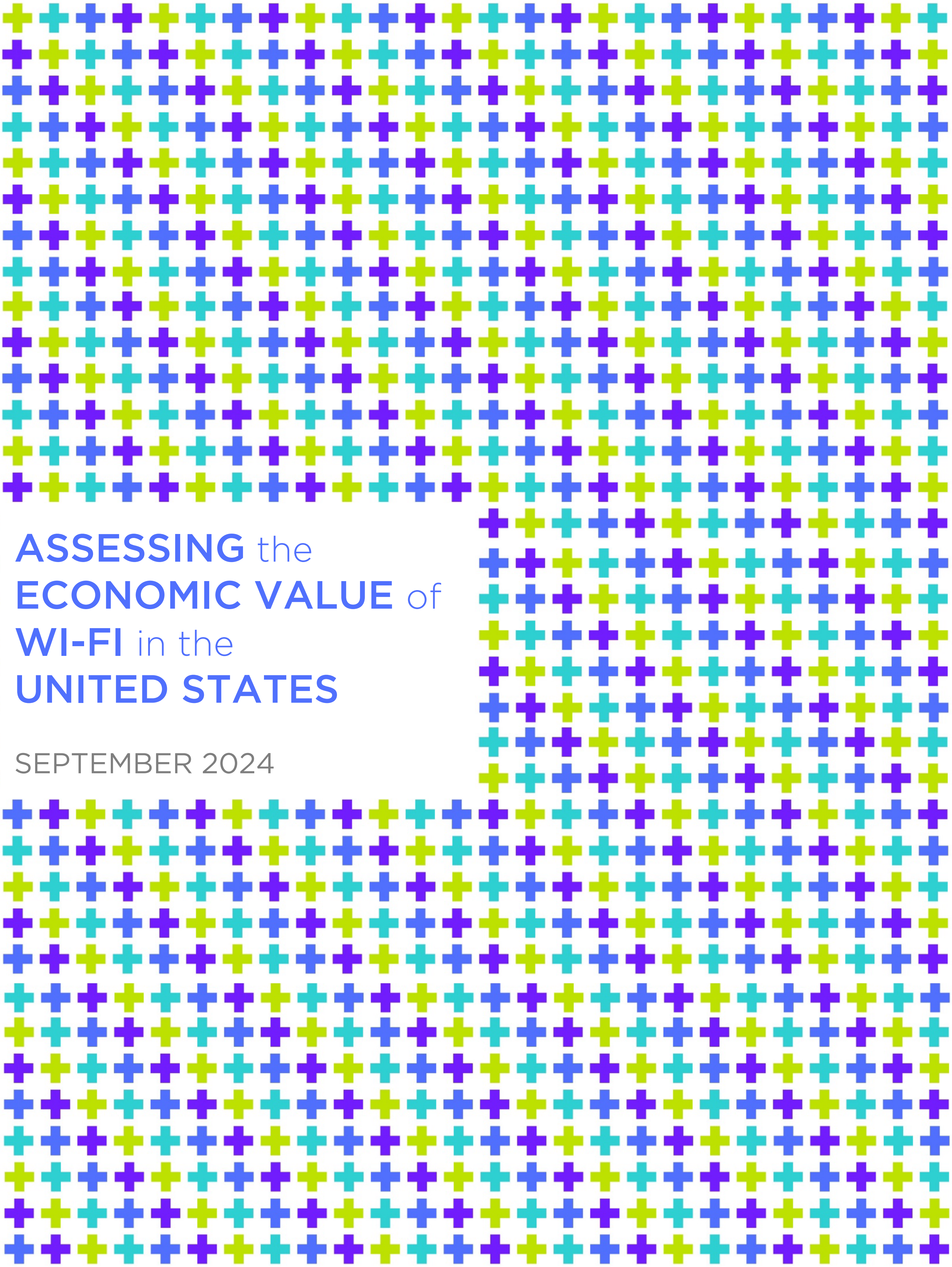


ASSESSING the ECONOMIC VALUE of WI-FI in the UNITED STATES

SEPTEMBER 2024

TELECOM ADVISORY SERVICES, LLC

AUTHORS

Raul Katz – Ph.D. in Political Science and Management Science, M.S. in Communications Technology and Policy from the Massachusetts Institute of Technology (United States), Maîtrise and Licence in Communication Sciences from the University of Paris (France), Maîtrise in Political Science from the University of Paris-Sorbonne (France). Dr. Katz worked at Booz Allen & Hamilton for 20 years as a Lead Partner in the Telecommunications Practice in the Americas and member of the firm's Leadership Team. After retiring from Booz Allen, he founded Telecom Advisory Services LLC in April 2006. In addition to his role as President of Telecom Advisory Services, Dr. Katz is Director of Business Strategy Research at the Columbia Institute for Tele-Information at Columbia Business School (New York) and Visiting Professor at the Telecommunications Management Graduate Program at the Universidad de San Andrés (Argentina).

Juan Jung – Ph.D. and M.A. in Economics, University of Barcelona (Spain), BA in Economics, University of the Republic (Uruguay). Dr. Jung is a Senior Economist at Telecom Advisory Services, specialized in the telecommunications and digital industries. His experience spans economic impact and regulatory assessment in the telecommunications sector. Before joining Telecom Advisory Services, Dr. Jung was Director of the Center of Telecommunication Studies of Latin America (cet.la) and Director of Public Policy at the Inter-American Association of Telecommunications Enterprises (ASIET). Dr. Jung is a professor at the Comillas Pontifical University (Madrid), where he teaches courses in macroeconomics and the digital economy.

Fernando Callorda — B.A. and M.A. in Economics from the University of San Andres (Argentina). Mr. Callorda is a project manager with Telecom Advisory Services, LLC, a researcher affiliated to the National Network of Public Universities of Argentina and professor of Political Economy at UNLAM, where he teaches courses in finance in regulated industries. Before joining Telecom Advisory Services, Mr. Callorda was a staff analyst in the Argentine Congress and auditor with Deloitte.

Ramiro Valencia – B.S. in Electrical and Telecommunications Engineering from the Escuela Politécnica Nacional (Ecuador) and M.A. in Development Economics, FLACSO (Ecuador). Mr. Valencia is a consultant with Telecom Advisory Services, based in Quito, Ecuador, specializing in economics of telecommunications regulation. Prior to joining Telecom Advisory Services, Mr. Valencia had a 12-year career in telecommunications regulation and policymaking in Ecuador. In his last assignment, he was Director of Telecommunications Policy at the Ministry of Telecommunications of Ecuador.

The authors would like to acknowledge the Communications Technology Association (CTA) & ABI Research for the data provided in support of this research.

Telecom Advisory Services LLC (URL: www.teleadvs.com) is a consulting firm registered in the state of New York (United States) with physical presence in New York, Madrid, Buenos Aires, Bogota, and Quito. Founded in 2006, the firm provides advisory and consulting services internationally, specializing in the development of business, economic analysis, and public policy strategies in the telecommunications and digital sectors. Its clients include telecommunications operators, electronic equipment manufacturers, Internet platforms, software developers, as well as the governments and regulators. The firm has conducted numerous economic impact and planning studies of digital technologies for the GSMA, NCTA (USA), Giga Europe, CTIA (USA), the Dynamic Spectrum Alliance, and the Wi-Fi Alliance. Among international organizations, the firm has worked for the International Telecommunication Union, the World Bank, the Inter-American Development Bank, the World Intellectual Property Organization, the UN Economic Commission for Latin America and the Caribbean, CAF Latin American Development Bank, and the World Economic Forum.

This report was commissioned by WiFiForward, a coalition of companies and business organizations to promote the free use of spectrum for unlicensed use. All of the study's content, including its conclusions, are the independent outcome of the analysis conducted solely by the authors and Telecom Advisory Services.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

In just three decades, Wi-Fi technology has become a workhorse of our nation's communications infrastructure and an economic powerhouse driving greater productivity, efficiency, and innovation for American consumers and businesses. As federal policymakers now work to evolve our national spectrum strategy, this study seeks to inform that process by quantifying the economic value of Wi-Fi, including the incremental economic value generated by the FCC's 2020 decision to open up additional unlicensed spectrum in the 6 GHz band. Further, this study seeks to project the incremental economic value that would follow from opening up the 7 GHz band for Wi-Fi use.

Key Economic Conclusions of This Report:

> **In 2027, the annual economic value of Wi-Fi is projected to reach $2.4 trillion**, including an estimated $514 billion in consumer benefit, $624 billion in producer surplus, and $1,286 billion in GDP contribution.

> **Opening the 7 GHz band for unlicensed use will generate at least $79.62 billion** in cumulative economic value between 2025 and 2027, with yearly values increasing significantly over time.

> The FCC's April 2020 decision to allocate additional **unlicensed spectrum in the 6 GHz band** was a massive policy success that **generated an estimated $870 billion of incremental economic value in 2023 and 2024 – projected to increase to $1.2 trillion by 2027.**

Key Policy Conclusions of This Report:

> **Wi-Fi's rapidly increasing social and economic value justify opening up the 7125 MHz-7250 MHz band and 7250 MHz-7625 MHz band for unlicensed use.**

> **Policymakers should vigorously and carefully evaluate the feasibility of opening up the remaining segment of the 7 GHz band for unlicensed use.**

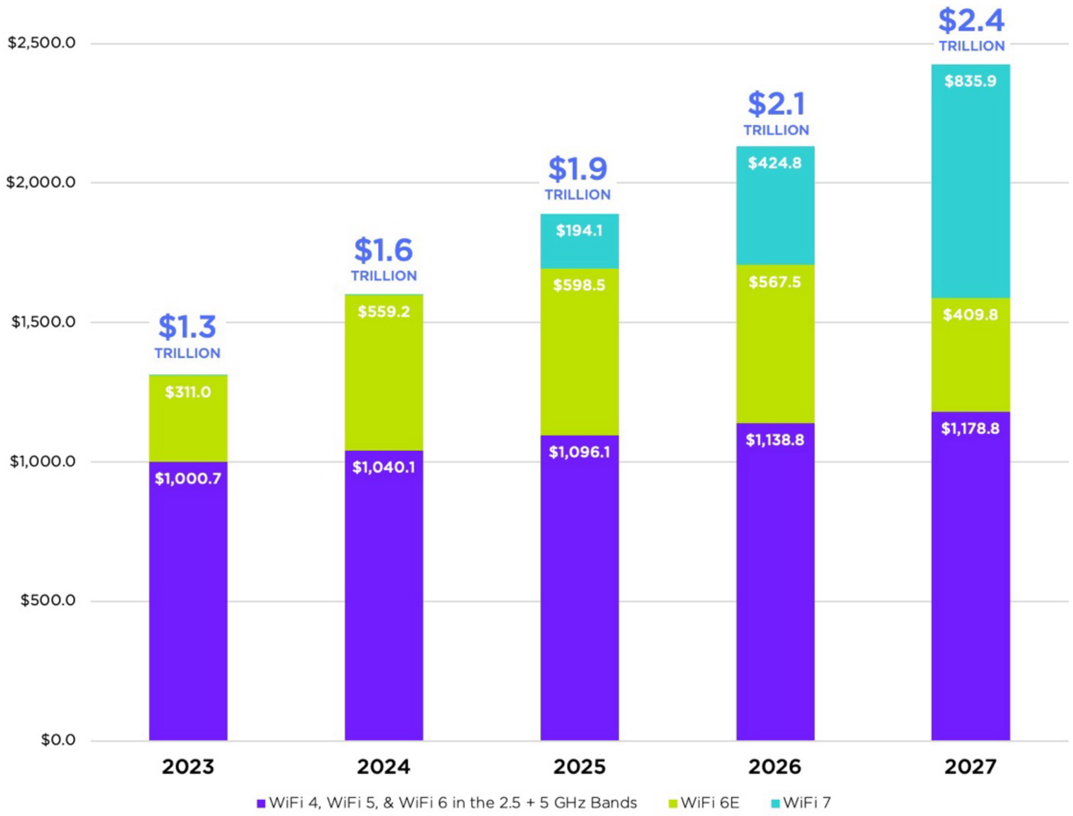
The National Telecommunications and Information Administration (NTIA)'s National Spectrum Strategy development study is expected to generate a recommendation for uses of the 7 GHz band (7125-8400 MHz)– a band heavily used currently by the federal government for military radars, NASA exploration and research, microwave technology and more). Opening up the 7 GHz band for unlicensed use (using the FCC's 6 GHz technical rules) would enhance Wi-Fi's ability to support broadband speeds of up to 10 Gbps by enabling multiple 320 MHz channels, which are required to support faster speeds, more devices and greater capacity. In addition, use of the 7 GHz band would also allow unlicensed technology to address the continued growth in indoor networking, improve channel diversity at wider channelization which enhances reliability, provide opportunities for outdoor use aligning to those in 6 GHz, provide a clear path to enable development of new generations of Wi-Fi such as Wi-Fi 8, and consequently continue to fuel the creation of significant economic value.

The findings in this report build upon and update a 2021 report by the same authors ("the 2021 Report")[1], analyzing how new technology and additional unlicensed spectrum have expanded – and will continue to expand – the economic value associated with Wi-Fi. Since the author's 2021 report, Wi-Fi demand and use has exploded, driven by a range of factors: faster-than-expected increases of consumers' home broadband speeds; faster-than-expected growth of Internet of Things (IoT) connected device deployments; "sticky" COVID-era increases in remote work; emerging uses crowded environments like stadiums and conference centers; and the growing offload of mobile carriers' cellular data to Wi-Fi.

This report seeks to update the projections set forth in the 2021 Report to reflect that significant growth and impact, while estimating Wi-Fi's economic value between 2023 and 2027. The findings of this report confirm the 2021 assessment, and also demonstrate how new technology and new unlicensed spectrum will continue to expand the economic value associated with Wi-Fi.

In 2027, the annual economic value of Wi-Fi is projected to reach $2.4 trillion, a robust 33% increase over the 2024 value. In addition, the updated report shows the 2021 findings were conservative. While the 2023 value in our new study has remained approximately in line with the 2021 Report forecast ($31 billion higher), the revised 2025 value of $1.9 trillion reflects a substantial increase ($211 billion higher). Furthermore, the updated findings reflect the growing importance of Wi-Fi 6E and the anticipated relevance of Wi-Fi 7 as drivers of significant near term value (see graphic A).

GRAPHIC A. **Economic Value** of **Wi-Fi**: **Current Study** (in Nominal $ Billions)
2023 – 2027



SOURCE: TELECOM ADVISORY SERVICES ANALYSIS

---

[1] Katz, R., Jung, J. and Callorda, F. (2021). The Economic value of Wi-Fi: A Global View (2021 and 2025): Study developed for the Wi-Fi Alliance. New York: Telecom Advisory Services. October. Retrieved in: https://www.wi-fi.org/system/files/The_Economic_Value_of_Wi-Fi-A_Global_View_2021-2025_202109.pdf

At the highest level, both studies – the 2021 Report and the current one – measure the value of Wi-Fi within three areas: GDP contribution, producer surplus and consumer benefit, differentiating effects among spectrum bands (see figure B).

FIGURE B. **Overall Studies Framework**

SOURCES of VALUE	AREAS of VALUE	SPECTRUM BANDS
Free Wi-Fi | Public Wi-Fi Internet access offered for free **Residential Wi-Fi** | Support of device connectivity at home **Enterprise Wi-Fi** | Support of device connectivity in enterprises **Internet Service Providers** | Public Wi-Fi sold for a fee and savings from Wi-Fi routing of cellular traffic **Wi-Fi Ecosystem** | Profits from production of Wi-Fi enabled equipment	**GDP Contribution** | Economic growth enabled by Wi-Fi, strictly considering the revenues added "above and beyond" what would have occurred had the Wi-Fi spectrum been licensed. **Producer Surplus** | Economic profit producers earn by relying on Wi-Fi **Consumer Benefit** | Amount consumers would be willing to pay to use the Wi-Fi service, compared to what they actually pay	**2.4 GHz – 5 GHz** | Value in original unlicensed bands and equipment in the Wi-Fi 4 and WiFi 5 generations **6 GHz** | 1200 MHz used by Standard Power access points, Low Power indoor devices, and Very Low Power devices **7 GHz** | Launch of additional 320 MHz channels in the 7 GHz band

SOURCE: TELECOM ADVISORY SERVICES

This study forecasts that by 2027, Wi-Fi will be responsible for an estimated $514 billion in consumer benefit, $624 billion in producer surplus, and $1,286 billion in GDP contribution (see Table C).

TABLE C. **Total Economic Value of Wi-Fi** (In Nominal $ Billion)

	2023	2024	2025	2026	2027
Consumer Benefit	$ 339	$ 392	$ 444	$ 483	$ 514
Producer Surplus	$ 382	$ 441	$ 510	$ 570	$ 624
GDP	$ 592	$ 769	$ 935	$ 1,078	$ 1,286
TOTAL	**$ 1,314**	**$ 1,602**	**$ 1,889**	**$ 2,131**	**$ 2,424**

SOURCE: TELECOM ADVISORY SERVICES ANALYSIS

The trend depicted in Table C indicates the growing importance of Wi-Fi 6E and the expected relevance of Wi-Fi 7 as Wi-Fi 7 shipments accelerate. Applications enabled by Wi-Fi 7, with faster speeds and a smooth connection to a much larger number of devices, are already developed and ready now, and manufacturers of Wi-Fi chips and network hardware are not waiting for the official release (see figure D).

FIGURE D. **Primary Factors Driving Wi-Fi Future Economic Value**

The Increasing Benefits of Wi-Fi Technology: Broadband & Speed	The enhancement in broadband speed contributes to 16.86% of the total economic value generated by Wi-Fi from 2024 to 2027
A Substantial Boost to Deployment of IoT Technology	Total spending in IoT is expected to grow at an 11% CAGR between 2004 and 2027
Bridging the Digital Divide: Use of Wi-Fi to Increase Coverage in Rural and Isolated Areas	Due to the implementation of Wi-Fi 6E and Wi-Fi 7, an additional 393,000 previously unconnected households will gain service from WISPs by 2027
Consumer Benefit Generated by Use of Residential Wi-Fi Devices and Equipment	The consumer benefit generated by residential Wi-Fi use drives 2.51% of total Wi-Fi economic value between 2024 and 2027
The Increasing Benefits of Wi-Fi Technology: Latency Reduction	Latency reduction from Wi-Fi technology is expected to significantly contribute to productivity gains and user experience improvements

SOURCE: TELECOM ADVISORY SERVICES ANALYSIS

The Policy Implications of These Findings Are Clear:

> **Wi-Fi is a key resource in the US communications ecosystem.**

> **Wi-Fi drives significant social and economic value, which includes addressing the needs of the broadband unserved and underserved population and propelling the development of an industrial base.**

> **Wi-Fi represents an environment of continuous innovation that is not constrained by the property rights generally attached to licensed spectrum.**

> **The FCC's April 2020 decision to allocate additional unlicensed spectrum in the 6 GHz band was a clear policy success, projected to generate $870 billion of incremental economic value in 2023 and 2024 increasing to $1.2 trillion by 2027.**

We note that there are many other public policy benefits that flow from releasing spectrum for unlicensed devices such as Wi-Fi. These include, for example, a more robustly competitive telecommunications market with the development of operators who build their network services on a "Wi-Fi First" model. This could provide a balance to the ongoing trend of carrier consolidation. Another derived benefit might be how the availability of additional technology choices to foreign nations might advance U.S. interests globally. These are enormously important benefits, although they are a step removed from what we seek to evaluate here, namely economic value that can be estimated on the three dimensions discussed above - consumer surplus, producer surplus and improvements to GDP.

1. INTRODUCTION: THE NEED to UPDATE the RESEARCH ON WI-FI ECONOMIC VALUE

The study of the economic value of Wi-Fi and unlicensed spectrum has been an area of research since 2009.[2] In February 2021, the authors of the present study published the 2021 report assessing, on a global basis, the potential economic contribution of Wi-Fi between 2021 and 2025.[3] The study's purpose was to measure Wi-Fi's economic value, both to consumers and producers[4], as well as its direct net contribution to output (Gross Domestic Product, or GDP). Based on data available through 2020, we estimated the 2023 economic value in constant prices of Wi-Fi for the United States to be $1,208.9 billion and projected that it would reach $1,580.1 billion by 2025.

The 2021 Report also concluded that the most important sources of economic value in 2025 were going to be residential and enterprise Wi-Fi use. Moreover, the study also found benefits from the sale of equipment (access points, controllers, routers, gateways, sensors, AR/VR devices, smart speakers, home security systems, and the like), while ISPs would benefit from additional revenues and savings by relying on Wi-Fi technology to offload traffic from their networks. Finally, Wi-Fi would also generate economic value through social contributions, such as addressing the digital divide, while also providing an important platform for free Internet access.

This range of effects had been fostered in part by two Federal Communications Commission (FCC) decisions. In April 2020, the FCC unanimously voted to allow two classes of unlicensed devices to operate in the 6 GHz band. Low power indoor devices were permitted to operate throughout the 6 GHz band, while standard power access points were allowed to operate in 850 megahertz in the 6 GHz sub bands. As a result, the capacity available for Wi-Fi quadrupled. Under this configuration, routers had access to seven new 160 MHz channels. The higher capacity available with 6 GHz suggested that the actual signal speed would be higher than the original speeds at 2.4 and 5 GHz.

Concurrent with its decision to permit standard power and low power indoor devices, the FCC proposed a third category of 6 GHz Equipment – Very Low Power devices (VLP). In 2023 the FCC authorized the full use of VLP devices in the 6 GHz band. These devices were authorized with power levels 60 times lower than standard-power Wi-Fi, and permitted for indoor or outdoor use in certain sub-bands, 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 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[5] tethering (watches, ear pods) or entertainment devices in the automobile.

Equipment manufacturers responded in kind to these decisions. At the time the FCC acted, Wi-Fi equipment manufacturers were producing a sixth generation of devices offering higher performance, lower latency, and faster data rates. Categorized as Wi-Fi 6, the sixth generation of Wi-Fi equipment adopted the 802.11ax standard, offering a base speed of 1.2 Gbps, and up to 4.8 Gbps under a quad-stream configuration.

---

[2] Among the original studies, we can count Thanki, R. (2009). The economic value generated by current and future allocations of unlicensed spectrum. Perspective Associates; Milgrom, P., Levin, J., & Eilat, A. (2011). The case for unlicensed spectrum. Stanford Institute for Economic Policy Research Discussion Paper No. 10-036; Cooper, M. (2011). The consumer benefits of expanding shared use of unlicensed radio spectrum: Liberating Long-Term Spectrum Policy from Short-Term Thinking. Washington D.C.: Consumer Federation of America; Katz, R. (2014a). Assessment of the economic value of unlicensed spectrum in the United States. New York: Telecom Advisory Services; Katz, R. (2014). Assessment of the future economic value of unlicensed spectrum in the United States. 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.

[3] Katz, R., Jung, J. and Callorda, F. (2021). The Economic value of Wi-Fi: A Global View (2021 and 2025): A report for the Wi-Fi Alliance. New York: Telecom Advisory Services. October.

[4] Producers are defined as enterprises benefitting from Wi-Fi to reduce their telecommunications spending, companies delivering products and services in the Wi-Fi ecosystem, and Internet Service Providers that reduce their infrastructure costs by relying on Wi-Fi access points.

[5] FCC ex parte notification from Apple Inc., Broadcom Inc., Facebook Inc., Google LLC, Hewlett Packard Enterprise, Intel Corp., Marvell Semiconductor Inc., Microsoft Corporation, Qualcomm Incorporated (July 2, 2019).

Subsequent to the decision, the Wi-Fi 6E standard operating in the 6 GHz spectrum band was introduced to take advantage of several 160 MHz channels. This additional spectrum addressed the congestion developing in the traditional bands by providing more contiguous spectrum blocks.

Triggered by the allocation of new Wi-Fi spectrum and the release of Wi Fi 6 and Wi-Fi 6E devices, other sources have been confirmed as important drivers for future value growth. The creation of the Low Power Indoor device categories drove the development of sources of economic value. The increase in Wi-Fi speed and capacity led to a broader scale IoT deployment. While IoT roll-out had been proceeding for a number of years, large scale deployment suffered from the risk of congestion. The additional unlicensed spectrum mitigated that congestion and, therefore, provided a boost to the growth of IoT. Additionally, the creation of the Very Low Power device category enabled the deployment of a new generation 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, including training in the medical field. Other areas of application include education and culture, sports, live broadcasting, real estate, advertising, architecture, and arts. 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. AR and VR can serve both consumers and professional users in the private and public sectors.

Other industry trends that haven taken place since 2021 have acted as further accelerators driving Wi-Fi economic value substantially upwards:

- The FCC report released in May 2024 indicated that as of June 2022, 74.7% of fixed broadband connections were higher than 100 Mbps. Based on this data, we estimate that as of June 2022, 59.48% homes are served by service above 150 Mbps. In contrast, our 2021 study's original assumption was that in 2022 50% of total connections would be higher than 150 Mbps. This threshold assumption drives both an increasing return to speed impact on GDP and consumer benefit.[6]
- Producer surplus from Wi-Fi enabled equipment was driven by 2022-25 cumulative sales of $298.5 billion and a gross profit margin of 39.44%; the most recent data from Consumer Technology Association released in 2024 estimates 2022-2025 cumulative sales to reach $334.5 billion, while annual gross profit margin has risen to 44.59%.[7]
- Deployment of IoT connections, originally forecast to reach 193 million (measured as M2M devices) by 2023, actually attained 201 million.[8]
- The acceleration of consumer behavior regarding data and video use triggered by COVID-19 is not retreating; in fact, it is remaining in place and even accelerating in some areas.[9]
- Carrier offload to Wi-Fi that reduces cellular network load has come in full force, well beyond the original forecast[10]. Furthermore, academic research is generating evidence that licensed and unlicensed spectrum bands are complementary goods where off-loading to wide swaths of unlicensed 6 GHz maximizes profit and consumer welfare.[11]
- Additional sources of Wi-Fi economic value not addressed in the original study have emerged (for example, the use of Wi-Fi in highly-dense heterogeneous environments, such as stadiums and conference halls).

---

[6] The phrase "return to speed" references the economic value associated with higher broadband speeds and lower latencies.

[7] CSI Market Inc., Industry Profitability Ratios.

[8] Source: GSMA Intelligence.

[9] Nosratzadeh, H. and Edrisi, A. (2022). "An assessment of tendencies toward teleworking using TAMs: lessons from Covid-19 era for post-pandemic days", International Journal of Workplace Health Management, 16 (1) 38–56. Retrieved in: https://doi.org/10.1108/IJWHM-10-2021-0198.; Inoue, H. and Todo, Y. (2023). "Has Covid-19 permanently changed online purchasing behavior? EPJ Data Sci. 12(1), 1. Retrieved in: https://doi.org/10.1140/epjds/s13688-022-00375-1.

[10] Hetting, C. (2023). "The Wi-Fi offload revival is coming your way – and it's coming soon". Wi-Fi Now

[11] Adams, G. and Yoo, C. (2023). Braess' Paradox in Wireless Broadband? Toward a principled basis for allocating licensed and unlicensed spectrum. Paper presented at 2023 TPRC.

- Finally, the newly released Wi-Fi 7 standard is intended to optimize the use of all unlicensed bands including 6 GHz and additionally operate in the 7 GHz band. Applications enabled by Wi-Fi 7, with faster speeds and a smooth connection to as many devices as possible, are already in the market; manufacturers of Wi-Fi chips and the routers, repeaters, and modules equipped with them did not wait for the official release.[12]

These trends confirm a Milgrom et al. (2011) statement that unlicensed spectrum actually acts as a stimulus of technological innovation.[13]

The federal government's National Spectrum Strategy process being conducted by NTIA is expected to generate a recommendation regarding the use of the 7 GHz band (7125-8400 MHz band). Several industry stakeholders support a decision that the 7 GHz band (a band heavily used currently by the federal government for military radars, NASA exploration and research, microwave technology and more) be opened for Wi-Fi using the FCC's 6 GHz technical rules. Opening the 7 GHz band would allow unlicensed technology to address the continued growth in indoor networking, improves channel diversity at wider channelizations which enhances reliability, provide opportunities for outdoor use aligning to those in 6 GHz, and continue to fuel the creation of significant economic value.

In this context of better informing spectrum policy and future allocation decisions, it is relevant to conduct a study that illustrates the general economic benefits associated with Wi-Fi 7, the unlicensed use of the 7 GHz band combined with a "refreshing" of the 2021 study results to better reflect the true Wi-Fi economic value in the United States between 2023 and 2027.

* * * * *

The following report presents an assessment of economic value and growth between 2023 and 2027 for the United States. Its purpose is to compare the changes that have taken place in the original 2021 study and consider the upside represented by Wi-Fi 6, by Wi-Fi 6E under the allocation of the 6 GHz band for unlicensed use, as well as the upcoming Wi-Fi 7 decision and the use of the 7 GHz band to provide additional channels of Wi-Fi capacity. Chapter 2 presents the theoretical concepts and methodologies that frame the analysis. Chapters 3 through 7 present the results of the analysis for each source of economic value, while Chapter 8 compares the results of the current study with those developed in 2021. Chapter 9 draws the conclusions and public policy implications of the study results. Detailed explanation of the methodologies and models used to calculate the economic value by source are available in the appendices.

---

[12] The Wi-Fi Alliance introduced "Wi-Fi CERTIFIED 7" at the Consumer Electronics Show in January 2024. Retrieved in: https://www.wi-fi.org/news-events/newsroom/wi-fi-alliance-introduces-wi-fi-certified-7. See also Rau, T. (2023). "Wi-Fi7: a deep-dive into the blistering new wireless standard", PC World, July 26.

[13] "Another drawback to property rights is that they can stifle third-party innovation: third-party innovators face a threat of hold-up. A company that comes up with a new mobile device or business model needs to convince the owner of the spectrum to let it develop its idea, and it may have to share a large fraction of the value that is created with the spectrum owner. If the new development threatens the owner's existing business, it is particularly unlikely to be allowed. And, if the innovation requires the assent and coordination of multiple spectrum owners, it is even more difficult to get the owners all to agree. The potential for this type of coordination failure is sometimes referred to as the tragedy of the anticommons. It has become a familiar problem in intellectual property, arising when product developers must license such a large number of patents that the process of innovation becomes cumbersome, unwieldy and inefficient." (Milgrom et al. (2011), p. 15).

2. STUDY THEORETICAL FRAMEWORK & METHODOLOGIES for ESTIMATING WI-FI ECONOMIC VALUE

2.1. Study Analytical Scope & Theoretical Framework

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

2.1.1. The Intrinsic Value of Wi-Fi

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

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

> “Diffusion of a novel technology in a user sector creates demand for products and services in the input sectors of the [technology value chain], making it imperative that input sectors are scalable enough to ensure a balance between supply and demand. Thus, economies of scale may emerge, driving further development and deployment in the user sector due to reduced costs, network effects, and increased availability of necessary services and products.” (p.9)

The complementarity between Wi-Fi, and wideband networks appears to be a clear example of amplification. Each technology was developed independently, although their combination acts as a multiplier of demand and impact. For example, Wi-Fi can enhance the effectiveness of devices, such as smartphones, which use licensed spectrum. Wi-Fi access points can enhance the value of cellular networks by allowing wireless devices to switch to Wi-Fi hotspots, thereby relieving the burden on the mobile wireless network - reducing the cost of broadband access and increasing the access speed rate. Consumers accessing the Internet within the reach of a Wi-Fi access point can also reduce their access costs by turning off their cellular service. They can also gain additional access speed as the transfer data rate of Wi-Fi sites is generally faster than that offered by current cellular technology—even 4G LTE at current loads.[14] Likewise, many wireless operators reduce their capital spending by complementing their cellular networks with carrier-grade Wi-Fi access points, which are considerably less expensive than cellular network equipment with similar capacity.[15] In addition to reducing capital expenditures, wireless carriers can offer fast access to service without a base station congestion challenge.

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

In addition to innovative applications, technologies relying on unlicensed spectrum used by Wi-Fi can help address the digital divide in broadband coverage. A portion of the population that has not adopted broadband access is located in rural and isolated areas. Many of them can gain access to the Internet through free Wi-Fi service offered by anchor public institutions such as libraries, municipalities or supplied for a fee by Wireless Internet Service Providers (WISPs), which typically provide end-connectivity to consumer devices through Wi-Fi.

2.1.2. The **Derived Value** of **Wi-Fi**

There is a significant amount of research-based evidence demonstrating that Wi-Fi technology has very high social and economic value. At a highest level, contrary to licensed bands where economic value can equate to whatever is paid at auction, the economic value of unlicensed spectrum, such as Wi-Fi, needs to be measured based on the concept of economic surplus.[16]

The concept of economic surplus is based on the difference between the value of units consumed and produced up to the equilibrium price and quantity, allowing for the estimation of consumer benefit and producer surplus.[17] Consumer benefit measures the total amount consumers would be willing to pay to have the service, compared to what they actually pay. Producer surplus measures the analogous quantity for producers, which is essentially the economic profit they earn from providing the service. Consumer and producer surplus together yield an economic surplus. Adding GDP contribution results in a total economic value estimate.

---

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

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

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

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

Consistent with the concept presented above, this study measures the economic value of Wi-Fi by focusing first on the economic surplus generated after its adoption.[18] The underlying assumption is that Wi-Fi generates a shift both in the demand and supply curves, resulting from changes in how services are produced, as well as the corresponding willingness-to-pay for such services. On the supply side, the approach measures changes in the value of inputs in the production of wireless communications. The most obvious example is, as mentioned above, whether Wi-Fi represents a positive contribution to wireless carriers' capital expenditures (CAPEX) and operating expenses (OPEX) insofar as they can control their spending, while meeting demand for increased wireless traffic. From an economic theory standpoint, the telecommunications industry can then increase its output, yielding a marginal benefit exceeding the marginal cost. This results in a shift in the supply curve by a modification in the production costs. The shift in the supply curve yields a new equilibrium price and quantity. Additionally, since the demand curve is derived from the utility function[19], the consumer benefits from stable Wi-Fi prices, yielding an increase in the willingness-to-pay, and consequently a shift in the demand curve. Under these conditions, total economic value is now represented by both changes in the consumer and producer surplus.

To quantify the incremental surplus derived from Wi-Fi adoption, we need to itemize all the effects linked to this technology. In addition, we complement the concept of economic surplus with an assessment of the direct contribution of the technologies and applications relying on Wi-Fi, such as Wi-Fi service providers, to national GDP. By including the GDP contribution measurement, we follow Greenstein et al. (2010) and prior research literature measuring the economic gains of new goods.[20] We focus on consumer and producer surplus, but also consider the new economic growth enabled by Wi-Fi. In measuring the direct contribution to GDP, we strictly consider the revenues added "above and beyond" what would have occurred had the Wi-Fi spectrum been licensed. After quantifying Wi-Fi's contribution to GDP, the impact on job creation can also be ascertained not only within the telecommunications industry but also in terms of the spillovers through the rest of the economy.

2.1.3. Sources & Economic Agents Driving Value of Wi-Fi

The economic value of Wi-Fi is generated from multiple sources of value, including (i) the capability to deliver traffic at faster speed and lower latency than other networking technologies, (ii) provide Internet access, and (iii) interconnect devices.

These sources of economic value are then channeled into economic gains for five economic agents:

- **Individual Consumers Accessing Free Wi-Fi Sites;**
- **Residential Consumers;**
- **Enterprises;**
- **Internet Service Providers (ISPs); and**
- **Companies that provide Wi-Fi products and Services or Manufacture Products Enabled by Wi-Fi (Participants in the Wi-Fi Ecosystem).**

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

- **Free Wi-Fi:** The providers of free Wi-Fi service (i.e., coffee shops, retailers, municipalities, public libraries) allow consumers to connect to the Internet without paying for access, creating a benefit to

---

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

[19] A utility function measures the consumer preference for a service beyond the explicit monetary value paid for it.

[20] Greenstein, S. and McDevitt, R. (2009). The broadband bonus: accounting for broadband Internet's impact on U.S. GDP. National Bureau of Economic Research Working Paper 14758. Cambridge, MA.

consumers.[21] Additionally, free Wi-Fi hotspots could also provide Internet access to those consumers that lack broadband service, thereby partially bridging the “digital divide”. While less important in metropolitan areas, this effect could be critical to increasing broadband adoption in some less developed geographies, and hence, convey impact on GDP.[22]

- **Residential Wi-Fi:** As calculated in our 2021 study, residential Wi-Fi also drives consumer benefits. Routers installed in home dwellings provide Internet access for devices that lack a wired port (i.e., tablets, smartphones, netbooks), allowing consumers to avoid the investment in Ethernet wiring.[23] Wi-Fi routers also support easy networking between devices (printers, storage devices, computers), allow for sharing and streaming media content (sound systems, home theaters, etc.), represent a network hub to handle home automation, and may interface with a smart grid. Additional benefit is generated as a Wi-Fi connection for last mile of fixed broadband is typically faster than that of a cellular network.[24] Finally, consumer benefit is generated if the willingness-to-pay exceeds the price paid for purchasing residential Wi-Fi devices and equipment. All of these benefits can be aggregated in terms of the residential consumer benefit.
- **Enterprise Wi-Fi:** Wi-Fi in office buildings and industrial campuses allows for voice and data communications without incurring the cost of “capped” connectivity and avoids the limited in-building coverage of cellular networks, as well as the cost of enterprise wiring. Additionally, Wi-Fi supports communication between enterprises and their customers (i.e., customer/client access in financial services, employee/guest connections in the hospitality industry), while also improving internal production efficiencies (product/inventory tracking, remote control equipment, and POS ordering in the retail industry). This equates to a producer surplus, composed of the cost savings enjoyed by enterprises that rely on Wi-Fi technology, rather than wideband cellular service. In addition, Wi-Fi allows faster access to the Internet than cellular networks do. These faster speeds have a positive contribution to the economy in terms of increased overall productivity, efficiency, and innovation. Finally, Wi-Fi technology facilitates the expansion of Internet of Things (IoT) platforms and Augmented Reality and Virtual Reality (AR/VR) applications. Those developments generate productivity spillovers on the economy, thereby contributing to the growth of GDP.
- **Internet Service Providers (ISPs):** Due to the explosive growth in data traffic, wireless carriers operating in licensed bands deploy Wi-Fi access points to reduce both capital and operating expenses and reduce congestion challenges. Since ISPs monetize the Wi-Fi access they provide, the producer surplus measures the difference in capital and operating expenses for the traffic that is off-loaded. This model is critical to understanding Wi-Fi’s contribution to 5G deployment, yielding economic value generated for wireless carriers who offload 5G traffic on to Wi-Fi in the home/business. Wi-Fi also allows service providers to launch paid Internet access in public places (such as venues, stadiums, airports, airlines, hotels, etc.). These access points generate new revenues that would not exist if Wi-Fi were not available. Similarly, Wireless Internet Service Providers (WISPs) rely on Wi-Fi to offer broadband connectivity in areas typically not served by wireline carriers, yielding additional revenues

---

[21] This category does not include providers of paid Wi-Fi access such as those operating in airports or hotels; this type of agent is included in the Internet Systems Providers category below.

[22] See Katz, R., & Jung, J. (2021). The economic impact of broadband and digitization through the COVID-19 pandemic – Econometric modelling (ITU report). International Telecommunication Union. Available at: https://www.itu.int/pub/D-PREF-EF.COV_ECO_IMPACT_B-2021. Barrero, J. M., Bloom, N., & Davis, S. J. (2021a). Internet access and its implications for productivity, inequality, and resilience. In M. S. Kearney & A. Ganz (Eds.), Rebuilding the post-pandemic economy. Aspen Institute Press. Retrieved in: https://www.economicstrategygroup.org/publication/barrero-bloom-davis/; Bertschek, I., Briglauer, W., Hüschelrath, K., Kauf, B., & Niebel, T. (2015). “The Economic Impacts of Broadband Internet: A Survey.” Review of Network Economics, 14(4), 201–227. Retrieved in: https://doi.org/10.1515/rne-2016-0032; De Clercq, M., D’Haese, M., & Buysse, J. (2023). “Economic growth and broadband access: The European urban-rural digital divide.” Telecommunications Policy, 47(6), Article 102579. https://doi.org/10.1016/j.telpol.2023.102579; Isley, C., & Low, S. A. (2022). “Broadband adoption and availability: Impacts on rural employment during Covid-19.” Telecommunications Policy, 46(7), Article 102310. https://doi.org/10.1016/j.telpol.2022.102310; Katz, R., & Jung, J. (2022a). The contribution of fixed broadband to the economic growth of the United States between 2010 and 2020. Telecom Advisory Services LLC.; Katz, R.; Jung, J. (2022b). “The Role of Broadband Infrastructure in Building Economic Resiliency in the United States during the COVID-19 Pandemic.” Mathematics 10, 2988. https://doi.org/10.3390/math10162988.

[23] This effect is not total since users can potentially purchase adapters for smartphones and tablets, although the most popular connectors (such as micro-USB to Ethernet) cannot deliver comparable speeds and require some consumer inputs to be activated.

[24] This effect is particularly important in 4G networks but could also be relevant in relation to indoor reception.

to be accounted for as part of the GDP. Since the technology allows for increasing broadband penetration, it becomes a key factor in driving service coverage and, consequently, GDP growth. This could have multiple positive effects, such as job creation, enhancing the productivity of rural businesses, and increasing access to public services.[25]

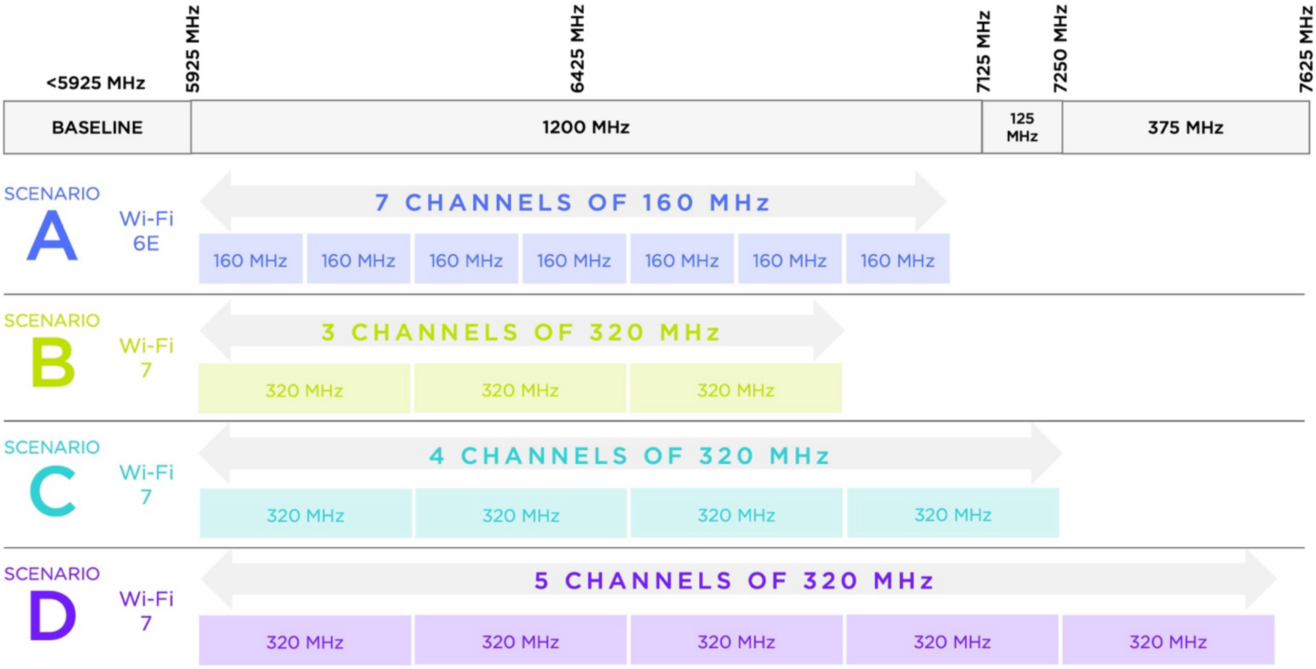
- **Wi-Fi Ecosystem:** Locally manufactured Wi-Fi devices generate revenues. The difference between the market price of these Wi-Fi enabled devices and the cost to manufacture them represents the manufacturer's profit margin (producer surplus). Such products include home networking devices, Wi-Fi enabled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

2.2. Methodologies for Estimating the Economic Value of Wi-Fi

Measuring the economic value of Wi-Fi requires a formal approach that can integrate the various economic gains, whether consumer or producer benefits, as well as their net direct contributions to the GDP.[26] The methodology used in this study is structured around the benefits captured by each of the five economic agents reviewed above (individuals benefitting from free Wi-Fi service, residential Wi-Fi, enterprise Wi-Fi, Internet Service Providers, and Wi-Fi ecosystem companies). As outlined above, the economic value for each agent will be measured based on three potential economic dimensions: consumer benefit, producer surplus, and GDP growth.

The assessment economic value will be conducted according to five scenarios (see figure 2-1), starting with a baseline scenario, and then evaluating four additional scenarios that add spectrum and/or channels:

FIGURE 2-1. **Alternative Wi-Fi Scenarios**



---

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

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

Scenario A	Improvement due to Wi-Fi 6E (effect already ongoing)
Scenario B	Improvement Due to Technological Change from Wi-Fi 6E to Wi-Fi 7 on the Same Band
Scenario C	Enhancement by increasing spectrum (125 MHz)
Scenario D	Improvement by a second increase in spectrum (375 MHz)

1. Under a so-called baseline scenario, all standards up to Wi-Fi 6, operating in the 2.4 GHz and 5 GHz bands.
2. Wi-Fi 6E operating in the 6 GHz band, which allows the aggregation in channels of 160 MHz, leading to doubling the maximum channel bandwidth from its predecessor technology and improving the maximum speed.
3. Wi-Fi 7 operating in the 6 GHz band. In addition to the aggregation of channels in 320 MHz, this standard introduces a combination of new features such as MRU (Multiple Resource Units), MLO (Multilink operation), maximum 4096-QAM modulation and spatial stream scaling (16SS), to improve spectral efficiency, increase speed and support many devices in a single area.
4. Wi-Fi 7 relying on the full 6 GHz band and 125 MHz of the 7 GHz band, thereby increasing the amount of frequency available in order to offer up to four channels of 320 MHz.
5. Wi-Fi 7 operating on the 6 GHz and multiple channels in the 7 GHz band, thereby adding yet a fifth 320 MHz channel, and potentially opening the path for Wi-Fi 8 use.

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

TABLE 2-1. **Sources** of **Economic Value** of **Wi-Fi** by **Economic Agent**

AGENT	SOURCES	TYPE of ECON. VALUE	STANDARDS SCENARIOS				
			WI-FI 6 & BELOW	WI-FI 6E IN 6 GHZ	WI-FI 7 IN 6 GHZ	WI-FI 7 IN LOW 7 GHZ	WI-FI 7 IN MID 7 GHZ
Free Wi-Fi	Benefit to Consumers of Free Wi-Fi Traffic Offered In Public Sites	CB	X	X	X	X	X
	Deployment of Free Wi-Fi In Public Sites	GD	X	X	X	X	X
	Benefit to Consumers of Faster Free Wi-Fi Under Wi-Fi 6E & Above	CB		X	X	X	X
	Use of Wi-Fi in Educational Institutions	CB	X				
	Use in Highly Dense Heterogeneous Environments	CB		X	X		
Residential Wi-Fi	Internet Access for Home Usage of Devices that Lack a Wired Port	CB	X				
	Avoidance Of Investment In In-House Wiring	CB	X				
	Benefit To Consumers From Speed Increases	CB		X	X		
	Residential Wi-Fi Devices & Equipment (Equip.)	CB	X	X	X		
	Closing The Digital Divide: Use of Wi-Fi to Increase Coverage In Rural & Isolated Areas	GDP	X	X	X	X	X
	Increasing Vehicular Use of Wi-Fi	CB			X		
Enterprise Wi-Fi	Business Internet Traffic Transmitted through Wi-Fi	PS	X	X	X		
	Avoidance of Enterprise Inside Wiring Costs	PS	X				
	Return to Speed: Contribution to GDP	GDP		X	X		
	Return to Speed: Contribution to GDP Derived from a Reduction In Average Latency	GDP	X	X	X		
	Wide Deployment of IoT	GDP	X	X	X	X	X
	Deployment of AR/VR Solutions	GDP	X	X	X		
ISPs	CAPEX & OPEX Savings Due to Cellular Off-Loading	PS		X	X	X	X
	Revenues of Service Providers Offering Paid Wi-Fi Access in Public Places	GDP	X	X	X	X	X
	Aggregated Revenues of WISPs	GDP	X	X	X	X	X
Wi-Fi Ecosystem	Manufacturing of Residential Wi-Fi Devices & Equip.	PS	X	X	X		
	Manufacturing of Wi-Fi Enterprise Equip.	PS	X	X	X		
	Benefits of Firms of Internet of Things Ecosystem	PS	X	X	X	X	X
	Benefits of Firms of AR/VR Solutions Ecosystem	PS	X	X	X		
	Benefits of Firms Developing Vehicular Technologies	PS			X		

CB = CONSUMER BENEFIT | PS = PRODUCER SURPLUS | GDP = GDP CONTRIBUTION

SOURCE: TELECOM ADVISORY SERVICES ANALYSIS

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

3. FREE WI-FI SERVICE

According to Wi-Fi Map (2024)[27], there are 953,099 free Wi-Fi sites in the United States, enabling individual consumers to access the internet. They include hotspots deployed in retail outlets (stores, coffee shops, etc.), transportation hubs, and points of delivery of public services (hospitals, doctors offices, public libraries, etc.) among others.

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

Savings Incurred by Consumers by **Accessing Free Wi-Fi** in **Public Sites Rather** than **Incurring Cellular Costs**	**Free Wi-Fi Service Supporting** the **Needs** of the **Broadband Unserved Population**	**Benefit** to **Consumers Enjoying Higher Speed** from **Free Wi-Fi Under Wi-Fi 6E** & **Wi-Fi 7**	**Benefit** to **Consumers Relying** on **Wi-Fi** in **Educational Institutions**	**Use of Wi-Fi** in **Highly Dense Heterogeneous Environments**
Using free Wi-Fi rather than cellular networks saves $7.0 billion in 2023, reaching $12.2 billion in 2027	Assuming conservatively that only 5% of 12.472 million unconnected households rely on free Wi-Fi sites to support their connectivity needs and considering the contribution of broadband lines to the GDP, Wi-Fi will increase GDP by $33.1 billion in 2023 and $24.6 billion in 2027.	Higher speeds amounts to $150 million in consumer benefits in 2023 increasing to $203 million in 2027.	Avoidance of the purchase of mobile data services in educational institutions saves between $3.0 billion in 2023 and $0.9 billion in 2027.	Consumer benefit in settings, such as stadiums where large numbers of users are accessing the network simultaneously, reaching $252 million in 2027.

Each source will be described and assessed in terms of economic value.

3.1. Savings Incurred by Consumers from Accessing Free Wi-Fi in Public Sites

Free Wi-Fi offered in retail shops, coffee shops, city halls, and corporate guest accounts allows consumers to save money that would otherwise be spent purchasing cellular service. In addition, free hotspots provide access to the Internet for consumers that cannot afford to purchase broadband service. This last effect was particularly important during the coronavirus pandemic, allowing broadband unserved households to access the Internet for telecommuting, telemedicine, and remote education, among other applications.

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

The increased adoption of devices combined with an increase in usage has driven overall Internet traffic growth. Forecasts of the installed base of these devices in the United States shows a steady rise from 2023 to 2027. (see Table 3-1).

---

[27] Retrieved in: https://www.wifimap.io/234-united-states on May 15, 2024. On July 31, 2024 it had increased to 965,413.

TABLE 3-1. **United States: Device Installed Base** & **Penetration**
2023-2027

DEVICE	METRICS	2023	2024	2025	2026	2027	CAGR
Smartphones	Units (in million)	338	349	354	358	363	1.81%
	Penetration (%)	101%	104%	105%	105%	106%	1.33%
Tablets	Units (in million)	127	127	127	127	128	0.16%
	Penetration (%)	38%	38%	38%	37%	37%	-0.31%
Laptops	Units (in million)	213	220	227	234	241	3.21%
	Penetration (%)	64%	65%	67%	69%	71%	2.73%
Devices per User		2.02	2.06	2.09	2.12	2.14	1.48%

SOURCES: CISCO ANNUAL INTERNET REPORT HIGHLIGHTS TOOL 2018-2023;
GSMA INTELLIGENCE; TELECOM ADVISORY SERVICES ANALYSIS

Adding to the proliferation of devices, traffic per device is also estimated to increase significantly. The average monthly traffic per device in the United States is projected to rise considerably from 2023 to 2027 (see Table 3-2).

TABLE 3-2. **United States: Average Traffic** per **Device** (Gigabytes per Month)
2023-2027

DEVICE	2023	2024	2025	2026	2027	CAGR
Smartphones	59	74	94	114	134	23.11%
Tablets	45	57	72	87	103	22.91%
Laptops	90	101	114	128	141	11.90%

SOURCES: CISCO ANNUAL INTERNET REPORT HIGHLIGHTS TOOL 2018-2023;
TELECOM ADVISORY SERVICES ANALYSIS

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

TABLE 3-3. **United States: Internet Traffic** (Exabytes[28] per Month)
2023-2027

DEVICE	2023	2024	2025	2026	2027	CAGR
Smartphones	18.4	24.1	31.1	38.2	45.4	25%
Tablets	5.3	6.7	8.6	10.4	12.2	23%
Laptops	17.8	20.7	24.2	27.8	31.6	15%

SOURCES: CISCO ANNUAL INTERNET REPORT HIGHLIGHTS TOOL 2018-2023;
TELECOM ADVISORY SERVICES ANALYSIS

---

[28] 1 Exabyte equals 1,073,741,824 gigabytes.

