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

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EXECUTIVE SUMMARY

The African Telecommunications Union (ATU) Task Group on Emerging Technologies that met in November 2020 recommended that African Administrations should review their national ICT policies, broadband, and digital economy strategies. The overriding objective of this recommendation is to incorporate the needs for new technological development as well as review and modernize existing regulations to adapt to new technological developments, including the elimination of regulations that have outlived their original purpose, or that create unnecessary burdens negatively impacting deployment and adoption. In this context, the Task Group recognized that the continent is at a pivotal point regarding the future of Wi-Fi, a major driver of economic growth and societal development. With suitable spectrum in short supply for the continued growth/expansion of Wi-Fi, the Task Group recognized that there is an urgent need to open the 6 GHz band for use by Wi-Fi and other technologies on a license-exempt basis.[1]

The objective of the following study is to provide an assessment of the economic value to be derived by opening the designated band to unlicensed use in Kenya by quantifying the impact on service quality, coverage, affordability, as well as focusing on specific applications and use cases likely to be introduced in the enterprise and consumer markets through three classes of 6 GHz devices[2] and favorable technical rules[3]. The methodology relied upon in this study identifies the different sources of economic value, estimates them independently, and then aggregates them within a single estimate (see table A).[4]

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[1] ATU Work on Spectrum Recommendations to Promote Innovative Wi-Fi/WiGig Connectivity Solutions in Africa, retrieved in: https://www.atuuat.africa/2020/12/29/atu-work-on-spectrum-recommendations-to-promote-innovative-wi-fi-wigig-connectivity-solutions-in-africa/

[2] The three classes of 6 GHz Restricted Radiation Radiocommunications Equipment are low power indoor devices, standard power devices, and very low power devices.

[3] 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.

[4] All estimates in this report are provided in US dollars.

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

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 Kenyan economy (e.g. automotive, food processing, logistics, etc.)	Margins of ecosystem firms (Hardware, software, services) involved in IoT deployment in Kenya	
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 Kenyan economy	Margins of ecosystem firms involved in AR/VR deployment in Kenya	
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 Kenya 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 Kenya	Consumer surplus from using Wi-Fi enabled residential devices and equipment

Source: Telecom Advisory Services analysis

While recognizing that the ATU Emerging Technologies Task Group recommended license-exempt access to the lower part of the 6 GHz band (5925-6425 MHz), 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.[5]

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

The cumulative economic value between 2021 and 2030 associated with allocating the 1200 MHz in the 6 GHz band in Kenya amounts to US$ 20.29 billion, broken down by US$ 14.28 billion in GDP contribution, US$ 1.12 billion in producer surplus to Kenyan enterprises, and US$ 4.89 billion in consumer surplus to the Kenyan population (see table B).

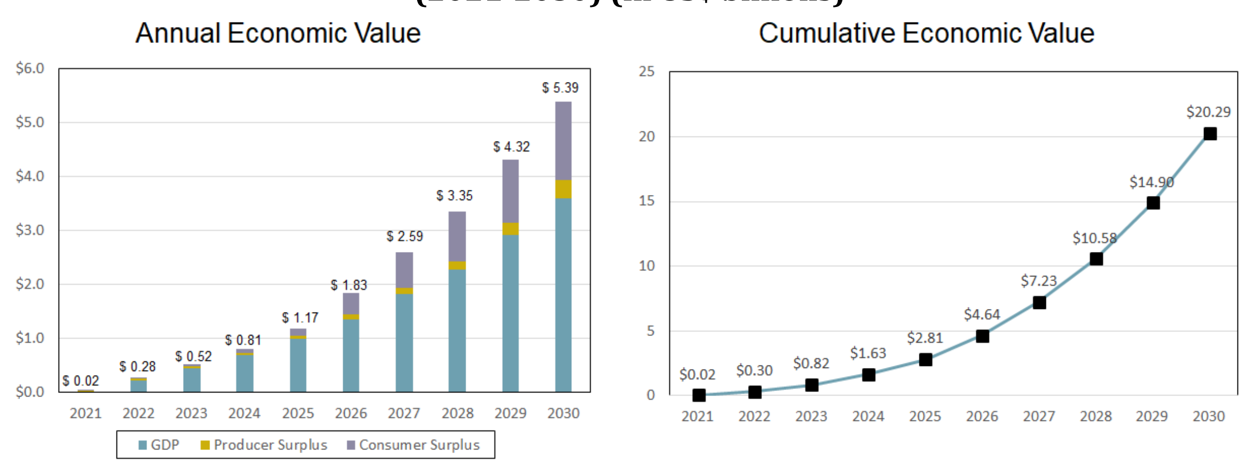
Table B. Kenya: Economic Value of Allocating 1200 MHz in 6 GHz Band (2021-2030) (in US$ billions)

Source of Value	GDP contribution	Producer surplus	Consumer surplus
Enhanced coverage and improved affordability	**$ 5.50**		**$ 0.04**
Increased broadband speed by reducing Wi-Fi congestion	**$ 1.44**		**$ 0.69**
Wide deployment of Internet of Things	**$ 0.59**	**$ 0.31**	
Reduction of enterprise wireless costs		**$ 0.05**	
Deployment of AR/VR solutions	**$ 1.92**	**$ 0.43**	
Enhanced deployment of municipal Wi-Fi	**$ 3.78**		**$ 2.37**
Deployment of Free Wi-Fi Hot Spots	**$ 1.05**		**$ 0.56**
Aligning spectrum decision with other advanced economies		**$0.02**	
Enhancing the capability for cellular off-loading		**$ 0.13**	
Increasing production of residential Wi-Fi devices and equipment		**$ 0.18**	**$ 1.23**
TOTAL	**$ 14.28**	**$ 1.12**	**$ 4.89**

Source: Telecom Advisory Services analysis

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).

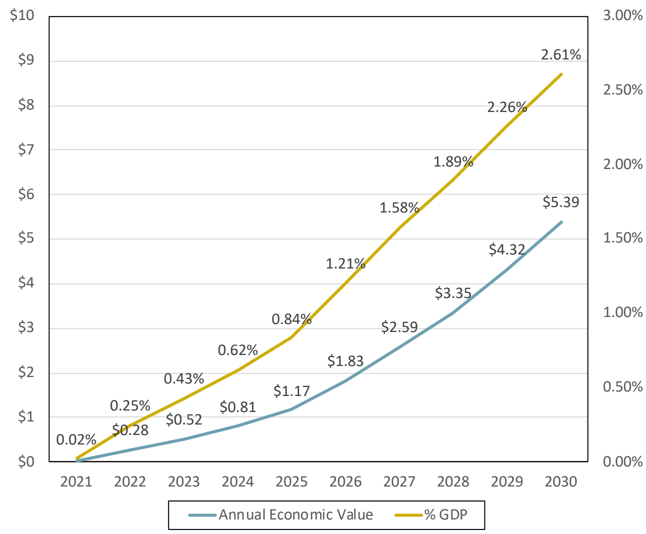
Graphic C. Kenya: Economic value of allocating 1200 MHz in the 6 GHz band (2021-2030) (in US$ billions)



Source: Telecom Advisory Services analysis

The total cumulative impact of $ 20.29 billion equates to 1.35 % of the country's accumulated GDP between 2021 and 2030. Furthermore, the cumulative economic impact of the allocation of the entire 6 GHz band to unlicensed use will be increasing over time, reaching over 2.6 % of the country's GDP in 2030 (see Graphic D).

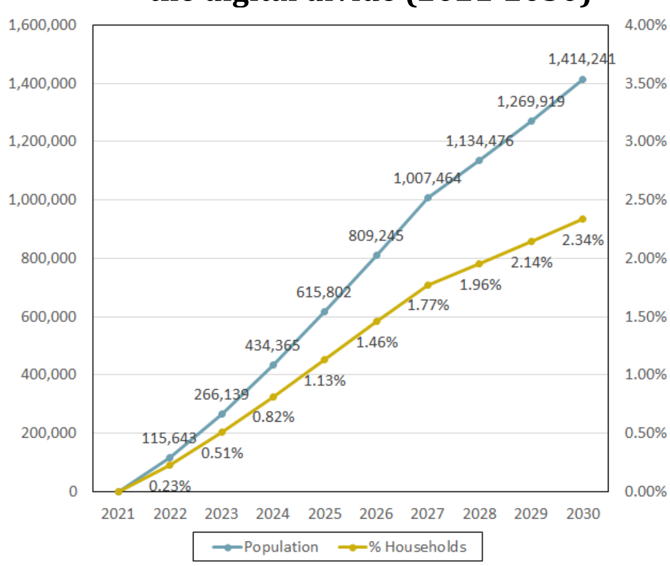
Graphic D. Kenya: Annual GDP Impact of Allocating 1200 MHz of the 6 GHz Band (2021-2030) (in US$ billions)



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 Kenya's digital divide. By providing affordable paid service and free access over hot spots as a result of allocating the full 6 GHz band to Wi-Fi, an incremental 1,414,000 Kenyans will be able to gain access to the Internet by 2030 (see Graphic E).

Graphic E. Kenya: Contribution of Allocating 1200 MHz of the 6 GHz Band to closing the digital divide (2021-2030)



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 standpoint. Based on the decisions made by regulators around the world, equipment capable of using the new band is starting to be approved.[6]

[6] 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 African Telecommunications Union (ATU) Emerging Technologies Task Group has formulated its recommendation on license-exempt access to the lower part of the 6 GHz band (5925-6425 MHz). The recommendation, sent to all ATU countries for written inputs, includes an annex containing the technical and regulatory conditions for operating unlicensed technologies in the lower 6 GHz band. If African administrations validate the recommendations, then the position of Africa will be like the one adopted by the European Union.[7] Some African countries are likely to move quickly to open the lower 6 GHz to enable Wi-Fi 6E to bring enhanced connectivity to citizens and businesses.

The objective of this study is to provide an assessment of the economic value to be derived by opening the full 6 GHz band to so-called unlicensed use in Kenya 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[8], Brazil[9], Colombia[10], Mexico[11], and Peru[12],whereby the different sources of economic value were estimated independently and then aggregated within a single estimate (this allows combining GDP impact, with consumer and producer surplus).

Chapter 2 provides the background and theoretical framework to frame the analyses. Chapter 3 presents the methodologies implemented in order 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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7 See Commission Implementing Decision (EU) 2021/1067 of 17 June 2021 on the harmonized use of radio spectrum in the 5 945-6 425 MHz frequency band for the implementation of wireless access systems including radio local area networks (WAS/RLANs). *Official Journal of the European Union*, L232/1, June 30, 2021.

8 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.

9 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).

10 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).

11 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).

12 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

Kenya has so far allocated two license-exempt frequency bands for Wi-Fi use. The 2400-2483.5 MHz band has been historically assigned to be used by fixed wireless access systems.[13] In addition, following the decisions of the World Radio Conference-19 in November 2019, the Communications Authority of Kenya voted to allocate additional spectrum to enable both indoor and outdoor usage of Wi-Fi to meet the growth in demand for wireless access systems, including Radio Local Areas Networks (RLANs) for end-user radio connections. Wi-Fi networks were allowed for indoor or outdoor usage with a maximum EIRP of 30 dBm (1W) in the band between 5150 and 5250 MHz, while Wi-Fi devices would be restricted to a maximum transmitter power of 250 mW in the band between 5470 and 5725 MHz.[14]

Following the recommendation formulated by the African Telecommunications Union (ATU) Emerging Technologies Task Group, the Communications Authority of Kenya is considering the extension of license-exempt access for Wi-Fi to the lower part of the 6 GHz band (5925-6415 MHz).[15] This potential decision reflects the growing importance that Wi-Fi technology represents in the fixed wireless eco-system in the country. 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 in this study.

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, it was only in 1985 that the United States Federal Communications Commission (FCC), recognizing its importance, opened new spectrum for unlicensed use at 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. 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.[16]

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[13] Communications Authority of Kenya (2016). *Kenya table of radiofrequency allocations*.

[14] Communications Authority of Kenya (2020). *Frequency Spectrum Management Report 2nd Quarter 2019/20* (October-December 29019), p. 2.

[15] ATU Work on Spectrum Recommendations to Promote Innovative Wi-Fi/WiGig Connectivity Solutions in Africa, retrieved in: https://www.atuuat.africa/2020/12/29/atu-work-on-spectrum-recommendations-to-promote-innovative-wi-fi-wigig-connectivity-solutions-in-africa/

[16] The success of both standards led to the assignment in the United States of additional 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 1,200 MHz in the 6 GHz band to unlicensed use.

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 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[17]. 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 study 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[18] and, consequently, were too conservative. Two years later, Milgrom et al. (2011) supported Thanki's estimates, but also provided additional quantification of value 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[19] 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

[17] This is contrary to research on the valuation of consumer welfare derived from the use of licensed spectrum which has been a fairly standard research practice given the availability of auction data and consumption series (see Hazlett (2005): Hausman, 1997).
[18] Thanki estimated that the three applications represented 15% of the unlicensed wireless chipsets to be shipped in the US in 2014.
[19] 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.

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 research 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).

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 • 3.6 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).[20]

[20] 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.

- **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. This last dimension will be particularly critical in Kenya.

2.2. Designating 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.[21] 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.[22]

Some countries have followed or are considering an approach to allocate only 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[23]. 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

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[21] 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[21] tethering (watches, ear pods) or entertainment devices in the automobile.

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

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

investigate the upper part in the future[24]. 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".[25]

The current state of the process in the allocation of the 6 GHz around the world can be summarized at the 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)

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 Kenya.

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

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

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

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 Kenya. 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 band. 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[26], 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[27]). Along those lines, we proceed to identify the sources of economic value, estimate their impact, and then combine them in the aggregate. The area of impact of each source of value varies (see table 3-1).

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[26] 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.

[27] 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 Kenya

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 Kenyan economy (e.g. automotive, food processing, logistics, etc.)	Margins of ecosystem firms (Hardware, software, services) involved in IoT deployment in Kenya	
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 Kenyan economy	Margins of ecosystem firms involved in AR/VR deployment in Kenya	
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 Kenya 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 Kenya	Consumer surplus from using Wi-Fi enabled residential devices and equipment

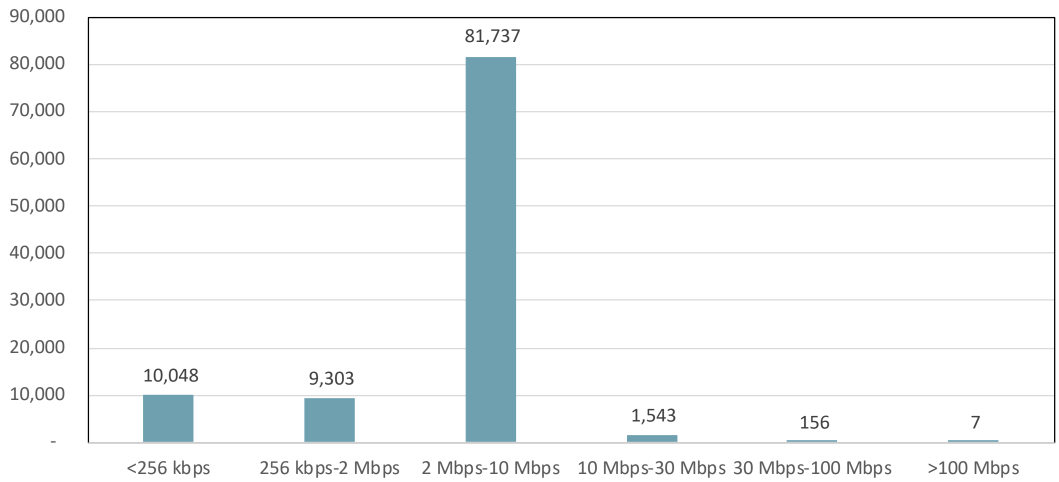
Source: Telecom Advisory Services analysis

The assessments of economic value have been estimated for the years 2021 to 2030.

3.1. Enhanced broadband coverage and improved affordability

This analysis will focus on estimating the impact of the 6 GHz decision on the wireless ISP (WISP) industry in Kenya. According to official statistics, there are a total of 102,794 registered fixed terrestrial wireless subscriptions in Kenya[28], accounting for 15.02% of the total fixed broadband market. This value is broken down by speed as follows (see graphic 3-1).

Graphic 3-1. Kenya: Fixed Terrestrial Wireless Subscriptions (by speed)



Source: Communications Authority of Kenya (2021). Second Quarter Sector Statistics Report for the Financial Year 2020/2021 (October-December 2020), p. 18

Of the licensed fixed wireless internet service providers, four should be highlighted (see table 3-2).

Table 3-2. Kenya: Fixed Wireless Internet Service Providers

Provider	Subscribers	Services	Coverage	Pricing
POA Internet Kenya Ltd.	56,614 (4Q20)	Home service • Unlimited data usage • Speeds up to 4 Mbps • Average download speed: 1 Mbps Hot spot service	• Ting'Ang'A • Kiambu • Kawangware • Kabiria • Jamhuri	Poa! Home: • One time connection feed: Ksh 7500 • Monthly subscription: Ksh 1500 Poa! Public Wi-Fi hotspots: • Free access
Mawingu Networks Ltd.	11,501 (4Q20)	Hot spot service	• Meru county • Laikipia county • Nyeri county • Embu county • Nanyuki Town	• Weekly subscription: $1 • Monthly subscription: $3
Syokinet		• Unlimited data usage • Speeds up to 10 Mbps		Monthly subscription • 3 Mbps: Ksh 2,620 • 6 Mbps: Ksh 3,930 • 10 Mbps: Ksh 5,240
Brck		• Moja		Free, advertising-based service

Source: Compiled from operator websites

[28] Communications Authority of Kenya (2021). *Second Quarter Sector Statistics Report for the Financial Year 2020/2021 (October-December 2020)*, p. 17.

In addition to the licensed wireless ISPs, several unlicensed providers exist. It is estimated that, when considering the unlicensed operators, total WISP subscribers in 2020 reached 216,000.[29] Beyond the typical commercial WISP player, several community networks operate in Kenya relying on a similar network architecture.[30] Community networks, supported by grants, charge a nominal fee of approximately $ 3 per month for unlimited access.

