LIFTOFF!

Internet Service Providers
Take Flight with Fixed-Wireless
and Hybrid Networks

THE 2021 FIXED-WIRELESS AND HYBRID ISP INDUSTRY REPORT

THE CARMEL GROUP

WISPA

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About This Report

The purpose of this report is to provide an independent, comprehensive, informational resource describing competitive U.S. internet service providers (ISPs) that deliver their services via fixed-wireless or hybrid fiber-wireless infrastructures. This report updates the data and analysis contained in The Carmel Group's 2017 report.[1]

The audience for this report includes ISP industry actors, equipment and software vendors, service providers, policy makers, financial institutions, legal and strategic advisors, industry analysts, and anyone with an interest in the broadband industry. The report should be especially interesting to anyone – from experts to laypersons – interested in closing the digital divisions that crisscross the American economy. The aim is to provide objective data and insights to help readers make informed business, investment, and policy decisions, particularly as they affect this industry.

Our 2017 report was entitled, "Ready for Takeoff" because the industry was poised for accelerated growth. The title of this report, "Liftoff," reflects the strong growth and improving conditions in the industry since then.

METHODOLOGY

This report is based on the author's independent, long-term research, supplemented with original primary and secondary research conducted during the first three quarters of 2020. The recent examination included thirty 90-minute interviews with representatives of fixed-wireless and hybrid fiber-wireless ISPs, their vendors, government agency officials, and others in the industry. Additionally, two in-depth surveys were conducted, involving hundreds of respondents each in two groups: one of hybrid fiber-wireless operators and another of fixed-wireless vendors.

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[1] The Carmel Group, Ready for Takeoff: Broadband Wireless Access Providers Prepare to Soar with Fixed Wireless: The BWA Industry Report: 2017, https://carmelgroup.com/wp-content/uploads/2017/12/TCG_2017_BWA_Full_Report.pdf

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HUDSON VALLEY WIRELESS: The Carmel Group thanks Hudson Valley Wireless for its generous support of this follow-up to the pioneering 2017 report. **hvwisp.com.**

Executive Summary

In the United States at the start of 2021, The Carmel Group estimates that a minimum of 2,800 fixed-wireless-centric operators comprise this rapidly growing and evolving industry.

- **Robust Growth and Maturation:** Fixed-wireless-centric ISPs are continuing to experience robust growth and maturation in the United States.
  - The number of subscribers is projected to rise from 6.9 million at the end of 2020 to 12.7 million by the end of 2025.
  - Core industry revenues are projected to grow from an estimated $4.4 billion annually at the end of 2020 to $10.9 billion by the end of 2025.
- **Multiple Growth Drivers:** There are at least five powerful growth drivers propelling fixed-wireless-centric ISPs to new heights, making them particulary attractive to investors:

  - **Favorable economics and speed:** The economics of fixed-wireless technology enable rapid, reliable, flexible network deployments at a fraction of the cost of other technology platforms. Return on investment (ROI) occurs much more quickly, and consumer and industry demand are addressed more rapidly.

  - **Strong consumer demand:** Demand for broadband connectivity and associated applications has been surging for years and shows no sign of slowing. The COVID-19 pandemic made at-home connectivity more essential than ever. Indeed, today's "work-from-home" trend will persist long after the pandemic. Meanwhile, millions of Americans live in rural and even some urban areas that remain unserved, under-served, or poorly served, creating a large pool of latent demand.

  - **Favorable policy:** Congress and the regulatory agencies have begun to show greater awareness of fixed wireless's role in closing America's broadband gaps. The regulation of spectrum has grown much more favorable for WISPs in recent years, and the positive trends appear likely to continue. Closing those gaps has become a top government priority at nearly every level: federal, state, and local.

Executive Summary

- **Improving technologies and more competition:** New and maturing standards-based technologies in network and antenna hardware, customer premises equipment (CPE), and wireless telecoms software and services are contributing to greater efficiencies and choices for ISPs. The number of technology vendors is growing rapidly, driving competition, innovation, and lower costs.

- **Funding flows:** Unprecedented funding flows from private and public sources are driving more investment.

- **Hybrid Network Trend:** An increasing number of fixed-wireless-centric ISPs are also investing in fiber and other technologies for parts of their networks. Where it makes economic sense, these "hybrid" networks blend the favorable characteristics of fixed wireless with the additional contributions of fiber.

- **Diversification of Operators:** Reflecting the industry's entrepreneurial roots, the majority of fixed-wireless-centric ISPs are relatively small companies with established roots in their local communities. However, a growing number are merging with and acquiring other providers to form larger companies with multi-state service areas. Another subset is developing in under-served urban markets to offer value-oriented competition to established incumbents. Larger telecom and cable companies are also beginning to make significant strategic investments in fixed-wireless infrastructure.

The business and policy case for enhanced support of fixed-wireless and hybrid ISPs is strong for policymakers and investors striving to rapidly build future-proof and sustainable services to fill America's broadband gaps.

- **Strong Business and Policy Case:** The combination of the five growth drivers – favorable economics, significant consumer and industry demand, helpful governmental policies, technology developments, and funding trends – along with persistent broadband gaps and the lack of ISP choices in many rural and urban areas – point to a clear conclusion. The business and policy case for greater support of fixed-wireless and hybrid networks is compelling. Not only does fixed wireless serve U.S. policy goals of rapidly connecting Americans; it also makes good business sense in many communities that are unserved, under-served, or poorly served.

- **Challenges Remain:** Although current and projected growth trends are robust, challenges remain, including obstacles to and from private and public funding; the physical limits of some spectrum bands; competition for spectrum access; powerful and entrenched competitors; and the government's traditional tilt toward incumbents.