Considering traffic from the three device classes above, and discounting that total to reflect only the traffic that we estimate would be utilizing Wi-Fi access points as seen in Table 3-4, we can then estimate the traffic that is using public Wi-Fi access points.[29]

TABLE 3-4. **United States: Total Public Wi-Fi Traffic**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Total Wi-Fi Traffic (exabytes per month)	20.59	26.29	33.36	40.59	48.03
Total Public Wi-Fi Traffic (exabytes per month)	0.89	1.14	1.44	1.75	2.08
Total Public Wi-Fi Traffic (exabytes per year)	10.68	13.64	17.30	21.06	24.91
Total Public Wi-Fi Traffic (million GB per year)	11,467	14,643	18,581	22,609	26,750

SOURCES: CISCO; TELECOM ADVISORY SERVICES ANALYSIS

3.1.1. Benefit of Free Wi-Fi Traffic Due to Wi-Fi 6 or Less Operating in the 2.4 GHz & 5 GHz bands

To isolate the effect from the increased capacity derived from the 6 GHz and 7 GHz allocations, we calculate the portion of free Wi-Fi traffic attributed to current spectrum bands. For this, we relied on the assumption that current traffic levels are already producing congestion in most free Wi-Fi hotspots at times of peak demand. Thus, we assume that traffic per hotspot beyond 2021 has remained at the average 2020 levels (6,199 GB per year, per hotspot) (See Table 3-5).

TABLE 3-5. **United States: Total Free Wi-Fi Traffic Projection**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Free Wi-Fi Traffic (Million GB Per Year) - Considering Current Trends	11,467	14,643	18,581	22,609	26,750
Free Wi-Fi Hotspots (Million)	0.91	0.95	1.00	1.04	1.09
Annual Traffic Per Hotspot - Considering Current Trends (GB)	12,595	15,363	18,624	21,648	24,468
Annual Traffic Per Hotspot - Capped Due To Congestion (GB)	6,199	6,199	6,199	6,199	6,199
Total Traffic (Not Attributed To 6 GHz And 7 GHz Allocation) (Billion GB)	5.64	5.91	6.19	6.47	6.78

SOURCES: CISCO; WI-FI MAP; TELECOM ADVISORY SERVICES ANALYSIS

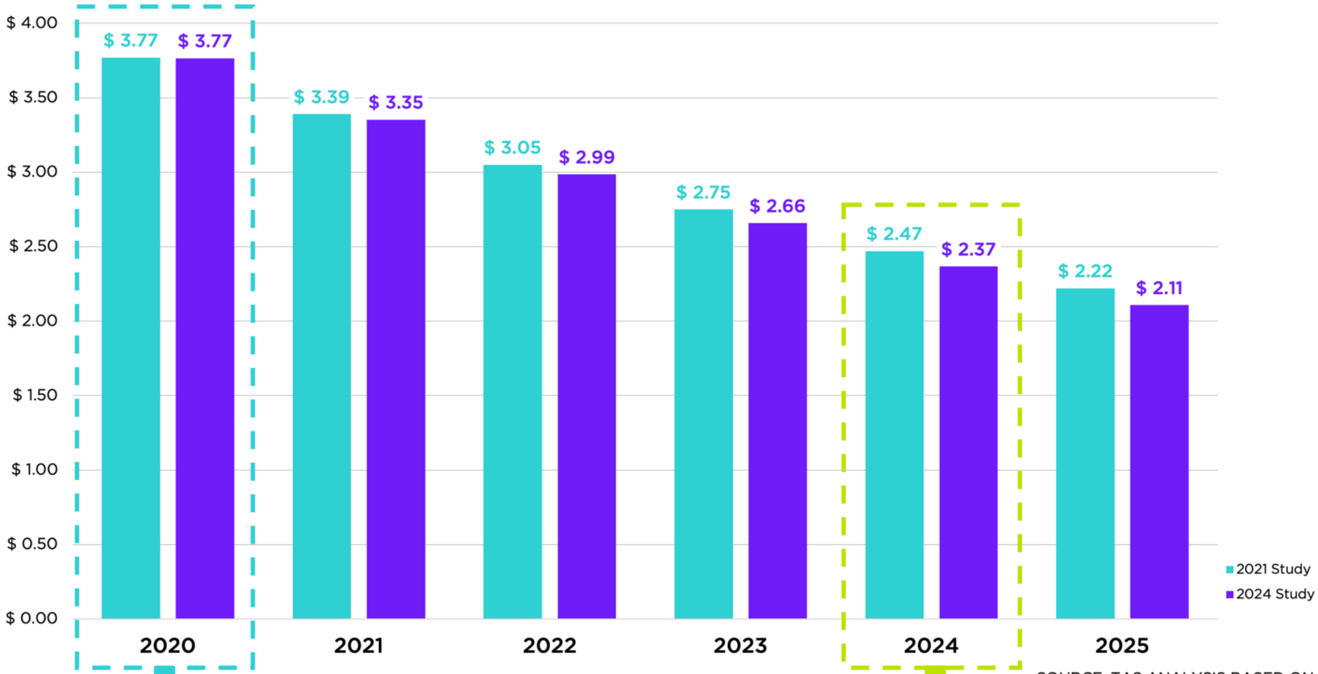
---

[29] The three classes of devices in Table 3-3 are ones that would typically be utilized by consumers on public Wi-Fi networks, and do not represent the sum total of all Wi-Fi traffic, device classes or use cases. Our analysis focuses on these devices because, in this section of our report, we are working toward an estimate of public Wi-Fi use so that we can calculate the benefits associated from having public hotspots available to consumers. Note also that we do not attempt here to estimate mobile offloading which is defined as the amount of Wi-Fi traffic associated with dual use (e.g., cellular and Wi-Fi) devices, as we are making no distinction in Table 3-3 about the type of connectivity these devices possess or utilize. The offloading topic is dealt with at section 6.1.2, infra, on cellular capex savings from offloading.

We calculate consumer benefit by multiplying the total free traffic (not attributed to 6 GHz or 7 GHz) by the difference between what the consumer would have to pay if she/he were to rely on a wireless carrier and the cost of offering free Wi-Fi (incurred by the retailer or public site). To do so, we need an estimate of the average price per GB of wireless data transmitted by wideband networks, which we calculated by averaging the most economic "dollar per GB" plan of three major U.S. wireless carriers.

The last data available for mobile price is marginally lower than was considered in the 2021 study ($2.37 vs. $2.47 per GB) (see graphic 3-1).

GRAPHIC 3-1. **Mobile Data Price** per **GB**
(US$)



SOURCE: TAS ANALYSIS BASED ON OPERATOR´S DATA ON WEBSITES

FEBRUARY 2020	PRICE (US$)	GB	PRICE per GB (US$)
AT&T Mobile Share Plus 9 GB	$ 60	9	$ 6.67
Verizon Connected Home	$ 150	40	$ 3.75
Sprint 50 GB Mobile; Hotspot	$ 50	50	$ 1.00
T-Mobile Magenta Plus	$ 85	20	$ 4.25
Average February 2020			$ 3.92
June 2020 Extrapolation			$ 3.77

SOURCE: OPERATOR´S DATA ON WEBSITES, BASED ON PLANS FOR TABLETS/ HOTSPOTS (FEBRUARY 2020)

JUNE 2024	PRICE (US$)	GB	PRICE per GB (US$)
AT&T: 50 GB Data 5G Access for Tablet	$ 55.00	50	$ 1.10
Verizon More Unlimited	$ 90.00	30	$ 3.00
T-Mobile Hotspot data plans	$ 30.00	10	$ 3.00
Average June 2024			$ 2.37

SOURCE: OPERATOR´S DATA ON WEBSITES, BASED ON PLANS FOR TABLETS/HOTSPOTS (JUNE 2024)

NOTE: Unlimited data plans were not considered in this analysis because all such plans includes speed restrictions or usage type limitations based on data consumption or network status, making them incomparable with Wi-Fi. Only plans specifically for tablets or personal hotspots with a guaranteed amount of high-speed data were considered. Prices were evaluated based on the purchase of these plans individually, without bundling with other services.

In the 2021 study we projected a mobile data price per GB for consumers of US $2.47 in 2024. Considering an average price from mobile operators to use mobile data on a tablet, the actual price is US $2.37 per GB, marginally lower than the price that we consider previously (see Table 3-6)[30].

---

[30] The mobile operators are now selling plans with unlimited mobile data (but with speed and use restrictions), so they are not strictly comparable with the use of Wi-Fi.

TABLE 3-6. **United States: Average Price** per **Gigabyte**
2024[31]

CARRIER	PLAN	PRICE PER GB ($)
AT&T	50 GB Data 5G Access for Tablet: $44/40 Gigabytes Cap	$ 1.10
Verizon	Verizon More Unlimited: $90/30 Gigabytes Cap	$ 3.00
T-Mobile	Hotspot data plan : $30/10 Gigabytes Cap	$ 3.00
Average		$ 2.37

SOURCES: OPERATOR WEBSITES; TELECOM ADVISORY SERVICES ANALYSIS

Starting from our previous estimate of a price per GB in 2020 of $3.77, , we expect the average price per GB will reach an estimated $1.67 in 2027, from an actual average (in 2024) of $2.37.[32]

As to the cost of offering the Wi-Fi service, this would include an additional router and bandwidth for the provider of free service.[33] We assume those costs to be prorated at $2.50 per gigabyte in 2020, which was what some Wi-Fi services in public sites charge per 2-hour service (assuming this to be costs passed through to the customer)[34]. By relying on the total free Wi-Fi traffic not attributed to 6 GHz allocation shown in Table 3-7 and the average price per cellular gigabyte minus the cost of provisioning Wi-Fi service, we calculated the consumer benefit of free Wi-Fi traffic using Wi-Fi 6 or lower standards. (see Table 3-7).

TABLE 3-7. **United States: Consumer Benefit** of **Free Non-6 GHz Wi-Fi Traffic**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Total Free Traffic (Not Attributed to 6 GHz) (Billion GB)	5.64	5.91	6.19	6.47	6.78
Price Per Cellular Gigabyte ($)	$ 2.66	$ 2.37	$ 2.11	$ 1.88	$ 1.67
Cost Per Wi-Fi Provisioning ($)	$ 1.70	$ 1.51	$ 1.34	$ 1.20	$ 1.07
Consumer Benefit Per Gigabyte ($)	$ 0.96	$ 0.86	$ 0.76	$ 0.68	$ 0.60
Total Consumer Benefit ($ Billion)	$ 5.43	$ 5.06	$ 4.72	$ 4.39	$ 4.10

SOURCES: WEBSITES OF CELLULAR OPERATORS; TELECOM ADVISORY SERVICES ANALYSIS

As indicated in Table 3-9, consumer benefit of free Wi-Fi traffic at 2.4 and 5 GHz in 2023 was an estimated $5.4 billion, decreasing to $4.1 billion in 2027, driven by our forecast reduction in the price per cellular gigabyte and congestion created if we do not consider the 6 GHz spectrum band.[35]

---

[31] We do not consider unlimited data plans (where the price per GB would tend to zero) in our analysis. Even if almost 75% of consumers have an unlimited data plan (see Ilumba, A. (2024). "How much is the average cellphone bill?" WhistleOut, February 21. Retrieved in: https://www.whistleout.com/CellPhones/Guides/average-phone-plan-price), these plans come with usage restrictions such as speed limits, usage constraints, or availability only during periods of low traffic.

[32] An alternative way of calculating the mobile broadband price per GB could be to rely on Table 4 of Census Bureau Survey of enterprises that estimate that in 2022 mobile operators reported $113 billion in internet access revenues. If divided this value by the CTIA GB volumes, that would yield $1.59 per GB. We have two concerns with this approach: (i) It is difficult to determine whether this captures all revenues since the difference between US$113 billion and $308 billion in total revenue in the survey report might indicate that mobile internet revenue excludes other mobile data issues and/or bundling effects; (ii) there is an issue in mixing data from CTIA and Census Bureau.

[33] The cost of provisioning fixed broadband are not accounted since those are already part of the existing infrastructure of the location where the user of free service is.

[34] This is assumed to decline to $1.34 per gigabyte by 2025, assuming the same decline rate as the price per GB for mobile broadband.

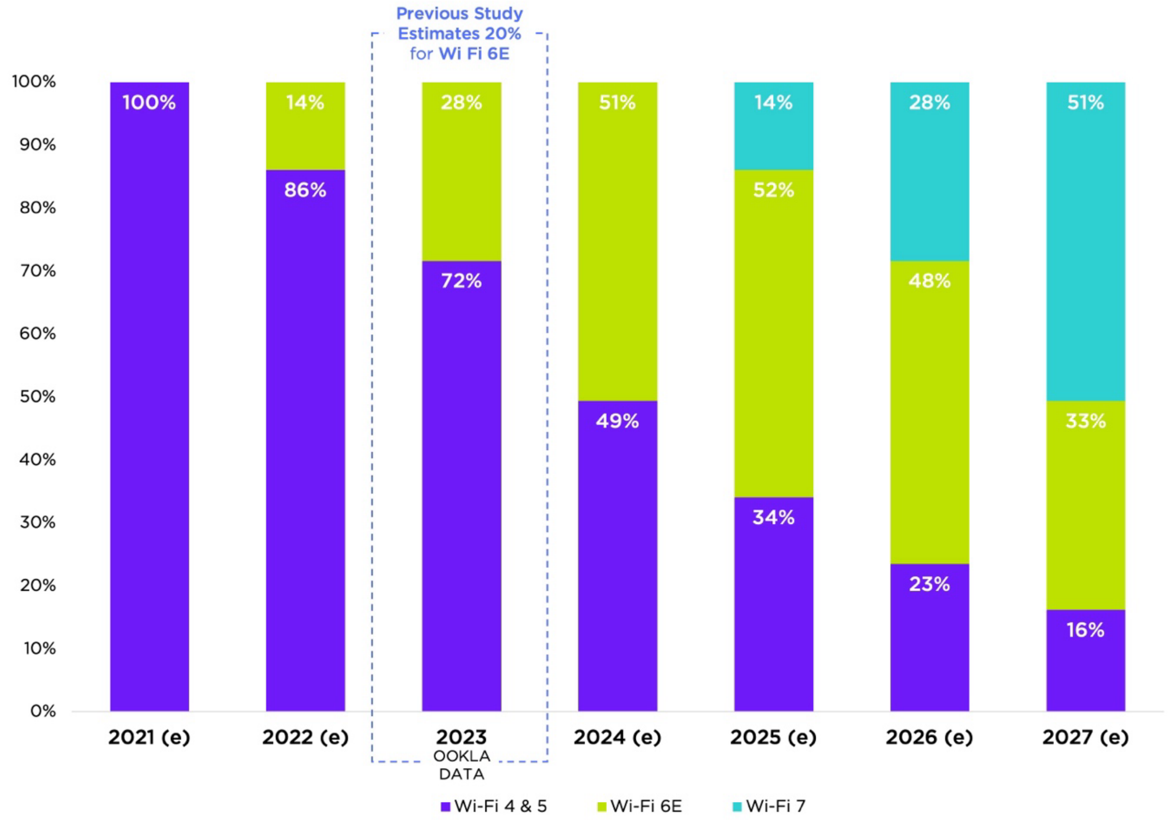
[35] This benefit assumes that savings apply to the total data being consumed. A question remains whether data usage would diminish if consumers had to pay for it in mobile data plans.

3.1.2. Benefit of Free Wi-Fi Traffic Due to Wi-Fi 6E & Wi-Fi 7 Operating in the 6 GHz & 7 GHz Bands

The allocation of the 6 GHz spectrum band for unlicensed use and the technological advancements provided by the Wi-Fi 6E standard have alleviated some of the previously mentioned bottlenecks causing congestion. Consequently, the traffic per hotspot will continue to grow at its natural rate, as determined by the extrapolation of recent trends.

However, it is important to note that Wi-Fi 6E also has a "restriction" in that not all Wi-Fi networks are continuously upgraded, so we conservatively assume free Wi-Fi to be saturated at 2024 traffic levels.[36] Also, not all Wi-Fi traffic will benefit immediately from Wi-Fi 6E even when access points are upgraded, as some part of current devices are not equipped to support the new standards. Thus, we expect the traffic through Wi-Fi 6E to gradually increase until reaching 52% of total traffic by 2025 (see graphic 3-2).[37]

GRAPHIC 3-2. Adoption of Wi-Fi Technologies



SOURCE: OOKLA (2023); TELECOM ADVISORY SERVICES ESTIMATION FOR THE REST OF THE YEARS BASED ON OOKLA DATA.

---

[36] The underlying assumption is that, if free hotsspots are not upgraded, the constant increase in usage leads to a decline in speeds and, consequently, a decrease in usage (less GB; that is the cap): under this scenario, users tend to download less data because the network does not perform appropriately. This is the cap that drives the difference between relying on mobile wireless and Wi-Fi. Implicitly, we are being conservative.

[37] To estimate the percent of traffic being handled through Wi-Fi 6E we rely on Ookla's adoption of Wi-Fi generation by market contained in Ookla Research Articles: "ISPs Need to Do More to Improve Wi-Fi Performance in the Home" (36.3% for Wi-Fi 6 at Q1-23). Since Ookla does not differentiate between Wi-Fi 6 and Wi-Fi 6E, we also rely on Broadcom's data that stipulates that, globally,18% of Wi-Fi 6/Wi-Fi 6E represent Wi-Fi 6E (as reported in Sbeglia, C. (2023). What does global Wi-Fi 6 and 6E adoption look like?", RCR Wireless News, November 17, retrieved in: https://www.rcrwireless.com/20231117/fundamentals/what-does-global-wi-fi-6-ad-6e-adoption-look-like)

Given that this last value is a global estimate, it reflects countries that are at an early stage of Wi-Fi 6E adoption. Consequently, we decide to reduce Ookla's original estimate and attribute only 28% of Wi-Fi traffic to be conducted through Wi-Fi 6E in 2023, reaching 52% in 2025 and gradually declining by growth of Wi-Fi 7 afterwards.

The usage of Wi-Fi 4 & 5 has seen a significant decline from 100% in 2021 to an estimated 72% by 2023. Thus, we estimate that Wi-Fi 6E represented 28% of Wi-Fi usage in 2023. This share is projected to peak at 52% in 2025 before gradually decreasing to 33% by 2027 as Wi-Fi 7 adoption increases. We also estimate that Wi-Fi 7 is expected to start gaining usage in 2025 with an initial adoption rate of 14%, increasing to 51% by 2027.[38]

Based on these projections, the total traffic attributable to Wi-Fi 6E will grow from 1.7 billion GB in 2023, to 4.8 billion GB in 2025. Going forward, that amount will decline due to the substitution of Wi-Fi 6E with Wi-Fi 7. So, the projection of the total traffic attributable to Wi-Fi 6E in 2027 is 3.3 billion GB (See Table 3-8).

TABLE 3-8. **United States: Additional Consumer Benefit** of **Free Wi-Fi Traffic Generated Due** to **Wi-Fi 6E**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Traffic per hotspot (capped due to congestion Wi-Fi 6E) (GB)	12,595	15,363	15,363	15,363	15,363
Free Wi-Fi hotspots (million)	0.91	0.95	1.00	1.04	1.09
Total Traffic (Billion GB)	11.47	14.64	15.33	16.04	16.80
Total Traffic (Not Attributed to 6 GHz & 7 GHz allocation) (Billion GB)	5.64	5.91	6.19	6.47	6.78
Additional Traffic If All the Users Use Wi-Fi 6E (Billion GB)	5.82	8.73	9.14	9.57	10.02
Traffic Through Wi-Fi 6E (%)	28.36%	50.60%	52.00%	48.15%	33.20%
Total Free Traffic (Attributable to Wi-Fi 6E) (Billion GB)	1.65	4.42	4.75	4.61	3.33

SOURCES: CISCO; WI-FI MAP; TELECOM ADVISORY SERVICES ANALYSIS

Once we compute the additional traffic due to Wi-Fi 6E, we follow a similar approach to calculate the consumer benefit, by multiplying it by the difference between what the consumer would have to pay if he were to utilize a wireless carrier and the cost of offering free Wi-Fi (Table 3-9). As a result, we project an additional consumer benefit of $2.0 billion from free Wi-Fi traffic attributed to Wi-Fi 6E in 2027.

TABLE 3-9. **United States: Consumer Benefit** of **Free Wi-Fi Traffic Due** to **Wi-Fi 6E**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Total Free traffic (attributable to Wi-Fi 6E) (billion GB)	1.65	4.42	4.75	4.61	3.33
Price per cellular gigabyte ($)	2.66	2.37	2.11	1.88	1.67
Cost per Wi-Fi provisioning ($)	1.70	1.51	1.34	1.20	1.07
Consumer benefit per gigabyte ($)	0.96	0.86	0.76	0.68	0.60
Total Consumer benefit ($ billion)	$ 1.59	$ 3.78	$ 3.62	$ 3.13	$ 2.01

SOURCES: WEBSITES OF CELLULAR OPERATORS; TELECOM ADVISORY SERVICES ANALYSIS

---

[38] Indeed, these numbers may be conservative. The Wi-Fi Alliance is projecting that 231 million Wi-Fi 7 chipsets will ship this year on a global basis. The Beacon (blog), State of Wi-Fi Momentum in 2024, May 30, 2024 retreived at https://www.wi-fi.org/beacon/the-beacon/the-state-of-connectivity-wi-fi-momentum-in-2024#:~:text=These%20advanced%20applications%20depend%20on,expected%20to%20ship%20in%202024.

Operating on the 6 GHz band, Wi-Fi 7 is expected to provide substantial improvements over its predecessors, including Wi-Fi 6E. To estimate the additional impact of Wi-Fi 7, first, we projected the traffic per hotspot based on the assumption that Wi-Fi 7 will allow continued growth beyond the saturation point of Wi-Fi 6E. Our technical analysis indicates that Wi-Fi 7 (under 6 GHz) supports 50.6% more traffic than Wi-Fi 6E. Additional traffic generated specifically by Wi-Fi 7 is expected to become significant starting from 2025, with an incremental increase of 3,253 million GB, growing to 8,494 million GB by 2027. However, to estimate the additional consumer benefit, we have to consider that not all Wi-Fi traffic will benefit immediately from Wi-Fi 7, as adoption rates mean not all current devices will be equipped to support the new standards. We estimate that the traffic through Wi-Fi 7 will be 14% of the total Wi-Fi traffic in 2025, rising to 51% in 2027. This will result in total traffic attributable to Wi-Fi 7 (under 6 GHz) rising from zero in the initial years to 9,367 million GB by 2027 (see Table 3-10).

TABLE 3-10. **United States: Additional Consumer Benefit** of **Free Wi-Fi Traffic Generated Due** to **Wi-Fi 7 Under 6 GHz**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Traffic per hotspot	12,595	15,363	18,624	21,648	23,132
Free Wi-Fi hotspots (million)	0.91	0.95	1.00	1.04	1.09
Total traffic (billion GB)	11.47	14.64	18.58	22.61	25.29
Total traffic (under 6E) (billion GB)	11.47	14.64	15.33	16.05	16.80
Additional traffic due to Wi-Fi 7 vs. Wi-Fi 6E (billion GB)	0	0	3.25	6.56	8.49
Additional traffic due to Wi-Fi 7 vs Wi-Fi 6 or lower (billion GB)	5.82	8.73	9.14	9.57	10.02
Traffic through Wi-Fi 7 (%)	0%	0%	14%	28%	51%
Total Free traffic (attributable to Wi-Fi 7 under 6 GHz) (billion GB)	0	0	1.73	4.58	9.37

SOURCES: CISCO; WI-FI MAP; TELECOM ADVISORY SERVICES ANALYSIS

This will translate into an additional consumer benefit of $5.7 billion from free Wi-Fi traffic attributed to Wi-Fi 7 under 6 GHz in 2027.

TABLE 3-11. **United States: Consumer Benefit** of **Free Wi-Fi Traffic Due** to **Wi-Fi 7 Under 6 GHz**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Total Free Traffic (Attributable to Wi-Fi 7 Under 6 GHz) (billion GB)	0	0	1.73	4.58	9.37
Price per Cellular Gigabyte ($)	2.66	2.37	2.11	1.88	1.67
Cost per Wi-Fi Provisioning ($)	1.70	1.51	1.34	1.20	1.07
Consumer Benefit per Gigabyte ($)	0.96	0.86	0.76	0.68	0.60
Total Consumer Benefit ($ billion)	$ 0	$ 0	$ 1.32	$ 3.11	$ 5.66

SOURCES: WEBSITES OF CELLULAR OPERATORS; TELECOM ADVISORY SERVICES ANALYSIS

In the scenario where Wi-Fi 7 operates on the lower portion of the 7 GHz band, the traffic per hotspot is projected to reach 24,106 GB by 2027, driven by increased spectrum and channels. Similarly, in the scenario where Wi-Fi 7 utilizes additional parts of the 7 GHz band, the traffic per hotspot is conservatively expected to increase even higher, reaching 24,468 GB by 2027.[39]

This increase in traffic per hotspot will consequently elevate the consumer benefit in 2027[40], by close to $350 million with the use of additional channels of spectrum in the 7 GHz band.

3.2. Free Wi-Fi Service Supporting the Needs of the Broadband Unserved Population

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

3.2.1. Free Wi-Fi Traffic Supporting the Needs of Unserved Population Due to Wi-Fi 6 Operating in the 2.4 GHz & 5 GHz Bands

The calculation of this economic impact starts by calculating which portion of U.S. households that lack broadband service are already accessing the Internet through free hotspots. The FCC reported in June 2022 there were 116.7 million fixed broadband residential connections.[41] The estimation of non-connected households is based on the estimated number of households from the US census (130.6 million), which results in a total non-connected as of June 2022 of 13.9 million. As indicated in table 3-12, we conservatively assume this number was reduced to 12.5 million by 2023 year-end. We continue to follow a conservative approach and assume that only 5% of unconnected households rely on free hotspots for accessing the Internet. After calculating the increase in broadband penetration due to households relying on free Wi-Fi, we rely on the broadband impact coefficient from Katz and Callorda (2024), that estimates for the Americas region a 1.86% increase in GDP for every 10% increase in penetration. As a result, the GDP contribution of this effect is expected to amount to $26.2 billion in 2023, declining to $13.8 billion in 2027 (See Table 3-12). This reduction is explained by the positive development that the digital divide is expected to diminish in the future with increased availability and adoption of broadband, and hence, fewer households will have to rely on free Wi-Fi hotspots.

---

[39] If the spectrum for Wi-Fi 7 is increased by 125 MHz, the impact would increase by 58.3% with respect to the initial scenario; and, if the spectrum is increased by an additional 375 MHz, the impact could result in 68.8% more connections with respect to the same scenario. Thus, the impact is related to the maximum number of simultaneous connections that Wi-Fi 7 could support with respect to its predecessor standard.

[40] The analysis for the scenarios involving 125 MHz and 500 MHz of the 7 GHz band follows the same methodology as outlined in Table 3-12 and Table 3-13. However, these scenarios consider an increased traffic per hotspot compared to the Wi-Fi 7 scenario under the 6 GHz band, which has data restrictions. Specifically, under the 7 GHz band with 125 MHz of spectrum, the technical analysis projects that traffic will grow by 56.9% compared to Wi-Fi 6E. With 500 MHz of the 7 GHz band, the traffic is expected to grow by 68.9% (see Appendix C).

[41] FCC (2024) Internet Access Service. Status as of June 30, 2022.

TABLE 3-12. **United States: GDP Contribution Due** to **Households Relying** on **Free Wi-Fi**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Households Without Internet (Million)	12.5[42]	10.7	9.0	7.5	6.0
Households That Don't Buy Because They Access The Internet Via Free Hotspots (%)	5%	5%	5%	5%	5%
Households Served By Free Wi-Fi Hot Spots	623,610	533,678	448,602	373,219	297,856
Households With Fixed Broadband (Million)	119.0	121.0	122.9	124.7	126.4
Increase In National Broadband Penetration	0.52%	0.44%	0.36%	0.30%	0.24%
Impact Of Fixed Broadband Adoption In GDP	18.6%	18.6%	18.6%	18.6%	18.6%
Increase In The GDP Due To The New Broadband Adoption (% GDP)	0.10%	0.08%	0.07%	0.06%	0.04%
GDP (US$ Billion)	$ 26,950	$ 27,967	$ 29,049	$ 30,224	$ 31,429
Total Impact In GDP (US$ Billion)	$ 26.22	$ 22.89	$ 19.68	$ 16.79	$ 13.74

SOURCES: FCC; STATISTA; PEW RESEARCH CENTER; IMF; KATZ CAND CALLORDA (2024);
TELECOM ADVISORY SERVICES ANALYSIS

3.2.2. Free Wi-Fi Traffic Supporting the Needs of the Unserved Population Due to Wi-Fi 6E & Wi-Fi 7 Operating in the 6 GHz & 7 GHz Bands

Wi-Fi 6E technology supports a high number of devices on a single access point. Accordingly, the improved throughput of free Wi-Fi hotspots under the 6 GHz allocation will allow for the possibility of serving additional unconnected households.

We follow again a conservative approach and assume that a further 5% of unconnected households are served through free hotspots with the technological advantages of Wi-Fi 6E. We have also considered that the expansion of traffic through the new band, with Wi-Fi 6E will take place gradually, reaching 52% in 2025.[43] All in all, we estimate that an additional 211,325 households will be served in 2025 due to free hotspots operating under 6 GHz spectrum with Wi-Fi 6E, yielding an additional GDP contribution of approximately $9.3 billion (Table 3-13). After 2025 the impact will decline due to the migration from Wi-Fi 6E to Wi-Fi 7, reaching an additional GDP contribution of approximately $4.1 billion in 2027.

---

[42] Starting with the FCC reported adoption as of June 2022, we extrapolated the number of non-adopters to 2023 year-end based on Statista fixed broadband connections.

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

TABLE 3-13. **United States: GDP Contribution Due** to **Households Relying on Free Wi-Fi Due** to **Wi-Fi 6E** & **6 GHz**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Households without Internet (not served by free Wi-Fi and not new adopters of WISP) (million)	11.6	9.8	8.1	6.7	5.3
Potential households that could be served through free Wi-Fi hotspots under increased capacity (% of those not connected)	5%	5%	5%	5%	5%
Traffic through Wi-Fi 6E (%)	28%	51%	52%	48%	33%
Additional households served by free Wi-Fi hot spots with Wi-Fi 6E	164,670	248,009	211,325	160,464	88,534
Increase in national broadband penetration	0.14%	0.20%	0.17%	0.13%	0.07%
Increase in the GDP due to the new broadband adoption (% GDP)	0.03%	0.04%	0.03%	0.02%	0.01%
Total impact in GDP ($ billion)	$ 6.92	$ 10.64	$ 9.27	$ 7.22	$ 4.09

SOURCES: FCC; STATISTA; CONNECT HOME; IMF; KATZ CAND CALLORDA (2024); TELECOM ADVISORY SERVICES ANALYSIS

From 2025, part of the traffic that is carried out over Wi-Fi 6E will begin to migrate to Wi-Fi 7, so it is necessary to study this effect as a complement to what has been done for Wi-Fi 6E. First, we will analyze the case of Wi-Fi 7 with no use of the 7 GHz band. That impact will be yielding an additional GDP contribution of approximately $2.48 billion in 2025, growing to $6.23 billion in 2027 due to the increase in traffic through Wi-Fi 7 (see Table 3-14).

TABLE 3-14. **United States: GDP Contribution Due** to **Households Relying On Free Wi-Fi Due** to **Wi-Fi 7** & **6 GHz**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Households without Internet (not served by free Wi-Fi and not new adopters of WISP)	11,613,598	9,772,769	8,094,337	6,728,828	5,378,010
Potential households that could be served through free Wi-Fi hotspots under increased capacity (% of those not connected)	5%	5%	5%	5%	5%
Traffic through Wi-Fi 7 (%)	0%	0%	14%	28%	51%
Additional Households Served by Free Wi-Fi hotspots with Wi-Fi 6E	0	0	56,612	94,506	134,913
Increase in National Broadband Penetration	0%	0%	0.05%	0.08%	0.11%
Increase in the GDP Due to the New Broadband Adoption (% GDP)	0%	0%	0.01%	0.01%	0.02%
Total Impact in GDP ($ billion)	$ 0	$ 0	$ 2.48	$ 4.25	$ 6.23

SOURCES: FCC; STATISTA; CONNECT HOME; IMF; KATZ CAND CALLORDA (2024); TELECOM ADVISORY SERVICES ANALYSIS

The analysis for the scenarios involving the lowest 125 MHz and a total of at least 500 MHz of the 7 GHz band, consider an increased traffic per hotspot compared to the Wi-Fi 7 scenario under the 6 GHz band. The increase in traffic will start in 2027 when the 6 GHz band could become saturated. Therefore, using the same methodology as in the previous section (see analysis in 3.1.2) the GDP impact in 2027 will evolve as follows:

- The GDP impact will increase by $358 million in the lowest 125 MHz scenario of the 7 GHz band
- The GDP impact will increase by $133 million in the additional 500 MHz scenario of the 7 GHz band

3.3. Benefit to Consumers Enjoying Higher Speed from Free Wi-Fi Under Wi-Fi 6E & Wi-Fi 7 Operating in the 6 GHz & in the 7 GHz Bands

When the 6 GHz band is adopted by free Wi-Fi access points using Wi-Fi 6E, it delivers service at faster broadband speeds. We estimate that public Wi-Fi hotspots last year averaged 25 Mbps of download speed.[44] Thus, the expanded capabilities due to the allocation of 6 GHz spectrum band will enhance free Wi-Fi speed using Wi-Fi 6E, and as a result, will increase consumer benefit.[45] After calculating the average speed by considering the expected share of traffic through Wi-Fi 6E, we follow Nevo et al. (2016) and calculate the additional consumer benefit per household relying on free Wi-Fi. We expect the benefit resulting from faster speed in free Wi-Fi sites to reach $66.04 million in 2027 due to Wi-Fi 6E (See Table 3-15).

TABLE 3-15. **United States: Consumer Benefit** for **Enjoying Higher Speed** from **Free Wi-Fi** with **Wi-Fi 6E**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Free Wi-Fi Mean Speed with No Wi-Fi 6E (Mbps)	25	33	42	52	62
Free Wi-Fi Mean Speed with Wi-Fi 6E (Mbps)	96	114	135	160	189
Traffic Through Wi-Fi 6E (%)	28.36%	50.60%	52.00%	48.15%	33.20%
Average Free Wi-Fi Mean Speed with Wi-Fi 6E (Mbps)	45.45	73.88	90.58	104.01	104.11
Willingness to Pay for Average Download Speed ($)	113.81	120.81	127.81	133.38	137.99
New Willingness to Pay for Average Download Speed ($)	129.69	142.90	148.45	152.21	152.24
Additional Monthly Consumer Benefit ($)	15.88	22.09	20.64	18.83	14.24
Additional Yearly Consumer Benefit ($)	190.57	265.12	247.63	225.98	170.90
Households that Rely on Free Wi-Fi	788,280	781,687	659,927	533,682	386,389
Impact ($ Million)	$ 150.22	$ 207.24	$ 163.42	$ 120.60	$ 66.04

SOURCES: NEVO ET AL. (2016); TELECOM ADVISORY SERVICES ANALYSIS

---

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

[45] Our starting point is the speed that we get from a single device when connected through Wi-Fi at home, which is reported by Ookla (289 Mbps) in 2023. Now, since we do not have the speed data in free Wi-Fi connections, we thought that this being a shared connection, the speed should be lower. Our assumption of a third of speed is qualitatively confirmed by interviews that the upgrade of free sites to higher standards is proceeding very slowly.

According to our technical analysis, Wi-Fi 7 (under 6 GHz) is expected to increase Wi-Fi speeds by 30.6% compared to Wi-Fi 6E. This significant enhancement in speed is reflected in the projected Wi-Fi speeds from mobile devices, which are expected to rise from 126 Mbps in 2023 to 247 Mbps by 2027. Considering the traffic through Wi-Fi 7, the average mean speed of free Wi-Fi is expected to improve substantially, reaching 156 Mbps by 2027. This increased speed results from the higher efficiency and capacity of Wi-Fi 7. After calculating the average speed by considering the expected share of traffic through Wi-Fi 7, we follow again Nevo et al. (2016) and calculate the additional consumer benefit per household relying on free Wi-Fi. We expect the benefit resulting from faster speed in free Wi-Fi sites to reach $116.8 million in 2027 due to Wi-Fi 7 (See Table 3-16).

TABLE 3-16. **United States: Consumer Benefit** for **Enjoying Higher Speed** from **Free Wi-Fi** with **Wi-Fi 7 Under 6 GHz**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Increase of Wi-Fi Speed with Wi-Fi 7	30.56%	30.56%	30.56%	30.56%	30.56%
Free Wi-Fi mean speed with Wi-Fi 7 (Mbps)	126	149	176	209	247
Traffic through Wi-Fi 7 (%)	0%	0%	13.93%	28.36%	50.60%
Average Free Wi-Fi Mean Speed with Wi-Fi 7 (Mbps)	25	33	61	97	156
Willingness to Pay for Average Download Speed ($)	113.81	120.81	127.81	133.38	137.99
New Willingness to Pay for Average Download Speed ($)	113.81	120.81	137.73	150.17	163.18
Additional Monthly Consumer Benefit ($)	0.00	0.00	9.91	16.80	25.18
Additional Yearly Consumer Benefit ($)	0.00	0.00	118.95	201.57	302.17
Households that Rely on Free Wi-Fi	788,280	781,687	659,927	533,682	386,389
Impact ($ Million)	$ 0.00	$ 0.00	$ 78.50	$ 107.57	$ 116.75

SOURCES: NEVO ET AL. (2016); TELECOM ADVISORY SERVICES ANALYSIS

According to our technical analysis, Wi-Fi 7 (under 7 GHz and with the addition of the lowest 125 MHz of 7 GHz) is expected to increase Wi-Fi speeds by 47.9% compared to Wi-Fi 6E. Therefore, we replicate the analysis for Wi-Fi 7 under 6 GHz, to estimate that effect and obtain that the additional consumer benefit resulting from faster speed in free Wi-Fi sites to reach $12.8 million in 2027 due to Wi-Fi 7 under 7 GHz with the addition of the lowest 125 MHz of 7 GHz (See Table 3-17).

TABLE 3-17. **United States: Consumer Benefit** for **Enjoying Higher Speed** from **Free Wi-Fi** with **Wi-Fi 7 under 7 GHz** with the **Addition** of the **Lowest 125 MHz**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Increase of Wi-Fi Speed with Wi-Fi 7 under 7 GHz & the addition of the lowest 125 MHz of 7 GHz (%)	47.9%	47.9%	47.9%	47.9%	47.9%
Free Wi-Fi mean speed with Wi-Fi 7 under 7 GHz &the addition of the lowest 125 MHz of 7 GHz (Mbps)	142	169	200	237	280
Traffic through Wi-Fi 7 (%)	0%	0%	13.93%	28.36%	50.60%
Average Free Wi-Fi mean speed with Wi-Fi 7 under 7 GHz and the addition of the lowest 125 MHz of 7 GHz (Mbps)	25.35	32.80	64.34	104.39	172.28
Willingness to Pay for Average Download Speed ($)	113.81	120.81	127.81	133.38	137.99
New Willingness to Pay for Average Download Speed ($)	113.81	120.81	139.14	152.31	165.94
Additional Monthly Consumer Benefit ($)	0.00	0.00	11.33	18.93	27.94
Additional Yearly Consumer Benefit ($)	0.00	0.00	135.95	227.17	335.33
Households that Rely on Free Wi-Fi	788,280	781,687	659,927	533,682	386,389
Impact ($ Million)	$ 0.00	$ 0.00	$ 89.72	$ 121.24	$ 129.57
Additional Impact ($ Million)	$ 0.00	$ 0.00	$ 11.22	$ 13.67	$ 12.82

SOURCES: NEVO ET AL. (2016); TELECOM ADVISORY SERVICES ANALYSIS

Finally, according to our technical analysis, Wi-Fi 7 (under 7 GHz and 500 MHz) is expected to increase Wi-Fi speeds by 58.33% compared to Wi-Fi 6E. We estimate the additional consumer benefit resulting from faster speed in free Wi-Fi sites to reach $7.10 million in 2027 due to Wi-Fi 7 under 7 GHz with 500 MHz (See Table 3-18).

TABLE 3-18. **United States: Consumer Benefit** for **Achieving Higher Speed** from **Free Wi-Fi** with **Wi-Fi 7 Under 7 GHz** with **500 MHz**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Increase of Wi-Fi Speed with Wi-Fi 7 under 7 GHz and 500 MHz	58.33%	58.33%	58.33%	58.33%	58.33%
Free Wi-Fi mean speed with Wi-Fi 7 under 7 GHz and 500 MHz (Mbps)	152.36	180.48	213.79	253.25	300.00
Traffic through Wi-Fi 7 (%)	0%	0%	13.93%	28.36%	50.60%
Average Free Wi-Fi mean speed with Wi-Fi 7 under 7 GHz and 500 MHz (Mbps)	25.35	32.80	66.30	109.11	182.26
Willingness to pay for average download speed ($)	113.81	120.81	127.81	133.38	137.99
New willingness to pay for average download speed ($)	113.81	120.81	139.96	153.51	167.47
Additional Monthly Consumer Benefit ($)	0.00	0.00	12.15	20.13	29.48
Additional Yearly Consumer Benefit ($)	0.00	0.00	145.74	241.61	353.72
Households that rely on Free Wi-Fi	788,280	781,687	659,927	533,682	386,389
Impact ($ million)	$ 0.00	$ 0.00	$ 96.18	$ 128.95	$ 136.67
Additional impact ($ million)	$ 0.00	$ 0.00	$ 6.46	$ 7.71	$ 7.10

SOURCES: NEVO ET AL. (2016); TELECOM ADVISORY SERVICES ANALYSIS

3.4. Benefit to Consumers Relying on Wi-Fi in Educational Institutions

This analysis is based on a detailed financial analysis of the cost of Wi-Fi in educational institutions, focusing on capital expenditures (CAPEX) and operational expenditures (OPEX) per 19,000 students, as a case study constructed for a particular school.[46] The CAPEX, which is a one-time investment, is amortized at $128,571 per year from 2023 to 2027, reaching a total investment of $900,000 over seven years. The OPEX, representing the annual operational costs, remains steady at $742,000 per year. Consequently, the yearly cost per student is calculated at $45.82, derived by dividing the sum of CAPEX and OPEX by the total number of students, which is 19,000.

Enrollment data from the US Census (2021)[47] is used to determine the total number of students at various educational levels: higher education, secondary school, and elementary school (grades 5 to 8), resulting in a consistent total population of 55,578,000 students from 2023 to 2027. The analysis assumes no increase in enrollment numbers for conservative purposes. Additionally, the share of time spent on homework is estimated for different education levels: 25% for higher education, 20% for secondary school, and 15% for elementary school. The weighted average share of time spent on homework, across all levels, is 20.4%.

The analysis also examines the counterfactual expenses associated with using Mobile Broadband (MBB) for educational purposes, considering it as an alternative to Wi-Fi. The total cost of using MBB is projected to decrease annually from $486 in 2023 to $305.44 in 2027, based on Verizon's $45 monthly plan in 2023 with a 10% bulk discount. This reduction is calculated using the same rate applied to the price of one gigabyte of

---

[46] The original estimate was developed in Katz, R. (2022). The "to and through" opportunity: An economic analysis of options to extend affordable broadband to students and households via anchor institutions: Economic analysis, Cost Calculation Toolkit and Public Policy Implications. New York: Telecom Advisory Services and is based on the case study of the East Side Union High School District (ESUHSD) (San Jose, CA).

[47] U.S. Census (2021). "School Enrollment in the United States: 2021". Available at https://www.census.gov/library/publications/2023/acs/acs-55.html

mobile broadband. Additionally, it is important to note that only 20.4% of this cost is relevant, as it represents the proportion of time spent using data for homework. Consequently, the adjusted cost ranges from $99 in 2023 to $62.22 in 2027.

The yearly benefit per student, calculated as the difference between the adjusted cost using MBB and the yearly cost per student to have Wi-Fi in schools, decreases from $53.18 in 2023 to $16.40 in 2027 (reflecting the declining cost of mobile broadband). Finally, the total consumer benefit, determined by multiplying the yearly benefit per student by the number of students, declines from $2.96 billion in 2023 to $0.91 billion in 2027 (see Table 3-19).

TABLE 3-19. **United States: Benefit** to **Consumers Relying** on **Wi-Fi** in **Educational Institutions**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
CAPEX per 19,000 students	$ 128,571	$ 128,571	$ 128,571	$ 128,571	$ 128,571
OPEX per 19,000 students	$ 742,000	$ 742,000	$ 742,000	$ 742,000	$ 742,000
Yearly cost per student	$ 45.82	$ 45.82	$ 45.82	$ 45.82	$ 45.82
Higher education enrollment (million)	21,197	21,197	21,197	21,197	21,197
Secondary school enrollment (million)	17,294	17,294	17,294	17,294	17,294
Elementary school enrollment (Grades 5 to 8) (million)	17,087	17,087	17,087	17,087	17,087
Total enrollment (million)	55,578	55,578	55,578	55,578	55,578
Share of time to do homework (Higher School)	2500%	25.00%	25.00%	25.00%	25.00%
Share of time to do homework (Secondary School	20.00%	20.00%	20.00%	20.00%	20.00%
Share of time to do homework (Elementary School)	15.00%	15.00%	15.00%	15.00%	15.00%
Share of time in education	20.37%	20.37%	20.37%	20.37%	20.37%
Total Cost using MBB	$ 486.00	$ 432.72	$ 385.28	$ 343.05	$ 305.44
Real Cost using MBB	$ 99.00	$ 88.14	$ 78.48	$ 69.88	$ 62.22
Yearly benefit by student	$ 53.18	$ 42.32	$ 32.66	$ 24.06	$ 16.40
Consumer benefit ($ billion)	$ 2.96	$ 2.35	$ 1.82	$ 1.34	$ 0.91

SOURCES: VERIZON WEBSITE; US CENSUS; TELECOM ADVISORY SERVICES ANALYSIS

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

3.5. Use of Wi-Fi in Highly Dense Heterogeneous Environments

By leveraging the 6 GHz band, Wi-Fi 6E can offer faster speeds and greater capacity, ensuring that attendees in highly dense environments such as at professional sporting events can enjoy seamless connectivity for activities such as streaming video, accessing social media, and utilizing various data-intensive applications. Sports venues have already started deploying these capabilities.[48]

Attendance at these events is expected to grow steadily,[49] with mobile data usage per user increasing significantly each year.[50] The adoption rate of Wi-Fi 6E is estimated at 28.36% in 2023, peaks at 52.00% in 2025, and then decreases to 33.20% by 2027 (due to the substitution by Wi-Fi 7). Yearly traffic handled by Wi-Fi 6E is projected to peak at 75,406,356 GB in 2026 before declining to 62,050,958 GB in 2027, as devices migrate to Wi-Fi 7.

In the calculation, we also consider the capital expenditure for Wi-Fi 6E infrastructure, that remains constant at $10 million per year.[51] Finally, the consumer benefit is calculated by comparing the savings from using Wi-Fi 6E to the costs of mobile data. The consumer benefit attributable to Wi-Fi 6E is projected to increase from $49 million in 2023 to $132 million in 2026, before decreasing to $94 million in 2027 (see Table 3-20).

TABLE 3-20. **United States: Use** of **Wi-Fi** in **Highly Dense Heterogeneous Environments Under Wi-Fi 6E Using 6 GHz**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Attendance to professional sporting events (yearly)	160,048,969	163,249,948	166,514,947	169,845,246	173,242,151
Mobile data usage per user, per match (GB)	0.48	0.61	0.77	0.92	1.08
Traffic through Wi-Fi 6E (%)	28.36%	50.60%	52.00%	48.15%	33.20%
Yearly traffic using Wi-Fi 6E (GB)	21,972,839	50,280,383	66,276,161	75,406,356	62,050,958
Cost of the traffic using mobile network	$ 2.66	$ 2.37	$ 2.11	$ 1.88	$ 1.67
CAPEX (in price of sporting event)	$ 10	$ 10	$ 10	$ 10	$ 10
Consumer benefit ($ million)	$ 49	$ 109	$ 130	$ 132	$ 94

SOURCE: TELECOM ADVISORY SERVICES ANALYSIS

With the same methodology we estimate the consumer benefit under Wi-Fi 7 using 6 GHz, estimating that it will reach $158 million in 2027 (see Table 3-21).

---

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

[49] Analysis based on number of stadiums and average assistance in major sports leagues (Major League Baseball; Major League Soccer; National Basketball Association; National Football League and National Hockey League) using information from https://askwonder.com/research/people-attend-professional-sporting-events-u-s-nc75ioow4

[50] The initial data use per match is based on Qatar Soccer World Cup, then we assume a significant increase per year using CISCO´s estimations for IP data traffic. The data increase per match could also be higher due to new uses.

[51] $49 million estimated cost of deployment, over 5 years

TABLE 3-21. **United States: Use of Wi-Fi in Highly Dense Heterogeneous Environments Under Wi-Fi 7 Using 6 GHz**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Traffic through Wi-Fi 7 (%)	0%	0%	13.93%	28.36%	50.60%
Yearly traffic using Wi-Fi 7(GB)	0	0	17,754,714	44,411,225	94,556,997
Cost of the traffic using mobile network	$ 2.66	$ 2.37	$ 2.11	$ 1.88	$ 1.67
Consumer benefit ($ million)	$ 0	$ 0	$ 37	$ 83	$ 158

SOURCE: TELECOM ADVISORY SERVICES ANALYSIS

* * * * *

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

- Free Wi-Fi offered in retail shops, coffee shops, city halls, and corporate guest accounts allows consumers to save money that would otherwise be spent purchasing cellular service: this amounts to $7.02 billion in 2023, reaching $12.21 billion in 2027
- Free Wi-Fi service supporting the needs of the broadband unserved population: assuming conservatively that only 5% of 12.472 million unconnected households rely on free Wi-fi sites to support their connectivity needs and considering the contribution of broadband lines to the GDP, Wi-Fi will increase GDP by $33.14 billion in 2023 and $24.55 billion in 2027.
- Benefit to consumers enjoying higher speed from free Wi-Fi under Wi-Fi 6E, and Wi-Fi 7, which amounts to $150 million in 2023 and $203 million in 2027.
- Benefit to consumers relying on Wi-Fi rather than purchasing mobile data services in educational institutions, which ranges between $2,955 million in 2023 and $911 million in 2027
- Use of Wi-Fi in highly dense heterogeneous environments: consumer benefit in settings, such as stadiums where large numbers of users are accessing the network simultaneously, reaching $252 million in 2027.

4. RESIDENTIAL WI-FI

Wi-Fi is a critical component of a home's infrastructure. It is an enabler of wireless communication between the point of access of fixed broadband and among multiple devices, such as data processing equipment, sound systems, home security, appliances, and the like. Park Associates estimated, based on a survey of 8,000 homes, that in 2023 the average U.S. household with internet access had 17 connected devices, including 11 computing and entertainment devices, 4 smart home components, and 2 health devices (see table 4-1)[52].

TABLE 4-1. **Average Number** of **Wi-Fi Enabled Devices** by **Household**

	COMPUTING & ENTERTAINMENT	SMART HOME	HEALTH DEVICES	TOTAL
2021	9	3	2	14
2022	11	3	2	16
2023	11	4	2	17
2024	12	4	2	18
2027	16	5	3	24

SOURCE: GRUENWEDEL, E. (2023). "PARKS: 92% OF U.S. INTERNET HOUSEHOLDS USE WI-FI AT HOME". MEDIA PLAY NEWS.

As a consequence, Wi-Fi is becoming essential to the fixed broadband wireless interface, but also critical to inter-device connectivity, which is the reason why Wi-Fi routers are becoming pervasive: as of 2024, 92% of US households are equipped with Wi-Fi networks[53].

This level of adoption drives economic contribution at multiple levels:

- Due to the technology features, Wi-Fi, especially Wi-Fi 6, Wi-Fi 6E and Wi-Fi 7, is faster than mobile broadband driving a total consumer benefit of $6.7 billion in 2023 increasing to $21.1 billion in 2027.
- Wi-Fi represents an infrastructure that supports in-home device connectivity avoiding the need to deploy Ethernet cable in each room, an expensive proposition. Avoidance of this saves consumers between $2 billion and $3 billion per year.
- In the absence of Wi-Fi, the traffic of devices lacking an Ethernet port, such as smartphones and tablets, would have to depend on the cellular networks to gain Internet access (although we acknowledge that adaptors exist that allow hooking up these devices to the wired Ethernet). Avoiding this results in consumer savings of $275.8 billion in 2023, reaching $416.7 billion in 2027.
- Wi-Fi enables the adoption of a multiplicity of devices that propel consumer benefit (such as alarm systems). The adoption of devices operating in all Wi-Fi standards in 2.4 GHz, 5 GHz, 6 GHz, and the 7 GHz band yields a consumer benefit equivalent to $42.0 billion in 2023 and $55.9 billion in 2027.
- Wi-Fi is an integral component for wireless ISPs (called WISPs) that provide broadband connectivity for unserved communities. The contribution to GDP of wireless broadband access materializes through multiple effects: creation of new businesses, increasing productivity of existing enterprises, and growth of average income per household, reaching $51.1 billion in 2023 and $93.0 billion in 2027.