The WISP sector represents a critical contributor to tackling the country's persistent digital divide. Broadband adoption in Kenya is estimated to have reached 46%[31]. However, if 3G subscriptions are excluded, penetration decreases to 21%. As stated by the Communications Authority of Kenya,

> "*Even though the average cost of ICT devices has been declining over the years, the current costs remain beyond the reach of majority of Kenyans hindering universal access and widening the digital divide.*"[32]

Broadband non-adopters are, as expected, concentrated on the lower income population in 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 is composed of backhaul to link the internet point of presence to local access points. While in many countries, access point back-haul is fulfilled through either fiber optic or microwave, in Kenya, the links are operated by radios operating in the 5 GHz band. In turn, each access point relies on Wi-Fi technology operating in the 2.4 GHz spectrum, to provide broadband service to consumers (see figure 3-1).

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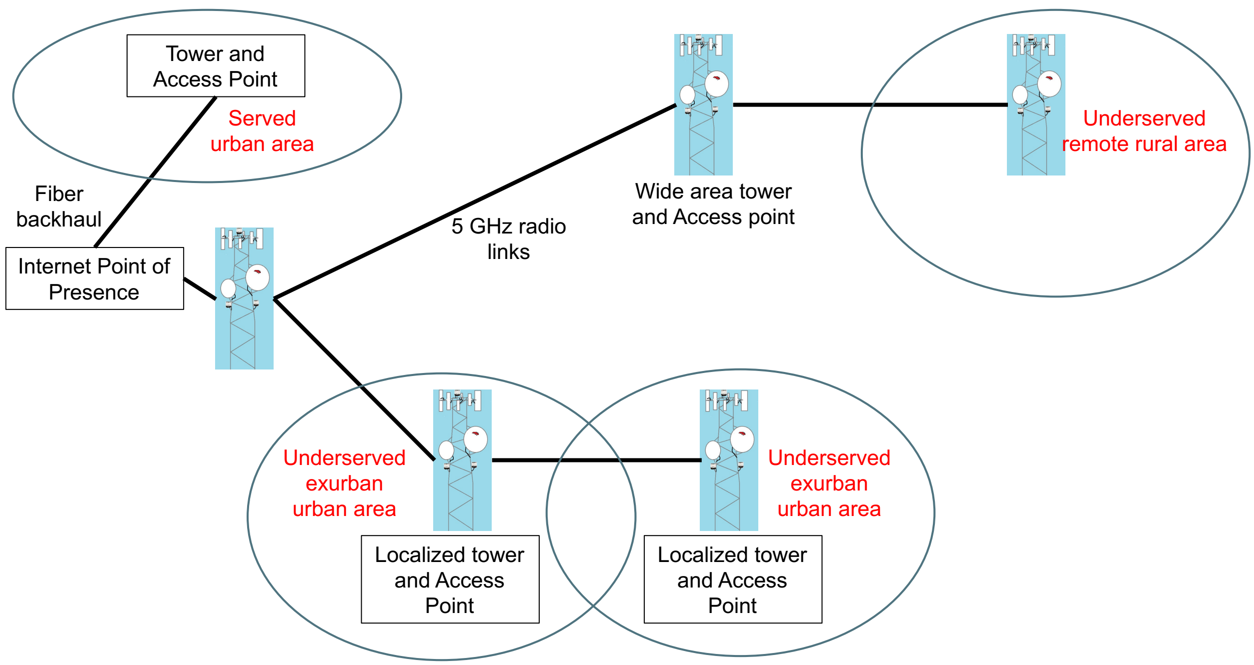
[29] This number was provided by interviews and reflects the sum of all Wireless ISP players.

[30] Among the networks, there is one operating in the outskirts of Nairobi, another one near Lake Victoria, and a third in Kibera.

[31] Calculated by dividing the total number of broadband subscriptions of 25,778,873 by an estimated total population of 54,909,395.

[32] Communications Authority of Kenya (2020). *Public consultation on strategies for increasing the uptake of ICT devices in Kenya.*

Figure 3-1. Kenya: WISP Network Architecture



Source: Telecom Advisory Services

Access to the 6 GHz spectrum band could have an impact on the WISP business at four levels:

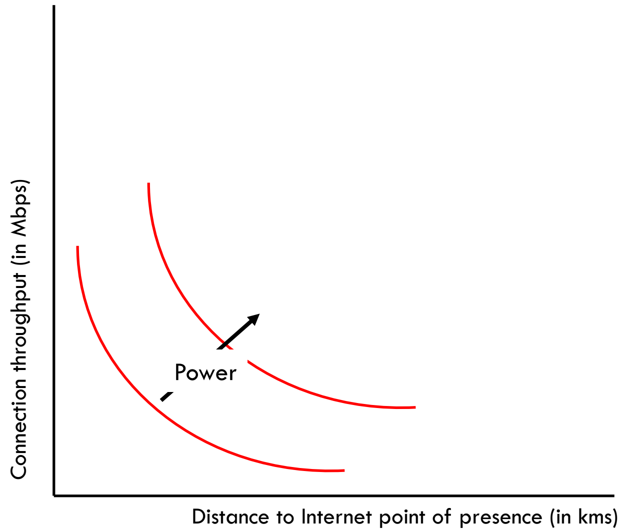
- **Enhanced point to point back-haul capacity which allows WISPs to increase coverage**: as mentioned above, the link between access points is generally handled by 5 GHz radios. Under current spectrum use, the 5 GHz band is very crowded, depicting high interference. Under current spectrum designation, scaling of 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. However, 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.[33]

  Access to the 6 GHz unlicensed spectrum band would allow the WISP to increase the number of access points with no backhaul constraint, since at this point 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 65% of the Kenyan population, which leaves 19,218,288 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

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

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 relationships 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.

- **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 users, a feature very popular among WISP subscribers in Kenya.

- **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). Under standard power allowance, increased coverage could be gained by bonding channels (a technology not yet frequently used as of yet 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**: As stated in interviews, Kenyan WISPs tend to currently have the capacity of handling 30 -40 subscribers per 10-20 Mbps channel. The use of 6 GHz channels 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.

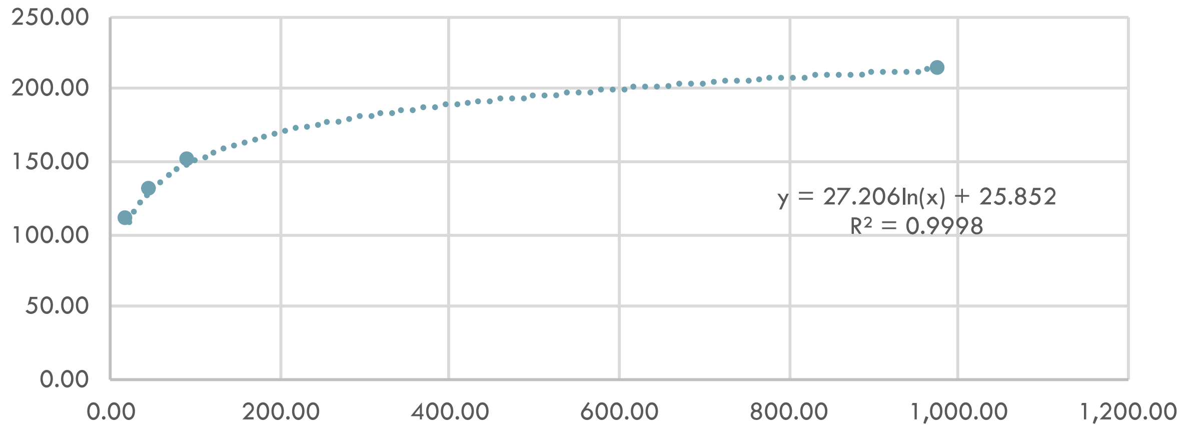
Contribution to consumer surplus as a result of increasing broadband speed

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 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.[34] In addition, the researchers 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).

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

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 Kenya, we multiplied it by Kenya's purchasing power parity of 0.40 estimated by the International Monetary Fund.

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 Kenyan WISPs to potentially increase their subscriber base within their same coverage footprint[35]. 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%.

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, rather than lowering prices to match the scale curve, they will remain stable. However, in a context of increasing GDP per capita, affordability would increase for those potential subscribers that indicate that they do not purchase broadband service because of its cost. A survey conducted by Research ICT Africa indicates

[35] 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.

that the main limitation to Internet use in Kenya is data cost (45% of respondents)[36]. With an increase in affordability, the penetration of broadband will grow.

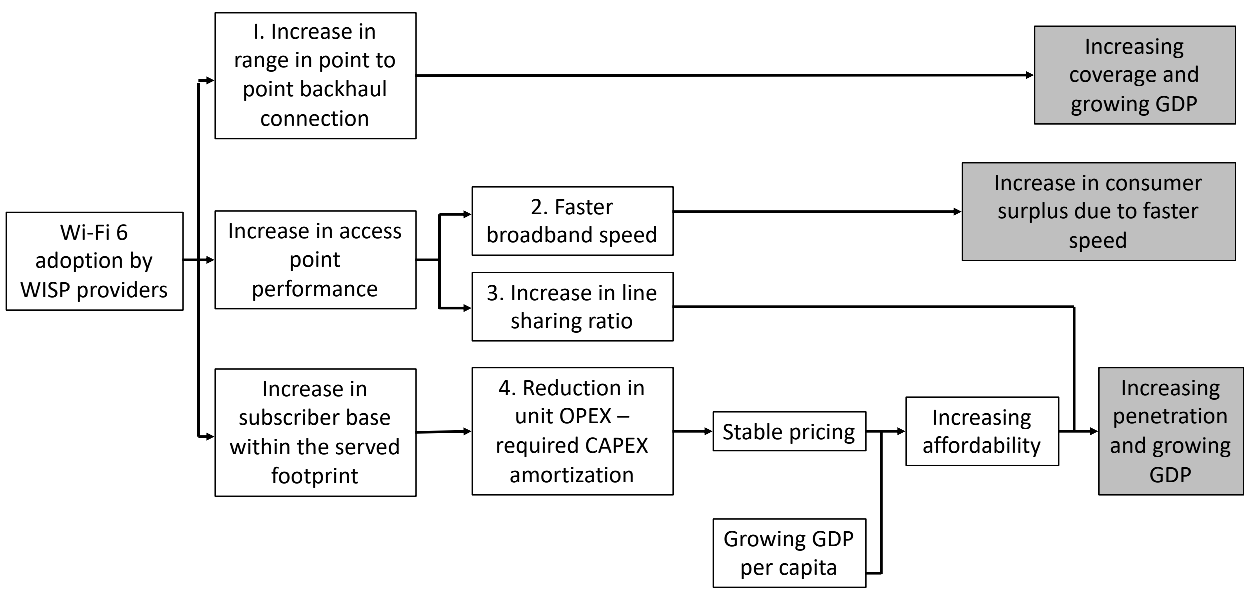
Higher capacity per access point

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 are frequently shared across neighbors. By factoring in the relationship between total homes with broadband and broadband connections (100%) as reported by the RIA After Access survey data and Communication Authority of Kenya respectively, we estimate that a 50% of fixed wireless broadband households share their line with a neighbor.[37] We assume that the sharing factor decreases to 25% in 2030, reflecting an increase in living standards.

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 yields a growth of 0.08 percent in the GDP[38].

The sum of all three effects on WISP performance reviewed above is displayed in figure 3-2.

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



Source: Telecom Advisory Services

[36] Nyambura Ndung'u, M., Lewis, C. and Mothobi, O. (2019). *The State of ICT in Kenya*. Research ICT Africa, p. 30.
[37] This is confirmed by a qualitative interview conducted with the Communications Authority of Kenya.
[38] Katz, R. and Callorda, F. (2018). *The economic contribution of broadband, digitization and ICT regulation: Econometric modelling for the Americas*. Geneva: International Telecommunications Union, p. 10

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. The increase in average speed yields 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 Kenyan 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.

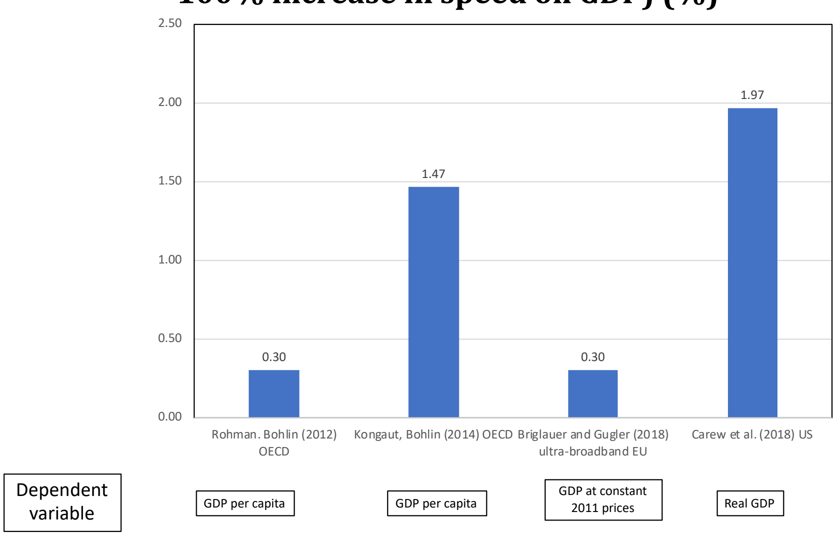
Each effect is explained in turn.

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 enable for 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 or business 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.[39] On the other hand, 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 effects 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[40] 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

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

[40] 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. For 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. For example, 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$1.7 trillion for 2021. GSMA Intelligence estimates that the number of M2M connections, a proxy for IoT, in Kenya has reached 652,708[41]. By interpolating data from IDC, GSMA Intelligence, and Frost & Sullivan, we estimate that the Kenyan IoT market approximates US$ 130 million.

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 are addressed[42]. Spectrum availability is one of the barriers to IoT development. While IoT roll-out in Kenya 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 a wider deployment of 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 Kenya, 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 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 3-3).

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[41] GSMA Intelligence.
[42] CompTIA (2016). *Sizing up the Internet of Things*.

Table 3-3. 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 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 around 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 the IoT case.

The development and diffusion of AR/VR applications in the production side of the economy is being driven by an ecosystem comprised of local 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 Kenyan 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 Research ICT Africa, only 10% of the Kenyan population lives in a household with access to an Internet connection. In a context of the affordability barrier pointed above, public Wi-Fi represents a viable option of Internet access. This is confirmed by the Research ICT Africa Survey, which reports that 7.5% Internet users use public Wi-Fi all the time, 12.9% once a day, and 5.7% once a month.[43] Consumers who do not have broadband at home because they lack economic resources to acquire service can rely on municipal Wi-Fi to gain Internet access.

However, 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 economically disadvantaged population with access to the Internet.

3.7. Deployment of Free Wi-Fi Hot Spots

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[43] Nyambura Ndung'u, M., Lewis, C. and Mothobi, O. (2019). *The State of ICT in Kenya*. Research ICT Africa, p. 29.

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 are approximately 39,000 free Wi-Fi hot spots in Kenya, distributed as follows (see Table 3-4).

Table 3-4. Kenya: Number of Free Wi-Fi Spots (2020)

City	Number
Nairobi	31,000
Mombasa	3,000
Nakuru	2,000
Eldoret	1,000
Kisumu	1,000
Thika	1,000
Total	39,000

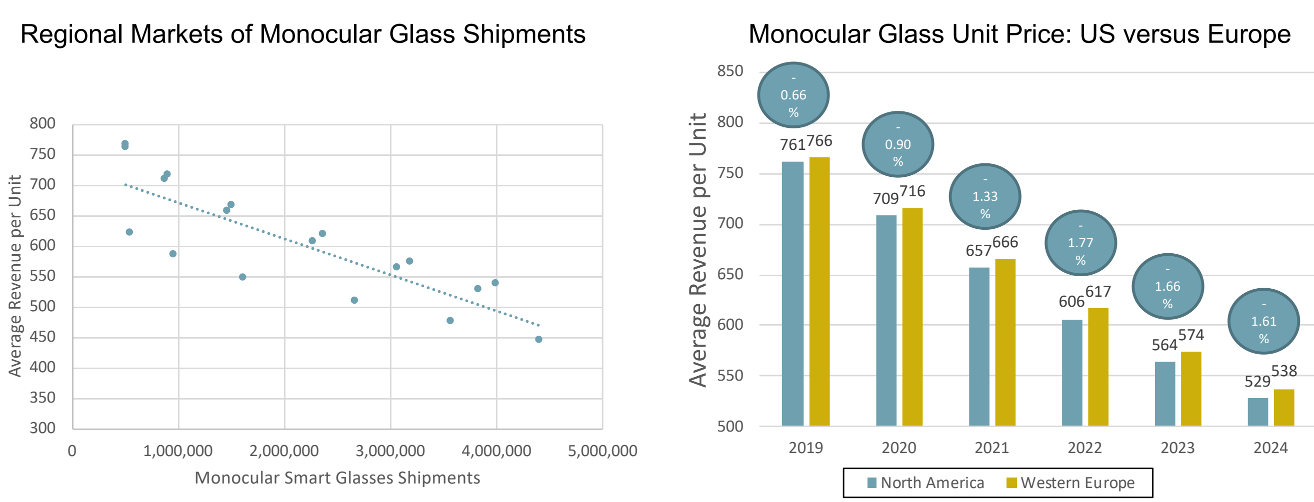
Source: Wiman (2021).

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, Kenya 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 Kenyan 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 Kenya's 6 GHz spectrum allocations issue with the full 6 GHz allocation model that has been adopted by Wi-Fi equipment leaders, such as the United States and South Korea, to allow Kenyan firms to benefit from lower input prices.

Secondly, the Kenyan market for equipment and services in areas related to implementation of the 6 GHz amounts to US$ 518 million in 2020 but will reach US$ 827 million in 2025 (see table 3-5).

Table 3-5 Kenya: Sales in markets impacted by the 6 GHz decision (in US$ billion) (2020-25)

Market	Categories	2020	2025
Augmented Reality/Virtual Reality	Hardware	$ 0.001	$ 0.025
	Software and applications	$ 0.002	$ 0.049
	Subtotal	$ 0.003	$ 0.074
IoT	Hardware	$ 0.048	$ 0.110
	Software and services	$ 0.061	$ 0.140
	Subtotal	$ 0.109	$ 0.250
Wi-Fi devices	Home networking devices	$ 0.029	$ 0.040
	Wi-Fi enabled devices	$ 0.343	$ 0.426
	Enterprise access points and controllers	$ 0.034	$ 0.037
	Subtotal	$ 0.406	$ 0.503
Total		$ 0.518	$ 0.827

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 Kenya 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 the full 6 GHz allocation model could potentially give Kenya the benefit of developing an export-led industry that could capitalize on foreign demand.