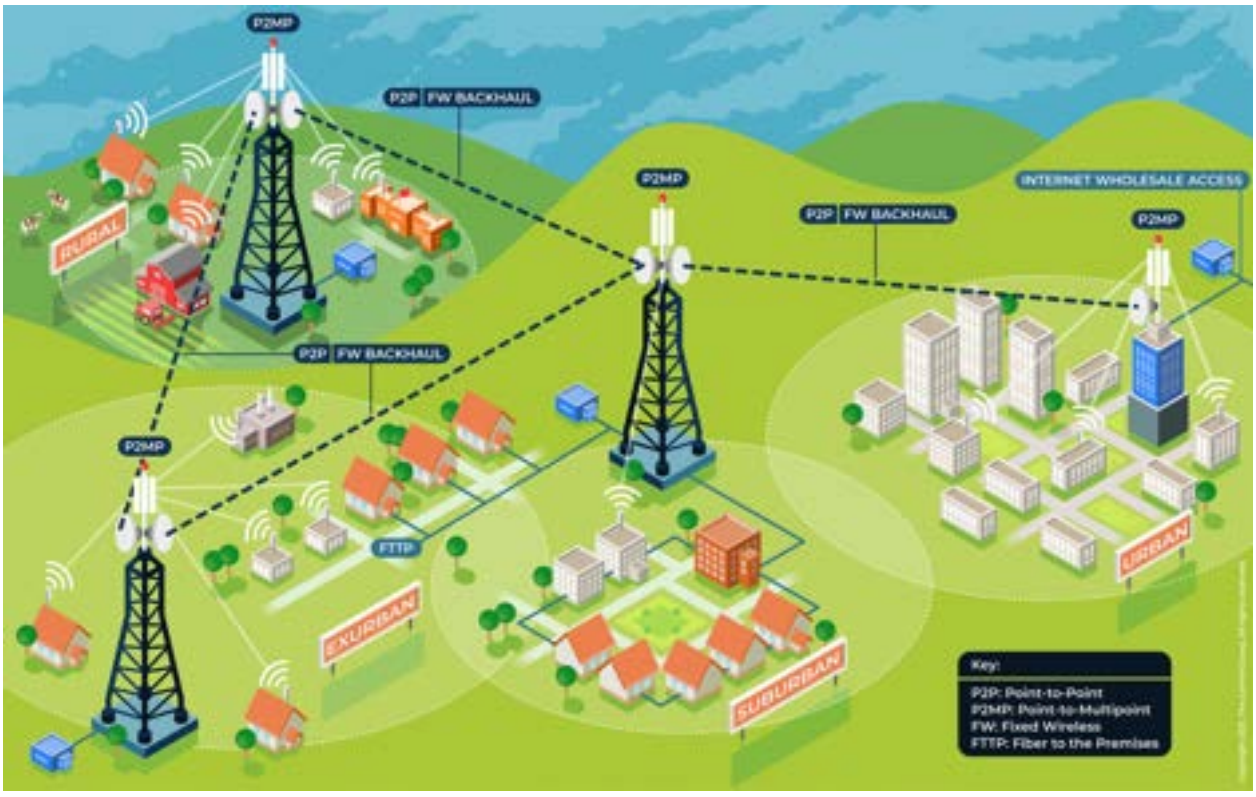
What Are Fixed-Wireless and Hybrid Networks?

ISPs use a variety of network technologies to deliver broadband internet services to customers. The ISPs studied in this report are those using "fixed-wireless" and "hybrid fiber-wireless" networks.

What most people think of as "wireless" networks are those built to serve mobile customers, e.g., to send radio signals from towers to customers on the move. On the other hand, "fixed" wireless refers to the fact that both the senders and receivers of wireless data streams are in fixed locations. For example, the radio transmitters may be on towers or other vertical structures, and the receivers are attached to the customers' premises. This point-to-point (P2P) or point-to-multipoint (P2MP) architecture allows for strong, stable, two-way connections, providing customers with reliable access to the internet.

Fixed-wireless and hybrid fiber-wireless networks are also called by several other names, including Broadband Wireless Access (BWA), Fixed Wireless Access (FWA), Fixed Wireless Hybrid (FWH), Competitive Broadband Provider (CBP), and/or Wireless Local Loop (WLL). Perhaps the most common acronym or nickname is WISP, for Wireless Internet Service Provider.

FIGURE 1: Typical Network Architecture of Fixed-Wireless and Hybrid ISPs



The majority of residential and business internet customers in the United States are served by companies that originated as telephone and/or cable TV providers using ground-based wire or fiber-centric networks. These are collectively called "wireline" networks. Most internet customer premises are still physically wired to the telephone or cable company.

The term "hybrid" refers to the fact that many fixed-wireless-centric ISPs may also have network elements composed of fiber-optic cables. For instance, fiber often serves as the "trunk" or "backhaul" that delivers data from network access points to a provider's P2MP equipment placed on a tower or other vertical structure. The data is then transmitted over the air to the customer premises. Where it makes economic sense, "last-mile" fiber is also being used to distribute high-bandwidth service directly to certain residential and non-residential customers. This hybrid fiber-wireless model and trend are making "future-proof" networks a reality in low-density markets. Hybrid fiber-wireless field teams can use the best mix of technologies to suit unique local conditions.

Although fixed-wireless and hybrid fiber-wireless ISP networks serve a relatively small share of U.S. internet consumers, their favorable economics are driving rapid growth in operators, subscribers, and vendors. This expansion is especially notable in small towns and rural areas that are relatively expensive to serve with wireline solutions. It is also occurring in underserved urban locales. (See, "Case Studies" and "Growth Drivers" below.)

COMMONLY USED FREQUENCIES

Wireless signals are radio signals, and most fixed-wireless and hybrid fiber-wireless ISPs use a mix of radio signal frequencies (also called "spectrum bands") to deliver internet service over the air.

Some of these spectrum bands are "licensed" by the Federal Communications Commission (FCC), which means entities are granted exclusive rights to use a particular spectrum band, subject to various requirements. Other spectrum bands are "licensed-by-rule," meaning the license does not grant exclusive rights or ownership, but does impose certain notice, usage, or other requirements. For example, the Citizens Broadband Radio Service (CBRS) band (3.55 – 3.7 GHz) is managed through an FCC regulatory regime that mitigates interference and allows multiple users to co-exist in the band through Spectrum Access Systems (SAS). And a third set of bands are "unlicensed," meaning they are available to everyone, subject only to FCC device certification, interference mitigation systems, and other requirements. Some unlicensed bands are used for products like baby monitors, garage door openers, and Wi-Fi, creating the potential for signal interference in some locations.

