs). The compilation of empirical evidence generated so far in four econometric studies[30] confirms the existence of these effects (see Graphic 3-4).

Graphic 3-4. Studies measuring the GDP impact on Broadband Speed (impact of 100% increase in speed on GDP) (%)



Source: Compiled by Telecom Advisory Services

[29] Estimate provided by Broadcom. This refers to the throughput received by each user device (PC, tablet, etc.) within the user premise.

[30] We have selected only four studies to review, although research has yielded many more papers (see, for example, Ford, G. (2018). *Is Faster Better? Quantifying the Relationship between Broadband Speed and Economic Growth*. Phoenix Center Policy Bulletin No. 44. Grimes, A., Ren, C., and Stevens, P. (2009). *The need for speed: Impacts of Internet Connectivity on Firm Productivity.* MOTU Working Paper 09-15. Mack-Smith, D. (2006). *Next Generation Broadband in Scotland*. Edinburgh: SQW Limited).

As indicated in Graphic 3-4, while all four studies coincide in concluding that broadband speed has an impact on GDP, the range of contribution varies: 100% (or doubling) increase of broadband speed generates a contribution to GDP ranging from 0.30% to 1.97%. Some of the difference is explained by the methodologies and variables used. As an example, Carew et. al (2018) did not include broadband adoption as an independent variable in their equations, which means that the effect of speed on GDP subsumes broadband penetration. In other cases, the difference can be explained by the timing of data used. Kongaut, and Bohlin (2014) rely on a data panel between 2008 and 2012, while the time series of Rohman, and Bohlin (2012) ends in 2010, both moments when the average broadband speed was 8.3 Mbps, which in turn resulted in high impact. That being said, the evidence of the positive effect with regards to the contribution of broadband speed to GDP growth remains consistent.

3.3. Wide deployment of Internet of Things

The economic relevance of IoT has already been well established by numerous analysts. IDC estimated that the 2020 IoT world market for overall IoT solutions was approximately US$1.7 trillion for 2021. The Indonesia government has placed big expectations on the potential of IoT for the local economy.[31] GSMA Intelligence estimates that the number of M2M connections, a proxy for IoT, in Indonesia has reached 7.5 million.[32] According to data estimated by Frost & Sullivan for Indonesia, we estimate that the local IoT market approximates US$ 1.35 billion.[33]

On the other hand, industry participants have been clear in stipulating that future development of IoT can only be fulfilled if several barriers ranging from business process redesign to technology standards and wireless connectivity are addressed[34]. Spectrum availability is one of the barriers on IoT development. While IoT roll-out in Indonesia has already been proceeding for several years, large scale deployment has suffered from the risk of congestion. The assignment of the 6 GHz band for unlicensed use will result in a broader scale IoT deployment.

The economic value linked to IoT is based on two sources: (i) the development of firms within the IoT ecosystem, which generate a producer surplus (i.e., margin) by selling their output in Indonesia, and (ii) the spillover of IoT on the economy, which is focused on those sectors that are IoT intensive (e.g., logistics, Health Care, Natural Resources).

With respect to the first source of value, it is important to distinguish the different components of the ecosystem, which include hardware, software, and services. As is clear, this distinction is grounded in traditional IT components, although their combination within

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[31] Statement by the Indonesian Industry Minister on IoT: https://www.kominfo.go.id/content/detail/15354/potensi-pasar-internet-of-things-di-indonesia-capai-rp-444-t/0/sorotan_media

[32] GSMA Intelligence.

[33] Frost and Sullivan (2018): *Digital Market Overview: Indonesia*. White Paper. Downloadable in: https://www.frost.com/files/3115/2878/4354/Digital_Market_Overview_FCO_Indonesia_25May18.pdf

[34] CompTIA (2016). *Sizing up the Internet of Things*.

the IoT value proposition represents a different format. The ecosystem contributing to delivery of the IoT economic value comprises multiple types of companies (see table 3-2).

Table 3-2. IoT Ecosystem

Categories	Components	Type of firms
Hardware	Sensors/chips	Manufacturers of sensors and compute components
	Miniature devices	Specialized providers of small-scale sensors
	Connectivity	Manufacturers of network equipment
Software	Apps	Connectivity software
	Cloud service providers	Software provided by public cloud providers
	Platform providers	New operating systems
	Carriers	Telecom players providing cloud-based solutions
Services	Systems integration	Integration of devices and components within a single platform
	Analytics	Providers of data warehousing and analytic tools
	IT services	Platform providers
	Security	Developers of security protocols and technologies

Source: Telecom Advisory Services

Within the second source of value, the use cases associated with IoT (such as predictive maintenance, asset tracking, smart grid demand management, traffic coordination, and the like) have a spillover impact on GDP growth.

3.4. Reduction of enterprise wireless costs

The increase in unlicensed channel capacity by designating the 6 GHz band enables more extensive delivery of ubiquitous, high throughput wireless connectivity across multiple access points in business facilities, such as industrial plants, enterprise campus, and the like. This will allow firms to leverage Wi-Fi infrastructure and generate further savings in the use of wideband wireless communications.

When the 6 GHz band is opened and added to the existing unlicensed bands in 2.4 GHz and 5 GHz, the combined spectrum will be able to support eight 160 MHz channels or three 320 MHz channels (under the allocation of the full 1200 MHz), which will be a source of economic value for production units. The first effect will result in the enabling of faster in-door broadband speeds. Moreover, the addition of channels in 6 GHz will enable providers to deliver fast next-generation speeds to businesses, industrial facilities, hospitals, ports, railyards, and airports across the country. The estimation of economic value in this domain will focus on the new applications and use cases. In addition, the additional spectrum will allow the support of a high number of devices on a single access point. Some Wi-Fi 6 solutions can handle up to 1,500 devices, which makes them ideal for enterprise applications.

3.5. Deployment of AR/VR solutions

Virtual Reality (VR) is already being used within a wide array of areas, ranging from the gaming industry and entertainment, to training and simulation, in particular in the medical field. Other areas of application include education and culture, sports, live broadcasting, real estate, advertising, architecture and the arts. On the other hand, Augmented Reality (AR) has an almost limitless range of uses in a wide variety of areas, be it commerce, technical applications, work processes or education. VR and AR serve both consumers and professional users who can be private and public. The AR/VR solutions market is developing at a fast pace driven by a broad range of applications. This development yields two effects similar to the one reviewed in IoT.

The development and diffusion of AR/VR applications in the production side of the economy is being driven by an ecosystem comprised of firms ranging from software development to hardware production and applications development. The margins of firms involved in this endeavor represent producer surplus.

On the other hand, the adoption of AR/VR among Indonesian enterprises will in turn have spillover effects on productivity, thereby contributing to the growth of GDP. The spillover effects range from improved training to the acceleration of product design and delivery. For example, manufacturing companies are already incorporating VR in their product development processes to reduce the time incurred between initial design and physical modelling. AR glasses also help warehouse workers provide parts information for engineers and technicians in the field. Finally, AR/VR solutions can be used to sell and showcase products in retailing.

3.6. Enhanced deployment of municipal Wi-Fi

Municipal Wi-Fi provides free Internet access to the population at large. In many cases, municipalities aiming to develop a smart city infrastructure require the deployment of Wi-Fi networks in public places to facilitate Internet access for their citizens. Based on ITU data, only 15% of the Indonesian households have access to a fixed-broadband connection, while according to GSMA, mobile broadband unique subscribers' penetration accounted for only 52% of the population in 2020. In a context of affordability barriers, public Wi-Fi represents a viable option of Internet access. This is confirmed by the APJII local survey, which reports that 0.7% of internet users (over 1.1 million people) rely mainly on public Wi-Fi hotspots as its source for internet connection. That figure expands to 9% if we consider those who rely on public Wi-Fi hotspots as a secondary source of connectivity (almost 15 million people). Consumers who do not have broadband at home because they lack economic resources to acquire service can rely on public or municipal Wi-Fi to gain Internet access.

Indonesia has yet to develop a full network of municipal Wi-Fi sites. The above-cited APJII survey indicated that only 17.2% of people declare to live in a place where the local government provides public Wi-Fi hotspots (although, there a lot of no answers). Wi-Fi infrastructure relying only on 2.4 GHz and 5.8 GHz bands is exposed to service degradation as well as inability to support a large user base. Municipal Wi-Fi is an application that is in critical need of additional spectrum to satisfy the growth in the number of clients but also to deal with interference from other devices operating in competing frequencies. As an example, the 2.4 GHz band currently handles may appliances and devices on wireless standards such as Bluetooth and Zigbee, creating significant interference for Wi-Fi.

We will assess the economic benefit of the 6 GHz allocation focusing on its capacity to increase speed of access with the consequent generation of consumer surplus while at the same time providing the poor population with access to the Internet.

3.7. Deployment of Free Wi-Fi Hot Spots

In addition to Municipal Wi-Fi, Free Wi-Fi sites represent a cost-advantaged approach for consumers “on the go” to access the Internet. As of 2020, there were approximately 384,000 free Wi-Fi hot spots in Indonesian main cities, distributed as follows (see Table 3-3).

Table 3-3. Indonesia: Number of Free Wi-Fi Spots (2020)

City	Number
Jakarta	216,000
Bekasi	82,000
Bandung	43,000
Surabaya	29,000
Medan	10,000
Palembang	4,000

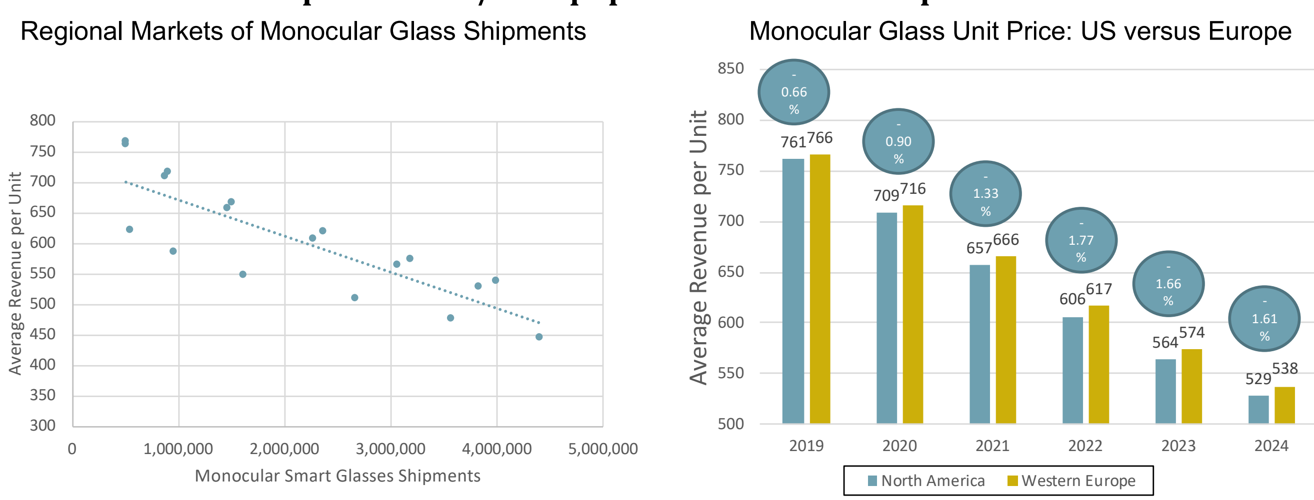
Source: Wiman (2021).

The assessment of economic value of allocating 6 GHz spectrum to free Wi-Fi hot spots will be conducted in a similar way as in the case of Municipal Wi-Fi. In other words, free hot spots supported by technology associated to 6 GHz will be capable of increasing the access speed (with consumer surplus implications) and providing an access point to the population who does not have broadband service.

3.8. Aligning spectrum decision with that of other advanced economies

By allocating the full 6 GHz band, Indonesia will not only alleviate the pressure on unlicensed spectrum resulting from explosive Wi-Fi usage but will also make a decision with implications for cost of inputs for local firms and for the country’s industrial policy. A comparative assessment of unit average selling price of AR/VR equipment indicates that the United States has an economic advantage (lower cost) over Europe, resulting from economies of scale (see graphic 3-5).

Graphic 3-5. AR/VR Equipment: Economics of production



Note: Chart on left comprises Data for North America; Western Europe and Asia-Pacific
Sources: ABI Research; Telecom Advisory Services analysis

As indicated in the left-hand chart, the production of AR/VR equipment is, as expected, driven by economies of scale. As a result, the chart of the right indicates a price advantage residing within North America. Consequently, it might be advantageous to align Indonesia's 6 GHz spectrum allocations issue with the full 6 GHz allocation model to allow local firms to benefit from lower input prices.

Secondly, the Indonesian market for equipment and services in areas related to implementation of the 6 GHz amounts to US$ 6 billion in 2020 but will reach almost US$ 10 billion by 2023 (see table 3-4).

Table 3-4 Indonesia: Sales in markets impacted by the 6 GHz decision (in US$ billion) (2020-23)

Market	Categories	2020	2023
Augmented Reality/Virtual Reality	Hardware	$0.089	$0.248
	Software and applications	$0.181	$0.504
	Subtotal	$0.270	$0.753
IoT	Hardware	$0.293	$0.746
	Software and services	$1.058	$2.697
	Subtotal	$1.350	$3.443
Wi-Fi devices	Home networking devices	$0.310	$0.452
	Wi-Fi enabled devices (wireless speakers & security systems)	$3.664	$4.791
	Enterprise access points and controllers (adapter routers gateways)	$0.365	$0.415
	Subtotal	$4.339	$5.658
Total		$5.959	$9.854

Sources: ABI Research; Frost & Sullivan; Telecom Advisory Services analysis

Under such attractive demand conditions, the decisions to be made in terms of the model allocating the 6 GHz spectrum band (lower part vs. full band) could put Indonesia on the path to both meet local demand and benefitting from the implicit economies of scale derived from advanced markets as well as increase the opportunity costs of those markets developing first. Additionally, the decision of aligning with a particular model could potentially give Indonesia the benefit of developing an export-led industry that could capitalize on foreign demand.

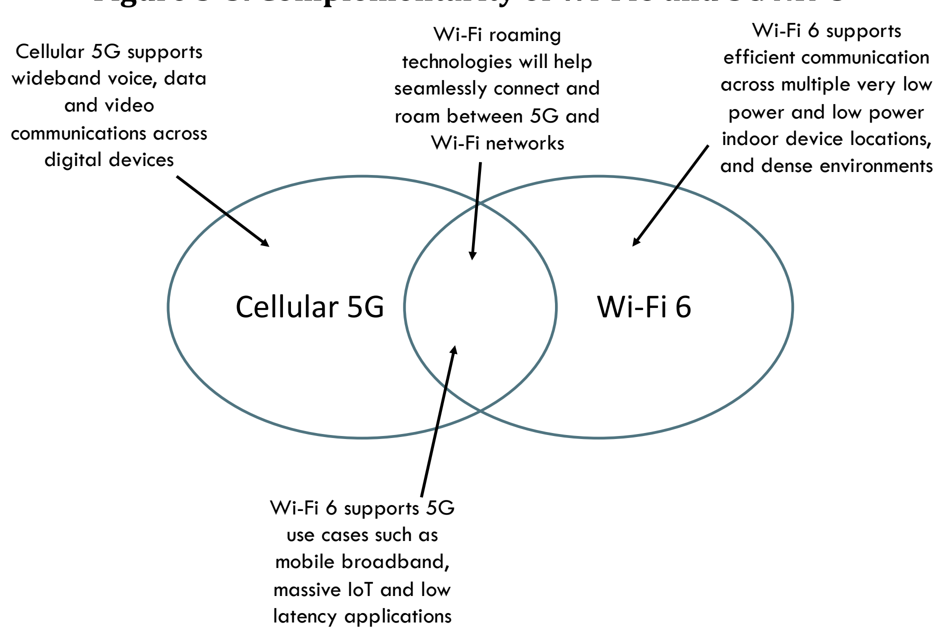
3.9. Enhancing the capability for cellular off-loading

This source of economic value, based on the complementarity between Wi-Fi and cellular networks was initially analyzed by Milgrom et al. (2011), and Cooper (2012), and further estimated in our prior studies (Katz, 2014a, 2014b, 2018a). As posited in earlier studies, the value of cellular off-loading is based on the congestion relief for licensed spectrum owners that comes from the additional spectrum (Bazelon, 2008). In this context, Wi-Fi acts as a complementary technology compensating for the economic limitations of cellular. In the case of spectrum management, unlicensed frequency bands can enhance the effectiveness of devices that use licensed spectrum. For example, Wi-Fi base stations operating in unlicensed bands can enhance the value of cellular networks by allowing wireless devices to switch to hot-spots, thereby reducing the cost of broadband access and increasing the access speed rate. Consumers accessing the Internet within the reach of a Wi-Fi site can reduce their costs of access by turning off their wideband service. They can also gain additional access speed because the transfer rate of Wi-Fi sites is generally faster than that offered by cellular technology.

Wi-Fi allows cellular service providers to decrease the capital and operating expenses required to accommodate exploding data traffic. Indonesian carriers have been deploying Wi-Fi access points to offload part of their traffic. The estimation of savings is predicated on the assumption that, in the absence of additional unlicensed spectrum bands, service providers would have to deploy expensive infrastructure to accommodate the growth in traffic. Thus, the calculation of economic value is based on the portion of capital investments (and potential incremental network operations and maintenance operating expenses) that service providers can avoid when they and consumers shift traffic from cellular networks to Wi-Fi.

While complementarity has been hailed for prior cellular and Wi-Fi technology generations, this feature remains for Wi-Fi 6 and 5G. To begin with, access devices like smartphones and sensors will tend to be equipped with both generations for users and service providers to optimize infrastructure use. This will be critical not only for traffic handling in densely packed environments such as apartment complexes and hospitals, but also to support surveillance cameras, point of sale terminals, environmental sensors and other IoT devices. Complementarity will also manifest itself at homes and enterprises, although this benefit has already been accounted for in the sections above (see figure 3-3).

Figure 3-3. Complementarity of Wi-Fi6 and 5G NR-U



Sources: Adapted from Suarez, M. (2020). Unlicensed spectrum access in the 6 GHz band. Presentation to ANATEL

As an example, the vast majority of data consumed on smartphones and other mobile devices flows over Wi-Fi networks, never touching mobile carrier spectrum or infrastructure. In fact, the share of data traffic offloaded via Wi-Fi is expected to increase sharply as mobile technology upgrades from 4G to 5G, since high- bandwidth applications are typically used at home, work and other indoor locations. Cisco projects that 76% of all data traffic on smartphone and other mobile devices will be offloaded onto Wi-Fi in North America by 2022[35]. As mentioned above, there are 384,000 free hot spots in Indonesia[36]. Even cellular providers acknowledge Wi-Fi's central role.

Consequently, the economic value of spectrum allocation in the 6 GHz band not only manifests itself in the ability of cellular carriers to reduce capital in future network deployment by off-loading traffic but, most importantly, to indirectly account for Wi-Fi use in calculating their investment.