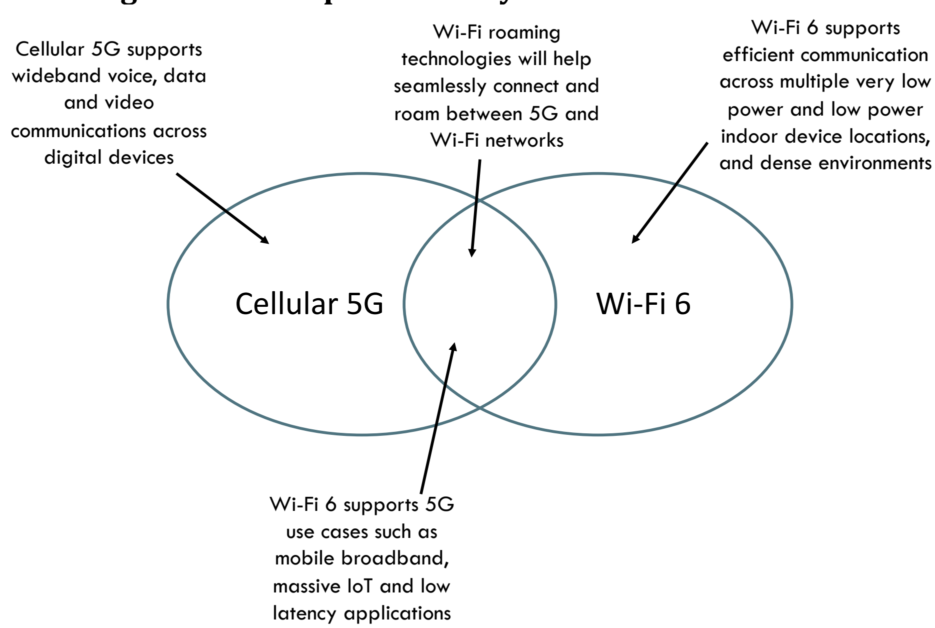
3.9. Enhancing the capability for cellular off-loading

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. Kenyan carriers have been deploying Wi-Fi access points to offload part of their traffic[44]. 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



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

[44] Per example Safaricom offers free Wi-Fi zone to their Platinum mobile users (Source: https://www.safaricom.co.ke/faqs/faq/578)

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[45]. As mentioned above, there are 39,000 public hot-spots in Kenya[46]. Even cellular providers acknowledge Wi-Fi's central role. For example, Verizon's Executive VP and Consumer Group CEO told an investor conference in January 2020 that between 70% and 75% of mobile device data traffic in the United States is offloaded onto Wi-Fi[47].

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 5G 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 3-6).

Table 3-6. 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.

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[45] C*isco 2019 VNI Report* at 104.
[46] C*isco and Wiman*
[47] Verizon, Citi 2020 Global TMT West Conference, Webcast (Jan. 7, 2020). Available: https://www.verizon.com/about/investors/citi- 2020-global-tmt-west-conference.

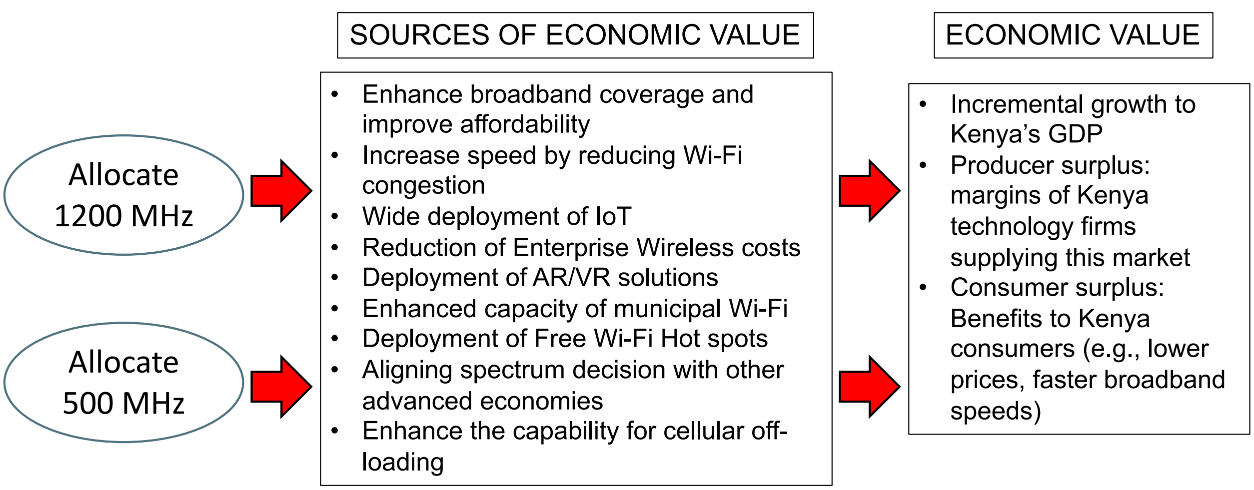
In all cases, to differentiate the value corresponding to the 6 GHz band, from the value corresponding to the other bands of Wi-Fi use, we follow the forecasts provided by IDC on the evolution of shipments of consumer 802.11ax devices for the 6 GHz band.

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 produced goods that are consumed locally in Kenya are considered, while when measuring producer surplus, only goods manufactured in Kenya 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 Kenya 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 Kenya



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.

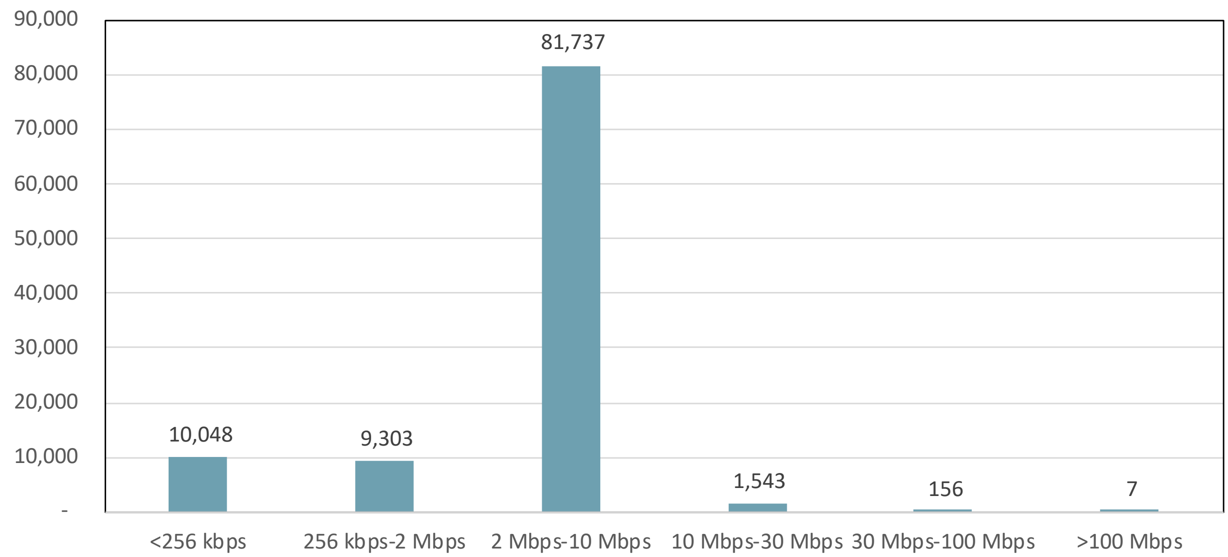
4. ENHANCED BROADBAND COVERAGE AND IMPROVED AFFORDABILITY

The latest official statistics for Kenya indicate a 4Q20 fixed broadband penetration of 5.93% (or 674,191 connections for 11,378,392 households)[48]. The total number of fixed broadband connections increase to 797,445 if we also consider the households with a WISP connection not registered in the telecom regulator (which results in a fixed broadband penetration of 7.01%). By extrapolating the national historical growth rate, we estimate that penetration will reach 17.70% by 2030. In this context, Wireless ISPs (WISPs) can fulfill a critical role in addressing the broadband gap.

4.1. The current situation in Kenya

According to official statistics, there are a total of 102,794 fixed terrestrial wireless subscriptions in Kenya[49], accounting for 15.02% of the total fixed broadband market. This value is broken down by speed as follows (see graphic 4-1).

Graphic 4-1. Kenya: Fixed Terrestrial Wireless Subscriptions (by speed)



Source: Communications Authority of Kenya (2021). Second Quarter Sector Statistics Report for the Financial Year 2020/2021 (October-December 2020), p. 18

In addition to the licensed wireless ISPs, several unlicensed providers exist. It is estimated that, when considering unlicensed operators, total WISP subscribers in 2020 reached 216,000. Beyond the typical commercial WISP player, a number of community networks operate in Kenya relying on a similar network architecture. Community networks, supported by grants, charge a nominal fee of approximately $ 3 per month for unlimited access.

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[48] Communications Authority of Kenya (4Q20)

[49] Communications Authority of Kenya (2021). *Second Quarter Sector Statistics Report for the Financial Year 2020/2021 (October-December 2020)*, p. 17.

Assuming that WISP subscribers will increase at the same rate as the total fixed broadband connections, we can expect that they will reach 687,000 in 2030. In addition, we should consider a second-order effect on broadband adoption from WISP providers, which relates to a household sharing ratio. As a result of the lower income population concentration, WISP Wi-Fi lines are frequently shared across neighbors. By factoring in the relationship between total homes with broadband and broadband connections (100%) as reported by the RIA After Access survey data and Communication Authority of Kenya respectively, we estimate that a 50% of fixed wireless broadband households share their line with a neighbor.[50] In addition, we assume that the sharing factor decreases to 25% in 2030, reflecting an increase in living standards. Based on the line sharing effect, the total number of households that use a WISP connection is 324,000, we can expect this number to increase to 858,000 in 2030 (see table 4-1).

Table 4-1. Kenya: WISP Lines (2020-2030)

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
WISP subscribers	216,000	281,083	345,621	406,094	460,240	507,002	546,257	578,487	612,619	648,764	687,042
Shared ratio	50%	47%	44%	41%	38%	35%	33%	31%	29%	27%	25%
Total	324,000	412,212	496,062	571,020	634,638	686,255	726,455	756,538	788,548	822,596	858,803

Sources: Communications Authority of Kenya (2021); Interviews with Kenyan´s WISP; Telecom Advisory Services analysis.

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

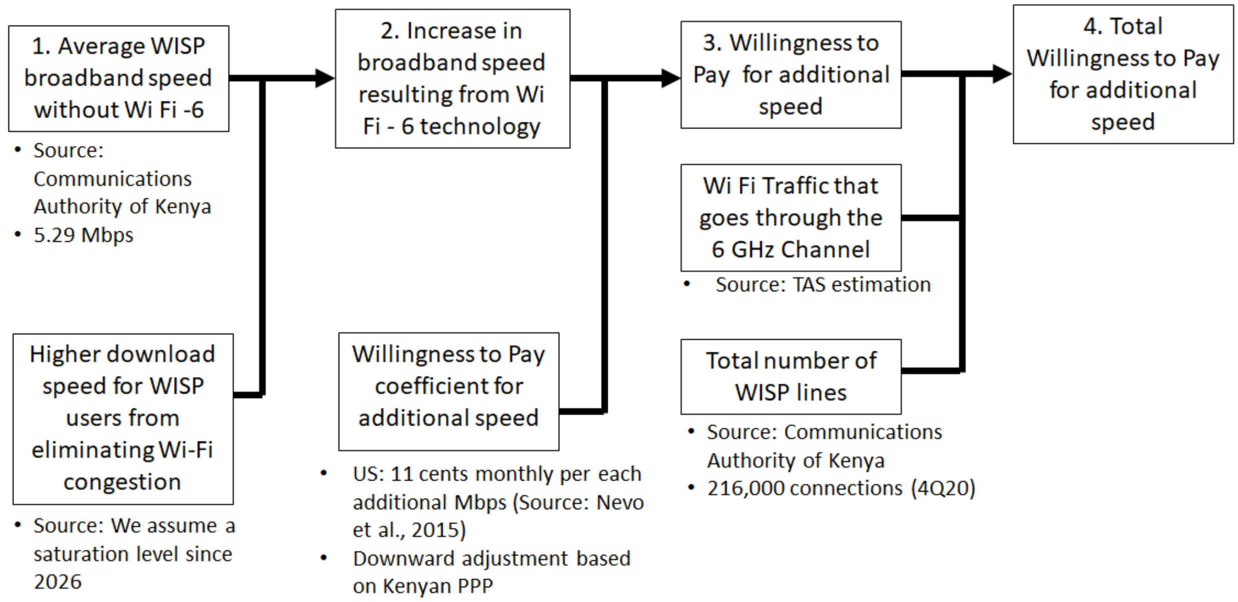
As reviewed in figure 3-1 in chapter 3, the 6 GHz allocation decision will have an impact in two factors driving the economic value of WISPs: (i) increasing consumer surplus of existing customers because of faster broadband service, and (ii) enhancing affordability and, consequently, penetration of broadband,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

Increasing consumer surplus due to enhanced base station performance

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

[50] This is confirmed by a qualitative interview conducted with the Communications Authority of Kenya.

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 (line 1 minus line 2 in table 4-2) by the willingness to pay (WTP) coefficient for incremental broadband speed yields an enhancement of consumer surplus by line (line 6). Finally, the WTP per line is multiplied by the number of WISP connections (line 7) (see table 4-2).

Table 4-2. Consumer surplus due to WISP user speed increase (2020-2030)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
(1) Average speed from WISP with 6 GHz	5.51	5.73	5.97	6.21	6.46	6.72	6.99	7.28	7.57	7.88
(2) Average speed from WISP with no 6 GHz	5.51	5.73	5.97	6.21	6.46	6.46	6.46	6.46	6.46	6.46
(3) Demand for average download speed with 6 GHz	$29	$29	$29	$29	$30	$30	$31	$31	$31	$32
(4) New Demand for average download speed with no 6 GHz	$29	$29	$29	$29	$30	$30	$30	$30	$30	$30
(5) Additional Monthly Consumer surplus	$0	$0	$0	$0	$0	$0	$1	$1	$2	$2
(6) Additional Yearly Consumer Surplus	$0	$0	$0	$0	$0	$5	$10	$15	$20	$25
(7) WISP Connections (*)	281,083	354,693	431,992	507,229	578,593	644,172	701,960	753,258	808,088	866,696
(8) Traffic through 6 GHz Band	0.00%	10.00%	20.00%	30.00%	40.00%	50.00%	60.00%	65.00%	70.00%	75.00%
(9) Impact (USD Millions)	0	0	0	0	0	2	4	7	11	16

(*) That number not consider the households that uses a share connection due that those households are not paying for the service. The WISP connections considers the natural growth and the new connections that are estimate in section 4.3.
Source: Telecom Advisory Services analysis.

Total 2021-2030 cumulative consumer surplus impact resulting from increasing broadband speed by reducing Wi-Fi congestion for WISP users amounts to US$ 41 million (sum of line 9).

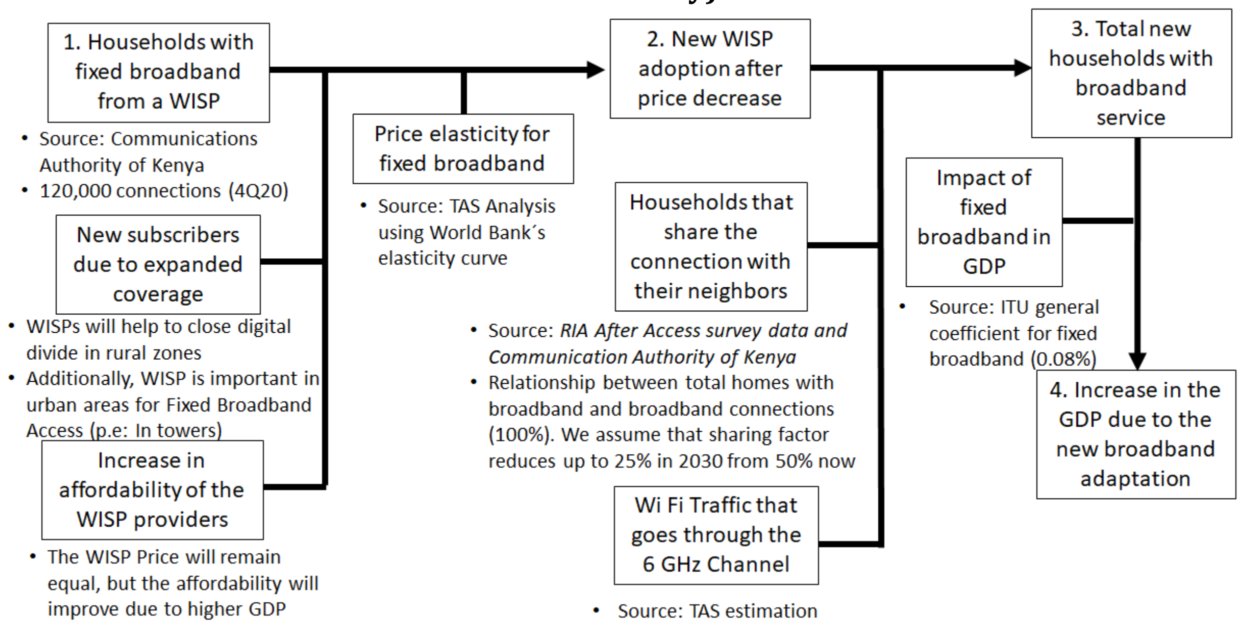
4.3. Impact of 6 GHz spectrum on GDP by expanding coverage, increasing affordability, and growing broadband penetration from WISPs

The purpose in this case is to estimate the impact on GDP of the expanded coverage, the change in broadband affordability and consequential enhanced broadband penetration within WISPs. To start with, the 6 GHz allocation to 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[51]. For conservative purposes, we assume that broadband service prices from Kenyan WISPs would not change from current levels. However, considering that the GDP per capita would increase in the future (per the IMF forecast), the overall affordability of service at 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 to expanded coverage), which should be added to the new adopters. A higher broadband penetration will in turn have an impact on the Kenyan GDP. Figure 4-2 presents the methodology followed to develop this estimate.

[51] 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.

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, which, according to historical growth, will reach 47,104 new subscribers by 2030 (line 1 in table 4-3). Based on the extrapolation of historical data, we should expect that the total number of WISP subscriptions would increase to 471,042 by 2030. However, for conservative purposes, we only attribute to expanded coverage a 10% of that growth. From this growth, it is considered that by 2030 only 75% will be using the 6 GHz band, so in total the increase in subscribers due to greater coverage with the 6 GHz band reaches 35,328 (located mainly in rural areas) (line 3).