---

[52] Park Associates (2024). Parks: Average U.S. Internet Home Had 17 Connected Devices in 2023. January 10. Retrieved in: https://www.parksassociates.com/blogs/in-the-news/parks-average-us-internet-home-had-17-connected-devices-in-2023

[53] Park Associates (2024) Vast majority (80%) of US households have a home network router; 28% report intentions to purchase (April 22). Retrieved in: https://www.parksassociates.com/blogs/ce-pr/vast-majority-80-of-us-households-have-a-home-network-router-28-report-intentions-to-purchase; and Gruenwedel, E. (2023). "Parks: 92% of U.S. Internet Households Use Wi-Fi at Home". Media Play News. Retrieved in: https://www.mediaplaynews.com/parks-92-percent-of-us-internet-households-use-wi-fi-at-home/

- The growing integration of digital technologies in the automotive industry is driving increased adoption of Wi-Fi in new use cases yielding a consumer benefit equivalent to $1.03 billion in 2023 and $2.04 billion in 2027.
- Wi-Fi is an integral component for wireless ISPs (called WISPs) that provide broadband connectivity for unserved communities.
- The growing integration of digital technologies in the automotive industry is driving increased adoption of Wi-Fi in new use cases.

4.1. Consumer Benefit Derived From Faster Broadband Speed

Consumer benefit increases if users enjoy faster Internet speeds, which is why they expect to pay more for faster broadband. Therefore, residential Wi-Fi customers are expected to benefit from faster services than those provided by cellular networks, as a counterfactual alternative.

After weighting the corresponding broadband speeds with the percentage of traffic carried through Wi-Fi at home, we calculated the average speed advantage of using Wi-Fi in comparison to cellular networks. The average download speed when using Wi-Fi is consistently higher, beginning at 251 Mbps in 2023 and growing to 514 Mbps in 2027, highlighting the superior performance of fast fixed broadband via Wi-Fi compared to mobile broadband (See Table 4-2).

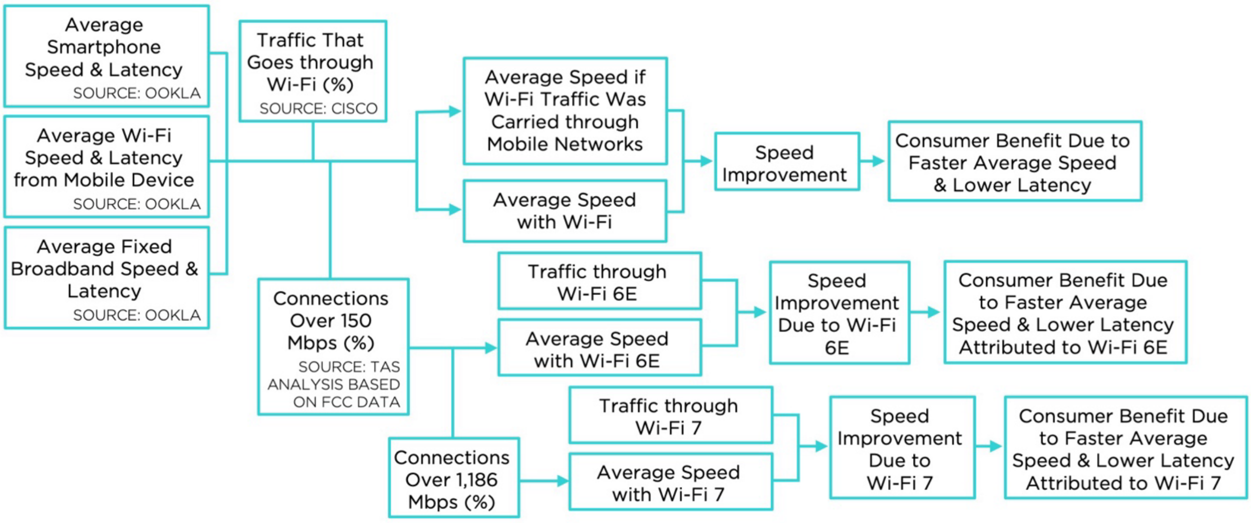
TABLE 4-2. **United States: Increasing Speeds Due** to **Wi-Fi Usage**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Wi-Fi Speeds from Mobile Devices (Mbps)	289	342	405	480	568
Mobile Broadband Speed from Mobile Devices (Mbps)	208	256	304	360	426
Percentage of Household Traffic that Goes through Wi-Fi	53.86%	56.37%	58.84%	60.54%	61.80%
Average Download Speed With no Wi-Fi	208	256	304	360	426
Average Download Speed Using Wi-Fi	251	305	363	432	514

SOURCES: OOKLA, TELECOM ADVISORY SERVICES ANALYSIS

The impact on consumer benefit was calculated based on estimates of broadband speed and latency as independent variables (see figure 4-1).

FIGURE 4-1. **Methodology** for **Calculating** the **Impact** of **Speed** on **Consumer Benefit**



SOURCE: TELECOM ADVISORY SERVICES ANALYSIS

4.1.1. Consumer Benefit Derived from Wi-Fi Speed Increase Due to Wi-Fi 6 or Less Operating in the 2.4 GHz & 5 GHz Bands

According to Quotient Associates (Wi-Fi Alliance, 2017), Wi-Fi 4 (802.11n) and Wi-Fi 5 (802.11ac) standards rely on 2.4 GHz and 5 GHz spectrum bands. Typical channel deployment and theoretical maximum speeds within those standards indicate that 80% of the traffic is generated by devices operating in the 2.4 GHz band[54] (See Table 4-3).

TABLE 4-3. **Relationship Between Speed** & **Bandwidth** in the **Most Widely Used Wi-Fi Standards**

SPATIAL STREAMS	TECHNOLOGY	BAND	CHANNEL SIZE			
			20MHz	40MHz	80MHz	160MHz
1x1	802.11n	2.4 & 5 GHz	72 Mbps	150 Mbps		
	802.11ac	5 GHz	87 Mbps	200 Mbps	433 Mbps	867 Mbps

SOURCE: ADAPTED FROM WI-FI ALLIANCE (2017)[55]

As indicated in table 4-3, the 802.11n standard with a typical 20 MHz configuration results in an average device speed of 72 Mbps. Additionally, real-world factors such as network congestion, signal interference, and device capabilities mean that the actual speeds experienced by users are often lower, thereby affecting the overall performance and reliability of Wi-Fi connections. For example, as explained in Appendix C, a household with 26 devices, equipped with a router operating on Wi-Fi 6 in the frequencies of 2.4 GHz and 5 GHz can accommodate 28 channels of 20 MHz, under the largest number of resource units by channel (242 RU), can handle a maximum of 28 of 1 spatial stream users, with a maximum speed of 103.79 Mbps.

Considering that mobile broadband speeds are 208 Mbps (see table 4-1 above), we assume an impact of zero consumer benefit. It is, therefore, implied that the consumer benefit derived from Wi-Fi speed materializes only under Wi-Fi 6E, and Wi-Fi 7 operating on the 6 GHz and in the 7 GHz band.

---

[54] Source: Gehlhaus, D et. al (2018) www.rand.org/t/RR2720

[55] Source: WiFi Alliance (2017), "Wi-Fi Spectrum Needs Study." Table 2-1.

4.1.2. Consumer Benefit Derived from Wi-Fi Speed Increase Under Wi-Fi 6E & Wi-Fi 7 Operating in the 6 GHz & 7 GHz Bands

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

As indicated in Appendix C, if a household is equipped with 21 devices and migrates to a Wi-Fi 6E router relying on the 6 GHz band, the assumptions to determine the theoretical maximum speed are four: (i) the maximum channelization of 80 MHz, (ii) the maximum number of resource units would be 980 (RU) in that bandwidth, (iii) the maximum modulation would be 1024-QAM with a transmission rate (BPS) of 10 bits per symbol and error correction rate (EC) of 5/6; and, (iv) the transmission time (TT) per symbol is considered to be 12. 8µs and its guard interval in 0.8µs. Thus, applying equation 1, the maximum speed reached in this scenario can be 1200.98 Mbps for 2 spatial streams (SS). However, this speed is a theoretical one; in reality, the feasible speed would be 840.68 Mbps. This estimate only considers an average signal degradation rate of 30% for interference (which according to research can reach up to 50%) and does account for distance between the router and the devices.

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

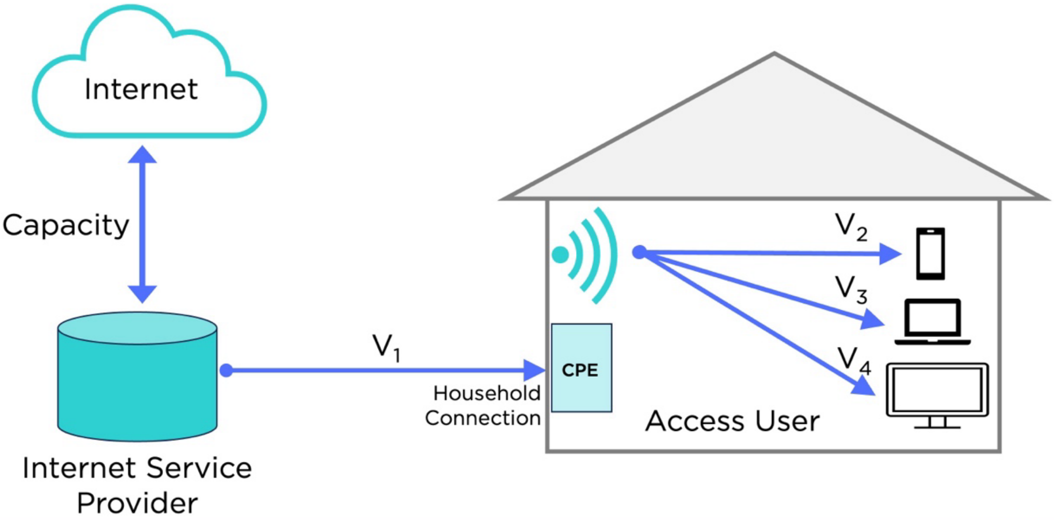
If the household is equipped with 22 devices and migrates to a Wi-Fi 7 router relying on the lowest 125 MHz in the 7 GHz band, the assumptions to determine the theoretical maximum speed are four: (i) the maximum channelization of 80 MHz, (ii) the maximum number of resource units would be 980 (RU) in that bandwidth, (iii) the maximum modulation would be 1024-QAM with a transmission rate (BPS) of 12 bits per symbol and error correction rate (EC) of 5/6; and, (iv) the transmission time (TT) per symbol is considered to be 12. 8µs and its guard interval in 0.8µs. Thus, applying equation 1, the maximum theoretical speed reached in this scenario can be 1,441.18 Mbps for 2 spatial streams (SS), which discounted for 30% reaches 1,008.82 Mbps.

$$V_{max} = \frac{BPS.CE}{TT} * RU * SS = \frac{12\ bps.\frac{5}{6}}{13.6x10^{-6}\ seg} * (980) * 2 = 1{,}441.18\ Mbps\ (1008.82\ Mbps)$$

Under an additional allocation of 375 MHz, the home could increase the number of devices by four, without no speed degradation.

That being said, the speed delivered at the device level is not only dependent on Wi-Fi's capability. In addition to Wi-Fi, the fixed broadband plan contracted with the Internet Service Provider (ISP) is also a key determinant. In general terms, the access speed within the home can never be higher than the effective speed of the connection (see Figure 4-1).

FIGURE 4-1. **Relationship Between Connection Speed** & **User Access**



Where: $V_1 > V_1, V_2, V_3$

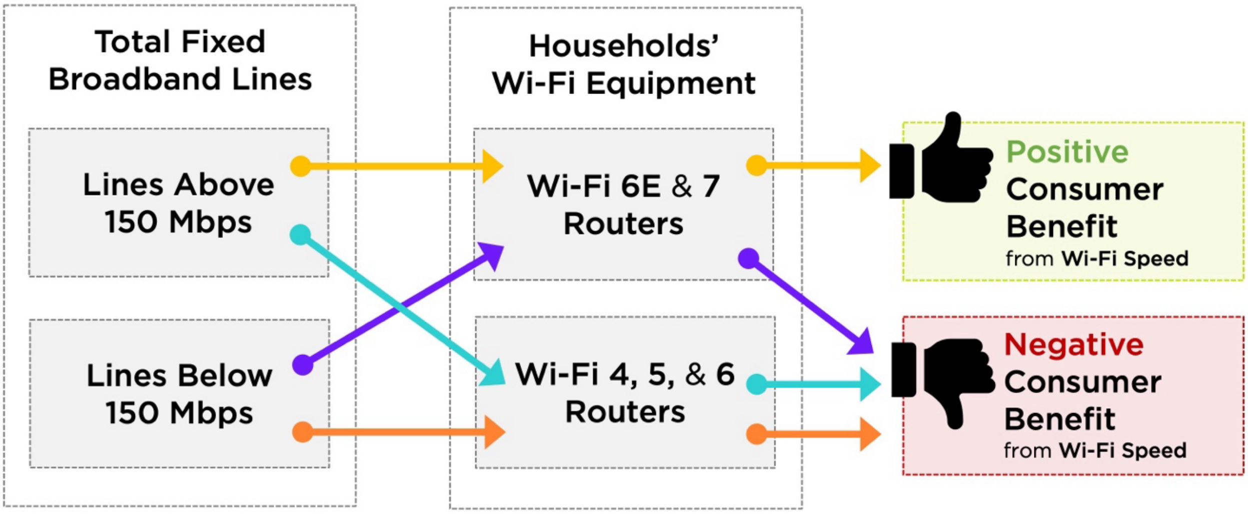
SOURCE: TELECOM ADVISORY SERVICES

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

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

On this basis, the estimation of consumer benefit derived from Wi-Fi speed under Wi-Fi 6E, and Wi-Fi 7 operating in the 6 GHz and in the 7 GHz bands, needs to exclude all fixed broadband lines in household equipped with a Wi-Fi router under the Wi-Fi threshold. We define such threshold to be 150 Mbps (which is conservative given the speed limits demonstrated above).

FIGURE 4-2. **Wi-Fi Residential Benefit Conditions**



Note: Broadband households can also address connectivity needs through wired Ethernet (see section 4.3)

SOURCE: TELECOM ADVISORY SERVICES

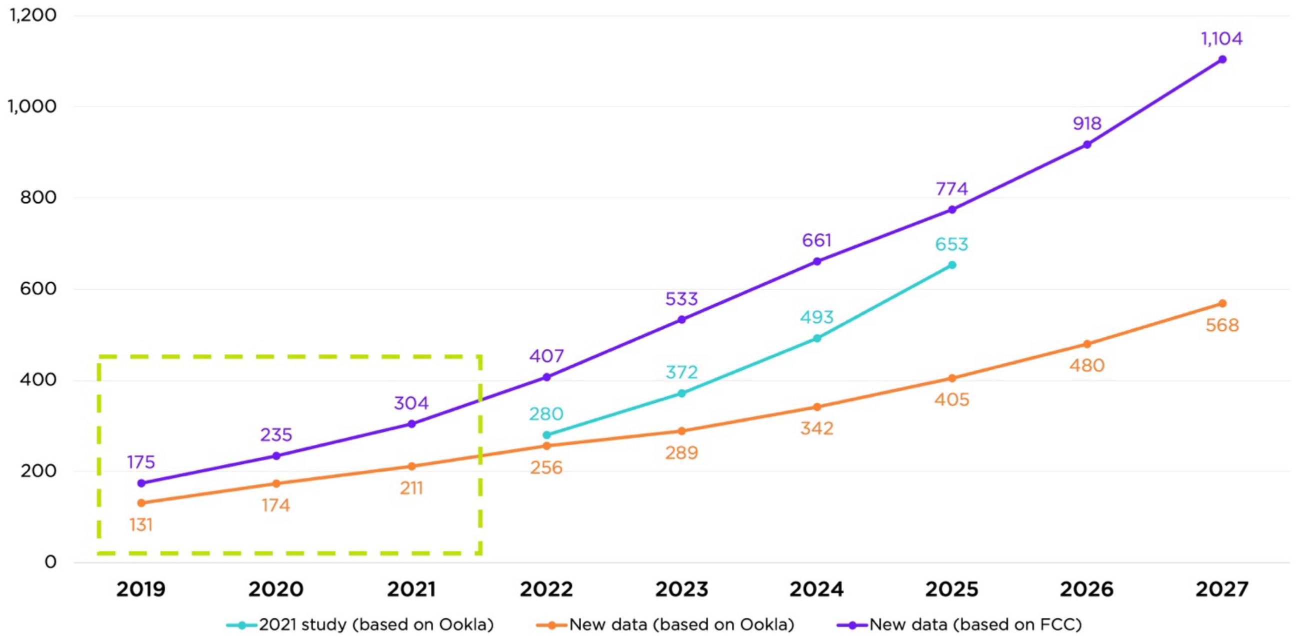
How do we reconcile the 150 Mbps threshold at the router level with the average download speed reported by Ookla at the time with practically no Wi-Fi 6E deployment (174 Mbps in 2020 and 211 Mbps in 2021)? Two factors are at play: (i) a portion of residences rely on Ethernet wiring, and consequently do not encounter a Wi-Fi bottleneck, (ii) overall speed is a function of channels and resource units, which can be driven by the number of devices. Following on the example cited above, if the residence has a significantly smaller number of devices than 26, speeds will necessarily improve. For example, in 2020 according to the survey from Parks Associates, the average number of connected devices in US households was 13, and in 2021, 14. It is not surprising then that the average speeds were faster than the threshold.

In other words, household residences benefit from Wi-Fi 6E additional speeds if the fixed line acquired is higher than 150 Mbps. The latest published data from the FCC (May 2024) on the distribution of fixed broadband connection speeds corresponds to June 2022.[56] However, the FCC breaks down broadband lines in five groups: 1) Less than 10 Mbps (3.8%); 2) At least 10 Mbps and less than 25 Mbps (5.7%); 3) At least 25 Mbps and less than 100 Mbps (15.9%); 4) At least 100 Mbps and less than 940 Mbps (59.3%) and 5) At least 940 Mbps (15.42%). Based on this information, the average download speed in December 2021 was 304 Mbps and 355 Mbps in June 2022, compared to a projection of 280 Mbps for 2022 from the 2021 study. Drawing upon the historical data from the FCC concerning download speed distribution and the impact of BEAD, our projections for future growth in average download speed is to reach 1,104 Mbps in December 2027 (see graphic 4-1).

---

[56] FCC Internet Access Services Report (May 2024), retrieved from https://docs.fcc.gov/public/attachments/DOC-402310A1.pdf

GRAPHIC 4-1. **Average Fixed Broadband Download Speed** (Mbps)

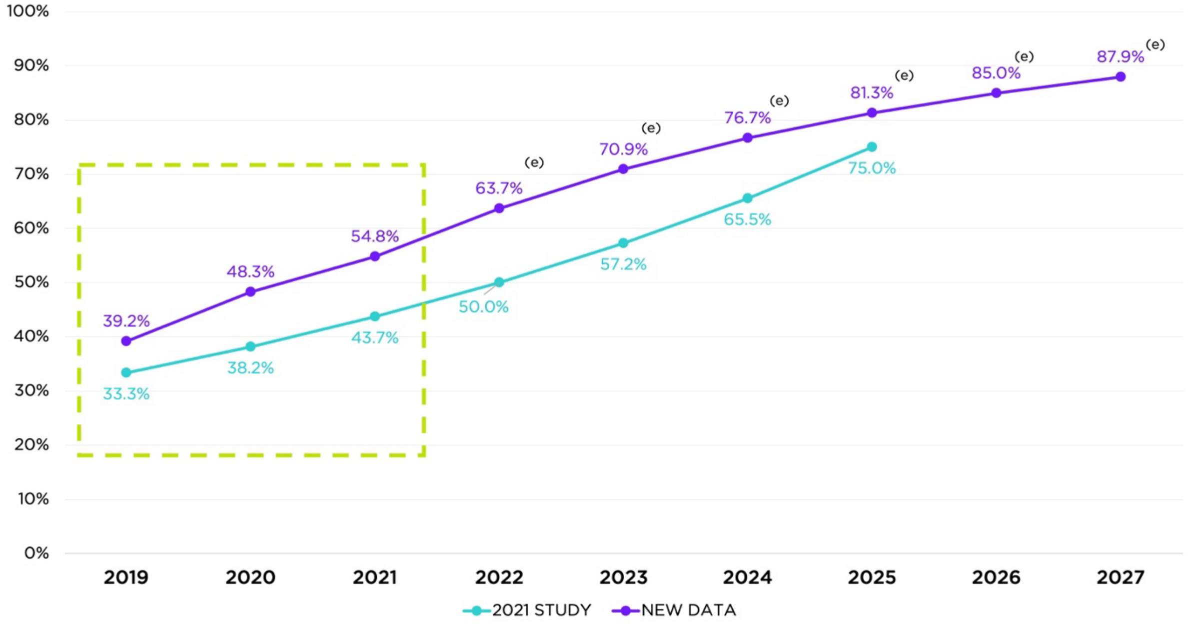


Note: The difference between the Ookla and FCC data could be partly explained by Ookla's reporting that the ratio of Wi-Fi to Ethernet performance is 42%, and that the Ookla data crowdsources all users.

SOURCE: OOKLA SPEEDTEST; TAS ANALYSIS BASED ON FCC INTERNET ACCESS SERVICES REPORT

Consequently, we need to estimate the breakdown that exceeds the 150 Mbps threshold by relying on the FCC reported median speed data. Based on this calculation, it is estimated that in 2021, 54.8% of broadband connections exceeded the 150 Mbps threshold. By extrapolating this value based on historical FCC data, we estimate that in December 2027, 87.9% of the fixed broadband connections will be over 150 Mbps download speed. Graphic 4-2 displays the difference between the historical and forecast of households with fixed broadband connections over 150 Mbps.

GRAPHIC 4-2. **Percent** of **Households** with **Fixed Broadband Connections Over 150 Mbps**

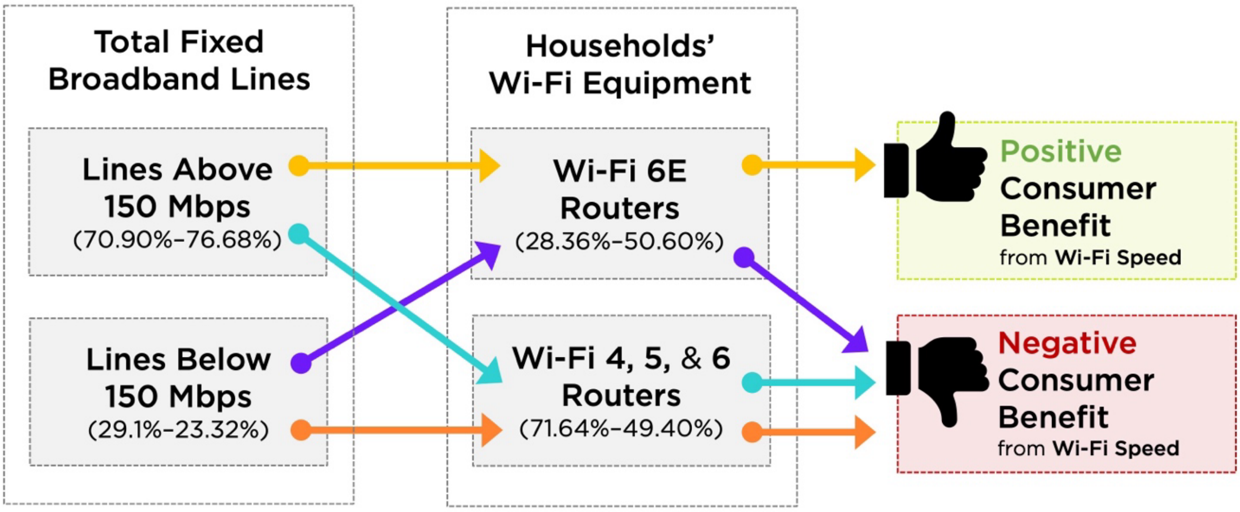


SOURCE: FCC; TELECOM ADVISORY SERVICES ANALYSIS

The average fixed broadband speed for connections over 150 Mbps also shows a significant increase, from 721 Mbps to 1,245 Mbps, based TAS estimations based on FCC data[57] about fixed broadband download speed distribution.

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

FIGURE 4-3. **Wi-Fi Residential Benefit Conditions**
2023-2024



SOURCE: TELECOM ADVISORY SERVICES

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

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

Finally, it is important to note that this consumer surplus only benefits households with Wi-Fi 6E and those with Internet and Wi-Fi. For example, in 2023, 28.36% of traffic went through Wi-Fi 6E, and there were 109,444,853 households with Internet and Wi-Fi. The impact is calculated by multiplying the additional consumer benefit, the percentage of traffic through Wi-Fi 6E, and the number of households. This results in an impact of $6,735 million in 2023, increasing to $11.7 billion in 2024, before gradually decreasing to $6.1 billion in 2027 (see Table 4-4) as Wi-Fi 7 is adopted.

---

[57] The last data available FCC data for 2021 (304 Mbps in December) and 2022 (355 Mbps in June), is higher than the value projected previously for 2022 using Ookla data (280 Mbps). The difference between both sources is that Ookla reports the real speed (considering router limitations) and the FCC data is information about the speed sold by the ISP provider (not considering router bottlenecks).

TABLE 4-4. **United States: Consumer Benefit From Faster Speed In Households with Wi-Fi 6E using 6 GHz**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Households that have connections over 150 Mbps (%)	70.90%	76.68%	81.28%	84.98%	87.94%
Percentage of household traffic that goes through Wi-Fi (%)	53.86%	56.37%	58.84%	60.54%	61.80%
Share of traffic affected (%)	38.19%	43.22%	47.82%	51.45%	54.35%
Avg Fixed broadband Speed (Mbps) - connections >150 Mbps (sell)	721	839	935	1,066	1,245
Max Download speed using Wi-Fi 6E (Mbps)	1,186	1,186	1,186	1,186	1,186
CAP Avg Fixed broadband Speed (Mbps) - connections >150 Mbps	721	768	802	835	869
Mean speed with no Wi-Fi 6E (Mbps)	208	256	304	360	426
Mean speed with Wi-Fi 6E (Mbps)	404	478	542	604	666
Willingness to pay for average download speed (Nevo Curve) ($)	171.02	176.74	181.35	185.96	190.56
New Willingness to pay for average download speed (Nevo Curve) ($)	$ 189.11	$ 193.68	$ 197.11	$ 200.08	$ 202.75
Additional Consumer Benefit with Wi-Fi 6E Yearly ($)	$ 216.99	$ 203.28	$ 189.17	$ 169.48	$ 146.18
Traffic through Wi-Fi 6E (%)	28.36%	50.60%	52.00%	48.15%	33.20%
Households with internet and Wi-Fi	109,444,853	113,733,281	118,010,102	122,174,732	126,408,999
Impact ($ billion)	$ 6.74	$ 11.70	$ 11.61	$ 9.97	$ 6.14

SOURCES: FCC; CISCO; OOKLA; NEVO ET AL. (2016); TELECOM ADVISORY SERVICES ANALYSIS

With Wi-Fi 7, the speed limitation issues present in Wi-Fi 6E in 2026 are resolved, meaning the speed will only be capped by the fixed broadband speed purchased by consumers. Under Wi-Fi 7 the average weighted mean speeds improve significantly, starting at 404 Mbps in 2023 and reaching 871 Mbps by 2027. Applying the Nevo Curve (see Nevo et al., 2015), the overall economic impact of Wi-Fi 7 escalates, starting from $3,707 million in 2025, and peaking at $14,940 million in 2027. This analysis demonstrates the significant potential benefits entailed by widespread adoption of Wi-Fi 7 (See Table 4-5).

TABLE 4-5. **United States: Consumer Benefit** from **Faster Speed In Households** with **Wi-Fi 7 Using 6 GHz**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Avg Fixed broadband Speed (Mbps) with Wi-Fi 7	721	839	935	1,066	1,245
Share of traffic affected	38.19%	43.22%	47.82%	51.45%	54.35%
Mean speed with no Wi-Fi 7 (Mbps)	208	256	304	360	426
Mean speed with Wi-Fi 7 (Mbps)	404	508	606	723	871
Willingness to pay for average download speed ($)	171.02	176.74	181.35	185.96	190.56
New Willingnes to pay for average download speed ($)	189.11	195.37	200.14	204.97	210.03
Additional Consumer Benefit with Wi-Fi 7 yearly ($)	216.99	223.61	225.51	228.13	233.59
Traffic through Wi-Fi 7 (%)	0%	0%	13.9%	28.36%	50.60%
Households with Wi-Fi	109,444,853	113,733,281	118,010,102	122,174,732	126,408,999
Impact ($ billion)	$ 0	$ 0	$ 3.71	$ 7.90	$ 14.94

SOURCES: FCC; CISCO; OOKLA; NEVO ET AL. (2016); TELECOM ADVISORY SERVICES ANALYSIS

4.2. Home Internet Access for Devices That Lack an Ethernet Port

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

- Most Android devices and newer iPad models will need a USB-C-to-Ethernet adapter, while older Android phones and tablets should require a micro USB-to-Ethernet adapter. In fact, micro USB to Ethernet cannot deliver speeds as fast as USB-C to Ethernet.
- Furthermore, since USB-C adapters are relatively new to be introduced, one has to reduce a portion of the likely universe out of the potential connectivity universe of users.
- Operationally, the user needs to purchase an Ethernet cable, turnoff the Wi-Fi, refresh the Internet page and then access the Internet.

To estimate the traffic of smartphones and tablets, we relied on Cisco and GSMA estimates and extrapolated those growth rates to 2027 considering both the increase in units and the increase in traffic. According to Cisco IBSG (2012), 43.12% of use time of devices that lack an Ethernet port occurs at home.[58] After that, we estimate that 75% of the traffic generated from smartphones and tablets is relying on Wi-Fi connectivity. Accordingly, the portion of Wi-Fi traffic generated at home will reach 249,415 million gigabytes in 2027 (see Table 4-6).

---

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

TABLE 4-6. **United States: Total Wi-Fi Traffic** at **Home** from **Mobile Devices**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Total Annual traffic – Smartphones (billion GB)	237.26	310.78	400.42	491.83	585.41
Total Annual traffic – Tablets (billion GB)	83.64	105.03	131.89	158.83	185.86
Share of traffic at Home	43.12%	43.12%	43.12%	43.12%	43.12%
Share of traffic at Home using Wi-Fi	75.00%	75.00%	75.00%	75.00%	75.00%
Total Traffic at Home – Smartphones (billion GB)	76.72	100.50	129.49	159.05	189.31
Total Traffic at Home – Tablets (billion GB)	27.05	33.96	42.65	51.36	60.10
Total Traffic at Home (billion GB)	103.77	134.46	172.14	210.41	249.42
Average Price per Gb	$ 2.66	$ 2.37	$ 2.11	$ 1.88	$ 1.67
Price per home traffic ($ billion)	$ 275.83	$ 318.23	$ 362.74	$ 394.78	$ 416.66

SOURCES: CISCO; GSMA INTELLIGENCE; WEBSITES OF CELLULAR OPERATORS; TELECOM ADVISORY SERVICES ANALYSIS

If this traffic had to be transported by cellular networks, at the average price per GB estimated previously, it would result in costs of $275.83 billion in 2023, reaching $416.66 billion in 2027. That is computed as a benefit to consumers.

4.3. Avoidance of Inside Wiring Investment

Residential Wi-Fi allows consumers to avoid paying for wiring to connect all home devices (printers, laptops, storage units, etc.). The average cost of deploying inside wiring in a U.S. residence is approximately $660 per household[59]. Considering that 92% of U.S. connected households have Wi-Fi in 2023[60], the avoidance costs of inside wiring for 109.4 million households yields a total savings of $72.23 billion in 2023. To estimate the forward-looking benefit, we only consider the additional value for each year of incremental households that avoid deploying Ethernet wiring.[61] The net result is a saving of $2.0 billions in 2023 and $2.8 billions in 2027 (See Table 4-7).

---

[59] National average for wiring a 2-room residence with CAT 6.

[60] Gruenwedel, E. (2023). "Parks: 92% of U.S. Internet Households Use Wi-Fi at Home". Media Play News. Retrieved in: https://www.mediaplaynews.com/parks-92-percent-of-us-internet-households-use-wi-fi-at-home/

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

TABLE 4-7. **United States: Consumer Benefit** from **Avoidance** of **Investment** in **In-House Wiring**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Total Wiring Cost	$ 660	$ 660	$ 660	$ 660	$ 660
Households with Internet (million)	118.96	120.99	122.93	124.67	126.41
Households with Internet & Wi-Fi (%)	92%	94%	96%	98%	100%
Households with Internet & Wi-Fi (million)	109.44	113.73	118.01	122.17	126.41
Inside Wiring Costs ($ million) Yearly	$ 72,234	$ 75,064	$ 77,887	$ 80,635	$ 83,430
Inside Wiring Costs ($ billion)	$ 2.03	$ 2.83	$ 2.82	$ 2.75	$ 2.80

SOURCES: U.S. CENSUS; GRUENWEDEL, E. PARKS (2023); TELECOM ADVISORY SERVICES ANALYSIS

4.4. Consumer Benefit Generated by Use of Residential Wi-Fi Devices & Equipment

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

4.4.1. Residential Wi-Fi Devices & Equipment Due to Wi-Fi 6 or Less Operating in the 2.4 GHz & 5 GHz Bands

Since our focus is estimating economic surplus in the United States, the estimation of economic value begins by compiling revenues of U.S. manufacturers for selling Wi-Fi enabled consumer products operating in the 2.4 GHz and 5 GHz bands. The Consumer Technology Association (2024) published an estimate of revenue by product category for 2023 with a forecast up to 2027. Additionally, the same entity indicated in a prior report (2020) that not all that revenue could be attributed to Wi-Fi, because part of those sales would also exist without it. So, we only consider the share of revenues generated by products enabled by Wi-Fi: $81.44 billions in 2023, growing to $89.87 billion in 2027.

After computing the global sales of U.S. manufacturers, we applied the margin estimated by CSI markets (44.59%) which yields an estimated producer surplus for these products of $36.31 billion in 2023 growing to $40.08 billion in 2027, which we assume to be of the same magnitude as consumer benefit (see Table 4-8).

TABLE 4-8. **United States: Economic Value** of **Wi-Fi Enabled Consumer Products**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Total Sales ($ million)	81,435	83,065	84,463	86,776	89,874
Gross Margin	44.59%	44.59%	44.59%	44.59%	44.59%
Producer Surplus ($ million)	$ 36,312	$ 37,039	$ 37,662	$ 38,694	$ 40,075
Total Consumer Benefit ($ billion)	$ 36.31	$ 37.04	$ 37.66	$ 38.69	$ 40.08

SOURCES: CONSUMER TECHNOLOGY ASSOCIATION; TELECOM ADVISORY SERVICES ANALYSIS

Finally, we must consider that part of those sales corresponds to devices in the 6 GHz band. According to IDC, global shipments of consumer devices linked to 6 GHz (802.11ax standard) will represent 39.59% of the shipments from previous generations in 2027. Therefore, the consumer benefit generated by products operating in 2.4 GHz and 5 GHz bands is $30.62 billion in 2023 and $24.21 billion in 2027 (see table 4-9).

TABLE 4-9. **United States: Economic Value** of **Wi-Fi Enabled Consumer Products Operating** in **2.4 GHz** & **5 GHz Bands**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Global: Total Wi-Fi 6E or More Shipments	15.67%	22.39%	28.72%	34.42%	39.59%
Total Consumer Benefit ($ billion)	$ 36.31	$ 37.04	$ 37.66	$ 38.69	$ 40.08
Total Consumer Benefit ($ billion) Wi-Fi 6 or Less	$ 30.62	$ 28.74	$ 26.85	$ 25.37	$ 24.21

SOURCES: CONSUMER TECHNOLOGY ASSOCIATION; IDC; TELECOM ADVISORY SERVICES ANALYSIS

4.4.2. Residential Wi-Fi Devices & Equipment Due to Wi-Fi 6E & Wi-Fi 7 Operating in the 6 GHz & 7 GHz Bands

As mentioned before, devices for 6 GHz are expected to gradually replace those of former generations. We divide that impact between devices and equipment for Wi-Fi 6E and Wi-Fi 7 based on our traffic projections for both technologies. Considering that, we estimate that the consumer benefit generated by products operating with Wi-Fi 6E was $5.69 billion in 2023 and will grow to $6.29 billion in 2027. In a similar way, we estimate that the consumer benefit generated by products operating with Wi-Fi 7 will be $2.29 billion in 2023, growing to $9.58 billion in 2027 (See Table 4-10).

TABLE 4-10. **United States: Economic Value** of **Wi-Fi-Enabled Consumer Products Operating** in **6 GHz Bands**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Global - Total Wi-Fi 6E or Wi-Fi 7 shipments	15.67%	22.39%	28.72%	34.42%	39.59%
Total Consumer Benefit ($ billion)	$ 36.31	$ 37.04	$ 37.66	$ 38.69	$ 40.08
Wi-Fi 6E Adoption	28.36%	50.60%	52.00%	48.15%	33.20%
Wi-Fi 7 Adoption	0%	0%	13.93%	28.36%	50.60%
Consumer Benefit Wi-Fi 6E Devices ($ billion)	$ 5.69	$ 8.30	$ 8.53	$ 8.38	$ 6.29
Consumer Benefit Wi-Fi 7 Devices ($ billion)	$ 0	$ 0	$ 2.29	$ 4.94	$ 9.58

SOURCES: CONSUMER TECHNOLOGY ASSOCIATION; IDC; TELECOM ADVISORY SERVICES ANALYSIS

4.5. Bridging the Digital Divide: Use of Wi-Fi to Increase Coverage in Rural & Isolated Areas

Wi-Fi is an appropriate technology to offer Internet access in rural and isolated areas. The increase in WISP connections is directly related to the growth of connections according to the scenarios differentiating Wi-Fi 6E from Wi-Fi 7. In this regard, in order to analyze the impact of the standard upgrade on the increase of connections in homes in rural and isolated areas, two main aspects must be established: (i) the number of maximum outdoor channels driving the amount of connections that could be deployed (160MHz for Wi-Fi 6E and 320MHz for Wi-Fi 7); and, (ii) the number of connections for the allocation of resource units with which similar speeds can be achieved in both standards (8 connections with 242 RU for Wi-Fi 6E to reach 1,186.27 Mbps and 32 connections with 102 RU for Wi-Fi 7 to reach 1,200 Mbps) (see Table 4-11).

TABLE 4-11. **Outdoor Channels** & **Resource Units** for **Wi-Fi 6E** & **Wi-Fi 7**

RU	**Channelization MHz**	**20**	**40**	**80**	**160 (Wi-Fi 6E)**	**320 (Wi-Fi 7)**	**320 (125MHz)**	**320 (375MHz)**
102 Wi-Fi 7	CHANNELS	41	20	10	5	2	1	1
	CONNECTIONS BY AVAILABLE RU	2	4	8	16	32	32	32
242 Wi-Fi 6E	CHANNELS	41	20	10	5	2	1	1
	CONNECTIONS BY AVAILABLE RU	1	2	4	8	16	16	16

SOURCE: TELECOM ADVISORY SERVICES ANALYSIS

In an initial scenario, the number of connections that Wi-Fi 7 would enable would be 37.5% higher than Wi-Fi 6E operating in the full 6 GHz band (1,200 MHz) (see Equation 4).

$$I_1 = \frac{C_{WiFI7}UR_{WiFi7} - C_{WiFI6E}}{C_{WiFI7}UR_{WiFi7}} = \frac{[(32*2)-(8*5)]}{(32*2)} = \frac{64-40}{64} = 37.5\% \;\; (Eq.4)$$

Where:

- C_Wi-Fi 7 represents the number of 320 MHz channels possessed by the Wi-Fi 7 standard (2).
- 〖UR〗_Wi-Fi 7 represents the number of connections available for the subchannels corresponding to the 102 Maximum Resource Units for Wi-Fi 7 (32).
- C_Wi-Fi 6E represents the number of 160 MHz channels owned by the Wi-Fi 6E standard (5).
- 〖UR〗_Wi-Fi 6E represents the number of connections available for the subchannels corresponding to the 242 Maximum Resource Units for Wi-Fi 6E (8).

If the spectrum for Wi-Fi 7 is increased by 125 MHz, the impact would increase by 58.33% with respect to the initial scenario; and, if the spectrum is further increased by additional frequency in the 7 GHz band, the impact could result in close to 70% more connections with respect to the same scenario. Thus, the impact is related to the maximum number of simultaneous connections that Wi-Fi 7 could support with respect to its predecessor scenario (see Table 4-12 and Equation 5).

TABLE 4-12. **Outdoor Channels** & **Resource Units** for **Additional Wi-Fi 7 Scenarios**

CHARACTERISTIC \ BAND	**2.4 GHz**	**5 GHz**	**6 GHz (Wi-Fi 7)**	**7 GHz (125 MHz)**	**7 GHz (375 MHz)**
Maximum Channels	40 MHz	160 MHz	320 MHz	320 MHz	320 MHz
Maximum Exterior Channels	1	1	2	1	1
Connections 125MHz	5				
Connections 375MHz	6				

SOURCE: TELECOM ADVISORY SERVICES ANALYSIS

$$I_2 = \frac{C_{WiFI7'}UR_{WiFi7'} - C_{WiFI6E}UR_{WiFi6E}}{C_{WiFI7'}UR_{WiFi7'}} = \frac{[(32 * 3) - (8 * 5)]}{(32 * 3)} = 58.33\%$$

$$I_3 = \frac{C_{WiFI7''}UR_{WiFi7''} - C_{WiFi6E}UR_{WiFi6E}}{C_{WiFI7''}UR_{WiFi7''}} = \frac{[(32 * 4) - (8 * 5)]}{(32 * 4)} = 68.75\% \quad (Eq.5)$$

From a technical point of view, the 6 GHz band for Wi-Fi 6E outdoor use is defined through the power characteristic of the equipment (standard power); that is, it occupies the U-NII 5 (5925-6425: 500MHz) and U-NII 7 (6525-6875: 350MHz) band classification; while, for indoor use of the technology, it is defined by the low power indoor (LPI) characteristic that could occupy the entire 1,200MHz band. In practical terms, for the installation of this type of networks, this band could support the deployment in rural areas, through WISPs.

Thus, if we take as an average scenario of Wi-Fi 6E deployment in a 102 RU configuration, for channel aggregation with the 2.4 GHz, 5 GHz and 6 GHz bands, the restriction of the latter band (D Cap), would represent a 27.12% lower deployment capacity of users that would have to be hosted in the lower bands (see Table 4-13 and Eq. 6).

TABLE 4-13. **Analysis** of **Allowed Connections** in **Wi-Fi 6**

FEATURES	**2.4 GHz** (20MHz)	**5 GHz** (80MHz)	**6 GHz** (80MHz)	
			UNII-5	UNII-7
Number Of Outdoor Channels	3	4	6	4
Connections In 102 RU	2	8	8	8
Maximum Connections	6	32	48	32

ANALYSIS AND CALCULATIONS: TELECOM ADVISORY SERVICES

$$(\text{Eq. }6) \quad \Delta\text{Cap} = \frac{\text{Cap}_{6\text{GHz alta}}}{\text{Cap}_{6\text{GHz total}}} = \frac{32}{6 + 32 + 48 + 32} = \frac{32}{118} = 27.12\%$$

Where:

- 〖Cap〗(6GHz high) represents the number of connections of 102 URs in the high part of the 6 GHz band for Wi-Fi 6E that would be constrained.
- 〖Cap〗(6GHz total) represents the number of total connections corresponding to the 102 Maximum Resource Units for Wi-Fi 6E in the 2.4 GHz, 5 GHz and 6 GHz bands.

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

4.5.1. **Bridging** the **Digital Divide Due** to **Wi-Fi 6** or **Less Operating** in the **2.4 GHz** & **5 GHz Bands**

The contribution to GDP materializes through multiple effects: creation of new businesses, and growth of average income per household. WISPA estimates that in 2023 there were 10 million WISP connections and it is expected that those connections to reach 16 million in 2027. Considering that, WISPs generate an increase in the number of broadband connections between 8.4% in 2023 to 12.7% in 2027. If we apply to that growth in the number of connections the coefficient of impact on GDP from Katz and Callorda (2024)[62], we have a total economic impact of WISPs from $420.5 billion 2023 to $740.3 billion in 2027. To that number we have to subtract the direct impact (revenues) and also consider that a fraction of those connections would also exist with other technologies. For the 2.4 GHz and 5 GHz band we assume that share of these technologies is 90%, and consequently only 10% would be met by WISPs. All in all, we expect a GDP contribution of $41.2 billion in 2023, increasing to $72.3 billion in 2027 (see Table 4-14).

TABLE 4-14. **United States: Estimation** of **GDP Contribution Derived** from **Reducing** the **Digital Divide**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
WISP Subscribers	10,000,000	11,300,000	12,700,000	14,273,451	16,041,844
Households with Fixed Broadband	118,961,797	120,992,852	122,927,190	124,668,094	126,408,999
Households	131,434,000	131,666,410	131,899,231	132,132,464	132,366,110
Adoption WISP (%)	7.61%	8.58%	9.63%	10.80%	12.12%
Adoption Broadband (%)	90.51%	91.89%	93.20%	94.35%	95.50%
WISP Additional (%)	8.41%	9.34%	10.33%	11.45%	12.69%
Impact of Fixed Broadband Adoption in GDP (%)	18.56%	18.56%	18.56%	18.56%	18.56%
GDP ($ billion)	$ 26,950	$ 27,967	$ 29,049	$ 30,224	$ 31,429
WISP Total impact ($ billion)	$ 420.46	$ 484.77	$ 557.01	$ 642.25	$ 740.26
WISP Revenues ($ billion)	$ 8.30	$ 10.40	$ 13.90	$ 15.62	$ 17.56
Share that Exist because WISP	10.00%	10.00%	10.00%	10.00%	10.00%
WISP Spillovers on GDP ($ billion)	$ 41.22	$ 47.44	$ 54.31	$ 62.66	$ 72.27

SOURCES: WISPA; IMF; TELECOM ADVISORY SERVICES ANALYSIS

4.5.2. **Bridging** the **Digital Divide Due** to **Wi-Fi 6E** & **Wi-Fi 7 Operating** in the **6 GHz** & **7 GHz Bands**

WISPs rely primarily on unlicensed spectrum to offer broadband accessibility in rural areas of the United States. While some WISPs utilize licensed spectrum in the 3.65 GHz, 24 GHz and 60 GHz bands, and shared spectrum (CBRS), many rely on U-NII and ISM unlicensed spectrum just above 900 MHz, 2.4 GHz and 5.8 GHz[63]. While WISPs initially utilized the 802.11b platform, they have mostly migrated to 802.11n, which allows

---

[62] Katz and Callorda (2024) find that a 10% increase in fixed broadband penetration generates an approximately 1.856% increase in GDP per capita in the Americas. This coefficient was derived using a econometric model that analyzed data spanning from 2010 to 2022. The study regressed GDP per capita on fixed broadband penetration, while also controlling for variables such as gross fixed capital formation, education levels, and mobile broadband penetration. The methodology included fixed effects to account for unobserved heterogeneity across countries and time periods and followed a structural model base on four functions: aggregate production function; demand function, supply function and output function.

[63] ISP Revolution (2023). Exploring the Spectrum: Understanding WISP Frequency Spectrums and Their Use Cases. Retrieved in : https://isprevolution.io/exploring-the-spectrum-understanding-wisp-frequency-spectrums-and-their-use-cases/

them to deliver 10 Mbps service or higher to 200 customers from a single four sector base station.

The allocation of the 6 GHz band to unlicensed use allowed WISPs to increase their subscriber base within their same coverage footprint. 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% (WISPA, 2021). In any case, we follow a conservative approach and consider that the expanded coverage yielded an additional 2%, adjusted by the share of the households that adopt Wi-Fi 6E. In addition, an increase of the user base allowed service providers to lower their operating costs. Thus, by assuming stability in prices, affordability would increase as GDP per capita grows. For conservative purposes we only consider the 30% of those affected, given that the other 70% of households could also be connected using an alternative technology, such as satellite. All in all, we estimate an overall increase in WISP connections due to Wi-Fi 6E of 234,995 connections in 2023 growing to 326,407 connections in 2027, contributing to an increase between 0.18% and 0.25% (2023 and 2027) of the national broadband penetration. Considering the impact coefficient of broadband on the economy, this increase will yield $15.1 billion of GDP contribution in 2027 (See Table 4-15).

TABLE 4-15. **United States: GDP Contribution**
Derived from **Reducing** the **Digital Divide Due** to **Wi-Fi 6E**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
New subscribers due to expanded coverage (%)	2%	2%	2%	2%	2%
New subscribers due to expanded coverage	56,716	114,349	132,084	137,452	106,528
GDP per capita	$ 80,412	$ 83,063	$ 85,877	$ 88,935	$ 92,052
Growth in GDP per capita (%)	5.33%	3.30%	3.39%	3.56%	3.50%
New WISP adoption after price decrease (% households)	9%	10%	11%	12%	14%
Traffic through Wi-Fi 6E (%)	28.36%	50.60%	52.00%	48.15%	33.20%
Increase in WISP connections due to lower prices (households that buy the service)	594,264	740,683	879,144	961,576	732,931
Share that exist because WISP	30.00%	30.00%	30.00%	30.00%	30.00%
Total Increase in WISP connections	234,995	336,554	395,827	425,925	326,407
Increase in national broadband penetration	0.18%	0.26%	0.30%	0.32%	0.25%
Impact of fixed broadband adoption in GDP	18.56%	18.56%	18.56%	18.56%	18.56%
Increase in the GDP due to the new broadband adoption (% GDP)	0.04%	0.05%	0.06%	0.06%	0.05%
Total impact in GDP (US$ billion)	$ 9.88	$ 14.44	$ 17.36	$ 19.17	$ 15.06

SOURCES: WORLD BANK; WISPA; KATZ AND CALLORDA (2024); TELECOM ADVISORY SERVICES ANALYSIS

Relying on the same methodology, we estimate the additional impact of Wi-Fi 7 using the 6 GHz band, considering only the impact on coverage due that the impact on price was cover in the Wi-Fi 6E case. In the Wi-Fi 7 case, the impact on coverage will be 37.50% higher than in the previous case, so that 14,596 connections are added in 2025 and 66,963 in 2027, which will yield an additional $3.09 billion of GDP contribution in 2027 (See Table 4-16).

TABLE 4-16. **United States: GDP Contribution Derived** from **Reducing** the **Digital Divide Due** to **Wi-Fi 7 Using 6 GHz Band**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Additional impact of Wi-Fi 7	37.50%	37.50%	37.50%	37.50%	37.50%
New subscribers due to expanded coverage (%)	3.00%	3.00%	3.00%	3.00%	3.00%
Traffic through Wi-Fi 7 (%)	0%	0%	13.93%	28.36%	50.60%
New subscribers due to expanded coverage	0	0	48,653	111,311	223,209
Share that exist because WISP	30.00%	30.00%	30.00%	30.00%	30.00%
Total Increase in WISP connections	0	0	14,596	33,393	66,963
Increase in national broadband penetration	0%	0%	0.01%	0.03%	0.05%
Impact of fixed broadband adoption in GDP	18.6%	18.6%	18.6%	18.6%	18.6%
Increase in the GDP due to the new broadband adoption (% GDP)	0%	0%	0%	0%	0.01%
Total impact in GDP (US$ billion)	$ 0	$ 0	$ 0.64	$ 1.50	$ 3.09

SOURCES: WORLD BANK; WISPA; KATZ AND CALLORDA (2024); TELECOM ADVISORY SERVICES ANALYSIS

Finally, if Wi-Fi 7 relies on multiple channels in the 7 GHz band, this impact increases to close to 70%, including close to $ 2 billion in an additional impact of contribution to GDP generated in 2027 (see Table 4-18).

TABLE 4-18. **United States: GDP Contribution Derived** from **Reducing** the **Digital Divide Due** to **Wi-Fi 7 Using 7 GHz Band**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Additional impact of Wi-Fi 7 using 6 GHz (%)	37.50%	37.50%	37.50%	37.50%	37.50%
Total impact in GDP (US$ billion) of Wi-Fi 7 Using 6 GHz	$ 0	$ 0	$ 0.64	$ 1.50	$ 3.09
Additional impact of Wi-Fi 7 Using 125 MHz of 7 GHz (%)	58.33%	58.33%	58.33%	58.33%	58.33%
Total impact in GDP (US$ billion) of Wi-Fi 7 Using the lowest 125 MHz of 7 GHz	$ 0	$ 0	$ 0.36	$ 0.84	$ 1.72
Additional impact of Wi-Fi 7 Using 500 MHz of 7 GHz (%)	68.75%	68.75%	68.75%	68.75%	68.75%
Total impact in GDP (US$ billion) of Wi-Fi 7 Using 500 MHz of 7 GHz	$ 0	$ 0	$ 0.18	$ 0.42	$ 0.86

SOURCE: TELECOM ADVISORY SERVICES ANALYSIS

4.6. Increasing Use of Wi-Fi in Vehicles

The growing integration of digital technologies in the automotive industry is driving significant changes, particularly in the Automotive Over the Air (OTA) market. OTA refers to the ability to deliver software updates and enhancements directly to vehicles via wireless communication. This market is increasingly relevant as it allows manufacturers to improve vehicle performance, security, and features without requiring physical interventions. The North American OTA market, as forecasted, shows substantial growth from $2.5 billion in 2023 to $5.0 billion in 2027, highlighting the expanding role of digital connectivity in vehicles.[64]

Table 4-19 provides a detailed analysis of the increasing usage of Wi-Fi in vehicles and its economic implications. The market for Automotive OTA in North America is projected to grow significantly, with the U.S. accounting for a consistent 92.3% share of this market. This translates to the U.S. market expanding from $2.3 billion in 2023 to $4.6 billion in 2027. The gross margin for this market remains stable at 44.6% throughout the period (based on CSI Market Inc.). By applying this margin, the producer surplus, which represents the net benefit to producers after covering costs, increases from $1.025 billion in 2023 to $2.036 billion in 2027. According to Milgrom, we associate the producer surplus directly with consumer benefit, suggesting that consumers derive equivalent value from these advancements. Thus, the consumer benefit is also projected to rise from $1.025 billion to $2.036 billion over the same period (See Table 4-19).