3.10. Production and adoption of Wi-Fi Equipment

This source of value is initially based on consumers receiving an economic surplus by purchasing Wi-Fi devices at a price lower than their willingness to pay for them. The value is calculated based on the devices operating in the 6 GHz band. Products in this ecosystem include a full range of consumer electronics (see Table 3-5).

Table 3-5. Wi-Fi enabled residential products

Market segment	Product
Consumers	• Wireless speakers • Home security systems • Household devices • Access points • External adapters • Routers • Gateways

Source: Telecom Advisory Services

The absence of data on willingness to pay for each type of equipment makes it very difficult to reliably estimate consumer surplus. To overcome this limitation, a possible approximation is to assume that consumer surplus would be equal to the producer surplus (see Milgrom et al., 2011). Therefore, we calculate the producer margin based on the total sales of Wi-Fi-enabled residential equipment in the 6 GHz band and attribute that value to consumer surplus.

In all cases, to differentiate the value corresponding to the 6 GHz band, from the value corresponding to the other bands of Wi-Fi use, we follow the forecasts provided by IDC on the evolution of shipments of consumer 802.11ax devices for the 6 GHz band.

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[35] C*isco 2019 VNI Report, p.* 104.

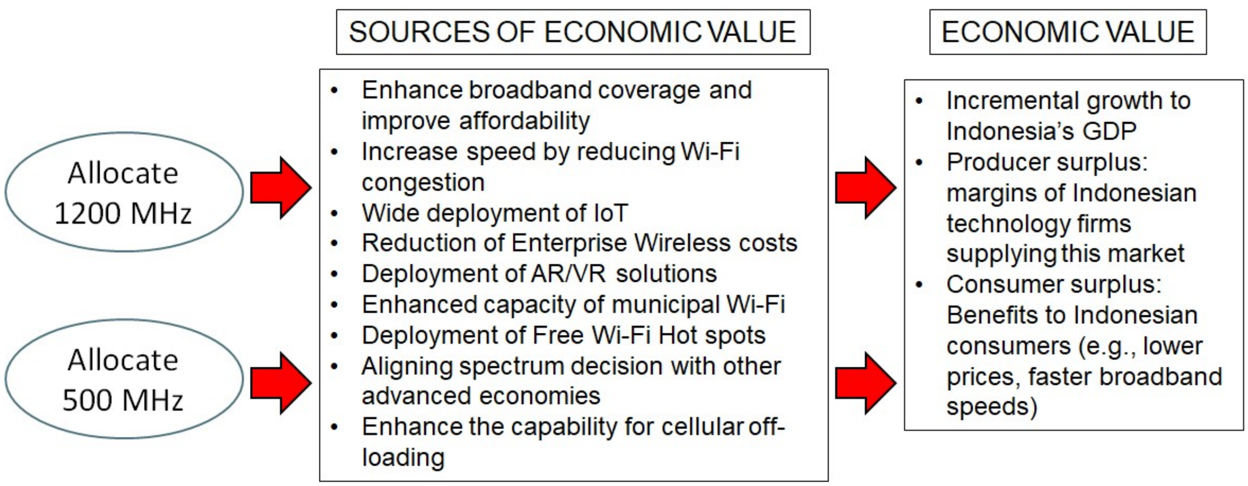
[36] Source: *Wiman*

In addition to the consumer surplus generated by the consumption of Wi-Fi equipment, we will also estimate the producer surplus resulting from their manufacturing. The methodology in both cases is the same. However, when estimating consumer surplus, imported and domestically goods that are consumed locally in Indonesia are considered, while when measuring producer surplus, only goods manufactured in Indonesia are measured, regardless of the country in which they are consumed.

3.11. A compilation of economic value

Based on the theoretical bases reviewed throughout chapter 3, the approach to be followed for estimating the economic value of allocating spectrum in the 6 GHz band to unlicensed use in Indonesia will quantify the effects of the 1200 MHz decision (see figure 3-4).

Figure 3-4. Approach to be followed in Estimating Economic Value of 6 GHz decision in Indonesia



Source: Telecom Advisory Services

A final clarification with regards to methodology: we consider that cumulating 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 producer surplus driven by equipment sales triggered by new unlicensed spectrum allocation. On the other hand, CAPEX savings triggered by wireless carriers offloading traffic to Wi-Fi access point has been occurring for a while and could be included in the GDP model estimates.

4. ENHANCED BROADBAND COVERAGE AND IMPROVED AFFORDABILITY

The latest statistics for Indonesia indicate fixed broadband penetration of 15% (or 9,982,973 connections for 66,968,012 households). This implies that most broadband connectivity in the country is fulfilled by wireless technology. In this context, Wireless ISPs (WISPs) can fulfill a critical role in addressing the broadband gap. Different sources indicate that WISPs serve approximately 100,000 (or 1% of the total number of subscribers).[37]

4.1. The current situation in Indonesia

While WISP currently serve 100,000 users, it is assumed that the base will increase at the same rate as the total fixed broadband connections, reaching 120,000 subscribers in 2030. In addition, we should consider a second-order effect on broadband adoption from WISP providers, which relates to household sharing ratio. As a result of lower income population concentration in the subscriber base, WISP Wi-Fi lines are frequently shared across neighbors. According to the last survey conducted by the Indonesia Internet Service Provider Association (APJII) in 2020 there were over 200,000 households that used internet from neighbors. Therefore, we can estimate a sharing rate of at least 100%. Under this assumption, the total number of households that use a WISP connection in 2020 is 200,000. Assuming a decreasing trend for the sharing ratio, we can expect this number to reach roughly 178,000 by 2031 (see table 4-1).

Table 4-1. Indonesia: WISP Lines (2021-2031)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
WISP subscribers	104,559	108,145	110,935	113,089	114,741	116,002	116,961	117,928	118,903	119,886	120,877
Shared ratio	93%	87%	81%	76%	71%	66%	62%	57%	54%	50%	47%
Total	202,115	202,290	201,043	198,794	195,874	192,534	188,958	185,659	182,621	179,828	177,689

Sources: Telecom Advisory Services analysis.

4.2. Impact of 6 GHz on consumer surplus of WISP customers

As reviewed in figure 3-1 in chapter 3, the 6 GHz allocation decision will have an impact in two areas of WISP economic value: (i) increasing consumer surplus of existing customers because of faster broadband service, and (ii) enhancing affordability and, consequently, improving broadband penetration, with a consequent GDP impact. Each area will be reviewed in turn.

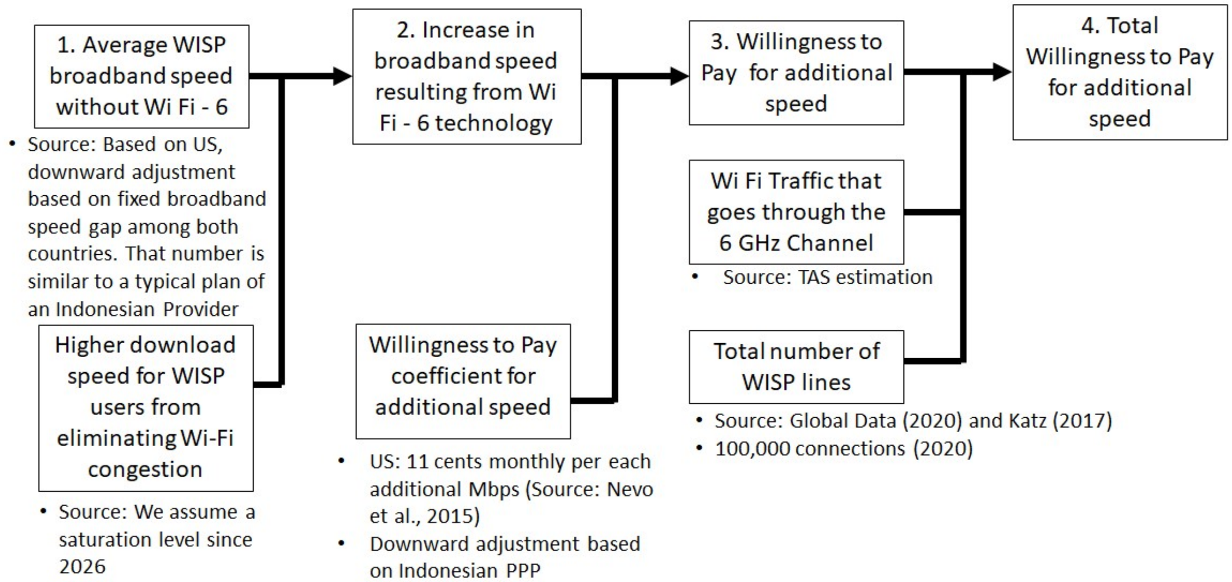
Increasing consumer surplus due to enhanced base station performance

When WISPs have the opportunity of relying on spectrum in the 6 GHz band, the consumer surplus for their subscribers is generated by an improvement in broadband speed as

[37] Global Data estimates (2020) and Katz (2017).

backhaul congestion is reduced. In other words, the higher speed of service has an impact on the consumers' willingness to pay (see figure 4-1).

Figure 4-1. Methodology to estimate consumer surplus as a result of faster download speed in WISP connections



Source: Telecom Advisory Services

The starting point of this estimate is to calculate the difference in broadband speed yielded by the 6 GHz spectrum allocation. The multiplication of the speed increase by the willingness to pay (WTP) coefficient for incremental broadband speed yields an enhancement of consumer surplus. Finally, the WTP per line is multiplied by the number of WISP lines (see table 4-2).

Table 4-2. Consumer surplus due to WISP user speed increase (2022-2031)

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
(1) Average speed from WISP with 6 GHz	5	7	10	13	17	21	26	33	42	53
(2) Average speed from WISP with no 6 GHz	5	7	10	13	13	13	13	13	13	13
(3) Demand for average download speed with 6 GHz	$22	$24	$26	$29	$30	$32	$34	$36	$38	$39
(4) New Demand for average download	$22	$24	$26	$29	$28	$28	$28	$28	$28	$28

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
speed with no 6 GHz										
(5) Additional Monthly Consumer surplus	$0	$0	$0	$0	$2	$4	$6	$7	$9	$11
(6) Additional Yearly Consumer Surplus	$0	$0	$0	$0	$22	$45	$67	$89	$112	$134
(7) WISP Connections (*)	114,110	122,672	128,211	134,254	140,171	145,501	148,388	151,258	154,118	156,973
(8) Traffic through 6 GHz Band	10.00%	20.00%	30.00%	40.00%	50.00%	60.00%	65.00%	70.00%	75.00%	80.00%
(9) Impact (USD Millions)	$0	$0	$0	$0	$2	$4	$6	$9	$13	$17

(*) This estimate does not consider the households that use a shared connection because, by definition, they are not paying for the service. The WISP connections estimate considers the natural growth and the new connections that are estimated in section 4.3.
Source: Telecom Advisory Services analysis.

Total 2022-2031 cumulative consumer surplus impact resulting from increasing broadband speed by reducing Wi-Fi congestion for WISP users amounts to US$ 51 million.

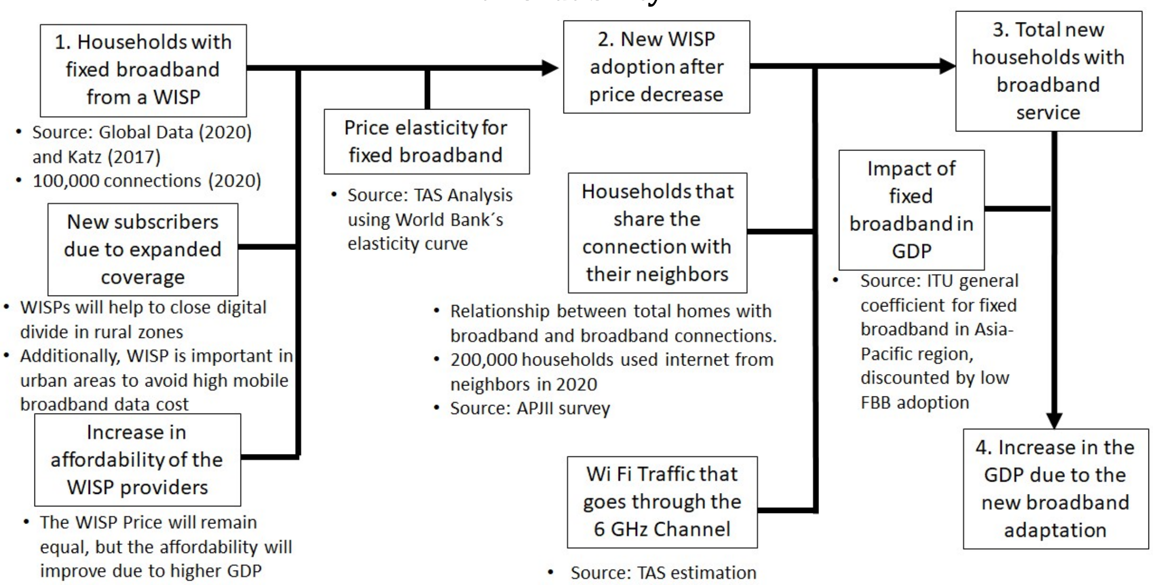
4.3. Impact on GDP by expanding coverage, increasing affordability, and growing broadband penetration from WISPs

The purpose in this case is to estimate the impact on GDP of the expanded WISP coverage, the change in broadband affordability, and consequential enhanced broadband penetration. To start with, the 6 GHz designation of unlicensed use will improve the number of households being served per WISP access point. In theory, given the conventional economies of scale in telecommunications, the unit cost to serve a higher number of subscribers from a single point would reduce the unit OPEX. Furthermore, this reduction could be partially neutralized by the amortization of CAPEX to migrate the electronics to the new standard.[38] For conservative purposes, we assume that broadband prices for Indonesian WISPs would not change from the current level. However, considering that the Indonesian GDP per capita would increase in the future (per the IMF forecast), the overall affordability of service in real prices will be higher. This will allow consumers who have argued that pricing represented a barrier to adoption to acquire broadband service. In addition, the higher performance of Wi-Fi 6 will allow an increase in coverage (we assume that 10% of the future growth will we due

[38] On a side note, the experience of United States WISPs indicates that, if the spectrum allocated is adjacent to the 5 GHz bands originally used, the existing SDR equipment can be converted for use in the newly allowed band and can be adjusted to work in at least the lower band of 6 GHz. Of course, the use of current equipment may be subject to standards and protocols as well as an AFC that may not be possible with current equipment. Its "International" designation may also impact the availability for use.

to expanded coverage), which should be added to the estimate of new adopters. A higher broadband penetration will in turn have an impact on the Indonesian GDP. Figure 4-2 presents the methodology followed to develop this estimate.

Figure 4-2. Methodology to estimate GDP impact of increasing broadband affordability



Source: Telecom Advisory Services

The starting point in this estimate is the increase in the number of WISP subscribers due to an increase in coverage and expansion of the service. Based on historical data, we expect that the WISP subscriptions would increase to 120,877 by 2031, although, for conservative purposes, we only attribute to expanded coverage a 10% of that increase. From this expansion, it is considered that by 2031 only 80% will be using the 6 GHz band, so in total the increase in subscribers due to greater coverage with the 6 GHz band reaches 2,088 (located mainly in rural areas).

At the same time, assuming stable prices and an improvement in Indonesia´s GDP (as projected by the IMF), an improvement in the affordability of the service can be estimated, which would affect mainly urban and suburban areas (we consider that this will impact all the urban population and half of the suburban population). This effect will increase the new subscriber base by 23,475 by 2031, which, once multiplied by the service sharing ratio (which we assume to exhibit a decreasing trend), will result in 34,426 new WISP subscribers. By adding all the effects, the designation of the 6 GHz band for free use in Indonesia, will allow WISPs to connect 36,096 new homes by 2031, which will contribute to narrowing down the Indonesian digital divide.

Table 4-3. Indonesia: New subscribers due to increased coverage and greater affordability (2022-2031)

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
(1) Increase in subscribers due to greater coverage	814	1,094	1,309	1,474	1,600	1,696	1,793	1,890	1,989	2,088
(2) Traffic on 6 GHz band	10.00%	20.00%	30.00%	40.00%	50.00%	60.00%	65.00%	70.00%	75.00%	80.00%
(3) GDP growth	7.38%	7.27%	6.27%	6.13%	6.16%	6.16%	6.16%	6.16%	6.16%	6.16%
(4) Increase in subscribers due to improvement in affordability	3,146	6,356	8,379	11,085	14,080	17,036	18,608	20,205	21,827	23,475
(5) Sharing rate	87%	81%	76%	71%	66%	62%	57%	54%	50%	47%
(6) Increase in subscribers due to improved affordability considering sharing	5,884	11,518	14,729	18,924	23,369	27,522	29,295	31,032	32,741	34,426
(7) Total new subscribers	5,966	11,737	15,122	19,513	24,169	28,540	30,461	32,356	34,232	36,096

Source: Telecom Advisory Services analysis

The accumulation of both effects drives an increase in broadband penetration due exclusively to the 6 GHz allocation in Indonesian WISPs, reaching 0.3% growth by 2031. Based on the coefficient of impact of fixed broadband on GDP for the Asia-Pacific region calculated by the authors in research for the ITU discounted by the low penetration of Indonesia, the total impact on GDP is estimated (see table 4-4).

Table 4-4. Indonesia: Contribution to GDP of new WISP lines

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
(1) Increase in broadband penetration	0.06%	0.11%	0.13%	0.17%	0.21%	0.24%	0.26%	0.27%	0.29%	0.30%
(2) Impact of fixed broadband on GDP (*)	16.32%	16.32%	16.32%	16.32%	16.32%	16.32%	16.32%	16.32%	16.32%	16.32%
(3) Increase in GDP due to the increase in broadband (%)	0.009%	0.017%	0.022%	0.028%	0.034%	0.040%	0.042%	0.044%	0.047%	0.049%
(4) Impact on GDP (US$ million)	$113	$235	$319	$434	$570	$714	$810	$914	$1,027	$1,150

(*) Katz and Jung (2021) Worldwide impact for Asia-Pacific
Source: Telecom Advisory Services analysis

In summary, the total cumulative impact on GDP because of the higher penetration of WISPs between 2022 and 2031 in Indonesia amounts to US$ 5.1 billion.

4.4. Growing revenues of Indonesian WISPs

A secondary contribution to the Indonesian GDP is driven by the incremental revenues flowing to WISPs because of the new lines deployed by allocating the 6 GHz spectrum. These revenues are estimated by multiplying the increase in the number of subscribers (line 7 in Table 4-3) by the WISP average revenue per user (estimated from the US figure, adjusted to Indonesia through PPP conversion).

Table 4-5. Indonesia: Contribution to GDP of new WISP lines

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
(1) Total new subscribers	5,966	11,737	15,122	19,513	24,169	28,540	30,461	32,356	34,232	36,096
(2) WISPs ARPU	$62	$65	$70	$75	$80	$86	$94	$101	$109	$118
(3) Additional revenue (US$ million)	$0	$1	$1	$1	$2	$2	$3	$3	$4	$4

Source: Telecom Advisory Services analysis.

In sum, the total cumulative impact on GDP because of the increase in WISP revenues between 2022 and 2031 in Indonesia is $ 22 million.