Spectrum bands may be:

- Licensed
- Licensed-by-rule
- Unlicensed

FIGURE 2: Frequencies Most Used by Fixed-Wireless and Hybrid ISPs

FREQUENCY	470-600 MHz	902- 928 MHz	2.4 GHz	2.5 GHz	3.55 – 3.7 GHz	5.15 - 5.35 GHz, 5.47 – 5.85 GHz	5.925-7.125 GHz	24.05-24.25 GHz	57-71 GHz
BAND NAME	TVWS (White Space)	ISM	ISM	EBS/ BRS, 3GPP Band 41	CBRS, 3GPP Band 48	U-NII	U-NII-5, U-NII-7	24 GHz	60 GHz
LICENSE	Exempt (1); database query	Exempt (1)	Exempt (1)	Licensed; usually mobile	GAA exempt (SAS control) or PAL (1)	Exempt (1)	Exempt (requires AFC control)	Exempt (1)	Exempt (1)
OPERATOR UTILIZATION LEVEL (2)	Low; niche	Medium	Medium	Low; leased	Medium; growing	High	Uncer-tain/ pending (2021)	Medium; point-to-point only	Low; growing
AVAILABLE BAND SIZE	Varies By Location	26 MHz	83.5 MHz	186 MHz	150 MHz	Up to 580 MHz	Up to 850 MHz	200 MHz	14 GHz
NON-LINE OF SIGHT PERFORMANCE	Excellent	Excellent	Fair	Good	Fair	Poor	Pending	None	None
PRIMARY TECHNOLOGY	Propri-etary TDD	Propri-etary TDD	802.11 variants	TDD-LTE	Mixed: TDD-LTE, Propri-etary non-LTE	Propri-etary TDD, some LTE-U, LAA	802.11 variants; propri-etary TDD, some LTE-U	Propri-etary	802.11 ad, 802.11ay variants, including Terra-graph

(1) "Exempt" includes unlicensed and licensed by rule.

(2) Clear cell coloration in this row indicates "uncertain/pending" operator utilization levels; light coloration suggests "low" or "medium" levels; dark suggests "high."

Sources: Rise Broadband, Interisle Consulting Group, FCC, and fixed wireless industry data.

Unlicensed spectrum is essentially free infrastructure, and in less densely populated areas it is lightly used. This made it a key part of the business model for the early fixed-wireless ISPs. For much of the industry's history, fixed-wireless providers have used primarily unlicensed spectrum such as 900 Megahertz (MHz), 2.4 Gigahertz (GHz), and the 5 GHz bands to deliver their services to homes and businesses.

Other unlicensed bands include the vacant "white spaces" between TV broadcasting bands (roughly 470 – 608 MHz), which were occupied by TV broadcasters prior to the federal mandate to change from analog to digital transmission; and the 24 GHz and 60 GHz "millimeter wave" (mmWave) bands. As of this writing, an additional 45 MHz of the 5.9 GHz band, plus 850 MHz of standard-power outdoor and 1200 MHz of low-power indoor spectrum in the 6 GHz band, are expected

to become available for commercial use by fixed-wireless providers.

Important caveats accompany the use of any spectrum. Radio airwaves are subject to their physical properties, which translate into a number of tradeoffs. Lower bands have better signal penetration through buildings and trees and can generally reach users without direct lines of sight (LoS). Higher bands travel shorter distances but can handle more bandwidth; they generally require LoS.

Similarly, because unlicensed spectrum may be employed by anyone with a certified device, fixed-wireless providers must resolve potential interference through network changes or coordination with other users. Combinations of advanced technologies, best practices, and network designs can prevent or mitigate most unlicensed interference.

COMPETITIVE DATA SPEEDS

Data transmission speeds are a significant network performance measure, determining how fast or slow one can upload or download data files. The FCC's current definition of "advanced telecommunications capability" is 25 Megabits per second (Mbps) for downloads and 3 Mbps for uploads, often referred to as "25/3." The upload/download allocation is based on typical consumer demand and usage patterns; most networks dedicate more capacity to downloads than uploads.

However, the present definition of "advanced" internet is not set in stone. From time-to-time, the FCC updates the definition as required by the Communications Act and as warranted by technological progress. As of this writing, policymakers are discussing when to raise the standard and by how much.

What do these numbers mean for consumers in the real world? In a 25/3 configuration, the total bandwidth of that package is 28 Mbps. General web surfing, email, and social media only require about 1 Mbps bi-directionally; online gaming about 3-4 Mbps bi-directionally; video conferencing 1-4 Mbps bi-directionally; and high-definition video streaming about 5-8 Mbps (primarily download). One can multiply these figures by the number of users on the broadband connection simultaneously during peak hours to determine how much speed that location needs. Thus, a two- to four-person household may need 20 to 40 Mbps of total bandwidth to cover its needs; while a 10-person office could require 80 Mbps or more, depending upon the technology needed to run its business. (See Figure 3.)

FIGURE 3: FCC Broadband Speeds Guide

ACTIVITY	MINIMUM DOWNLOAD SPEED (MBPS)
GENERAL USAGE	
General Browsing and Email	1
Streaming Online Radio	Less than 0.5
VoIP Calls	Less than 0.5
Student	5 - 25
Telecommuting	5 - 25
File Downloading	10
Social Media	1
WATCHING VIDEO	
Streaming Standard Definition Video	3 - 4
Streaming High Definition (HD) Video	5 - 8
Streaming Ultra HD 4K Video	25
VIDEO CONFERENCING	
Standard Personal Video Call (e.g., Skype)	1
HD Personal Video Call (e.g., Skype)	1.5
HD Video Teleconferencing	6
GAMING	
Game Console Connecting to the Internet	3
Online Multiplayer	4

Source: Broadband Speed Guide | Federal Communications Commission (fcc.gov/consumers/guides/broadband-speed-guide)