TABLE 4-19. **United States: Increasing Use of Wi-Fi in Vehicles**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Automotive over the Air Market (US$ billion), North America	$ 2.49	$ 2.96	$ 3.51	$ 4.17	$ 4.95
US Share of North America	92.25%	92.25%	92.25%	92.25%	92.25%
Automotive Over the Air Market (US$ billion)	$ 2.30	$ 2.73	$ 3.24	$ 3.85	$ 4.57
Gross Margin	44.59%	44.59%	44.59%	44.59%	44.59%
Producer Surplus (US$ billion)	$ 1.03	$ 1.22	$ 1.45	$ 1.72	$ 2.04
Consumer Benefit (US$ billion)	$ 1.03	$ 1.22	$ 1.45	$ 1.72	$ 2.04

SOURCES: MARKET RESEARCH FUTURE; CSI MARKET INC.; MILGROM ET AL. (2011); TELECOM ADVISORY SERVICES ANALYSIS

* * * * *

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

- Wi-Fi devices, especially those operating in the Wi-Fi 6E and Wi-Fi 7 standards in 6 GHz and 7 GHz bands, provide faster than mobile broadband device interfacing, driving a total consumer benefit of $6.74 billion in 2023 increasing to $21.08 billion in 2027.
- In the absence of Wi-Fi, users of devices lacking an Ethernet port, such as smartphones and tablets, would have to depend on the cellular network to gain Internet access (although we acknowledge that adaptors exist that allow hooking up these devices to the wired Ethernet). If this traffic had to be transported by cellular networks, it would result in a consumer saving of $275.83 billion in 2023, reaching $416.66 billion in 2027.
- Wi-Fi represents an infrastructure that supports in-home device connectivity avoiding the need to deploy Ethernet cable in each room, an expensive proposition. Considering the additional annual value

---

[64] Market Research Future (2020). Automotive Over-The-Air (OTA) Updates Market Overview. Retrieved in: https://www.marketresearchfuture.com/reports/automotive-over-the-air-updates-market-7606

of incremental households that avoid deploying Ethernet wiring, results in consumer savings of $2.03 billions in 2023 and $2.80 billions in 2027.

- Wi-Fi enables the adoption of a multiplicity of devices that propel consumer benefit (such as alarm systems). The consumer benefit associated with the adoption of devices operating in all Wi-Fi standards in 2.4 GHz, 5 GHz, 6 GHz, and the 7 GHz band yields a consumer benefit equivalent to $42.00 billion in 2023 and $55.94 billion in 2027.
- Wi-Fi is an integral component of wireless ISPs (called WISPs) that provide broadband connectivity for unserved communities. The contribution to GDP of wireless broadband access materializes through multiple effects: creation of new businesses, increasing productivity of existing enterprises, and growth of average income per household, reaching $51.10 billion in 2023 and $93.00 billion in 2027.
- The growing integration of digital technologies in the automotive industry is driving increased adoption of Wi-Fi in new use cases, yielding a consumer benefit equivalent to $1.03 billion in 2023 and $2.04 billion in 2027.

5. ENTERPRISE WI-FI

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

- Benefits derived from an increase in average speed: the improvements of average download speed for enterprises as a result of using Wi-Fi within in-building connectivity.
- Benefits derived from reduced latency: The total improvements of latency from Wi-Fi (principally from Wi-Fi 6E but also from Wi-Fi 7) for enterprises.
- Savings in business Internet traffic transmitted through Wi-Fi: Total Wi-Fi enterprise savings results from wireless traffic that is routed through Wi-Fi access points.
- Avoidance of campus and enterprise facilities inside wiring.
- Enhanced IoT deployment: the spillover impact of Wi-Fi enabled IoT terminals.
- Deployment of Augmented Reality/Virtual Reality solutions: the adoption of AR/VR among U.S. business has a spillover effect on productivity, thereby contributing to the growth of GDP.
- Deployment of Augmented Reality/Virtual Reality solutions.

5.1. Benefits Derived from an Increase in Average Speed

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

5.1.1. Benefit Resulting from an Increase in Average Speed Due to Wi-Fi 6 or Less Operating in the 2.4 GHz & 5 GHz Bands

As described in section 4.1.1 in the area of consumer benefit of Wi-Fi impact operating in the 2.4 GHz and 5 GHz bands, we assume, for conservative purpose, no impact, given Wi-Fi technological limitations. These constraints create a discrepancy between the fixed broadband purchased speed and the actual speed delivered at the device. As a result, while the theoretical maximum speeds of Wi-Fi might be high, real-world factors such as network congestion, signal interference, and device capabilities mean that the actual speeds experienced by users are often lower, thereby affecting the overall performance and reliability of Wi-Fi connections.

5.1.2. Benefit Resulting from an Increase in Average Speed Due to Wi-Fi 6E & Wi-Fi 7 Operating in the 6 GHz & 7 GHz Bands

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

To translate the increase in speed with Wi-Fi 6E into GDP growth, we rely on the results of the econometric model explained in Appendix B. This model quantifies the relationship between quality improvement in fixed broadband with its economic effect. In this way, after calculating the difference in average download speed attributed to Wi-Fi 6E, the additional GDP contribution will yield $115.28 billion in 2027 (Table 5-1).

TABLE 5-1. **United States: Estimation** of **Speed Differential Due** to **Wi-Fi 6E**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Mean speed with no Wi-Fi 6E (Mbps)	208	256	304	360	426
Mean speed with Wi-Fi 6E (Mbps)	404	478	542	604	666
Speed increase due to Wi-Fi 6E (%)	94%	86%	79%	68%	56%
Impact speed on GDP	1.96%	1.96%	1.96%	1.96%	1.96%
Increase in GDP	1.85%	1.69%	1.54%	1.33%	1.10%
Traffic through Wi-Fi 6E (%)	28.36%	50.60%	52.00%	48.15%	33.20%
GDP increase ($ billion)	$ 141.08	$ 239.08	$ 231.93	$ 193.71	$ 115.28

SOURCES: OOKLA SPEEDTEST; TELECOM ADVISORY SERVICES ANALYSIS

Also, as explained in section 4.1.2, the average download speed will be faster using Wi-Fi 7. Therefore, an additional impact due to that standard operating in the 6 GHz band should be considered. The additional GDP contribution will yield $325.07 billion in 2027 (Table 5-2).

TABLE 5-2. **United States: Estimation** of **Speed Differential Due** to **Wi-Fi 7**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Mean speed with no Wi-Fi 7 (Mbps)	208	256	304	360	426
Mean speed with Wi-Fi 7 (Mbps)	403.71	508.26	605.60	723.16	871.08
Speed increase due to Wi-Fi 7 (%)	94%	98%	100%	101%	105%
Impact speed on GDP (%)	1.96%	1.96%	1.96%	1.96%	1.96%
Increase in GDP (%	1.85%	1.92%	1.95%	1.98%	2.04%
Traffic through Wi-Fi 7 (%)	0%	0%	13.93%	28.36%	50.60%
GDP increase ($ billion)	$ 0	$ 0	$ 78.77	$ 169.52	$ 325.07

SOURCES: OOKLA SPEEDTEST; TELECOM ADVISORY SERVICES ANALYSIS

5.2. Benefits Derived from Reduced Latency

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

5.2.1. Benefit Resulting from Reduced Latency Due to Wi-Fi 6 or Less Operating in the 2.4 GHz & 5 GHz Bands

In this section, we measure the latency gains between using Wi-Fi and relying on mobile broadband. We estimate, using historical Ookla Speedtest data, that in the United States average Wi-Fi latency decreased from 21.00 ms in 2023 to 19.81 in 2024 and is projected to decline to 16.64 ms by 2027. On the other hand, mobile networks latency also dropped from 36.00 ms to 33.32 between 2023 and 2024 and is projected to reach 26.41 ms in 2027. Considering that the percentage of household traffic going through Wi-Fi will increase from 54% to 62%, we forecast a latency reduction due to Wi-Fi ranging from -22% to -23%.

To estimate the economic impact of latency reduction, we developed an econometric model linking the improvement in speed and latency to GDP (see details in Appendix B). The starting point in model development is to build a construct, called “quality” that synthesizes the speed and latency variable for countries around the world. The “quality” construct is needed because both variables are correlated, which yields results with both coeffients biased. The construct was developed through Principal Components Analysis.[65]

Once the quality construct is defined, a regression is specified to measure its impact on GDP. Utilizing the econometric model that analyzes the relationship between a reduction in latency and GDP growth, we find that a 10% reduction in latency increases GDP by 0.45%. In the same way as we do for the impact of download speed, we include the economic benefit of lower latency in households in the enterprise section, because we assume that the economic impact primarily stems from increased labor productivity.

Relying on this coefficient, we estimate that the increase in GDP due to reduced latency ranges from 1.01% to 1.04%. Considering that the traffic through the Wi-Fi 6 standard or less decreases over the years, the resulting GDP contribution due to latency reduction is $195,137 million in 2023, declining to $52,411 million in 2027 (see table 5-3) as Wi-Fi 7 devices are increasingly adopted.

---

[65] Principal Components Analysis is designed to handle multicollinearity among variables by transforming them into a set of linearly uncorrelated components. A construct, by definition, is an abstract concept that is measured through a set of observable variables or indicators. For these indicators to reflect the construct validly and reliably, they must be logically related to each other and to the underlying theoretical framework. This logical coherence ensures that the construct is both conceptually sound and practically useful. The necessity for logical coherence among indicators means that they should share a common underlying theme or dimension. For example, if a construct is designed to measure "quality," the indicators should all pertain to aspects of quality. Introducing indicators that measure entirely different dimensions, such as "quantity" or "efficiency," would dilute the construct and potentially lead to misleading conclusions. This is because the mixed indicators would not collectively reflect a single, coherent construct but rather a conflation of disparate dimensions. Furthermore, logical coherence facilitates the interpretability of the construct. When indicators logically align, the construct can be more easily understood and communicated. This interpretability is crucial for the application of the construct.

TABLE 5-3. **United States: Estimation** of **Latency Reduction Due** to **Wi-Fi 6** or **Less Operating** in the **2.4 GHz** & **5 GHz Bands**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Average Latency using Wi-Fi (Ms)	21.00	19.81	18.70	17.64	16.64
Average Latency Using Mobile network (Ms)	36.00	33.32	30.84	28.54	26.41
Percentage of household traffic that goes through Wi-Fi (%)	53.86%	56.37%	58.84%	60.54%	61.80%
Average Latency with no Wi-Fi (Ms)	36.00	33.32	30.84	28.54	26.41
Average Latency using Wi-Fi (Ms)	27.92	25.71	23.69	21.94	20.38
Latency reduction (%)	-22.44%	-22.85%	-23.17%	-23.12%	-22.86%
Impact of latency in GDP (%)	4.50%	4.50%	4.50%	4.50%	4.50%
Increase in GDP (%)	1.01%	1.03%	1.04%	1.04%	1.03%
GDP ($ billion)	$ 26,950	$ 27,967	$ 29,049	$ 30,224	$ 31,429
Traffic through Wi-Fi 6 or less (%)	71.64%	49.40%	34.07%	23.49%	16.20%
GDP increase ($ billion)	$ 195.14	$ 142.14	$ 103.24	$ 73.94	$ 52.41

SOURCES: OOKLA SPEEDTEST; IMF; TELECOM ADVISORY SERVICES ANALYSIS

5.2.2. Benefit Resulting from Reduced Latency Due to Wi-Fi 6E & Wi-Fi 7 Operating in the 6 GHz & 7 GHz Bands

When comparing Wi-Fi 6E with Wi-Fi 6 or less, latency diminishes by 40% (see detail calculation in Appendix C). This significant reduction translates to enhanced performance and user experience across various applications and services. Table 5-4 analyzes the economic impact of this latency reduction from 2023 to 2027. The analysis begins by estimating the share of traffic that could be affected by that improvement (i.e., the traffic through Wi-Fi 6E, considering the share of household traffic that goes through Wi-Fi). When considering all connections, the overall latency reduction due to Wi-Fi 6E varies, starting at 6% in 2023, increasing to 12% in 2025, and then reducing to 8% by 2027 (due to the substitution from Wi-Fi 6E to Wi-Fi 7). By relying on the same methodology as in the previous section, we obtain that the corresponding increase in is $74,152 million in 2023, rising to $160,094 million in 2025, and then decreasing to $116,165 million in 2027 (See Table 5-4).

TABLE 5-4. **United States: Estimation** of **Latency Differential Due** to **Wi-Fi 6E**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Percentage of household traffic that goes through Wi-Fi (%)	53.86%	56.37%	58.84%	60.54%	61.80%
Traffic through Wi-Fi 6E (%)	28.36%	50.60%	52.00%	48.15%	33.20%
Latency reduction due to Wi-Fi 6E (%)	40.00%	40.00%	40.00%	40.00%	40.00%
Latency reduction due to Wi-Fi 6E (Considering all connections) (%)	6.11%	11.41%	12.24%	11.66%	8.21%
Impact latency on GDP (%)	4.50%	4.50%	4.50%	4.50%	4.50%
Increase in GDP (%)	0.28%	0.51%	0.55%	0.53%	0.37%
GDP increase ($ billion)	$ 74.15	$ 143.67	$ 160.09	$ 158.71	$ 116.17

SOURCES: OOKLA SPEEDTEST; IMF; TELECOM ADVISORY SERVICES ANALYSIS

Wi-Fi 7 offers substantial improvements in latency compared to Wi-Fi 6E, creating even greater economic potential. Our technical analysis quantifies this improvement at 50.57%. By relying on the same methodology as in the previous analysis, we obtain that in monetary terms, the GDP increase due to Wi-Fi 7 is substantial, reaching $223,796 million by 2027. These results highlight the significant economic benefits of adopting Wi-Fi 7, driven by its superior latency performance (see Table 5-5).

TABLE 5-5. **United States: Estimation** of **Latency Differential Due** to **Wi-Fi 7**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Percentage of household traffic that goes through Wi-Fi (%)	53.86%	56.37%	58.84%	60.54%	61.80%
Traffic through Wi-Fi 7 (%)	0.00%	0.00%	13.93%	28.36%	50.60%
Latency reduction due to Wi-Fi 7 (%)	50.57%	50.57%	50.57%	50.57%	50.57%
Latency reduction due to Wi-Fi 7 (considering all connections) (%)	0.00%	0.00%	4.14%	8.68%	15.81%
Impact latency on GDP (%)	4.50%	4.50%	4.50%	4.50%	4.50%
Increase in GDP (%)	0.00%	0.00%	0.19%	0.39%	0.71%
GDP increase ($ billion)	$ 0	$ 0	$ 54.22	$ 118.18	$ 223.80

SOURCES: OOKLA SPEEDTEST; IMF; TELECOM ADVISORY SERVICES ANALYSIS

5.3. Savings in Business Internet Traffic Transmitted through Wi-Fi

U.S. corporations generate substantial wireless Internet traffic. Using the last Cisco estimate we project 274,501 million GB of internet traffic for 2023. Wi-Fi enterprise savings results from wireless traffic that is routed through Wi-Fi access points rather than cellular networks.

5.3.1. Savings resulting from an increase in average mobile speed due to Wi-Fi 6 or less operating in the 2.4 GHz and 5 GHz bands

Considering Cisco projections, we estimate that total business Internet traffic will reach 499.3 billion GB in 2027, of which 273.6 billion GB would have been transported through Wi-Fi access points. Considering the average price per GB transported by cellular carriers, savings from Wi-Fi will reach $456.98 billion, assuming the amount of data consumed would stay constant,[66]. (See Table 5-6)

TABLE 5-6. **United States: Savings** in **Business Wireless Traffic**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Share of Business Internet Traffic by Wi-Fi (%)	46.69%	48.65%	50.70%	52.74%	54.79%
Total Business Internet Traffic (billion GB)	224.1	281.8	354.3	426.8	499.3
Total GB Wi-Fi enterprise traffic (billion GB)	104.6	137.1	179,.6	225.1	273.5
Average Price per GB	$ 2.66	$ 2.37	$ 2.11	$ 1.88	$ 1.67
Economic Impact ($ billion)	$ 278.10	$ 324.42	$ 378.47	$ 422.33	$ 456.98

SOURCES: CISCO; WEBSITES OF CELLULAR OPERATORS; TELECOM ADVISORY SERVICES ANALYSIS

5.3.2. Savings Resulting from an Increase in Average Mobile Speed Due to Wi-Fi 6E & Wi-Fi 7 Operating in the 6 GHz & 7 GHz Bands

The deployment of the latest enterprise applications will generate an exponential growth in data traffic that will be handled by devices operating in unlicensed spectrum, through the combination of the existing bands and the 6 GHz band using Wi-Fi 6E. In 2019, an updated Cisco traffic forecast based on the explosion of IoT and AR/VR applications, among other factors, increased the estimates of future total business Internet traffic. We assume that part of the growth was driven by "natural" growth (that is to say, the extrapolation of historical growth rate by averaging the growth rate between 2018 and 2019 and between 2017 and 2018), and another portion was triggered by Wi-Fi traffic stimulated by changes in 6 GHz using Wi-Fi 6E. The sum of the difference due to broader Wi-Fi traffic between will reach $16.6 billion in 2027 (see Table 5-7).

---

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

TABLE 5-7. **United States: Savings** in **Business Wireless Traffic Due** to **6 GHz Using Wi-Fi 6E**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Share of Business Internet Traffic by Wi-Fi (%)	51.56%	54.25%	57.07%	59.90%	62.73%
Total Business Internet Traffic (billion GB)	274.50	340.00	421.13	502.26	583.39
Total GB Wi-Fi enterprise traffic (billion GB)	141.52	184.43	240.36	300.87	365.98
Total ($ billion)	$ 376.17	$ 436.49	$ 506.49	$ 564.50	$ 611.38
Difference between the 2 estimations ($ billion)	$ 98.08	$ 112.07	$ 128.02	$ 142.17	$ 154.40
Difference because natural growth(billion)	$ 87.50	$ 99.99	$ 114.22	$ 126.84	$ 137.76
Difference due to Wi-Fi 6E ($ billion)	$ 10.57	$ 12.08	$ 13.80	$ 15.33	$ 16.64

NOTE: The data used in this table is based on two different reports by Cisco. Given the available data, this methodology was determined to be the only potential approach for this analysis

SOURCES: CISCO; TELECOM ADVISORY SERVICES ANALYSIS

Wi-Fi 7 is expected to achieve even greater improvement in efficiency and quality of business internet traffic compared to its predecessors. Based on our technical analysis (see Appendix C), we estimate an incremental benefit of 60% over the existing benefits of Wi-Fi 6E. This substantial enhancement in traffic management and efficiency is projected to result in significant economic impacts. Specifically, the economic impact reaches $5,053 million by 2027 (see Table 5-8). These figures underscore the transformative potential of Wi-Fi 7 in driving economic growth and productivity through superior internet traffic management capabilities.

TABLE 5-8. **United States: Savings** in **Business Wireless Traffic Due** to **6 GHz Using Wi-Fi 7**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Traffic through Wi-Fi 7 (%)	0%	0%	13.93%	28.36%	50.60%
Additional impact Wi-Fi 7 (%)	60.00%	60.00%	60.00%	60.00%	60.00%
Economic Impact ($ billion)	$ 0	$ 0	$ 1.15	$ 2.61	$ 5.05

SOURCES: CISCO; TELECOM ADVISORY SERVICES ANALYSIS

5.4. Avoidance of Enterprise Building Inside Wiring

Similar to residential Wi-Fi savings due to capital investment avoidance in inside wiring, we take the total number of business establishments are equipped with Wi-Fi access points and multiply this value by a standard cost of deploying a CAT 6 network ($2,200 per building). We only consider the savings due to the yearly increase in the number of connections, so we estimate a producer surplus of $167 million in 2023, and $192 million in 2027 (See Table 5-9).

TABLE 5-9. **United States: Savings** in **Business Wiring CAPEX**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Total Wiring Cost (*)	$ 2,200	$ 2,200	$ 2,200	$ 2,200	$ 2,200
Number of establishments (million)	8,304.83	8,385,62	8,473.63	8,571.63	8,658.83
Establishments with Wi-Fi (million)	8,304.83	8,385,62	8,473.63	8,571.63	8,658.83
Inside Wiring Costs ($ million)	$ 18,271	$ 18,448	$ 18,642	$ 18,858	$ 19,049
Inside Wiring Costs, Yearly increase ($ million)	$ 167	$ 178	$ 194	$ 216	$ 192

(*) Wiring costs assumed to be stable in the future based on the trend between the 2018 and 2020.

SOURCES: U.S. CENSUS; TELECOM ADVISORY SERVICES ANALYSIS

5.5. Enhanced IoT Deployment

IoT adoption has a contribution to GDP growth through the multiplicity of use cases that improve efficiency in processes such as preventive maintenance, production monitoring and the like. IoT deployment is directly dependent on the amount of Wi-Fi bandwidth available at sites of sensor deployment (e.g., warehouses, factory floors). Along those lines, if the 6 GHz and 7 GHz bands are not available for IoT sensor connectivity, adopting businesses are constrained in terms of achieving full benefit of the technology. Allocating these bands for unlicensed use will, in consequence, eliminate any constraints on IoT development, thereby accruing its impact on productivity and ultimately on output. To estimate this, we rely on a coefficient of GDP impact calculated through an aggregate simple production function which estimates that a 10% rise in M2M connections results in annual increases in GDP of 0.7%.[67]

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

- The difference between two forecasts of M2M connections from the same source (GSMA Intelligence, 2024)
- The difference in yearly forecasts of M2M connections (GSMA Intelligence)
- The percent of IoT installed base that is supported by Wi-Fi, which is 31% (IoT Analytics (2023)). Also this source indicates that the CAGR for the Wi-Fi IoT connected devices is expected to be 16% between 2022 and 2027.[68]

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

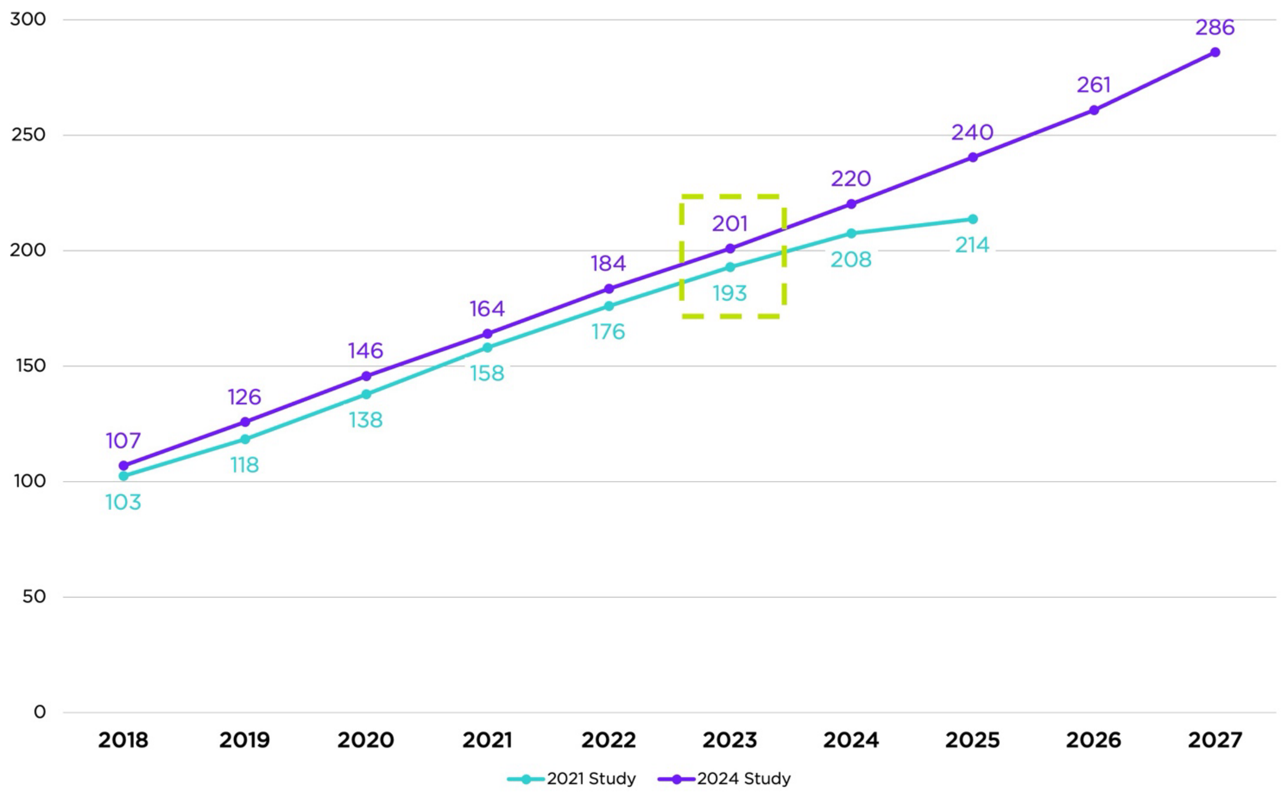
Starting with a 2023 installed base of 200.959.226 M2M connections, we estimated that higher Wi-Fi speeds explain the growth from 192,981,251 connections based on previous M2M estimations for 2023 (a 4.13% increase). The incremental growth rates range from 4.13% in 2023 to 10.67% in 2027 (see graphic 5-1).

---

[67] See Frontier Economics (2018).

[68] Retrieved in: https://iot-analytics.com/number-connected-iot-devices/.

GRAPHIC 5-1. **M2M Connections** (in Millions)



SOURCE: GSMA INTELLIGENCE

According to this metric, we are assuming that the percentage change in Wi-Fi enabled IoT (or in this case M2M) devices is related to the difference between both forecasts, as Wi-Fi acts as a crucial enabler for the increase in connections. A second approach may be to consider the yearly difference between the number of M2M connections in United States between the two GSMA Intelligence forecasts. For example, considering the growth rate between the 220 million M2M connections projected for 2024 against the 201 million in 2023.

A third alternative approach is available, relying on IoT Analytics projections of a worldwide CAGR for Wi-Fi M2M devices of 16%. That alternative has several problems: First, it is a global rather than US value. Second, we lack the base of total IoT terminals against which we can calculate the number of terminals that are Wi-Fi enabled.

We decided to rely on the first approach, although, cognizant of its limitations, we will provide the results of the second and the third approximation to demonstrate that the first one provides a more conservative Wi-Fi value estimate.

Regarding the first approach, we calculate the incremental number of devices between both estimates from GSMA Intelligence, apply the coefficient of GDP impact of 0.7%. In this way, the impact on GDP, expressed as a percentage, grows from 0.29% in 2023 to 0.75% in 2027. The annual economic impact, calculated as a product of GDP impact and GDP itself, ranges from $77.99 billion in 2023 to $234.70 billion in 2027 (see table 5-10).

TABLE 5-10. **United States: GDP Contribution** of **IoT Deployment Due** to **Wi-Fi |** 2023-2027

VARIABLE	2023	2024	2025	2026	2027
Connections, M2M (2021 est.) (million)	192.98	207.59	223.30	240.20	258.38
Connections, M2M (2024 est.) (million)	200.96	220.32	240.47	261.01	285.95
Incremental (%)	4.13%	6.14%	7.69%	8.66%	10.67%
Impact of 100% M2M Growth on GDP	7.00%	7.00%	7.00%	7.00%	7.00%
Impact on GDP (%)	0.29%	0.43%	0.54%	0.61%	0.75%
GDP ($ billion)	$26,950	$27,967	$29,049	$30,224	$31,429
Annual Impact ($ billion)	$77.99	$120.11	$156.31	$183.23	$234.70

SOURCES: GSMA INTELLIGENCE; FRONTIER ECONOMICS; IMF; TELECOM ADVISORY SERVICES ANALYSIS

The second approach, relying on the yearly growth of M2M connections from GSMA, generates an economic value that ranges from $178,094 million in 2023 to $210,236 million in 2027 (see table 5-11).

TABLE 5-11. **United States: GDP Contribution** of **IoT Deployment Due** to **Wi-Fi, Second Approach**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Connections, M2M (2024 est.) (billion)	200.96	220.32	240.47	261.01	285.95
Incremental (%)	9.44%	9.64%	9.14%	8.54%	9.56%
Impact of 1% M2M Growth on GDP(%)	7.00%	7.00%	7.00%	7.00%	7.00%
Impact on GDP (%)	0.66%	0.67%	0.64%	0.60%	0.67%
GDP ($ billion)	$26,950	$27,967	$29,049	$30,224	$31,429
Annual Impact ($ billion)	$178.09	$188.64	$185.89	$180.71	$210.24

SOURCES: GSMA INTELLIGENCE; FRONTIER ECONOMICS; IMF; TELECOM ADVISORY SERVICES ANALYSIS

A third approach, relying on the worldwide CAGR projected by IoT Analytics for Wi-Fi M2M connections of 16%, generates an economic value that ranges from $301.84 billion in 2023 to $352.00 billion in 2027 (see table 5-12).

TABLE 5-12. **United States: GDP Contribution** of **IoT Deployment Due** to **Wi-Fi, Third Approach**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Incremental (%)	16%	16%	16%	16%	16%
Impact Of 1% M2M Growth on GDP (%)	7.00%	7.00%	7.00%	7.00%	7.00%
Impact on GDP (%)	1.12%	1.12%	1.12%	1.12%	1.12%
GDP ($ Billion)	$26,950	$27,967	$29,049	$30,224	$31,429
Annual Impact ($ Billion)	$301.84	$313.23	$325.35	$338.51	$352.00

SOURCES: IOT ANALYTICS; FRONTIER ECONOMICS; IMF; TELECOM ADVISORY SERVICES ANALYSIS

A comparison of all three approaches indicates that while the three estimates are fairly aligned in 2026 and 2027, the second and third one are more optimistic in terms of Wi-Fi economic impact. For conservative purposes, we decided to rely on the first one.

5.5.1. Enhanced IoT Deployment Due to Wi-Fi Operating in the 2.4 GHz & 5 GHz Bands

In the prior section, we estimated the total impact of M2M connections, considering all categories of Wi-Fi. Now, we break down the effect for Wi-Fi operating in the 2.4 GHz and 5 GHz bands. To account for the differential impact by frequency bands, we considered a decline in traffic as a result of diminishing impact of Wi-Fi 6 or lower standards. This results in a decrease in GDP contribution from $55.87 billion in 2023 to $38.021 billion in 2027 (See Table 5-13).

TABLE 5-13. **United States: GDP Contribution** of **IoT Deployment Due** to **Wi-Fi 6** or **Lower**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Connections, M2M (2021 est.)	192.98	207.59	223.30	240.20	258.38
Connections, M2M (2024 est.)	200.96	220.32	240.47	261.01	285.95
Incremental (%)	4.13%	6.14%	7.69%	8.66%	10.67%
Impact of 1% M2M Growth on GDP (%)	7.00%	7.00%	7.00%	7.00%	7.00%
Impact on GDP (%)	0.29%	0.43%	0.54%	0.61%	0.75%
GDP ($ billion)	$26,950	$27,967	$29,049	$30,224	$31,429
Annual Impact (US$ billion)	$77.99	$120.11	$156.31	$183.23	$234.70
Traffic through Wi-Fi 6 or lower	71.64%	49.40%	34.07%	23.49%	16.20%
Impact (US$ billion)	$55.87	$59.34	$53.26	$43.05	$38.02

SOURCES: GSMA INTELLIGENCE; FRONTIER ECONOMICS; IMF; TELECOM ADVISORY SERVICES ANALYSIS

5.5.2. Enhanced IoT Deployment Due to Wi-Fi 6E & Wi-Fi 7 Operating in the 6 GHz & 7 GHz Bands

For estimating the effect in the 6 GHz band, we first break down the effect for Wi-Fi 6E and Wi-Fi 7 using the 6 GHz band. We estimate that the use of Wi-Fi 6E along all Wi-Fi categories varies from 28.36% in 2023 to 33.20% in 2027 (see graphic 3-2 in section 3.1.2), with its impact ranging from $22,116 million in 2023 to $77,927 million in 2027. The Wi-Fi 7 share begins to emerge in 2025, starting at 13.93% and increasing to 50.60% by 2027. The additional impact of Wi-Fi 7, once it becomes relevant, significantly contributes to the overall economic impact, with figures rising from $21,776 million in 2025 to $118,750 million in 2027 (see Table 5-14).

TABLE 5-14. **United States: GDP Contribution** of **IoT Deployment Boost Caused** by **6 GHz** 2023-2027

VARIABLE	2023	2024	2025	2026	2027
Wi-Fi 6E share (%)	28.36%	50.60%	52.00%	48.15%	33.20%
Impact (US$ billion)	$22.12	$60.77	$81.29	$88.23	$77.93
Wi-Fi 7 share (%)	0%	0%	13.93%	28.36%	50.60%
Additional impact Wi-Fi 7 (%)	0%	0%	0%	0%	0%
Impact (US$ billion)	$0	$0	$21.78	$51.96	$118.75

SOURCES: GSMA INTELLIGENCE; FRONTIER ECONOMICS; IMF; TELECOM ADVISORY SERVICES ANALYSIS

With the introduction of Wi-Fi 7 and the allocation of at least the lowest 125 MHz from the 7 GHz band, the impact increases by 9.43% based on our technical analysis (see Appendix C). If 500 MHz from the 7 GHz band is allocated for unlicensed use, the impact will increase by 29.41%. For a 9.43% additional impact, the contribution in million US dollars is projected to be $2,053 million in 2025, $4,900 million in 2026, and $11,198 million in 2027. For a 29.41% additional impact, these values rise significantly, with impacts of $4,351 million in 2025, $10,382 million in 2026, and $23,726 million in 2027. This analysis demonstrates the substantial economic benefits that can be achieved with higher frequency allocations in the 7 GHz band for Wi-Fi 7 (See Table 5-15).

TABLE 5-15. **United States: GDP Contribution** of **IoT Deployment Boost Caused** by **7 GHz** 2023-2027

VARIABLE	2023	2024	2025	2026	2027
Additional impact of Wi-Fi 7 with the addition of the lowest 125 MHz of 7 GHz band (%)	9.43%	9.43%	9.43%	9.43%	9.43%
Impact (US$ billion) of Wi-Fi 7 with the addition of the lowest 125 MHz of 7 GHz band	$0	$0	$2.05	$4.90	$11.20
Additional impact Wi-Fi 7 of Wi-Fi 7 with 500 MHz of 7 GHz band (%)	29.41%	29.41%	29.41%	29.41%	29.41%
Impact (US$ billion) of Wi-Fi 7 with 500 MHz of 7 GHz band	$0	$0	$4.35	$10.38	$23.73

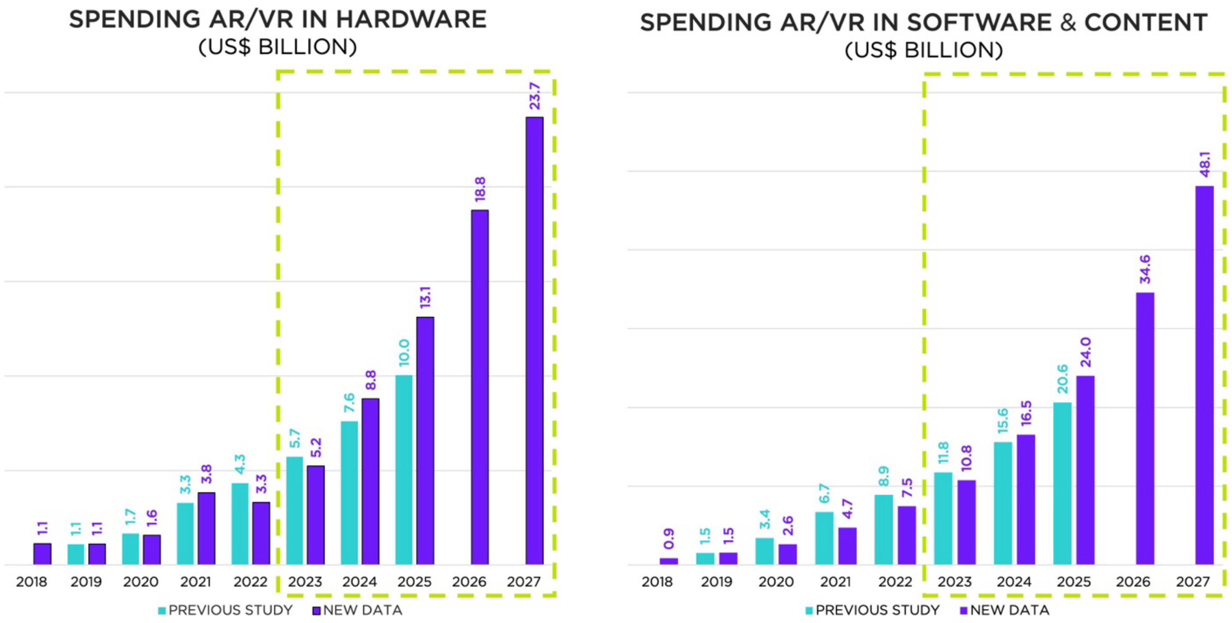
SOURCES: GSMA INTELLIGENCE; FRONTIER ECONOMICS; IMF; TELECOM ADVISORY SERVICES ANALYSIS

5.6. Deployment of Augmented Reality/Virtual Reality Solutions

The adoption of AR/VR among U.S. business has a spillover effect on productivity, thereby contributing to the growth of GDP. Estimating spillover effects of AR/VR is a not a trivial exercise considering the embryonic adoption of some of these use cases. Since the objective is to estimate the spillover effect of AR/VR in U.S., we will take as points of departure the estimate by PwC of the total GDP contribution of AR/VR, and the sales of AR/VR components as estimated by ABI Research. These two parameters allow estimating the indirect (spillover) contribution of AR/VR to the U.S. economy for the period under analysis.

The 2023 spending in AR/VR components in the prior study was $17.52 billion (higher than current one), although the projection for 2025 is now higher ($37.12 billion vs $ 0.64 billion).

GRAPHIC 5-2. **United States: AR/VR Market** (In $ Billions)
2018–2027



SOURCES: 2021 STUDY DATA FROM ECORYS AND IDC; NEW DATA FROM ABI RESEARCH

5.6.1. Deployment of Augmented Reality/Virtual Reality Solutions Due to Wi-Fi Operating in the 2.4 GHz & 5 GHz Bands

Starting with the total estimated impact for AR/VR provided by PwC, we then subtract the portion attributable to Wi-Fi 6 or lower technologies. Next, we deduct the direct impact of AR/VR estimated using data from ABI Research. This calculation results in a total indirect impact figure.

To maintain a conservative approach, we assume that the indirect impact does not exceed the direct impact. If we do not consider this restriction, the indirect impact of AR/VR is projected to be $24.20 billion in 2023, growing to $71.28 billion in 2027[69]. But if we apply the restriction, the indirect impact could as high be the same as the direct impact, the contribution in million US dollars is projected to be $5,144 million in 2023, growing to $18,818 million in 2027 (See Table 5-16).

---

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

TABLE 5-16. **United States: GDP Contribution Resulting** from **AR/VR Spillovers**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Spending in AR/VR - Hardware ($ billion)	$5.23	$8.80	$13.11	$18.76	$23.68
Spending in AR/VR - Software, Contents, Services ($ billion)	$10.76	$16.52	$24.00	$34.58	$48.12
Total Spending in AR/VR ($ billion)	$15.99	$25.32	$37.12	$53.35	$71.81
Share attributable to Wi-Fi (Wi-Fi 6 or less) (%)	32.18%	30.88%	29.32%	27.76%	26.21%
Direct Impact Wi-Fi 6 or less ($ billion), spending	$5.14	$7.82	$10.88	$14.81	$18.82
Total Impact on GDP ($ billion)	$91.20	$122.60	$171.90	$248.70	$343.80
Share attributable to Wi-Fi (Wi-Fi 6 or less) (%)	32.18%	30.88%	29.32%	27.76%	26.21%
Total Impact (Wi-Fi 6 or less) ($ billion)	$29.34	$37.86	$50.41	$69.05	$90.10
Indirect impact ($ billion)	$24.20	$30.04	$39.52	$54.24	$71.28
Indirect / direct impact	4.71	3.84	3.63	3.66	3.79
Max indirect/direct	1.00	1.00	1.00	1.00	1.00
Annual Indirect Impact ($ billion)	$5.14	$7.82	$10.88	$14.81	$18.82

SOURCES: ABI RESEARCH; PWC; TELECOM ADVISORY SERVICES ANALYSIS

5.6.2. Deployment of Augmented Reality/Virtual Reality Solutions Due to Wi-Fi 6E & Wi-Fi 7 Operating in the 6 GHz & 7 GHz Bands

Higher throughput enabled by Wi-Fi 6E, and the allocation of the 6 GHz band is expected to spur further adoption and use of AR/VR among enterprises, hence increasing the associated spillover effects. By relying on the ratio built from 5 GHz and 6 GHz AR/VR related products[70], we were able to isolate the specific economic contribution of the new spectrum allocation. Also, we divide that impact between Wi-Fi 6E and Wi-Fi 7 based on the projected traffic for each technology.

Following a similar procedure as the one described in the section above, spillovers from AR/VR attributed to Wi-Fi 6E will account for $5.50 billion in 2023 and are expected to increase by 2027 to $11.49 billion. Also, for Wi-Fi 7 that impact will account for $2.92 billion in 2025 and are expected to increase by 2027 to $17.51 billion (see Table 5-17).

---

[70] We constructed the ratio using the estimates from AR/VR sales by Wi-Fi bands,by dividing sales of equipment attributed to Wi-Fi 7 and Wi-Fi 6E by sales of equipment attributed to Wi-Fi 6 or less (see

tables 7.12 and 7.11 in section 7.4.

TABLE 5-17. **United States: GDP Contribution Resulting** from **AR/VR Spillovers Due** to **Wi-Fi 6E** & **Wi-Fi 7**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Impact Wi-Fi 6E/Wi-Fi 6 or less	106.97%	115.66%	100.26%	88.02%	61.06%
Impact Wi-Fi 6E ($ billion)	$5.50	$9.04	$10.91	$13.04	$11.49
Impact Wi-Fi 7/Wi-Fi 6 or less	0%	0%	26.86%	51.84%	93.05%
Impact Wi-Fi 7 ($ billion)	$0	$0	$2.92	$7.68	$17.51

SOURCES: ABI RESEARCH; PWC; TELECOM ADVISORY SERVICES ANALYSIS

* * * * *

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

- Benefits derived from an increase in average speed. The improvements of average download speed for enterprises as a result of using Wi-Fi for in-building connectivity are estimated at $141.08 billion in 2023 and projected to reach $440.35 billion in 2027.
- Benefits derived from reduced latency. The total improvements of latency from Wi-Fi (principally from Wi-Fi 6E but more particularly from Wi-Fi 7) for enterprises are estimated at $269.29 billion in 2023, reaching $392.37 billion in 2027.
- Savings in business Internet traffic transmitted through Wi-Fi. Total Wi-Fi enterprise savings results from wireless traffic that is routed through Wi-Fi access points is estimated to have reached $288.67 billion in 2023 and will amount to $478.68 billion in 2027
- Avoidance of campus and enterprise facilities inside wiring: Similar to residential Wi-Fi savings due to capital investment avoidance in inside wiring, we assume that the total number of business establishments are equipped with Wi-Fi access points and consider only the savings due to the yearly increase in the number of connections, yielding a producer surplus of $167 million in 2023, and $192 million in 2027
- Enhanced IoT deployment. It is conservatively estimated that the spillover impact of Wi-Fi enabled IoT devices is estimated at $77.99 billion in 2023 and will grow to reach $269.62 billion in 2027
- Deployment of Augmented Reality/Virtual Reality solutions: the adoption of AR/VR among U.S. business has a spillover effect on productivity, thereby contributing to the growth of GDP. Total spillovers driven by successive generation of Wi-Fi standards are estimated to reach $47.82 billion in 2027.

6. WI-FI & INTERNET SERVICE PROVIDERS

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

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

6.1. Cellular Network CAPEX Savings from Off-Loading Traffic to Wi-Fi

The value of cellular off-loading lies in its ability to reduce the amount of capital cellular operators spend on their networks by leveraging Wi-Fi at the edge of broadband networks to send or receive data, thereby reducing the need for cellular capacity expansions. Two types of traffic off-loading effect exist: (i) off-loading resulting from Wi-Fi usage of dual mode devices at home (referred to as "user-initiated off-loading"), (ii) outdoor or away-from-home traffic off-loading where carriers rely on carrier-grade Wi-Fi access points to supplement wideband networks (called "carrier initiated off-loading").

Based on interviews and carrier data, we estimate cellular networks CAPEX savings in Table 6-1 below for user-initiated off-loading. User-initiated Wi-Fi off-loading constitutes a substantial share of traffic from dual mode devices, conservatively amounting to 77.29% in 2023, and growing to 77.98% in 2027.[71] This results in CAPEX savings ranging from $36.08 billion in 2023 to $33.36 billion in 2027 (See Table 6-1).

TABLE 6-1. **United States: Cellular Network CAPEX Savings** by **Off-Loading Traffic** to **Wi-Fi**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Total mobile CAPEX ($ billion)	$46.68	$42.68	$42.67	$42.60	$42.78
Share of traffic off-load	77.29%	77.38%	77.52%	77.71%	77.98%
Total CAPEX savings by traffic off-loading ($ billion)	$36.08	$33.03	$33.08	$33.10	$33.36

SOURCES: GSMA INTELLIGENCE; TELECOM ADVISORY SERVICES ANALYSIS

However, despite the actual savings generated by user-initiated off-loading for cellular operators, we do not add it to the calculation of economic value since that would result in double-counting the benefits already considered in Section 4.2, where we assess consumer benefits from using Wi-Fi instead of cellular data services at home.[72] We have chosen this approach to ensure the accuracy of our economic impact assessment.

---

[71] We estimate that, for user-generated offloads, traditional MNOs off-load 77% of their traffic and cable operators offering mobile services off-load 85% of their traffic using Wi-Fi, with the overall off-load a weighted average of these two percentages with weights based on the connection shares of these two segments of the industry. These values differ from those cited in Table 4-6 (75%) since they cover only offloading for smartphones and laptops, therefore excluding other devices.

[72] At section 4.2, we note the cost to consumers if all traffic had to be transported on cellular networks as measured by our estimate of cost per gigabit of data. A retail price estimate such as this one necessarily implies the carrier is covering its cost - including capex, operating expenses, and overheads associated with the provision of capacity that a carrier delivers. Therefore, the consumer benefit cited in 4.2 of this study implicitly reflects capex savings from user-initiated off-loading.

However, it is important to understand that savings for service providers indeed exist and the savings are substantial.

On the other hand, “carrier-initiated” off-loading is indeed part of cellular networks’ producer surplus, which is quantified here to produce a complete economic value measure. By constructing and relying on hybrid networks, carriers can preserve spectrum and reduce capital expenditures necessary to deploy additional base stations. Moreover, some service providers are able to monetize their Wi-Fi offerings by directly charging customers, thereby creating an additional revenue stream. This approach not only generates revenue but also enhances service differentiation and improves the overall customer experience.

A critical component of these hybrid networks is the use of carrier-grade routers, which offer substantial benefits over standard home routers. These routers are specifically designed to manage higher user densities, provide enhanced reliability, and support advanced features such as Quality of Service (QoS) management—essential for maintaining optimal performance in congested environments. Additionally, they come equipped with robust security features, including enterprise-grade encryption and advanced firewall protection, which are vital for safeguarding network integrity in public and commercial settings. Unlike home routers, which are tailored for residential use, carrier-grade routers are engineered to deliver consistent performance across expansive networks, making them indispensable for the successful integration of Wi-Fi and cellular technologies in hybrid networks.

In our research, we measure the specific effects of Wi-Fi across standards ranging from Wi-Fi 6 or less, Wi-Fi 6E and Wi-Fi 7. This assumption acknowledges the continued relevance of earlier technologies but recognizes that the migration to more advanced solutions will yield substantial benefits.

Based on carrier interviews, we estimate that for cellular networks, carrier-initiated offloading (as distinct from user-initiated offloading) amounts to 8.07% of traffic in 2023, growing to 8.24% in 2027.[73] This translates to savings ranging from $3.77 billion in 2023 to $3.53 billion in 2027 (See Table 6-2).

TABLE 6-2. **United States: Cellular Network CAPEX Savings** by **Carrier-Initiated Wi-Fi Off-Loading**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Total mobile CAPEX ($ billion)	$46.68	$42.68	$42.67	$42.60	$42.78
Share of carrier-initiated traffic off-load	8.07%	8.10%	8.13%	8.18%	8.24%
Total CAPEX savings by traffic off-loading ($ billion)	$3.77	$3.46	$3.47	$3.48	$3.53

SOURCES: GSMA INTELLIGENCE; TELECOM ADVISORY SERVICES ANALYSIS

The introduction of Wi-Fi 7 significantly enhances data transmission efficiency compared to previous technologies. Based on our technical analysis (included in Appendix C), Wi-Fi 7 operating in the 6 GHz band provides a 30.56% improvement in download speed that allows more traffic at the same time. Additionally, Wi-Fi 7 used in multiple channels in the 7 GHz band with the addition of at least the lowest 125 MHz allocation (i.e., 7125-7250 MHz) results in an improvement in download speed of close to 60%.

Based on the 30.56% improvement scenario, the economic impact is $148 million in 2025, $302 million in 2026, and $545 million in 2027, reflecting the increase in adoption rates of Wi-Fi 7 over time. In the scenario with Wi-Fi 7 operating in the 125 MHz of the 7 GHz band, the economic impact increases incrementally by $84 million in 2025, $172 million in 2026, and $310 million in 2027. Lastly, if 500 MHz of spectrum were made available up to 7625 MHz, the economic impact increases another increment of an additional $50 million in 2025, $103 million in s2026. and $186 million in 2027. (See Table 6-3).

---

[73] We estimate that telecommunications MNOs off-load 8% of their traffic and cable operators offering mobile services off-load 10% of their traffic using Wi-Fi, with the overall off-load being a weighted average of these two percentages with weights based on the share of connections of these two industry players.

TABLE 6-3. **United States: Cellular Network CAPEX Savings** by **Off-Loading Traffic** to **Wi-Fi Using Wi-Fi 7**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Additional impact of Wi-Fi 7 using 6GHz band (%)	30.56%	30.56%	30.56%	30.56%	30.56%
Wi-Fi 7 Adoption (%)	0%	0%	13.93%	28.36%	50.60%
Economic impact of Wi-Fi 7 using 6GHz band ($ million)	$0	$0	$148	$302	$545
Additional impact of Wi-Fi 7 using additional 125 MHz of 7GHz band (%)	47.92%	47.92%	47.92%	47.92%	47.92%
Economic impact of Wi-Fi 7 using at least additional 125 MHz of 7GHz band ($ million)	$0	$0	$84	$172	$310
Additional impact of Wi-Fi 7 using 500 MHz of 7GHz band (%)	58.33%	58.33%	58.33%	58.33%	58.33%
Economic impact of Wi-Fi 7 using 500 MHz of 7GHz band ($ million)	$0	$0	$50	$103	$186

SOURCES: GSMA INTELLIGENCE; TELECOM ADVISORY SERVICES ANALYSIS

In sum, by 2027, we estimate that Wi-Fi6E and legacy technologies will result in $3.53 billion in annual capex savings to carriers from carrier-initiated offloading. When we add in the incremental benefits of Wi-Fi7, those benefits increase capex savings to a total of $4.075 billion when the technology is using the 6 GHz band, and to an annual $4.571 billion in capex savings by 2027 if Wi-Fi can utilize spectrum up to 7625 MHz. Viewed from another perspective, the combination of all generations of Wi-Fi networks, assuming operations are permitted up to 7625 MHz, would generate capex savings from carrier-initiated offloading of $12.38 billion in the 2025-2027 period alone. As referenced above, this economic value is separate and apart from the significant economic value created through user-initiated offloading which generates well over $30 billion in capex savings for providers.