At the same time, assuming stable prices and an improvement in Kenya´s GDP in the order of 5.70% per year (as projected by the IMF), an improvement in the affordability of the service can be estimated, which would affect mainly urban and suburban areas. This situation will increase the new subscriber base by 115,460 by 2030 (line 5), which, once it is multiplied by the line sharing ratio (25%), will result in 144,325 new WISP subscribers (line 7). By aggregating all the effects, the designation of the 6 GHz band for free use in Kenya, will allow WISPs to add 179,653 new homes connected by 2030, a contribution to narrowing down the Kenyan digital divide.

Table 4-3. Kenya: New subscribers due to increased coverage and greater affordability (2021-2030)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
(1) Increase in subscribers due to greater coverage	6,508	12,962	19,009	24,424	29,100	33,026	36,249	39,662	43,276	47,104
(2) Traffic on the 6 GHz band	0.00%	10.00%	20.00%	30.00%	40.00%	50.00%	60.00%	65.00%	70.00%	75.00%
(3) Increase in subscribers due to coverage with the 6 GHz band	0	1,296	3,802	7,327	11,640	16,513	21,749	25,780	30,294	35,328
(4) GDP growth	4.43%	3.98%	4.92%	5.29%	5.55%	5.70%	5.70%	5.70%	5.70%	5.70%
(5) Increase in subscribers due to improvement in affordability	0	5,417	15,714	28,763	44,292	61,210	77,783	89,233	101,763	115,460
(6) Sharing rate	47%	44%	41%	38%	35%	33%	31%	29%	27%	25%
(7) Increase in subscribers due to improvement in affordability considering sharing	0	7,776	22,096	39,662	59,951	81,402	101,724	114,859	129,030	144,325
(8) Total new subscribers	0	9,072	25,898	46,989	71,591	97,915	123,473	140,639	159,323	179,653

Sources: International Monetary Fund; Telecom Advisory Services analysis

The increase in the number of WISP subscribers drives due exclusively to the 6 GHz allocation, will increase broadband penetration, reaching 7.08% in 2030 (line 1 in table 4-4). Based on the coefficient of impact of fixed broadband on GDP calculated by the authors in a study for the International Telecommunication Union[52] (line 2), the total impact on GDP is estimated (line 3) (see table 4-4).

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

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
(1) Increase in broadband penetration	0.00%	0.71%	1.73%	2.77%	3.82%	4.86%	5.78%	6.22%	6.65%	7.08%
(2) Impact of fixed broadband on GDP	8.00%	8.00%	8.00%	8.00%	8.00%	8.00%	8.00%	8.00%	8.00%	8.00%
(3) Increase in GDP due to the increase in broadband (%)	0.000%	0.057%	0.138%	0.221%	0.306%	0.388%	0.463%	0.497%	0.532%	0.567%
(4) Impact on GDP (US$ million)	$0	$64	$167	$288	$430	$589	$757	$880	$1,016	$1,169

Source: Telecom Advisory Services analysis

In summary, the total cumulative impact on GDP because of the higher penetration of WISPs between 2021 and 2030 in Kenya is US$ 5.36 billion (sum of line 4 in table 4-4).

4.4. Growing revenues of Kenyan WISPs

Another contribution to the Kenyan GDP is driven by the incremental revenues flowing to WISPs because of the new lines deployed by the allocation of the 6 GHz spectrum. These revenues are estimated by multiplying the increase in the number of subscribers (line 8 in

[52] Katz, R. and Callorda, F. (2018). *The economic contribution of broadband, digitization, and ICT regulation: Econometric modelling*. Geneva: International Telecommunications Union, p. 10

Table 4-3) by the WISP average revenue per user, which is assumed to be stable at $ 1,500 Kenyan shilling (converted to US$ in line 2 of table 4-5).

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

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
(1) Total new subscribers	0	9,072	25,898	46,989	71,591	97,915	123,473	140,639	159,323	179,653
(2) Average annual income of WISPs	$167	$167	$167	$167	$167	$167	$167	$167	$167	$167
(3) Additional revenue (US$ million)	$0	$2	$4	$8	$12	$16	$21	$24	$27	$30

Source: Telecom Advisory Services analysis.

In sum, the total cumulative impact on GDP because of the increase in WISP revenues between 2021 and 2030 in Kenya is US $ 143 million.

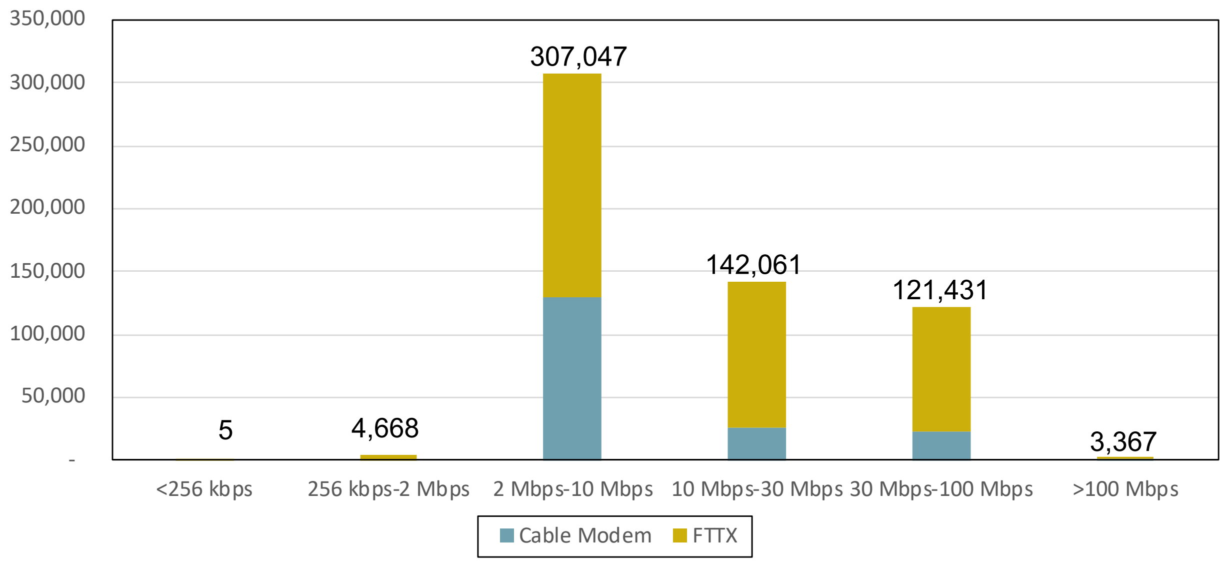
5. INCREASED BROADBAND SPEED BY REDUCING Wi-Fi CONGESTION

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 Kenyan 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 Kenya and the importance of Wi-Fi congestion

The Communications Authority of Kenya reports that out of the 674,191 licensed fixed broadband lines (December 2020), 573,906 (or 84.54%) have the potential to deliver up to 150 Mbps since they are either based on FTTx or cable modem technology.[53] (see graphic 5-1).

Graphic 5-1. Kenya: Cable broadband and FTTx subscriptions by speed (4Q20)



Source: Telecom Advisory Services based on data from Communications Authority of Kenya

This is confirmed by the fact that the three largest fixed broadband service providers already offer plans with at least 100 Mbps (see table 5-1).

Table 5-1. Kenya: Fixed Data subscriptions and plans

Name of service provider	Number of data/internet subscriptions	Percentage Market Share	Technology	Broadband Plans (in Mbps)
Safaricom PLC	243,623	35.6%	Fiber	100
Wananchi Group (Kenya) Ltd.	206,989	30.2%	Fiber/Cable/Satellite	100, 200, 500
Jamii Telecommunications Ltd.	131,793	19.3%	Fiber	125

Sources: Telecom Advisory Services based on data from Communications Authority of Kenya; Operator websites

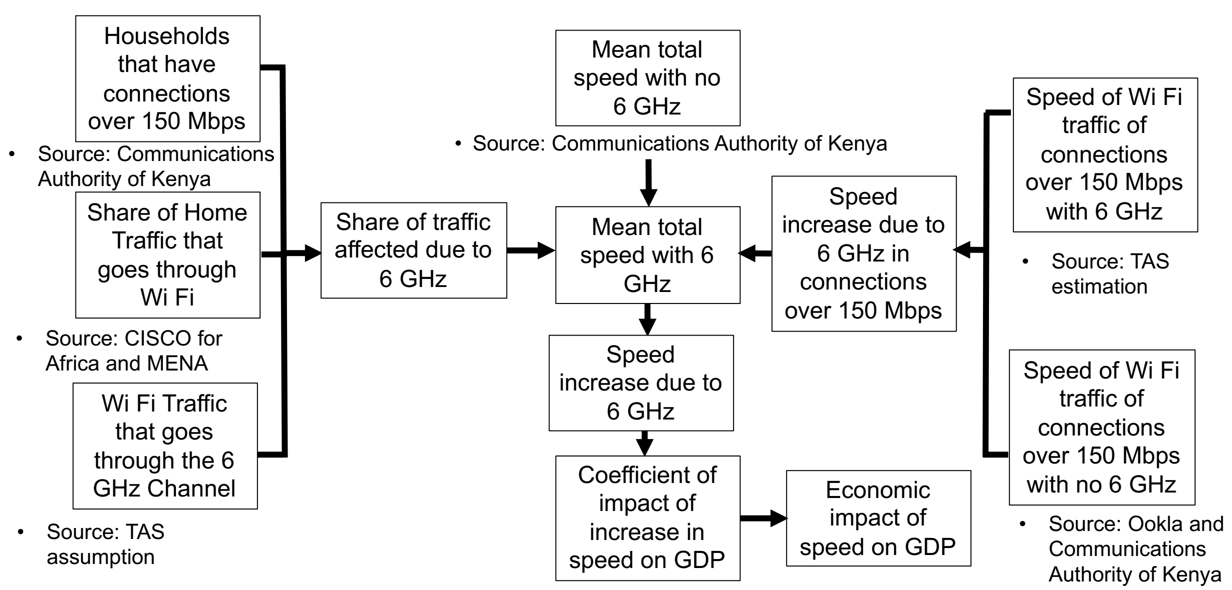
[53] The values reported by the regulator include household and business connections. Therefore, part of the effect estimated in this section can also be attributed to the business sector.

As explained in chapter 3, if a household or business establishment 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 given the statistics review above, the number of lines undergoing a potential bottleneck at the router level in Kenya is low (0.11%), a projection over the next five years indicates that by 2030 this will increase to 520,721 lines (or 20.53% of 2,536,475 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 user will not be equivalent to that delivered by the fixed network. Conversely, by increasing the spectrum in the 6 GHz band allocated to Wi-Fi, the speed will increase with the consequent additional economic effect.

5.2. Contribution of 6 GHz spectrum 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 broadband connections undergoing a Wi-Fi bottleneck (those purchasing a fixed broadband plan more than 150 Mbps now and in the future). As explained above, despite the broadband capacity reaching the premise, 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 users in Kenya that have a connection over 150 Mbps that would undergo a Wi-Fi congestion problem as a result of routers relying only on the 2.4 GHz and 5 GHz bands. As mentioned in chapter 3, based on the current 2.4 GHz and 5 GHz allocation, dual band 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)[54]. 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[55]. This calculation assumes that 10% of the traffic will be routed through the 6 GHz band in 2022, reaching 75% in 2030.

Because not all households subscribe to a fixed broadband connection that undergoes a bottleneck at the CPE, we only consider in our analysis the Kenyan users that have a connection of more than 150 Mbps (this is estimated for 2021 from the Communications Authority of Kenya data: 0.11% of broadband connections in 2021, increasing to 20.35% by 2030). 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 based on interviews, starting at 85.57% and reaching 88.10% 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 75% by 2030 (see table 5-1).

Table 5-1. Kenya: Estimation of fixed broadband connections affected by 6 GHz decision (2021-2030)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
(1) Households that have connections over 150 Mbps (%)	0.11%	0.27%	0.66%	1.57%	4.28%	6.14%	8.60%	11.71%	15.63%	20.53%
(2) Share of Home Traffic that goes through Wi Fi (%)	85.57%	88.10%	88.10%	88.10%	88.10%	88.10%	88.10%	88.10%	88.10%	88.10%
(3) Traffic through the 6 GHz Channel (%)	0.00%	10.00%	20.00%	30.00%	40.00%	50.00%	60.00%	65.00%	70.00%	75.00%
(4) Share of traffic affected due to 6 GHz (%)	0.00%	0.02%	0.12%	0.41%	1.51%	2.70%	4.54%	6.71%	9.64%	13.56%

Sources: Communications Authority of Kenya; 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 200 Mbps in 2021, reaching 750 Mbps by 2030 (see table 5-2).

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

[55] 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 5-2. Kenya: Estimation of fixed broadband speed in connections affected by 6 GHz decision (2021-2030)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
(5) Speed of Wi Fi traffic of connections over 150 Mbps (no 6 GHz) (Mbps)	200	225	250	300	350	425	500	500	500	500
(6) Speed of Wi Fi traffic of connections over 150 Mbps (with 6 GHz) (Mbps)	200	225	250	300	350	425	500	575	650	750

Sources: Communications Authority of Kenya; 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 0.05 Mbps for the average broadband connection in 2022, reaching 91.85 Mbps in 2030.

Table 5-3. Kenya: Increase in Speed resulting from 6 GHz allocation (2012-2030)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
(8) Mean speed with no 6 GHz (Mbps)	16.80	21.61	28.17	33.51	38.14	43.42	49.42	56.25	64.02	72.87
(9) Mean speed with 6 GHz (Mbps)	16.80	21.66	28.43	34.62	42.85	53.73	69.90	91.04	120.50	164.72
(10) Speed increase due to 6 GHz	0.00%	0.23%	0.91%	3.29%	12.32%	23.76%	41.44%	61.85%	88.21%	126.04%

Sources: Communications Authority of Kenya; 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.[56] The data comprised 575 observations of quarterly data for:

- Average fixed broadband download speed[57](source: Speedtest Global Index)
- Gross Domestic Product (at current prices US$) (source: IMF)[58]
- 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:

[56] 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.
[57] The data panel on the Speedtest Global Index covers 159 countries.
[58] 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.

- 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

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

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 yields 0.73% in GDP growth (see Table 5-4).

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 (line 1 in table 5-5), we estimate the overall GDP impact resulting from an increase in speed due to the allocation of the 6 GHz band.[59] To be conservative with the result, we discount that

[59] 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.

coefficient considering that Kenya has a fixed broadband adoption lower than the worldwide mean.

Table 5-5. Kenya: Estimation of economic impact by reducing Wi-Fi congestion (2012-2030)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
(11) Impact speed on GDP	0.26%	0.26%	0.26%	0.26%	0.73%	0.73%	0.73%	0.73%	0.73%	0.73%
(12) Discount factor due Kenyan lower FBB adoption	15.69%	18.85%	21.65%	23.97%	25.81%	27.17%	28.12%	29.10%	30.11%	31.16%
(13) Increase in GDP (%)	0.00%	0.00%	0.00%	0.00%	0.02%	0.05%	0.09%	0.13%	0.19%	0.29%
(14) Kenya GDP Billion US$	$106	$113	$121	$130	$140	$152	$164	$177	$191	$206
(15) Impact (US$ Billion)	$0	$0	$1	$3	$33	$71	$139	$232	$370	$591

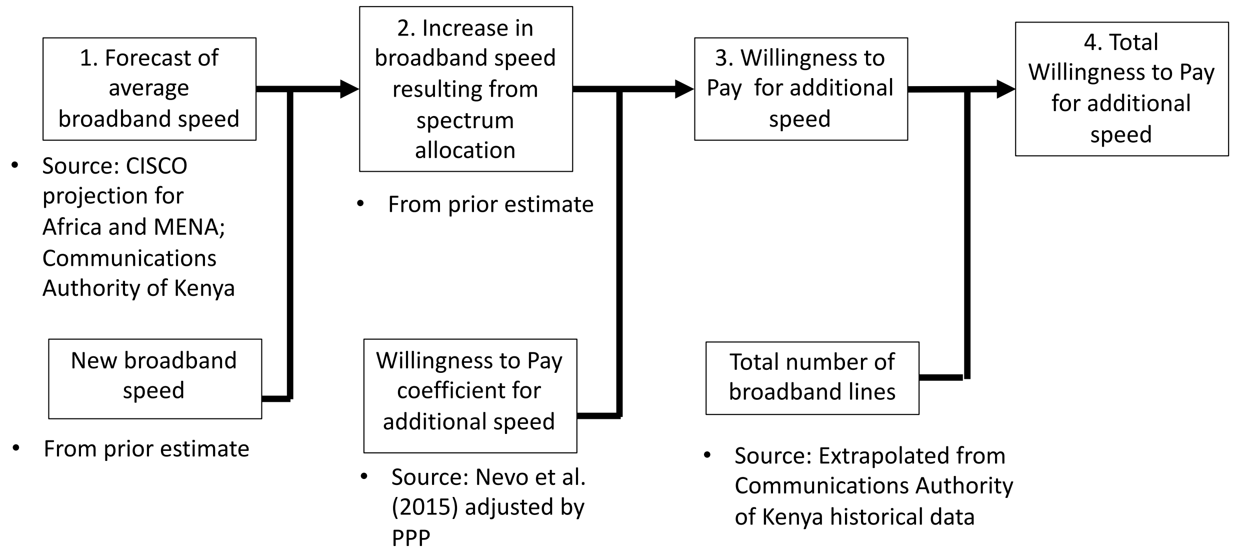
Sources: Katz and Callorda (2019); IMF; Communications Authority of Kenya; Telecom Advisory Services analysis

Total cumulative GDP contribution of the 6 GHz band allocation between 2021 and 2030 will reach US$1.44 billion (sum of line 15 in table 5-5).