5. INCREASED BROADBAND SPEED BY REDUCING Wi-Fi CONGESTION

As in the case of WISPs, the value to be generated by the increase in average wireless speed resulting from allocating spectrum in the 6 GHz band for all Indonesian broadband households relying on Wi-Fi connectivity in the premise translates into a contribution to the GDP and an increase in consumer surplus.

5.1. Current broadband speeds in Indonesia and the importance of Wi-Fi congestion

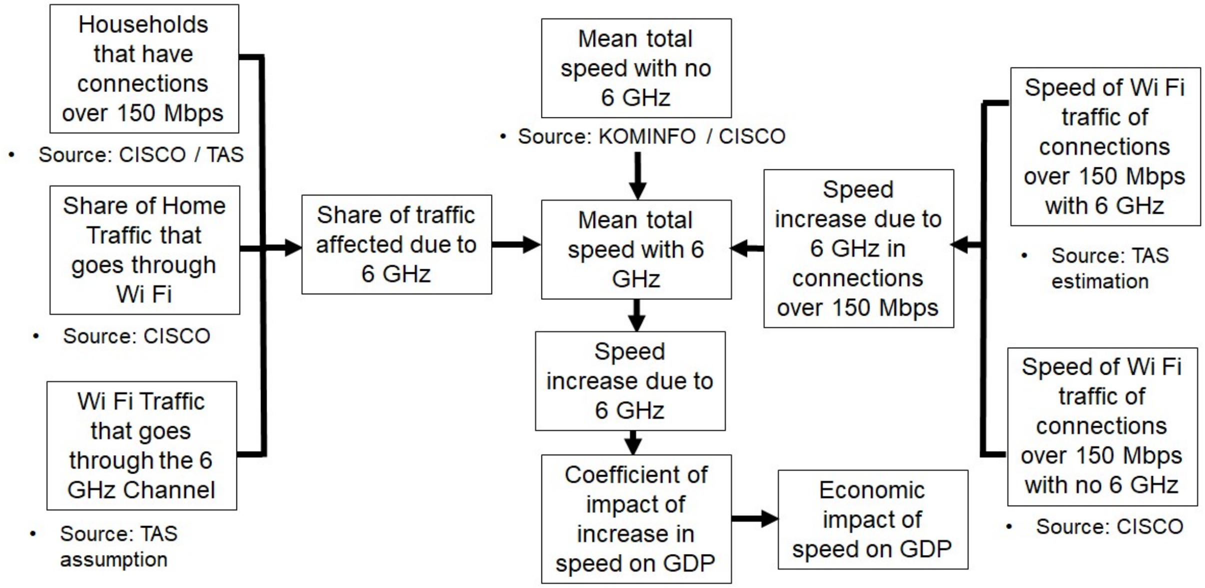
By relying on 2020 Cisco estimates for Indonesia, we estimate that 1.22% of fixed broadband connections in Indonesia have a speed greater than 100 Mbps. Given the current small number of high-speed connections in the country, we assume that only 15% of them reach speed of over 150 Mbps (0.18% of the total connections). Despite the current marginal impact of this effect, it is important to consider it as it will become relevant in the future.

As explained in chapter 3, if a household acquires a 150 Mbps fixed broadband line, the router relying only on 2.4 MHz and 5 MHz spectrum becomes a “choke” point in the network, and the speed experienced at the device level will be well below that delivered by the fixed network. While the current number of lines undergoing a potential bottleneck at the router level in Indonesia is low, a projection over the next ten years indicates that by 2031 this will increase to 4,874,667 lines (or 40.40% of 12,066,007 total lines). In other words, given the increase in download speed of fixed broadband lines, if Wi-Fi performance is not improved by opening additional spectrum, the in-premise equipment becomes a network bottleneck, and the speed experienced by a consumer at home will not be equivalent to that delivered by fixed networks. Conversely, by increasing the spectrum in the 6 GHz allocated to Wi-Fi, the speed will increase with the consequent economic effect.

5.2. Contribution to GDP by reducing Wi-Fi congestion

The purpose in this case is to estimate the impact on GDP of the future change in average broadband speed resulting from the improvement in speed for those households undergoing a Wi-Fi bottleneck (those purchasing a fixed broadband plan in excess of 150 Mbps now and in the future). As explained above, despite the broadband capacity reaching the house, these users would undergo a “bottleneck” in network performance as a result of spectrum-limited CPE (e.g., Wi-Fi router). Figure 5-1 presents the methodology followed to develop the estimate.

Figure 5-1. Methodology to estimate GDP impact of reducing Wi-Fi congestion



Source: Telecom Advisory Services

The starting point of the methodology is to estimate the number of households in Indonesia that have a connection over 150 Mbps that would undergo a Wi-Fi congestion problem as a result of routers relying on the 2.4 GHz and 5 GHz bands. Based on the current 2.4 GHz and 5 GHz allocation, dual router performance currently reaches 266.50 Mbps, which results from assuming an even split of traffic between the 2.4 GHz band (at 173 Mbps) and 5 GHz band (at 360 Mbps)[39]. The assignment of spectrum in the 6 GHz band would increase the average router capacity and reduce congestion, and with that, the average broadband speed would increase[40]. This calculation assumes that 10% of the traffic will be routed through the 6 GHz band in 2022, reaching 80% in 2031.

Because not all households subscribe to a fixed broadband connection that undergoes a bottleneck at the CPE, we only consider in our analysis the Indonesian households that have a connection of more than 150 Mbps (this is estimated for 2021: 0.18% of broadband households in 2021, increasing to 40.40% by 2031). In addition, not all traffic undergoes a router bottleneck, because a portion of it is being distributed through ethernet cabling, thereby bypassing Wi-Fi. This portion is relatively stable according to Cisco, starting at 80% and reaching 87% at the end of the time period. Finally, it is assumed that in 2022, 10% of Wi-Fi traffic is distributed through the router's 6 GHz radio, reaching 80% by 2031 (see table 5-1).

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[39] See RAND study, table 5.2, p. 22, Scenario 1.

[40] An important clarification: while this analysis is conducted for a router's total throughput, it is important to establish that the key driver is the perceived performance of a single user, which is less than 468.00 Mbps. Through the use of multiple bands and spatial streams, routers today commonly today have total throughput capabilities well in excess of the speeds they can enable for individual devices. For example, a high-end 802.11ax device can, in theory, handle total throughput of 4.8 Gbps. The addition of 1,200 MHz in the 6 GHz band has an impact at the device level that could be higher than the total router throughput.

Table 5-1. Indonesia: Estimation of fixed broadband connections affected by 6 GHz decision (2022-2031)

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
(1) Households that have connections over 150 Mbps (%)	0.56%	1.63%	4.49%	6.90%	9.94%	13.75%	18.48%	24.34%	31.55%	40.40%
(2) Share of Home Traffic that goes through Wi Fi (%)	80.89%	81.63%	82.34%	83.03%	83.71%	84.35%	84.98%	85.59%	86.18%	86.74%
(3) Traffic through the 6 GHz Channel (%)	10.00%	20.00%	30.00%	40.00%	50.00%	60.00%	65.00%	70.00%	75.00%	80.00%
(4) Share of traffic affected due to 6 GHz (%)	0.05%	0.27%	1.11%	2.29%	4.16%	6.96%	10.21%	14.58%	20.39%	28.03%

Sources: Cisco Virtual Networking Index; Telecom Advisory Services analysis.

By addressing the router bottleneck, the 6 GHz allocation will have an impact on Wi-Fi download speed of an incremental 225 Mbps in 2022, reaching 850 Mbps by 2031 (see table 5-2).

Table 5-2. Indonesia: Estimation of fixed broadband speed in connections affected by 6 GHz decision (2022-2031)

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
(5) Speed of Wi Fi traffic of connections over 150 Mbps (no 6 GHz) (Mbps)	225	250	300	350	425	500	500	500	500	500
(6) Speed of Wi Fi traffic of connections over 150 Mbps (with 6 GHz) (Mbps)	225	250	300	350	425	500	575	650	750	850

Source: Telecom Advisory Services analysis

Having removed the spectrum bottleneck, the forecast of average fixed broadband household speed tends to grow unencumbered. This results in a speed increase of 0.09 Mbps for the average broadband connection in 2022, reaching 210.15 Mbps in 2031.

Table 5-3. Indonesia: Increase in Speed resulting from 6 GHz allocation (2022-2031)

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
(8) Mean speed with no 6 GHz (Mbps)	21.88	25.95	30.77	36.47	43.21	51.17	60.59	71.72	84.86	100.39
(9) Mean speed with 6 GHz (Mbps)	21.98	26.55	33.76	43.66	59.10	82.41	113.11	156.05	220.51	310.54
(10) Speed increase due to 6 GHz	0.42%	2.29%	9.71%	19.72%	36.78%	61.04%	86.69%	117.60%	159.84%	209.32%

Source: Telecom Advisory Services analysis

This increase is used to calculate the impact on GDP. The economic impact coefficient of incremental speed was calculated through an econometric model based on a historical data panel constructed for 49 countries with average data speeds higher than 40 Mbps for a time series between 2008 and 2019.[41] The data comprised 575 observations of quarterly data for:

- Average fixed broadband download speed[42](source: Speedtest Global Index)
- Gross Domestic Product (at current prices US$) (source: IMF)[43]
- Population (source: IMF)
- Fixed broadband adoption (percent of households with fixed broadband with a speed of at least 256 kbps) (source: International Telecommunication Union)
- Controls for country and time periods

The model includes:

- a control for the previous quarter's GDP, to isolate the inertial effect of country growth
- download speed lagged by four quarters (1 year) to avoid a reversed causality effect
- changes in employment, to isolate the effect on GDP of the evolution of the labor market
- the country's investment rate (% of GDP) lagged by four quarters (1 year) to isolate the effect of investment on GDP
- the fixed broadband penetration rate to separate the broadband adoption effect from the speed effect

$$\boldsymbol{lnGDP_{it} = \beta_0 + \beta_1 lnGDP_{it-1} + \beta_2 lnDownload\ Speed_{it-4} + \beta_3 lnEmployment_{it} + \beta_4 lnInvestment\ Rate} \\ \boldsymbol{+ \beta_5 lnFixed\ Broadband\ Adoption_{it} + \delta Country_i + \vartheta Time_t + \mu_{it}}$$

We believe the inclusion of the country's investment rate as percent of GDP lagged by four quarters and broadband penetration rate and the model specification run on a worldwide panel help correct for any omitted variable bias. For example, the inclusion of fixed broadband adoption, which is correlated with broadband speed, allows for capturing a portion of the GDP impact that otherwise would be incorrectly attributed to broadband speed. With this in mind, the model yields the following results: every doubling of fixed broadband speed has an impact equivalent to 0.73% in GDP growth (see Table 5-4).

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[41] Of the 176 countries published now by Speedtest, we could only use a times series to run the model, which limited the number of countries to 159. Of those, we only run the model for those countries that exhibited an average fixed broadband speed higher than 40 Mbps at any point in time.

[42] The data panel on the Speedtest Global Index covers 159 countries.

[43] The models used GDP at current prices in USD because the objective is to measure the impact of GDP in USD, without considering PPP as a deflator.

Table 5-4. Impact of Fixed Broadband Download Speed on GDP

Impact on ln GDP	Download Speed higher than 40 Mbps
Ln Download Speed $_{t-4}$	0.00730 (0.00211) ***
Ln Employment $_{t}$	0.00458 (0.00165) ***
Ln Investment $_{t-4}$	-0.00085 (0.00481)
Control for Fixed Broadband adoption	0.00284 (0.00414)
Control for growth of previous GDP	0.99454 *** (0.00168)
Country Fixed Effect	Yes
Time Fixed Effect	Yes
Number of countries	49
Observations	575
R-Square	0.9438

***, **, * significant at 1%, 5% and 10% critical value respectively.
Source: Telecom Advisory Services analysis

By applying the coefficient of GDP impact of 0.73% for a 100% increase in speed when the mean speed is higher than 40 Mbps, we estimate the overall GDP impact resulting from an increase in speed because of the allocation of the 6 GHz[44]. To be conservative, we discount that coefficient considering that Indonesia has a fixed broadband adoption lower than the worldwide mean.

Table 5-5. Indonesia: Estimation of economic impact by reducing Wi-Fi congestion (2022-2031)

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
(11) Impact speed on GDP	0.26%	0.26%	0.26%	0.73%	0.73%	0.73%	0.73%	0.73%	0.73%	0.73%
(12) Discount factor due Indonesian lower FBB adoption	27.74%	28.14%	28.36%	28.45%	28.44%	28.35%	28.26%	28.17%	28.09%	28.00%
(13) Increase in GDP (%)	0.00%	0.00%	0.01%	0.04%	0.08%	0.13%	0.18%	0.24%	0.33%	0.43%
(14) Indonesia GDP Billion US$	$1,256	$1,360	$1,459	$1,562	$1,673	$1,791	$1,918	$2,054	$2,199	$2,355
(15) Impact (US$ Million)	$4	$23	$106	$640	$1,277	$2,262	$3,430	$4,967	$7,207	$10,074

Sources: Katz and Callorda (2019); IMF; Telecom Advisory Services analysis

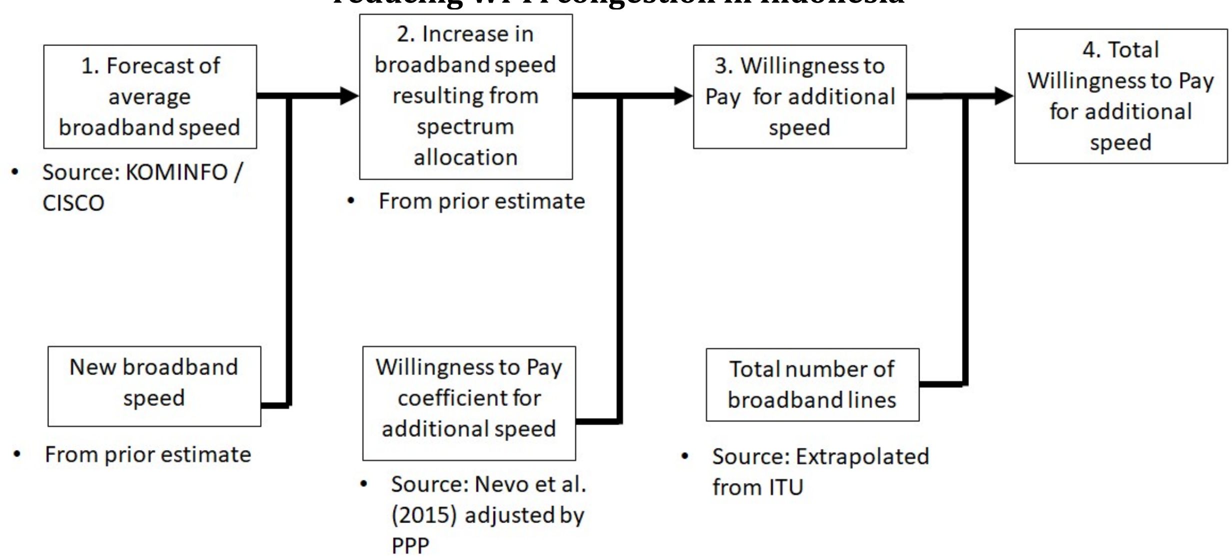
[44] It is important to note that, while the fixed broadband adoption coefficient is not statistically significant, this is due to the fact that the countries included in the sample have extremely high fixed broadband penetration; for these countries, the primary economic impact is not on adoption (e.g. late adopters will have less impact) but on speed.

In summary, the GDP contribution associated to speed improvements of the 6 GHz band allocation between 2022 and 2031 will reach a cumulative figure of US$ 30 billion.

5.3. Contribution to consumer surplus by reducing Wi-Fi congestion

As shown above, the allocation of the 6 GHz band to unlicensed use will have a net positive effect in terms of increased router throughput and therefore, average broadband speed. To reiterate, the consumer surplus to be estimated in this case should not be part of the GDP contribution but can be considered as part of the aggregate economic value. The purpose here is to estimate the increase in consumers' willingness to pay derived from the acceleration in average broadband speeds. The approach to estimate consumer surplus relies on the same calculations presented above in terms of the increase in Wi-Fi speed but factors them in terms of incremental wireless speed and the consequent impact on willingness to pay (see Figure 5-2).

Figure 5-2. Methodology to estimate Consumer Surplus contribution resulting from reducing Wi-Fi congestion in Indonesia

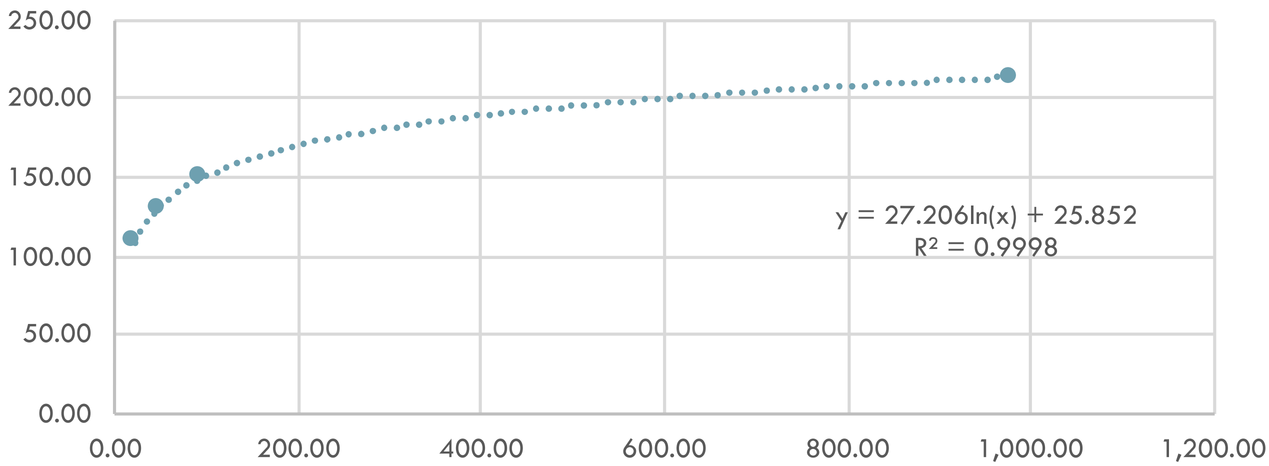


Source: Telecom Advisory Services

As calculated above, the average broadband speed in 2021 in Indonesia is estimated at 21.88 Mbps. By addressing the bottleneck for users acquiring service in excess of 150 Mbps, average speed will increase to 310.54 Mbps in 2031, which results in a net increase in speed of 210.15 Mbps (the difference between the 310.54 Mbps and the 100.39 Mbps without the 6 GHz band, estimated in Table 5-3).