6.2 Revenues of Wi-Fi Based Public Internet Service Providers

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

6.2.1. Revenues of Wi-Fi Based Public Internet Service Providers Due to Wi-Fi 6 or Less Operating in the 2.4 GHz & 5 GHz Bands

To estimate the total revenues of these providers, we start by calculating the number of commercial Wi-Fi hotspots in the United States. According to Cisco and Wi-Fi Map, in 2023 there were 0.99 million commercial Wi-Fi hotspots, which will gradually decrease, to 0.55 million in 2027 as a consequence of substitution from either free sites or mobile broadband. Based on revenue figures from Boingo financial[74] statements and the number of hotspots deployed by this company in the U.S., we estimate an average revenue figure per hotspot. By extrapolating that amount to the overall number of paid Wi-Fi hotspots in the country, we estimate total revenues generated by this sector in the United States: $612 million in 2023, gradually decreasing to reach $343 million in 2027 (Table 6-4).

TABLE 6-4. **United States: Revenues** of **Wi-Fi Carriers**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Pay Wi-Fi hotspots (million)	0.99	0.88	0.77	0.66	0.55
Revenue per hotspot	$619	$619	$619	$619	$619
Revenue ($ million)	$612	$545	$477	$410	$343

SOURCES: CISCO, WI-FI MAP; BOINGO, TELECOM ADVISORY SERVICES

6.2.2. Revenues of Wi-Fi Based Public Internet Service Providers Due to Wi-Fi 6E & Wi-Fi 7 Operating in the 6 GHz & 7 GHz Bands

The allocation of the 6 GHz spectrum band offers an opportunity for commercial Wi-Fi carriers to enhance their business. As Wi-Fi 6E developments will allow up to 1,500 connected devices per access point, Wi-Fi carriers will have the possibility of adding more customers without quality limitations due to congestion. By considering a conservative potential increase of 40% in the number of connected devices in public venues and weighting that figure by the gradual expansion of the latest technology, we expect commercial Wi-Fi carriers using Wi-Fi 6E to increase their user base from 11% in 2023 to 21% in 2025, then decreasing to 13% again in 2027 (due to Wi-Fi 6E replacement by Wi-Fi 7). If the revenue per hotspot increases in the same amount, that will yield an increase in overall revenues for the sector of an additional $46 million by 2027 (Table 6-5).

TABLE 6-5. **United States: Revenues** of **Wi-Fi Carriers Due** to **Wi-Fi 6E** in **6 GHz**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Potential increase in connected devices in public venues (%)	40.00%	40.00%	40.00%	40.00%	40.00%
Traffic through Wi-Fi 6E (%)	28%	51%	52%	48%	33%
Increase in connected devices due to Wi-Fi 6E (%)	11%	20%	21%	19%	13%
Revenue per hotspot if Wi-Fi 6E allocated ($)	$ 689	$ 744	$ 747	$ 738	$ 701
Revenue if Wi-Fi 6E allocated ($ million)	$69	$110	$99	$79	$46

SOURCES: BOINGO; TELECOM ADVISORY SERVICES ANALYSIS

Wi-Fi 7 also enhances the potential for paid hotspots due to its technological advancements. Based on our technical analysis from Appendix C, Wi-Fi 7 operating in the 6 GHz band yields a 37.50% improvement in the maximum number of simultaneous connections; in the 7 GHz band with at least the addition of the lowest 125 MHz, it provides a 58.33% improvement, and with 500 MHz, the improvement increases to 68.75%. These

---

[74] Based on Boingo latest published financial statements, adjusted for North America, available at https://www.annualreports.com/HostedData/AnnualReportArchive/b/NASDAQ_WIFI_2020.pdf

enhancements significantly impact the economic outcome of public Wi-Fi service providers. Considering the traffic enhancement through the 7 GHz band, and the capacity improvement conveyed by Wi-Fi 7 in the 6 GHz band, this will lead to additional revenues of $37 million in 2025, $64 million in 2026, and $95 million in 2027. For a 58.33% additional impact (Wi-Fi 7 in the lowest 125 MHz of the 7 GHz band), the additional revenues will increase by $20 million in 2025, $36 million in 2026 and $53 million in 2027. In the scenario with a 68.75% additional impact (Wi-Fi 7 with an allocation of 500 MHz in the 7 GHz band), additional revenues begin at $4 million in 2025, rising to $6 million in 2026 and $9 million in 2027. (see Table 6-6).

TABLE 6-6. **United States: Revenues** of **Wi-Fi Carriers Due** to **Wi-Fi 7**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Additional impact of Wi-Fi 7 using 6GHz band (%)	37.50%	37.50%	37.50%	37.50%	37.50%
Potential increase in connected devices in public venues (%)	40.00%	40.00%	40.00%	40.00%	40.00%
Traffic through Wi-Fi 7 (%)	0%	0%	14%	28%	51%
Increase in connected devices due to Wi-Fi 7 operating in the 6GHz band (%)	0%	0%	8%	16%	28%
Revenue per hotspot if Wi-Fi 7 allocated ($)	$ 619	$ 619	$ 666	$ 715	$ 791
Revenue if Wi-Fi 7 using 6GHz band allocated ($ million)	$0	$0	$37	$64	$95
Additional impact of Wi-Fi 7 using lowest 125 MHz of 7GHz band ($)	58.33%	58.33%	58.33%	58.33%	58.33%
Revenue if Wi-Fi 7 using lowest 125 MHz of 7GHz band allocated ($ million)	$0	$0	$20	$36	$53
Additional impact of Wi-Fi 7 using 500 MHz of 7GHz band (%)	68.75%	68.75%	68.75%	68.75%	68.75%
Revenue if Wi-Fi 7 using 500 MHz of 7GHz band allocated ($ million)	$0	$0	$4	$6	$9

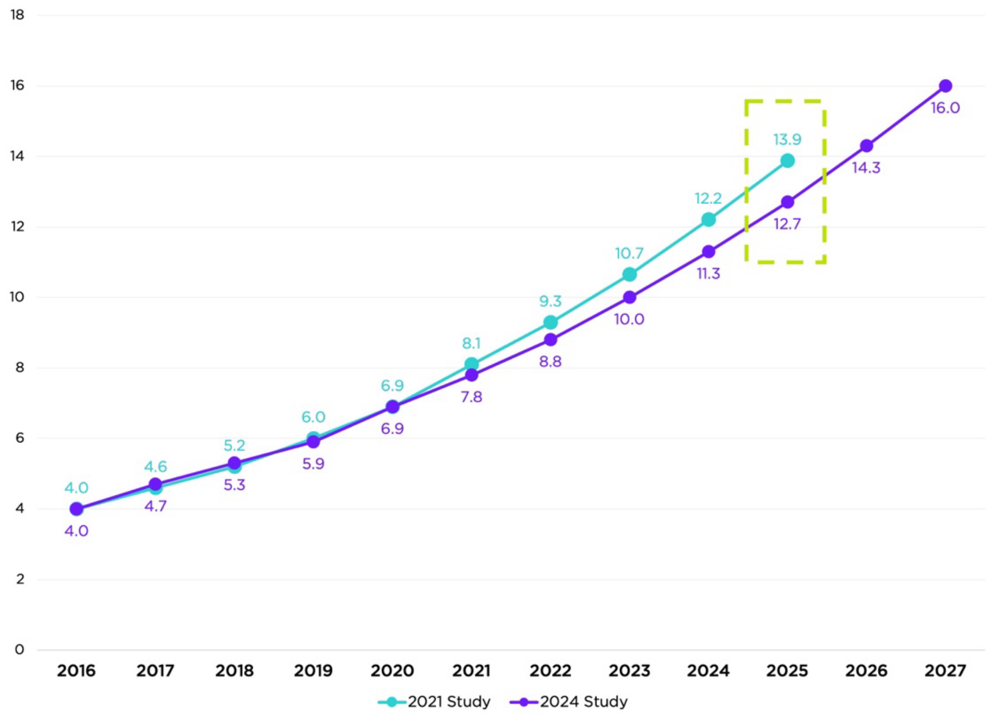
SOURCES: BOINGO; TELECOM ADVISORY SERVICES ANALYSIS

6.3. Revenues of Wi-Fi Based Wireless Internet Service Providers (WISPs)

6.3.1. Revenues of Wi-Fi Based Wireless Internet Service Providers Due to Wi-Fi 6 or Less Operating in the 2.4 GHz and 5 GHz Bands

In a 2021 study, WISPA estimated 12.7 million WISP lines for 2025 but now estimates there will 13.9 million lines next year (see graphic 6-1).

GRAPHIC 6-1. **WISP Number Of Lines (In Millions)**



SOURCE: WISPA BWA REPORT (2017), WISPA (2021) "2021 FIXED-WIRELESS AND HYBRID ISP INDUSTRY"

In the 2021 study we utilized WISPA (2017) report that estimated 13.9 million WISP lines for 2025. WISPA (2021) re-estimated downwards that projection to 12.7 million for 2025. One of the possible causes for this variation is the shift from wireless technology to fiber optics in areas where high-speed networks are deployed. Also, the last available report estimates 16 million WISP lines for 2027[75].

The 2023 GDP contribution driven by the WISP industry was calculated as a function of the number of subscribers (10,000,000, as projected by WISPA report in 2021) and the ARPU ($830 per year), yielding a total of $8.3 billion. That number grows to a total revenue of $ 17.56 billion in 2027 (see Table 6-7).

TABLE 6-7. **United States: WISP Revenues**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Subscribers (million)	10.00	11.30	12.70	14.27	16.04
WISP Annual ARPU ($)	$830	$920	$1,094	$1,094	$1,094
Revenues ($ billion)	$8.30	$10.40	$13.90	$15.62	$17.56

SOURCES: WISPA, TELECOM ADVISORY SERVICES ANALYSIS

6.3.2. Revenues of Wi-Fi Based Wireless Internet Service Providers Due to Wi-Fi 6 & Wi-Fi 7 Operating in the 6 GHz & 7 GHz Bands

As described, the allocation of 6 GHz spectrum band using Wi-Fi 6E will potentially increase the WISP user base in 0.23 million subscribers in 2023, due to expanded coverage and better affordability. Assuming the

---

[75] WISPA (2021): "The 2021 Fixed-Wireless and hybrid ISP industry report" available at https://www.carmelgroup.com/wp-content/uploads/2021/04/The-Carmel-Group-2021-Fixed-Wireless-Report-4-23-2021.pdf

same ARPU values as described above, the new subscriptions will account for an additional $195 million in revenues in 2023 and $357 million in 2027 (Table 6-8).

TABLE 6-8. **United States: WISP Revenues Due** to **6 GHz Using Wi-Fi 6E**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
WISP annual ARPU ($)	$830	$920.35	$1,094.49	$1,094.49	$1,094.49
New subscribers with Wi-Fi 6E (million)	0.23	0.34	0.40	0.43	0.33
New revenue ($million)	$195	$310	$433	$466	$357

SOURCES: WISPA; TELECOM ADVISORY SERVICES ANALYSIS

In section 4.5 we also detail the additional users that could be generated with the introduction of Wi-Fi 7 in three different scenarios (using 6 GHz band; using at least the lowest 125 MHz of the 7 GHz band and using 500 MHz of the 7 GHz band). In those scenarios the additional impact in 2027 would be $73 million; $41 million and $20 million using the same methodology (see Table 6-9).

TABLE 6-9. **United States: WISP Revenues Due** to **Wi-Fi 7**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
New subscribers if Wi-Fi 7 allocated using 6GHz band (million)	0.00	0.00	0.01	0.03	0.07
New revenue due to Wi-Fi 7 using 6GHz band ($ million)	$0	$0	$16	$37	$73
New subscribers if Wi-Fi 7 allocated using at least the lowest 125 MHz of 7GHz band (million)	0.00	0.00	0.01	0.02	0.04
New revenue of Wi-Fi 7 using at least the lowest 125 MHz of 7GHz band ($ million)	$0	$0	$9	$20	$41
New subscribers if Wi-Fi 7 allocated using at least the lowest 500 MHz of 7GHz band (million)	0.00	0.00	0.01	0.01	0.02
New revenue of Wi-Fi 7 using 500 MHz of 7GHz band ($ million)	$0	$0	$4	$10	$20

SOURCES: WISPA; TELECOM ADVISORY SERVICES ANALYSIS

* * * * *

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

- Producer surplus of cellular operators resulting from CAPEX savings incurred in network deployment and operations. The value of cellular off-loading relates to the total cost of ownership required to accommodate future capacity requirements using Wi-Fi to complement cellular networks. Estimated at 8.07% of total CAPEX in 2023, it amounts to $3.77 billion in 2023, increasing to $4.57 billion in 2027.
- Revenues of Wi-Fi carriers offering service in public spaces. Based on the revenues per site of Wi-Fi service providers, it reaches $682 million in 2023, reducing to $546 million in 2027.
- Revenues of Wireless ISPs: The WISPs relying on Wi-Fi bands to deliver service to their customers generate revenues totaling $8.50 billion in 2023, increasing to $18.05 billion in 2027.

7. DEVELOPMENT of the WI-FI ECOSYSTEM

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

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

7.1 Manufacturing of Wi-Fi Devices & Equipment for Residential Use

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

Since our focus is estimating producer surplus, the estimation begins by compiling revenues of U.S. manufacturers for each Wi-Fi enabled product. The Consumer Technology Association (2024) produces current and five-year forecast of U.S. revenues by consumer technology products and forecast that revenue up to 2027.[76] In addition, the Consumer Technology Association published a report indicating the percent of sales generated by U.S. manufacturers of consumer technology products.[77] Considering only the share of revenues generated by U.S. manufacturers of Wi-Fi-enabled products, sales amount to $76.5 billion in 2023, growing to $84.4 billion in 2027. After computing the global sales of U.S. manufacturers, we applied the prorated margin estimated by CSI markets (44.6%) which yields an estimated producer surplus for these products of $34.1 billion in 2023 growing to $37.6 billion in 2027 (see Table 7-1)

TABLE 7-1. **United States: Producer Surplus** from **Locally Manufactured Residential Wi-Fi Devices & Equipment**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Total sales ($ billion)	$ 76.49	$ 78.03	$ 79.34	$ 81.51	$ 84.42
Gross margin (%)	44.59%	44.59%	44.59%	44.59%	44.59%
Producer surplus ($ billion)	$ 34.11	$ 34.79	$ 35.38	$ 36.35	$ 37.64

SOURCES: CONSUMER TECHNOLOGY ASSOCIATION; TELECOM ADVISORY SERVICES ANALYSIS

---

[76] CTA (2024). CTA Consumer Technology Extended Forecast 2022-2028.

[77] CTA (2018). Consumer technology US sales and forecast.

7.1.1. Manufacturing of Wi-Fi Devices & Equipment for Residential Use Due to Wi-Fi 6 or Less Operating in 2.4 GHz & 5 GHz Bands

We must consider that a portion of the revenues estimated above corresponds to devices operating within the Wi-Fi 6E or Wi-Fi 7 standards. According to IDC, global shipments of consumer devices linked to Wi-Fi 6E or more will represent 39.59% of the shipments from previous generations in 2027. So, the producer surplus generated by products with Wi-Fi 6 or less is $28.76 billion in 2023 and $22.74 billion in 2027 (see table 7-2).

TABLE 7-2. **United States: Producer Surplus** from **Locally Manufactured Residential Wi-Fi Devices & Equipment** with **Wi-Fi 6** or **Less**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Global - Total Wi-Fi 6E or more shipments (%)	15.67%	22.39%	28.72%	34.42%	39.59%
Total Producer Surplus ($ billion)	$ 34.11	$ 34.79	$ 35.38	$ 36.35	$ 37.64
Total Producer Surplus ($ billion) Wi-Fi 6 or less	$ 28.76	$ 27.00	$ 25.22	$ 23.83	$ 22.74

SOURCES: CONSUMER TECHNOLOGY ASSOCIATION; IDC; TELECOM ADVISORY SERVICES ANALYSIS

7.1.2. Manufacturing of Wi-Fi Devices & Equipment for Residential Use Due to Wi-Fi 6E & Wi-Fi 7 Operating in the 6 GHz & 7 GHz Bands

As mentioned above, devices using Wi-Fi 6E or more are expected to gradually replace those of prior generations. In addition, we need to break down revenues between devices and equipment for Wi-Fi 6E and Wi-Fi 7 based on our traffic projections for both technologies. On this basis, we estimate that the producer surplus generated by products operating with Wi-Fi 6E was $5.35 billion in 2023 and will increase to $5.9 billion in 2027. In a similar way, we estimate that the producer surplus generated by products operating within Wi-Fi 7 will be $2.15 billion in 2025, growing to $9.00 billion in 2027 (See Table 7-3).

TABLE 7-3. **United States: Economic Value** of **Wi-Fi Enabled Consumer Products Due** to **Wi-Fi 6E** & **Wi-Fi 7**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Global - Total Wi-Fi 6E or Wi-Fi 7 shipments (%)	15.67%	22.39%	28.72%	34.42%	39.59%
Total Producer Surplus ($ billion)	$ 34.11	$ 34.79	$ 35.38	$ 36.35	$ 37.64
Wi-Fi 6E Adoption (%)	28.36%	50.60%	52.00%	48.15%	33.20%
Wi-Fi 7 Adoption (%)	0%	0%	13.93%	28.36%	50.60%
Producer Surplus Wi-Fi 6E Devices ($ billion)	$ 5.34	$ 7.79	$ 8.01	$ 7.88	$ 5.90
Producer Surplus Wi-Fi 7 Devices ($ billion)	$ 0	$ 0	$ 2.15	$ 4.64	$ 9.00

SOURCES: CONSUMER TECHNOLOGY ASSOCIATION; IDC; TELECOM ADVISORY SERVICES ANALYSIS

7.2. Manufacturing of Enterprise Wi-Fi Devices & Equipment

U.S. manufacturers control the largest share of the enterprise access points and controller's world market. For example, in 2020 Cisco controlled 45.7% of the enterprise wireless local area network market share worldwide[78]. The relevant margin estimated by CSI markets is 44.59%, which yields a producer surplus for U.S. manufacturers of these products of $2.65 billion in 2023, growing to 2.90 billion in 2027 (see Table 7-4). In addition, the same producer surplus is generated for the local firms that buy that equipment (using the same methodology as in Milgrom´s paper, we assume an equivalency between the estimation for producer surplus and consumer surplus). We effectively add this value twice, considering the producer surplus from two perspectives. Firstly, there is the producer surplus generated by the company that sells the devices. Secondly, we must account for the benefit enjoyed by the company that purchases the devices. In this case, since the purchasing entity is also a business, this benefit is also considered as a producer surplus.

TABLE 7-4. **United States: Producer Surplus** from **Locally Manufactured Enterprise Equipment**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Total sales ($ million)	$5,951	$6,074	$6,221	$6,361	$6,509
Gross margin (%)	44.59%	44.59%	44.59%	44.59%	44.59%
Producer surplus ($ billion) buy	$2.65	$2.71	$2.77	$2.84	$2.90
Producer surplus ($ billion) sell	$2.65	$2.71	$2.77	$2.84	$2.90

SOURCES: CONSUMER TECHNOLOGY ASSOCIATION; TELECOM ADVISORY SERVICES ANALYSIS

7.2.1. Manufacturing of Wi-Fi Equipment for Enterprise Use, Due to Wi-Fi 6 or Less Operating in the 2.4 GHz & 5 GHz Bands

We must consider that part of those sales corresponds to devices for Wi-Fi 6E or Wi-Fi 7. As mentioned above, according to IDC, global shipments of consumer devices linked to Wi-Fi 6E or more will represent 83.8% of the shipments from previous generations in 2027. Therefore, the producer surplus generated by products with Wi-Fi 6 or less is $3.8 billion in 2023 and $0.9 billion in 2027 (see table 7-5).

TABLE 7-5. **United States: Producer Surplus** from **Locally Manufactured Enterprise Wi-Fi Equipment** with **Wi-Fi 6** or **Less**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Global - Total Wi-Fi 6E or more shipments (%)	28.36%	50.60%	65.93%	76.51%	83.80%
Total Producer Surplus ($ billion)	$ 5.31	$ 5.42	$ 5.55	$ 5.67	$ 5.81
Total Producer Surplus ($ billion) Wi-Fi 6 or less	$ 3.80	$ 2.68	$ 1.89	$ 1.33	$ 0.94

SOURCES: CONSUMER TECHNOLOGY ASSOCIATION; IDC; TELECOM ADVISORY SERVICES ANALYSIS

7.2.2. Manufacturing of Wi-Fi Equipment for Enterprise Use, Due to Wi-Fi 6E, & Wi-Fi 7 Operating in the 6 GHz & 7 GHz Bands

Similarly, as mentioned above, devices for Wi-Fi 6E or more are expected to gradually replace those of former generations. Further, we divide that impact between devices and equipment for Wi-Fi 6E and Wi-Fi 7 based on our traffic projections for both technologies. Based on this assumption, we estimate that the producer surplus generated by products operating with the Wi-Fi 6E standard was $1.5 billion in 2023 and will increase

---

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

to $1.9 billion in 2027. In a similar way, we estimate that the producer surplus generated by products operating with Wi-Fi 7 will be $0.8 billion in 2025, growing to $2.9 billion in 2027 (See Table 7-6).

TABLE 7-6. **United States: Economic Value** of **Wi-Fi Enterprise Wi-Fi Equipment Products Due** to **Wi-Fi 6E** & **Wi-Fi 7**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Global – Total Wi-Fi 6E or Wi-Fi 7 shipments (%)	28.36%	50.60%	65.93%	76.51%	83.80%
Total Producer Surplus ($ billion)	$ 5.31	$ 5.42	$ 5.55	$ 5.67	$ 5.81
Wi-Fi 6E Adoption (%)	28.36%	50.60%	52.00%	48.15%	33.20%
Wi-Fi 7 Adoption (%)	0%	0%	13.93%	28.36%	50.60%
Producer Surplus Wi-Fi 6E Devices ($ billion)	$ 1.51	$ 2.74	$ 2.89	$ 2.73	$ 1.93
Producer Surplus Wi-Fi 7 Devices ($ billion)	$ 0	$ 0	$ 0.77	$ 1.61	$ 2.94

SOURCES: CONSUMER TECHNOLOGY ASSOCIATION; IDC; TELECOM ADVISORY SERVICES ANALYSIS

7.3. Benefits of Firms in the IoT Ecosystem

According to estimates from Statista for the United States[79], we expect total industrial IoT revenue in the United States to reach $339.0 billion in 2027. That figure includes revenues attributed to IoT connectivity, apps, platforms, and related professional services. By weighting those amounts by the share of local production (49.8% for hardware, 90.0% for software and services) and the assumed margins (44.6% and 77.5%, respectively), we can estimate the overall producer surplus (see Table 7-7).

TABLE 7-7. **United States: IoT Ecosystem Direct Contribution**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
IoT Revenue - Hardware ($ billion)	$13	$13	$13	$13	$13
IoT Revenue - Software, Contents, Services ($ billion)	$203	$235	$265	$295	$326
Total Industrial IoT Revenue in ($ billion)	$215	$248	$279	$309	$339
Local production (%) - Hardware	49.80%	49.80%	49.80%	49.80%	49.80%
Local production (%) - Software & Services	90.00%	90.00%	90.00%	90.00%	90.00%
Margins (%) - Hardware	44.59%	44.59%	44.59%	44.59%	44.59%
Margins (%) - Software & Services	77.46%	77.46%	77.46%	77.46%	77.46%
Margins - IoT Hardware Revenue ($ billion)	$ 3	$ 3	$ 3	$ 3	$ 3
Margins - Software, Contents and Services IoT Revenue ($ billion)	$ 141	$ 164	$ 185	$ 206	$ 227
Producer Surplus ($ billion)	$ 144.14	$ 166.67	$ 187.93	$ 208.92	$ 230.10

SOURCES: STATISTA, CSI, TELECOM ADVISORY SERVICES ANALYSIS

---

[79] Statista Market Insights, retrieved 04/10/2024 from https://www.statista.com/outlook/tmo/internet-of-things/united-states?currency=USD

7.3.1. Benefits of Firms in the IoT Ecosystem Due to Wi-Fi 6 or Less Operating in the 2.4 GHz & 5 GHz Bands

Next, we must limit the estimates developed in the previous analysis to the share of sales that are generated due to Wi-Fi: we estimate that value to be 31% based on IoT Analytics data.[80] Additionally, we should subtract the share attributed to Wi-Fi 6 E or higher standards. To do so, we relied on our analysis of the shares by Wi-Fi category presented in section 5.5. Thus, we estimate a producer surplus attributed to Wi-Fi 6 or less of $32.01 billion in 2023, decreasing to $10.06 billion in 2027 (Table 7-8).

TABLE 7-8. **United States: IoT Ecosystem Direct Contribution Due to Wi-Fi 6 or Less**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Producer Surplus ($ billion)	$144.14	$166.67	$187.93	$208.92	$230.10
Share Due to Wi-Fi (%)	31%	31%	31%	31%	31%
Share Due to Wi-Fi 6 or Less (%)	71.64%	49.40%	32.73%	21.68%	14.1%
Producer Surplus Attributable to Wi-Fi 6 or Less ($ Billion)	$32.01	$25.52	$19.07	$14.04	$100.60

SOURCES: STATISTA, CSI, TELECOM ADVISORY SERVICES ANALYSIS

7.3.2. Benefits of Firms in the IoT Ecosystem Due to Wi-Fi 6E & Wi-Fi 7 Operating in the 6 GHz & the 7 GHz Bands

Following the previous analysis, we were able to estimate which portion of IoT producer surplus growth can be attributed to the Wi-Fi 6E and Wi-Fi 7 standards. As Table 5-32 indicates, we expect the additional IoT surplus generated by Wi-Fi 6E to account for $20.6 billion in 2027. Also, the additional surplus generated by Wi-Fi 7 in the 6 GHz band is expected to be $31.4 billion in 2027, with $2.96 additional billion if Wi-Fi 7 operates in at least the lowest 125 MHz of the 7 GHz band; and another $6.28 additional billion if Wi-Fi 7 operates in 500 MHz of the 7 GHz band (See Table 7-9).

---

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

TABLE 7-9. **United States: IoT Ecosystem Direct Contribution Due** to **Wi-Fi 6E** & **Wi-Fi 7**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Share Due to Wi-Fi 6E (%)	28.36%	50.60%	49.96%	44.44%	28.90%
Additional surplus due to Wi-Fi 6E ($ billion)	$12.67	$26.14	$29.10	$28.78	$20.62
Share Due to Wi-Fi 7 in the 6 GHz band (%)	0%	0%	13.38%	26.18%	44.04%
Additional surplus due to Wi-Fi 7 in the 6 GHz band ($ billion)	$0	$0	$7.80	$16.95	$31.42
Share Due to Wi-Fi 7 with at least the addition of the lowest 125 MHz of the 7 GHz band (%)	0%	0%	1.26%	2.47%	4.15%
Additional surplus due to Wi-Fi 7 with at least the addition of the lowest 125 MHz of the 7 GHz band ($ billion)	$0	$0	$0.74	$1.60	$2.96
Share Due to Wi-Fi 7 with 500 MHz of the 7 GHz band (%)	0%	0%	2.67%	5.23%	8.80%
Additional surplus due to Wi-Fi 7 with 500 MHz of the 7 GHz band ($ billion)	$0	$0	$1.56	$3.39	$6.28

SOURCES: STATISTA MARKET INSIGHTS , CSI, TELECOM ADVISORY SERVICES ANALYSIS

7.4. Benefits of Firms in the AR/VR Ecosystem

Following an approach similar to the one used for estimating the IoT contribution, we can calculate the direct contribution of the AR/VR ecosystem to the U.S. economy. Starting with the local spending in AR/VR by category (hardware, software, and contents), and weighting those figures by the respective shares of local production and margins, we were able to estimate the total producer surplus (See Table 7-10).

TABLE 7-10. **United States: AR/VR Ecosystem Direct Contribution**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Spending in AR/VR - Hardware ($ billion)	$5.23	$8.80	$13.11	$18.76	$23.68
Spending in AR/VR - Software, Contents, Services ($ billion)	$10.76	$16.52	$24.00	$34.58	$48.12
Total Spending in AV/VR ($ billion)	$15.99	$25.32	$37.12	$53.35	$71.81
Share of local production – Hardware (%)	49.80%	49.80%	49.80%	49.80%	49.80%
Share of local production - Software, Contents, Services (%)	90.00%	90.00%	90.00%	90.00%	90.00%
Local production for local consumption - Hardware ($ billion)	$2.60	$4.38	$6.53	$9.34	$11.79
Local production for local consumption - Software, Contents, Services ($ billion)	$9.68	$14.87	$21.60	$31.13	$43.31
Total Local production for local consumption ($ billion)	$12.28	$19.25	$28.13	$40.47	$55.10
Local Producer Surplus - Hardware ($ billion)	$1.16	$1.95	$2.91	$4.17	$5.26
Local Producer Surplus - Software, Contents, Services ($ billion)	$7.50	$11.52	$16.73	$24.11	$33.55
Total Producer Surplus ($ billion)	$8.66	$13.47	$19.64	$28.28	$38.81

SOURCES: STATISTA MARKET INSIGHTS; TELECOM ADVISORY SERVICES ANALYSIS

7.4.1. Wider Deployment of AR/VR Solutions Due to Wi-Fi 6 or Less Operating in the 2.4 GHz & 5 GHz Bands

By relying on a ratio estimated for 5 GHz and 6 GHz AR/VR related products based on the estimations of indirect impact made in section 5.6, we were able to isolate the specific economic contribution of Wi-Fi 6E and Wi-Fi 7. Following a similar procedure as that described above for IoT, the direct contribution from the AR/VR ecosystem in the United States attributed to Wi-Fi 6 or less is estimated at $10.2 billion in 2027 (see Table 7-11).

Table 7-11. **United States: AR/VR Ecosystem Direct Contribution Due to Wi-Fi 6 or Less**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Total Producer Surplus ($ Billion)	$ 8.66	$ 13.47	$ 19.64	$ 28.28	$ 38.81
Share Due to Wi-Fi 6 or Less (Includes a Discount for Wi-Fi Usage)	32.18%	30.88%	29.32%	27.76%	26.21%
Producer Surplus Attributable to Wi-Fi 6 or Less ($ Billion)	$ 2.79	$ 4.16	$ 5.76	$ 7.85	$ 10.17

SOURCES: ABI RESEARCH; TELECOM ADVISORY SERVICES ANALYSIS

7.4.2. Benefits of Firms in the AR/VR Ecosystem Due to Wi-Fi 6E or Wi-Fi 7 Operating in the 6 GHz & 7 GHz Bands

Following the previous analysis, we were able to estimate which portion of AR/VR producer surplus growth can be attributed to the Wi-Fi 6E and Wi-Fi 7 standards. As Table 7-12 indicates, we expect the additional AR/VR surplus generated by Wi-Fi 6E to account for $6.21 billion in 2027. Also, the additional surplus generated by Wi-Fi 7 is expected to be $9.46 billion in 2027 (See Table 7-12).

TABLE 7-12. **United States: AR/VR Ecosystem Direct Contribution Due to Wi-Fi 6E & Wi-Fi 7**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Total Producer Surplus ($ billion)	$ 8.66	$ 13.47	$ 19.64	$ 28.28	$ 38.81
Attributable Wi-Fi 6E or superior (%)	34.42%	35.72%	37.27%	38.83%	40.39%
Attributable to Wi-Fi (%)	66.60%	66.60%	66.60%	66.60%	66.60%
Share due to Wi-Fi 6E/Wi-Fi 7 (%)	100.00%	100.00%	78.87%	62.93%	39.62%
Impact of Wi-Fi 6E ($ billion)	$ 2.98	$ 4.81	$ 5.78	$ 6.91	$ 6.21
Impact of Wi-Fi 7 ($ billion)	$ 0	$ 0	$ 1.55	$ 4.07	$ 9.46

SOURCES: ABI RESEARCH; TELECOM ADVISORY SERVICES ANALYSIS

7.5. Benefits of Firms Developing Vehicular Technologies

As mentioned in section 4.6, the North American OTA market shows substantial growth from $2.492 billion in 2023 to $4.950 billion in 2027, highlighting the expanding role of digital connectivity in vehicles. Table 7-13 provides a detailed analysis of the increasing vehicular usage and its economic implications.

The market for Automotive OTA in North America is projected to grow significantly, with the U.S. accounting for a consistent 92.25% share of this market. This translates to the U.S. market expanding from $2.299 billion in 2023 to $4.567 billion in 2027. The gross margin for this market is assumed to remain stable at 44.59% throughout the period (based on CSI Market Inc.). By applying this margin, the producer surplus, which represents the net benefit to producers after covering costs, increases from $1.025 billion in 2023 to $2.036 billion in 2027 (See Table 7-13).

TABLE 7-13. **United States: Increasing Use of Wi-Fi in Vehicles**
2023-2027

VARIABLE	2023	2024	2025	2026	2027
Automotive over the Air Market (US$ billion), North America	$ 2.49	$ 2.96	$ 3.51	$ 4.17	$ 4.95
Share US from North America (%)	92.25%	92.25%	92.25%	92.25%	92.25%
Automotive over the Air Market (US$ billion)	$ 2.30	$ 2.73	$ 3.24	$ 3.85	$ 4.57
Gross Margin (%)	44.59%	44.59%	44.59%	44.59%	44.59%
Producer Surplus (US$ billion)	$ 1.03	$ 1.22	$ 1.45	$ 1.72	$ 2.04

SOURCES: MARKET RESEARCH FUTURE; CSI MARKET INC.; TELECOM ADVISORY SERVICES

* * * * *

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

- The producer surplus of residential Wi-Fi devices and equipment manufactured in the United States. Total producer surplus across Wi-Fi standards amounts to $34.11 billion in 2023 and $37.64 billion in 2027.
- The producer surplus of enterprise Wi-Fi equipment manufactured in the United States. Similarly, the producer surplus generated for US manufacturers of Wi-Fi enabled equipment across Wi-Fi standards amounts to $5.31 billion in 2023 and $5.81 billion in 2027.
- The producer surplus of US firms providing products and services in the IoT ecosystem (connectivity, apps, platforms, and related professional services) in the United States amounts to $44.68 billion in 2023, and forecast to reach $71.33 billion in 2027
- The total producer surplus of local firms providing products and services in the AR/VR ecosystem (hardware, software and content) across Wi-Fi standards in the United States is estimated at $5.77 billion in 2023 and $25.84 billion in 2027.
- Producer surplus of US firms developing Wi-Fi enabled vehicular technologies for the US market, representing the net benefit to producers after covering costs, increases from $1.025 billion in 2023 to $2.036 billion in 2027.

8. COMPARISON of CURRENT STUDY with 2021 STUDY RESULTS

8.1. Total Economic Value of Wi-Fi in the 2021 Study (2021-2025)

The overall economic value (in constant prices) of Wi-Fi estimated in the 2021 study was $ 1,208.9 billion in 2023, increasing to $1,580.1 billion in 2025 (see Table 8-1).

TABLE 8-1. **Total Economic Value** of **Wi-Fi: 2021 Study** (Including Wi-Fi 6 & Wi-Fi 6E)
2023-2025

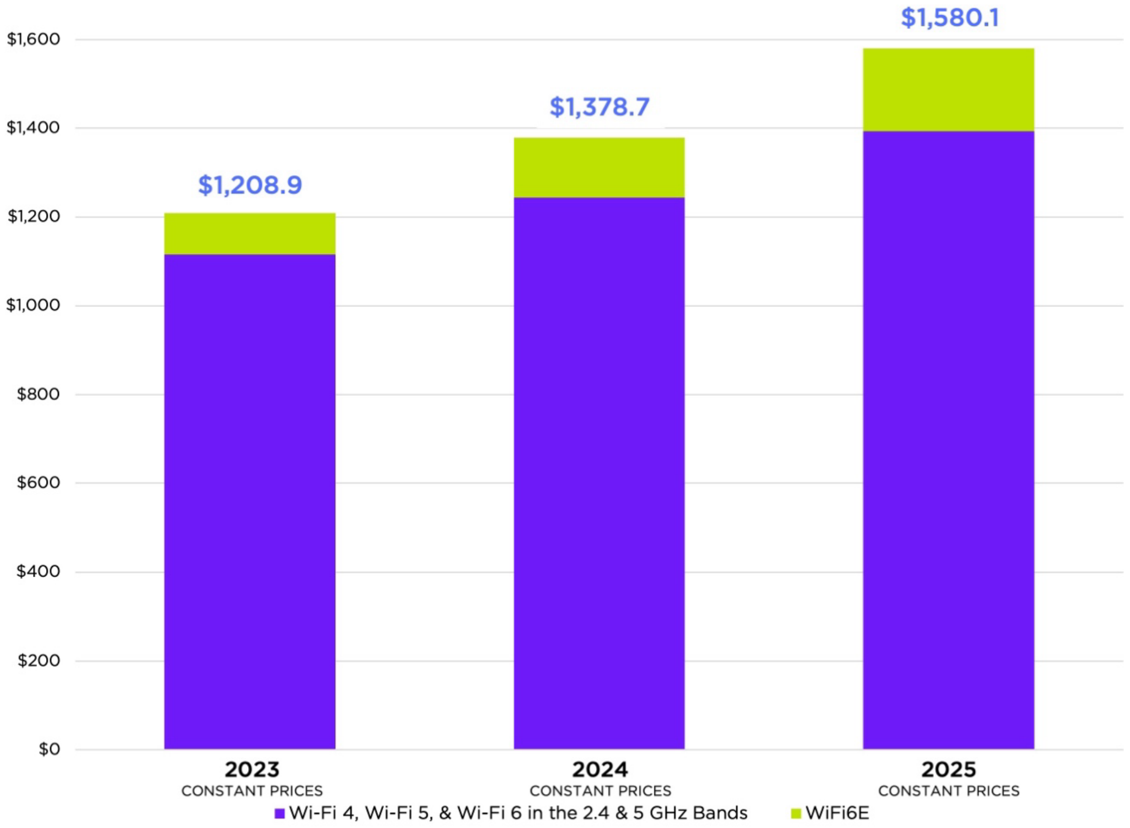
SOURCE	CATEGORY	ECONOMIC VALUE ($ Billions) 2023	2024	2025	CATEGORY
Free Wi-Fi	Savings to consumers of free Wi-Fi traffic offered in public sites	$8.3	$8.1	$7.8	CB
	Deployment of free Wi-Fi in public sites	$11.3	$7.0	$5.9	GDP
	Benefit of faster free Wi-Fi with Wi-Fi 6E devices	$0.1	$0.1	$0.1	CB
Residential Wi-Fi	Internet access for home usage of devices that lack a wired port	$380.0	$439.5	$507.7	CB
	Avoidance of investment in in-house wiring	$80.3	$83.1	$84.5	CB
	Benefit to consumers from speed increases	$11.2	$13.0	$14.4	CB
	Residential Wi-Fi devices and equipment deployed	$37.5	$40.0	$42.1	CB
	Bridging digital divide: use of Wi-Fi to increase coverage in rural and isolated areas	$35.9	$44.5	$57.1	GDP
Enterprise Wi-Fi	Business Internet traffic transmitted through Wi-Fi	$298.4	$351.8	$414.7	PS
	Avoidance of enterprise inside wiring costs	$18.2	$18.4	$18.5	PS
	Return to speed: contribution to GDP derived from an increase in average mobile speed	$41.6	$48.9	$58.0	GDP
	Wide deployment of IoT	$54.1	$55.0	$56.2	GDP
	Deployment of AR/VR solutions	$10.3	$13.6	$17.8	GDP
ISPs	CAPEX and OPEX savings due to cellular off-loading	$2.7	$2.7	$2.7	PS
	Revenues of service providers offering paid Wi-Fi access in public	$1.3	$1.1	$0.9	GDP
	Aggregated revenues of WISPs	$8.7	$10.7	$13.3	GDP
Wi-Fi Ecosystem	Locally manufactured residential Wi-Fi devices and equipment	$40.4	$42.7	$44.6	PS
	Locally manufactured Wi-Fi enterprise equipment	$6.7	$7.9	$8.9	PS
	Locally produced IoT products and services	$156.4	$183.4	$215.4	PS
	Locally produced of AR/VR solutions	$5.5	$7.2	$9.5	PS
	TOTAL	**$1,208.9**	**$1,378.7**	**$1,580.1**	

CB – CONSUMER BENEFIT | PS = PRODUCER SURPLUS | GDP = GDP CONTRIBUTION

SOURCE: TELECOM ADVISORY SERVICES ANALYSIS

Graphic 8-1 provides a perspective of the growing importance of Wi-Fi 6E in driving economic value over time.

GRAPHIC 8-1. **Total Economic Value** of **Wi-Fi: 2021 Study** (In Constant Prices) (In $ Billion)
2023-2025

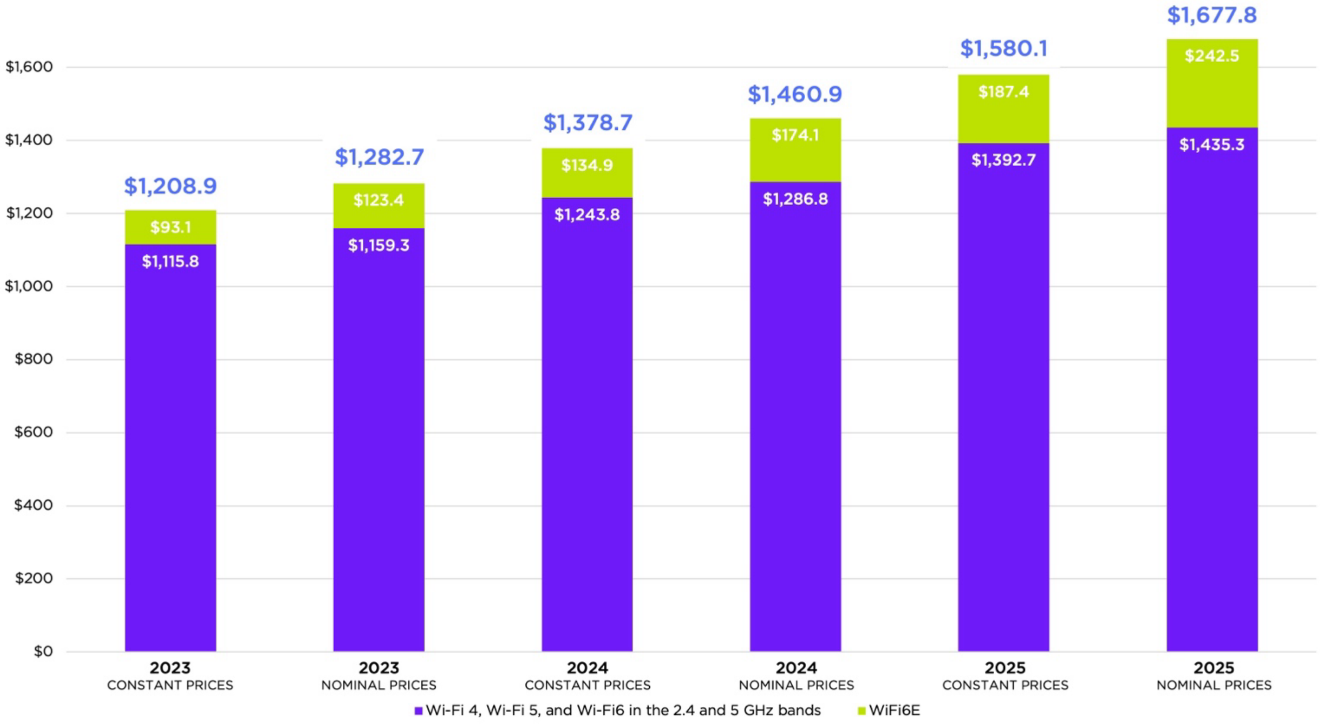


SOURCE: TELECOM ADVISORY SERVICES ANALYSIS

The study results were originally presented in constant prices. The advantage of using real GDP is that it measures only changes in quantities, effectively isolating real growth by removing the effects of price changes. This is particularly useful for understanding long-term growth trends and for making historical comparisons that are free from the influence of fluctuating price levels. Also, it is crucial to use nominal GDP in an analysis that includes the decline in mobile prices (in nominal terms). In the context of the previous study, we were indifferent between using one alternative or the other, as the differences between both approaches was not significant. This was because the inflation rate was relatively stable at very low levels, and the differences between constant and nominal GDP were small. However, in the current context of higher inflation, using nominal GDP allows us to align our analysis with the economic indicators currently considered, keeping consistency with other variables of the model such as broadband prices, that are not deflated (as broadband prices per GB typically evolve with a decreasing trend over years).

For comparability purposes, the estimates of the 2021 study have been converted to nominal dollars (see Graphic 8-2).

GRAPHIC 8-2. **Total Economic Value** of **Wi-Fi: 2021 Study** (In $ Billion)
2023–2025



SOURCE: TELECOM ADVISORY SERVICES ANALYSIS

At the time of the 2021 study, the total economic value for 2023 (in nominal prices) was estimated to include $517 billion in consumer benefit (in terms of savings to consumers relying on free Wi-Fi sites, faster service under Wi-Fi 6E, and the ability to support a larger number of devices), $528 billion in producer surplus (based on benefits from traffic off-loading and sales of Wi-Fi enabled equipment), and $234.7 billion in contribution to GDP (primarily driven by faster broadband speed and revenues from Wi-Fi based ISPs). The 2025 forecast was estimated at $657 billion in consumer benefit, $714 billion in producer surplus, and $307 billion in GDP contribution (see Table 8-2).

TABLE 8-2. **Total Economic Value of Wi-Fi** (In Nominal Prices)**:**
2021 Study (Including Wi-Fi 6 & Wi-Fi 6E)

	2023	2024	2025
Consumer benefit	$517	$584	$657
Producer surplus	$528	$614	$714
GDP	$237	$263	$307
Total	$1,283	$1,461	$1,678

SOURCE: TELECOM ADVISORY SERVICES ANALYSIS

8.2. Total Economic Value of Wi-Fi in the Current Study (2023-2025)

The overall economic value of Wi-Fi estimated in the current study (in nominal prices) is $1,313.7 billion in 2023, increasing to $1,888.7 billion in 2025 (see Table 8-3).

TABLE 8-3. **Total Economic Value of Wi-Fi: Current Study** (In Nominal Prices)
(Including Wi-Fi 6, Wi-Fi 6E & Wi-Fi 7)

AGENT	SOURCE	**ECONOMIC VALUE** ($BILLION)			CATEGORY
		2023	2024	2025	
FREE WI-FI	Savings to consumers of free Wi-Fi traffic offered in public sites	$7.01	$8.84	$9.66	CB
	Deployment of free Wi-Fi in public sites	$33.14	$33.53	$31.43	GDP
	Benefit of faster free Wi-Fi with Wi-Fi 6E devices	$0.15	$0.20	$0.26	CB
	Use of Wi-Fi in educational institutions	$2.96	$2.35	$1.82	CB
	Use in highly dense heterogeneous environments	$0.5	$0.11	$0.17	CB
RESIDENTIAL WI-FI	Internet access for home usage of devices that lack a wired port	$275.83	$318.23	$362.74	CB
	Avoidance of investment in in-house wiring	$2.03	$2.83	$2.82	CB
	Benefit to consumers from speed increases	$6.74	$11.70	$15.32	CB
	Residential Wi-Fi devices & equipment deployed	$42.00	$45.33	$48.48	CB
	Bridging digital divide: use of Wi-Fi to increase coverage in rural and isolated areas	$51.10	$61.88	$72.85	GDP
	Increasing vehicular use of Wi-Fi	$1.03	$1.22	$1.45	CB
ENTERPRISE WI-FI	Business Internet traffic transmitted through Wi-Fi	$288.67	$336.51	$393.42	PS
	Avoidance of enterprise inside wiring costs	$0.17	$0.18	$0.19	PS
	Return to speed: contribution to GDP derived from an increase in average mobile speed	$141.08	$239.08	$310.70	GDP
	Benefits derived from reduced latency	$269.29	$285.81	$317.55	GDP
	Wide deployment of IoT	$77.99	$120.11	$162.72	GDP
	Deployment of AR/VR solutions	$10.65	$16.86	$24.72	GDP
ISPS	CAPEX & OPEX savings due to cellular off-loading	$3.77	$3.46	$3.75	PS
	Revenues of service providers offering paid Wi-Fi access in public	$0.68	$0.66	$0.64	GDP
	Aggregated revenues of WISPs	$8.50	$10.71	$14.36	GDP
WI-FI ECOSYSTEM	Locally manufactured residential Wi-Fi devices and equipment	$34.11	$34.79	$35.38	PS
	Locally manufactured Wi-Fi enterprise equipment	$5.31	$5.42	$5.55	PS
	Locally produced IoT products and services	$44.68	$51.67	$58.26	PS
	Locally produced of AR/VR solutions	$5.77	$8.97	$13.08	PS
	Benefits of firms developing vehicular technologies	$1.03	$1.22	$1.45	PS
TOTAL		**$1,313.7**	**$1,601.7**	**$1,888.7**	

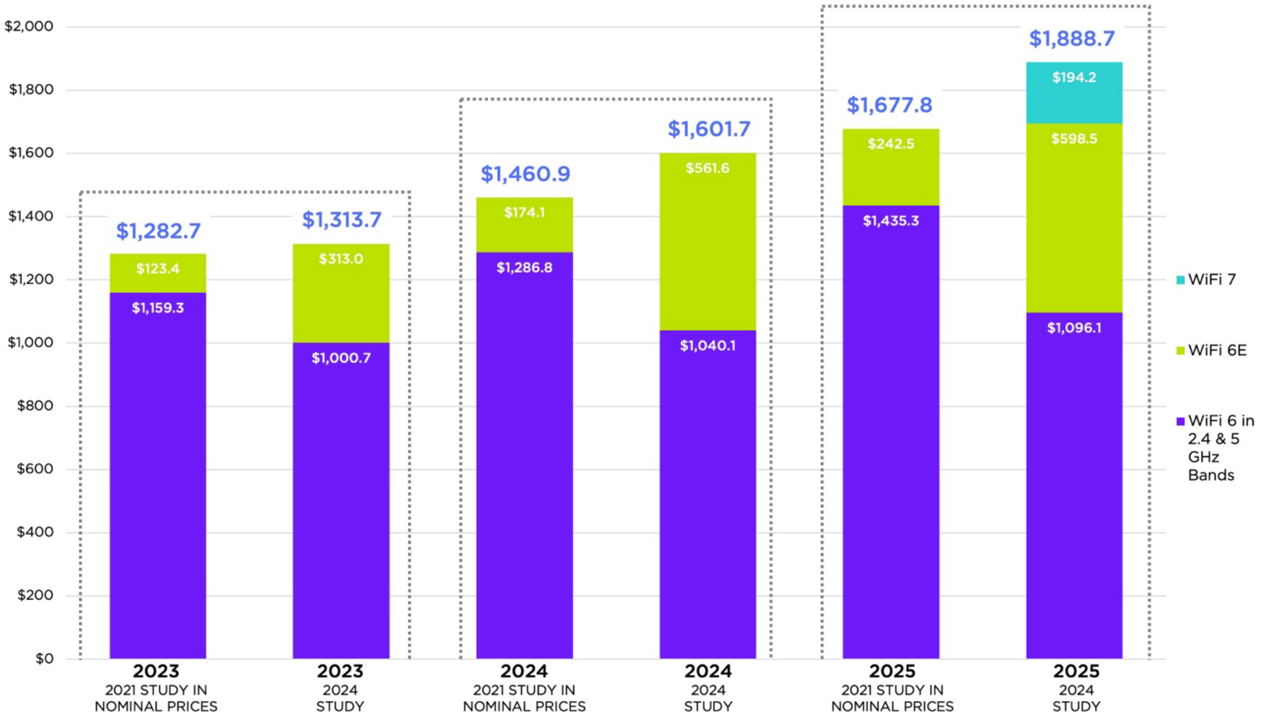
CB – CONSUMER BENEFIT | PS = PRODUCER SURPLUS | GDP = GDP CONTRIBUTION

SOURCE: TELECOM ADVISORY SERVICES ANALYSIS

The current study estimates that, while the 2023 value has remained approximately in line with the forecast from the prior study ($31 billion higher), the 2025 results point to an increase of $211 billion, thereby reaching $1,888.7 billion. The trend indicates the growing importance of Wi-Fi 6E and the expected relevance of Wi-Fi

7 as a driver next year. Applications enabled by Wi-Fi 7, with faster speeds and a smooth connection to as many devices as possible are ready now, and manufacturers of Wi-Fi chips and the routers, repeaters, and modules equipped with them are not waiting for the official release (see graphic 8-3).