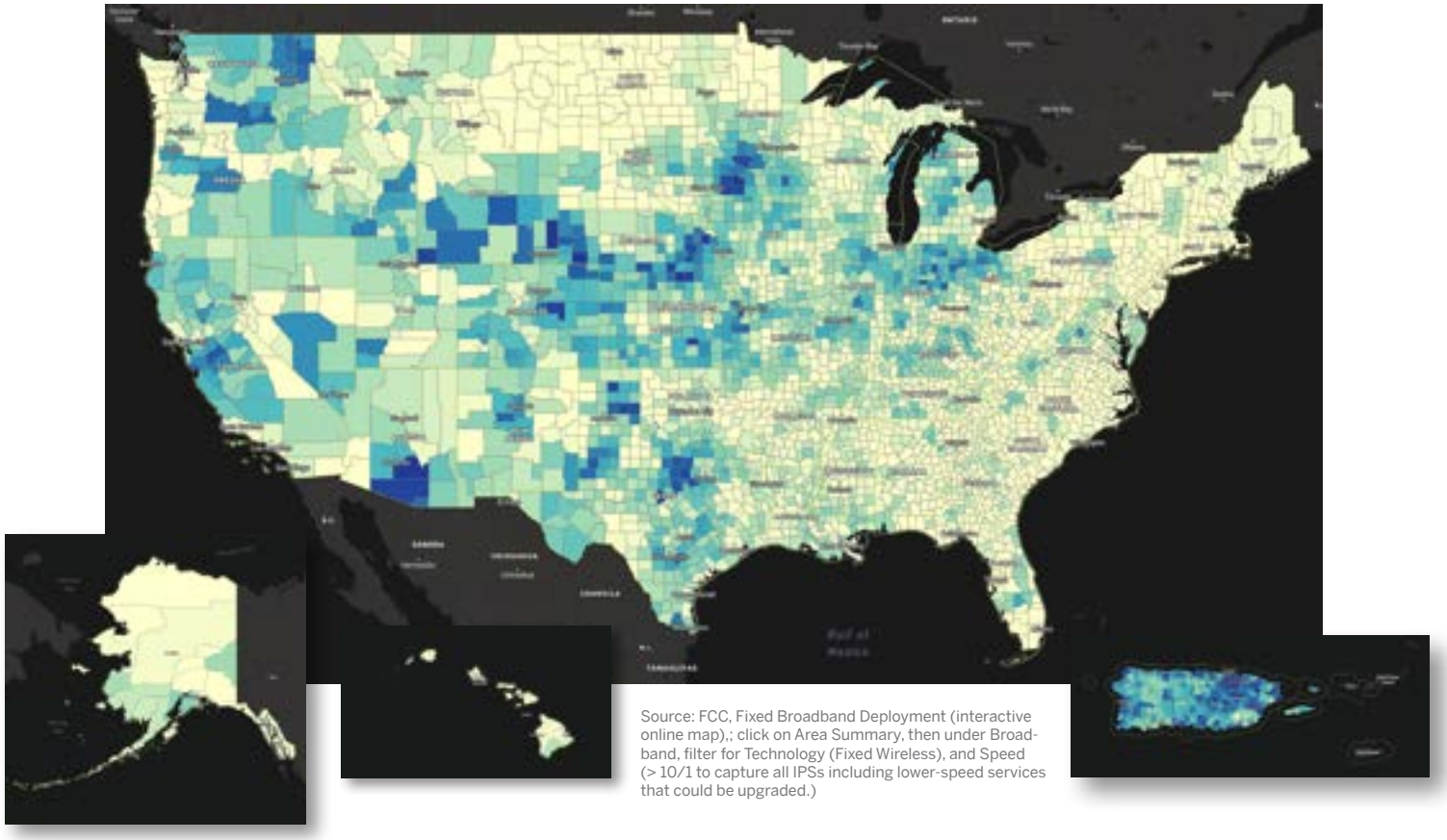
Today, most fixed-wireless and hybrid fiber-wireless ISPs offer several tiers of data packages, with varying speeds and features. Common packages offer unlimited data with download speeds in the range of 25 Mbps to 100 Mbps, although much higher-speed packages may be available. The average speed is constantly rising as technology improves and the cost of advanced equipment falls.

At the upper end, fixed-wireless technology can provide download and upload speeds at up to 10 Gigabits per second (Gbps) in P2P service links, and 1 Gbps in P2MP deployments. This capacity is valuable to some customers, but it is far beyond what most homes, businesses, and schools need for typical daily online activities. Even where 1 Gbps service is available, most customers generally opt for more cost-effective speed plans, such as 25/3 and 50/5.

Current Industry Snapshot

In the United States at the start of 2021, The Carmel Group estimates there are at least 2,800 fixed-wireless-centric operators of varied descriptions comprising this rapidly growing and evolving industry. These companies deliver internet services to an estimated 6.9 million subscribers, a five-year increase of more than 70 percent above The Carmel Group's 2016 estimate of 4.0 million subscribers.

FIGURE 4: U.S. Fixed-Wireless and Hybrid ISP Availability



Source: FCC, Fixed Broadband Deployment (interactive online map),; click on Area Summary, then under Broadband, filter for Technology (Fixed Wireless), and Speed (> 10/1 to capture all IPSs including lower-speed services that could be upgraded.)

The map shown in Figure 4 indicates that fixed-wireless broadband services are available in portions of every U.S. state, as well as the District of Columbia, Puerto Rico, and the Virgin Islands. The largest concentration of fixed-wireless and hybrid fiber-wireless ISPs are in the rural Midwest, Northwest, and Southwest regions of the United States.

Services and/or content delivered by fixed-wireless operators include data, voice-over-internet-protocol (VOIP), streaming video, two-way video, gaming, security (such as cameras and alarms), and other ancillary products and services. The burgeoning Internet of Things (IoT) and especially the Industrial Internet of Things (IIoT), tying together an expanding web of self-regulating and interconnected

machines, is creating even more demand. The IoT trend is especially prevalent in business, industry, and "smart city" applications.

Another useful application for fixed wireless is providing back-up and redundancy for businesses that require 24/7 connectivity. The portability, efficiency, and stability of fixed-wireless infrastructure accentuate this feature.

Size-wise, many U.S. fixed-wireless ISPs are small- and medium-sized businesses. Among the larger privately held operators is Rise Broadband, with a subscriber base well into the six-figure range. Yet Rise Broadband is moderate in size compared to the telecom industry's large incumbents. Other fixed-wireless providers, such as @Link, Cal.net, Midco, and Nextlink Internet, have subscribers in the five-figure range, and a significant number have localized operations with customers in the four-figure range.

The combination of flexibility and local presence gives many fixed-wireless-centric operators a distinct market advantage in customer service and community loyalty.

Telecommunications have long been based in wireline technology. But as demand continues to grow, and higher-cost technologies such as copper lines are being phased out, lower-cost alternatives with greater efficiency and future flexibility are being deployed. Each year, a growing portion of what was once a pure wireline network is being transitioned to wireless, fiber, and mixed mode networks.

Problem: Broadband Gaps. Solution: Fixed Wireless.

Because so much of the United States is characterized by rugged terrain and low population density, and because traditional wireline infrastructure is relatively expensive in low-density areas, many rural, small-town, and exurban areas lack high-speed internet service beyond a few local hot spots. Inadequate or non-existent internet services are proven to be a serious hindrance to economic opportunity and quality of life in the modern economy.[2]

Bringing broadband to under-served markets is a difficult challenge. At this time, BWA providers using wireless technologies are the most cost-effective solution in vast areas of the United States and the world.

As of year-end 2019, an estimated 14.5 million Americans lacked access to broadband service at the FCC's benchmark speed of 25/3 Mbps. This leaves approximately 20% of rural Americans and 25% of those living in Tribal Lands without FCC-defined broadband.[3]

However, it is widely acknowledged that the FCC over-counts the number of Americans with access to 25/3 service. A 2020 study by the online service BroadbandNow estimated the number of unserved Americans is roughly 42 million, more than double the official count.[4] Data gathered by Microsoft from users of its online services indicated that 157.3 million Americans do not routinely use the internet at broadband speeds.[5]

Bottom line: While the digital divide is shrinking in a respectable number of the hardest-to-serve areas of the country, tens of millions of Americans still lack basic access to online services.