The next step is to estimate what consumers would be willing to pay for the additional speed. Given the lack of Indonesian willingness to pay data, the analysis conducted for this study relies on the data specifying the relationship between speed and consumer surplus generated in the Nevo et al. (2016) study for the United States.[45] This research provides empirical evidence stating that consumers' willingness to pay (WTP) to improve broadband speed by 1 Mbps ranges from nearly zero to just over US $5.00. The range is determined by heterogeneity in WTP, although the average value is US $2.02, and the median is US $2.48. Furthermore, the study also indicates that the higher speed does indeed generate substantial surplus. However, due to a declining marginal value of speed, speeds of more than 10 times those offered by the typical broadband plans imply only 1.5 times the surplus.[46] The data provided in the Nevo et al. (2016) study allows estimating a log curve depicting the relationship between willingness to pay and speed (see Graphic 5-1).

Graphic 5-1. Log Curve of relationship between broadband speed and willingness to pay (based on Nevo et al., 2016)



Note: Based on data points of table VII and table VI of Nevo et al., 2016.
Sources Nevo et al. (2016); Telecom Advisory Services analysis

According to the data in Graphic 5-1, an increase in speed from 92.50 Mbps to 977.90 Mbps (ten times) increases willingness to pay from $149.90 to $212.90 (close to 1.5 times). The equation linking speed to consumer surplus was then used to estimate the value to be derived by faster download speeds enabled by allocation of the 6 GHz band to unlicensed use. For this purpose, the difference between average download speed enabled by 6 GHz frequencies and current average download speed as increased annually at the current growth rate was multiplied by the coefficient of the log curve as depicted in the Graphic 5-1. To adapt the curve in Graphic 5-1 to Indonesia, we multiplied it by the local purchasing power parity of 0.32, as reported by the World Bank.

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45 Nevo, A., Turner, J., and Williams, J. (Mar. 2016). "Usage-based pricing and demand for residential broadband", *Econometrica*, vol. 84, No.2, p. 441-443.

46 This finding is consistent with the evidence provided in Liu et al. (2017), who found that the shape of households' valuation of broadband speed is concave. "Households are willing to pay about $2.34 per Mbps ($14 total) monthly to increase bandwidth from 4 Mbps to 10 Mbps, $1.57 per Mbps ($24) to increase from 10 to 25 Mbps, and only $0.02 per Mbps ($19) for an increase from 100 Mbps to 1000 Mbps."

Under these two assumptions the consumer surplus impact would be $3 million in 2022 (see results and calculations in Table 5-6).

Table 5-6. Consumer Surplus from 6 GHz unlicensed (2022)

	Data	Source
(1) Average Download Speed (at end user device)	21.88	Return to speed analysis
(2) New Average Download Speed	21.98	Return to speed analysis
(3) Demand for average download speed	34.19	Equation in graphic 5-1
(4) New demand for average download speed	34.23	Equation in graphic 5-1
(5) Additional Yearly Consumer Surplus	0.43	(4-3) * 12
(6) Fixed Broadband Connections with Wi-Fi (Millions)	6.013	Estimation
(7) Impact (US$ Millions)	$3	(6)*(7)

Source: Telecom Advisory Services analysis

As in the case of the return to speed analyzed above, the annual consumer surplus generated by faster Wi-Fi will also be influenced by the same trends that evolve after 2022. These trends will affect the annual contribution to faster speeds resulting from the 6 GHz allocation as follows (see Table 5-7).

Table 5-7. Consumer Surplus from 6 GHz unlicensed (2022-2031)

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
(1) Average Download Speed	21.88	25.95	30.77	36.47	43.21	51.17	60.59	71.72	84.86	100.39
(2) New Average Download Speed	21.98	26.55	33.76	43.66	59.10	82.41	113.11	156.05	220.51	310.54
(3) Demand for average download speed	34.19	35.13	36.03	36.89	37.72	39.08	40.43	41.77	43.12	44.47
(4) New Demand for average download speed	34.23	35.32	36.79	38.35	40.23	42.89	45.42	47.99	50.76	53.50
(5) Additional Yearly Consumer Surplus	0.43	2.27	9.16	17.52	30.06	45.73	59.92	74.62	91.65	108.38
(6) Fixed Broadband Connections with Wi–Fi (Millions)	6.013	6.389	6.739	7.067	7.376	7.671	7.969	8.273	8.580	8,893
(7) Impact (USD Millions)	$3	$14	$62	$124	$222	$351	$478	$617	$786	$964

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

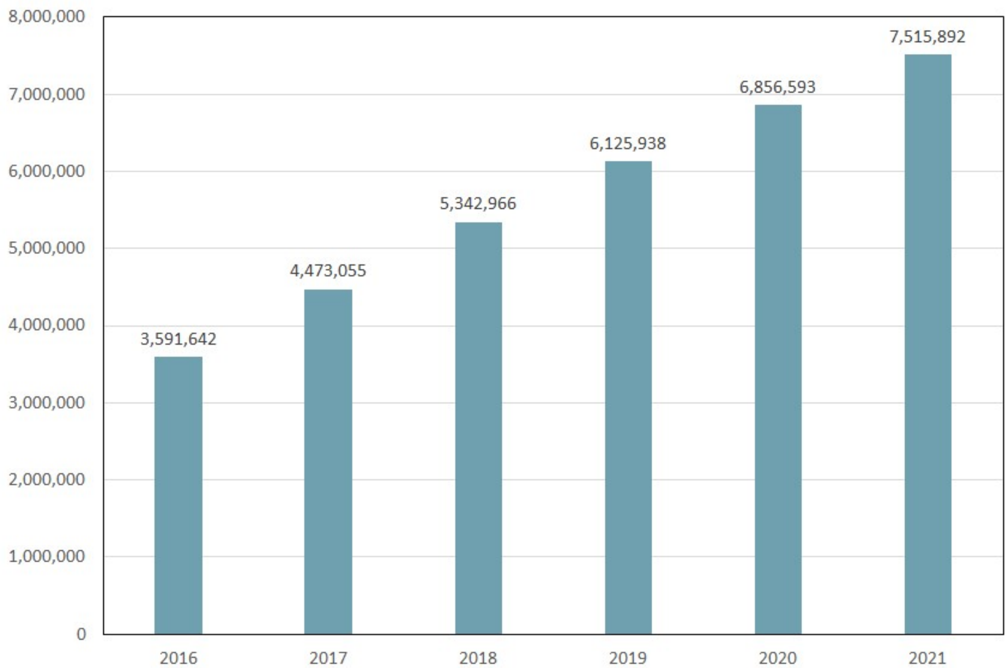
The yearly increase of the average household in consumer surplus will evolve from US$ 0.43 in 2022 to US$ 108.38 in 2031 (the households with bottleneck will have an increase higher than that, but the households with no bottleneck will have $0). Thereby, total consumer surplus associated with the allocation of the 6 GHz band between 2022 and 2031 will reach US$ 3.6 billion.

6. WIDE DEPLOYMENT OF INTERNET OF THINGS

6.1. The critical importance of IoT in Indonesia

Considering that IoT devices have been deployed in Indonesia for several years, the economic value estimation of "broader" deployment resulting from the combination of a significant amount of spectrum capacity requires teasing out the impact due to the natural growth of IoT based on the extrapolation of current penetration rates. M2M adoption, as a metric of IoT deployment (the only available indicator to measure IoT), has reached an installed base of 7,515,892 in 2021 (see Graphic 6-1).

Graphic 6-1. Indonesia: Installed base of M2M devices (2016-2021)



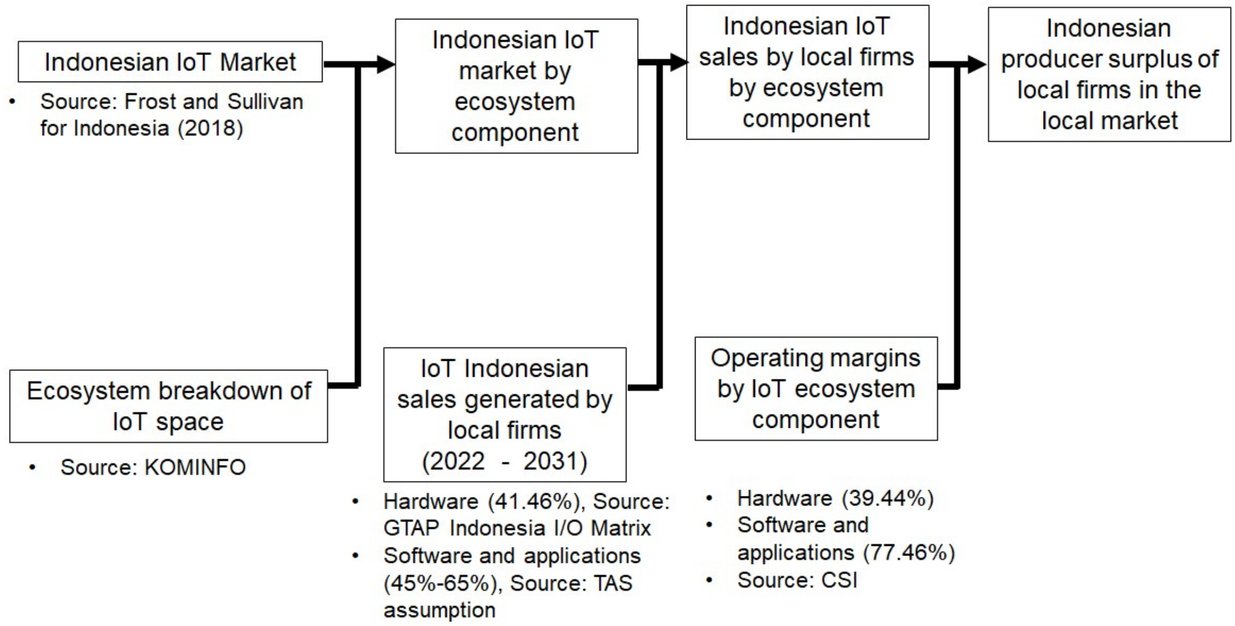
Source: GSMA Intelligence

On the other hand, the IoT Indonesian market in 2021 is estimated at US$1.84 billion. The enhanced deployment of IoT because of the 6 GHz allocation to unlicensed use will trigger two economic effects: (i) the generation of producer surplus (i.e., margins) of Indonesian eco-system suppliers in the IoT segment, and (ii) the spillover of IoT on the efficiency of Indonesian industries.

6.2. Producer surplus of Indonesian IoT eco-system firms

The objective in this case is to calculate the impact that the allocation of the 6 GHz band would have in terms of expanding the IoT installed base, thereby generating consumer surplus (i.e. operating margins) for the Indonesian suppliers of hardware, software, and systems integration (see figure 6-1).

Figure 6-1. Methodology for estimating producer surplus from IoT Indonesian suppliers



Source: Telecom Advisory Services

To estimate the producer surplus, we begin by estimating the local IoT market, disaggregating it by ecosystem components. The starting point is the Frost and Sullivan estimation for Indonesia for 2020, on which a constant growth rate is assumed until 2031. The total market is disaggregated in terms of the ecosystem components based on the estimates provided by the local government[47] (see Table 6-1).

Table 6-1. Indonesia: IoT market (2022-2031)

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
(1) Industrial IoT revenue in Indonesia (US$ billion)	$2.52	$3.44	$4.70	$6.43	$8.78	$12.00	$16.40	$22.40	$30.61	$41.82
(2) Hardware IoT revenue in Indonesia (US$ billion)	$0.55	$0.75	$1.02	$1.39	$1.90	$2.60	$3.55	$4.85	$6.63	$9.06
(3) Software and Services IoT revenue in Indonesia (US$ billion)	$1.97	$2.70	$3.69	$5.04	$6.88	$9.40	$12.84	$17.55	$23.98	$32.76

Sources: Frost and Sullivan (2018); KOMINFO; Telecom Advisory Services analysis

On this basis, the market share served by Indonesian companies is estimated. The share of the hardware segment is estimated from the proportion of local manufacturing of the electronic equipment sector presented in the input / output matrix for Indonesia, which is calculated with data from the General Trade Accounting Project (GTAP). The share of the

[47] Umali, T. (2018): The potential of IoT in Indonesia. *OpenGov* (November 18th). Downloadable in: https://opengovasia.com/the-potential-of-iot-in-indonesia/

software and systems integration segment is assumed to account for an initial value of 45%, increasing to 65% at the end of the period, indicating a growing importance of the digital services industry in the country (see table 6-2).

Table 6-2. Indonesia: Share of IoT market served by Indonesian suppliers (2022-2031)

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Hardware	41.5%	41.5%	41.5%	41.5%	41.5%	41.5%	41.5%	41.5%	41.5%	41.5%
Software and Apps	50%	55%	60%	65%	65%	65%	65%	65%	65%	65%

Sources: Indonesia I/O Matrix; Telecom Advisory Services analysis

Based on the operating margins by component, the producer surplus for Indonesian providers of IoT solutions was estimated (see table 6-3).

Table 6-3. Indonesia: Producer surplus of Indonesian IoT suppliers (in US$ million) (2022-2031)

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Hardware	$89	$122	$167	$228	$311	$425	$581	$794	$1,084	$1,482
Software and Apps	$765	$1,149	$1,713	$2,535	$3,464	$4,733	$6,467	$8,835	$12,072	$16,494
Total Surplus	$854	$1,271	$1,880	$2,763	$3,775	$5,158	$7,048	$9,629	$13,156	$17,976
Surplus attributable to 6 GHz	$395	$423	$625	$919	$1,256	$1,716	$2,345	$3,204	$4,377	$5,981

Sources: Frost & Sullivan (2018); KOMINFO; Telecom Advisory Services analysis

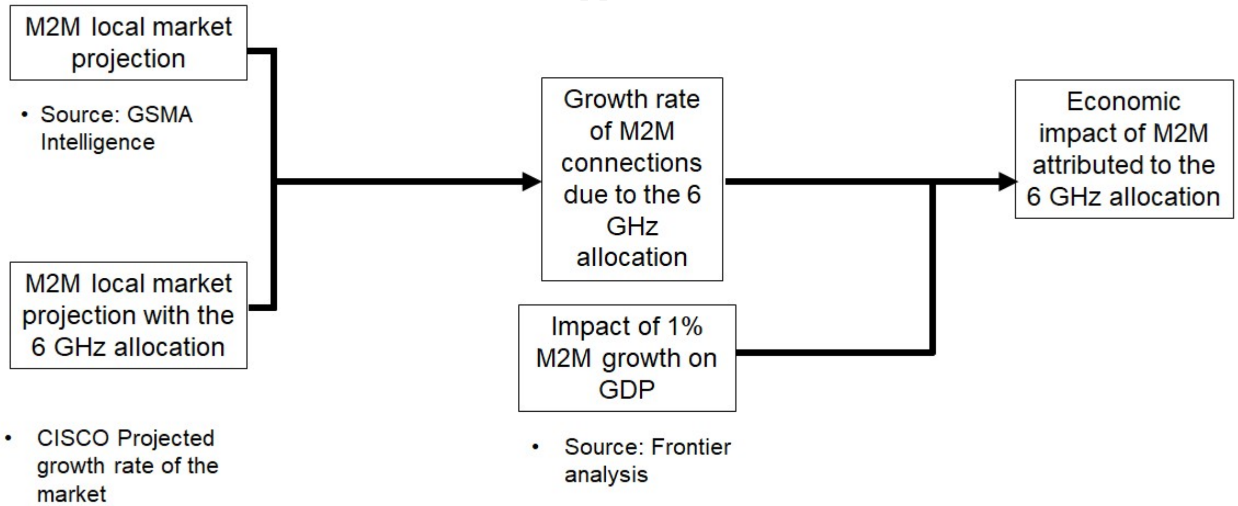
The total cumulative value of producer surplus driven by sales of IoT by Indonesian firms in Indonesia amounts to US$ 21.2 billion.

6.3. Spillover of IoT deployment propelled by 6 GHz allocation in Indonesia

IoT adoption contributes to GDP growth through the multiplicity of use cases that improve efficiency in business processes, such as preventive maintenance and production monitoring. To estimate this, we relied on a coefficient of GDP impact calculated through an aggregate simple production function that estimates that a 10% rise in M2M connections results in annual increases in GDP of between 0.3% and 0.9% (see figure 6-2).[48]

[48] *See* Frontier Economics (2018). *The economic impact of IoT: putting numbers on a revolutionary technology.*

Figure 6-2. Methodology for estimating producer surplus from IoT Indonesian suppliers



Source: Telecom Advisory Services

By relying on the middle coefficient of the GDP impact contribution (0.7% for each 10% of the installed base), we estimate that in 2023, the impact of IoT would be 0.03% of GDP. Considering that Indonesian GDP in 2023 will reach US$ 1,360 billion, it is estimated that the IoT impact for 2023 would reach $ 396 million (see Table 6-4).

Table 6-4. Indonesia: IoT Spillover (in US$ billion) (2022-2031)

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
(1) M2M Growth Rate without 6 GHz (%)	4.17%	4.17%	4.17%	4.17%	4.17%	4.17%	4.17%	4.17%	4.17%	4.17%
(2) M2M Growth Rate with 6 GHz (%)	7.75%	6.25%	6.25%	6.25%	6.25%	6.25%	6.25%	6.25%	6.25%	6.25%
(3) Impact of 1% M2M Growth on GDP	7.00%	7.00%	7.00%	7.00%	7.00%	7.00%	7.00%	7.00%	7.00%	7.00%
(4) Use of the 6 GHz Band	10.00%	20.00%	30.00%	40.00%	50.00%	60.00%	65.00%	70.00%	75.00%	80.00%
(5) Impact on GDP (%)	0.03%	0.03%	0.04%	0.06%	0.07%	0.09%	0.09%	0.10%	0.11%	0.12%
(6) Indonesian GDP (US$ Billion)	$1,256	$1,360	$1,459	$1,562	$1,673	$1,791	$1,918	$2,054	$2,199	$2,355
(7) Total Impact (US$ Million)	$315	$396	$637	$909	$1,217	$1,564	$1,814	$2,092	$2,400	$2,742

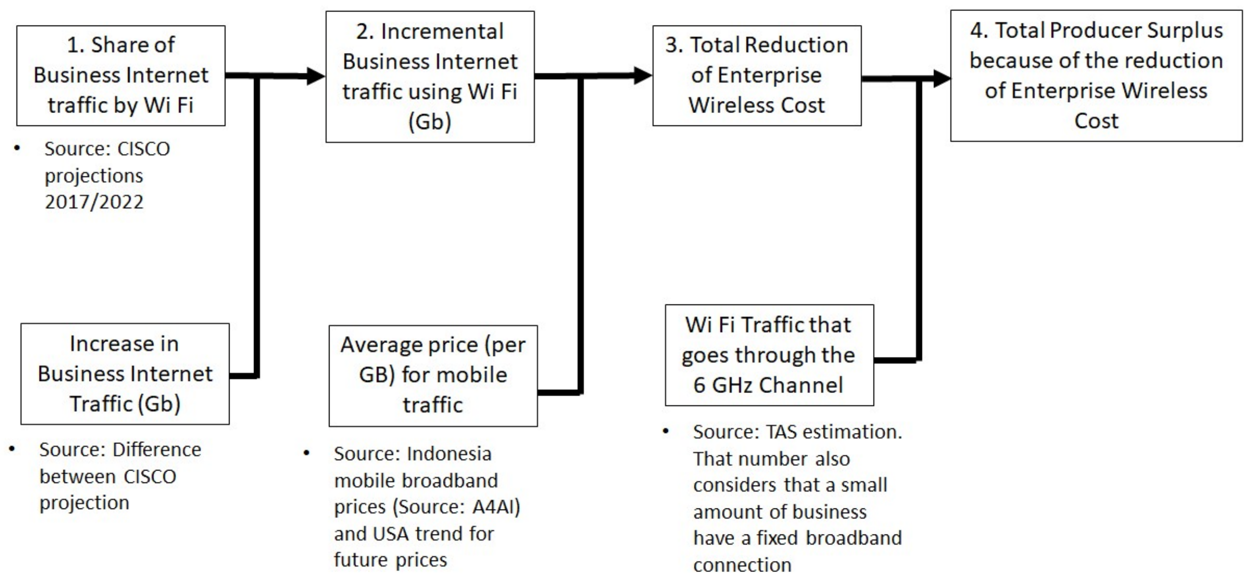
Source: GSMA Intelligence; Frontier Economics; Telecom Advisory Services analysis

According to the data in line 7 of table 6-4, cumulative impact of enhanced IoT deployment driven by 6 GHz spectrum proposals will reach US$ 14.1 billion by 2031.