GRAPHIC 8-3. **Economic Value** of **Wi-Fi** (2023-2025)**:**
2021 Study vs. **Current Study** (In $ Billion in Nominal Prices)



SOURCE: TELECOM ADVISORY SERVICES ANALYSIS

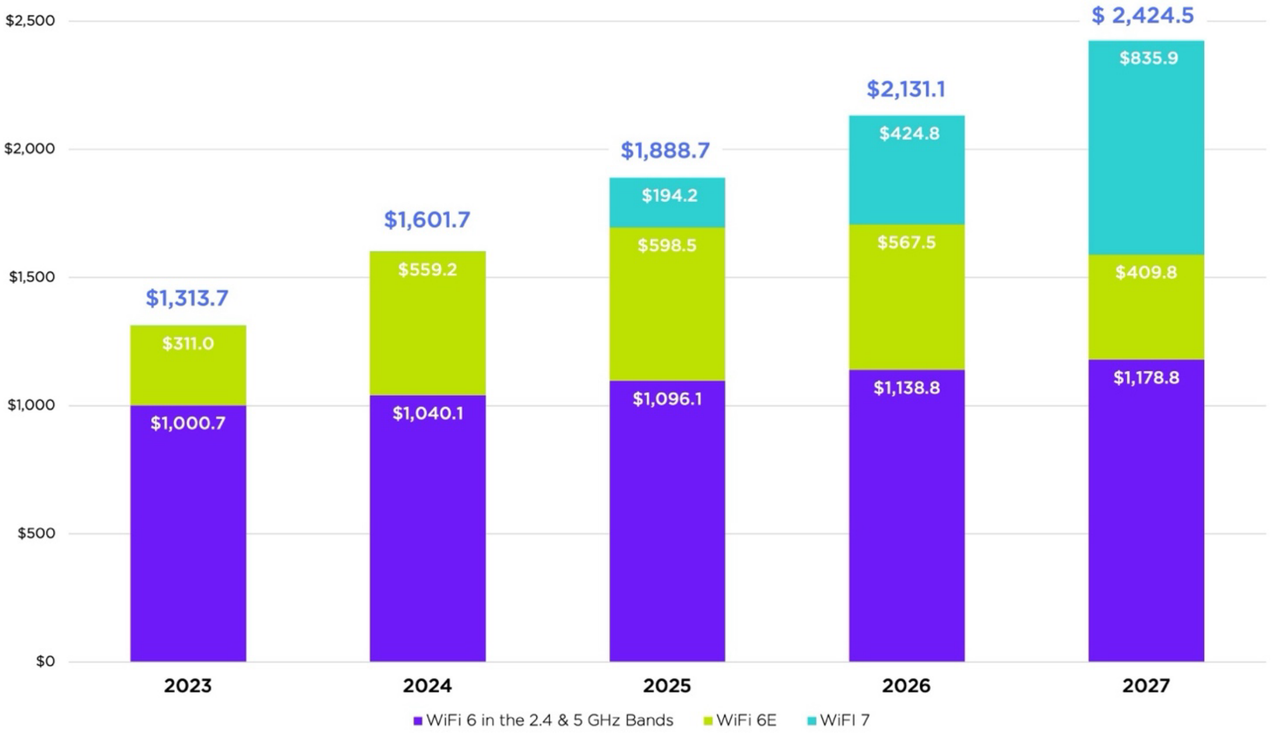
The increase in economic value between the 2021 study and the current one is driven by multiple factors:

- Growing importance of Wi-Fi 6E operating in the 6 GHz band yielding significant growth in value of free Wi-Fi applications, and the contribution to GDP as a result of increased speed and a reduction of latency.
- Wi-Fi 6E also represents an important performance improvement in comparison to prior standards, supporting a higher number of devices on a single public access point, allowing Wireless ISPs to increase the number of subscribers within their same coverage footprint.
- Through the use of multiple bands and spatial streams, Wi-Fi 6E routers have total throughput capabilities well in excess of the speeds they can enable for individual devices, eliminating congestion and consequently driving additional consumer benefit.
- Enterprises benefit from additional Wi-Fi speed and the enablement of newly developed use cases built around advanced technologies such as AR/VR.
- Wi-Fi 6E results in a broader scale of IoT deployment, without the risk of congestion.
- In addition to the sources of value identified in the prior study, four new sources have been assessed: use of Wi-Fi in educational contexts, use of Wi-Fi in highly dense heterogeneous environments, increasing use of Wi-Fi in vehicular settings, and manufacturing of Wi-Fi-enabled vehicular equipment.

8.3. Forecast of Wi-Fi Economic Value Up to 2027

The trends highlighted through 2025 will drive an acceleration of economic value up to 2027, primarily fostered by the growing importance of Wi-Fi 6E, combined with the emergence of Wi-Fi 7, operating not only within the lowest 125 MHz of the 7 GHz band but also in an additional 375 MHz of that band (see graphic 8-4).

GRAPHIC 8-4. **Economic Value of Wi-Fi: Current Study** (In $ Billion)
2023-2027



SOURCE: TELECOM ADVISORY SERVICES ANALYSIS

The value of the additional spectrum band is not proportional to its size; its contribution to the overall unlicensed ecosystem acts as a value multiplier. Wi-Fi 7 improves the performance of Wi-Fi connectivity, by allowing simultaneous communication of the router with multiple devices, supporting highly dense networks and extremely low latency, potentially supporting new use cases.

9. CONCLUSIONS AND POLICY IMPLICATIONS

The purpose of this report has been to present an updated assessment of Wi-Fi economic value for the United States. We compared the changes that have taken place since our last 2021 study, in particular the impact of the FCC 2020 6 GHz decision and the potential impact of multiple channels of Wi-Fi in the 7 GHz band (125 MHz and 500 MHz). The results also factor in demand and supply changes that have taken place since 2021: new Wi-Fi use cases, acceleration of broadband speed, and the development of a vibrant manufacturing and service sector in the Wi-Fi ecosystem.

When comparing the 2021 results (converted to nominal prices) with the current assessment, the results are significant:

> **For 2023, our current assessment of W-Fi economic value in nominal terms is $1,313 billion, an increase of $31 billion over our prior study of $1,282 billion.**

> **For 2025, our forecast reaches $1,889 billion, $211 billion higher than the $1,678 of the 2021 study.**

These numbers confirm a number of important perspectives already raised in the research literature:

> **As a complementary factor of production, Wi-Fi is a key resource in the U.S. communications ecosystem.**

> **Wi-Fi drives significant social and economic value, including addressing the needs of the broadband unserved and underserved population and propelling the development of an industrial base.**

> **Wi-Fi represents an environment of continuous innovation that is not constrained by the property rights generally attached to licensed spectrum.**

In addition, the findings confirm the positive impact of decisions taken by the FCC since April 2020 regarding the use of unlicensed spectrum in the 6 GHz band. The economic value generated by the allocation of this band in 2023 and 2024 is projected to reach $870 billion.

So where do we go from here? The National Spectrum Strategy process being conducted by the NTIA is expected to generate a recommendation regarding the use of the 7 GHz band. We believe that this study provides evidence in support of the following decisions:

> **Immediately open the 7125 MHz-7250 MHz band under the FCC's 6 GHz technical rules.** While this initial decision would represent only 125 MHz, it will provide an additional contiguous 320 MHz channel, with an impact that is larger than what it represents in terms of aggregate spectrum. In light of the results generated by this study, the decision for allocating the 7125-7250 MHz band is fairly straight forward. In fact, the cumulative economic value between 2025 and 2027 of opening the low part of the 7 GHz band

will generate $27.8 billion in economic value, although yearly values are increasing significantly over time. From a band usage standpoint, the existing federal users of this band can be managed similar to the ones encountered in the 6 GHz band and the stranded Wi-Fi channel can be allocated fairly quickly.

Open the mid-band between 7250 and 7625 MHz for unlicensed use. The addition of a fifth 320 MHz channel allows an important increase in the number of devices to be handled by a single router with extremely fast speeds while supporting the use of traffic heavy devices. The economic value of opening this mid-band will generate $51.8 billion in economic value between 2025 and 2027. From a technical standpoint, Wi-Fi can be introduced because the pre-dominant federal use case is satellite downlink (Wi-Fi coexists with satellite uplink in 6 GHz, along with a few downlinks). The allocation of additional Wi-Fi spectrum in the 7 GHz band for unlicensed shared use would ensure that the spectrum necessary for WiFi 7 and 8 is available. Wi-Fi must support up to 10 Gbps and higher Wi-Fi speeds, preventing capacity issues and ensuring that the speeds of fiber networks being built today do not stop at the doorstep and can be used throughout the home, which will further increase Wi-Fi's economic impact.

Launch an analysis of the remaining segment of the 7 GHz band. While the remaining band (above 7625 MHz) presents challenges due to because of incumbent uses (e.g., satellite uplink and other federal), it would be worth launching a technical and economic assessment effort. The ever increasing social and economic value of Wi-Fi would compel all interested parties to do so.

BIBLIOGRAPHY

ABI Research. Augmented and Mixed Reality Market Data: devices, use cases, verticals and value chain. MD-ARMR-103, QTR 4 2019,

ABI Research (2023). Virtual Reality Market Data: devices, verticals, and value chain (July 12). MD-VR-113.

ABI Research (2023). Augmented and Mixed Reality: Devices, Use cases, verticals and Value Chain (July 17), MD-ARMR-108

ACMA (2019). Five-year spectrum outlook 2019-23, Canberra (September), p. 22

Adams, G. and Yoo, C. (2023). Braess' Paradox in Wireless Broadband? Toward a principled basis for allocating licensed and unlicensed spectrum. Paper presented at 2023 TPRC.

Alston, J.M. and Wohlgenant, M.K. (1990). "Measuring Research Benefits Using Linear Elasticity Equilibrium Displacement Models". John D. Mullen and Julian M. Alston, The Returns to Australian Wool Industry from Investment in R&D, Sydney, Australia: New South Wales Department of Agriculture and Fisheries, Division of Rural and Resource Economics

ANRITSU. (2022). Key Technologies for IEEE 802.11be (Wi-Fi 7). Retrieved in: https://dl.cdn-anritsu.com/zh-tw/test-measurement/files/Brochures-Datasheets-Catalogs/White-Paper/Wi-Fi 7-er1100.pdf.

Bain & Company (2018). Unlocking Opportunities on the Internet of Things. Brief (August 7th)

Barrero, J. M., Bloom, N., & Davis, S. J. (2021a). Internet access and its implications for productivity, inequality, and resilience. In M. S. Kearney & A. Ganz (Eds.), Rebuilding the post-pandemic economy. Aspen Institute Press. Retrieved in: https://www.economicstrategygroup.org/publication/barrero-bloom-davis/

Bertschek, I., Briglauer, W., Hüschelrath, K., Kauf, B., & Niebel, T. (2015). "The Economic Impacts of Broadband Internet: A Survey." Review of Network Economics, 14(4), 201–227. Retrieved in: https://doi.org/10.1515/rne-2016-0032

Blackman, J. (2020). "UK to release 6 GHz and 100 GHz spectrum for Wi-Fi in smart homes, offices, factories". Enterprise IoT insights (January 27).

Bohlin, E. and Rohman, I. (2012). Does Broadband Speed Really Matter for Driving Economic Growth? Investigating OECD Countries? Available at SSRN: http://ssrn.com/abstract=2034284 or http://dx.doi.org/10.2139/ssrn.2034284. , 2013

CGI.br/NIC.br, Centro Regional de Estudos para o Desenvolvimento da Sociedade da Informação (Cetic.br) (2019), Pesquisa sobre o uso das tecnologias de informação e comunicação nos domicílios brasileiros - TIC Domicílios 2019

Cho Mu-Hyun (2020). "South Korea makes 6 GHz band available for Wi-Fi", ZDNet (October 16).

Cisco IBSG (2012). What do consumers want from Wi-Fi, authors: Taylor, S., Young, A., and Noronha, A. May

Cisco (2019). Visual Networking Index. Global Mobile data Traffic Forecast Update, 2016- 2021. Retrieved from https://www.cisco.com/c/en/us/solutions/collateral/service- provider/visual-networking-index-vni/mobile-white-paper-c11-520862.html.

CISCO. (2020). Wi-Fi 6 OFDMA: Resource unit (RU) allocations and mappings https://blogs.cisco.com/networking/wi-fi-6-ofdma-resource-unit-ru-allocations-and-mappings https://blogs.cisco.com/networking/wi-fi-6-ofdma-resource-unit-ru-allocations-and-mappings.

Consumer Technology Association (2018). US Consumer Technology Sales and forecast 2013-2018. Virginia: Consumer technology Association.

Consumer Technology Association (2024). CTA Consumer Technology Extended Forecast 2022-2028

Consumer Technology Association (2022). "UNLICENSED SPECTRUM AND THE U.S. ECONOMY: Quantifying the Market Size and Diversity of Unlicensed Devices". https://docs.house.gov/meetings/IF/IF16/20230310/115463/HHRG-118-IF16-20230310-SD006.pdf

Cooper, M. (2011). The consumer benefits of expanding shared used of unlicensed radio spectrum: Liberating Long-Term Spectrum Policy from Short-Term Thinking. Washington DC: Consumer Federation of America.

CSI Market Inc. (2020). Industry Profitability ratios. Retrieved in: https://csimarket.com/Industry/Industry_Profitability.php#google_vignette

De Clercq, M., D'Haese, M., & Buysse, J. (2023). "Economic growth and broadband access: The European urban-rural digital divide." Telecommunications Policy, 47(6), Article 102579. https://doi.org/10.1016/j.telpol.2023.102579

Dosi, G., Pavitt, K., Soete, L., 1990. The Economics of Technical Change and International Trade. Laboratory of Economics and Management (LEM). Sant'Anna School of Advanced Studies, Pisa (Eds).

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

Ericsson (2019). "Connecting things in the city". https://www.ericsson.com/en/reports-and-papers/mobility-report/articles/connecting-things-in-the-city-wef-edition

European Conference of Postal and Telecommunications Administrations (2020). On the harmonized use of the frequency bands 5945 to 6425 MHz for the implementation of Wireless Access Systems including Radio Local Area Networks (WAS/RLAN). Copenhagen.

FCC ex parte notification from Apple Inc., Broadcom Inc., Facebook Inc., Google LLC, Hewlett Packard Enterprise, Intel Corp., Marvell Semiconductor Inc., Microsoft Corporation, Qualcomm Incorporated (July 2, 2019).

FCC (2024). Internet Access Services Report (May), Retrieved from: https://docs.fcc.gov/public/attachments/DOC-402310A1.pdf

Forenbacher, I., Husnjak, S.; Jovović, I. and Bobić, M., Raffaele Bruno. "Throughput of an IEEE 802.11 Wireless Network in the Presence of Wireless Audio Transmission: A Laboratory Analysis", Sensors DOI: 10.3390/s21082620

Frontier Economics (2018). The economic impact of IoT: putting numbers on a revolutionary technology.

Frost & Sullivan (2021). Industrial Internet of Things (IoT) revenue in Brazil (2016-2021).

Gehlhaus, D. Martin, N.; Blumenthal, M., Armour, P. Lastunen, J. (2018). The Potential Economic Value of Unlicensed Spectrum in the 5.9 GHz Frequency Band: Insights for Future Spectrum Allocation Policy. Retrieved in: https://www.rand.org/pubs/authors/m/martin_nicholas.html

Grimes, A., Ren, C., and Stevens, P. (2009). The need for speed: Impacts of Internet Connectivity on Firm Productivity. MOTU Working Paper 09-15.

Greenstein, S. and McDevitt, R. (2009). The broadband bonus: accounting for broadband Internet's impact on U.S. GDP. National Bureau of Economic Research Working Paper 14758. Cambridge, MA.

Greenstein, S. and McDewitt, R. (2011). The global broadband bonus: Broadband Internet's impact on seven countries. Available at http://ictlinkedworld.com/eng/pdfs/ICT_Chapter_II_B.pdf Accessed 1st October 2011

Gruenwedel, E. (2023). "Parks: 92% of U.S. Internet Households Use Wi-Fi at Home". Media Play News. Retrieved in: https://www.mediaplaynews.com/parks-92-percent-of-us-internet-households-use-wi-fi-at-home/

GSMA Intelligence (2024). US mobile market. February 2, 2024/

GTAP (2014). Global Trade Analysis Project. Center for Global Trade Analysis, Department of Agricultural Economics, Purdue University, Global Economic Analysis

Jennifer P. (2017). "How many people attend professional sporting events in the US?" (May 2). Retrieved in: https://askwonder.com/research/people-attend-professional-sporting-events-u-s-nc75ioow4

Hetting, C. (2019). "Europe's process to release 6 GHz spectrum to Wi-Fi on track, expert says", Wi-Fi Now (June 2).

Hetting, C. (2020). "South Korea could become Asia's first 6 GHz nation". Wi-Fi Now (June 27).

Hetting, C. (2023). "The Wi-Fi offload revival is coming your way – and it's coming soon". Wi-Fi Now

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

Ilumba, A. (2024). "How much is the average cellphone bill?" WhistleOut, February 21. Retrieved in: https://www.whistleout.com/CellPhones/Guides/average-phone-plan-price

Inoue, H. and Todo, Y. (2023). "Has Covid-19 permanently changed online purchasing behavior? EPJ Data Sci. 12(1), 1. Retrieved in: https://doi.org/10.1140/epjds/s13688-022-00375-1.

INTEL (2023), Next Generation Wi-Fi: Spectrum Needs of Wi-Fi 7. Retrieved in: https://www.intel.com/content/www/us/en/products/docs/wireless/wi-fi-7/spectrum-needs-of-wi-fi-7.html

IoT Analytics (2023). State of IoT 2023: Number of connected IoT devices growing 16% to 16.7 billion globally (May). Retrieved in: http://iot-analytics.com/number-connected-iot-devices/

Isley, C., & Low, S. A. (2022). "Broadband adoption and availability: Impacts on rural employment during Covid-19." Telecommunications Policy, 46(7), Article 102310. https://doi.org/10.1016/j.telpol.2022.102310

ISP Revolution (2023). Exploring the Spectrum: Understanding WISP Frequency Spectrums and Their Use Cases. Retrieved in : https://isprevolution.io/exploring-the-spectrum-understanding-wisp-frequency-spectrums-and-their-use-cases/

Katz, R. (2014). Assessment of the economic value of unlicensed spectrum in the United States. New York: Telecom Advisory Services. Retrieved from: wififorward.org/resources

Katz, R. (2018). A 2017 assessment of the current and future economic value of unlicensed spectrum. Washington, DC: Wi-Fi Forward, Retrieved from: wififorward.org/resources

Katz, R. (2020). Assessing the Economic Value of Unlicensed use in the 5.9 GHz & 6 GHz bands. Washington, DC: WiFi Forward. April. Retrieved from: wififorward.org/resources

Katz, R. (2022). The “to and through” opportunity: An economic analysis of options to extend affordable broadband to students and households via anchor institutions: Economic analysis, Cost Calculation Toolkit and Public Policy Implications. New York: Telecom Advisory Services. Retrieved in: https://www.ntia.gov/sites/default/files/publications/shlb_oti.pdf

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

Katz, R. and Callorda, F. (2018a). The Economic value of Wi-Fi: A Global View (2018 and 2023). New York: Telecom Advisory Services. October.

Katz, R. and Callorda, F. (2018b). The Economic Contribution of Broadband, Digitization, and ICT Regulation. Geneva: International Telecommunications Union. Retrieved from: www.itu.int › D-PREF-EF.BDT_AM-2019-PDF-E.pdf

Katz, R. and Callorda, F. (2020a). How broadband, digitization and ICT regulation impact the global economy. Geneva: International Telecommunications Union. Retrieved from: http://handle.itu.int/11.1002/pub/81377c7f-en

Katz, R. and Callorda, F. (2020b). Assessment of the economic value of 10G networks. New York: Telecom Advisory Services. Retrieved from: www.10gplatform.com/sites/files/TAS_10G_FINAL

Katz, R., Jung, J. and Callorda, F. (2021). The Economic value of Wi-Fi: A Global View (2021 and 2025): Study developed for the Wi-Fi Alliance. New York: Telecom Advisory Services. October. Retrieved in: https://www.wi-fi.org/system/files/Global_Economic_Value_of_Wi-Fi_2021-2025_202109.pdf

Katz, R., & Jung, J. (2021). The economic impact of broadband and digitization through the COVID-19 pandemic – Econometric modelling (ITU report). International Telecommunication Union. Available at: https://www.itu.int/pub/D-PREF-EF.COV_ECO_IMPACT_B-2021

Katz, R., & Jung, J. (2022a). The contribution of fixed broadband to the economic growth of the United States between 2010 and 2020. Telecom Advisory Services LLC.

Katz, R.; Jung, J. (2022b). “The Role of Broadband Infrastructure in Building Economic Resiliency in the United States during the COVID-19 Pandemic.” Mathematics 10, 2988. https://doi.org/10.3390/math10162988.

Katz, R., Callorda, F. and Jung, J. (2024). The impact of digital transformation on the economy - Econometric Modelling. (in print)

Khatri, H. and Fenwick, S. (2020). “Analyzing mobile experience during the coronavirus pandemic: Time on Wi-Fi”. Opensignal (March 30).

Kongaut, Ch.; Bohlin, E. (2014). Impact of broadband speed on economic outputs: An empirical study of OECD countries, 25th European Regional Conference of the International Telecommunications Society (ITS), Brussels, Belgium, 22-25 June 2014,

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

Law 360 (2020). DC Circuit won’t block new FCC rules on 6 GHz for now (October 1)

LCC Wireless (2012). Madden, J. Reaching a Balance between Macro, Small cells, and Carrier Wi-Fi. Mobile Experts LLC.

Liu, Y-H; Prince, J., and Wallsten, J. (2017). Distinguishing bandwidth and latency in households' willingness-to-pay for broadband internet speed. Washington, DC: Technology Policy Institute

Mäkitie, T., Hanson, J., Steen, M., Hansen, T. and Andersen, A. (2022). "Complementary formation mechanisms in technology value chains. Research Policy 51

Marcus, S. and Burns, J. (2013). Study on Impact of Traffic off-loading and related technological trends on the demand for wireless broadband spectrum: a study prepared for the European Commission DG Communications Networks, Content & Technology. Brussels: European Union

Market Research Future (2020). Automotive Over-The-Air (OTA) Updates Market Overview. Retrieved in: https://www.marketresearchfuture.com/reports/automotive-over-the-air-updates-market-7606

Mensah, E., and Wohlgenant, M. (2010). "A market impact analysis of Soybean Technology Adoption", Research in Business and Economics Journal

Milgrom, P., Levin, J., & Eilat, A. (2011). The case for unlicensed spectrum. Stanford Institute for Economic Policy Research Discussion paper No. 10-036, p. 2. Retrieved from https://web.stanford.edu/~jdlevin/Papers/UnlicensedSpectrum.pdf.

National Instruments (2023). Introduction to 802.11ax High-Efficiency Wireless. Retrieved in: https://shorturl.at/jEGL7

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

Ngo, D. (2020). "Wi-Fi 6 in Layman's Terms: Speed, Range, and More". Dong Knows Tech (April 29th)

Nikolikj, V. and Janevski, T. (2014). "A Cost Modeling of High-Capacity LTE-Advanced and IEEE 802.11ac based Heterogeneous Networks, Deployed in the 700 MHz, 2.6 GHz and 5 GHz Bands," Procedia Computer Science 40 (2014) 49-56.

Nosratzadeh, H. and Edrisi, A. (2022). "An assessment of tendencies toward teleworking using TAMs: lessons from Covid-19 era for post-pandemic days", International Journal of Workplace Health Management, 16 (1) 38–56. Retrieved in: https://doi.org/10.1108/IJWHM-10-2021-0198

Giles, M (2023). "ISPs Need to Do More to Improve Wi-Fi Performance in the Home", Ookla Research Articles (May 17). Retrieved in: https://www.ookla.com/articles/improve-wi-fi-in-the-home-q1-2023#:~:text=It's%20clear%20from%20the%20gap,the%20dominant%20technologies%20deployed%20globally.

Oughton, E. & Frias, Z. (2016). Exploring the cost, coverage and rollout implications of 5G in Britain. Engineering and Physical Sciences Research Council. Retrieved from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/577965/Exploring_the_Cost_Coverage_and_Rollout_Implications_of_5G_in_Britain_-_Oughton_and_Frias_report_for_the_NIC.pdf.

Oughton, E. and Frias, Z. (2017, July 29). The cost, coverage and rollout implications of 5G infrastructure in Britain. Telecommunications Policy, 1-17. Retrieved from: https://www.sciencedirect.com/science/article/pii/S0308596117302781.

Oughton, E., Geraci, G., Polese, M., Shah, V., Bubley, D. and Blue, S. (2023). "Reviewing wireless broadband technologies in the peak smartphone era: 6G versus Wi-Fi 7 and 8", Telecommunications Policy. Retrieved in: https://doi.org/10.1016/j.telpol.2024.102766

Park Associates (2024). Parks: Average U.S. Internet Home Had 17 Connected Devices in 2023. January 10. Retrieved in: https://www.parksassociates.com/blogs/in-the-news/parks-average-us-internet-home-had-17-connected-devices-in-2023

Park Associates (2024) Vast majority (80%) of US households have a home network router; 28% report intentions to purchase (April 22). Retrieved in: https://www.parksassociates.com/blogs/ce-pr/vast-majority-80-of-us-households-have-a-home-network-router-28-report-intentions-to-purchase

Perrin, A. (2021). Mobile Technology and Home Broadband 2021. Pew Research Center (June 3). Retrieved from: https://www.pewresearch.org/internet/2021/06/03/mobile-technology-and-home-broadband-2021/

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

Rau, T. (2023). "Wi-Fi7: a deep-dive into the blistering new wireless standard", PC World, July 26.

Rosenberg, N., 1976. Perspectives on Technology. Cambridge University Press, New York.

Rosston, G., Savage, S. and Waldman, D. (2010), Household demand for broadband internet service. Available at http:// siepr.stanford.edu/system/files/shared/Household_demand_for_broadband.pdf.

Savage, S. J. and Waldman, D. (2004), 'United States Demand for Internet Access', Review of Network Economics, Vol. 3(3), pp.228–47.

Sbeglia, C. (2023). "What does global Wi-Fi 6 and 6E adoption look like?", RCR Wireless News, November 17, retrieved in: https://www.rcrwireless.com/20231117/fundamentals/what-does-global-wi-fi-6-ad-6e-adoption-look-like

Schmookler, J., 1966. Invention and Economic Growth. Harvard University Press, Cambridge, MA.

Spirent. Wi-Fi Offload: Is your gateway ready? Retrieved in: https://assets.ctfassets.net/wcxs9ap8i19s/0CmCW0buQpAINDJKN2z9NJ/b860733ac8cc6b724a55080b89f1cc60/WiFi_Offload_Whitepaper.pdf; ENEA. The drivers for Wi-Fi offloading. Retrieved in: https://www.enea.com/insights/the-drivers-for-wifi-offloading/

SVG Staff (2024). "San Francisco Giants Oracle Park, BYU's Lavell Edwards Stadium Tap 6 GHz Wi-Fi Connectivity". SVG News (April 24). https://www.sportsvideo.org/2024/04/24/san-francisco-giants-oracle-park-byus-lavell-edwards-stadium-tap-6-ghz-wi-fi-connectivity/

Suarez, M. (2020). Unlicensed spectrum access in the 6 GHz band. Presentation to ANATEL. Dynamic Spectrum Alliance.

Thanki, R. (2009). The economic value generated by current and future allocations of unlicensed spectrum. Perspective Associates (September 8)

Thanki, R. (2012). The Economic Significance of License- Exempt Spectrum to the Future of the Internet. London.

Verizon. How AR and VR technology can enhance IoT applications. Retrieved in: https://www.verizon.com/about/blog/vr-and-iot

Ward, L; Kopp, J. (2022). "IEEE 802.11be Technology Introduction". Page 8, Rohde & Schwarz, https://cdn.rohde-schwarz.com/sg_media/downloads/common_library/brochures_and_datasheets/IEEE-802-11be-technology-introduction_wp_en_3683-4026-52_v0100.pdf

Watkins, D. (2012). Broadband and Wi-Fi Households Global Forecast 2012. Strategy Analytics. Retrieved in: https://www.strategyanalytics.com/access-services/devices/connected-home/consumer-electronics/reports/report-detail/broadband-and-wi-fi-households-global-forecast-2012

Wi-Fi Alliance (2017). Wi-Fi Spectrum Needs Study: Final Report. Quotient Associates Limited. Histon, Cambridge. https://vaunix.com/resources/wi-fi-spectrum-needs-study.pdf

Wi-Fi Alliance (2021). Reduced latency benefits of Wi-Fi 6 OFDMA. Retrieved in: https://shorturl.at/acHLP

Wi-Fi Alliance (2023). Special Feature: The Road to WRC-23: Important decision-making that will affect the future of connectivity. https://shorturl.at/szKVY

Wiman (2020). Map of Free Wi-Fi hotspots. Retrieved from: https://www.wiman.me

WISPA. (2017). Ready for Take-Off: Broadband Wireless Access providers prepare to soar with fixed wireless. Retrieved from http://www.wispa.org/News/wispa_news_09-2517_Fixed_Wireless_Broadband_Industry_Projected_to_Nearly_Double_in_Five_Years.

WISPA, 2020: Letter to the FCC Commissioners, March 5

WISPA (2021): “The 2021 Fixed-Wireless and hybrid ISP industry report” available at https://www.carmelgroup.com/wp-content/uploads/2021/04/The-Carmel-Group-2021-Fixed-Wireless-Report-4-23-2021.pdf

Yonhap (2020). “Unlicensed frequency band to boost Wi-Fi speed, smart factory penetration: ministry”, The Korea Herald, (June 27).

APPENDIX A.

THEORETICAL FRAMEWORK for ESTIMATING the ECONOMIC VALUE of WI-FI

Wi-Fi is what economists call a factor of production (or enabling resource) that yields economic value by complementing wireline and cellular technologies, enabling the development of alternative technologies that expand consumer choice, supporting the creation of innovative business models, and expanding access to communications services. This chapter defines the intrinsic value of Wi-Fi as a complementary technology that is part of the telecommunications ecosystem, enhancing the performance of networks and providing a platform for developing innovative applications. Next, we present the concept of economic value, calculated as gains to consumer and producer surplus, a contribution to GDP, and a creation of employment. Having formalized these sources of value, we then move to categorize the five economic agents that benefit from them:

- Individual consumers benefitting from accessing free Wi-Fi service
- consumer residences
- enterprises
- Internet Service Providers; and
- manufacturers of communications equipment and consumer electronics.

A.1. The Intrinsic Value Of Wi-Fi

Considered as a factor of production, a complementary technology is a resource that, due to its intrinsic strengths, compensates for the limitations of another one. In this regard, Wi-Fi can enhance the effectiveness of devices, such as smartphones, which also use licensed spectrum. Wi-Fi access points can enhance the value of cellular networks by allowing wireless devices to switch to Wi-Fi hotspots, thereby reducing the cost of broadband access and increasing the access speed rate.[81] Likewise, many wireless operators reduce their capital spending by complementing their cellular networks with carrier-grade Wi-Fi access points, which are considerably less expensive than cellular network equipment with similar capacity. In addition to reducing capital expenditures, wireless carriers can offer fast access service without a base station congestion challenge.

In addition to complementing cellular networks, Wi-Fi can provide the environment needed for operating technologies that can substitute for those operating under licensed uses, thereby providing consumers with a larger set of choices. By limiting transmission power and relying on spectrum with low propagation, Wi-Fi avoids interference. This ensures the need for licensed spectrum property rights is not a barrier to innovation. In fact, some of the most important technological innovations in communications are intimately linked to Wi-Fi. Numerous products and services, such as the multi-AP/mesh networking systems and smart speakers, launched in the past ten years were developed leveraging Wi-Fi.

By providing consumers with service choices in addition to those offered through cellular services, Wi-Fi also supports the development of innovative business models. Firms developing new applications that rely on Wi-Fi do not need approval from cellular operators, do not incur time-to-market penalties, and do not face financial disincentives derived from costly revenue splits.

In addition to innovative applications, technologies that rely on Wi-Fi spectrum can help address the digital gap in broadband coverage. A large portion of the population that has not adopted the Internet around the world is located in rural and isolated areas. Many of them can gain access to broadband services provided by Wireless Internet Service Providers (WISPs), which typically operate through Wi-Fi.

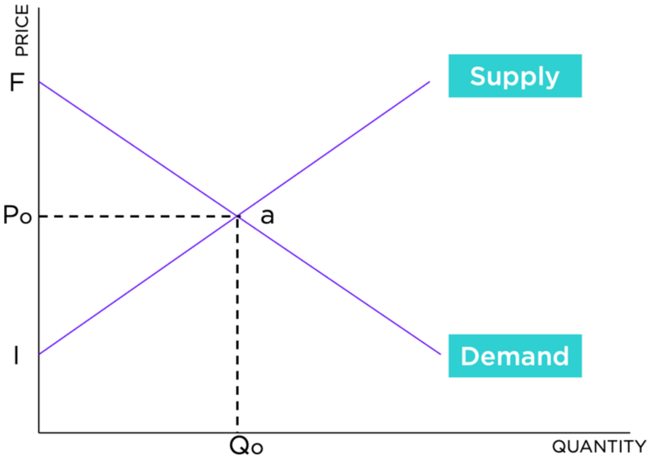
---

[81] For example, in December 2023 the average mobile connection speed in the United States is estimated at 208 Mbps while the average Wi-Fi speed from a mobile device using a fixed broadband connection is 289 Mbps (Source: Ookla Speedtest).

A.2. The Derived Value Of Wi-Fi

Wi-Fi yields economic gains at several levels, both to consumers and producers, as well as a direct net contribution to output (GDP) and employment. Prior research agrees that, contrary to licensed bands where economic value could equate to whatever is paid at auction, the economic value of unlicensed spectrum, such as Wi-Fi, needs to be measured based on the concept of economic surplus.[82] The methodology implicit in relying on the economic surplus approach is captured in Figure A-1.

FIGURE A-1. MEASUREMENT OF ECONOMIC SURPLUS



SOURCE: TELECOM ADVISORY SERVICES

The concept of economic surplus is based on the difference between the value of units consumed and produced up to the equilibrium price and quantity).[83] Consumer benefit measures the total amount consumers would be willing to pay to have the service, compared to what they actually pay (area of F, Po, a), while producer surplus measures the analogous quantity for producers (area of Po, I, a), which is essentially the economic profit they earn from providing the service. Thus, in Figure 1 the total surplus is contained in the area F, I, a.

Consistent with the concept presented above, the approach relied upon in this study to measuring economic value of Wi-Fi focuses first on the surplus generated after its adoption.[84] The underlying assumption is that Wi-Fi as a 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 for its acquisition. On the supply side, the approach measures changes in the value of inputs in the production of wireless communications. The most obvious example is, as mentioned above, whether Wi-Fi represents a positive contribution to wireless carriers' capital expenditures (CAPEX) and operating expenses (OPEX) insofar as they can control their spending while meeting demand for increased wireless traffic. From an economic theory

---

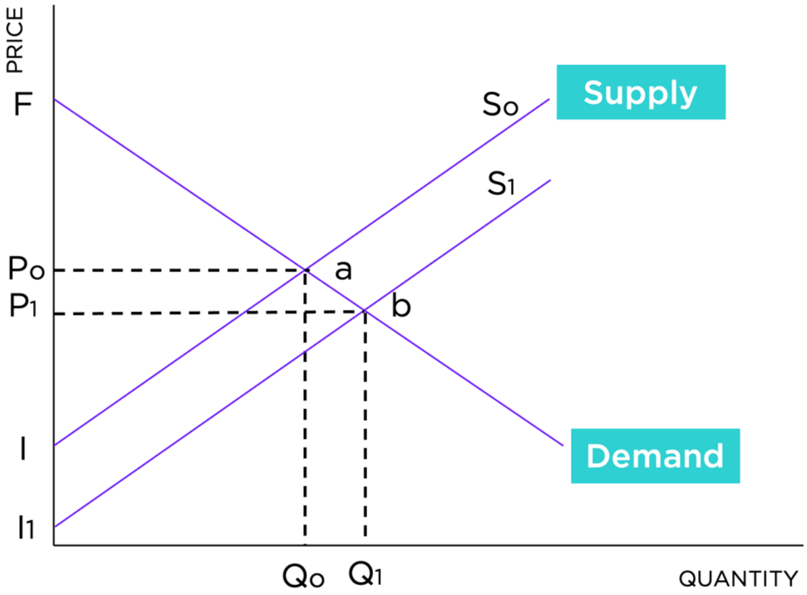
[82] Thanki, R. (2009). The economic value generated by current and future allocations of unlicensed spectrum. London: Perspective Associates; Thanki, R. (2012). The Economic Significance of License- Exempt Spectrum to the Future of the Internet. London; Perspective Associates; Milgrom, P., Levin, J., and Eilat, A. (2011). The case for unlicensed spectrum. Stanford Institute for Economic Policy Research Discussion Paper No. 10-036; Katz, R. ibid.

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

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

standpoint, the telecommunications industry can then increase its output, yielding a marginal benefit exceeding the marginal cost. This results in a shift in the supply curve by a modification in the production costs (see Figure A-2).

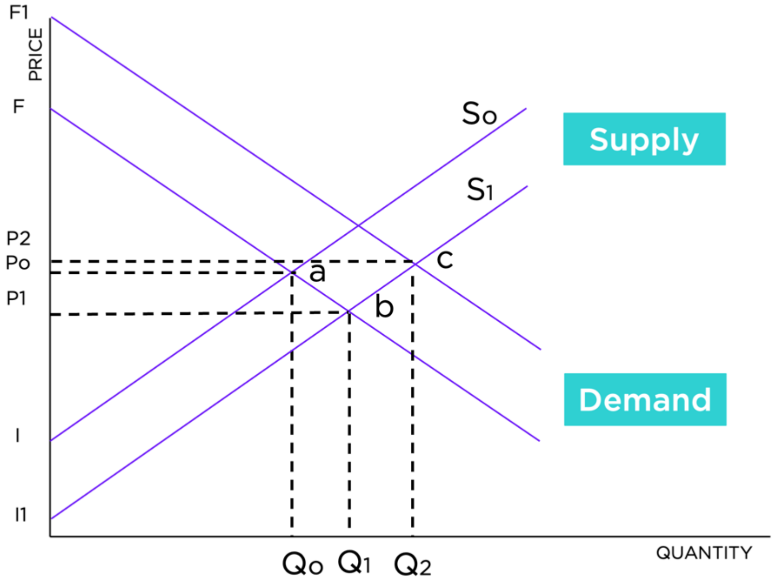
FIGURE A-2. MEASUREMENT OF ECONOMIC SURPLUS RESULTING FROM A SUPPLY SHIFT



SOURCE: TELECOM ADVISORY SERVICES

The development and adoption of carrier-grade Wi-Fi technology causes a shift in the supply curve, yielding a new equilibrium price and quantity. Under this condition, consumer benefit is represented by the triangle F, b, P_1, and producer surplus by the area within P_1, b, I_1. Additionally, since the demand curve is derived from the utility function[85], higher benefit to the consumer derived from the reliance on Wi-Fi at a stable price will yield an increase in the willingness-to-pay, and consequently a shift in the demand curve (see Figure A-3).

FIGURE A-3. MEASUREMENT OF ECONOMIC SURPLUS RESULTING FROM A SUPPLY AND DEMAND SHIFT



SOURCE: TELECOM ADVISORY SERVICES

---

[85] A utility function measures the consumer preference for a service beyond the explicit monetary value paid for it.

Under these conditions, total economic value is now represented by the area I_1, c, F_1, in Figure A-3, representing both changes in consumer and producer surplus.

To quantify the incremental surplus derived from the adoption of Wi-Fi, we need to itemize all the effects linked to this standard. We complement the concept of economic surplus with an assessment of the direct contribution of the technologies and applications that rely on Wi-Fi, such as Wi-Fi service providers, to the nation's GDP. By including the GDP contribution measurement, we follow Greenstein et al. (2010) and prior literature measuring the economic gains of new goods.[86] We focus on consumer and producer surplus, but we also consider the new economic growth enabled by Wi-Fi. In measuring the direct contribution to GDP, we strictly consider the revenues added "above and beyond" what would have occurred had the Wi-Fi spectrum been licensed. After quantifying the contribution of Wi-Fi to GDP, the impact on job creation can also be ascertained not only on the telecommunications industry itself, but, more importantly, in terms of the spillovers through the rest of the economy.

---

[86] Greenstein, S. and McDevitt, R. (2009). The broadband bonus: accounting for broadband Internet's impact on U.S. GDP. National Bureau of Economic Research Working Paper 14758. Cambridge, MA.

APPENDIX B.

PRINCIPAL COMPONENT ANALYSIS & ECONOMETRIC MODEL to ESTIMATE the IMPACT of SPEED AND LATENCY on GDP

B.1. Background

A key objective in our study is to estimate the effect of both download speed and latency on GDP. The starting point to develop an econometric model to estimate the impact of the improvement of speed and latency on GDP, was a regression similar to one specified for a prior U.S. study.[87] Latency did not appear in the prior regression due to lack of data (see figure B-1).

FIGURE B-1. MODEL FOR ESTIMATING THE IMPACT OF FIXED BROADBAND SPEED & LATENCY ON GDP

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

The previous model was based on:

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

The new econometric model utilizes monthly data from January 2019 to December 2022, covering 63 countries, including Algeria, Argentina, Australia, Austria, Belarus, Belgium, Bolivia, Brazil, Bulgaria, Canada, Chile, China, Colombia, Costa Rica, Croatia, Czech Republic, Denmark, Dominican Republic, Ecuador, Egypt, El Salvador, Estonia, Finland, France, Germany, Greece, Hungary, Iran, Ireland, Israel, Italy, Jamaica, Japan, Jordan, Kazakhstan, Korea, Latvia, Lithuania, Malaysia, Mexico, Netherlands, New Zealand, Norway, Paraguay, Peru, Philippines, Poland, Portugal, Romania, Russia, Saudi Arabia, Singapore, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Thailand, Turkey, Ukraine, United Kingdom, United States, and Uruguay. The choice of January 2019 as the starting point is due to the availability of latency data from this month onwards using Ookla Speedtest as the data source. Also we use GDP data from International Financial Statistics (IFS) and data for unemployment and investment from International Monetary Fund, World Economic Outlook Database, April 2024.

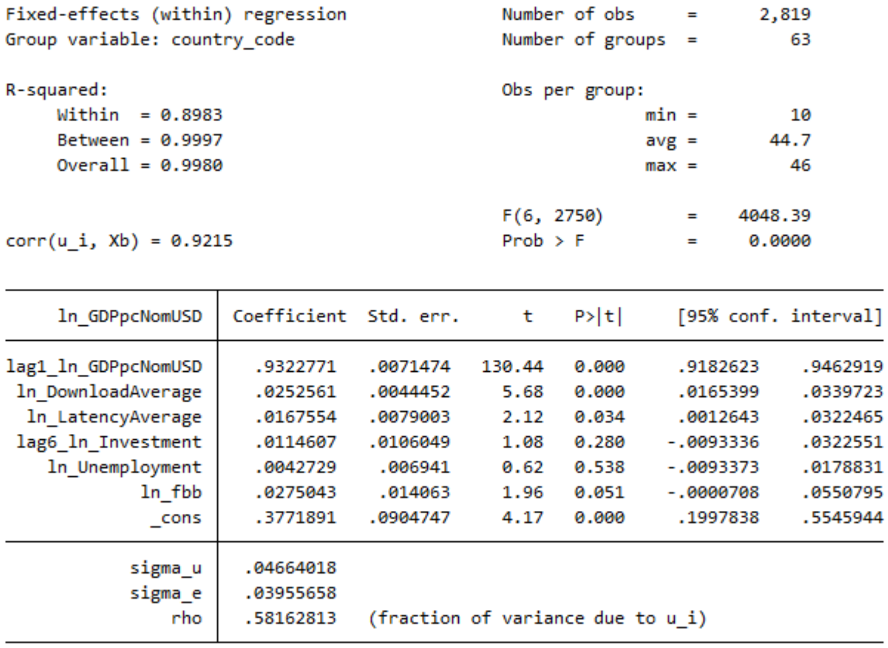
Our model was run using the natural logarithm of per capita GDP as the explained variable, and including the natural logarithm of latency as an independent variable, with the following results (see table B-1):

---

[87] Katz, R. and Callorda, F. (2020). Assessing the economic potential of 10G networks. New York: Telecom Advisory Services. Retrieved in: https://www.10gplatform.com/news/next-great-leap-broadband-10g-will-boost-americas-economy

TABLE B-1. RESULTS OF ECONOMETRIC MODEL EXPLAINING THE IMPACT OF A CHANGE IN DOWNLOAD SPEED & LATENCY OF FIXED BROADBAND ON A CHANGE IN GDP PER CAPITA

2019-2022[88]



```
Fixed-effects (within) regression               Number of obs     =      2,819
Group variable: country_code                    Number of groups  =         63

R-squared:                                      Obs per group:
     Within  = 0.8983                                         min =         10
     Between = 0.9997                                         avg =       44.7
     Overall = 0.9980                                         max =         46

                                                F(6, 2750)        =    4048.39
corr(u_i, Xb) = 0.9215                          Prob > F          =     0.0000

------------------------------------------------------------------------------------
    ln_GDPpcNomUSD | Coefficient  Std. err.      t    P>|t|     [95% conf. interval]
-------------------+----------------------------------------------------------------
lag1_ln_GDPpcNomUSD |   .9322771   .0071474   130.44   0.000     .9182623    .9462919
 ln_DownloadAverage |   .0252561   .0044452     5.68   0.000     .0165399    .0339723
  ln_LatencyAverage |   .0167554   .0079003     2.12   0.034     .0012643    .0322465
 lag6_ln_Investment |   .0114607   .0106049     1.08   0.280    -.0093336    .0322551
    ln_Unemployment |   .0042729    .006941     0.62   0.538    -.0093373    .0178831
             ln_fbb |   .0275043    .014063     1.96   0.051    -.0000708    .0550795
              _cons |   .3771891   .0904747     4.17   0.000     .1997838    .5545944
-------------------+----------------------------------------------------------------
            sigma_u |  .04664018
            sigma_e |  .03955658
                rho |  .58162813   (fraction of variance due to u_i)
------------------------------------------------------------------------------------
```

As indicated in the model results, latency (indicated by the term “ln_LatencyAverage”) has a positive sign which means that an increase in latency is associated with an increase in GDP, which is the opposite of the expected relationship. However, there is a high correlation between latency and speed, with a simple correlation between the two of a -0.6. This indicates that if latency and speed are included in the original model as two independent variables, we have high co-linearity between both terms, which could mean that the results of both coefficients are biased.

B.2. Principal Components Analysis

Given this high collinearity, we rely on Principal Components Analysis (PCA), which is designed to handle multicollinearity among variables by transforming them into a set of linearly uncorrelated components. PCA simplifies the complexity in high-dimensional data while retaining trends and patterns. It does this by transforming the data into a new coordinate system (or construct), thereby reducing the number of dimensions without losing significant information.

The inclusion of all variables in a PCA, including those that are not highly correlated with each other (e.g., investment, employment) may provide limited benefit. It is essential to recognize the indicators must possess a logical coherence within a construct. This principle extends beyond the mere statistical correlation among indicators, since it requires that the indicators collectively provide a meaningful and interpretable representation of the construct. A construct, by definition, is an abstract concept that is measured through a set of observable variables or indicators. For these indicators to reflect the construct validly and reliably, they must be logically related to each other and to the underlying theoretical framework. This logical coherence ensures that the construct is both conceptually sound and practically useful. The necessity for logical coherence among indicators means that they should share a common underlying theme or dimension. For example, if a construct is designed to measure "quality," such as the one we use in our analysis here, it is better if the indicators pertain to aspects of quality. Introducing indicators that measure entirely different dimensions, would dilute the construct and potentially lead to misleading conclusions. This is because the mixed indicators would not collectively reflect a single, coherent construct but rather a conflation of disparate dimensions.

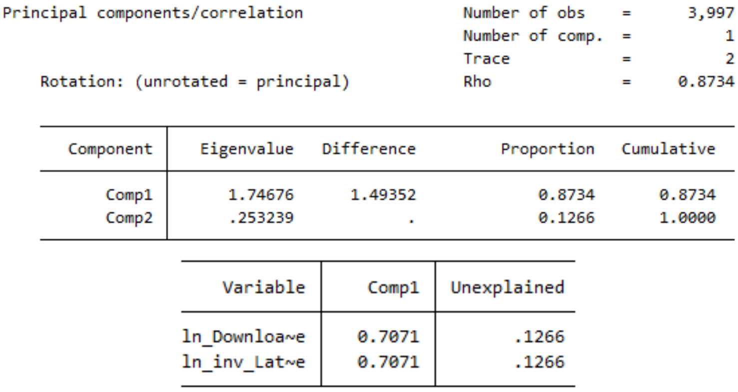
---

[88] We run the model using different lags for download speed and latency, obtaining similar results

Furthermore, logical coherence facilitates the interpretability of the construct. When indicators logically align, the construct can be more easily understood and communicated. This interpretability is crucial for the application of the construct. In light of these considerations, we decided to focus only on the two correlated variables: speed and latency. However, as discussed below, the tradeoff with this approach is that it constrains the effect of the two variables to be the same.

To transform the speed and latency data into a new coordinated system (or construct), the first thing we must do is take the inverse of latency so that both indicators have a positive correlation (a decrease in latency is associated with an improvement in download speed). Once this first step is completed, we run the PCA in STATA using the command “pca ln_DownloadAverage ln_inv_LatencyAverage, components (1)”, considering both the natural logarithm of the download speed and the natural logarithm of the inverse of the latency. This command performs PCA on the transformed latency variable and the download speed variable, generating the first principal component, which captures the maximum possible variance in the data (see table B-2).

TABLE B-2. RESULTS OF PRINCIPAL COMPONENTS ANALYSIS



```
Principal components/correlation                 Number of obs    =      3,997
                                                 Number of comp.  =          1
                                                 Trace            =          2
    Rotation: (unrotated = principal)            Rho              =     0.8734

    --------------------------------------------------------------------------
       Component |   Eigenvalue   Difference         Proportion   Cumulative
    -------------+------------------------------------------------------------
           Comp1 |      1.74676      1.49352             0.8734       0.8734
           Comp2 |      .253239            .             0.1266       1.0000
    --------------------------------------------------------------------------

                   ----------------------------------------
                       Variable |    Comp1 | Unexplained
                   -------------+----------+-------------
                   ln_Downloa~e |   0.7071 |       .1266
                   ln_inv_Lat~e |   0.7071 |       .1266
                   ----------------------------------------
```

SOURCE: TELECOM ADVISORY SERVICES

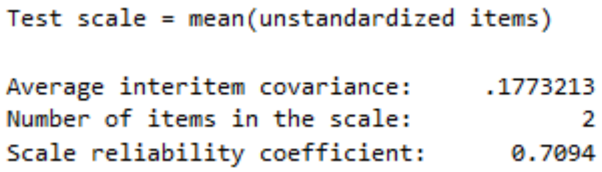
The identical weights of 0.7071 on both variables indicate that the first principal component is capturing an equal contribution from both variables. When the dataset is limited to two variables, the PCA algorithm aims to identify the axes (principal components) that maximize the variance. However, with only two variables, the information available to distinguish between the importance of these variables is constrained. Specifically, the variance in the dataset is distributed between these two variables, and the covariance structure, which could indicate a correlation, may not provide sufficient differentiation to assign significantly different weights to each variable. So, when dealing with only two variables, PCA assigns equal weights to both variables in the principal components because the variance-covariance structure does not provide enough information to differentiate the variables significantly. This equal weighting reflects the inherent limitation of having only two variables, where the capacity to discern varying contributions to the overall variance is inherently limited.

To determine if the effects in PCA are statistically significant, one does not rely on significance tests in the traditional sense (like p-values). PCA is primarily a descriptive tool used to reduce the dimensionality of data and to identify patterns by transforming the original variables into principal components. To find out if the application of the PCA is correct, what is done is Cronbach's Alpha test. If the test gives more than 0.5[89], it suggests that the test is reliable. In the present case the result is 0.7094 (see table B-3.)

---

[89] According to Hair, J., Anderson, R., Tatham, R., and Black, W. in their paper Multivariate Data Analysis (NJ: Pearson/Prentice Hall, Inc., 2006), the Cronbach's alpha coefficient should be greater than 0.5 to be considered valid.

TABLE B-3. RESULTS OF CRONBACH'S ALPHA COEFFICIENT



```
Test scale = mean(unstandardized items)

Average interitem covariance:     .1773213
Number of items in the scale:            2
Scale reliability coefficient:      0.7094
```

SOURCE: TELECOM ADVISORY SERVICES ANALYSIS

A final point to highlight is that within principal components more variables that are positively correlated with each other can be included, but since the objective of the construct is to correct for the correlation between latency and speed, alternative models that include more indicators were not tested.

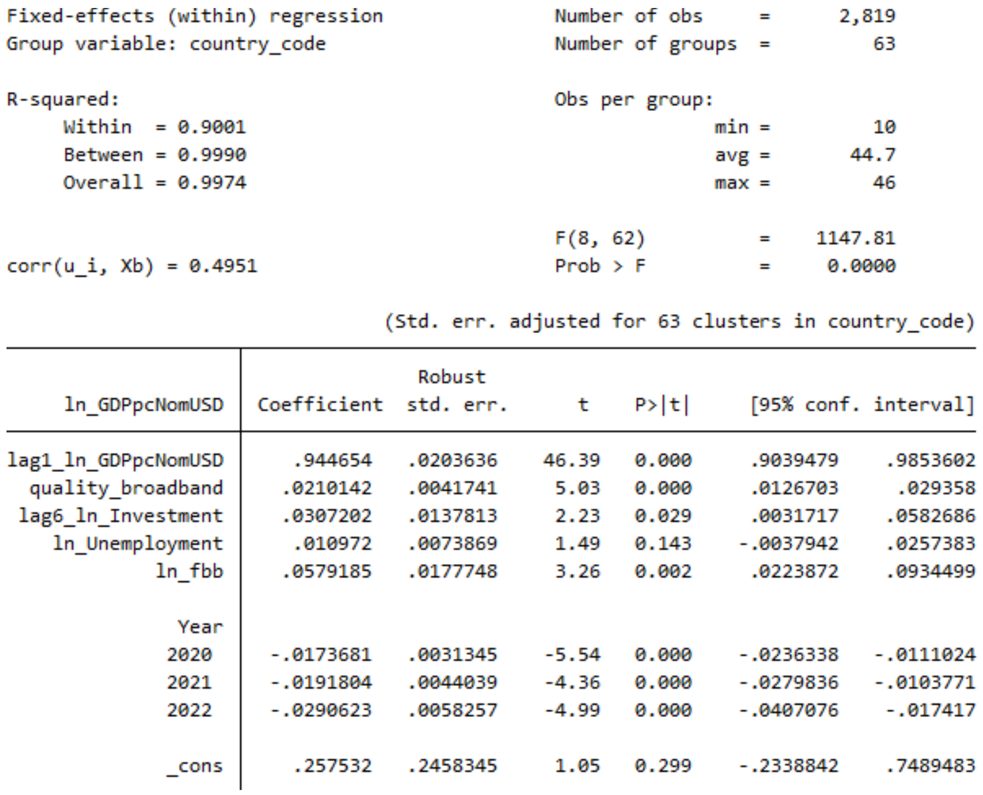
Subsequently, we generate a new variable that represents a composite measure of broadband quality by using the command "predict quality_broadband, score". This command creates a new variable called quality_broadband that represents the scores of the first principal component, derived from the PCA analysis. Through these steps, we create a indicator of broadband quality that encapsulates essential information from both speed and latency measures. Once we have this new indicator, we can use it to run the econometric model to replace the download speed and latency variables.