5.3. Contribution of 6 GHz spectrum 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 Kenya



Source: Telecom Advisory Services

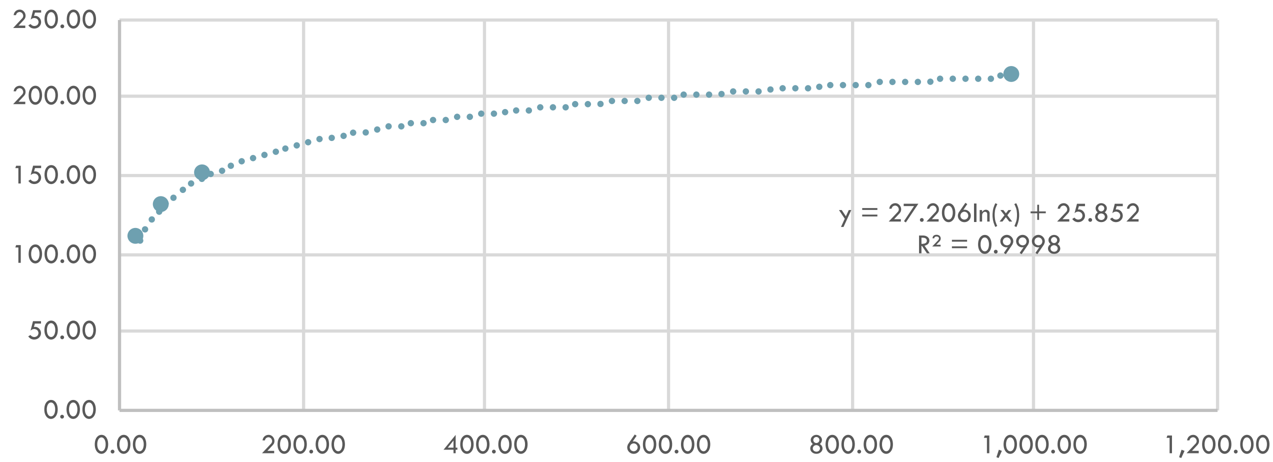
As calculated based on broadband speed, the average broadband speed in 2021 in Kenya is estimated at 16.80 Mbps (line 8 in table 5-3). By addressing the bottleneck for users acquiring service more than 150 Mbps, average speed will increase to 164.72 Mbps in 2030 (line 9 in table 5-3), which results in a net increase in speed of 91.85 Mbps (the difference between the 164.72 Mbps and the 72.87 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 Kenyan 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.[60] 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 across users, 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.[61] 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).

[60] 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.

[61] 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."

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 in Graphic 5-1, 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 Kenya, we multiplied it by the Kenya's purchasing power parity of 0.40, zas reported by the International Monetary Fund.

Under these two assumptions the consumer surplus impact would be $0.3 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 Fixed Broadband Download Speed (at end user device)	21.61	Return to speed analysis
(3) New Average Fixed Broadband Download Speed	21.66	Return to speed analysis
(4) Demand for average download speed	$ 43.46	Equation in graphic 5-1
(5) New demand for average download speed	$ 43.48	Equation in graphic 5-1
(6) Additional Monthly Consumer surplus	$ 0.02	(4 – 3)
(7) Additional Yearly Consumer Surplus	$ 0.29	(5) * 12
(8) Fixed Broadband Connections with Wi-Fi (Millions)	1.046	Estimation
(9) Impact (US$ Millions)	$ 0.31	(7)*(8)

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 (2021-2030)

	2021	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
(1) Average Download Speed	16.80	21.61	28.17	33.51	38.14	43.42	49.42	56.25	64.02	72.87
(2) New Average Download Speed	16.80	21.66	28.43	34.62	42.85	53.73	69.90	91.04	120.50	164.72
(3) Demand for average download speed	41.43	43.46	45.77	47.33	48.56	49.88	51.25	52.62	53.98	55.35
(4) New Demand for average download speed	41.43	43.48	45.87	47.67	49.79	52.13	54.91	57.70	60.67	63.97
(5) Additional Monthly Consumer surplus	$0.00	$0.02	$0.10	$0.34	$1.23	$2.25	$3.66	$5.09	$6.68	$8.62
(6) Additional Yearly Consumer Surplus	$0.00	$0.29	$1.16	$4.13	$14.75	$27.02	$43.96	$61.05	$80.18	$103.40
(7) Fixed Broadband Connections with Wi–Fi (Millions)	0.841	1.046	1.244	1.427	1.591	1.734	1.858	1.990	2.132	2.283
(8) Impact (USD Millions)	$0	$0.31	$1	$6	$23	$47	$82	$122	$171	$236

Sources: Communication Authority of Kenya; Nevo et al. (2016); Telecom Advisory Services analysis

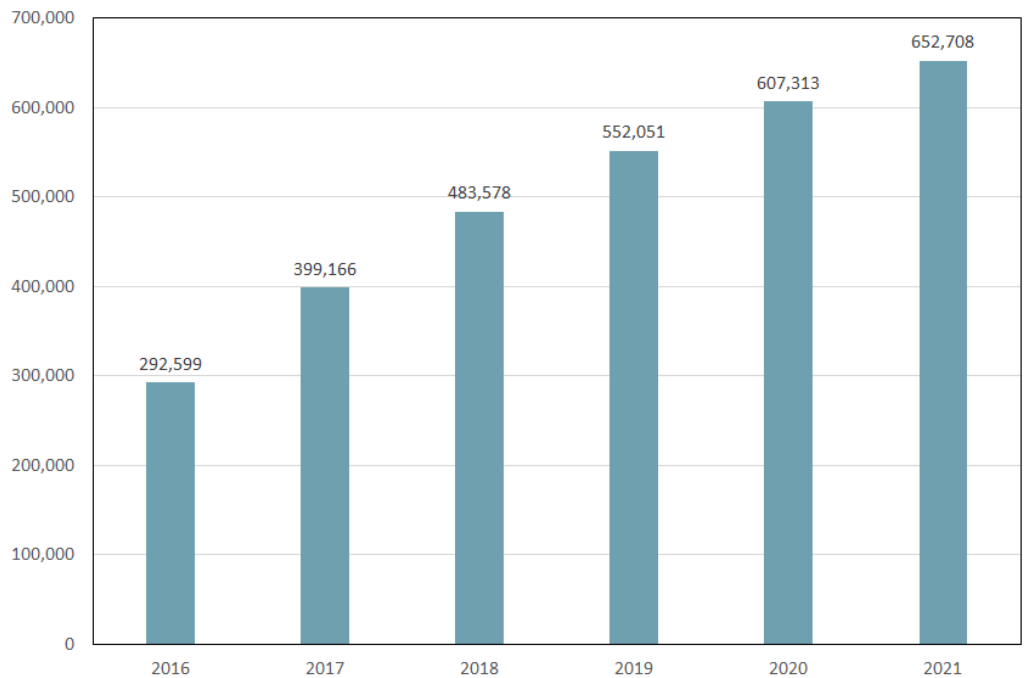
The increase of the average household in consumer surplus evolves from US$ 0.31 million in 2022 to US$ 236 million in 2030 (the households with bottleneck will have an increase higher than that, but the households with no bottleneck will have $0); this is the value multiplied by the total number of connections. Thereby, total consumer surplus associated with the allocation of the 6 GHz band between 2021 and 2030 will reach US$ 688 million (sum of line 8 in table 5-7).

6. WIDE DEPLOYMENT OF INTERNET OF THINGS

6.1. The critical importance of IoT in Kenya

Considering, as mentioned above, that IoT devices have been deployed in Kenya for a number of 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 653,000 in 2021 (see Graphic 6-1).

Graphic 6-1. Kenya: Installed base of M2M devices (2010-2020)



Source: GSMA Intelligence

On the other hand, the IoT Kenyan market in 2021 is estimated at US$130 million.[62] 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 Kenyan eco-system suppliers in the IoT segment, and (ii) the spillover of IoT on the efficiency of Kenyan industries.

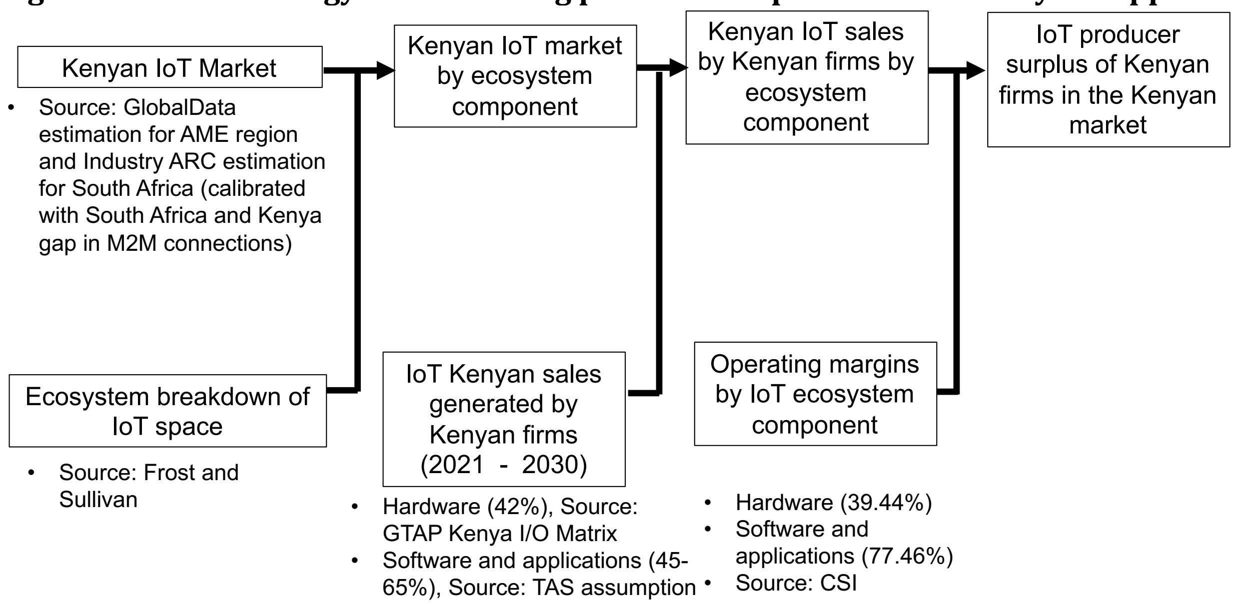
6.2. Producer surplus of Kenyan IoT eco-system firms

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

[62] Telecom Advisory Services estimation based on Global Data for AME Region and Industry ARC, GSMA, and Frost & Sullivan.

surplus (i.e., operating margins) for the Kenyan suppliers of hardware, software, and systems integration (see figure 6-1)

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



Source: Telecom Advisory Services

To estimate the producer surplus, we begin by estimating the Kenyan IoT market, disaggregating it by ecosystem components. The starting point is the Global Data estimation for AME region and Industry ARC estimation for South Africa (calibrated by the gap between Kenya and South Africa in M2M adoption) for 2021, on which a constant growth rate is assumed until 2030. The total market is disaggregated in terms of the ecosystem components based on the estimates provided by Frost & Sullivan (see Table 6-1).

Table 6-1. Kenya: IoT market (2021-2030)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
(1) Industrial IoT revenue in Kenya (US$ billion)	$0.13	$0.16	$0.18	$0.21	$0.25	$0.30	$0.37	$0.45	$0.55	$0.67
(2) Hardware IoT revenue in Kenya (US$ billion)	$0.06	$0.07	$0.08	$0.09	$0.11	$0.13	$0.16	$0.20	$0.24	$0.29
(3) Software and Services IoT revenue in Kenya (US$ billion)	$0.07	$0.09	$0.10	$0.12	$0.14	$0.17	$0.21	$0.25	$0.31	$0.38

Sources: Global Data (2021); GSMA; Industry ARC; Frost & Sullivan (2018); Telecom Advisory Services analysis

On this basis, the market share served by Kenyan 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 Kenya, which is calculated with data from the General Trade Accounting Project (GTAP). The share of the software and systems integration segment is assumed with an initial value of 45%, increasing to 65% at the end of the period, indicating a growing importance of the digital economy in the country (see table 6-2) .

Table 6-2. Kenya: Share of IoT market served by Kenyan suppliers (2021-2030)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Hardware	42%	42%	42%	42%	42%	42%	42%	42%	42%	42%
Software and Apps	45%	50%	55%	60%	65%	65%	65%	65%	65%	65%

Sources: Frost & Sullivan (2018); GTAP; ABI Research (2020); Telecom Advisory Services analysis

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

Table 6-3. Kenya: Producer surplus of Kenyan IoT suppliers (in US$ million) (2021-2030)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Hardware	$10	$11	$13	$15	$18	$22	$27	$33	$40	$49
Software and Apps	$26	$34	$43	$53	$71	$86	$105	$127	$155	$189
Total Surplus	$35	$45	$56	$68	$89	$108	$132	$160	$195	$238
Surplus attributable to 6 GHz	$0	$21	$16	$19	$25	$30	$37	$45	$54	$66

Sources: Global Data (2021); Industry ARC; Frost & Sullivan (2018); Telecom Advisory Services analysis

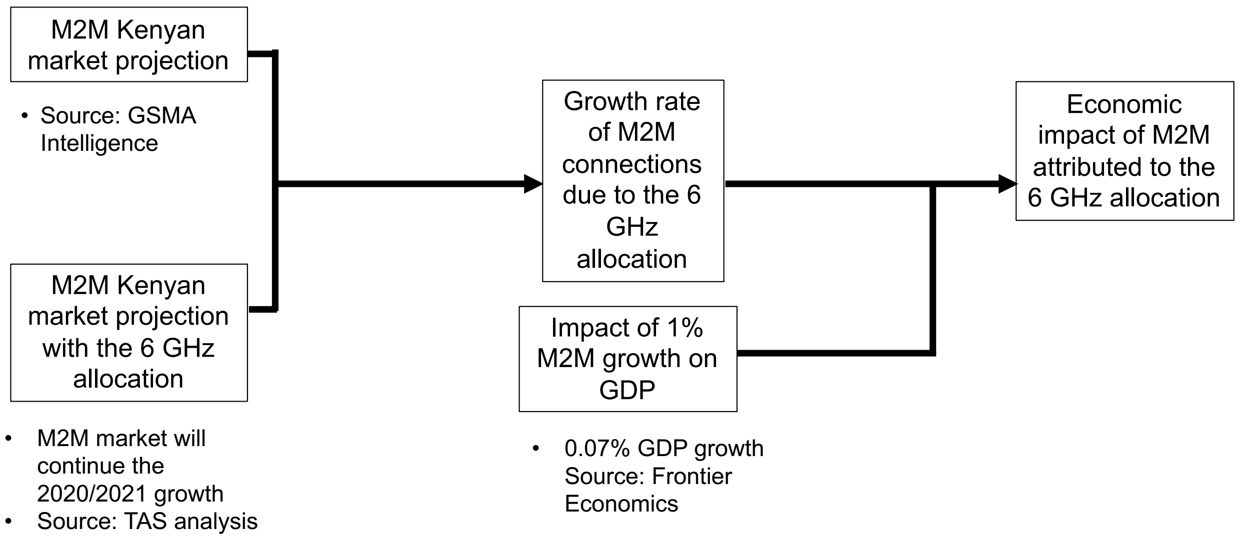
The total cumulative value of producer surplus driven by sales of IoT by Kenyan firms in Kenya amounts to US$312 million.

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

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).[63]

[63] *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 Kenyan 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 2022, the impact of IoT would be 0.02% of GDP. Considering that Kenyan GDP in 2022 will reach US$ 113 billion (line 6 in table 6-4) (source: IMF), it is estimated that the IoT impact for 2022 would reach 20 million (see Table 6-4).

Table 6-4. Kenya: IoT Spillover (in US$ billion) (2021-2030)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
(1) M2M Growth Rate without 6 GHz (%)	7.47%	3.01%	3.01%	3.01%	3.01%	3.01%	3.01%	3.01%	3.01%	3.01%
(2) M2M Growth Rate with 6 GHz (%)	7.47%	5.58%	4.17%	4.17%	4.17%	4.17%	4.17%	4.17%	4.17%	4.17%
(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	0.00%	10.00%	20.00%	30.00%	40.00%	50.00%	60.00%	65.00%	70.00%	75.00%
(5) Impact on GDP (%)	0.00%	0.02%	0.02%	0.02%	0.03%	0.04%	0.05%	0.05%	0.06%	0.06%
(6) Kenyan GDP Billions US$	$106	$113	$121	$130	$140	$152	$164	$177	$191	$206
(7) Total Impact (US$ Billion)	$0	$20	$20	$32	$46	$62	$80	$93	$108	$126

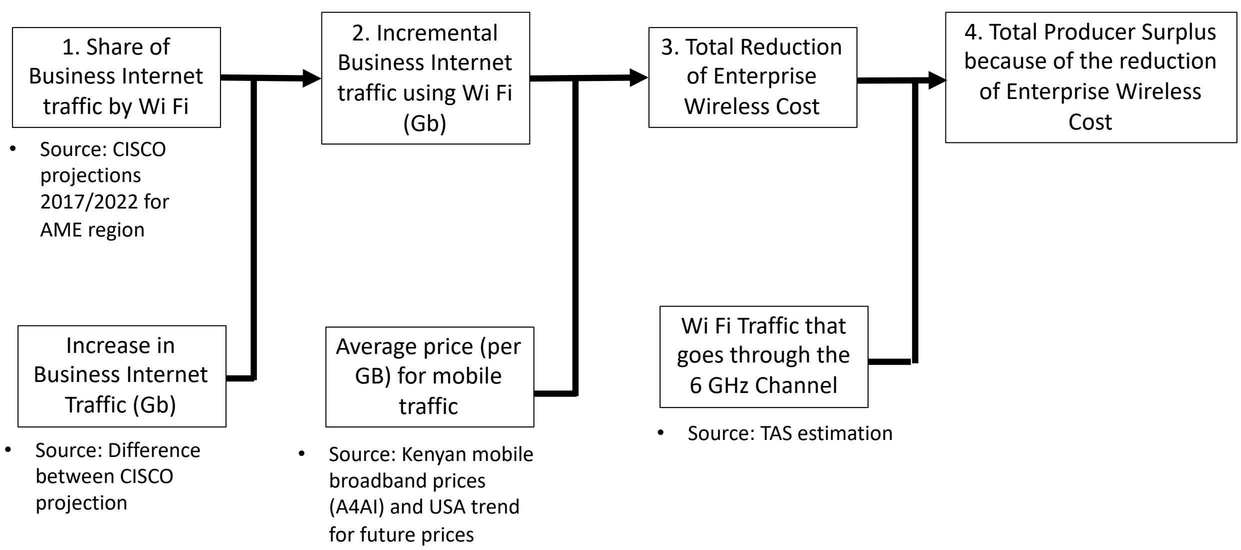
Sources: GSMA Intelligence; Frontier Economics; Telecom Advisory Services analysis

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$ 586 million by 2030.

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, the 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 the Alliance for Affordable Internet (A4AI)[64] (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 Kenya would reach 434 million GB (line 2 in Table 7-1), of which 35.19% 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 444 million GB, of which 35.74 would be transported through Wi-Fi[65] (see line 5 in Table 7-1).