7. REDUCTION OF ENTERPRISE WIRELESS COSTS

The deployment of the enterprise applications based on IoT and AR/VR, among other use cases, (will generate an exponential growth in data traffic that will be handled by devices operating in unlicensed spectrum, through the combination of the existing 2.4 GHz, 5 GHz, and the 6 GHz band. Under current conditions, enterprise Wi-Fi networks run 20 or 40 MHz channels due to spectrum shortfall and device restrictions. Wi-Fi requires 80 MHz channels to offer 1 Gb of throughput, which provides an indication of existing constraints. Thus, 6 GHz allocation is critical to handle enterprise applications. The impact on GDP of having a suitable spectrum environment to run these applications has been addressed in the IoT and AR/VR chapters under the heading of spillovers. That being said, the allocation of 6 GHz also has an economic effect in enterprise margins (or producer surplus), in terms of the savings from cellular usage resulting from using unlicensed spectrum to handle traffic from high-capacity Wi-Fi devices rather than cellular networks. The methodology to assess this benefit proceeds by multiplying the average price per Gigabyte of wireless data transmitted by wideband networks, which we calculate using data from Alliance for Affordable Internet (A4AI)[49] (see figure 7-1).

Figure 7-1. Methodology for estimating a reduction in enterprise wireless cost



Source: Telecom Advisory Services

In 2018, the Cisco VNI estimated that for 2023 total business Internet traffic in Indonesia would reach 5,024 million GB (line 2 in Table 7-1), of which 34.28% would be transported through Wi-Fi access points. In 2019, an updated Cisco traffic forecast based on the explosion of IoT and AR/VR applications, among other factors, increased total Internet traffic reaching

[49] Alliance for Affordable Internet. Data-only mobile broadband. Retrieved in: https://a4ai.org/extra/baskets/A4AI/2020/mobile_broadband_pricing_usd

an estimated value for 2023 of 5,328 million GB, of which 34.28% would be transported through Wi-Fi[50] (see line 5 in Table 7-1).

Table 7-1. Indonesia: Enterprise Wireless Traffic ('000) (2022-2031)

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
(1) Share of Business Internet Traffic by Wi Fi (2016-21)	36.00%	34.28%	32.64%	31.08%	29.59%	28.17%	26.83%	25.54%	24.32%	23.16%
(2) Total Business Internet Traffic (M Gb) (2016-21)	4,055	5,024	6,224	7,712	9,555	11,838	14,667	18,173	22,515	27,896
(3) Total Wi-Fi Enterprise Traffic (M Gb) (2016-21)	1,460	1,722	2,032	2,397	2,827	3,335	3,935	4,642	5,476	6,460
(4) Share of Business Internet Traffic by Wi Fi (2017-22)	36.00%	34.28%	32.64%	31.08%	29.59%	28.17%	26.83%	25.54%	24.32%	23.16%
(5) Total Business Internet Traffic (M Gb) (2017-22)	4,226	5,328	6,717	8,468	10,675	13,458	16,967	21,390	26,966	33,995
(6) Total Wi-Fi Enterprise Traffic (M Gb) (2017-22)	1,521	1,826	2,192	2,632	3,159	3,792	4,552	5,464	6,558	7,872
(7) Incremental Business Internet Traffic (M Gb)	62	104	161	235	332	456	617	822	1,082	1,412

Source: Cisco Visual Networking Index (2017), (2019)

Each growth forecast was converted to dollar values based on the price per GB[51] (see Table 7-2).

Table 7-2. Indonesia: Cost of Enterprise Internet Traffic (2022-2031) (IN US$)

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
(5) Average Price per Gb	$0.55	$0.49	$0.44	$0.40	$0.36	$0.32	$0.29	$0.26	$0.24	$0.21
(6) Economic Impact (US$ Million)	33.66	51.19	71.07	93.52	118.83	147.29	179.21	214.95	254.90	299.48

Sources: A4AI; Telecom Advisory Services analysis

We assume that part of the traffic growth presented in table 7-2 will be driven by "natural" growth (that is to say, the extrapolation of historical growth rate of enterprise wireless traffic by averaging the growth rate between 2018 and 2019 and between 2016 and 2019), while

[50] Cisco's new forecast includes in its assumption set the deployment of Wi-Fi 6.
[51] According to the Alliance for Affordable Internet, in 2020 the price for a 10 GB plan in Indonesia was US$6.73 (US$ 0.673 per GB).

the remainder will be triggered by Wi-Fi traffic stimulated by changes in 6 GHz (see Table 7-3).

Table 7-3. Indonesia: Enterprise Wireless Traffic: Growth triggered by broader Wi-Fi traffic (2022-2031) (in '000'000 US$)

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
(7) Traffic through 6 GHz Band	10%	20%	30%	40%	50%	60%	65%	70%	75%	80%
(8) Economic impact of 6 GHz Band (US$ million)	$3	$10	$21	$37	$59	$88	$116	$150	$191	$240

Source: Telecom Advisory Services analysis

The sum of the difference due to broader Wi-Fi traffic between 2022 and 2031 will reach US$ 918 million.

8. DEPLOYMENT OF AR/VR SOLUTIONS

The worldwide AR/VR solutions market is developing at a fast pace driven by a broad range of applications (see table 8-1).

Table 8-1. Examples of AR/VR applications

Sector	Domain	Use Case	Example
Health Care	Diagnostic	Augmented reality has the potential to help patients before they are diagnosed with Alzheimer or Dementia	Altoida, is a company that develops virtual and augmented reality tools to predict the onset of mental illness in older patients, specifically neurodegenerative diseases[52]
	Surgical procedures	Platforms that combine visualization and display technologies with a new class of operating robots to support remote surgical interventions	Medivis, a company specialized in augmented reality suites in the health care domain, offers an augmented reality holographic visualization tool that guides surgical navigation, which can decrease complications and improve patient outcomes, while lowering surgical costs[53].
	Training in ER procedures	Since pediatric emergencies are rare, doctors have little training experience for helping children in emergencies, and traditional mannequin-based simulations are expensive.	VR is helping doctors at Children's Hospital Los Angeles be better prepared for real life scenarios by helping doctors learn their knowledge gaps. The program has also been expanded to 11 other sites, including Johns Hopkins and Stanford University health systems[54].
Retailing	Guest engagement	Provide customers with mall-wide Wi-Fi coverage, combined with guest engagement content as part of marketing campaigns[55].	Retailers are experimenting with the roll-out of enhanced Wi-Fi based portal and analytics platforms deployed in brick-and-mortar facilities.
Oil and Gas	Maintenance	Oil firms have adopted AR headsets and glasses, which superimpose digital images on what the wearer sees in real life to fix problems on rigs, refineries and plants. The technology transmits information in real-time to experts located anywhere in the world, who can then respond with instructions and guidance to a technician on-site.	Fieldbit, among many firms, is creating[56] technology that aims to prevent technician issues and oil spills in the oil and gas industry. This emerging technology is already being used by Chevron, BP, and Baker Hughes
Mining	Emergency rescue operations training	Virtual reality creates situations that are impossible to recreate in the physical world in order to train rescue personnel	Volunteer rescuers navigate emergency underground simulations to train rescue volunteers to hone their emergency-response skills in a safe but realistic environment[57]

Source: Compilation by Telecom Advisory Services

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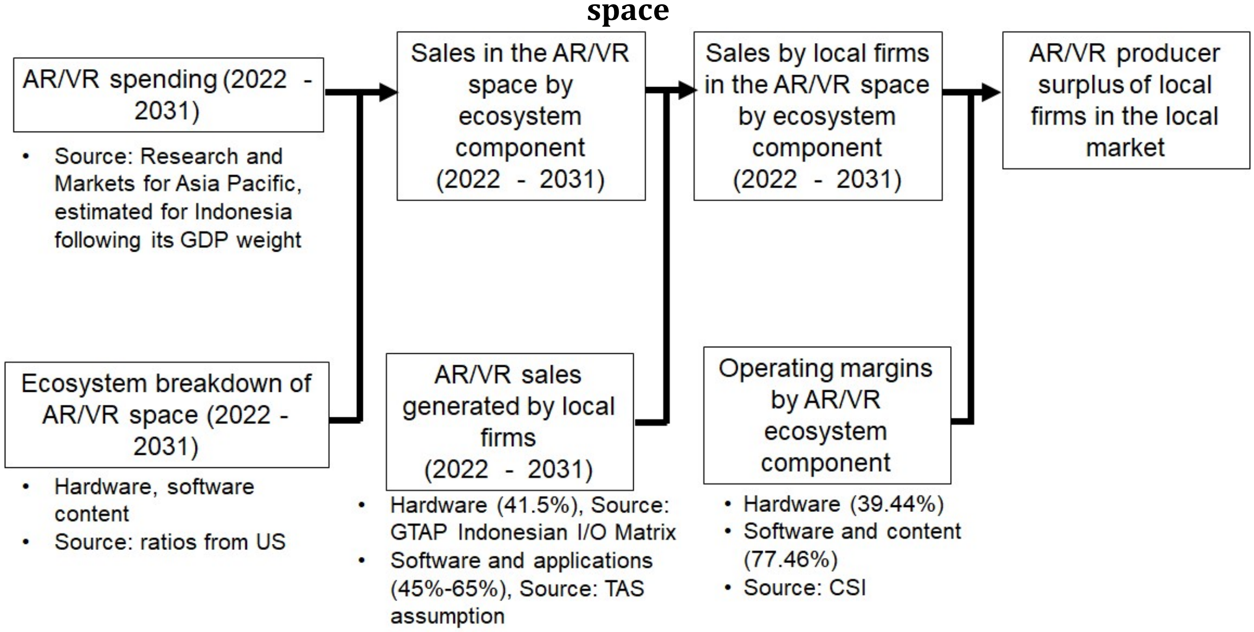
[52] Shieber, J. "Using augmented reality, Altoida is identifying the likely onset of neurodegenerative diseases", *Techcrunch*, May 30, 2019.
[53] Shrieber, J. "Robotics, AR and VR are poised to reshape health-care, starting in the operating room". *Techcrunch*, February 21, 2019.
[54] Preparing for emergencies before they happen
[55] See example of American Dream Megamall, one of the largest US malls located in New Jersey.
[56] Margit, M. (2019). *How Augmented Reality is Transforming the Oil Industry*
[57] Mine rescue teams discover a new tool for training

The AR/VR market in Indonesia is estimated at US$380 million, of which US$125 million is composed of hardware (such as smart and non-smart glasses), and US$254 million is driven by software and applications (including systems integration, platform, and licensing). We estimate that by 2024 the market will reach US$ 1.1 billion (US$ 350 million in hardware and US$ 710 million from software and applications)[58], and US$ 11.59 billion (US$ 3.82 billion hardware and US$ 7.77 billion software and applications) by 2031. Sales by Indonesian firms to Indonesian businesses will generate producer surplus (i.e., margins), while the technology will yield spillovers in enterprise productivity.

8.1. Producer surplus derived from sales of Virtual Reality and Augmented Reality solutions

The development and diffusion of AR/VR applications in the production side of the economy is being driven by an ecosystem comprised of firms ranging from software development to hardware production and content creation. The key objective in this case is to estimate the producer surplus generated in Indonesia because of the sales of AR/VR applications produced by domestic firms (see Figure 8-1).

Figure 8-1. Methodology for estimating Indonesian producer surplus in the AR/VR space



Source: Telecom Advisory Services

Our starting point is the sales of AR/VR applications and systems within Indonesia between 2022 and 2031 (one could potentially include exports to other countries, although we exclude this for conservative purposes). We estimate this by prorating Asia-Pacific

[58] Data calculated based on Asia-Pacific totals as estimated by Research and Markets

projections for Indonesia based on its weight in the regional GDP and breaking it down by ecosystem component according to US ratios (see table 8-2).

Table 8-2. Indonesia: AR/VR market by component (2022-2031) (in US$ billions)

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Hardware	$0.18	$0.25	$0.35	$0.49	$0.69	$0.97	$1.37	$1.93	$2.72	$3.82
Software & Applications	$0.36	$0.50	$0.71	$1.00	$1.41	$1.98	$2.79	$3.92	$5.52	$7.77
TOTAL	$0.53	$0.75	$1.06	$1.49	$2.10	$2.95	$4.16	$5.85	$8.24	$11.59

Sources: Research and Markets; Telecom Advisory Services analysis

Sales are broken down by two ecosystem components: hardware, and applications/ software, but each component is restricted to Indonesian firms, because our purpose is to estimate the value generated by domestic producers (therefore, we exclude sales generated by foreign firms in Indonesia). The domestic share of the hardware market is estimated from the proportion of local manufacturing of the electronic equipment sector presented in the input / output matrix for Indonesia, which is calculated with data from the General Trade Accounting Project (GTAP). The share of the software and systems integration segment is assumed to reach an initial value of 45%, increasing to 65% at the end of the period, indicating the growing importance of digital services in Indonesia. We acknowledge that the development of this market should be accompanied by a concerted industrial policy aimed at developing local firms in these two sectors (see Table 8-3).

Table 8-3. Indonesia: AR/VR sales by Indonesian firms by component (2022-2031) (in US$ billions)

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Hardware	$0.07	$0.10	$0.14	$0.20	$0.29	$0.40	$0.57	$0.80	$1.13	$1.59
Software & Applications	$0.18	$0.28	$0.43	$0.65	$0.91	$1.29	$1.81	$2.55	$3.59	$5.05
TOTAL	$0.25	$0.38	$0.57	$0.85	$1.20	$1.69	$2.38	$3.35	$4.71	$6.63

Sources: Research and Markets; Telecom Advisory Services analysis

Once sales by Indonesian firms in the Indonesian market are calculated, producer surplus for the AR/VR local industry is estimated based on standard margin metrics: 39.44% for hardware, and 77.46% for software and content (see Table 8-4).

Table 8-4. Indonesia: Producer surplus derived from AR/VR sales by Indonesian firms by component (2022-2031) (in US$ billions)

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Hardware	$0.03	$0.04	$0.06	$0.08	$0.11	$0.16	$0.22	$0.32	$0.44	$0.63
Software & Applications	$0.14	$0.21	$0.33	$0.50	$0.71	$1.00	$1.40	$1.97	$2.78	$3.91
TOTAL	$0.17	$0.26	$0.39	$0.58	$0.82	$1.16	$1.63	$2.29	$3.22	$4.54

Sources: CSI Market Inc; Research and Markets; Telecom Advisory Services analysis

A portion of this surplus is not due exclusively to the designation of Very Low Power devices within the 6 GHz band. The development of AR/VR already begun before this potential spectrum designation. Therefore, the producer surplus estimated in table 8-4 must be broken down between the portion that is due to the "natural" growth in the industry and the boost resulting from the spectrum allocation mentioned above. In the absence of any precise metric, we applied the ratio used to determine the impact on AR/VR market growth ranging between 25.59% of sales in 2022 and 56.37% in 2031. Based on this analysis, the cumulative producer surplus to be generated by Indonesian AR/VR firms from sales in the local market between 2022 and 2031 due to the 6 GHz allocation will amount to US $7.24 billion (see Table 8-5).

Table 8-5. Indonesia: AR/VR sales by US firms by component attributed to the designation of Very Low Power devices within the 6GHz band (2022-2031) (in US$ millions)

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Due to 6 GHz (%)	25.59%	26.64%	27.73%	28.87%	33.87%	38.87%	43.87%	48.87%	53.87%	56.37%
Due to 6 GHz (US$ M)	$43	$68	$107	$168	$278	$449	$714	$1,119	$1,736	$2,557

Sources: CSI Market Inc*: Industry Profitability ratios; ABI Research; Telecom Advisory Services analysis.*

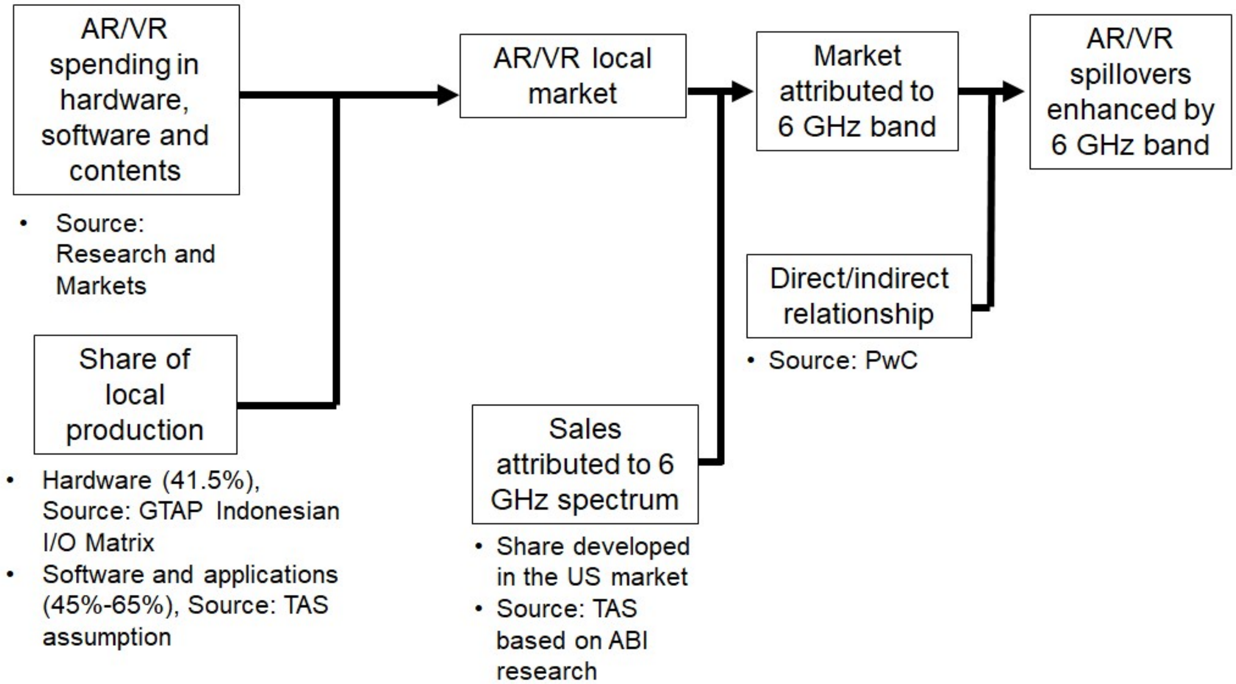
8.2. Spillovers from Virtual Reality and Augmented Reality

The adoption of AR/VR among Indonesian businesses will in turn have a spillover effect on local productivity, thereby contributing to the growth of GDP. The impact ranges from improved training to the acceleration of product design and delivery. For example, manufacturing companies in advanced economies are already incorporating VR in their product development processes to reduce the time incurred between initial design and physical modelling. AR glasses also help warehouse workers provide parts information for engineers and technicians in the field. Finally, as shown in the applications table above, AR/VR solutions can be used to sell and showcase products in retailing.