B.3. Regression

Once, the "quality" construct is defined, we ran a regression against the natural logarithm of the GDP per capita, controlling by the natural logarithm of the GDP per capita lagged 1 month; the natural logarithm of the investment lagged 6 months, the natural logarithm of the unemployment, and the natural logarithm of the fixed broadband adoption (see table B-4).

TABLE B-4. ECONOMETRIC MODEL EXPLAINING THE IMPACT OF THE QUALITY OF FIXED BROADBAND CONSTRUCT ON A CHANGE IN GDP PER CAPITA

2019-2022



```
Fixed-effects (within) regression               Number of obs     =      2,819
Group variable: country_code                    Number of groups  =         63

R-squared:                                      Obs per group:
     Within  = 0.9001                                         min =         10
     Between = 0.9990                                         avg =       44.7
     Overall = 0.9974                                         max =         46

                                                F(8, 62)          =    1147.81
corr(u_i, Xb) = 0.4951                          Prob > F          =     0.0000

                             (Std. err. adjusted for 63 clusters in country_code)
-------------------------------------------------------------------------------
                  |               Robust
    ln_GDPpcNomUSD | Coefficient  std. err.      t    P>|t|     [95% conf. interval]
-------------------------------------------------------------------------------
lag1_ln_GDPpcNomUSD |    .944654   .0203636    46.39   0.000     .9039479    .9853602
  quality_broadband |   .0210142   .0041741     5.03   0.000     .0126703     .029358
  lag6_ln_Investment |   .0307202   .0137813     2.23   0.029     .0031717    .0582686
    ln_Unemployment |    .010972   .0073869     1.49   0.143    -.0037942    .0257383
             ln_fbb |   .0579185   .0177748     3.26   0.002     .0223872    .0934499
                   |
              Year |
              2020  |  -.0173681   .0031345    -5.54   0.000    -.0236338   -.0111024
              2021  |  -.0191804   .0044039    -4.36   0.000    -.0279836   -.0103771
              2022  |  -.0290623   .0058257    -4.99   0.000    -.0407076    -.017417
                   |
             _cons |    .257532   .2458345     1.05   0.299    -.2338842    .7489483
```

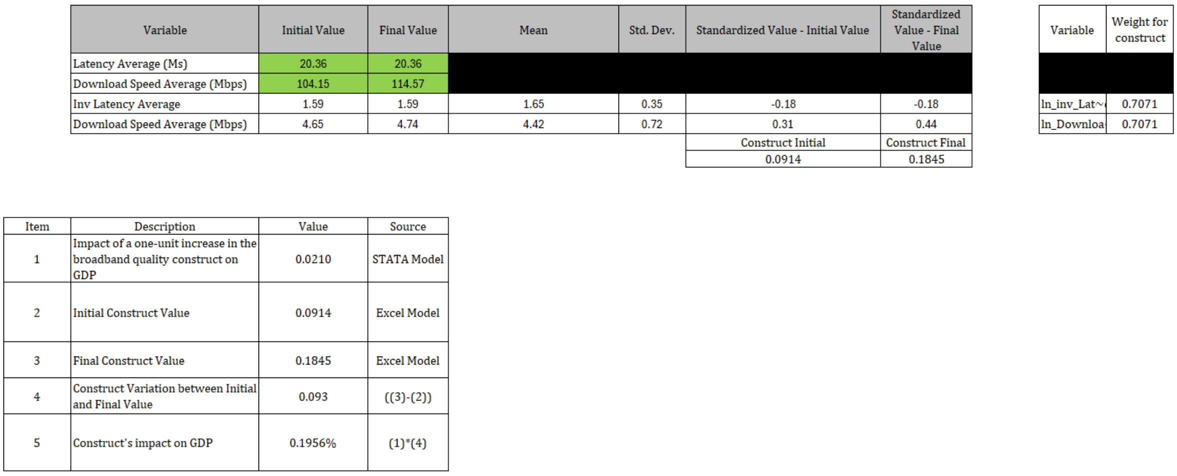
SOURCE: TELECOM ADVISORY SERVICES ANALYSIS

The econometric model reveals several key findings from the coefficients. Firstly, as expected, the one-month lag of GDP positively influences the current GDP, with a coefficient of 0.9447, indicating a strong positive relationship. Secondly, an increase in investment also positively impacts GDP, as evidenced by the significant positive coefficient of 0.0307. Thirdly, the unemployment level does not show a significant effect on GDP, given the p-value of 0.143, indicating that changes in unemployment are not statistically significant in predicting GDP changes. Lastly, a 10% increase in fixed broadband adoption results in a 0.58% increase in GDP per capita, reflecting the positive impact of broadband penetration on economic performance, independent of broadband quality which is evaluated separately. Finally, we have that a one unit increase in the construct of fixed broadband quality is related to a significative and positive increase in GDP per capita.

That value doesn´t have an interpretation itself, it only indicates a positive relationship between the quality of broadband and GDP per capita. To interpret the result, we need to disaggregate ("back out") the effect of latency and speed on GDP.

We first analyzed how much the construct increases if the average download speed increases by 10% (for example, from 104.15 to 114.57), which implies that the construct increased from a value of 0.0914 to 0.1845, or by 0.093 units. Multiplying this value by the coefficient obtained from the econometric model (0.0210) we obtain that a 10% increase in download speed generates an increase in GDP of 0.1956% (see table B-5).

TABLE B-5. ESTIMATION OF THE IMPACT OF AN INCREASE IN 10% IN DOWNLOAD SPEED



Variable	Initial Value	Final Value	Mean	Std. Dev.	Standardized Value - Initial Value	Standardized Value - Final Value
Latency Average (Ms)	20.36	20.36				
Download Speed Average (Mbps)	104.15	114.57				
Inv Latency Average	1.59	1.59	1.65	0.35	-0.18	-0.18
Download Speed Average (Mbps)	4.65	4.74	4.42	0.72	0.31	0.44
					Construct Initial	Construct Final
					0.0914	0.1845

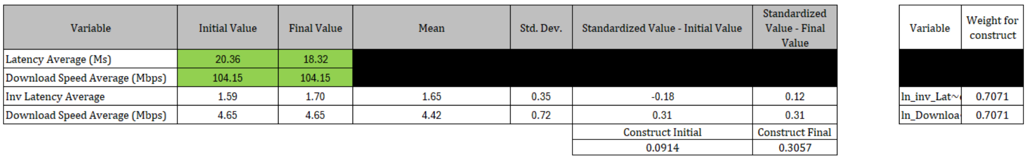
Variable	Weight for construct
ln_inv_Lat~	0.7071
ln_Downloa	0.7071

Item	Description	Value	Source
1	Impact of a one-unit increase in the broadband quality construct on GDP	0.0210	STATA Model
2	Initial Construct Value	0.0914	Excel Model
3	Final Construct Value	0.1845	Excel Model
4	Construct Variation between Initial and Final Value	0.093	((3)-(2))
5	Construct's impact on GDP	0.1956%	(1)*(4)

SOURCE: TELECOM ADVISORY SERVICES

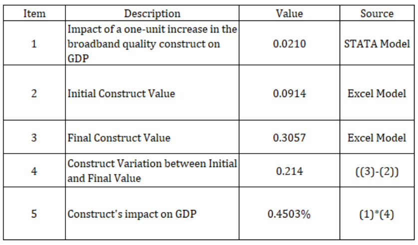
Similarly, we obtain that with a 10% reduction in latency, the construct increased from 0.0914 to 0.3057, which implies an increase of 0.214 units. Multiplying this value by the coefficient obtained from the econometric model (0.0210) we obtain that a 10% decrease in latency generates an increase in GDP of 0.4503% (see Table B-6).

TABLE B-6. ESTIMATION OF THE IMPACT OF A REDUCTION IN 10% IN LATENCY



Variable	Initial Value	Final Value	Mean	Std. Dev.	Standardized Value - Initial Value	Standardized Value - Final Value
Latency Average (Ms)	20.36	18.32				
Download Speed Average (Mbps)	104.15	104.15				
Inv Latency Average	1.59	1.70	1.65	0.35	-0.18	0.12
Download Speed Average (Mbps)	4.65	4.65	4.42	0.72	0.31	0.31
					Construct Initial	Construct Final
					0.0914	0.3057

Variable	Weight for construct
ln_inv_Lat~	0.7071
ln_Downloa	0.7071



Item	Description	Value	Source
1	Impact of a one-unit increase in the broadband quality construct on GDP	0.0210	STATA Model
2	Initial Construct Value	0.0914	Excel Model
3	Final Construct Value	0.3057	Excel Model
4	Construct Variation between Initial and Final Value	0.214	((3)-(2))
5	Construct's impact on GDP	0.4503%	(1)*(4)

SOURCE: TELECOM ADVISORY SERVICES

In conclusion, with the new coefficients the impacts are:

- A 10% increase in download speed results in a 0.1956% increase in GDP per capita
- A 10% decrease in latency results in a 0.4503% increase in GDP per capita

These two coefficients are used in the estimation of GDP contribution of business speeds and latency in sections 5.1 and 5.2.

APPENDIX C.

TECHNICAL ANALYSIS of WI-FI PERFORMANCE UNDER Wi-Fi 6, Wi-Fi 6E & Wi-Fi 7

The assessment of Wi-Fi economic value is contingent upon a technical analysis of performance under different scenarios combining the standards and alternate frequency band allocations – i.e. 2.4 GHz and 5 GHz for Wi-Fi 4, Wi-Fi 5, and Wi-Fi 6, and 6 GHz for Wi-Fi 6Eand Wi-Fi 7. Impact of additional frequency band allocations such as 125 MHz in 7 MHz, and 500 MHz in 7 GHz is also evaluated in this study. This document explains the assumptions, methodology and calculations used to estimate the economic impact according to technical performance of each scenario. It has been conducted for five scenarios:

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

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

- Wi-Fi 7 operating in the 6 GHz band. In addition to the aggregation of channels in 320 MHz of the case above, this standard introduces a combination of new features such as MRU (Multiple Resource Units), MLO (Multilink operation), maximum 4096-QAM modulation and spatial stream scaling (16SS), to improve spectral efficiency, increase speed and support many devices in a single area.

- Wi-Fi 7 relying on the full 6 GHz band and 125 MHz of the 7 GHz band, thereby increasing the amount of frequency available in order to offer up to four channels of 320 MHz.

- Wi-Fi 7 operating on the 6 GHz and 500 MHz of the 7 GHz band, which adds a fifth 320 MHz channel.

This Appendix is structured in seven sections. Section C.1 presents the variables and equations used to estimate Wi-Fi performance under different bands and standards. Section C.2 presents calculations to support the performance of Wi-Fi 6 operating in the 2.4, and 5 GHz bands. Section C.3 presents the calculations supporting the added benefit in performance when using Wi-Fi 6E operating in the 2.4 GHz, 5 GHz and 6 GHz bands. Section C.4 presents the performance assessment of Wi-Fi 7 operating in 2.4 GHz, 5 GHz, and 6 GHz bands. Section C.5 presents the performance of Wi-Fi 7 operating in the 2.4 GHz, 5 GHz, 6 GHz bands and the lower part of the 7GHz band (7125-7250). Section C.6 details the performance of Wi-Fi 7 operating within the 2.4 GHz, 5 GHz, 6 GHz bands and the low and mid part of the7GHz band (7250-7625). Finally, Section C.7 draws the implications of the technical analysis in the assessment of economic value of each source and effect studied in the main report.

C.1. Theoretical Framework for Assessing Wi-Fi Performance

Each Wi-Fi standard can be used in different spectrum bands. The operations of Wi-Fi4 (802.11n), Wi-Fi5 (802.11ac) and Wi-Fi 6 (802.11ax) rely on the 2.4 GHz and 5 GHz bands. Wi-Fi 6E (802.11ax) operates within the 2.4 GHz, 5 GHz and 6 GHz bands. The operation of Wi-Fi 7 (802.11be) relies on the prior bands, however, we are proposing different allocations to be considered under the 7 GHz. . Our overarching objective is to assess Wi-Fi performance, operating under different frequency band and standard scenarios, in terms of the number of potential devices to be served simultaneously and the speed and latency received by each device. The impact on speed, latency and number of devices are critical inputs in estimating Wi-Fi economic contribution. The estimation of number of devices, speed and latency is based on the following parameters:

- The number of channels available in different frequency bands defines the total bandwidth available in a frequency band, following the Unlicensed National Information Infrastructure (UNII) scheme.
- The bandwidth allocated by channel determines the number of devices to be supported by each standard.

- The spatial streams available by device determine Wi-Fi spatial streaming is a MIMO (Multiple Input Multiple Output) transmission technique used in wireless communications to transmit or receive independent and separately coded data signals. Spatial streams allow a single device to transmit and receive at the same time simultaneously. The number of spatial streams (defined by the number of antennas) in the router and receiving device allows a reduction in the time required to receive the information flow.
- The number of resource units available by channel. A Resource Unit is a subdivision of the primary channel that allows the transmission of information required by a device, following specific Wi-Fi modulation techniques.[90] Each standard stipulates the type and number of resource units that can accommodate the maximum number of devices by channel.
- The modulation technique allows compressing information to allow the transmission of packets in bits per symbol (BPS) within a fixed time interval (TT). Modulation techniques are roughly divided into four types: Analog modulation, Digital modulation, Pulse modulation, and Spread spectrum method. Wi-Fi relies on different digital modulation characteristics by standard (see table C-1). Each modulation adds bits for redundancy (Error Correction codes) that allow the recovery of information in case errors occur during the transmission.

TABLE C-1. WI-FI STANDARDS TRANSMISSION CHARACTERISTICS

STANDARD	**MODULATION**	**BITS** per **SYMBOL** (BPS)	**ERROR CORRECTION** (EC)	**TRANSMISSION TIME** (TT)
Wi-Fi 5	256 QAM	8	5/6	3.6 us
Wi-Fi 6	1024 QAM	10	5/6	13.6 us
Wi-Fi 6E	1024 QAM	10	5/6	13.6 us
Wi-Fi 7	4096 QAM	12	5/6	13.6 us

SOURCE: IEEE COMPUTER SOCIETY, (2021). “WIRELESS LAN MEDIUM ACCESS CONTROL (MAC) AND PHYSICAL LAYER (PHY) SPECIFICATIONS” HTTPS://IEEEXPLORE.IEEE.ORG/DOCUMENT/9442429

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

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

SOURCE: NATIONAL INSTRUMENTS. “INTRODUCTION TO WIRELESS LAN MEASUREMENTS FROM 802.11a to 802.11ac”
Reference to IEEE. (2016), “Performance comparison of IEEE 802.11n and IEEE 802.11ac”
https://download.ni.com/evaluation/rf/Introduction_to_WLAN_Testing.pdf

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

---

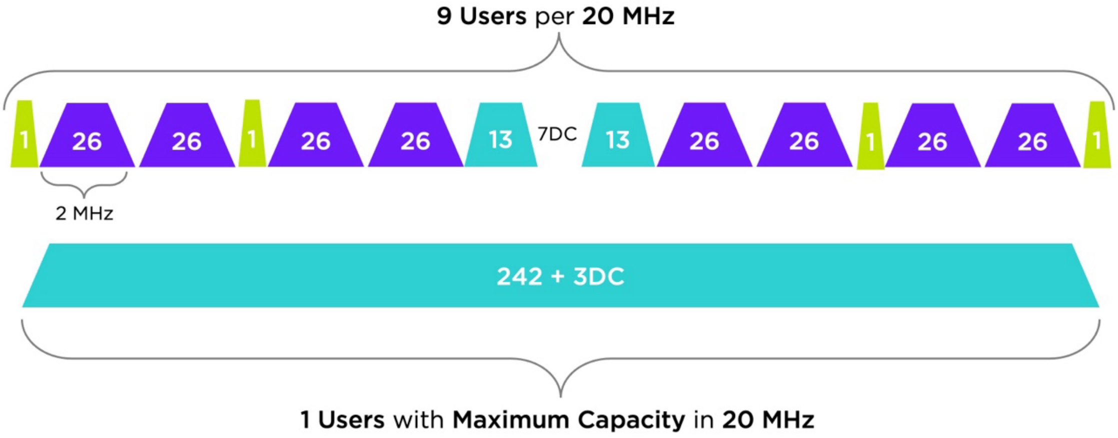
[90] In technical terms, (RU) is a unit in OFDMA terminology used in 802.11ax WLAN to denote a group of 78.125 kHz bandwidth subcarriers (tones) used in both DownLink (DL) and UpLink (UL) transmissions. With OFDMA, different transmit powers may be applied to different Resource Units.

C.2. Wi-Fi 6 Performance Operating Under 2.4 GHz & 5 GHz Bands

Taking into consideration that the Wi-Fi 4 and 5 standards have been presenting challenges in terms of saturation due to the large amount of equipment and devices deployed, as well as the restriction of the maximum available bandwidth, 802.11ax technology, known as Wi-Fi 6, offered a solution. The main features of Wi-Fi 6 can be summarized in five areas according to the following reference[91]: (i) increased channel aggregation[92] due to increased bandwidth at the 6 GHz frequency, (ii) channel splitting by multiple access of multiple users by orthogonal frequency division[93] (OFDMA), (iii) transmission link adaptation through maximum 1024-QAM modulation,[94] ,(iv) guard or guard interval to avoid information overlap;[95] and, (v) transmission of multiple simultaneous information streams over the same channel to increase bandwidth.[96]

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

FIGURE C-1. CHANNELIZATION FOR WI-FI 6 IN A 20 MHZ WIDE CHANNEL



---

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

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

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

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

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

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

SOURCE: TELECOM ADVISORY SERVICES ADAPTED FROM CISCO[97]

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

TABLE C-2. WI-FI 6 PARAMETERS

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

SOURCE: TELECOM ADVISORY SERVICES COMPILATION

By relying on the parameters of table 2 and equation 1, we calculate the maximum speed for channels of 20 MHz with 242 resource units of one spatial stream (which means one user per channel). As the equation indicates, under the Wi-Fi 6 standard operating within the 2.4 and 5 GHz frequencies, we can theoretically accommodate 28 devices with speeds of up 148.28 Mbps.

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

According to this, it could be estimated that the maximum theoretical value that can be reached by a user in a high traffic environment, with a minimum operating channel, can be determined at 150 Mbps. In this case, Wi-Fi 6 solves both performance and coverage challenges of Wi-Fi 5. In addition, the technology introduces a combination of features including OFDMA and 1024-QAM peak modulation which improve spectral efficiency, thereby increasing speed while supporting many devices in a congested area.

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

---

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

TABLE C-3. PERFORMANCE OF WI-FI 6 OPERATING IN THE 2.4 GHZ AND 5 GHZ BANDS

Scenario	**Number of Channels** (A)	**Bandwidth by Channel** (B)	**Spatial Streams** (C)	**Resource Units** (D)	**Maximum Devices per Resource Unit** (E)	**BPS**	**CE**	**TT** (µs)	**Total Number of Devices** (A*E)	**Channel Speed** (V=C*D*CE/T) (Mbps)
1	28	20	1	26 (2MHz)	9	10	5/6	13.6	252	15.93
2	28	20	2	26 (2MHz)	9	10	5/6	13.6	252	31.86
3	28	20	1	242 (20MHz)	1	10	5/6	13.6	28	148.28
4	12	40	1	484 (20MHz)	1	10	5/6	13.6	12	296.57
5	12	40	2	484 (20MHz)	1	10	5/6	13.6	12	593.14

SOURCE: TELECOM ADVISORY SERVICES ANALYSIS

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

- Scenario 1 (theoretical): this scenario allows 28 channels of 20 MHz. Under the largest number of resource units by channel (26 RU), Wi-Fi 6 can handle a maximum of 252 of 1 spatial streams users, at a maximum speed of 15.93 Mbps.
- Scenario 2 (theoretical): this scenario allows 28 channels of 20 MHz. Under the largest number of resource units by channel (26 RU), Wi-Fi 6 can handle a maximum of 252 of 2 spatial streams users, with a maximum speed of 31.86 Mbps.
- Scenario 3 (theoretical): this scenario allows 28 channels of 20 MHz. Under the largest number of resource units by channel (242 RU), Wi-Fi 6 can handle a maximum of 28 of 1 spatial stream users, with a maximum speed of 148.28 Mbps.
- Scenario 4 (theoretical): this scenario allows 12 channels of 40 MHz. Under the largest number of resource units by channel (484 RU), Wi-Fi 6 can handle a maximum of 12 of 1 spatial stream users, with a maximum speed of 296.57 Mbps.
- Scenario 5 (theoretical): this scenario allows 12 channels of 40 MHz. Under the largest number of resource units by channel (484 RU), Wi-Fi 6 can handle a maximum of 12 of 2 spatial stream users, with a maximum speed of 593.14 Mbps.

It is important to consider these results to be valid only theoretically. The following factors come into play to significantly reduce the estimated speed. While the theoretical maximum speed for a user in a saturation scenario can reach 150 Mbps, this could be affected by a greater number of users making use of the channel. In fact, as described in Figure C-1, the 802.11ax standard could distribute the bandwidth to up to 9 users; and if this number increases, the user experience will be degraded due to a reduction in speed, generally in applications with high resource requirements. Considering the interference in bands allocated for indoor use, more likely feasible scenarios[98] are as follows:

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

---

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

- Scenario 2 (feasible): this scenario allows 28 channels of 20 MHz. Under the largest number of resource units by channel (26 RU), Wi-Fi 6 can handle a maximum of 252 of 2 spatial streams users, with a maximum speed of 22.30 Mbps.
- Scenario 3 (feasible): this scenario allows 28 channels of 20 MHz. Under the largest number of resource units by channel (242 RU), Wi-Fi 6 can handle a maximum of 28 of 1 spatial stream users, with a maximum speed of 103.79 Mbps.
- Scenario 4 (feasible): this scenario allows 12 channels of 40 MHz. Under the largest number of resource units by channel (484 RU), Wi-Fi 6 can handle a maximum of 12 of 1 spatial stream users, with a maximum speed of 207.59 Mbps.
- Scenario 5 (feasible): this scenario allows 12 channels of 40 MHz. Under the largest number of resource units by channel (484 RU), Wi-Fi 6 can handle a maximum of 12 of 2 spatial stream users, with a maximum speed of 415.19 Mbps (again, as stipulated in footnote 8, the degradation of speed does not include the distance factor).

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

C.3. Wi-Fi 6E Performance Under 2.4 GHz, 5 GHz, & 6 GHz Bands

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

TABLE C-4. WI-FI 6E PARAMETERS

Commercial denomination		Wi-Fi 6E
IEEE standard		802.11 ax
Frequency bands		2.4GHz, 5 GHz y 6GHz
Industrial, Scientific and Medical (ISM) band		(B1) 2412-2472: 60MHz (ISM)
UNII (Unlicensed National Information Infrastructure)		(B2i) 5170-5330: 160MHz (UNII-1-2) (B3) 5490-5730: 240MHz (UNII-2Ex) (B4) 5735-5835: 100MHz (UNII-3) (B5) 5925-6425: 500MHz (UNII-5) (B6i) 6425-6525: 100MHz (UNII-6) (B7) 6525-6875: 350MHz (UNII-7) (B8i) 6875-7125: 250MHz (UNII-8)
Total available bandwidth (MHz)		1760
Possible channelization		20MHz, 40 MHz, 80MHz, 160MHz
Maximum number of channels	20 MHz	88
	40 MHz	43
	80 MHz	21
	160 MHz	9
	320 MHz	
Maximum allowed modulation (QAM)		1024
Maximum speed (Mbps) 1SS		1,200.98
Maximum medium access		OFDMA
Type of transmission		MU-MIMO
Maximum spatial streams (SS)		8
Maximum speed (Mbps) under maximum spatial streams		9,607.84
Improvement relative to Wi-Fi 6		Increase of bandwidth to accommodate a larger number of users with similar speeds as the prior standard; in addition, channel aggregation allows increasing the speed in a dynamic fashion according to device requirements

SOURCE: TELECOM ADVISORY SERVICES COMPILATION

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

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

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

TABLE B-5. PERFORMANCE OF WI-FI 6E OPERATING IN THE 2.4GHZ, 5GHZ AND 6 GHZ BANDS

Scenario	**Number of Channels** (A)	**Bandwidth by Channel** (B)	**Spatial Streams** (C)	**Resource Units** (D)	**Maximum Devices per Resource Unit** (E)	**BPS**	**CE**	**TT** (µs)	**Total Number of Devices** (A*E)	**Channel Speed** (V=C*D*CE/T) (Mbps)
1	88	20	1	26 (2MHz)	9	10	5/6	13.6	792	15.93
2	88	20	2	26 (2MHz)	9	10	5/6	13.6	792	31.86
3	88	20	1	242 (20MHz)	1	10	5/6	13.6	88	148.28
4	43	40	1	484 (20MHz)	1	10	5/6	13.6	43	296.57
5	43	40	2	484 (20MHz)	1	10	5/6	13.6	43	593.14
6	18	160	2	980	1	10	5/6	13.6	18	1,200.98

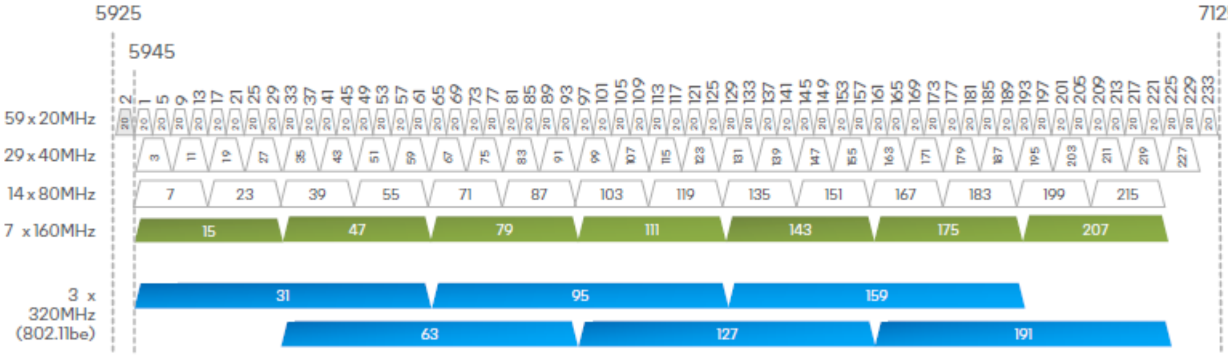
Under this case, the feasible performance of scenarios discounted from the theoretical case, are estimated as follows:

- Scenario 1 (feasible): this scenario allows 88 channels of 20 MHz. Under the largest number of resource units by channel (26 RU), Wi-Fi 6E can handle a maximum of 792 of 1 spatial streams users, at a maximum speed of 11.15 Mbps.
- Scenario 2 (feasible): this scenario allows 88 channels of 20 MHz. Under the largest number of resource units by channel (26 RU), Wi-Fi 6E can handle a maximum of 792 of 2 spatial streams users, with a maximum speed of 22.30 Mbps.
- Scenario 3 (feasible): this scenario allows 88 channels of 20 MHz. Under the largest number of resource units by channel (242 RU), Wi-Fi 6E can handle a maximum of 88 of 1 spatial stream users, with a maximum speed of 103.79 Mbps.
- Scenario 4 (feasible): this scenario allows 43 channels of 40 MHz. Under the largest number of resource units by channel (484 RU), Wi-Fi 6E can handle a maximum of 43 of 1 spatial stream users, with a maximum speed of 207.59 Mbps.
- Scenario 5 (feasible): this scenario allows 43 channels of 40 MHz. Under the largest number of resource units by channel (484 RU), Wi-Fi 6E can handle a maximum of 43 of 2 spatial stream users, with a maximum speed of 415.19 Mbps.

C.4. Wi-Fi 7 Performance Under 2.4 GHz, 5 GHz, & 6 GHz Bands

One difference between Wi-Fi 6E and Wi-Fi 7 is that the maximum channel bandwidth of the 802.11ax standard (Wi-Fi 6E) is 160MHz, whereas for Wi-Fi 7 (802.11be) the maximum allowed channel bandwidth is 320MHz. This feature allows doubling the maximum channel bandwidth and improving its maximum speed. Moreover, both technologies can operate in the 2.4 GHz, 5 GHz and 6 GHz frequency bands (see Figure C-2).

FIGURE C-2. FREQUENCY BAND AND CHANNEL WIDTH FOR WI-FI 6E AND WI-FI 7



SOURCES: INTEL (2023), "NEXT GENERATION WI-FI: SPECTRUM NEEDS OF WI-FI 7"

In addition, with respect to Wi-Fi 6E, 802.11be technology introduces a combination of new features such as MRU (Multiple Resource Units), MLO (Multilink operation), maximum 4096-QAM modulation and spatial stream scaling (16SS), to improve spectral efficiency, increase speed and support many devices in a single area.

In this context, if we consider a scenario for a single user per channel, using 802.11be technology (Wi-Fi 7), the assumptions for determining the theoretical maximum speed would be fourfold: (i) the technology could be executed in a maximum channelization of 320 MHz (in the 6 GHz band), (ii) the maximum number of subchannels occupied by that user would be 3920 resource units (RU) in the entire allocated bandwidth (see Figure 1), (iii) the maximum modulation would be 4096-QAM with a transmission rate (BPS) of 12 bits per symbol and error correction (EC) rate of 5/6; and, (iv) the transmission time (TT) per symbol is considered to be 12.8µs and its guard interval in 0.8µs. Thus, the maximum speed achieved in this scenario can be 2.8 Gbps (see Eq.2) for 1SS (spatial stream) or 46 Gbps[99] for 16SS (maximum spatial stream allowed).

$$(Eq.2)\quad V_{max} = \frac{BPS.CE}{TT} * RU * SS = \frac{12\ bps.\frac{5}{6}}{13.6x10^{-6}\ seg} * (3920) * 1 = 2{,}882.35\ Mbps$$

$$V_{max} = \frac{BPS.CE}{TT} * RU * SS = \frac{12\ bps.\frac{5}{6}}{13.6x10^{-6}\ seg} * (3920) * 16 = 46{,}117.65\ Mbps$$

Regarding the maximum bandwidth per channel allowed by Wi-Fi 6 technology (160MHz), the theoretical maximum speed for Wi-Fi 7 exceeds Wi-Fi 6 by 1.6 Gbps with 1 spatial stream (58.33%) and 36.5 Gbps (79.17%) with the maximum spatial stream capacity established by each standard (Wi-Fi 6: 8 SS and Wi-Fi 7: 16 SS).

C.4.1. Multiple Resource Units (MRU)

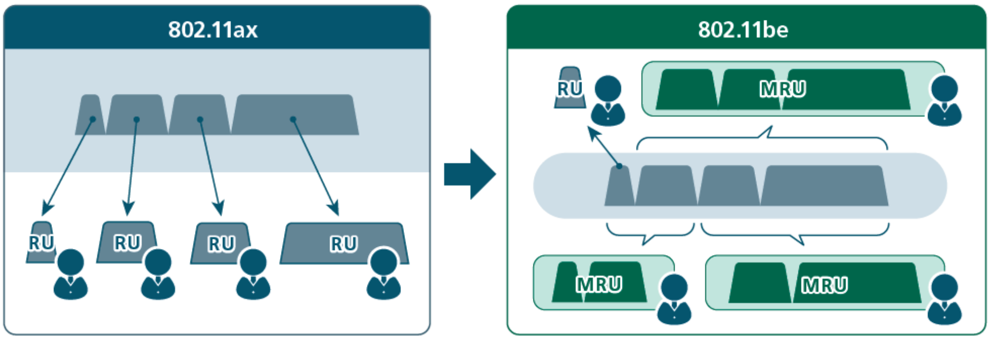
A key differentiator of IEEE 802.11be is the ability to assign more than one resource unit to a single user. Assigning multiple resource units (MRUs) per user provides flexibility to take advantage of frequency diversity and efficiently allocate resources within the spectrum.

---

[99] Ward, L; Kopp, J. (2022). "IEEE 802.11be Technology Introduction".

The large RU combinations allowed are used to achieve an aggregate bandwidth that would not be possible with a single RU. For example, using MRUs of 484 plus 242 tones on an 80 MHz channel would produce an aggregate bandwidth of 60 MHz, but supporting MRUs of 484 plus 484 tones on an 80 MHz channel would result in an aggregate bandwidth of 80 MHz, which could be obtained using a single channel. In other words, this feature allows the use of unoccupied resources from other channels that can be pooled to increase the bandwidth and speed that a user may require. This achieves greater resource utilization and spectral efficiency (see Figure C-3).

FIGURE C-3. CHANNEL ASSIGNMENT FOR WI-FI 6E AND WI-FI 7



SOURCE: ANRITSU. (2022). "KEY TECHNOLOGIES FOR IEEE 802.11BE (WI-FI 7)."

C.4.2. Multiple Operating Links (MLO)

This feature allows the aggregation of multiple channels or frequency bands to improve or increase the bandwidth, and thus the maximum theoretical speed. Using the multi-link feature in the 6 GHz band, where a wider range of channels is available, can achieve a transmission rate of more than 100 Gbps (see Table C-6).

TABLE C-6. ESTIMATED MAXIMUM TRANSMISSION RATE PER NUMBER OF AVAILABLE CHANNELS.

Number of Channels	**Modulation Configuration** (4096QAM-16SS)		**Maximum Speed Rate**
	BAND (GHZ)	CHANNEL WIDTH	
2	6	320 MHz x 2 channels	92 Gbps
3	6	320 MHz x 3 channels	138 Gbps
4	5/6	80 MHz x 1 channel + 320 MHz x 3 channels	149 Gbps
11	2.4/5/6	40 MHz x 2 channels + 80 MHz x 2 channels + 160 MHz x 7 channels	194 Gbps

SOURCE: ANRITSU. (2022). "KEY TECHNOLOGIES FOR IEEE 802.11BE (WI-FI 7)."

Channel aggregation uses two or more links for transmission. MLO can be used to dynamically allocate channel links depending on the number of users. Thus, for example, fewer users on the medium means that latency due to channel access retries is reduced.

C.4.3. Latency

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

TABLE C-7. SUMMARY OF LATENCY AND THROUGHPUT REQUIREMENTS FOR INDUSTRIAL APPLICATION USE CASES

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

SOURCE: INTEL (2023), "NEXT GENERATION WI-FI: SPECTRUM NEEDS OF WI-FI 7"

Initially, a comparison of the technical aspects on latency for Wi-Fi 6, a Wi-Fi Alliance analysis[100] refers to field tests conducted by Qualcomm Technologies in three environments: home, office and classrooms, where the response of sending information is reduced by 40%, 53% and 93%, respectively (see Table C-8).

TABLE C-8. LATENCY SCENARIOS IN USE CASES FOR WI-FI 6 ENVIRONMENTS.

ENVIRONMENTS	LATENCY (MS) DOWNLOAD (DL)	% DL LATENCY REDUCTION	LATENCY (MS) UPLOAD (UL)	% LATENCY REDUCTION UL
Home (Normal)	15	40	76	63
Home (Wi-Fi 6)	9		28	
Office (Normal)	53	53	70	23
Office (Wi-Fi 6)	25		54	
Classroom (Normal)	452	93	5,875	99
Classroom (Wi-Fi 6)	31		66	

SOURCE: WI-FI ALLIANCE

According to INTEL, Wi-Fi 7 will reduce latency and jitter and increase transmission reliability to meet the QoS requirements of various applications. This technology provides enhanced support for existing indoor and outdoor residential and enterprise deployments, while enabling vertical and industrial IoT applications that require an advanced level of determinism and reliability performance.

Importantly, within the findings of the INTEL (2023) study, it is determined that network performance with Wi-Fi 7 technology for emerging residential, enterprise and industrial (delay-sensitive) applications such as AR/VR and industrial IoT is affected by the amount of available spectrum. In isolated, lightly loaded scenarios with a single 320 MHz channel, the end-to-end delay of AR/VR packets can remain below the target level of

---

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

10 ms for 99.9% of the time. However, in environments characterized by moderate to high traffic load, e.g., enterprises, homes, access points, it is demonstrated that a single 320 MHz channel would not be able to maintain the end-to-end delay and reliability requirements of AR/VR applications. Only the availability of three or more non-overlapping 320 MHz channels could cope with the increased demand and maintain performance at acceptable levels even in heavily loaded scenarios.

Thus, the following is a summary of the relevant quantitative aspects that promote an improvement in the indicators between Wi-Fi 6E and Wi-Fi 7. Among them are: (i) data transmission rate related to speed, (ii) latency, and (iii) number of users. In general, Wi-Fi 7 can also be used under the 2.4, 5 and 6 GHz bands according to the following characteristics (see table C-9).

TABLE C-9. WI-FI 7 PARAMETERS

Commercial denomination		Wi-Fi 7
IEEE standard		802.11 be
Frequency bands		2.4GHz, 5 GHz y 6GHz
Industrial, Scientific and Medical (ISM) band		(B1) 2412-2472: 60MHz (ISM)
UNII (Unlicensed National Information Infrastructure)		(B2i) 5170-5330: 160MHz (UNII-1-2) (B3) 5490-5730: 240MHz (UNII-2Ex) (B4) 5735-5835: 100MHz (UNII-3) (B5) 5925-6425: 500MHz (UNII-5) (B6i) 6425-6525: 100MHz (UNII-6) (B7) 6525-6875: 350MHz (UNII-7) (B8i) 6875-7125: 250MHz (UNII-8)
Total available bandwidth (MHz)		1760
Possible channelization		20MHz, 40 MHz, 80MHz, 160MHz, 320MHz
Maximum number of channels	20 MHz	88
	40 MHz	43
	80 MHz	21
	160 MHz	9
	320 MHz	4
Maximum allowed modulation (QAM)		4096
Maximum speed (Mbps) 1SS		2,882.35
Maximum medium access		OFDMA
Type of transmission		MU-MIMO
Maximum spatial streams (SS)		16
Maximum speed (Mbps) under maximum spatial streams		46,117.65
Improvement relative to Wi-Fi 6E		Improvement of modulation technique in order to reach faster speeds y larger bandwidth to accommodate more devices

SOURCE: TELECOM ADVISORY SERVICES COMPILATION

Relying on equation 1 and based on the Wi-Fi 7 characteristics presented above, we can estimate the maximum speed for 40 MHz bandwidth with 484 resource units (one user per channel) and 1 spatial stream.

$$Velocidad = \frac{BPS.CE}{TT} * RU * SS = \frac{12bps.\frac{5}{6}}{13.6\ us} * (484) * 1 = 355.88\ Mbps$$

In a similar way, we calculate the theoretical performance levels for different scenarios (see table C-10).

TABLE C-10. THEORETICAL PERFORMANCE OF WI-FI 7 OPERATING IN THE 2.4GHZ, 5GHZ AND 6 GHZ BANDS

Scenario	**Number of Channels** (A)	**Bandwidth by Channel** (B)	**Spatial Streams** (C)	**Resource Units** (D)	**Maximum Devices per Resource Unit** (E)	**BPS**	**CE**	**TT** (µs)	**Total Number of Devices** (A*E)	**Channel Speed** (V=C*D*CE/T) (Mbps)
1	88	20	1	26 (2MHz)	9	12	5/6	13.6	792	19.12
2	88	20	2	26 (2MHz)	9	12	5/6	13.6	792	38.24
3	88	20	1	242 (20MHz)	1	12	5/6	13.6	88	177.94
4	43	40	1	484 (40MHz)	1	12	5/6	13.6	43	355.88
5	43	40	2	484 (40MHz)	1	12	5/6	13.6	43	711.76

As indicated in table 10, the key improvement under Wi-Fi 7 relative to Wi-Fi 6E is that by accessing the 6 GHz band with a 320MHz configuration channels and better way of modulation technique (4096-QAM). These features allow increasing speed. Under this case, the feasible performance of scenarios is as follows:

- Scenario 1 (feasible): this scenario allows 88 channels of 20 MHz. Under the largest number of resource units by channel (26 RU), Wi-Fi 7 can handle a maximum of 792 of 1 spatial streams users, at a maximum speed of 13.38 Mbps.
- Scenario 2 (feasible): this scenario allows 88 channels of 20 MHz. Under the largest number of resource units by channel (26 RU), Wi-Fi 7 can handle a maximum of 792 of 2 spatial streams users, with a maximum speed of 26.76 Mbps.
- Scenario 3 (feasible): this scenario allows 88 channels of 20 MHz. Under the largest number of resource units by channel (242 RU), Wi-Fi 7 can handle a maximum of 88 of 1 spatial stream users, with a maximum speed of 124.55 Mbps.
- Scenario 4 (feasible): this scenario allows 43 channels of 40 MHz. Under the largest number of resource units by channel (484 RU), Wi-Fi 7 can handle a maximum of 43 of 1 spatial stream users, with a maximum speed of 249.11 Mbps.
- Scenario 5 (feasible): this scenario allows 43 channels of 40 MHz. Under the largest number of resource units by channel (484 RU), Wi-Fi 7 can handle a maximum of 43 of 2 spatial stream users, with a maximum speed of 498.23 Mbps.

C.5. Wi-Fi 7 Performance Under the 2.4 GHz, 5 GHz, 6 GHz & 7GHz (7125-7250) Bands

Wi-Fi 7 could be used in the 2.4 GHz, 5 GHz, 6 GHz and the lower part of 7 GHz band (7125 MHz – 7250 MHz) bands according to the following performance features (see table C-11).

TABLE C-11. WI-FI 7 (7125 – 7250 MHZ) PARAMETERS

Commercial denomination		Wi-Fi 7
IEEE standard		802.11 be
Frequency bands		2.4GHz, 5 GHz, 6GHz, 7GHz (7125-7250)
Industrial, Scientific and Medical (ISM) band		(B1) 2412-2472: 60MHz (ISM)
UNII (Unlicensed National Information Infrastructure)		(B2i) 5170-5330: 160MHz (UNII-1-2) (B3) 5490-5730: 240MHz (UNII-2Ex) (B4) 5735-5835: 100MHz (UNII-3) (B5) 5925-6425: 500MHz (UNII-5) (B6i) 6425-6525: 100MHz (UNII-6) (B7) 6525-6875: 350MHz (UNII-7) (B8i) 6875-7125: 250MHz (UNII-8) (B9) 7125 MHz – 7250MHz: 125MHz
Total available bandwidth (MHz)		1885
Possible channelization		20MHz, 40 MHz, 80MHz, 160MHz, 320MHz
Maximum number of channels	20 MHz	94
	40 MHz	46
	80 MHz	22
	160 MHz	9
	320 MHz	4
Maximum allowed modulation (QAM)		4096
Maximum speed (Mbps) 1SS		2,882.35
Maximum medium access		OFDMA
Type of transmission		MU-MIMO
Maximum spatial streams (SS)		16
Maximum speed (Mbps) under maximum spatial streams		46,117.65
Improvement relative to Wi-Fi 7 up to 6 GHz band only		Increase of bandwidth to accommodate a larger number of users with similar speeds

SOURCE: TELECOM ADVISORY SERVICES COMPILATION

It is important to consider that bandwidth for the application of Wi-Fi 7 technology would be increased in the spectrum between 7125MHz and 7250MHz; that is, 125 MHz in the lower part of the 7 GHz band, which corresponds to an additional 9.43% bandwidth. This variation, at a technical level, compared to previous Wi-Fi 7 usage characteristics over the 6 GHz band (5925 MHz - 7125 MHz) mainly increases the number of connections and theoretical maximum users. Initially, the 125 MHz increase could increase the maximum channelization to 320 MHz, enabling the simultaneous use of users or connections with similar maximum speed characteristics.

For the case of maximum available users, the difference with Wi-Fi 7 related to access to 1,200MHz of the 6 GHz band, there is a 14.29% higher capacity. The value is calculated as follows:

$$Diference = \frac{Total\ Channels_{WiFi7-7Ghz} - Total\ Channels_{WiFi7-6Ghz}}{Total\ Channels_{WiFi7-7GHz}} = \frac{7-6}{7} = \frac{1}{7} = 14.29\%$$

See results in Table C-12.

TABLE C-12. DIFFERENCE BETWEEN WI-FI 7 (1,200MHZ) & WI-FI 7 (1,325MHZ) ON MAXIMUM AVAILABLE USERS

Band Feature	2.4 GHz	5 GHz	6 GHz	7 GHz (125MHz)	Difference
Maximum Indoor Channelization	40 MHz	160 MHz	320 MHz	320 MHz	-
Maximum Indoor Channels	1	2	3	1	
Maximum Resource Units (RU)	242	1,960	3,920	3,920	
Users by RU	1	1	1	1	
Maximum Users	1	2	3	1	14.29%
Total simultaneous users	7				

ANALYSIS AND CALCULATIONS: TELECOM ADVISORY SERVICES

For the case of maximum available connections, the difference with Wi-Fi 7 is related to the access to 1,200MHz of the 6 GHz band, with a 20% higher capacity, which is calculated according to the following formula:

$$Diference = \frac{Total\ Channels_{WiFi7-7GHz} - Total\ Channels_{WiFi7-6GHz}}{Total\ Channels_{WiFi7-7GHz}} = \frac{5-4}{5} = \frac{1}{5} = 20\%$$

See results in Table C-13.

TABLE C-13. DIFFERENCE BETWEEN WI-FI 7 (1,200MHZ) AND WI-FI 7 (1,325MHZ) ON MAXIMUM AVAILABLE CONNECTIONS

Band Feature	2.4 GHz	5 GHz	6 GHz	7 GHz (125MHz)	Difference
Maximum outdoor channelization	40 MHz	160 MHz	320 MHz	320 MHz	-
Maximum outdoor channels	1	1	2	1	
Maximum Resource Units (RU)	242	1,960	3,920	3,920	
Connections by RU	1	1	1	1	
Maximum Connections	1	1	2	1	20%
Total simultaneous connections	5				

ANALYSIS AND CALCULATIONS: TELECOM ADVISORY SERVICES

Relying on equation 1 and based on the Wi-Fi 7 operating in the lower part of 7 GHz band only, we estimate the maximum speed for 20 MHz bandwidth with 242 resource units (one user per channel) and 1 spatial stream.

$$Speed = \frac{BPS.CE}{TT} * RU * SS = \frac{12bps.\frac{5}{6}}{13.6\ us} * (242) * 1 = 177.94\ Mbps$$

In a similar way as the cases above, we calculate the theoretical performance levels for different scenarios (see table C-14).

TABLE C-14. PERFORMANCE OF WI-FI 7 OPERATING IN THE 2.4GHZ, 5GHZ, 6 GHZ AND 7GHZ (7125-7250) BANDS

Scenario	**Number of Channels** (A)	**Bandwidth by Channel** (B)	**Spatial Streams** (C)	**Resource Units** (D)	**Maximum Devices per Resource Unit** (E)	**BPS**	**CE**	**TT** (µs)	**Total Number of Devices** (A*E)	**Channel Speed** (V=C*D*CE/T) (Mbps)
1	94	20	1	26 (2MHz)	9	12	5/6	13.6	846	19.12
2	94	20	2	26 (2MHz)	9	12	5/6	13.6	846	38.24
3	94	20	1	242 (20MHz)	1	12	5/6	13.6	94	177.94
4	94	20	2	242 (20MHz)	1	12	5/6	13.6	94	355.88
5	46	40	2	484 (40MHz)	1	12	5/6	13.6	46	711.76

As indicated in table C-14, the key improvement under Wi-Fi 7 up to 6 GHz only relative to Wi-Fi 7 operating up to lower part of 7 GHz band (7125 -7250 MHz), we increase the number of users with no improvement in speed relative to the use of Wi-Fi 7 operating in the 6 GHz band with a similar number of resource units. Under this case, the feasible performance of scenarios is as follows:

- Scenario 1 (feasible): this scenario allows 94 channels of 20 MHz. Under the largest number of resource units by channel (26 RU), we could handle a maximum of 846 of 1 spatial streams users, at a maximum speed of 13.38 Mbps.

- Scenario 2 (feasible): this scenario allows 94 channels of 20 MHz. Under the largest number of resource units by channel (26 RU), we could handle a maximum of 846 of 2 spatial streams users, with a maximum speed of 26.76 Mbps.

- Scenario 3 (feasible): this scenario allows 94 channels of 20 MHz. Under the largest number of resource units by channel (242 RU), we could handle a maximum of 94 of 1 spatial stream users, with a maximum speed of 124.55 Mbps.

- Scenario 4 (feasible): this scenario allows 94 channels of 20 MHz. Under the largest number of resource units by channel (242 RU), we could handle a maximum of 94 of 2 spatial stream users, with a maximum speed of 249.11 Mbps.

- Scenario 5 (feasible): this scenario allows 46 channels of 40 MHz. Under the largest number of resource units by channel (484 RU), we could handle a maximum of 43 of 2 spatial stream users, with a maximum speed of 498.23 Mbps.

C.6. Wi-Fi 7 Performance Under The 2.4 GHz, 5 GHz, 6 GHz And 7 GHz (7250-7625 MHz) Bands

Wi-Fi 7 could also be used in the 2.4 GHz, 5 GHz, 6 GHz and middle part of 7 GHz band (7250 MHz – 7625 MHz) bands according to the following performance features (see table C-15).

TABLE C-15. WI-FI 7 (7250 – 7625 MHZ) PARAMETERS

Commercial denomination		Wi-Fi 7
IEEE standard		802.11 be
Frequency bands		2.4GHz, 5 GHz, 6GHz, 7GHz (7250-7625)
Industrial, Scientific and Medical (ISM) band		(B1) 2412-2472: 60MHz (ISM)
UNII (Unlicensed National Information Infrastructure)		(B2i) 5170-5330: 160MHz (UNII-1-2) (B3) 5490-5730: 240MHz (UNII-2Ex) (B4) 5735-5835: 100MHz (UNII-3) (B5) 5925-6425: 500MHz (UNII-5) (B6i) 6425-6525: 100MHz (UNII-6) (B7) 6525-6875: 350MHz (UNII-7) (B8i) 6875-7125: 250MHz (UNII-8) (B9) 7125 MHz – 7250MHz: 125MHz (B10) 7250 MHz – 7625MHz: 375MHz
Total available bandwidth (MHz)		2260
Possible channelization		20MHz, 40 MHz, 80MHz, 160MHz, 320MHz
Maximum number of channels	20 MHz	112
	40 MHz	55
	80 MHz	26
	160 MHz	11
	320 MHz	5
Maximum allowed modulation (QAM)		4096
Maximum speed (Mbps) 1SS		2,882.35
Maximum medium access		OFDMA
Type of transmission		MU-MIMO
Maximum spatial streams (SS)		16
Maximum speed (Mbps) under maximum spatial streams		46,117.65
Improvement relative to Wi-Fi 7 up to lower part of 7 GHz band (7125-7250 MHz)		Increase of bandwidth to accommodate a larger number of users with similar speeds

Relative to the previous section, there is the possibility of accessing additional spectrum space, which would increase bandwidth in the range between 7250MHz and 7625MHz; that is, 375 MHz in the 7 GHz band, which corresponds to an additional 29.41% bandwidth with respect to the initial scenario (1,200 MHz).

$$\Delta Spectrum = \frac{S_{WiFi7''} - S_{WiFi6E}}{S_{WiFi7''}} = \frac{1{,}700MHz - 1{,}200MHz}{1{,}700MHZ} = \frac{500}{1{,}700} = 29.41\%$$

This change, compared to previous Wi-Fi 7 usage of the 6 GHz band (5.925 MHz - 7.125 MHz), increases the number of connections and theoretical maximum users. Initially, the 375 MHz increase could increase the maximum channelization to 320 MHz, enabling the increase in simultaneous users or connections with similar maximum speed characteristics. Compared to Wi-Fi 7 operating under 1,200MHz of the 6 GHz band, this allocation yields a 25% higher capacity under indoor use (see Table C-16).

$$Diference = \frac{Total\ Channels_{WiFi7-7GHz} - Total\ Channels_{WiFi7-6GHz}}{Total\ Channels_{WiFi7-7GHz}} = \frac{8-6}{8} = \frac{2}{8} = 25\%$$

TABLE C-16. DIFFERENCE BETWEEN WI-FI 7 (1,200MHZ OF 6 GHZ) AND WI-FI 7 (1,700MHZ INCLUDES 6 GHZ AND PART OF 7 GHZ) ON MAXIMUM AVAILABLE USERS

Band **Feature**	**2.4 GHz**	**5 GHz**	**6 GHz**	**7 GHz (125MHz+375MHz)**	**Difference**
Maximum Indoor channelization	40 MHz	160 MHz	320 MHz	320 MHz	-
Maximum Indoor Channels	1	2	3	2	
Maximum Resource Units (RU)	242	1,960	3,920	3,920	
Users by RU	1	1	1	1	
Maximum Users	1	2	3	2	25%
Total simultaneous users	8				

ANALYSIS AND CALCULATIONS: TELECOM ADVISORY SERVICES

In the case of maximum available connections (outdoor use), the increase from Wi-Fi 7 operating under 1,200MHz in the 6 GHz band amounts to 33.33% (see Table C-17).

$$Diference = \frac{Total\ Channels_{WiFi7-7GHz} - Total\ Channels_{WiFi7-6GHz}}{Total\ Channels_{WiFi7-7GHz}} = \frac{6-4}{6} = \frac{2}{6} = 33.33\%$$

TABLE C-17. DIFFERENCE BETWEEN WI-FI 7 (1,200MHZ OF 6 GHZ) AND WI-FI 7 (1,700MHZ INCLUDES 6 GHZ AND PART OF 7 GHZ) ON MAXIMUM AVAILABLE CONNECTIONS

Band Feature	2.4 GHz	5 GHz	6 GHz	7 GHz (125MHz)	Difference
Maximum outdoor channelization	40 MHz	160 MHz	320 MHz	320 MHz	-
Maximum outdoor channels	1	1	2	2	
Maximum Resource Units (RU)	242	1,960	3,920	3,920	
Connections by RU	1	1	1	1	
Maximum Connections	1	1	2	2	33.33%
Total simultaneous connections	6				

ANALYSIS AND CALCULATIONS: TELECOM ADVISORY SERVICES

Applying equation 1 for Wi-Fi 7 operating up to middle part of 7 GHz results in a maximum speed for 20 MHz bandwidth with 242 resource units (one user per channel) and 1 spatial stream, yields a speed of 177.94 Mbps.

$$Speed = \frac{BPS.CE}{TT} * RU * SS = \frac{12bps.\frac{5}{6}}{13.6\,us} * (242) * 1 = 177.94\,Mbps$$

In a similar case as the one above, we calculate the theoretical performance levels for different scenarios (see table C-18).