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

[65] Cisco's new forecast includes in its assumption set the deployment of Wi-Fi 6.

Table 7-1. Kenyan: Enterprise Wireless Traffic ('000) (2021-2030)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
(1) Share of Business Internet Traffic by Wi Fi (2016-21)	37.91%	36.53%	35.19%	35.19%	35.19%	35.19%	35.19%	35.19%	35.19%	35.19%
(2) Total Business Internet Traffic (M Gb) (2016-21)	311	374	435	496	613	757	936	1,156	1,429	1,766
(3) Total Wi-Fi Enterprise Traffic (M Gb) (2016-21)	118	136	153	175	216	267	329	407	503	622
(4) Share of Business Internet Traffic by Wi Fi (2017-22)	38.30%	37.00%	35.74%	35.74%	35.74%	35.74%	35.74%	35.74%	35.74%	35.74%
(5) Total Business Internet Traffic (M Gb) (2017-22)	318	382	444	507	626	774	957	1,182	1,461	1,805
(6) Total Wi-Fi Enterprise Traffic (M Gb) (2017-22)	122	141	159	181	224	277	342	422	522	645
(7) Incremental Business Internet Traffic	4	5	6	7	8	10	13	15	19	24

Sources: Cisco Visual Networking Index (2017, 2019)

Each growth forecast was converted to dollar values based on the price per GB[66] (see Table 7-2).

Table 7-2. Kenyan: Cost of Enterprise Internet Traffic (2021-2030) (IN US$)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
(5) Average Price per Gb	$1.68	$1.51	$1.36	$1.23	$1.10	$0.99	$0.89	$0.81	$0.72	$0.65
(6) Economic Impact (US$ Million)	$6	$7	$8	$8	$9	$10	$11	$12	$14	$15

Sources: A4AI; Telecom Advisory Services analysis

We assume that part of the traffic growth presented in table 7-2 will be driven 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 the remainder will be triggered by Wi-Fi traffic stimulated by changes in 6 GHz (see Table 7-3).

[66] According to the Alliance for Affordable Internet, in 2020 the price for a 10 GB plan was US$18.65. When converted to price per GB for the highest capacity plan, it resulted in US$ 1.87. The coefficient of decline per annum was 0.8994 based on international price evolution per GB

Table 7-3. Kenya: Enterprise Wireless Traffic: Growth triggered by broader Wi-Fi traffic (2020-2030) (in '000'000 US$)

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
(7) Traffic through 6 GHz Band	0.00%	7.50%	15.00%	22.50%	30.00%	37.50%	45.00%	52.50%	60.00%	67.50%	75.00%
(8) Economic impact of 6 GHz Band (US$ million)	$0	$1	$2	$2	$4	$5	$7	$8	$10	$12	$0

Source: Telecom Advisory Services analysis

The sum of the difference due to broader Wi-Fi traffic between 2020 and 2030 will reach US$ 50 million (sum of line 8 in table 7-3).

8. DEPLOYMENT OF AR/VR SOLUTIONS

The 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[67]
	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[68].
	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[69].
Retailing	Guest engagement	Provide customers with mall-wide Wi-Fi coverage, combined with guest engagement content as part of marketing campaigns[70].	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[71] 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[72]

Source: Compilation by Telecom Advisory Services

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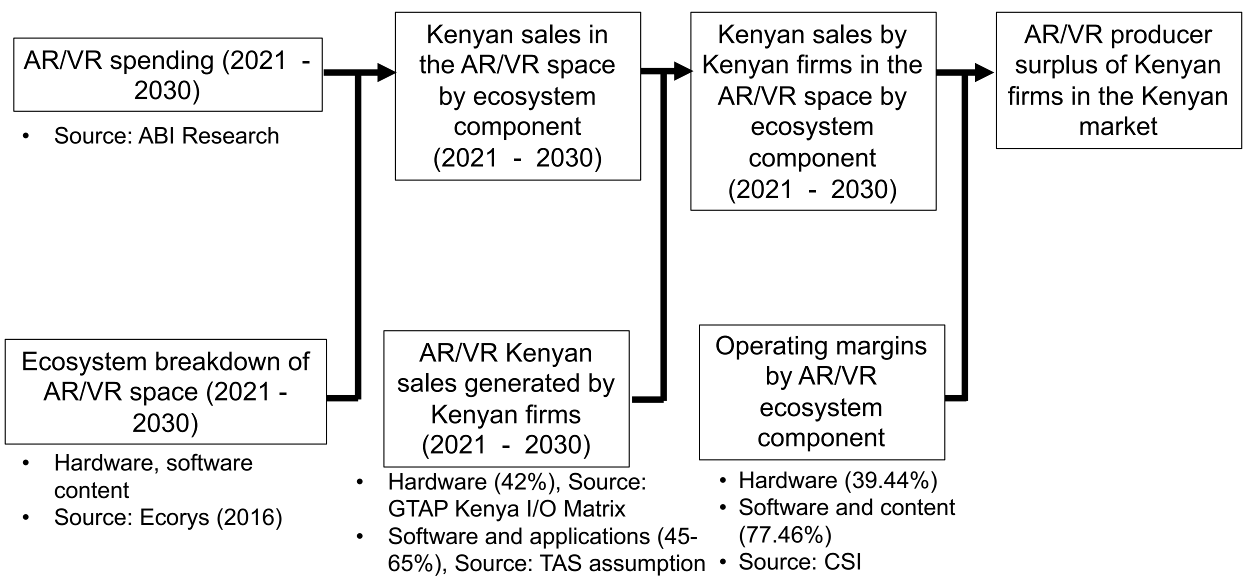
[67] Shieber, J. "Using augmented reality, Altoida is identifying the likely onset of neurodegenerative diseases", *Techcrunch*, May 30, 2019.
[68] Shrieber, J. "Robotics, AR and VR are poised to reshape health-care, starting in the operating room". *Techcrunch*, February 21, 2019.
[69] Preparing for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

The AR/VR market in Kenya is estimated at US$7 million, of which US$2 million is composed of hardware (such as smart and non-smart glasses), and US$5 million is driven by software and applications (including systems integration, platform, and licensing). We estimate that by 2024 the market will reach US$45 billion (US$15 million hardware and US$30 billon software and applications)[73], and US$ 949 million (US$ 319 million hardware and US$630 million software and applications) by 2030. Sales by Kenyan firms to Kenyan businesses will generate producer surplus (i.e. margins), while the technology will also 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 Kenya because of the sales of AR/VR applications produced by domestic firms (see Figure 8-1).

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



Source: Telecom Advisory Services

Our starting point is the sales of AR/VR applications and systems within Kenya between 2021 and 2030 (one could potentially include exports to other countries, although we exclude these for conservative purposes). We estimate this value by prorating MEA projections for Kenya based on its M2M adoption and breaking it down by ecosystem component according to ABI Research (2019, 2020) studies (see table 8-2).

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[73] Data calculated based on MEA totals as estimated by ABI Research (2019, 2020).

Table 8-2. Kenya: AR/VR market by component (2020-2030) (in US$ millions)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Hardware	$25	$42	$69	$115	$192	$319	$25	$42	$69	$115
Software & Applications	$49	$82	$137	$227	$378	$630	$49	$82	$137	$227
TOTAL	$74	$124	$206	$343	$570	$949	$74	$124	$206	$343

Sources: ABI Research (2020); Telecom Advisory Services analysis

Sales are broken down by two ecosystem components: hardware, and applications/ software, but each component is restricted to Kenyan firms, because our purpose is to estimate the value generated by the domestic producers (therefore, we exclude sales in Kenya generated by foreign firms). 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 Kenya, which is calculated with data from the General Trade Accounting Project (GTAP). The share of the software and systems integration segment is assumed to be of an initial value of 45%, increasing to 65% at the end of the period, indicating a growing importance of the digital economy in the country. This recognizes that the development of this market should be accompanied by a concerted industrial policy aimed at developing local firms in these two components (see Table 8-3).

Table 8-3. Kenya: AR/VR sales by Kenyan firms by component (2021-2030) (in US$ millions)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Hardware	$1	$2	$3	$6	$11	$18	$29	$49	$81	$134
Software & Applications	$2	$5	$10	$18	$32	$53	$89	$148	$246	$409
TOTAL	$3	$7	$14	$24	$43	$71	$118	$196	$327	$544

Sources: ABI Research (2019; 2020); Telecom Advisory Services analysis

Once sales by Kenyan firms in the Kenyan market are calculated, producer surplus for the AR/VR Kenyan 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. Kenya: Producer surplus derived from AR/VR sales by Kenyan firms by component (2021-2030) (in US$ millions)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Hardware	$0	$1	$1	$2	$4	$7	$12	$19	$32	$53
Software & Applications	$2	$4	$8	$14	$25	$41	$69	$115	$191	$317
TOTAL	$2	$5	$9	$16	$29	$48	$80	$134	$222	$370

Sources: CSI Market Inc*: Industry Profitability ratios; ABI Research (2019, 2020); Telecom Advisory Services analysis*

It is clear that 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 has already begun before this potential spectrum change. 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 24.58% of sales in 2021 and 53.87% in 2030. Based on this analysis, the cumulative producer surplus to be generated by Kenyan AR/VR firms from sales in the Kenyan market between 2020 and 2030 due to the 6 GHz allocation will amount to US $431 millions (see Table 8-5).

Table 8-5. Kenya: AR/VR sales by US firms by component attributed to the designation of Very Low Power devices within the 6GHz band (2020-2030) (in US$ billions)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Due to 6 Ghz (%)	24.58%	25.59%	26.64%	27.73%	28.87%	33.87%	38.87%	43.87%	48.87%	53.87%
Due to 6 GHz (US$ M)	$1	$1	$2	$5	$8	$16	$31	$59	$109	$199

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

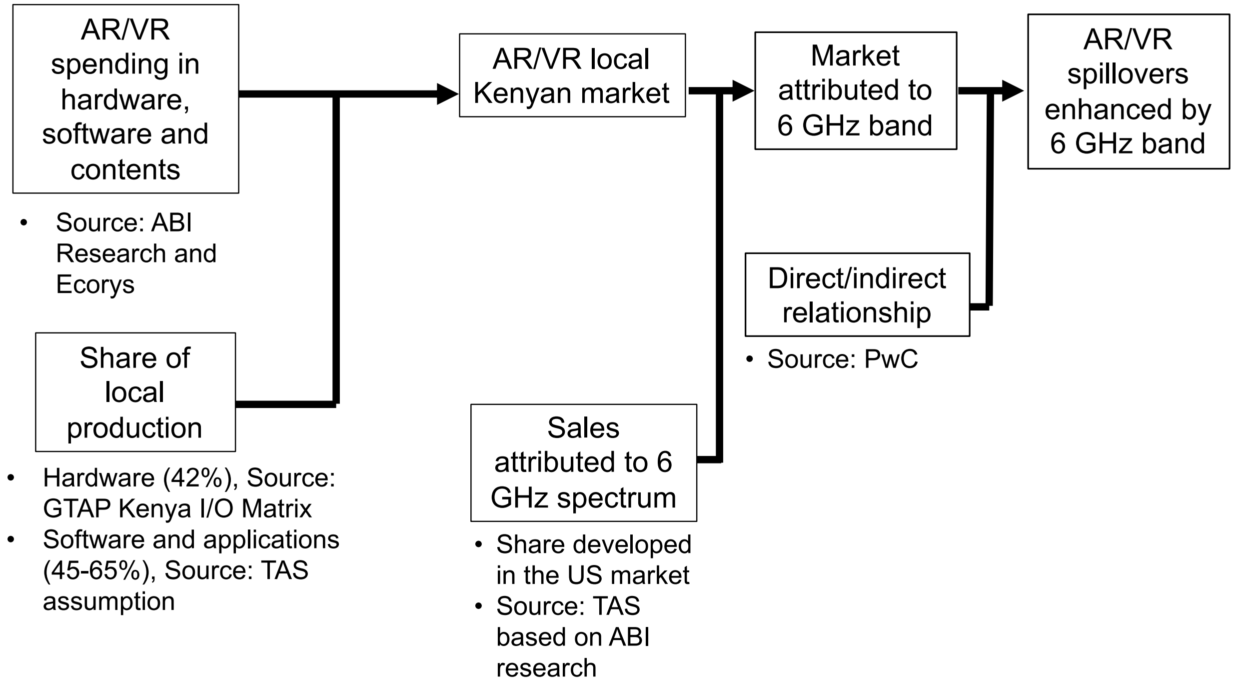
8.2. Spillovers from Virtual Reality and Augmented Reality

The adoption of AR/VR among Kenyan businesses will in turn have a spillover effect on 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 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 Kenyan 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[74], and the sales of AR/VR components as derived from ABI Research data (see table 8-1). These two parameters allow estimating the indirect (that is to say spillover) contribution of AR/VR to the Kenyan economy (see Figure 8-2).

[74] 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 Kenya



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. Kenya: GDP Contribution resulting from AR/VR Spillovers (2020-2030) (in US$ billion)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
AR/VR Boost to GDP (% GDP)	0.15%	0.20%	0.25%	0.31%	0.38%	0.46%	0.56%	0.70%	0.89%	1.12%
Kenya GDP (US$ Billions)	$106	$113	$121	$130	$140	$152	$164	$177	$191	$206
AR/VR Boost to GDP (US$ Billions)	$0.16	$0.23	$0.30	$0.40	$0.53	$0.70	$0.92	$1.24	$1.70	$2.31
AR/VR Boost to GDP without 6.0 GHz Band (US$ Billions)	$0.12	$0.17	$0.22	$0.29	$0.38	$0.46	$0.56	$0.69	$0.87	$1.07
AR/VR Boost to GDP due to 6.0 GHz Band (US$ Billions)	$0.04	$0.06	$0.08	$0.11	$0.15	$0.24	$0.36	$0.54	$0.83	$1.24
Direct impact (US$ Billions)	$0.00	$0.00	$0.01	$0.01	$0.02	$0.04	$0.08	$0.15	$0.28	$0.51
Indirect impact (US$ Billions)	$0.04	$0.05	$0.07	$0.10	$0.13	$0.19	$0.28	$0.39	$0.55	$0.73
Indirect impact considered (US$ Millions)	$3	$7	$14	$25	$43	$84	$160	$301	$552	$733

Sources: ABI Research (2019); CSI Market Inc*: Industry Profitability ratios; Telecom Advisory Services analysis.*

Total spillover value of AR/VR in Kenya (the indirect impact) between 2021 and 2030 is US$1.92 billion, considering a maximum multiplier between the direct effect and the indirect effect of 2.0.

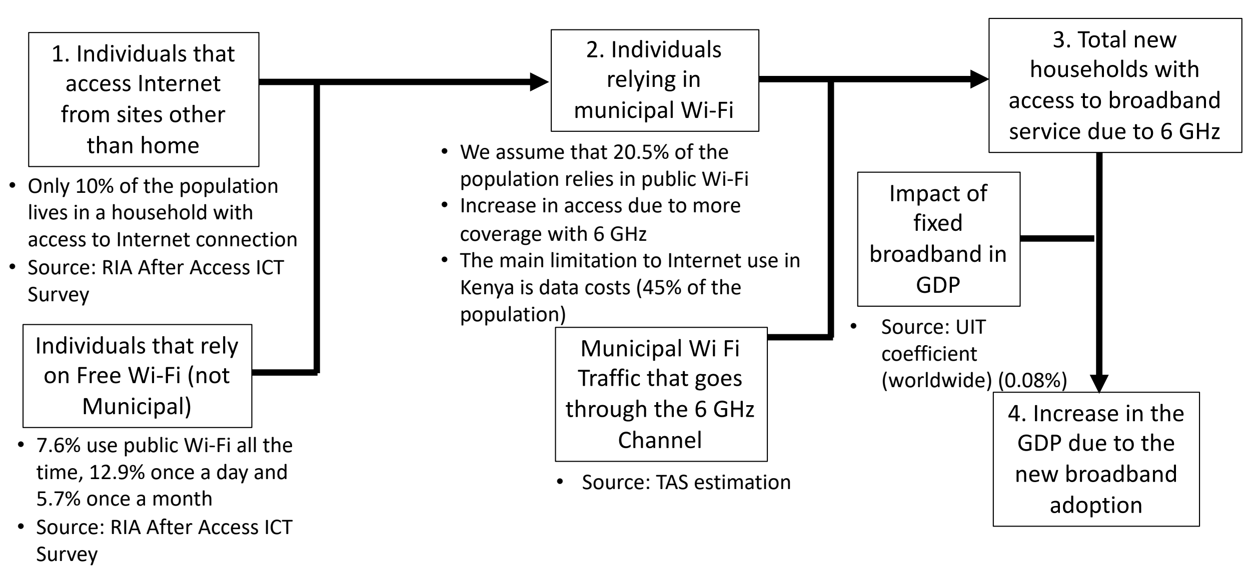
9. ENHANCED DEPLOYMENT OF MUNICIPAL WI-FI

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. For example, the Nairobi County government provides free Wi-Fi access in select areas of the city.[75] Based on Research ICT Africa, only 10% of the Kenyan population lives in a household with access to an Internet connection. In a context of the affordability barrier pointed above, public Wi-Fi represents a viable option of Internet access. This is confirmed by the Research ICT Africa Survey, which reports that 7.5% Internet users use public Wi-Fi all the time, 12.9% once a day, and 5.7% once a month.[76] Consumers who do not have broadband at home because they lack economic resources to acquire service can rely on municipal Wi-Fi to gain Internet access. Along these lines, allocating spectrum in the 6 GHz band will increase the ability of municipal Wi-Fi to provide free service to 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

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[75] Lukhanyu, M. (2019). *Telkom & Nairobi County to provide free public Wi-Fi to city residents*. Retrieved in: https://techmoran.com/2019/06/06/telkom-nairobi-county-to-provide-free-public-wi-fi-to-city-residents/
[76] Nyambura Ndung'u, M., Lewis, C. and Mothobi, O. (2019). *The State of ICT in Kenya*. Research ICT Africa, p. 29.