Another aspect of the broadband gap is a lack of service choices in too many areas. The FCC estimates that 7% of U.S. households have only one choice or no choice in fixed broadband providers.[6]

The combination of persistent broadband gaps in high-cost, low-density areas; the lack of ISP choices in too many rural and even some urban areas; and the cost-effectiveness and speedy deployment and ROI of fixed-wireless-centric networks points clearly to one conclusion: fixed-wireless broadband must be among the top solutions in any strategy aimed at closing America's broadband gaps.

Fixed wireless is robust, cost-effective, rapid to build and deploy, and constantly evolving in an incremental and competitive fashion. Not only does fixed wireless serve U.S. policy goals of helping all Americans connect to the internet, wherever they live. It also makes good business sense in most communities that are unserved, under-served, or poorly served.

[2] U.S. Department of Agriculture, "Broadband," web page, https://www.usda.gov/broadband; Deloitte, "The Economic Impact of Disruptions to Internet Connectivity," October 2016, https://www2.deloitte.com/global/en/pages/technology-media-and-telecommunications/articles/the-economic-impact-of-disruptions-to-internet-connectivity-report-for-facebook.html.
[3] Federal Communications Commission, "2019 Broadband Deployment Data Show Digital Divide Is Closing," Press Release, November 12, 2020. https://docs.fcc.gov/public/attachments/DOC-368112A1.pdf
[4] BroadbandNow Research, "FCC Reports Broadband Unavailable to 21.3 Million Americans, BroadbandNow Study Indicates 42 Million Do Not Have Access," February 3, 2020, https://broadbandnow.com/research/fcc-underestimates-unserved-by-50-percent
[5] Shelley McKinley, Microsoft on the Issues Blog, "Microsoft Airband: An Annual Update on Connecting Rural America," March 5, 2020, https://blogs.microsoft.com/on-the-issues/2020/03/05/update-connecting-rural-america/
[6] U.S. Telecom, "U.S. Telecom Industry Metrics & Trends 2020," Presentation, April 2020, slide 8. https://www.ustelecom.org/research/ustelecom-industry-metrics-and-trends-2020-update/

Case Studies

Affordable, robust internet service makes an enormous difference in a community's quality of life and its ability to participate in the broader economy. Without such services, entrepreneurs cannot run a modern business; doctors and patients are unable to come together via telemedicine; students are unable to take online classes; and farmers are cut off from precision agriculture techniques. The dramatic increase in demand tied to remote learning and working from home during the COVID-19 pandemic highlighted and accelerated the need for ubiquitous, advanced broadband services.

The following are a few examples of how fixed-wireless-centric ISPs are making meaningful differences in their communities.

A RURAL ENTREPRENEUR RAISES QUALITY OF LIFE

In 2015, Cam McCurdy of Marion, Illinois faced a life-changing choice. Should he continue to work as an electrical engineer in a family business, or expand his after-hours IT services and computerized metal-cutting businesses? The 25-year-old chose the latter, but then faced a major problem: His hometown's only broadband option was inadequate to support a burgeoning IT business. Like many WISP entrepreneurs before him, he cobbled together seed money from his family, an in-kind commitment from a local fiber provider, and a tower in his backyard. He then began offering fixed-wireless internet service to his neighbors, who also craved connectivity and could share the costs. Five years and 1,400 subscribers later, ProTek Communications plans to secure another 500 subscribers in the coming year, but this time also offering fiber-to-the-home (FTTH) to roughly 100 customers. Aided by the enhanced connectivity, his wife has taken on the metal-cutting business, growing it into a full-time venture. "Like most of our neighbors, we were struggling to live a 21st century life with limited connectivity," he recalls. "Fixed wireless was the simple answer."

URBAN WISP OFFERS ENHANCED CHOICES IN NEIGHBORHOODS

While most fixed-wireless-centric ISPs are focused on rural areas, small towns, and urban fringes, a growing subset are finding niches in urban markets. One of these is DC Access, which has been providing broadband services in Washington, D.C. for more than 15 years. The company serves about 2,000 subscribers in the neighborhoods of Adams Morgan and Capitol Hill, including dozens of multifamily properties. "Our niche market is customers who feel like the big guys aren't providing them with the quality and personalized customer service they need," says Martha Huizenga, Chief Operating Officer and Co-Owner. Most customers do not take the highest-speed, highest-cost plans, because DC Access takes the time to educate them on what they actually need. From millennial cord cutters to low-income households, urban WISPs are serving customers that are typically neglected and overcharged by other providers.

SERVING THE UNSERVED WITH A HYBRID MODEL

Jim Bouse owns Brazos WiFi, which serves approximately 2,000 subscribers in College Station, Texas near Houston. The nearby small town of Hearne was long challenged by low incomes and a lack of job opportunities, and city officials realized better fixed broadband service would help attract business and create jobs. Although Brazos WiFi traditionally relied on unlicensed spectrum to deliver its services, it answered Hearne's call with a targeted rollout of FTTH. The company connected existing homes and businesses and attracted a new business park, whose sales pitch included "low rent and fast internet." Like a growing number of WISPs, Brazos WiFi now puts fiber into its buildouts where it makes economic sense. Since 2018, the company has installed 32 miles of fiber and hooked up hundreds of customers to its fiber network.

LEVERAGING FCC FUNDS TO EXPAND RURAL ACCESS

Wisper ISP is one of the nation's fastest-growing WISPs, delivering high-speed internet service in parts of Illinois, Kansas, Missouri, and Oklahoma. In recent years, Wisper has been able to expand and upgrade its networks to reach more under-served areas in part with support from the U.S. government. Wisper was the second-largest winner in the FCC's Connect America Fund Phase II (CAF II) auction in 2018, authorized to receive $220.3 million in federal support to expand fixed broadband deployment in historically hard-to-serve rural areas.

Until the CAF II auction, the vast majority of WISPs were ineligible for FCC high-cost support. Based in part on the recognition of the benefits that fixed-wireless-centric networks can bring to rural communities, the FCC, the U.S. Department of Agriculture (USDA), and many state governments have increased the availability of such funding, augmenting self-financing, and other private investment. Significant numbers of WISPs are now partnering with governments at all levels to bring new service to the unserved and to grow their businesses.

The recently concluded Rural Digital Opportunity Fund (RDOF) Phase I auction will inject another $9.2 billion in funding for broadband deployment, and a significant amount of that funding is expected to be authorized for use by WISPs.