TABLE C-18. THEORETICAL PERFORMANCE OF WI-FI 7 OPERATING IN THE 2.4GHZ, 5GHZ, 6 GHZ AND 7GHZ (7250-7625) BANDS

Scenario	Number of Channels (A)	Bandwidth by Channel (B)	Spatial Streams (C)	Resource Units (D)	Maximum Devices per Resource Unit (E)	BPS	CE	TT (µs)	Total Number of Devices (A*E)	Channel Speed (V=C*D*CE/T) (Mbps)
1	112	20	1	26 (2MHz)	9	12	5/6	13.6	1008	19.12
2	112	20	2	26 (2MHz)	9	12	5/6	13.6	1008	38.24
3	112	20	1	242 (20MHz)	1	12	5/6	13.6	112	177.94
4	112	20	2	242 (20MHz)	1	12	5/6	13.6	112	355.88
5	55	40	2	484 (40MHz)	1	12	5/6	13.6	55	711.76

As indicated in table C-18, the key improvement under Wi-Fi 7 operating up to lower part of 7GHz band relative to Wi-Fi 7 occupying up to middle part of 7GHz band (7250 -7625 MHz), is measured in the number of devices with no improvement in speed under a similar number of resource units. By discounting the theoretical performance due to signal degradation, the feasible performance scenarios is as follows:

- **Scenario 1 (feasible):** this scenario allows 112 channels of 20 MHz. Under the largest number of resource units by channel (26 RU), it can handle a maximum of 1008 of 1 spatial streams users, at a maximum speed of 13.38 Mbps.
- **Scenario 2 (feasible):** this scenario allows 112 channels of 20 MHz. Under the largest number of resource units by channel (26 RU), it can handle a maximum of 1008 of 2 spatial streams users, with a maximum speed of 26.76 Mbps.
- **Scenario 3 (feasible):** this scenario allows 112 channels of 20 MHz. Under the largest number of resource units by channel (242 RU), it can handle a maximum of 112 of 1 spatial stream users, with a maximum speed of 124.55 Mbps.
- **Scenario 4 (feasible):** this scenario allows 112 channels of 20 MHz. Under the largest number of resource units by channel (242 RU), it can handle a maximum of 112 of 2 spatial stream users, with a maximum speed of 249.11 Mbps.
- **Scenario 5 (feasible):** this scenario allows 55 channels of 40 MHz. Under the largest number of resource units by channel (484 RU), it can handle a maximum of 55 of 2 spatial stream users, with a maximum speed of 498.23 Mbps.

APPENDIX D.

IMPACT OF TECHNICAL ANALYSIS ON ASSESSMENT OF ECONOMIC VALUE

Based on the analyses of Wi-Fi performance presented in the prior chapters, the implications for assessing the economic value of Wi-Fi are detailed. Each area of analysis is assessed independently following the sources of value outlined in the study methodology (see table D-1).

TABLE D-1. SOURCES OF WI-FI ECONOMIC VALUE

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

The objective is to calculate, based on the technical analysis developed above, the performance improvement from Wi-Fi 6, Wi-Fi 6E, and Wi-Fi 7 (operating under different spectrum allocations) in the variables driving economic value used in the quantitative model (speed, latency, number of users).

D.1. Savings incurred by Consumers by Accessing Free Wi-Fi in Public Sites

One of the main benefits of Wi-Fi 7 technology is the reduction of latency, and, therefore, an increase in traffic in public places, which depends on the number of connected devices that a Wi-Fi site can host, simultaneously.

If it is considered that the number of total devices (US) that a Wi-Fi site can host depends on the allocated bandwidth (AB), the usage factor (FU), the traffic demand profile of the average user (CM) and the simultaneity factor that depends on the number of devices connected at the same time (FS). Equation 3 specifies their relationship as follows:

$$(Eq.3) \qquad US = \frac{AB}{FS.\sum_{i=1}^{n} CM_i.FU_i}$$

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

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

Demand Profile (DC)

The demand profile represents the maximum download capacity for four types of user requirements (web pages, email, social networking, calls, video, etc.). For calculation purpose, we compile the traffic of an average US user: (i) web page browsing, (ii) video conferencing, (iii) music or video streaming, and (iv) calls and social networks. Traffic by service allows calculating download capacity. For example, when a user is accessing the Internet, if it is considered that a user accesses every 20 seconds one type of the most visited web content, whose average size is around 1.63 MB (1,672.59 KB). Consequently, the maximum capacity assigned to the device is 669.04Kbps (see Table D-2).

TABLE D-2. SIZE AND CAPACITY OF MOST VISITED PAGES IN THE US

TYPE	MOST VISITED PAGES	SIZE (T) KB	CAPACITY (CM) KBPS
Navegation	Google	609.40	$CM = \frac{\bar{T}}{t}.\frac{8\,bits}{1\,byte}$ $= \frac{1{,}672.59KB}{20s}.\frac{8\,bits}{1\,byte} = \mathbf{669.04\ Kbps}$
	YouTube	3,379.20	
	Reddit	197.70	
	Facebook	353.50	
	Amazon	5,017.60	
	Wikipedia	78.30	
	Yahoo	3,788.80	
	Duck Duck Go	24.60	
	Twitter	1,843.20	
	Instagram	1,433.60	
Average size and capacity		1,672.59	669.04

SOURCES: MOST VISITED PAGES USA: SEMRUSH, SIZE PER WEB PAGE: PINGDOM.
TELECOM ADVISORY SERVICES ANALYSIS

In the case of other applications such as video streaming or videoconferencing, the average maximum capacity assigned to the device is around 2,154.51 Kbps (2.10 Mbps) (see Table D-3).

TABLE D-3. APPLICATION CAPACITY

APPLICATIONS	CAPACITY (CM) KBPS
Videoconferencing (e.g., Skype)	3,000
Video streaming (e.g., YouTube)	3,300
Phone calls / Social networks (e.g., WhatsApp)	12.33

SOURCE: WEBPAGE SIZE: PINGDOM

By adding all usage traffic, the average capacity of a device connected to a Wi-Fi site reaches 1,783.14 Kbps (1.74 Mbps) (see Table D-4).

TABLE D-4. CAPACITY OF WEB PAGES AND APPLICATIONS APPLICATIONS AND WEB PAGES

APPLICATIONS * WEBPAGES	CAPACITY (CM) KBPS
Internet browsing	669.04
Broadcast and Streaming (Video)	3,300
Social networks (calling)	12.33
Podcast (Videoconference)	3,000
Average total capacity	1,783.14

SOURCE: TELECOM ADVISORY SERVICES ANALYSIS

Usage Factor (UF)

The usage factor corresponds to the percentage of content accessed by a single device. This value depends on the time or amount of information that the average user collects from the Internet via the Wi-Fi site. The usage factor is calculated by the daily time spent by an average user which, for the most part, is linked to Internet browsing (6h 59m - 32.7%, see Table D-5). According to the U.S. Digital Status Statistics 2023 report published by We Are Social, users spend 70.2% of their time on commonly consumed services; and, 29.8% on other types of services (media content access, video games).

TABLE D-5. COMMON TIME SPENT USING INTERNET APPLICATIONS IN THE US

INTERNET BROWSING	HOURS	MINUTES	TOTAL (H)	% USE
Broadcast and Streaming (Video)	6	59	6.98	32.7%
Social networks (calling)	4	42	4.70	22.0%
Podcast (Videoconference)	2	16	2.27	10.6%
Internet browsing	1	2	1.03	4.8%
Other	4	142	6.37	29.8%

SOURCES: WE ARE SOCIAL; TELECOM ADVISORY SERVICES ANALYSIS

Simultaneity Factor

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

Bandwidth

Considering that a Wi-Fi site uses the outdoor spectrum portions, the useful bandwidth in the 6 GHz band corresponds to 850 MHz (UNII-5 and UNII-7) while, for the bandwidth increase scenarios in the lower part of the 7 GHz band (7125 MHz - 7250 MHz) there are 125 MHz; and, in addition, and 375 MHz additional in the portion of the 7 GHz band that corresponds to the range 7250 MHz - 7625 MHz.

Users

According to equation 3, the number of users that could reach a Wi-Fi 6E access point would be 1,528 while, for Wi-Fi 7 operating in the 6 GHz band it would reach 3,091. For the 125 MHz bandwidth increase scenarios (lower part of the 7 GHz band) the maximum number of users is 3,545 while for the additional 375 MHz the maximum number of users is 4,909. Consequently, the percent variation of users that could host an open Wi-Fi site due to Wi-Fi 7 in the 6 GHz band corresponds to 50.57%; while, for the bandwidth increase by 125 MHz in the 7 GHz band corresponds to 56.91% and 68.88% in relation to 375 MHz in the 7 GHz band.

$$Variation_{7-6E} = \frac{US_{WiFi7} - US_{WiFi6E}}{US_{WiFi7}} = \frac{3{,}091 - 1{,}528}{3{,}091} = 50.57\%$$

$$Variation_{7'-6E} = \frac{US_{WiFi7'} - US_{WiFi6E}}{US_{WiFi7}'} = \frac{3{,}545 - 1{,}528}{3{,}545} = 56.91\%$$

$$Variation_{7''-6E} = \frac{US_{WiFi7''} - US_{WiFi6E}}{US_{WiFi7''}} = \frac{4{,}909 - 1{,}528}{4{,}909} = 68.88\%$$

D.2. Free Wi-Fi Service Supporting The Needs Of The Broadband Unserved Population

In this case, the number of new broadband connections that can be connected per free Wi-Fi site and the change in traffic generated by the adoption of a new standard are the determining variables that drive economic impact.

In other words, for both Wi-Fi 6E and Wi-Fi 7, there is an increase in the percentage of traffic that goes through the network, which, in turn, has an impact on the number of additional households served by free Wi-Fi sites that increase every year in locations that allow access to unserved population.

For the case of Wi-Fi 7 with additional 125 MHz (7125-7250 MHz) and 500 MHz (7125-7650 MHz), the percentage increase reported in section 7.1, is assumed to be similar.

D.3. Benefit To Consumers Enjoying Higher Speed From Free Wi-Fi Under Wi-Fi 6E And Wi-Fi 7

To estimate consumer benefit in this case, it is necessary to calculate the speed increase since this is the variable that drives the benefit to users for access in public places. When comparing the different standards, it is important to mention that speed is also determined by the aggregation characteristic of maximum channels assigned for outdoor use within a band. In other words, the maximum speed achieved is directly related to the channelization and number of channels that can be aggregated in a band used by a standard (see Table D-6).

TABLE D-6. NUMBER OF MAXIMUM EXTERNAL CHANNELS

Band Channele Width	**2.4 GHz**	**5 GHz**	**6 GHz**	**7 GHz** (125 MHz)	**7 GHz** (375 MHz)
40 MHz	1				
160 MHz Wi-Fi 6E		2	5		
320 MHz Wi-Fi 7			3		
320 MHz Wi-Fi 7 (125 MHz in 7 GHz)			3	1	
320 MHz Wi-Fi 7'' (375 MHz in GHz)			3	1	1

SOURCE: TELECOM ADVISORY SERVICES ANALYSIS

By applying equation 1, we estimate that the maximum speed for 1 spatial stream in Wi-Fi 6E is 1,200.98 Mbps and for Wi-Fi 7 it is 2,882.35 Mbps, assuming channel aggregation for a maximum occupancy scenario.

$$V_{max-6E} = \frac{BPS.CE}{TT} * RU * SS = \frac{10\ bps.\frac{5}{6}}{13.6x10^{-6}\ seg} * (1960) * 1 = 1{,}200.98\ Mbps$$

$$V_{max-7} = \frac{BPS.CE}{TT} * RU * SS = \frac{12\ bps.\frac{5}{6}}{13.6x10^{-6}\ seg} * (3920) * 1 = 2{,}882.35\ Mbps$$

In sum, we can derive an increase in access speed ranging from 30.56% to 58.33% (see Table D-7).

TABLE D-7. DIFFERENCE BETWEEN ACCESS SPEED IN EXTERNAL CHANNELS

BAND FEATURE	SPEED	CHANNELS MAX.	SPEED PER CONNECTION	DIFFERENCE
Wi-Fi 6E Ch Aggregation speed	1,200.98	5	6,004.90	
Wi-Fi 7 speed 7 MLO	2,882.35	3	8,647.06	30.56%
Wi-Fi 7 speed 7 (125 MHz in 7 GHz) MLO	2,882.35	4	11,529.41	47.92%
Wi-Fi 7 Speed 7 (375 MHz in 7 GHz) MLO	2,882.35	5	14,411.76	58.33%

SOURCE: TELECOM ADVISORY SERVICES ANALYSIS

D.4. Benefit to Consumers Relying on Wi-Fi in Educational Institutions

For this case, we estimate the savings from traffic conducted by Wi-Fi networks operated by educational sites rather than relying on mobile data services. Therefore, although Wi-Fi 6E and Wi-Fi 7 could increase Wi-Fi traffic, we prefer to be conservative and, therefore, not include additional benefit.

D.5. Use of Wi-Fi in Highly Dense Heterogeneous Environments

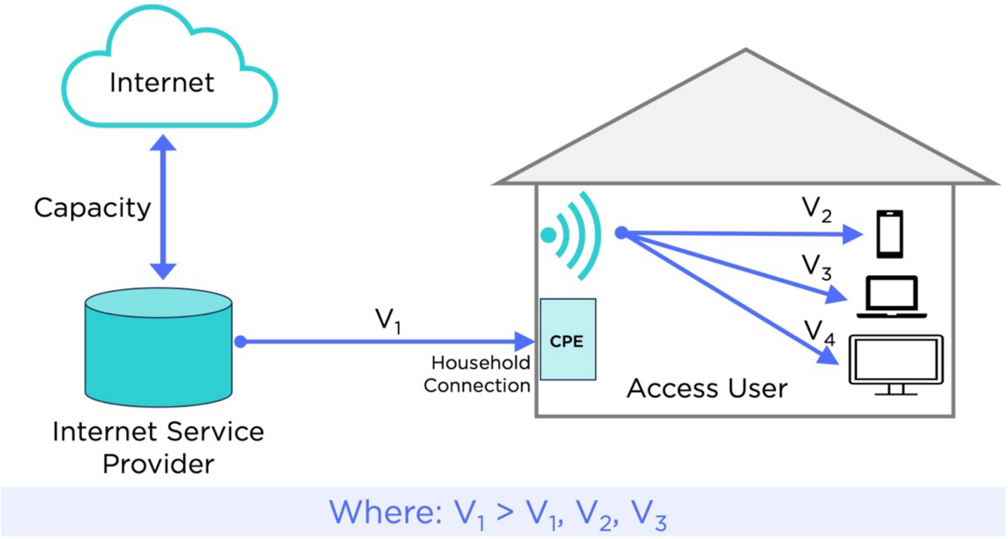
As in section C.7.2, the increase in traffic generated by the adoption of a new standard depends on the number of users connecting at each Wi-Fi site used for high-density scenarios. As a result, there is a direct correlation between the standard and the number of people served in high-density sites.

In general terms, it should be noted that based on the technical characteristics of Wi-Fi 6 or less standards, the implementation of massive access networks, i.e., in places with high user density of people, is not feasible. In the case of Wi-Fi 6E and Wi-Fi 7 there is a positive evolution in the percentage of traffic passing through the network, which increases the number of users connecting in high-density environments.

D.6. Consumer Benefit Derived From Faster Broadband Speed Within The Household

The network elements that play a crucial role in residential speed are the fixed broadband plan contracted with the Internet Service Provider (ISP) and the access mechanism (wired or wireless) by which a user connects[101] to the service. In general terms, the access speed within the home can never be higher than the effective speed of the connection (see Figure D-1).

FIGURE D-1. RELATIONSHIP BETWEEN CONNECTION SPEED AND USER ACCESS



SOURCE: TELECOM ADVISORY SERVICES

Access to the fixed broadband connection through Wi-Fi technology determines the maximum speed that can be accessed by a user device. According to Quotient Associates (Wi-Fi Alliance, 2017), Wi-Fi4 (802.11n) and Wi-Fi5 (802.11ac) standards rely on 2.4 GHz and 5 GHz spectrum bands. Typical channel deployment and theoretical maximum speeds within those standards indicate that 80% of the traffic is generated by devices operating in the 2.4 GHz band[102] (See Table D-8).

TABLE D-8. RELATIONSHIP BETWEEN SPEED AND BANDWIDTH IN THE MOST WIDELY USED WI-FI STANDARDS

SPATIAL STREAMS	TECHNOLOGY	BAND	CHANNEL SIZES			
			20MHz	40MHz	80MHz	160MHz
1x1	802.11n	2.4 & 5 GHz	72 Mbps	150 Mbps		
	802.11ac	5 GHz	87 Mbps	200 Mbps	433 Mbps	867 Mbps

SOURCE: ADAPTED FROM WI-FI ALLIANCE (2017).[103]

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

---

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

[102] Source: Gehlhaus, D et. al (2018) www.rand.org/t/RR2720

[103] Source: Wi-Fi Alliance (2017), "Wi-Fi Spectrum Needs Study." Wi-Fi Alliance, Table 2-1.

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

If a household has 13 devices, the assumptions to determine the theoretical maximum speed at the device level are four: (i) the minimum channelization is 40 MHz, (ii) the maximum number of resource units would be 484 (RU) in each channel, (iii) the maximum modulation would be 1024-QAM with a transmission rate (BPS) of 10 bits per symbol and error correction rate (EC) of 5/6; and, (iv) the transmission time (TT) per symbol is considered to be 12.8µs and its guard interval 0.8µs. In this case, applying equation 1, the maximum theoretical speed reached in this scenario can be 296.57 Mbps for 1 spatial stream (SS), which has to be discounted by 30% due to signal degradation, thus reaching 207.59 Mbps.

The average American household comprises 20 devices according to service providers. Parks Associates based on a survey of 8,000 households estimates that in 2024 there are 19 devices (12 computing ad related equipment, 4 in smart home technology, and 3 in health devices), projected to reach 24 devices by 2027. Therefore, even if a household purchases a fixed broadband plan of 300 Mbps or higher and is equipped with a router with Wi-Fi5 (802.11ac) and has 26 devices, each device receives a Wi-Fi speed of 103.20 Mbps.

If the household is equipped with 21 devices and migrates to a Wi-Fi 6E router relying on the 6 GHz band, the assumptions to determine the theoretical maximum speed are four: (i) the maximum channelization of 80 MHz, (ii) the maximum number of resource units would be 980 (RU) in that bandwidth, (iii) the maximum modulation would be 1024-QAM with a transmission rate (BPS) of 10 bits per symbol and error correction rate (EC) of 5/6; and, (iv) the transmission time (TT) per symbol is considered to be 12. 8µs and its guard interval in 0.8µs. Thus, applying equation 1, the maximum speed reached in this scenario can be 1200.98 Mbps for 2 spatial streams (SS).

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

However, this speed is a theoretical one; in reality, the feasible speed would be 840.68 Mbps. This estimate only considers an average signal degradation rate of 30% for interference (which according to research can reach 50%) and does account for distance between the router and the devices.

If the household is equipped with 22 devices and migrates to a Wi-Fi 7 router relying on 125 MHz in the 7 GHz band, the assumptions to determine the theoretical maximum speed are four: (i) the maximum channelization of 80 MHz, (ii) the maximum number of resource units would be 980 (RU) in that bandwidth, (iii) the maximum modulation would be 1024-QAM with a transmission rate (BPS) of 12 bits per symbol and error correction rate (EC) of 5/6; and, (iv) the transmission time (TT) per symbol is considered to be 12. 8µs and its guard interval in 0.8µs. Thus, applying equation 1, the maximum theoretical speed reached in this scenario can be 1,441.18 Mbps for 2 spatial streams (SS), which discounted for 30% reaches 1,008.82 Mbps.

$$V_{max} = \frac{BPS.CE}{TT} * RU * SS = \frac{12\ bps.\frac{5}{6}}{13.6x10^{-6}\ seg} * (980) * 2 = 1{,}441.18\ Mbps\ (1008.82\ Mbps)$$

In this context, a 22 device home purchasing a 1 Gbps line and relying on a router equipped with Wi-Fi 7 standard operating in the low 125 MHz of the 7 GHz band would be able to deliver (without considering distance degradation) a speed at the device level equivalent to that provided by the ISP. Under an additional allocation of 375 MHz, the home could increase the number of devices by four, without no speed degradation.

D.7. Home Internet Access for Devices that Lack an Ethernet Port

In this case, internet access capacity due to standard upgrading does not indicate a variation due to the lack of a wired port in the home, since internet access through Wi-Fi networks, regardless of the standard used, represents 80%. It should even be noted that, as presented in section 7.7, the adoption of Wi-Fi 6E or Wi-Fi 7 standards yields an increase in the traffic carried inside the home, although for conservative purposes, this proportion was chosen to remain constant. That is, in this case, the impact of the lack of a wired port and without a Wi-Fi connection, assumes that the traffic resolution is generated through a mobile network that could be used by a user in the home. Therefore, no differential effects are included for the standards change of Wi-Fi networks.

Of note, other factors have to be included in this case regarding the use of adaptors for allowing non-Ethernet devices to be able to connect to a wired network.

D.8. Avoidance of Inside Wiring Investment

In this case, the internet access capacity in a home due to the technological upgrade does not present a change due to the investment made for the installation of internal wiring, since it does not influence the operation of Wi-Fi wireless technologies. In this sense, the impact of the internal wiring investment without a Wi-Fi connection, assumes that the household would have to allocate the total cost of internal wiring to access the Internet.

D.9. Consumer Benefit Generated by Use of Residential Wi-Fi Devices & Equipment

The amount of equipment and devices that are distributed and sold nationwide depends on the level of technological adoption of users and its benefit is related to the percentage of adoption of equipment for both Wi-Fi 6E and Wi-Fi 7.

In this sense, the level of adoption of these devices is linked to the percentage of traffic within each standard that is increasing over time.

D.10. Bridging the Digital Divide: Use of Wi-Fi to Increase Coverage in Rural & Isolated Areas

The increase in WISP connections is directly related to the growth of connections according to the scenarios differentiating Wi-Fi 6E from Wi-Fi 7.

In this regard, in order to analyze the impact of the standard upgrade on the increase of connections in homes in rural and isolated areas, two main aspects must be established: (i) the number of maximum outdoor channels influences the number of connections that could be deployed (160MHz for Wi-Fi 6E and 320MHz for Wi-Fi 7); and, (ii) the number of connections for the allocation of resource units with which similar speeds can be achieved in both standards (8 connections with 242 RU for Wi-Fi 6E to reach 1,186.27 Mbps and 32 connections with 102 RU for Wi-Fi 7 to reach 1,200 Mbps) (see Table D-9).

TABLE D-9. OUTDOOR CHANNELS AND RESOURCE UNITS FOR WI-FI 6E AND WI-FI 7

RU	Channelization MHz	20	40	80	160 (Wi-Fi 6E)	320 (Wi-Fi 7)	320 (125MHz)	320 (375MHz)
102 Wi-Fi 7	Channels	41	20	10	5	2	1	1
	Connections by available RU	2	4	8	16	32	32	32
242 Wi-Fi 6E	Channels	41	20	10	5	2	1	1
	Connections by available RU	1	2	4	8	16	16	16

SOURCE: TELECOM ADVISORY SERVICES ANALYSIS

In an initial scenario, the number of connections that Wi-Fi 7 would enable would be 37.5% higher than Wi-Fi 6E operating in the full 6 GHz band (1,200 MHz) (see Equation 4).

$$I_1 = \frac{C_{WiFI7}UR_{WiFi7} - C_{WiFI6E}}{C_{WiFI7}UR_{WiFi7}} = \frac{[(32 * 2) - (8 * 5)]}{(32 * 2)} = \frac{64 - 40}{64} = 37.5\% \ \ (Eq.4)$$

Where:

- C_Wi-Fi 7 represents the number of 320 MHz channels possessed by the Wi-Fi 7 standard (2).
- 〖UR〗 Wi-Fi 7 represents the number of connections available for the subchannels corresponding to the 102 Maximum Resource Units for Wi-Fi 7 (32).
- C_Wi-Fi 6E represents the number of 160 MHz channels owned by the Wi-Fi 6E standard (5).
- 〖UR〗 Wi-Fi 6E represents the number of connections available for the subchannels corresponding to the 242 Maximum Resource Units for Wi-Fi 6E (8).

If the spectrum for Wi-Fi 7 is increased by 125 MHz, the impact would increase by 58.33% with respect to the initial scenario; and, if the spectrum is further increased by an additional 375 MHz, the impact could result in 68.75% more connections with respect to the same scenario.

Thus, the impact is related to the maximum number of simultaneous connections that Wi-Fi 7 could support with respect to its predecessor scenario (see Table D-10 and Equation 5).

TABLE D-10. OUTDOOR CHANNELS AND RESOURCE UNITS FOR ADDITIONAL WI-FI 7 SCENARIOS

BAND **CHARACTERISTIC**	**2.4 GHZ**	**5 GHZ**	**6 GHZ** (WI-FI 7)	**7 GHZ** (125 MHZ)	**7 GHZ** (375 MHZ)
Maximumn channels	40 MHz	160 MHz	320 MHz	320 MHz	320 MHz
Maximum exterior channels	1	1	2	1	1
Connections 125MHz	5				
Connections 375MHz	6				

SOURCE: TELECOM ADVISORY SERVICES ANALYSIS

$$I_2 = \frac{C_{WiFI7'}UR_{WiFi7'} - C_{WiFI6E}UR_{WiFi6E}}{C_{WiFI7'}UR_{WiFi7'}} = \frac{[(32 * 3) - (8 * 5)]}{(32 * 3)} = 58.33\%$$

$$I_3 = \frac{C_{WiFI7''}UR_{WiFi7''} - C_{WiFi6E}UR_{WiFi6E}}{C_{WiFI7''}UR_{WiFi7''}} = \frac{[(32 * 4) - (8 * 5)]}{(32 * 4)} = 68.75\% \ \ \ (Eq.5)$$

From a technical point of view, the 6 GHz band for Wi-Fi 6E outdoor use is defined through the power characteristic of the equipment (standard power); that is, it occupies the U-NII-5 (5925-6425: 500MHz) and U-NII-7 (6525-6875: 350MHz) band classification; while, for indoor use of the technology, it is defined by the low power indoor (LPI) characteristic that could occupy the entire 1,200MHz band. In practical terms, for the installation of this type of networks, this band could support the deployment in rural areas, through the so-called WISPs.

Thus, if we take as an average scenario of Wi-Fi 6E deployment in a 102 RU configuration, for channel aggregation with the 2.4 GHz, 5 GHz and 6 GHz bands, the restriction of the latter band (D Cap), would represent a 27.12% lower deployment capacity of users that would have to be hosted in the lower bands (see Table D-11 and Eq. 6).

TABLE D-11. ANALYSIS OF ALLOWED CONNECTIONS IN WI-FI 6

FEATURES	**2.4 GHz** (20MHz)	**5 GHz** (80MHz)	**6 GHz** (80MHz)	
			UNII-5	UNII-7
Number of outdoor channels	3	4	6	4
Connections in 102 RU	2	8	8	8
Maximum Connections	6	32	48	32

ANALYSIS AND CALCULATIONS: TELECOM ADVISORY SERVICES

$$(Eq.6)\quad \Delta Cap = \frac{Cap_{6GHz\ alta}}{Cap_{6GHz\ total}} = \frac{32}{6+32+48+32} = \frac{32}{118} = 27.12\%$$

Where:

- 〚Cap〛(6GHz high) represents the number of connections of 102 URs in the high part of the 6 GHz band for Wi-Fi 6E that would be constrained.
- 〚Cap〛(6GHz total) represents the number of total connections corresponding to the 102 Maximum Resource Units for Wi-Fi 6E in the 2.4 GHz, 5 GHz and 6 GHz bands.

D.11. Increasing use of Wi-Fi in vehicles

Here, the impact of the introduction of Wi-Fi systems on vehicles (Automotive Over-The-Air) is related to the economic development generated by the industry of wireless equipment installed on board for communication applications between mobile devices and these devices placed in the vehicles.

In this sense, the communication capacity between on-board devices and personal communication equipment does not vary with the introduction of a new technology, since communication takes place independently of the Wi-Fi technology used.

D.12. Benefits Derived From an Increase in Average Speed

In this case, as in section C.7.6, the variation in the average speed over non-Wi-Fi wireless networks shows an improvement when the transmission of information over Wi-Fi wireless networks does not exceed the threshold speed of 150 Mbps for Wi-Fi 6E and 1,186 Mbps for Wi-Fi 7.

In other words, the economic benefit is established on the basis of the increase in speed due to the technological adoption of Wi-Fi 6E and Wi-Fi 7, as well as the percentage of traffic participation of each standard.

D.13. Benefits derived from reduced latency

According to INTEL, Wi-Fi 7 will reduce latency and jitter and increase transmission reliability to meet the quality of service (QoS) requirements of various applications. This technology provides enhanced support for existing indoor and outdoor residential and enterprise deployments, while enabling vertical and industrial IoT applications that require an advanced level of determinism and reliability performance.

Initially, in a comparison of the technical aspects on latency for Wi-Fi 6, a Wi-Fi Alliance analysis refers to field tests conducted by Qualcomm in a home environment where the data delivery response is reduced by 40% (see Table D-12 and Equation 7).

TABLE D-12. LATENCY SCENARIOS IN USE CASES FOR WI-FI 6 ENVIRONMENTS

ENVIRONMENTS	LATENCY (ms) DOWNLOAD (DL)	% LATENCY REDUCTION
Household Wi-Fi 5	15	40%
Household Wi-Fi 6	9	

SOURCE: WI-FI ALLIANCE

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

By means of a practical example of information transmission to quantitatively analyze the latency ratio between Wi-Fi 7 and Wi-Fi 6E, the following considerations are taken into account: (i) transmission of 3 information packets of 1MB size, (ii) 160 MHz transmission channel width for Wi-Fi 6E over a single frequency band (6 GHz - OFDMA), (iii) 160 MHz transmission channel width divided into two 80 MHz channels for Wi-Fi 7 over two frequency bands (5 GHz and 6 GHz - OFDMA, MLO), (iv) occupancy of 242 resource units for Wi-Fi 6E and 102 RU for Wi-Fi 7 corresponding to the maximum channel width to achieve similar rates; and, (v) transmission rate associated with the maximum spatial throughput (1,186. 27 Mbps in 8SS for Wi-Fi 6E and 1,200Mbps in 16SS for Wi-Fi 7).

In this sense, the time it takes for the information packets to arrive from the transmitter to the receiver, occupying each technology is determined by the size and transmission speed. Thus, simplifying the calculation, for Wi-Fi 7, the latency level in this scheme is 50.57% lower than Wi-Fi 6E (see Equation 7, and Equation 8).

$$L_1 = \frac{T}{V} = \frac{3\ MB}{1{,}186.27\ Mbps} = 2.53ms \ \ (Eq.\ 7)$$

$$L_2 = \frac{T}{V} = \frac{1.5\ MB}{1{,}200\ Mbps} = 1.25ms \ \ (Eq.\ 8)$$

$$\Delta L = \frac{2.53ms - 1.25ms}{2.53\ ms} = 50.57\%$$

D.14. Savings in Business Internet Traffic Transmitted through Wi-Fi

On the one hand, demand for new high-performance, low-latency services, such as AR/VR, remote offices, cloud computing and gaming, is increasing rapidly. These applications, which are intended for use in a variety of environments, including homes, enterprises and industrial plants, require improved performance and reliability, reduced latency. Advanced AR/VR applications require 4K-8K video, minimum throughput of 400-2,350 Mbps and maximum transmission/interactivity latency on the order of 10 ms.

In this case, latency determines the traffic variation. In an internal business environment, the latency limit for AR/VR solutions, remote HMI, real-time cyclic control, machine control, production lines is 10ms in Wi-Fi 7 (see table D-13 – Maximum limit of latency in Class B)

TABLE D-13. SUMMARY OF LATENCY AND THROUGHPUT REQUIREMENTS IN INDUSTRIAL APPLICATION USE CASES

APPLICATIONS & REQUIREMENTS	CLASS A	CLASS B	CLASS C
Applications	Interactive video, real-time software control, mobile robotics, automated guided vehicles (AGV)	AR/VR, remote HMI, real-time cyclic control, machine control, production lines	Asynchronous real-time control, motion control, printing, packaging.
Synchronization Time	10-1µs	~1 µs	~1 µs
Latency Limit	50 -10 ms	10 – 1 ms	1ms – 250 µs
Reliability	99% - 99.9%	99.9% - 99.99%	> 99.999%
Performance	High (Video) Low (Control, robotics, AGV)	High (VR) Moderate-Low (control, automation, AR)	Moderate-Low

SOURCE: INTEL (2023), “NEXT GENERATION WI-FI: SPECTRUM NEEDS OF WI-FI 7”

On the other hand, a comparison of technical aspects on latency for Wi-Fi 6, a Wi-Fi Alliance analysis refers to field tests conducted by Qualcomm Technologies in three environments: home, office and classrooms. For the case of latency in indoor office uses, the value is found to be 25 ms (see Table D-14).

TABLE D-14. LATENCY SCENARIOS IN USE CASES OF ENVIRONMENTS FOR WI-FI 6

ENVIRONMENTS	LATENCY (ms) DOWNLOAD (DL)	LATENCY (ms) UPLOAD (UL)
Household Normal	15	76
Household Wi-Fi 6	9	28
Office Normal	53	70
Office Wi-Fi 6	25	54
Classroom Normal	452	5,875
Classroom Wi-Fi 6	31	66

SOURCE: WI-FI ALLIANCE

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

Consequently, the percentage variation of latency between Wi-Fi 6E and Wi-Fi 7 technologies is 60%. Latency is defined as the relationship between the size of the information and the speed, under comparative conditions for each technology; therefore, this relationship does not change if the bandwidth is increased (see Eq. 9).

$$(Ec.9) \quad \Delta Latency_{business} = \frac{L_{WiFi6E} - L_{WiFi7}}{L_{WiFi6E}} = \frac{25 - 10}{25} = \frac{15}{25} = 60\%$$

Where:

- L_Wi-Fi 7 represents the latency for Wi-Fi 7 in industrial environments
- L_Wi-Fi 6E represents the latency for Wi-Fi 6 or Wi-Fi 6E in office

D.15. Avoidance of Enterprise Building Inside Wiring

As in point 7.8, in this case, the internet access capacity in a business environment due to the technological upgrade does not change due to the investment made for the installation of internal cabling, since it does not influence the operation of Wi-Fi wireless technologies.

In that sense, the impact of the internal wiring investment and without a Wi-Fi connection, assumes that the company or industry would have to allocate the total cost of internal wiring to access the Internet.

D.16. Enhanced IoT Deployment

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

For the scenario of occupying the 6GHz band (1200MHz) there would be no increase since Wi-Fi 6E and Wi-Fi 7 under the 6 GHz band would occupy the same amount of spectrum. However, for the scenario of additional allocation of 125 MHz in the 7GHz band, the impact on M2M connections would be 9.43% (see Equation 10), while for the allocation of 500 MHz, the impact on connection metrics would be 29.41% in relation to Wi-Fi 6E technology (see Equation 11).

$$(Eq.10) \quad \Delta Spectrum = \frac{S_{WiFi7'} - S_{WiFi6E}}{S_{WiFi7'}} = \frac{1{,}325 - 1{,}200}{1{,}325} = \frac{125}{1{,}325} = 9.43\%$$

$$(Eq.11) \quad \Delta Spectrum = \frac{S_{WiFi7''} - S_{WiFi6E}}{S_{WiFi7''}} = \frac{1{,}700 - 1{,}200}{1{,}700} = \frac{500}{1{,}700} = 29.41\%$$

Where:

- 'S_Wi-Fi 6E' represents the amount of spectrum allocated for the Wi-Fi 6E standard (1,200 MHz).
- S_Wi-Fi 7' represents the amount of spectrum assigned for the Wi-Fi 7 standard taking into account the 6 GHz band plus the 7,125-7,250 MHz portion (1,325 MHz).
- S_Wi-Fi 7'' represents the amount of spectrum allocated for the Wi-Fi 7 standard taking into account the 6 GHz band plus the 7,125-7,250 MHz and 7,250-7,625 MHz (1,700 MHz) portions.

D.17. Deployment of Augmented Reality/Virtual Reality Solutions

It is possible that latency, both indoor home and outdoor enterprise may influence the number of devices that can be developed and placed in the market. Therefore, it is assumed that the average of these two metrics could directly impact the growth of AR/VR spending.

That is, the impact attributable to the adoption of Wi-Fi standard 6E or higher is indexed to the market share (software, hardware and content) that portion has over the entire set of Wi-Fi standards.

D.18. Cellular Networks CAPEX Savings by Off-Loading Traffic to Wi-Fi

The increase in traffic due to the technological upgrade from Wi-Fi 6E to Wi-Fi 7 has a direct influence on the reduction of CAPEX due to the overflow of mobile traffic to Wi-Fi networks. It is possible to relate the average speed variation with this indicator to establish a relationship between CAPEX and Wi-Fi traffic (see 7.5 section and Table D-15).

TABLE D-15. DIFFERENCE BETWEEN ACCESS SPEED IN EXTERNAL CHANNELS

BAND FEATURE	SPEED	CHANNELS MAX.	SPEED PER CONNECTION	DIFFERENCE
Wi-Fi 6E Ch Aggregation Speed	1,200.98	5	6,004.90	
Wi-Fi speed 7 MLO	2,882.35	3	8,647.06	30.56%
Wi-Fi speed 7' MLO	2,882.35	4	11,529.41	47.92%
Wi-Fi Speed 7'' MLO	2,882.35	5	14,411.76	58.33%

SOURCE: TELECOM ADVISORY SERVICES ANALYSIS

That is, as a new Wi-Fi standard is adopted, speed is the variable that allows us to establish an impact relationship between Wi-Fi network overflow traffic and the mobile network. So, we obtain an increase in access speed from 30.56% to 58.33%.

D.19. Revenues of Wi-Fi Based Public Internet Service Providers

The main variable driving economic value is related to the number of public Wi-Fi access points, which makes the following analysis similar to 7.10. item above. Following that analysis, the number of connections that Wi-Fi 7 would make possible would be 37.5% above Wi-Fi 6E using the full spectrum of the 6 GHz band.

If the spectrum for Wi-Fi 7 is increased by 125 MHz, the impact would augment by 58.33% with respect to the initial scenario. Finally, if the spectrum is increased by an additional 375 MHz, the impact could result in 68.75% more connections with respect to Wi-Fi 6E.

In this regard, in order to analyze the impact of the technological upgrade on the increase of connections in homes in rural and isolated areas, two main aspects must be established: (i) the number of maximum outdoor channels influences the number of connections that could be deployed (160MHz for Wi-Fi 6E and 320MHz for Wi-Fi 7); and, (ii) the number of connections for the allocation of resource units with which similar speeds could be achieved in both standards (8 connections with 242 RU for Wi-Fi 6E to reach 1,186. 27 Mbps and 32 connections with 102 RU for Wi-Fi 7 to reach 1,200 Mbps) (see Table D-16).

TABLE D-16. OUTDOOR CHANNELS AND RESOURCE UNITS FOR WI-FI 6E AND WI-FI 7

RU	Channelization MHz	20	40	80	160 (Wi-Fi 6E)	320 (Wi-Fi 7)	320 (125MHz)	320 (375MHz)
102 Wi-Fi 7	Channels	41	20	10	5	2	1	1
	Connections per available RU	2	4	8	16	32	32	32
242 Wi-Fi 6E	Channels	41	20	10	5	2	1	1
	Connections per available RU	1	2	4	8	16	16	16

SOURCE: TELECOM ADVISORY SERVICES ANALYSIS

In an initial scenario, the number of connections that Wi-Fi 7 would enable would be 37.5% higher than Wi-Fi 6E operating in the full 6 GHz band (1,200 MHz) (see Equation 12).

$$I_1 = \frac{C_{WiFI7}UR_{WiFi7} - C_{WiFI6E}}{C_{WiFI7}UR_{WiFi7}} = \frac{[(32 * 2) - (8 * 5)]}{(32 * 2)} = \frac{64 - 40}{64} = 37.5\% \ \ (Eq. 12)$$

Where:

- C_Wi-Fi 7 represents the number of 320 MHz channels owned by the Wi-Fi 7 standard (2)
- 〖UR〗_Wi-Fi 7 represents the number of connections available for the subchannels corresponding to the 102 Maximum Resource Units for Wi-Fi 7
- C_Wi-Fi 6E represents the number of 160 MHz channels owned by the Wi-Fi 6E standard (5)
- 〖UR〗_Wi-Fi 6E represents the number of connections available for the subchannels corresponding to the 242 Maximum Resource Units for Wi-Fi 6E.

If the spectrum for Wi-Fi 7 is increased by 125 MHz, the impact would increase by 58.33% with respect to the initial scenario; and, if the spectrum is further increased by an additional 375 MHz, the impact could result in 68.75% more connections with respect to the same scenario.

Thus, the impact is related to the maximum number of simultaneous connections that Wi-Fi 7 could support with respect to its predecessor scenario (see Table D-17 and Equation 13).

TABLE D-17. OUTDOOR CHANNELS AND RESOURCE UNITS FOR ADDITIONAL WI-FI 7 SCENARIOS

Characteristic / Band	2.4 GHz	5 GHz	6 GHz (Wi-Fi 7)	7 GHz (125 MHz)	7 GHz (375 MHz)
Maximum channels	40 MHz	160 MHz	320 MHz	320 MHz	320 MHz
Maximim channels for exterior	1	1	2	1	1
Connections 125MHz	5				
Connections 375MHz	6				

SOURCE: TELECOM ADVISORY SERVICES ANALYSIS

$$I_2 = \frac{C_{WiFI7'}UR_{WiFi7'} - C_{WiFI6E}UR_{WiFi6E}}{C_{WiFI7'}UR_{WiFi7'}} = \frac{[(32 * 3) - (8 * 5)]}{(32 * 3)} = 58.33\%$$

$$I_3 = \frac{C_{WiFI7''}UR_{WiFi7''} - C_{WiFi6E}UR_{WiFi6E}}{C_{WiFI7''}UR_{WiFi7''}} = \frac{[(32*4)-(8*5)]}{(32*4)} = 68.75\% \quad (Eq.13)$$

From a technical point of view, the 6 GHz band for Wi-Fi 6E outdoor use is defined through the power characteristic of the equipment (standard power); that is, it occupies the U-NII-5 (5925-6425: 500MHz) and U-NII-7 (6525-6875: 350MHz) band classification; while, for indoor use of the technology, it is defined by the low power indoor (LPI) characteristic that could occupy the entire 1,200MHz space. In practical terms, for the installation of this type of networks, this band could support the deployment in rural areas, through the so-called WISPs.

D.20. Revenues of Wi-Fi Based Wireless Internet Service Providers

The number of WISP-related subscribers increases as the number of connections enabled by Wi-Fi 7 technology increases with respect to Wi-Fi 6E. This results in a 37.5% higher increase due to the adoption of Wi-Fi 7 in the same 6 GHz band, while 58.33% higher increase of subscribers due to an increase of 125MHz in the 7GHz band and 68.75% if an additional 375MHz is increased in the same band.

In other words, WISP revenues are linked to the number of connections that depend on the number of external use channels established for each standard and the frequency band in which it is used.

D.21. Manufacturing of Wi-Fi Devices & Equipment for Residential Use

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

In this sense, the percentage increase in indoor users is linked to the estimated traffic generated by the adoption of each standard, which has a direct impact on the manufacture of equipment for residential use.

D.22. Manufacturing of Enterprise Wi-Fi Devices & Equipment

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

As in section C.7.21, the percentage increase in users of business environments is linked to the estimated traffic generated by the adoption of each standard, which has a direct impact on the manufacture of this equipment.

D.23. Benefits of Firms in the IoT ecosystem

Considering that IoT-related revenue is the main variable in this calculation, it is possible that the total revenue ratio is linked to the amount of assigned spectrum. However, it would be necessary to validate whether only part of the percentage increase in spectrum (125 MHz or 375 MHz) is applicable to this case considering the technological upgrade to Wi-Fi 7. In this sense, while leaving the values that increase the spectrum, it would be important to look for a market-related value rather than a technical one. Finally, regarding the scenario of only use of the 6 GHz band (1,200MHz) there would be no increase since Wi-Fi 6E and Wi-Fi 7 would occupy the same space.

In other words, considering section C.7.16, the indirect impact of the technological upgrade is linked to the additional 125 MHz (9.43%) and 375 MHz (29.41%) that could be allocated in the 7 GHz band for Wi-Fi 7 in relation to Wi-Fi 6E.

D.24. Benefits of Firms in the AR/VR Ecosystem

Similar to point 7.17 it is possible that latency, both indoor home and outdoor enterprise may influence the number of devices that can be developed and placed in the market. Therefore, it is assumed that the average of these two metrics could directly impact the growth of AR/VR spending.

D.25. Benefits of Firms Developing Vehicular Technologies

As in section C.7.11, the impact of the introduction of Automotive Over-The-Air (AOTA) Wi-Fi systems is related to the economic development generated by the on-board wireless equipment industry for communication applications between mobile devices and these devices placed in automobiles.

The communication capacity between on-board devices and personal communication equipment does not change with the introduction of a new technology, since communication takes place independently of the Wi-Fi technology used.

D.26. Compilation of improvement Ratios by Source of Economic Value

TABLE D-18. IMPROVEMENT OF WI-FI STANDARDS & BAND ALLOCATION ON SOURCES OF WI-FI ECONOMIC VALUE (IN PERCENTAGE)

SOURCES	EFFECTS	IMPROVEMENT WI-FI 6E OVER PRIOR STANDARDS			IMPROVEMENT WI-FI 7 ON 6 GHZ OVER WI-FI 6E			IMPROVEMENT WI-FI 7 (125MHz) OVER WI-FI 6E			IMPROVEMENT WI-FI 7 (375MHz) OVER WI-FI 6E		
		Speed (Mbps)	Latency (Ms)	# Users	Speed (Mbps)	Latency (Ms)	# Users	Speed (Mbps)	Latency (Ms)	# Users	Speed (Mbps)	Latency (Ms)	# Users
FREE WI-FI	Savings incurred by consumers by accessing free Wi-Fi in public sites						50.57%			56.91%			68.88%
	Free Wi-Fi service supporting the needs of the broadband unserved population						50.57%			56.91%			68.88%
	Benefit to consumers enjoying higher speed from free Wi-Fi under Wi-Fi 6E, and Wi-Fi 7				30.56%			47.92%			58.33%		
	Benefit to consumers relying on Wi-Fi in educational institutions	While consumers can benefit from additional speed and latency derived from adoption Wi-Fi 6 and Wi-Fi 7 in educational institutions, the effect is calculated over the cost of relying on cellular mobile data services											
	Use of Wi-Fi in highly dense heterogeneous environments	Economic impact in highly dense environments is driven by increase in traffic as a result of user increase and additional use cases											
RESIDENTIAL WI-FI	Consumer benefit derived from faster broadband speed	840.68		21	1008.82		21	1008.82		22	1008.82		26
	Home internet access for devices that lack an Ethernet port	Calculated as share of wireless traffic at home (43.12%) * share of traffic using Wi-Fi (80%)											
	Avoidance of inside wiring investment												
	Consumer benefit generated by use of residential Wi-Fi devices and equipment												
	Bridging the digital divide: use of Wi-Fi to increase coverage in rural and isolated areas			27.12%			37.5%			58.33%			68.75%
	Increasing use of Wi-Fi in vehicles												
ENTERPRISE WI-FI	Benefits derived from an increase in average speed	840.68		21	1186.27			1008.82		22	1008.82		26
	Benefits derived from reduced latency		40%			50.57%			50.57%			50.57%	
	Savings in business Internet traffic transmitted through Wi-Fi					60							
	Avoidance of enterprise building inside wiring												
	Enhanced IoT deployment			0%			0%			9.43%			29.41%
	Deployment of Augmented Reality/ Virtual Reality solutions												
ISPS	Cellular networks CAPEX savings by off-loading traffic to Wi-Fi				30.56%			47.92%			58.33%		
	Revenues of Wi-Fi based Public Internet Service Providers			0%			37.5%			58.33%			27.12%
	Revenues of Wi-Fi based Wireless Internet service Providers			0%			37.5%			58.33%			27.12%
WI-FI ECOSYSTEM	Manufacturing of Wi-Fi devices and equipment for residential use												
	Manufacturing of enterprise Wi-Fi devices and equipment												
	Benefits of Firms in the IoT ecosystem									9.43 %			29.41%
	Benefits of firms in the AR/VR ecosystem												
	Benefits of firms developing vehicular technologies												

BIBLIOGRAPHY

CISCO. (2020). "Wi-Fi 6 OFDMA: Resource unit (RU) allocations and mappings." https://blogs.cisco.com/networking/wi-fi-6-ofdma-resource-unit-ru-allocations-and-mappings.

Consumer Technology Association (2022). "UNLICENSED SPECTRUM AND THE U.S. ECONOMY: Quantifying the Market Size and Diversity of Unlicensed Devices". https://docs.house.gov/meetings/IF/IF16/20230310/115463/HHRG-118-IF16-20230310-SD006.pdf

Ericsson (2019). "Connecting things in the city". https://www.ericsson.com/en/reports-and-papers/mobility-report/articles/connecting-things-in-the-city-wef-edition

Gehlhaus, D; Martin, N; Blumenthal, M; Armour, P; Lastunen, J. (2018). "The Potential Economic Value of Unlicensed Spectrum in the 5.9 GHz Frequency Band: Insights for Future Spectrum Allocation Policy". RAND Social and Economic Well-Being. Santa Monica, California. www.rand.org/t/RR2720

IOT Analytics (2023). "State of IoT 2023". https://iot-analytics.com/number-connected-iot-devices/

National Instruments (2023) "Introduction to 802.11ax High-Efficiency Wireless" https://shorturl.at/jEGL7

Verizon. "How AR and VR technology can enhance IoT applications" https://www.verizon.com/about/blog/vr-and-iot

Wi-Fi Alliance (2017). "Wi-Fi Spectrum Needs Study: Final Report." Quotient Associates Limited. Histon, Cambridge. https://vaunix.com/resources/wi-fi-spectrum-needs-study.pdf

Wi-Fi Alliance (2023). "Special Feature: The Road to WRC-23: Important decision-making that will affect the future of connectivity". https://shorturl.at/szKVY

ANRITSU. (2022). "Key Technologies for IEEE 802.11be (Wi-Fi 7)." https://dl.cdn-anritsu.com/zh-tw/test-measurement/files/Brochures-Datasheets-Catalogs/White-Paper/Wi-Fi 7-er1100.pdf.

INTEL. (2023) "Next Generation Wi-Fi: Spectrum Needs of Wi-Fi 7". https://www.intel.com/content/www/us/en/products/docs/wireless/wi-fi-7/spectrum-needs-of-wi-fi-7.html

Ward, L; Kopp, J. (2022). "IEEE 802.11be Technology Introduction". Page 8, Rohde & Schwarz, https://cdn.rohde-schwarz.com/sg_media/downloads/common_library/brochures_and_datasheets/IEEE-802-11be-technology-introduction_wp_en_3683-4026-52_v0100.pdf

Wi-Fi Alliance (2021). "Reduced latency benefits of Wi-Fi 6 OFDMA". https://shorturl.at/acHLP