Because the objective is to estimate the spillover effect of AR/VR sales by Indonesian firms in the domestic market resulting from the growth driven by designating VLP devices as part of the 6 GHz band, our point of departure is the total GDP contribution of AR/VR, as estimated by PwC that indicates the weight of AR/VR in the GDP by region[59], and the sales of AR/VR components (see table 8-1). These two parameters allow estimating the indirect (spillover) contribution of AR/VR to the Indonesian economy (see Figure 8-2).

[59] PWC (2019). *Seeing is believing how virtual reality and augmented reality are transforming business and the economy.*

Figure 8-2. Methodology for estimating AR/VR spillovers in Indonesia



Source: Telecom Advisory Services

Both starting values are reduced by the proportion that can be attributed to the impact of the 6 GHz spectrum allocation of VLP devices (in other words, it would be wrong to estimate that the whole economic value of the AR/VR is driven by the spectrum changes). Once the amount to be attributed in both GDP contribution and direct sales is estimated, the annual indirect to direct multiplier can be calculated (see Table 8-6).

Table 8-6. Indonesia: GDP Contribution resulting from AR/VR Spillovers (2022-2031) (in US$ billion)

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
AR/VR Boost to GDP (% GDP)	0.20%	0.25%	0.31%	0.38%	0.46%	0.56%	0.70%	0.89%	1.12%	1.41%
Indonesia GDP (US$ Billions)	$1,256	$1,360	$1,459	$1,562	$1,673	$1,791	$1,918	$2,054	$2,199	$2,355
AR/VR Boost to GDP without 6.0 GHz Band (US$ Billions)	$0.97	$1.09	$1.40	$1.74	$1.87	$1.94	$1.92	$1.70	$1.06	$0.60
AR/VR Boost to GDP due to 6.0 GHz Band (US$ Billions)	$0.64	$0.91	$1.25	$1.71	$2.61	$3.90	$5.89	$8.93	$13.27	$18.71
Direct impact (US$ Billions)	$0.14	$0.20	$0.29	$0.43	$0.71	$1.15	$1.82	$2.86	$4.44	$6.53
Indirect impact (US$ Billions)	$0.51	$0.71	$0.96	$1.28	$1.90	$2.75	$4.07	$6.07	$8.83	$12.17
Indirect impact considered (US$ Millions)	$274	$401	$588	$861	$1,422	$2,296	$3,648	$6,072	$8,831	$12,173

Sources: PwC; Telecom Advisory Services analysis.

Total spillover value of AR/VR in Indonesia (the indirect impact) between 2022 and 2031 is US$ 36.57 billion.

9. ENHANCED DEPLOYMENT OF MUNICIPAL WI-FI

Municipal Wi-Fi provides free Internet access to the population at large. In many cases, municipalities aiming to develop a smart city infrastructure require the deployment of Wi-Fi networks in public places to facilitate Internet access for their citizens. Based on ITU data, only 15% of the Indonesian households have access to a fixed-broadband connection, while according to GSMA, mobile broadband unique subscribers' penetration accounted for only 52% of the population in 2020. In a context of the affordability barrier pointed above, public Wi-Fi represents a viable option of Internet access. This is confirmed by the APJII local survey, which reports that 0.7% of internet users (over 1.1 million people) rely mainly on public Wi-Fi hotspots as its source for internet connection. That figure should increase to 9% if we consider those who rely on public Wi-Fi hotspots as a secondary source of connectivity (almost 15 million people). Consumers who do not have broadband at home because they lack economic resources to acquire service can rely on public or municipal Wi-Fi to gain Internet access.

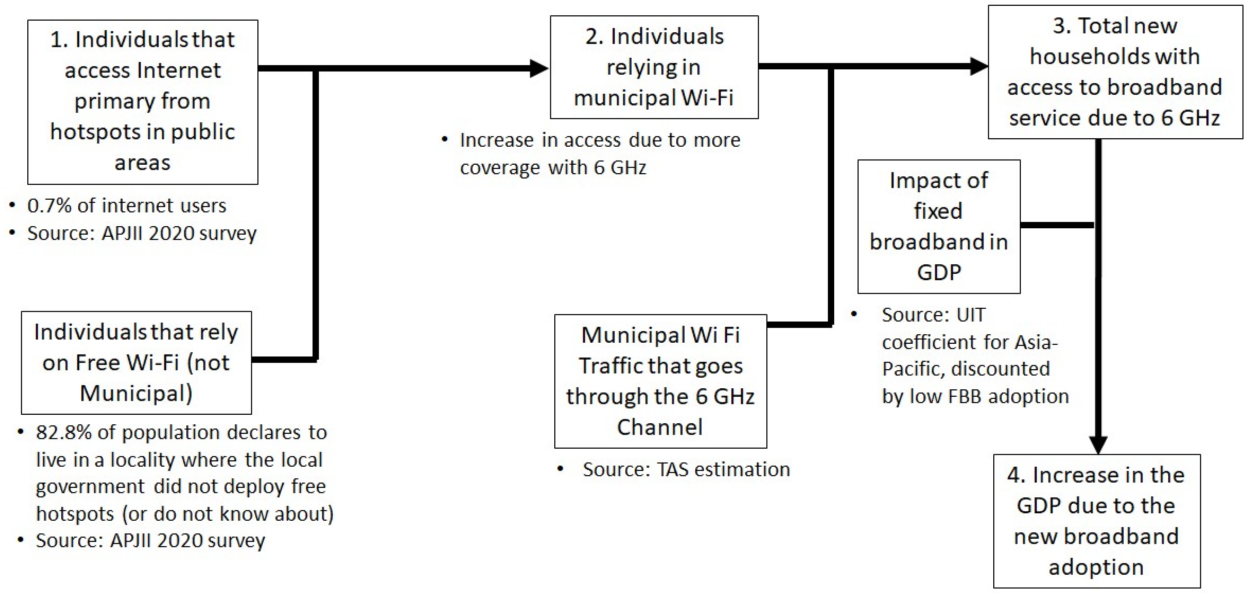
Indonesia has yet to develop a full network of municipal Wi-Fi sites. The above-cited APJII survey indicated that only 17.2% of people live in a place where the local government provides public Wi-Fi hotspots. Wi-Fi infrastructure relying only on 2.4 GHz and 5.8 GHz bands is exposed to service degradation as well as inability to support a large user base. Municipal Wi-Fi is an application that is in critical need of additional spectrum to satisfy the growth in the number of clients but also to deal with interference from other devices operating in competing frequencies. As an example, the 2.4 GHz band currently handles may appliances and devices on wireless standards such as Bluetooth and Zigbee, creating significant interference for Wi-Fi.

Along these lines, allocating spectrum in the 6 GHz band will increase the ability of municipal Wi-Fi to provide free service to the unserved population or increase the speed of access for current users. These two effects translate into a contribution to GDP and an increase in consumer surplus.

9.1. Impact of enhanced Municipal Wi-Fi on GDP

The municipal Wi-Fi sites that incorporate technology relying on 6 GHz spectrum will be able to handle a larger number of users than under the current spectrum conditions. This will in turn have an impact on the GDP. The methodology to estimate this effect is presented in figure 9-1.

Figure 9-1. Methodology for estimating GDP impact of Municipal Wi-Fi



Source: Telecom Advisory Services

The estimation of the universe for assessing the impact of municipal Wi-Fi starts considering current service users (line 1 in table 9-1). For this purpose, we consider the population that reports using public Wi-Fi (0.7% of internet users). That share of the population could connect using Municipal Wi-Fi (estimated in 17.2% of the initial universe) or could connect using Wi-Fi hotspots (the remaining 82.8%). In addition, we must consider the population with access to fixed broadband at home (42 million in 2021). Finally, based on GSMA Intelligence projections for mobile broadband unique subscribers, we estimate that 153 million Indonesians have a smartphone. By subtracting total broadband users from total smartphone holders, we estimate that 110 million Indonesians are potential users of municipal Wi-Fi in 2021. Under this scenario, some of those could access the Internet through municipal Wi-Fi to avoid costs of a data plan. Considering that only 0.7% of that universe (discounted by the traffic through 6 GHz band) will be future users of the service, we can estimate the impact of future deployment of municipal Wi-Fi benefitting from the designation of the 6 GHz band (Table 9-1).

Table 9-1. Indonesia: GDP impact of Municipal Wi-Fi networks with 6 GHz spectrum

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
(1) Individuals that connect from Free Wi-Fi (M)	1.312	1.492	1.696	1.928	1.994	2.012	2.029	2.046	2.064	2.082
(2) Individuals that rely on Municipal Wi-Fi (M)	0.226	0.257	0.292	0.332	0.343	0.346	0.349	0.352	0.355	0.358
(3) Individuals that rely on free Wi-Fi traffic offered in public sites (M)	1.086	1.235	1.404	1.596	1.651	1.666	1.680	1.694	1.709	1.724
(4) Individuals that lives in a household with FBB (M)	43.337	44.387	45.160	45.722	46.115	46.386	46.648	46.912	47.176	47.442
(5) Individuals with a smartphone (M)	167.784	176.547	185.725	192.682	199.850	205.858	212.046	217.511	223.118	228.869
(6) Potential Free Wi-Fi Market (M)	123.136	130.668	138.870	145.033	151.740	157.460	163.368	168.553	173.877	179.345
(7) Share of the potential Free Wi-Fi Market that would be covered by Free Wi-Fi	0.70%	0.70%	0.70%	0.70%	0.70%	0.70%	0.70%	0.70%	0.70%	0.70%
(8) Share of the potential Free Wi-Fi Market that would be covered by Municipal Wi Fi	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%
(9) Traffic through 6 GHz Band	10%	20%	30%	40%	50%	60%	65%	70%	75%	80%
(10) New individuals that now can have broadband (M)	0.015	0.031	0.050	0.070	0.091	0.114	0.128	0.142	0.157	0.173
(11) New households that now can have broadband (M)	0.004	0.008	0.013	0.018	0.023	0.029	0.032	0.036	0.040	0.044
(12) Households with Fixed Broadband (M)	10.801	11.085	11.304	11.473	11.604	11.704	11.802	11.901	12.001	12.102
(13) Increase in national broadband penetration	0.03%	0.07%	0.11%	0.15%	0.20%	0.25%	0.27%	0.30%	0.33%	0.36%
(14) Impact of fixed broadband adoption in GDP	16.32%	16.32%	16.32%	16.32%	16.32%	16.32%	16.32%	16.32%	16.32%	16.32%
(15) Increase in the GDP due to the new broadband adoption (% GDP)	0.01%	0.01%	0.02%	0.02%	0.03%	0.04%	0.04%	0.05%	0.05%	0.06%
(16) GDP (US$ Billion)	$1,256	$1,360	$1,459	$1,562	$1,673	$1,791	$1,918	$2,054	$2,199	$2,355
(17) Total impact in GDP (US$ Billion)	$0.07	$0.16	$0.26	$0.39	$0.54	$0.72	$0.86	$1.01	$1.19	$1.40

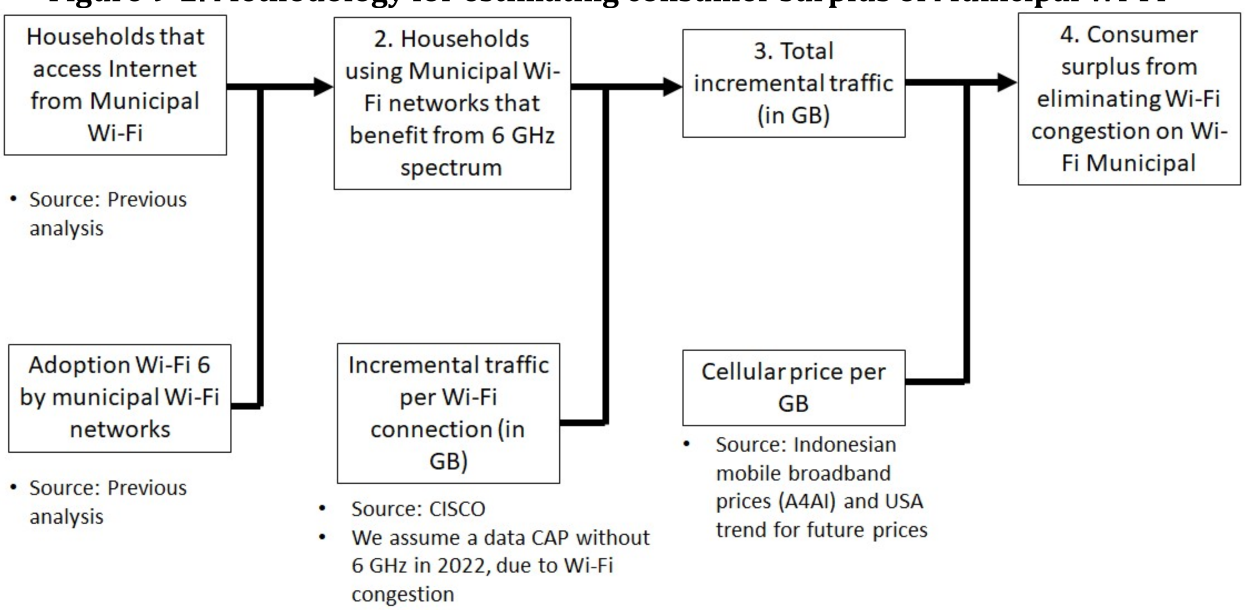
Sources: IMF; GSMA; ITU; RIA; Telecom Advisory Services analysis.

In sum, the cumulative contribution of GDP of the benefit accorded to municipal Wi-Fi networks by allocating spectrum in the 6 GHz band will reach US$ 6.6 billion (the sum of line 17).

9.2. Contribution of enhanced Municipal Wi-Fi to consumer surplus

In addition to the contribution to GDP, municipal Wi-Fi networks with the capacity to leverage spectrum in 6 GHz can enhance their performance, providing faster broadband service, and thereby generating incremental consumer surplus (see Figure 9-2).

Figure 9-2. Methodology for estimating consumer surplus of Municipal Wi-Fi



Source: Telecom Advisory Services analysis

The basis of this analysis is to estimate the difference in the download speed of municipal Wi-Fi service before and after the allocation of 6 GHz spectrum for those households that do not purchase broadband service and are compelled to rely on this service to gain Internet access. We start by relying on the analysis of table 9-1 for the number of municipal Wi-Fi users. This yields the population that accesses the Internet away from home who benefit from municipal Wi-Fi that has adopted Wi-Fi 6: 240,000 in 2022, increasing to 531,000 in 2031.

Table 9-2. Indonesia: Households benefiting from municipal Wi-Fi that have adopted Wi-Fi 6

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
(1) Individuals that rely on Municipal Wi-Fi (M)	0.226	0.257	0.292	0.332	0.343	0.346	0.349	0.352	0.355	0.358
(2) New individuals that now can have broadband using Municipal Wi-Fi(M)	0.015	0.031	0.050	0.070	0.091	0.114	0.128	0.142	0.157	0.173
(3) Total Individuals that rely on Municipal Wi-Fi (M)	0.240	0.288	0.342	0.401	0.434	0.460	0.477	0.494	0.512	0.531

Sources: RIA; Telecom Advisory Services analysis.

These households will benefit from the incremental traffic generated under Wi-Fi 6. To estimate this, we assume that current traffic per line remains at current level, while under Wi-Fi 6 it will grow as projected by Cisco VNI. The difference is multiplied by the price per GB in Indonesia as reported by the Alliance for Affordable Internet (see table 9-3).

Table 9-3. Indonesia: Consumer surplus of households benefitting from municipal Wi-Fi in networks that have adopted Wi-Fi 6

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
(1) Total Individuals that rely on Municipal Wi-Fi (M)	0.240	0.288	0.342	0.401	0.434	0.460	0.477	0.494	0.512	0.531
(2) Traffic after speed increase (Gb)	7.64	8.40	9.24	10.17	11.19	12.30	13.53	14.89	16.38	18.01
(3) Traffic with speed without 6 GHz (Gb)	7.64	8.40	9.24	10.17	10.17	10.17	10.17	10.17	10.17	10.17
(4) Yearly Increase in traffic (Billions of Gb)	0.000	0.000	0.000	0.000	0.005	0.011	0.018	0.026	0.036	0.047
(5) Price per Gb	0.55	0.49	0.44	0.40	0.36	0.32	0.29	0.26	0.24	0.21
(6) Total impact in consumer surplus (US$ Billion)	0.000	0.000	0.000	0.000	0.002	0.004	0.005	0.007	0.008	0.010

Sources: CISCO VNI 2017-2022; Alliance for Affordable Internet; Telecom Advisory Services analysis.

The cumulative consumer surplus to be generated by this effect amounts to US$ 36 million.