EXPANDING TO REACH THOUSANDS OF HEARTLAND CUSTOMERS WITH CBRS AIRWAVES

Nextlink Internet of Hudson Oaks, Texas was one of the top investors in the CBRS spectrum auction (see page 23, "Spectrum policy trends are highly favorable"), and is an exemplar of that program's success. Nextlink Internet invested $28.4 million in mostly privately raised capital to win an FCC spectrum auction for 1,072 pending Priority Access Licenses (PALs). These licenses cover 491 counties in 11 states. For a company that had its origins in the rural territory north and west of Dallas-Ft. Worth, the CBRS investments will enable it to expand its 70,000-strong subscriber base and reach out to 14 million potential customers. Company CEO Bill Baker declares, "We want to become the top internet service provider in small towns and rural markets across the central USA, enhancing their quality of life. The CBRS licenses we won will enable us to do that."

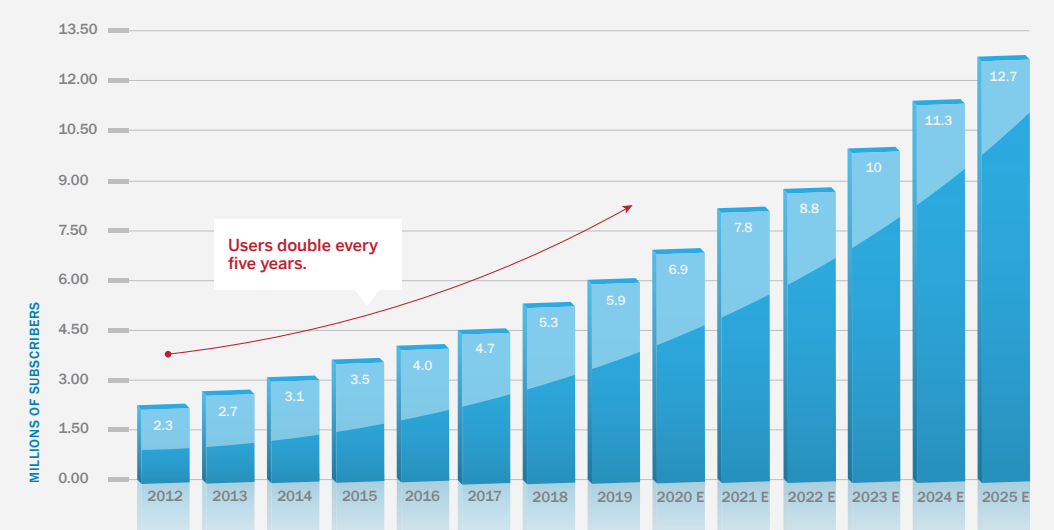
Growth Forecasts

The positive trajectory of subscribers and revenues in the U.S. fixed-wireless broadband industry is real cause for objective optimism. Based upon our surveys and other research, realistic projections indicate this arc will continue for years to come.

SUBSCRIBERS

The number of customer subscriptions in this sector was estimated at 4.0 million as of year-end 2016. The Carmel Group estimates this figure reached 6.9 million by the end of 2020 and will reach 12.7 million by the end of 2025. (See Figure 5.)

FIGURE 5: U.S. Fixed-Wireless and Hybrid ISP Subscriber Growth, 2012-2025

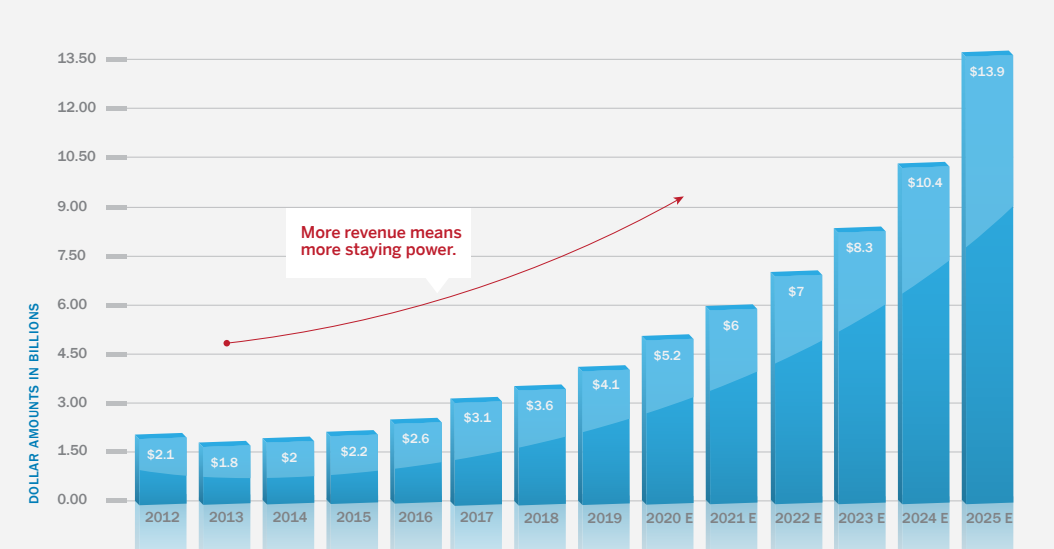


(E) Estimated/Projected.
Source: The Carmel Group
Numbers and estimates by The Carmel Group are for U.S. operators serving residential subscribers and non-residential subs.

REVENUES

Core industry revenues from the provision of internet services to end-users are estimated at $4.4 billion as of the end of 2020. They are projected to reach $10.9 billion by the end of 2025. (See Figure 6.)

FIGURE 6: U.S. Fixed-Wireless and Hybrid ISP Revenues, 2012-2025

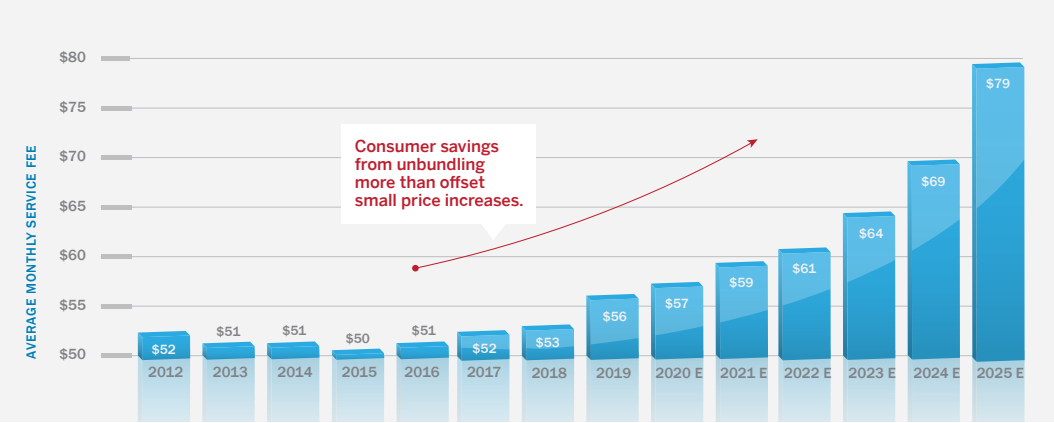


(E) Estimated/Projected. Source: The Carmel Group

AVERAGE REVENUE PER USER (ARPU)

Per-customer monthly revenues (ARPU) from residential subscribers have risen steadily. The combination of better spectrum access, technological upgrades to equipment, and provision of multiple ancillary services is driving the ARPU estimates in Figure 7.