The estimation of municipal Wi-Fi benefit from gaining access to the 6 GHz band begins by considering current service users (line 1 in table 9-1). This is based on the population that reports using public Wi-Fi all the time (7.5% of the population) and the ones that report using public Wi-Fi once a day (12.9% of the population). That universe (10,209,205 in 2021) (line 2 in table 9-1) will be impacted by the 6 GHz in terms of their consumer surplus. In addition, a percentage of the Kenyan population uses Wi-Fi hotspots (2,838,657 in 2021) (line 3 in table 9-1) or fixed broadband (4,438,379) (line 4 in table 9-1). By adding the three groups, we estimate that 17,486,241 Kenyans have access to broadband. In addition, GSMA Intelligence projects that 27,405,490 Kenyans have a smartphone. By subtracting total broadband users from total smartphone holders, we estimate that 9,919,250 Kenyans are potential users of municipal Wi-Fi in 2021 (line 6 of table 9-1). This is because since they do not have Internet access through broadband service, they must rely on mobile broadband. Under this scenario, they could access the Internet through municipal Wi-Fi to avoid cellular data cost. Considering that only 7.50% of that group will be future users of the service, we estimate the impact of future deployment of municipal Wi-Fi with the 6 GHz band (Table 9-1).

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

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
(1) Individuals that connect from Free Wi-Fi (M)	13.05	13.34	13.64	13.94	14.25	14.56	14.88	15.20	15.53	15.87
(2) Individuals that rely on Municipal Wi-Fi (M)	10.21	10.44	10.67	10.91	11.15	11.39	11.64	11.89	12.15	12.42
(3) Individuals that rely on free Wi-Fi traffic offered in public sites (M)	2.84	2.90	2.97	3.03	3.10	3.17	3.24	3.31	3.38	3.45
(4) Individuals that live in a household with FBB (M)	4.44	5.49	6.51	7.45	8.28	8.99	9.59	10.18	10.81	11.48
(5) Individuals with a smartphone (M)	27.41	29.08	30.52	31.79	32.89	34.03	35.21	36.42	37.69	38.99
(6) Potential Free Wi-Fi Market (M)	9.92	10.25	10.37	10.40	10.36	10.48	10.74	11.04	11.34	11.64
(7) Share of the potential Free Wi-Fi Market that would be covered by Free Wi-Fi	7.50%	7.50%	7.50%	7.50%	7.50%	7.50%	7.50%	7.50%	7.50%	7.50%
(8) Share of the potential Free Wi-Fi Market that would be covered by Municipal Wi Fi	78.24%	78.24%	78.24%	78.24%	78.24%	78.24%	78.24%	78.24%	78.24%	78.24%
(9) Traffic through 6 GHz Band	0.00%	10.00%	20.00%	30.00%	40.00%	50.00%	60.00%	65.00%	70.00%	75.00%
(10) New individuals that now can have broadband (M)	0.00	0.06	0.12	0.18	0.24	0.31	0.38	0.42	0.47	0.51
(11) New households that now can have broadband (M)	0.00	0.01	0.03	0.04	0.06	0.07	0.09	0.10	0.11	0.12
(12) Households with Fixed Broadband (M)	1.04	1.29	1.53	1.75	1.94	2.11	2.26	2.40	2.55	2.72

(13) Increase in national broadband penetration	0.00%	1.10%	1.87%	2.46%	2.94%	3.42%	3.94%	4.13%	4.31%	4.46%
(14) Impact of fixed broadband adoption in GDP	8.00%	8.00%	8.00%	8.00%	8.00%	8.00%	8.00%	8.00%	8.00%	8.00%
(15) Increase in the GDP due to the new broadband adoption (% GDP)	0.00%	0.09%	0.15%	0.20%	0.24%	0.27%	0.32%	0.33%	0.34%	0.36%
(16) GDP (US$ Billion)	$106	$113	$121	$130	$140	$152	$164	$177	$191	$206
(17) Total impact in GDP (US$ Billion)	$0.00	$0.10	$0.18	$0.26	$0.33	$0.41	$0.52	$0.58	$0.66	$0.74

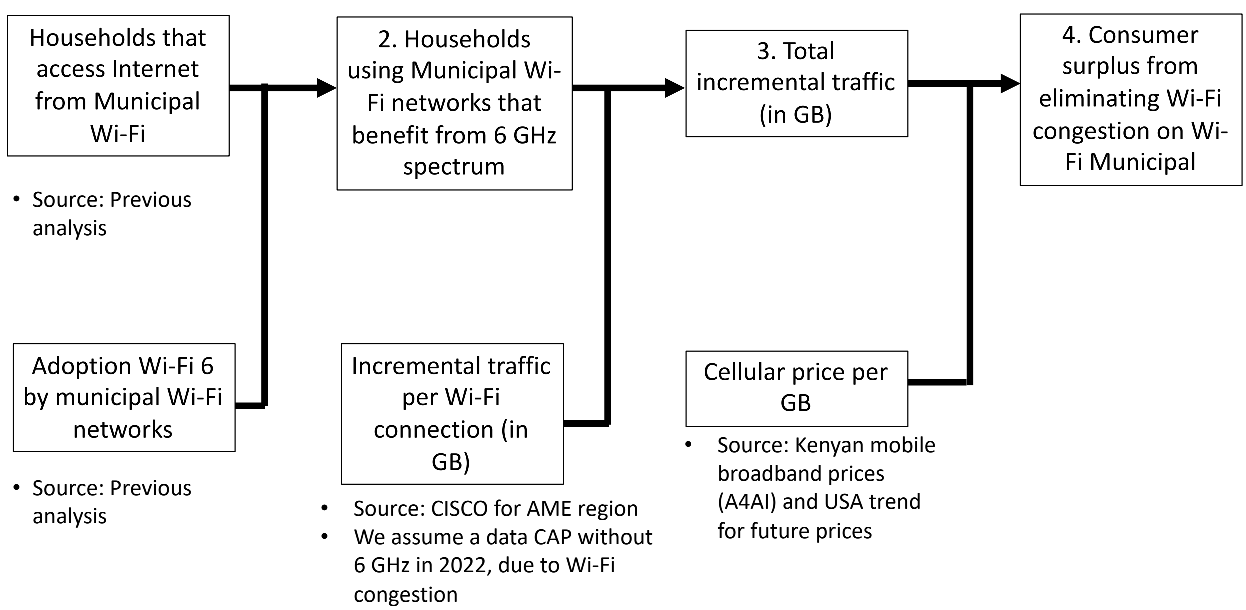
Sources: IMF; GSMA; ITU; Communication Authority of Kenya; RIA; Telecom Advisory Services analysis.

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$3.78 billion (sum of line 17 of table 9-1).

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

This analysis estimates the difference in the download speed of municipal Wi-Fi service before and after the allocation of 6 GHz spectrum for those users 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: this amount is 10,209,205 users in 2021, reaching 12,927,657 in 2030 (line 2 in table 9-1).

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

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
(1) Individuals that rely on Municipal Wi-Fi (M)	10.21	10.44	10.67	10.91	11.15	11.39	11.64	11.89	12.15	12.42
(2) New individuals that now can have broadband using Municipal Wi-Fi(M)	0.00	0.06	0.12	0.18	0.24	0.31	0.38	0.42	0.47	0.51
(3) Total Individuals that rely on Municipal Wi-Fi (M)	10.21	10.50	10.79	11.09	11.39	11.70	12.02	12.31	12.62	12.93

Sources: RIA; Telecom Advisory Services analysis.

These users will benefit from the incremental traffic generated under Wi-Fi 6. To estimate this, we assume that current traffic per line stays 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 Kenya as reported by the Alliance for Affordable Internet for Kenya (see table 9-3).

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

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
(1) Total Individuals that rely on Municipal Wi-Fi (M)	10.21	10.50	10.79	11.09	11.39	11.70	12.02	12.31	12.62	12.93
(2) Traffic after speed increase (Gb)	3.70	5.20	6.70	8.20	9.70	11.20	12.69	14.19	15.69	17.19
(3) Traffic with speed without 6 GHz (Gb)	3.70	5.20	6.70	8.20	9.70	9.70	9.70	9.70	9.70	9.70
(4) Yearly Increase in traffic (Billions of Gb)	0.000	0.000	0.000	0.000	0.000	0.196	0.403	0.619	0.845	1.083
(5) Price per Gb	$1.68	$1.51	$1.36	$1.23	$1.10	$0.99	$0.89	$0.81	$0.72	$0.65
(6) Total impact in consumer surplus (US$ Billion)	0.000	0.000	0.000	0.000	0.000	0.195	0.360	0.498	0.613	0.707

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$ 2.37 billion (sum of line 6 in table 9-3).

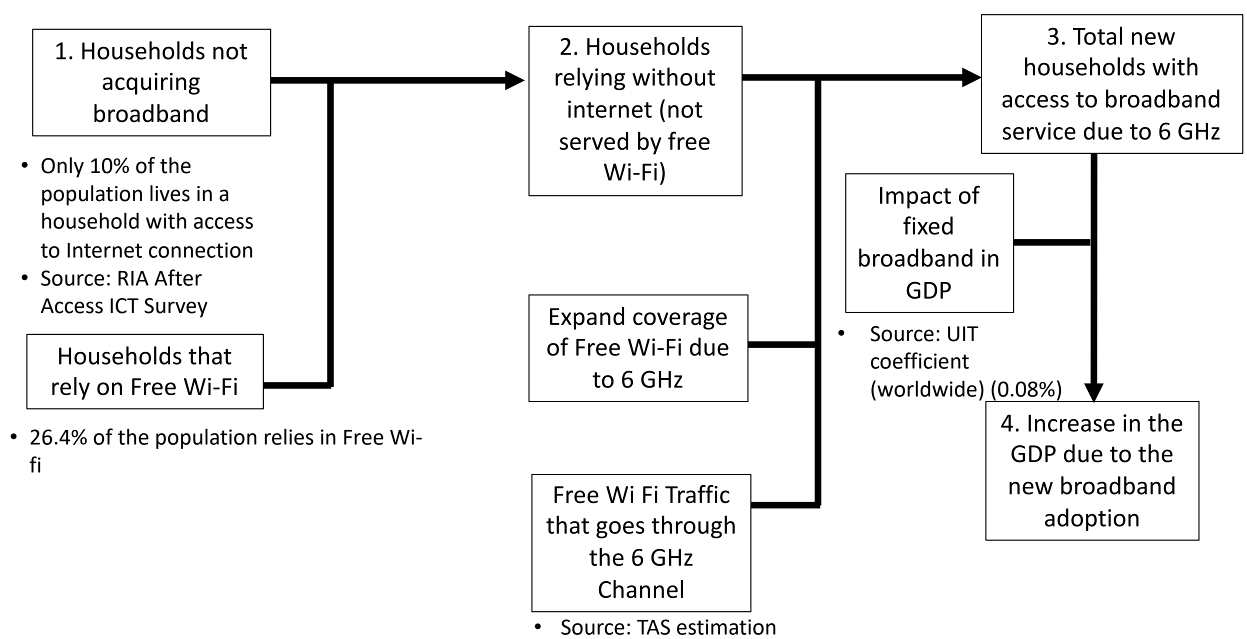
10. DEPLOYMENT OF FREE WI-FI HOT SPOTS

The assessment of economic impact of the 6 GHz allocation in the case of free hot spots is like 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 effect 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 consider the universe of users that can access broadband 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 fixed broadband connection). From this universe, we consider that only 7.50% will be future users of free Wi-Fi (the rest will be using mobile broadband or will not have broadband access). This is the incremental broadband penetration that is used to quantify the impact on GDP by relying on the same coefficient as the one used in the case of municipal Wi-Fi (see table 10-1).

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

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
(1) Individuals that connect from Free Wi-Fi (M)	13.05	13.34	13.64	13.94	14.25	14.56	14.88	15.20	15.53	15.87
(2) Individuals that rely on Municipal Wi-Fi (M)	10.21	10.44	10.67	10.91	11.15	11.39	11.64	11.89	12.15	12.42
(3) Individuals that rely on free Wi-Fi traffic offered in public sites (M)	2.84	2.90	2.97	3.03	3.10	3.17	3.24	3.31	3.38	3.45
(4) Individuals that lives in a household with FBB (M)	4.44	5.49	6.51	7.45	8.28	8.99	9.59	10.18	10.81	11.48
(5) Individuals with a smartphone (M)	27.41	29.08	30.52	31.79	32.89	34.03	35.21	36.42	37.69	38.99
(6) Potential Free Wi-Fi Market (M)	9.92	10.25	10.37	10.40	10.36	10.48	10.74	11.04	11.34	11.64
(7) Share of the potential Free Wi-Fi Market that would be covered by Free Wi-Fi	7.50%	7.50%	7.50%	7.50%	7.50%	7.50%	7.50%	7.50%	7.50%	7.50%
(8) Share of the potential Free Wi-Fi Market that would be covered by Municipal Wi Fi	22%	22%	22%	22%	22%	22%	22%	22%	22%	22%
(9) Traffic through 6 GHz Band	0.00%	10.00%	20.00%	30.00%	40.00%	50.00%	60.00%	65.00%	70.00%	75.00%
(10) New individuals that now can have broadband (M)	0.00	0.02	0.03	0.05	0.07	0.09	0.11	0.12	0.13	0.14
(11) New households that now can have broadband (M)	0.00	0.00	0.01	0.01	0.02	0.02	0.02	0.03	0.03	0.03
(12) Households with Fixed Broadband (M)	1.04	1.29	1.53	1.75	1.94	2.11	2.26	2.40	2.55	2.72
(13) Increase in national broadband penetration	0.00%	0.30%	0.52%	0.68%	0.82%	0.95%	1.10%	1.15%	1.20%	1.24%
(14) Impact of fixed broadband adoption in GDP	8.00%	8.00%	8.00%	8.00%	8.00%	8.00%	8.00%	8.00%	8.00%	8.00%
(15) Increase in the GDP due to the new broadband adoption (% GDP)	0.00%	0.02%	0.04%	0.05%	0.07%	0.08%	0.09%	0.09%	0.10%	0.10%
(16) GDP (US$ Billion)	$106	$113	$121	$130	$140	$152	$164	$177	$191	$206
(17) Total impact in GDP (US$ Billion)	$0.00	$0.03	$0.05	$0.07	$0.09	$0.12	$0.14	$0.16	$0.18	$0.20

Sources: IMF; GSMA; ITU; Communication Authority of Kenya; RIA; Telecom Advisory Services analysis.

The cumulative GDP contribution to be generated by this effect amounts to US$1.05 billion (sum of line 17 in table 10-1).

In addition to this effect, the 6 GHz band will contribute to incremental revenues from paid Hot Spot service. Assuming that paid Wi-Fi sites will be able to increase their capacity by 40%, the cumulative contribution of this effect between 2021 and 2030 to GDP of US $ 1 million.

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 bring two advantages for users: (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 residential traffic, the value of the additional speed achieved from the 6 GHz band allocation can be estimated (see Table 10-2).

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

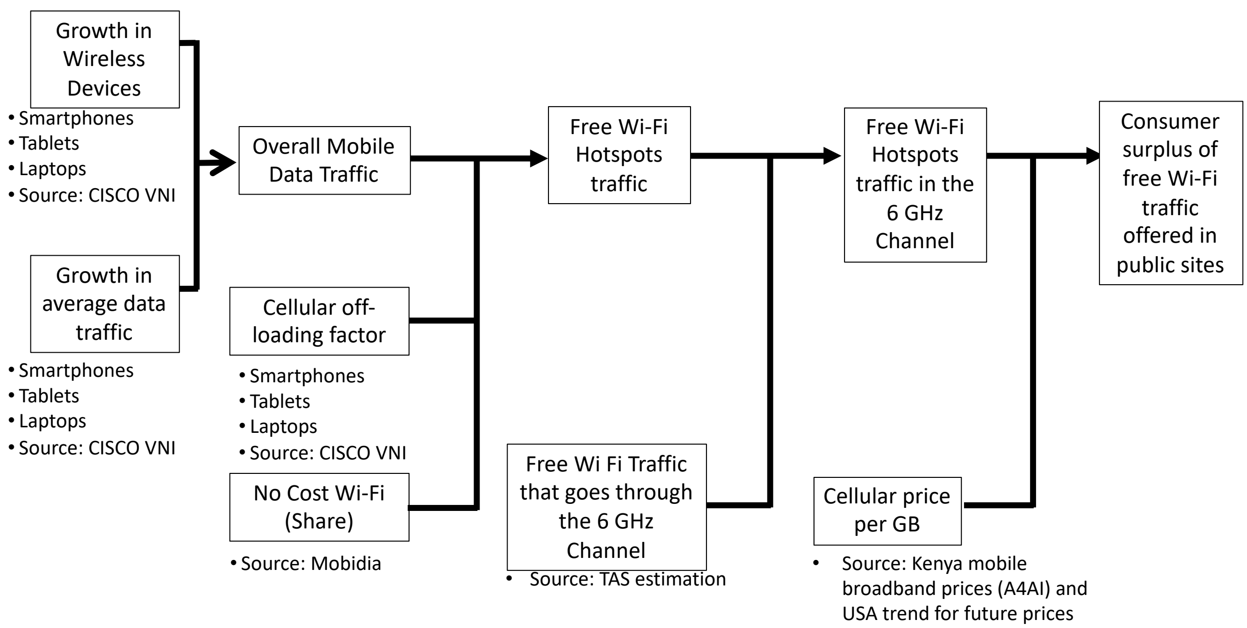
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
(1) Free Wi-Fi mean speed with no 6 GHz (Mbps)	6	6	6	6	6	6	6	6	6	6
(2)Wi-Fi Speeds with 6 GHz (Mbps)	6	6	6	6	6	7	7	7	8	8
(3) Traffic through the 6 GHz Channel (%)	0.00%	10.00%	20.00%	30.00%	40.00%	50.00%	60.00%	65.00%	70.00%	75.00%
(4) Free Wi-Fi mean speed with 6 GHz (Mbps)	6	6	6	6	6	7	7	7	7	8
(5)Demand for average download speed	$29	$29	$29	$29	$30	$30	$30	$30	$30	$30
(6)New Demand for average download speed	$29	$29	$29	$29	$30	$30	$30	$31	$31	$31
(7)Additional Monthly Consumer surplus	$0	$0	$0	$0	$0	$0	$1	$1	$1	$2
(8)Additional Yearly Consumer Surplus	$0	$0	$0	$0	$0	$3	$6	$10	$14	$19
(9)Households that rely on Public Wi-Fi	2.838	2.919	3,001	3.084	3.167	3.252	3.341	3.423	3.508	3.594
(10)Impact ($ million)	$0	$0	$0	$0	$0	$8	$21	$34	$51	$70

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

Based on the estimates from table 10-1, the cumulative contribution of this effect to consumer surplus is US $ 184 million between 2021 and 2030.