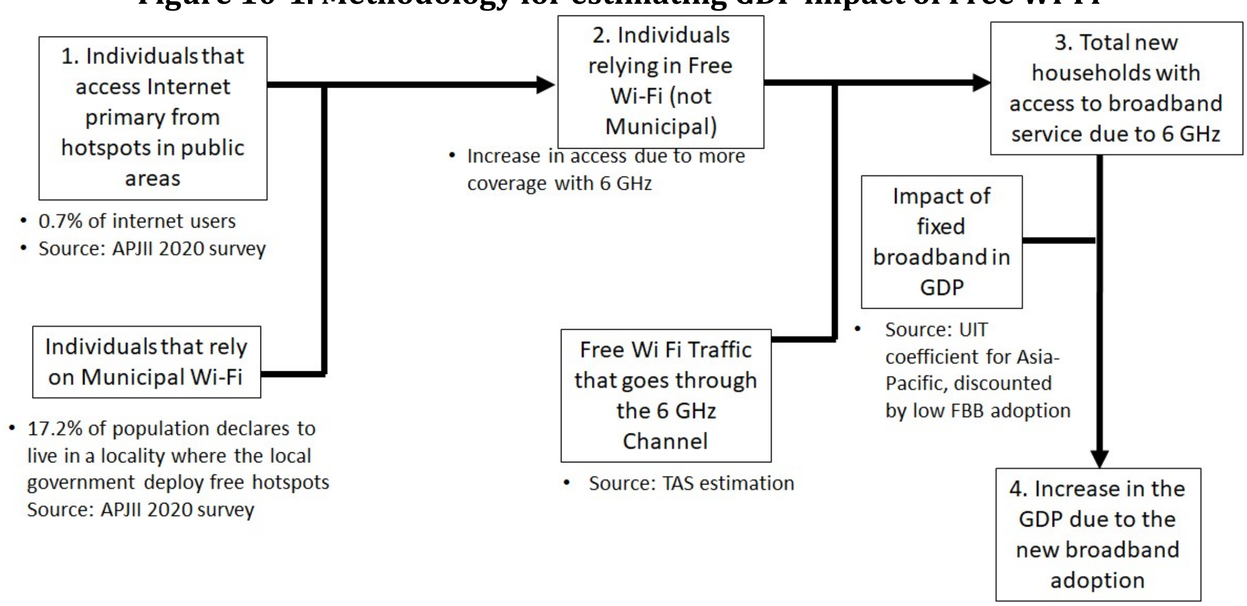
10. DEPLOYMENT OF FREE WI-FI HOT SPOTS

The assessment of economic impact of the 6 GHz allocation in the case of free hot spots is similar to the one conducted for municipal Wi-Fi networks. The underlying assumption in this case is that free Wi-Fi hot spots that benefit from 6 GHz spectrum will be capable of handling a higher number of devices, which in turn will contribute to broadband adoption. On the other hand, these sites will be able to deliver faster speed of service, which can be transferred to increasing consumer well-being.

10.1. Impact of enhanced free Wi-Fi hot spots on GDP

As in the case of municipal Wi-Fi networks, the free hot spot sites that incorporate technology relying on 6 GHz spectrum will be able to handle a larger number of users than under the current spectrum conditions which would in turn have an impact on the GDP. The methodology to quantify this benefit is presented in figure 10-1.

Figure 10-1. Methodology for estimating GDP impact of Free Wi-Fi



Source: Telecom Advisory Services

The methodology is the same that was applied in section 9 for Municipal Wi-Fi. First, we considered the users that can gain access to the Internet because they have a device (a smartphone), and then we subtract the actual users of broadband (because they are using free Wi-Fi, or they have a broadband connection). We assume that only 0.7% on this group will be future users of free Wi-Fi. This is the incremental broadband penetration that is used to quantify the impact on GDP by relying on the same impact coefficient as the one used in the case of municipal Wi-Fi (see table 10-1).

Table 10-1. Indonesia: GDP impact of Free Wi-Fi hot spots with 6 GHz spectrum

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
(1) Individuals that connect from Free Wi-Fi (M)	1.312	1.492	1.696	1.928	1.994	2.012	2.029	2.046	2.064	2.082
(2) Individuals that rely on Municipal Wi-Fi (M)	0.226	0.257	0.292	0.332	0.343	0.346	0.349	0.352	0.355	0.358
(3) Individuals that rely on free Wi-Fi traffic offered in public sites (M)	1.086	1.235	1.404	1.596	1.651	1.666	1.680	1.694	1.709	1.724
(4) Individuals that lives in a household with FBB (M)	43.337	44.387	45.160	45.722	46.115	46.386	46.648	46.912	47.176	47.442
(5) Individuals with a smartphone (M)	167.784	176.547	185.725	192.682	199.850	205.858	212.046	217.511	223.118	228.869
(6) Potential Free Wi-Fi Market (M)	123.136	130.668	138.870	145.033	151.740	157.460	163.368	168.553	173.877	179.345
(7) Share of the potential Free Wi-Fi Market that would be covered by Free Wi-Fi	0.70%	0.70%	0.70%	0.70%	0.70%	0.70%	0.70%	0.70%	0.70%	0.70
(8) Share of the potential Free Wi-Fi Market that would be covered by Municipal Wi Fi	83%	83%	83%	83%	83%	83%	83%	83%	83%	83%
(9) Traffic through 6 GHz Band	10%	20%	30%	40%	50%	60%	65%	70%	75%	80%
(10) New individuals that now can have broadband (M)	0.07	0.15	0.24	0.34	0.44	0.55	0.62	0.68	0.76	0.83
(11) New households that now can have broadband (M)	0.02	0.04	0.06	0.08	0.11	0.14	0.16	0.17	0.19	0.21
(12) Households with Fixed Broadband (M)	10.80	11.09	11.30	11.47	11.60	11.70	11.80	11.90	12.00	12.10
(13) Increase in national broadband penetration	0.16%	0.34%	0.53%	0.74%	0.95%	1.18%	1.32%	1.46%	1.60%	1.75%
(14) Impact of fixed broadband adoption in GDP	16.32%	16.32%	16.32%	16.32%	16.32%	16.32%	16.32%	16.32%	16.32%	16.32%
(15) Increase in the GDP due to the new broadband adoption (% GDP)	0.03%	0.06%	0.09%	0.12%	0.16%	0.19%	0.22%	0.24%	0.26%	0.29%
(16) GDP (US$ Billion)	$1,256	$1,360	$1,459	$1,562	$1,673	$1,791	$1,918	$2,054	$2,199	$2,355
(17) Total impact in GDP (US$ Billion)	$0.34	$0.76	$1.27	$1.87	$2.60	$3.45	$4.13	$4.89	$5.75	$6.74

Sources: IMF; GSMA; ITU; RIA; Telecom Advisory Services analysis.

The cumulative GDP contribution to be generated by this effect amounts to US$32 billion.

In addition to this effect, the 6 GHz band will contribute to incremental revenues from paid Hot Spot services. Assuming that paid Wi-Fi sites will be able to increase their capacity by 40%, the cumulative contribution of this effect to GDP between 2022 and 2031 will reach US $ 2.2 billion.

10.2. Impact of enhanced free Wi-Fi hot spots on consumer surplus

The adoption of Wi-Fi 6 in free Wi-Fi sites will generate two consumer benefits: (i) faster access speed; and (ii) higher traffic per device. In the case of faster access speed, it is assumed that, if the 6 GHz band is not adopted by 2025, traffic through these networks will not be able to continue increasing its speed. Therefore, using the same methodology that was used for home traffic, the value of the additional speed achieved from the 6 GHz band allocation can be estimated (see Table 10-2).

Table 10-2. Indonesia: Impact on consumer surplus of higher access speed thanks to spectrum in the 6 GHz band on free Wi-Fi

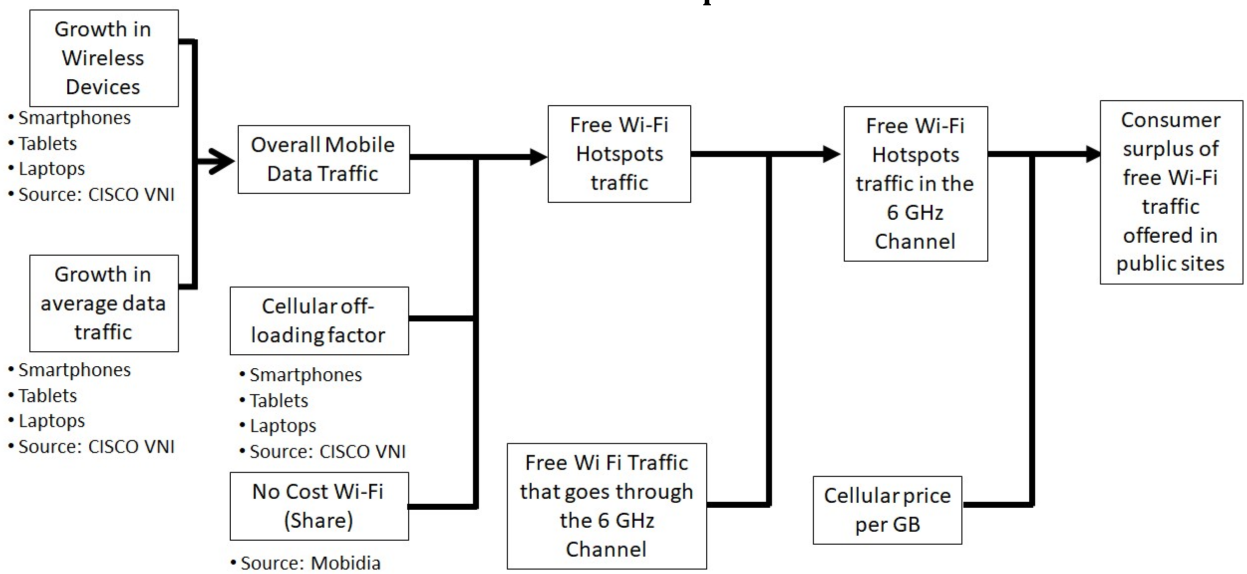
	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
(1) Free Wi-Fi mean speed with no 6 GHz (Mbps)	5	7	10	13	13	13	13	13	13	13
(2) Wi-Fi Speeds with 6 GHz (Mbps)	5	7	10	13	17	21	26	33	42	53
(3) Traffic through the 6 GHz Channel (%)	10.00%	20.00%	30.00%	40.00%	50.00%	60.00%	65.00%	70.00%	75.00%	80.00%
(4) Free Wi-Fi mean speed with 6 GHz (Mbps)	5	7	10	13	15	18	22	27	35	45
(5) Demand for average download speed	$22	$24	$26	$29	$28	$28	$28	$28	$28	$28
(6) New Demand for average download speed	$22	$24	$26	$29	$29	$31	$32	$34	$36	$38
(7) Additional Monthly Consumer surplus	$0	$0	$0	$0	$1	$2	$4	$6	$8	$10
(8) Additional Yearly Consumer Surplus	$0	$0	$0	$0	$12	$29	$48	$70	$94	$118
(9) Households that rely on Public Wi-Fi	1,157,639	1,386,676	1,645,708	1,932,280	2,091,001	2,213,110	2,295,396	2,378,294	2,464,928	2,555,438
(10) Impact ($ million)	$0	$0	$0	$0	$25	$65	$111	$167	$231	$302

Sources: CISCO VNI 2017-2022; Alliance for Affordable Internet; Telecom Advisory Services analysis.

Based on the estimates from table 10-2, the cumulative contribution of this effect to consumer surplus between 2022 and 2031 is US $ 900 million.

As per the second advantage, the adoption of Wi-Fi 6 by free Wi-Fi sites will yield an increase of traffic of connected devices (see Figure 10-2).

Figure 10-2. Indonesia: Consumer surplus of users benefitting from free Wi-Fi in networks that have adopted Wi-Fi 6



Source: Telecom Advisory Services

Based on Cisco VNI traffic projections per device and the total number of devices estimated by GSMA and Cisco VNI, it is projected that, if Wi-Fi 6E is not adopted, traffic congestion at free Wi-Fi sites will limit traffic per device from 2024 onwards (see table 10-3)

Table 10-3. Indonesia: Consumer surplus of households benefitting from free Wi-Fi in networks that have adopted Wi-Fi 6

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
(1) Unmet demand due to Free Wi-Fi Congestion (M GB)	0	0	0	180	470	921	1,602	2,613	4,092	6,230
(2) Traffic through 6 GHz Band	10%	20%	30%	40%	50%	60%	65%	70%	75%	80%
(3) Feasible traffic on the 6 GHz band (M GB)	0	0	0	72	235	552	1,041	1,829	3,069	4,984
(4) Average price per mobile GB	0.55	0.49	0.44	0.40	0.36	0.32	0.29	0.26	0.24	0.21
(5) Cost of provisioning free Wi-Fi (per GB)	0.36	0.32	0.29	0.26	0.23	0.21	0.19	0.17	0.15	0.14
(6) Consumer surplus per GB	0.19	0.17	0.15	0.14	0.12	0.11	0.10	0.09	0.08	0.07
(7) Consumer surplus generated by 6 GHz band (US$ M)	$0	$0	$0	$10	$29	$61	$104	$165	$249	$364

Sources: Wiman; CISCO VNI 2017-2022; Alliance for Affordable Internet; Telecom Advisory Services analysis.

Alternatively, if the 6 GHz band is designated for unlicensed use, the cumulative consumer surplus to be generated by this effect amounts to US$ 982 million.

11. ALIGNING SPECTRUM DECISION WITH THAT OF OTHER ADVANCED ECONOMIES

As stated in chapter 3, by designating the 6 GHz band for unlicensed use, Indonesia will not only address the demand for spectrum resulting from explosive Wi-Fi usage but will also have implications for the cost of inputs for Indonesian firms and for the country's industrial policy. If Indonesia were to align itself with the United States, Korean, Brazilian, and Canadian 6 GHz allocation model, it would benefit from acquiring equipment whose average selling price would be lower than the equipment manufactured in Europe. Our comparison of unit prices of AR monocular glasses indicates a persistent advantage of the US model relative to the European model (see table 11-1).

Table 11-1. United States versus Europe: Average Selling Price of Monocular glasses

	2019	2020	2021	2022	2023	2024
United States	761.16	709.14	656.94	606.29	564.49	528.85
Europe	766.25	715.60	665.82	617.24	574.03	537.53
Percent difference	-0.66%	-0.90%	-1.33%	-1.77%	-1.66%	-1.61%

Source: ABI Research 2020-2024; Telecom Advisory Services analysis

By extrapolating the trend through 2031 and applying the price difference to the AR/VR hardware and IoT hardware markets, the following effect can be quantified (see table 11-2).

Table 11-2. Advantage of aligning the 6 GHz decision with the US model

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
(1) AR-VR hardware market	$0.176	$0.248	$0.349	$0.492	$0.692	$0.975	$1.372	$1.931	$2.717	$3.825
(2) IoT Hardware Market	$0.546	$0.746	$1.019	$1.393	$1.903	$2.600	$3.552	$4.854	$6.632	$9.061
(3) Price reduction due to aligning spectrum decision	-1.77%	-1.66%	-1.61%	-1.54%	-1.47%	-1.40%	-1.34%	-1.28%	-1.22%	-1.16%
(4) Share due to 6GHz	10.00%	20.00%	30.00%	40.00%	50.00%	60.00%	65.00%	70.00%	75.00%	80.00%
(5) Impact on producer surplus	$0.001	$0.003	$0.007	$0.012	$0.019	$0.030	$0.043	$0.061	$0.085	$0.120

Source: Telecom Advisory Services analysis

Furthermore, as mentioned in chapter 3, the Indonesian market for equipment and services in areas related to the implementation of the 6 GHz allocation amounts to US$ 5.96 billion in 2020 but will reach US$ 9.85 billion in 2023 (see table 11-3).

Table 11-3. Indonesia: Sales in markets impacted by the 6 GHz decision (in US$ billion) (2020-23)

Market	Categories	2020	2023
Augmented Reality/Virtual Reality	Hardware	$0.089	$0.248
	Software and applications	$0.181	$0.504
	Subtotal	$0.270	$0.753
IoT	Hardware	$0.293	$0.746
	Software and services	$1.058	$2.697
	Subtotal	$1.350	$3.443
Wi-Fi devices	Home networking devices	$0.310	$0.452
	Wi-Fi enabled devices (wireless speakers & security systems)	$3.664	$4.791
	Enterprise access points and controllers (adapter routers gateways)	$0.365	$0.415
	Subtotal	$4.339	$5.658
Total		$5.959	$9.854

Sources: Research and Markets; Frost & Sullivan; Telecom Advisory Services analysis

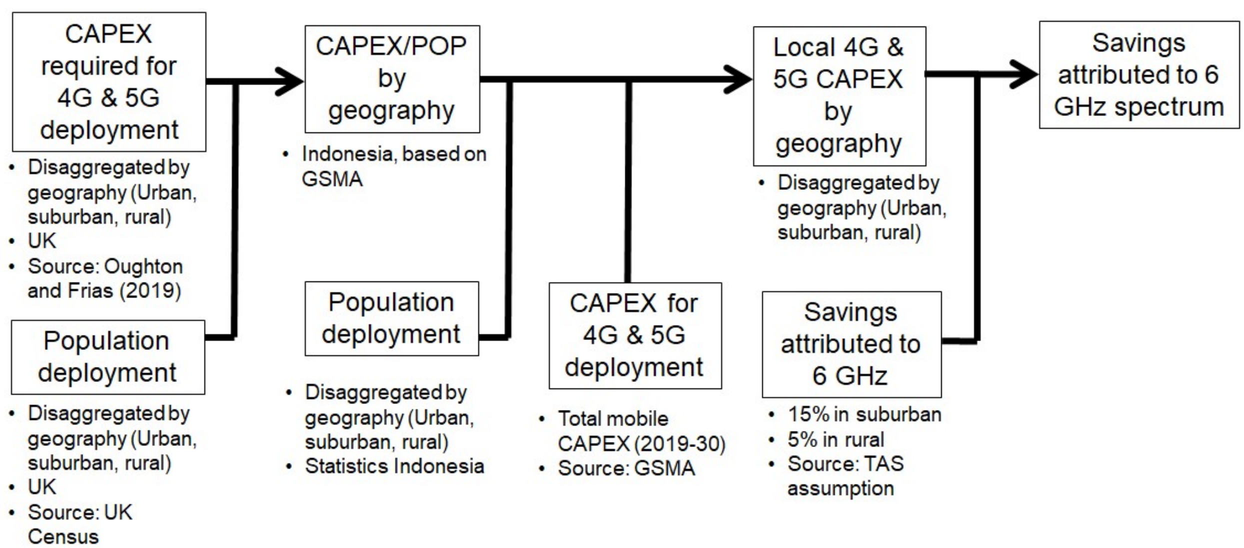
Under such an attractive demand condition, the decisions to be made in terms of the model of allocating the 1200 MHz of the 6 GHz band could put Indonesia on the path to both meet the needs on local demand and benefitting from the implicit economies of scale derived from advanced markets as well as to increase the opportunity costs of those markets developing first. Additionally, the decision of aligning with a particular model could potentially give Indonesia the benefit of developing an export-led industry that could capitalize on foreign demand.

12. ENHANCING THE CAPABILITY OF CELLULAR OFF-LOADING

5G networks promise faster speeds, lower latency, and greater capacity to mobile users. However, 5G network operators cannot deliver on that promise without robust Wi-Fi networks to carry the majority of that traffic. Cisco estimates that 71% of 5G mobile traffic will be offloaded to Wi-Fi by 2022, even more offload than we have seen from lower speed networks in the past. The availability of spectrum in the 6 GHz band is particularly suited to accommodate this.

The key objective is to estimate the savings in capital investment as a result of an increase in traffic offloading with Wi-Fi benefits from the additional spectrum in the 6 GHz band, but more importantly, the ability to deliver multiple 160 MHz contiguous channels (see Figure 12-1).

Figure 12-1. Methodology for estimating CAPEX savings



Source: Telecom Advisory Services analysis

The analysis starts with an estimate of 4G & 5G deployment costs, absent the Wi-Fi offloading benefit. One approach (Step 1) is to sum wireless CAPEX estimated by GSMA Intelligence for Indonesia between 2019 and 2030: US$56 billion. To split the total investment by region of the country, we rely on the only known rigorous cost estimation of 5G deployment to date: the one developed by Oughton and Frias (2016) for OFCOM in the United Kingdom. The authors' baseline case estimates a CAPEX of US$53.34 million, of which urban coverage investment amounts only to US$890 million, while suburban deployment demands US$7.13 billion, and rural coverage US$45.32 billion (see Table 12-1).