FIGURE 7: U.S. Fixed-Wireless and Hybrid ISP Average Revenue Per User, 2012-2025



(E) Estimated/Projected. Source: The Carmel Group

Growth Drivers

The fixed-wireless and hybrid fiber-wireless ISP industry is expected to continue its bullish growth in multiple dimensions for as long as reasonable estimates and analysis can predict. At least five mega-trends are driving this growth.

1 Fixed-wireless and hybrid networks cost much less.

The economics of fixed wireless are already very attractive and only becoming more so. Networks can be deployed for roughly 10% of the capital cost of fiber, and they can generally be installed in a matter of days. This makes the fixed wireless solution an especially attractive option in areas that are unprofitable to serve with fiber and wireline technologies.

Fiber typically costs from $12,000 to $50,000 per mile, and sometimes more, depending on the terrain and whether the market is rural, suburban, or urban. There is also the cost of accessing rights-of-way, which is expensive and time-consuming. In contrast, unlicensed spectrum is essentially a cost-free, last-mile delivery platform to convey internet services; and licensed-by-rule spectrum is free but for the low regulatory and coordination costs to use it correctly.

For the average, fixed-wireless-centric ISP, the capital cost of adding subscribers is one-fifth or less of the cost of that for wireline- and satellite-based networks.

On the equipment side, fixed-wireless hardware is relatively inexpensive compared to wireline solutions, the latter of which also incur extensive costs for installation, maintenance, and repairs. Fixed-wireless networks typically need nothing more than access to vertical infrastructure and suitable line of sight characteristics. Fixed wireless is generally not hampered by the physical placement of wires, rights of way, or access to heavily regulated infrastructure.

Each generation of wireline technology ultimately requires replacement of a large part of the physical network. In contrast, fixed wireless can be expanded incrementally. Upgrades are often accomplished with rapid software uploads or replacements of unburied network components.

Advances in radio technology are improving wireless speeds to the point where they are approaching cable and ultimately are expected to begin rivaling fiber in marketplace acceptance. At the same time, compression technology continues to evolve such that more data can be transmitted at slower speeds, improving the overall economics.

Another unique cost factor is that as the density of subscribers in a given area drops, the capital expenditure per subscriber of wireline inevitably increases; but it remains relatively constant for wireless.

As a result of these multiple cost advantages, for the average fixed-wireless and hybrid ISP, capital expenditures are a fraction of the cost of wireline or fiber. For example, as indicated in Figure 8, it generally costs less than $500 in network capital outlay for a WISP to connect a fixed-wireless customer versus approximately $4,500 to connect a fiber subscriber.

FIGURE 8: Comparative Economics of U.S. Internet Access Solutions

	FIBER	CABLE	SATELLITE	MOBILE	FIXED WIRELESS (1)
CAPEX/SUB RELATIVE TO FIXED WIRELESS (1)	9	5	6	3	1
YE 2020 BROADBAND SUBS IN MILLIONS (2)	15	76	2.5	315	6.9
EST. TYPICAL SUBSCRIBER SPEED DOWN (MBPS)	940	200	20	15	25
MAX SPEED DOWN (MBPS) (3)	2,000	2,000	50	200 +	1,000
UPGRADE COST	Moderate	High	Low/High	High/Modest	Low/Moderate
UPGRADE COMMENT	Only replace the endpoint; fiber remains the same.	Moderating with DOCSIS 3.1; less with linear TV.	Low incremental cost until the satellite dies; higher when satellite cost is included.	3G to 4G High; 4G to 5G Modest.	Requires modest incremental upgrades in CPE, towers, and networks.
AVERAGE REVENUE PER USER (ARPU) (4)	$65	$70	$90	$60	$57
CAPITAL OUTLAY PER SUBSCRIBER (INCLUDES PROVIDED CPE) (5)	$4,500	$2,200	$3,000	$1,300	$475
PAYBACK TIME IN MONTHS	69	31	32	22	8

1) This is a relative presentation comparing all of the technologies to fixed wireless, which is set to an index value of 10.
2) Subscriber numbers come from company filings, the CIA's "World Factbook," and estimates by The Carmel Group.
3) Mobile speeds can be higher during low traffic periods.
4) ARPU comes from a blend of advertised prices and company financial reports.
5) Capital Outlay figures come from company financial reports and estimates by The Carmel Group.

Figure 8 compares relative capital expenditures per subscriber as well as speed, upgrade costs, ARPU, and ROI-breakeven timeframes for the five most popular U.S. broadband technologies. This is a relative presentation, comparing the four other technologies to fixed wireless, which is set to an index value of 1.

Fiber ends up on the high side, costing about nine times what fixed wireless costs. Cable is more than five times higher. For networks based upon geostationary and low earth orbiting (LEO) satellites, adding subscribers typically costs more than six times that of fixed wireless, including the costs of satellites.

The capex/sub of mobile/cellular is about three times more than fixed wireless. Mobile bandwidth is more limited than fixed, but the compensating benefit is mobility. The FCC does not consider mobile services to be a full substitute for fixed services, but both may meet the statutory definition of "advanced telecommunications capability."

Finally, and perhaps of greatest importance to investors, the ROI timeframe for fixed wireless is under one year. This compares to a minimum of almost two years to as much as six years for the other technologies.

Altogether, fixed-wireless-centric networks offer the most attractive economics among the top U.S. broadband technologies.

2 Consumer demand is robust.

Consumer demand for broadband connectivity and many online services and applications was already surging before the COVID-19 pandemic. But the pandemic created even more demand for high-quality internet services, especially for home-based workers and students. Demand is also exploding in many categories of network-enabled services. More than ever, broadband has become an essential service.