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

Figure 10-2. Kenya: 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 traffic congestion at free Wi-Fi sites will limit traffic per device from 2024 onwards, if Wi-Fi 6E is not implemented (see table 10-3)

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

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
(1) Unmet demand due to Free Wi-Fi Congestion (M GB)	14	31	58	108	166	242	340	467	630	840
(2) Traffic through 6 GHz Band	0%	10%	20%	30%	40%	50%	60%	65%	70%	75%
(3) Feasible traffic on the 6 GHz band (M GB)	0	3	12	32	66	121	204	303	441	630
(4) Average price per mobile GB	$1.68	$1.51	$1.36	$1.23	$1.10	$0.99	$0.89	$0.81	$0.72	$0.65
(5) Cost of provisioning free Wi-Fi (per GB)	$0.86	$0.81	$0.76	$0.72	$0.68	$0.65	$0.62	$0.58	$0.56	$0.53
(6) Consumer surplus per GB	$0.82	$0.70	$0.60	$0.51	$0.42	$0.35	$0.28	$0.22	$0.17	$0.12
(7) Consumer surplus generated by 6 GHz band (US$ M)	$0	$2	$7	$16	$28	$42	$57	$67	$75	$78

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

Alternatively, if W-Fi 6E technology is adopted in 2024, the cumulative consumer surplus to be generated by this effect amounts to US$ 372 million (sum of line 7 in table 10-3).

11. ALIGNING SPECTRUM DECISION WITH THAT OF OTHER ADVANCED ECONOMIES

As stated in chapter 3, by allocating spectrum in the 6 GHz band, Kenya will not only alleviate the pressure on unlicensed spectrum resulting from explosive Wi-Fi usage, but will also have implications for the cost of inputs for Kenyan firms and for the country's industrial policy. If Kenya 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 an example such as 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%

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

By extrapolating the trend through 2030 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

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
(1) AR-VR hardware market	$2	$4	$8	$15	$25	$42	$69	$115	$192	$319
(2) IoT Hardware Market	$58	$68	$79	$90	$110	$134	$163	$199	$242	$295
(3) Price reduction due to aligning spectrum decision	-1.33%	-1.77%	-1.66%	-1.61%	-1.54%	-1.47%	-1.40%	-1.34%	-1.28%	-1.22%
(4) Share due to 6GHz	0 %	10 %	20 %	30 %	40 %	50 %	60 %	65 %	70 %	75 %
(5) Impact on producer surplus	$0	$0	$0	$1	$1	$1	$2	$3	$4	$6

Source: Telecom Advisory Services analysis

Furthermore, as mentioned in chapter 3, the Kenyan market for equipment and services in areas related to the implementation of the 6 GHz allocation amounts to US$ 518 million in 2020 but will reach US$ 827 million in 2025 (see table 11-3).

Table 11-3. Kenya: Sales in markets impacted by the 6 GHz decision (in US$ billion) (2020-25)

Market	Categories	2020	2025
Augmented Reality/Virtual Reality	Hardware	$ 0.001	$ 0.025
	Software and applications	$ 0.002	$ 0.049
	Subtotal	$ 0.003	$ 0.074
IoT	Hardware	$ 0.048	$ 0.110
	Software and services	$ 0.061	$ 0.140
	Subtotal	$ 0.109	$ 0.250
Wi-Fi devices	Home networking devices	$ 0.029	$ 0.040
	Wi-Fi enabled devices	$ 0.343	$ 0.426
	Enterprise access points and controllers	$ 0.034	$ 0.037
	Subtotal	$ 0.406	$ 0.503
Total		$ 0.518	$ 0.827

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

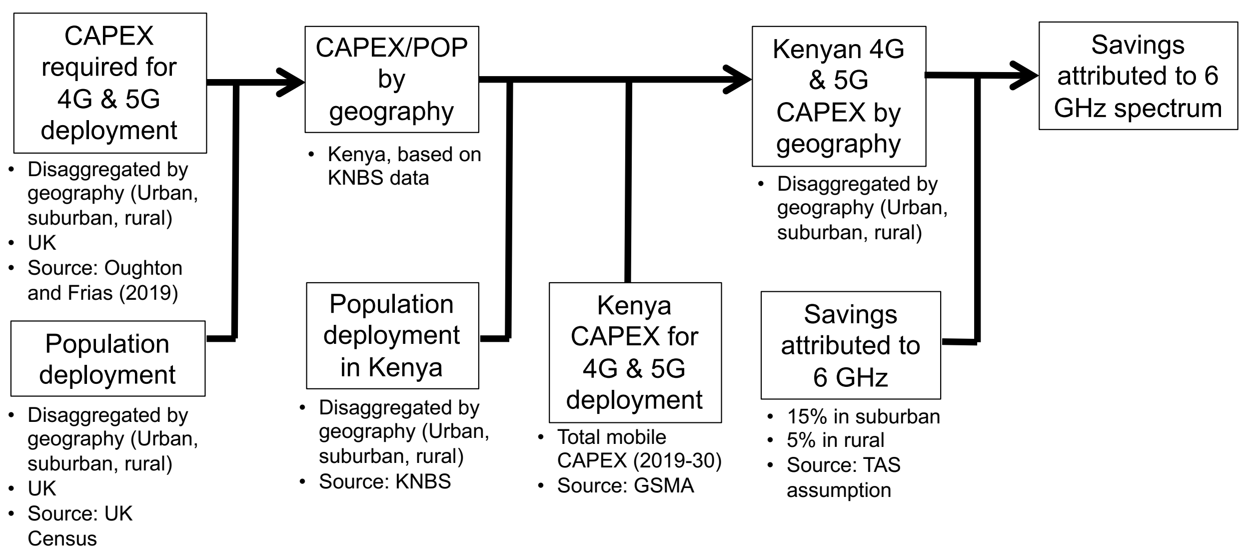
Under such attractive demand conditions, the decisions to be made in terms of the model of allocating the complete 6 GHz spectrum could put Kenya on the path to both meet the needs on local demand and benefitting from the implicit economies of scale derived from advanced markets as well as to increase the opportunity costs of those markets developing first. Additionally, the decision of aligning with this model could potentially give Kenya 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 leverage 160 MHz within a single contiguous channel (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 Kenya between 2019 and 2030: US$2.61 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 $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 Kenya are calculated (Table 12-2).

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

	Population (million)	4G & 5G CAPEX (US$ B)	CAPEX saving (US$ B)
Urban (cities>1 million)	6.07	$0.01	$0.00
Suburban	9.98	$0.04	$0.01
Rural	35.46	$2.57	$0.13
Total	51.51	$2.61	$0.13

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 $0.04 billion for suburban coverage and US$2.57 billion for rural coverage, the implementation of Wi-Fi hotspots leveraging 6 GHz will yield CAPEX savings of US$ 130 million[77]. These will be critical in terms of allowing carriers to extend their 5G coverage further into rural geographies.

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

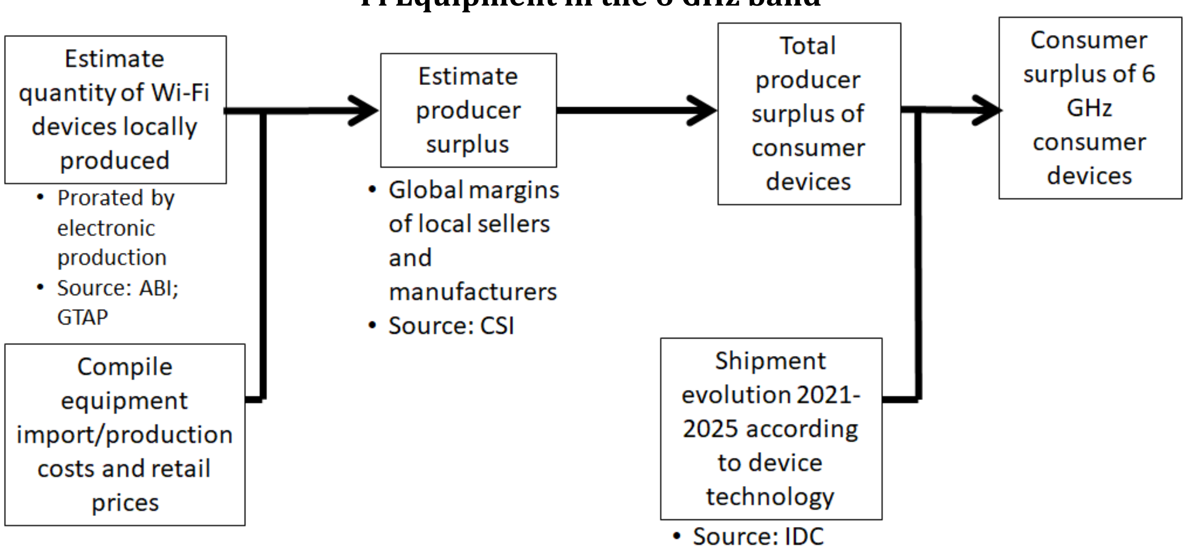
13. PRODUCTION AND ADOPTION OF WI-FI EQUIPMENT

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 Kenya and for the producer surplus we consider the equipment that is manufactured in Kenya. 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 Kenya. We proceed by interpolating data from the US and world markets and assume a level for Kenya based on the corresponding GDP share. After that, we apply the prorated margin estimated by CSI markets which yields an estimated producer surplus for these particular 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 consumer surplus in Kenya generated by the sale of Wi-Fi devices in the 6 GHz band between 2021 and 2030.

To this end, the producer surplus generated by Wi-Fi devices on bands other than 6 GHz (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 Kenya (2021-2030)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
(1) Wireless speakers	$338	$366	$400							
(2) Security systems	$24	$25	$26							
(3) Home networking systems	$32	$36	$40							
(4) Access points	$16	$16	$17							
(5) External adapters	$0	$0	$0							
(6) Routers	$9	$9	$10							
(7) Gateways	$9	$9	$10							
(8) Gross margin	39.44%	39.44%	39.44%	39.44%	39.44%	39.44%	39.44%	39.44%	39.44%	39.44%
(9) Producer surplus (US$ millions)	$169	$182	$198	$196	$190	$177	$156	$123	$74	$1

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 (2021-2030)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
(1) Producer surplus (US$ millions)	$169	$182	$198	$196	$190	$177	$156	$123	$74	$1
(2) Global shipments ratio in the 6 GHz band / without the 6 GHz band	4%	9%	19%	29%	40%	58%	90%	154%	349%	31321%
(3) Consumer surplus (US$ millions)	$6	$16	$37	$57	$77	$104	$140	$190	$256	$347

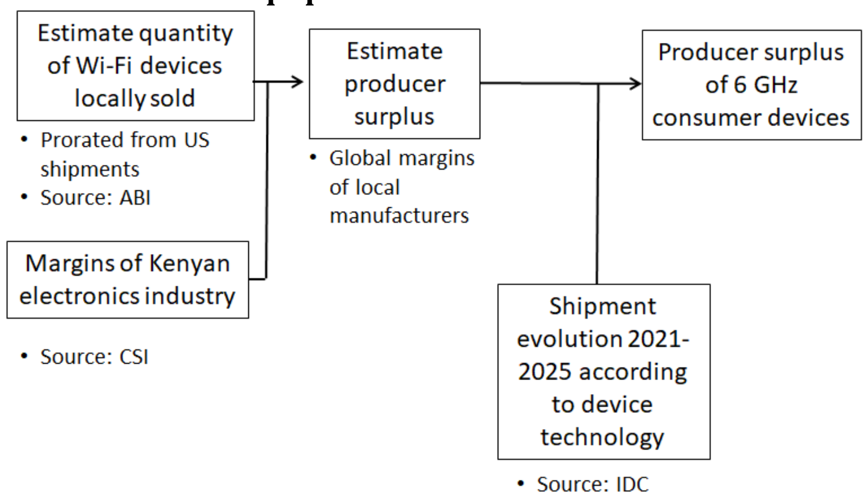
Sources: ABI; CSI; IDC; Telecom Advisory Services analysis

The total accumulated impact of consumer surplus between 2021-2030 due to this effect amounts to US $ 1.23 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 Kenya we start by compiling global manufacturers' sales for each product category in Kenya. Since in this case, what we are trying to estimate the local production instead of 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 the methodology presented, it is possible to estimate the producer surplus in Kenya generated by the sale of Wi-Fi devices in the 6 GHz band between 2021 and 2030 (see Table 13-3)

Table 13-3. Producer surplus as a result of Wi-Fi Equipment sales of devices manufactured in Kenya outside the 6 GHz band (2021-2030)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
(1) Wireless speakers	$58	$60	$63							
(2) Security systems	$4	$4	$4							
(3) Home networking systems	$5	$6	$6							
(4) Access points	$0	$0	$0							
(5) External adapters	$0	$0	$0							
(6) Routers	$0	$0	$0							
(7) Gateways	$0	$0	$0							
(8) Gross margin	39.44%	39.44%	39.44%	39.44%	39.44%	39.44%	39.44%	39.44%	39.44%	39.44%
(9) Producer surplus (US$ millions)	$27	$28	$29	$28	$27	$26	$23	$18	$11	$0

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 Kenya (2021-2030)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
(1) Producer surplus (US$ millions)	$27	$28	$29	$28	$27	$26	$23	$18	$11	$0
(2) Global shipments ratio in the 6 GHz band / without the 6 GHz band	4%	9%	19%	29%	40%	58%	90%	154%	349%	31321%
(3) Producer surplus (US$ millons)	$1	$2	$5	$8	$11	$15	$20	$27	$37	$50

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

The total accumulated impact of the producer surplus between 2021-2030 due to this effect amounts to US $ 178 million (sum of line 3 in table 13-4).

14. AGGREGATE 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 Kenya will generate cumulative economic value between 2021 and 2030 reaching US$20.29 billion, broken down in US$14.28 billion in additional GDP, US$1.12 in producer surplus (which includes both margins for Kenyan technology suppliers to meet local demand and savings from enterprise wireless use and capital from telecommunications carriers engaged in 5G deployment), and US$4.89 billion in consumer surplus (benefits to consumers in terms of lower cost per Mbps and faster speed) (see table 14-1).

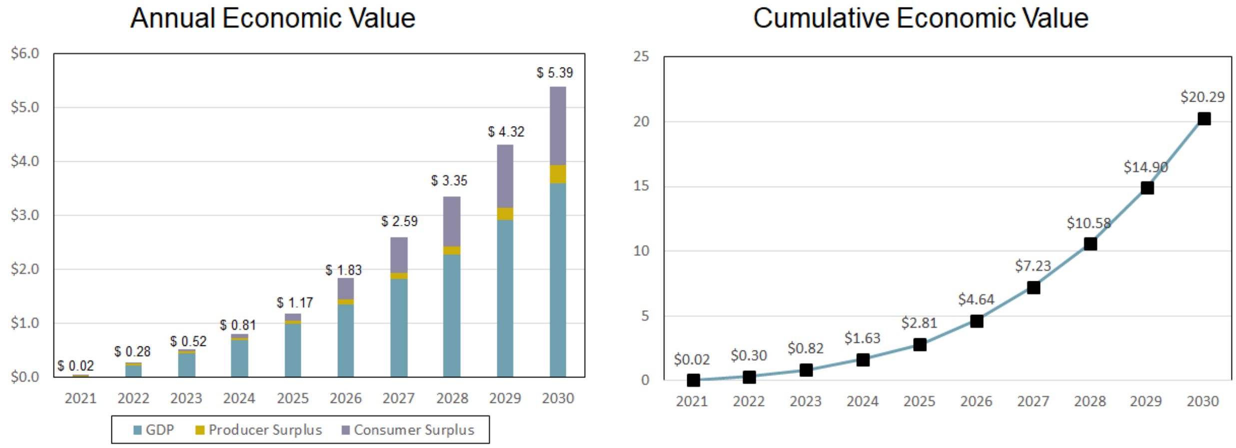
Table 14-1. Kenya: Economic Value of Allocating 1200 MHz in 6 GHz Band (2021-2030) (in US$ billions)

Source of Value	GDP contribution	Producer surplus	Consumer surplus
Enhance coverage and improve affordability	**$ 5.50**		**$ 0.04**
Increased speed by reducing Wi-Fi congestion	**$ 1.44**		**$ 0.69**
Wide deployment of Internet of Things	**$ 0.59**	**$ 0.31**	
Reduction of enterprise wireless costs		**$ 0.05**	
Deployment of AR/VR solutions	**$ 1.92**	**$ 0.43**	
Enhanced deployment of municipal Wi-Fi	**$ 3.78**		**$ 2.37**
Deployment of Free Wi-Fi Hot Spots	**$ 1.05**		**$ 0.56**
Aligning spectrum decision with other advanced economies		**$0.02**	
Enhancing the capability for cellular off-loading		**$ 0.13**	
Increasing production of residential Wi-Fi devices and equipment		**$ 0.18**	**$ 1.23**
TOTAL	**$ 14.28**	**$ 1.12**	**$ 4.89**

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).

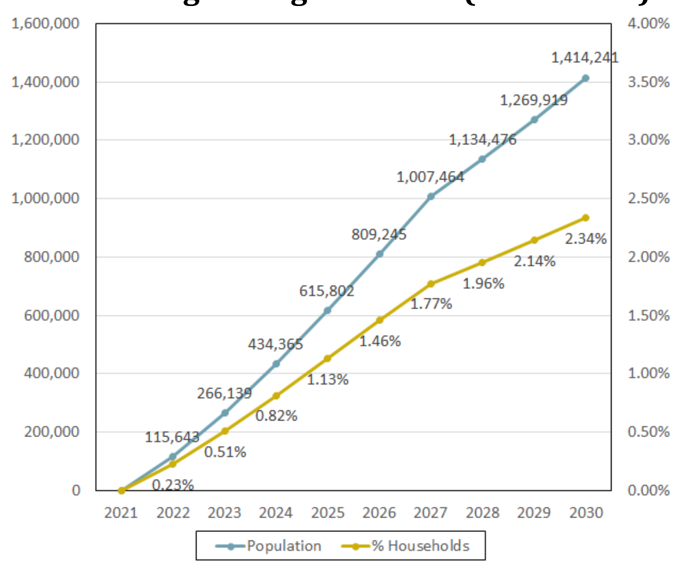
Graphic 14-1. Kenya: Economic value of allocating 1200 MHz in the 6 GHz band



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 Kenya's digital divide. By providing affordable paid service and free access over hot spots as a result of allocating the full 6 GHz band to Wi-Fi, an incremental 1,414,000 Kenyans will be able to gain access to the Internet by 2030 (see Graphic 14-2).

Graphic 14-2. Kenya: Contribution of Allocating 1200 MHz of the 6 GHz Band to closing the digital divide (2021-2030)



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 standpoint.

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