Table 12-1. United Kingdom: 5G Investment

	Town/City (Million)	Population distribution	5G CAPEX ($ billion)	5G CAPEX (%)	CAPEX per POP
Urban (cities >1 million)	19.42	29%	$0.89	1.66%	$45.71
Suburban	36.16	54%	$7.13	13.37%	$197.16
Rural	11.38	17%	$45.32	84.97%	$3,981.22
Total	66.96	100%	$53.34	100%	$796.58

Sources: Oughton and Frias (2017). Exploring the cost, coverage and rollout implications of 5G in Britain; Telecom Advisory Services analysis

Using capital investment per POP as a starting point (which does not include spectrum acquisition costs), deployment costs for networks aimed at providing 4G and 5G services in Indonesia are calculated (Step 2).

Table 12-2. Indonesia: 4G and 5G Investment

	Population (million)	4G & 5G CAPEX (US$ B)	CAPEX saving (US$ B)
Urban (cities>1 million)	72.55	$0.37	$0.00
Suburban	79.91	$1.78	$0.27
Rural	119.79	$53.84	$2.69
Total	272.25	$55.99	$2.96

Sources: Oughton and Frias (2017). Exploring the cost, coverage and rollout implications of 5G in Britain; GSMA; Telecom Advisory Services analysis

We conservatively assume that Wi-Fi will not be critical in sustaining investment in urban areas, but that it will play a significant role in suburban and rural geographies. Based on the cost advantage of carrier grade Wi-Fi, we assume that it will become effective for a portion of the suburban (approximately 15%) and rural network (approximately 5%) deployment. Therefore, using the estimation of $1.78 billion for suburban coverage and US$53.84 billion for rural coverage, the implementation of Wi-Fi hotspots leveraging 6 GHz will yield CAPEX savings of US$ 2.96 billion[60]. These will be critical in terms of allowing carriers to extend their 4G and 5G coverage further into rural geographies.

[60] An additional contribution could include Wi-Fi-like service operating within AFC channels.

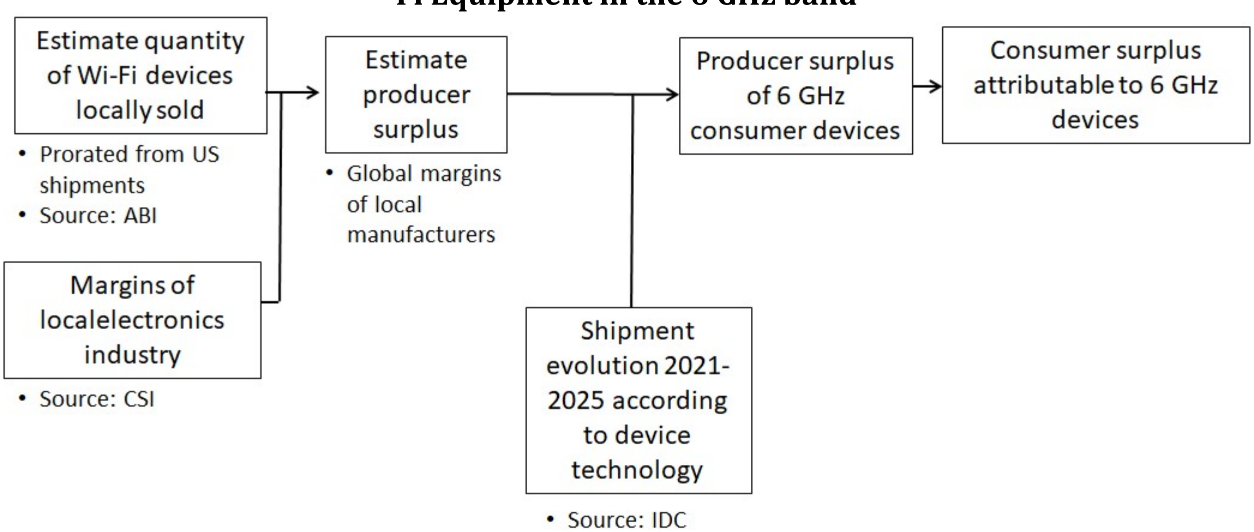
13. PRODUCTION AND ADOPTION OF WI-FI EQUIPMENT

The difference between market prices and local manufacturing costs for Wi-Fi-enabled products represents the manufacturer's margin and, consequently, the producer's surplus. It is assumed, following Milgrom et al. (2011), that the consumer surplus is approximately equal to the producer surplus, with the difference that for consumer surplus we consider only the devices that are consumed in Indonesia and for the producer surplus we consider the equipment that is manufactured in Indonesia. As detailed in Chapter 3, we identified seven consumer products that are intrinsically linked to Wi-Fi 6: smart home devices and systems, such as speakers and home security systems, home network systems, Wi-Fi enabled tablets, access points, adapters, routers and gateways.

13.1 Increase in consumer surplus due to Wi-Fi equipment in the 6 GHz band

Our estimate of economic value begins by compiling global manufacturers' sales for each product category in Indonesia. We proceed by interpolating data from the US and world markets and assume a level for Indonesia based on the corresponding GDP share. Once this value is estimated, we apply the prorated margin estimated by CSI markets which yields an estimated producer surplus for these products of 39.44%. As mentioned above, consumer surplus is assumed to be of the same magnitude. As this analysis is carried out for the total market of Wi-Fi devices, to differentiate the value corresponding to the 6 GHz band, from the value corresponding to the other bands of use, we follow the forecast provided by IDC regarding the evolution of shipments of 802.11ax consumer devices for the 6 GHz band (See Figure 13-1).

Figure 13-1. Methodology for estimating consumer surplus as a result of sales of Wi-Fi Equipment in the 6 GHz band



Source: Telecom Advisory Services analysis

Based on the methodology presented above, it is possible to estimate the producer surplus in Indonesia generated by the sale of Wi-Fi devices in the 6 GHz band between 2022 and

2031. To this end, the producer surplus generated by Wi-Fi devices on bands other than 6 GHz is calculated (see Table 13-1).

Table 13-1. Producer surplus as a result of sales of Wi-Fi Equipment from devices outside the 6 GHz band in Indonesia (2022-2031)

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
(1) Wireless speakers	$4,081	$4,504								
(2) Security systems	$275	$287								
(3) Home networking systems	$397	$452								
(4) Access points	$183	$196								
(5) External adapters	$4	$4								
(6) Routers	$101	$107								
(7) Gateways	$101	$107								
(8) Gross margin	39.44%	39.44%	39.44%	39.44%	39.44%	39.44%	39.44%	39.44%	39.44%	39.44%
(9) Producer surplus (US$ millions)	$2,028	$2,232	$2,204	$2,136	$1,996	$1,759	$1,386	$827	$12	$3

Sources: ABI; CSI; Telecom Advisory Services analysis.

To estimate the sales attributable to the 6 GHz band, we rely on the forecast provided by IDC on the evolution of shipments of consumer devices for the band of 6 GHz (see Table 13-2).

Table 13-2. Consumer surplus as a result of Wi-Fi Equipment sales of devices in the 6 GHz band (2022-2031)

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
(1) Producer surplus (US$ millions)	$2,028	$2,232	$2,204	$2,136	$1,996	$1,759	$1,386	$827	$12	$3
(2) Global shipments ratio in the 6 GHz band / without the 6 GHz band	9%	19%	29%	40%	58%	90%	154%	349%	31321%	121341%
(3) Consumer surplus (US$ millions)	$179	$415	$636	$861	$1,164	$1,576	$2,132	$2,885	$3,903	$4,128

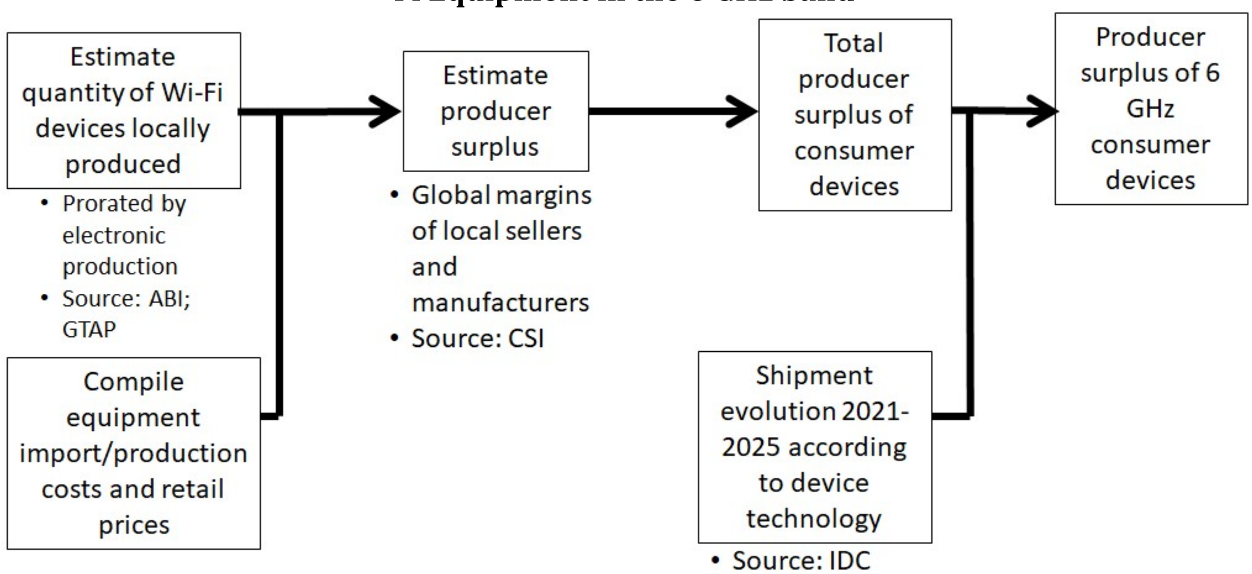
Sources: ABI; CSI; IDC; Telecom Advisory Services analysis

The total accumulated impact of consumer surplus between 2022-2031 due to this effect amounts to US $ 17.88 billion.

13.2 Increase in producer surplus due to Wi-Fi equipment in the 6 GHz band

To estimate the producer surplus of 6 GHz enabled equipment manufactured in Indonesia we start by compiling global manufacturers' sales for each product category in Indonesia. Since in this case, we are estimating local production rather than sales as was done in the prior section, we rely on data from the United States market, and assume a production gap based on the comparison of the input / output matrices of both countries. Once the local production is estimated, we apply the prorated margin estimated by CSI markets which yields an estimated producer surplus for these particular products of 39.44%. As this analysis is carried out for the total market of Wi-Fi devices, to differentiate the value corresponding to the 6 GHz band, from the value corresponding to the other bands of use of Wi-Fi, we follow the forecasts provided by IDC on the evolution of shipments of 802.11ax consumer devices for the 6 GHz band (See Figure 13-2).

Figure 13-2. Methodology for estimating producer surplus as a result of sales of Wi-Fi Equipment in the 6 GHz band



Source: Telecom Advisory Services analysis

Based on this methodology, it is possible to estimate the producer surplus in Indonesia generated by the sale of Wi-Fi devices in the 6 GHz band between 2022 and 2031 (see Table 13-3)

Table 13-3. Producer surplus as a result of Wi-Fi Equipment sales of devices manufactured in Indonesia outside the 6 GHz band (2022-2031)

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
(1) Wireless speakers	$1,309.20	$1,355.53								
(2) Security systems	$88.14	$86.38								
(3) Home networking systems	$127.20	$136.10								
(4) Access points	$0.00	$0.00								
(5) External adapters	$0.00	$0.00								
(6) Routers	$0.00	$0.00								
(7) Gateways	$0.00	$0.00								
(8) Gross margin	39.44%	39.44%	39.44%	39.44%	39.44%	39.44%	39.44%	39.44%	39.44%	39.44%
(9) Producer surplus (US$ millions)	$601	$622	$615	$596	$557	$491	$387	$231	$3	$1

Sources: ABI; CSI; Telecom Advisory Services analysis.

In order to isolate the sales attributable to the 6 GHz band from the value that corresponds to the other bands of Wi-Fi use, we follow the forecasts provided by IDC on the evolution of shipments of consumer devices 802.11ax for the band of 6 GHz (see Table 13-4).

Table 13-4. Producer surplus as a result of sales of Wi-Fi equipment of devices in the 6 GHz band manufactured in Indonesia (2022-2031)

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
(1) Producer surplus (US$ millions)	$601	$622	$615	$596	$557	$491	$387	$231	$3	$1
(2) Global shipments ratio in the 6 GHz band / without the 6 GHz band	9%	19%	29%	40%	58%	90%	154%	349%	31321%	121341%
(3) Producer surplus (US$ millons)	$53	$116	$177	$240	$325	$439	$595	$805	$1,089	$1,151

Sources: ABI; CSI; IDC; Telecom Advisory Services analysis

The total accumulated impact of the producer surplus between 2022-2031 due to this effect amounts to US$ 4.99 billion.

14. TOTAL ECONOMIC VALUE

This study provided the cumulative economic impact of allocating 1200 MHz in the 6 GHz band. Based on the aggregated results, the allocation of 1200 MHz in the 6 GHz for unlicensed use in Indonesia will generate cumulative economic value between 2022 and 2031 reaching US$ 187.63 billion, broken down in US$ 126.44 billion in additional GDP, US$ 37.73 in producer surplus (which includes both margins for Indonesian technology suppliers to meet local demand and savings from enterprise wireless use and capital from telecommunications carriers engaged in 5G deployment), and US$ 23.47 billion in consumer surplus (benefits to consumers in terms of lower cost per Mbps and faster speed) (see Table 14-1).

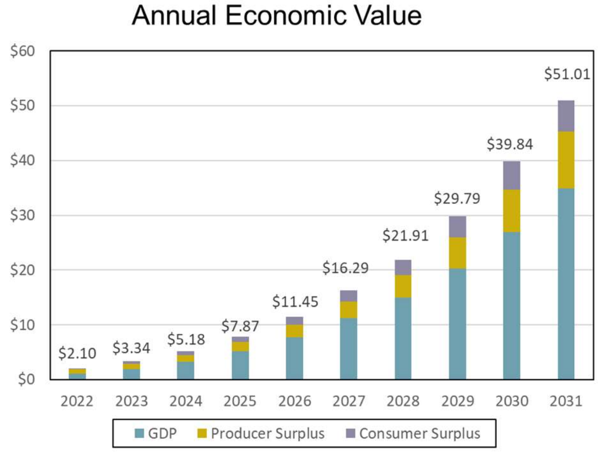
Table 14-1. Indonesia: Economic Value of Allocating 1200 MHz in 6 GHz Band (2022-2031) (in US$ billions)

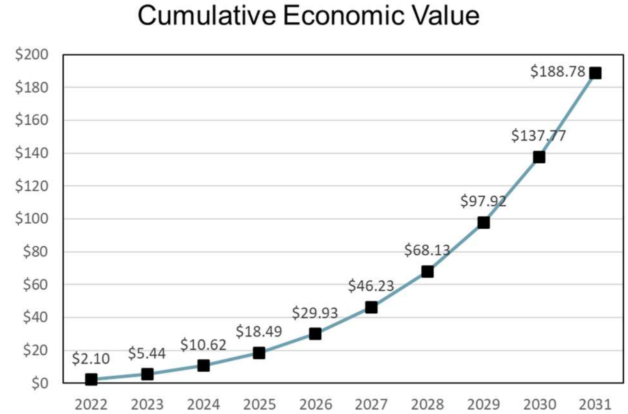
Source of Value	GDP contribution	Producer surplus	Consumer surplus
Enhanced coverage and improved affordability	**$ 5.16**		**$ 0.05**
Increased broadband speed by reducing Wi-Fi congestion	**$ 29.99**		**$ 3.62**
Wide deployment of Internet of Things	**$ 14.09**	**$ 21.24**	
Reduction of enterprise wireless costs		**$ 0.92**	
Deployment of AR/VR solutions	**$ 36.57**	**$ 7.24**	
Enhanced deployment of municipal Wi-Fi	**$ 6.61**		**$ 0.04**
Deployment of Free Wi-Fi Hot Spots	**$ 34.03**		**$ 1.88**
Aligning spectrum decision with other advanced economies		**$0.38**	
Enhancing the capability for cellular off-loading		**$ 2.96**	
Increasing production of residential Wi-Fi devices and equipment		**$ 4.99**	**$ 17.88**
TOTAL	**$ 126.44**	**$ 37.73**	**$ 23.47**

Source: Telecom Advisory Services analysis

The total economic value increases over time with significant acceleration towards the end of the time period due to the leverage capability of 6 GHz (see graphic 14-1).

Graphic 14-1. Indonesia: Economic value of allocating 1200 MHz in the 6 GHz band

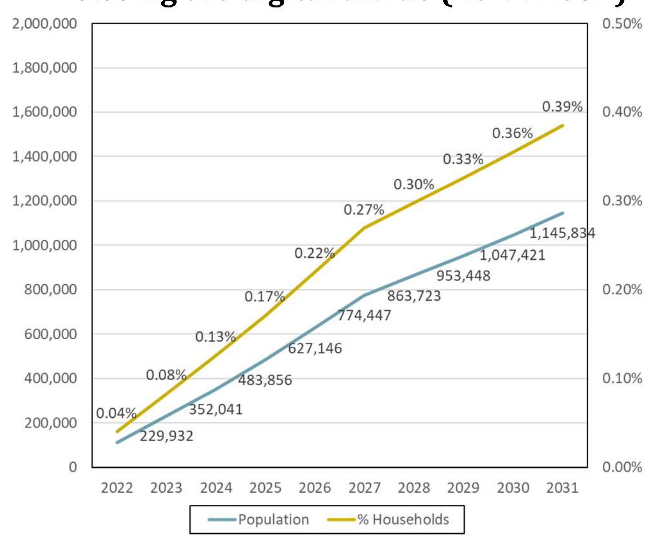




Source: Telecom Advisory Services analysis

In addition, the allocation of the entire band to unlicensed use will result in a significant contribution to a reduction of Indonesia´s digital divide. By providing affordable paid service and free access over hot spots because of allocating the full 6 GHz band to Wi-Fi, an incremental 1,145,834 Indonesians will be able to gain access to the Internet by 2031 (see Graphic E).

Graphic E. Indonesia: Contribution of Allocating 1200 MHz of the 6 GHz Band to closing the digital divide (2022-2031)



Source: Telecom Advisory Services analysis

In conclusion, the allocation of the full 1200 MHz of the 6 GHz band is an advantageous approach from an economic impact and digital divide reduction standpoints. Based on the decisions made by regulators around the world, equipment capable of using the new band is starting to be approved.[61]

[61] For example, the FCC already approved a transmitter chipset capable of operating in the 1200 MHz of the 6 GHz band produced by Broadcom, and a Tri-band system on a chip manufactured by NXP Semiconductors.

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