The Cisco *2020 Global Networking Trends Report* shows burgeoning home broadband demand being complemented by surging enterprise and business deployments, the latter especially for home-based work. Cisco projects 50% of workloads will take place outside corporate data centers by year-end 2021.[7]

The ongoing explosion in streaming video, online shopping, and internet-connected devices – including everything from home appliances to security cameras, business equipment, health monitors, and drones used in agriculture and industry – is another powerful growth driver. Consumers also are continuing to cut the cord from pay TV services and to replace expensive programming bundles with less expensive "over the top" (OTT) apps via broadband. Fixed-wireless ISPs are making this cost-saving option – once offered only to urban dwellers – available now to rural and exurban customers.

Technological advances are also dramatically reducing the latency of wireless networks, i.e., the delay between transmitting and receiving data. Broadband applications that depend on speed, reliability, and low latency – such as gaming, video-on-demand, finance, critical function communications, IoT, and data backup for business and government – are among the fastest-growing segments in the broadband market, adding more fuel to the demand fire.

Another consumer-relevant advantage for most fixed-wireless ISPs is that they tend to offer superior customer service and a hometown presence. This shows itself in the form of prompt service in the field and personal relationships with customers, in contrast to the impersonal, mass-market nature of larger incumbents. Most fixed-wireless operators experience much lower subscriber churn compared to their competitors. (See Figure 13.)

The favorable customer experience offered by fixed-wireless-centric companies is attracting customers not only in rural areas, but also in urban areas. This trend is evidenced by providers like DC Access (see page 14 among the "Case Studies") and Starry (see www.Starry.com).

Fixed wireless is also well suited for business and industrial facilities, multiple-dwelling-unit buildings (MDUs), and venues such as stadiums and universities. Based on industry data, executive interviews, and surveys, The Carmel Group estimates that urban, non-residential customers will make up 35% of total industry revenues by 2025.

Moreover, particularly in rural markets, low maintenance standards leading to the recent abandonment of Digital Subscriber Line (DSL) service have led to a rapid user migration to fiber and fixed-wireless network offerings.

[7] Cisco, "2020 Global Networking Trends Report," p. 11. https://www.cisco.com/c/dam/m/en_us/solutions/enterprise-networks/networking-report/files/GLBL-ENG_NB-06_0_NA_RPT_PDF_MOFU-no-NetworkingTrends Report-NB_rpten018612_5.pdf

COVID-19 SPAWNS NEW NETWORK TRAFFIC DYNAMICS AND USES

The COVID-19 pandemic had enormous impacts on internet use. According to a WISPA survey of its members in August 2020, during peak hours WISPs experienced an average 43% increase in download traffic and a 70% increase in upload traffic. The main drivers of this trend were two-way teleconferencing, distance learning, HD movie streaming, telemedicine, and web browsing. WISPA data shows that more than 80% of WISPs upgraded their networks to better manage these new dynamics.

Although the U.S. economy contracted significantly during the pandemic, it is no exaggeration to say that high-speed internet access is helping Americans weather the crisis far better – and certainly far better than they would have without it.

3 Spectrum policy trends are highly favorable.

Since the last iteration of this report in late 2017, the FCC has made more than 1,200 MHz of unlicensed and licensed-by-rule spectrum available to the public nationwide. Not unlike the land rushes of old, the fresh availability of these resources is expected to set off unprecedented levels of entrepreneurship, investment, and innovation in broadband equipment, networks, and services.

As described elsewhere in this report, from its inception, the fixed-wireless industry has relied primarily on unlicensed spectrum bands, including the 900 MHz, 2.4 GHz, 5 GHz, and "TV White Spaces" (TVWS) bands, to provide internet access to customers. (See Figure 2.)

Meanwhile, the FCC has recognized that fixed-wireless technology is a quick and cost-effective means to shrink the digital divide. To that end, that agency has increased access to a significant amount of free/unlicensed, and low-cost/licensed-by-rule spectrum bands. The FCC has also made licensed spectrum more accessible to smaller entities.

For example, one of the biggest events ever to reshape the fixed-wireless ISP industry occurred in 2020, when the FCC auctioned licenses in the CBRS band (3.55 – 3.7 GHz). Historically, much of this band was reserved for the U.S. Navy, which used the airwaves only intermittently and only within a few miles of the U.S. coastline. Under the new rules, 100 MHz of the band are to be shared between private operators and the incumbents through FCC-authorized Spectrum Access Systems (SAS). SAS automatically facilitates local access to the airwaves, while preventing harmful interference.

In another innovation in the CBRS band, the FCC offered exclusive access licenses to much smaller geographic areas than usual. This made it possible for smaller and more diverse bidders to bid successfully. The SAS technology makes it possible to have a spectrum-sharing model that allows all users to coexist, mostly interference-free, in lightly regulated, licensed-by-rule airwaves.

The CBRS auction proved that when the rules enable smaller entrepreneurial players – such as WISPs – to participate, they do. Almost 70 WISPs won more than 3,600 CBRS licenses to serve 1,235 counties, marking the industry's largest-ever role in an FCC spectrum auction. The auction also reflected a growing maturity and sophistication of the fixed-wireless industry, given its traditional primary reliance on unlicensed spectrum.

In another landmark spectrum policy decision, the FCC in 2020 opened 1,200 MHz of the 6 GHz band for unlicensed uses. This move included up to 850 MHz for shared outdoor uses governed by an automated frequency coordination system. This action makes it possible for fixed-wireless ISPs to increase capacity and bring high-speed, broadband access to more remote areas, while concurrently avoiding harmful interference with licensed incumbents in the band.

Spectrum sharing – as reflected in both CBRS and 6 GHz – is a critically important trend, freeing up underutilized spectrum for commercial use. With little "greenfield" (unused) spectrum available, the FCC is expected to increase spectrum-sharing opportunities in the coming years. Industry surveys suggest the vendor and operator communities are eager to adopt them.

Finally, the upcoming 2.5 GHz and 3.45-3.55 GHz auctions, as well as unlicensed and licensed uses of mmWave spectrum in the 60 GHz and higher bands, show additional growth and investment opportunities for the U.S. fixed-wireless industry.

ACCESS TO 5.9 GHZ BAND EXPANDS NETWORK BANDWIDTH OVERNIGHT

In March 2020, at the beginning of the COVID-19 pandemic, the FCC granted Special Temporary Authority (STA) for WISPs to use the 5.9 GHz band for unlicensed commercial use. For more than 20 years, the band had been reserved for the automotive industry, but it was largely unused. Because the band is adjacent to unlicensed airwaves in the 5 GHz band, and accessible via software downloads from manufacturers to WISPs, it was a perfect candidate to quickly alleviate some of the "COVID crunch" on WISP and Wi-Fi networks. More than 100 WISPs applied for and received permission to use it. An example is Amplex of Luckey, Ohio, which was able to increase bandwidth by 50% across its network of 8,000 subscribers.

The key takeaway: Unlike wired infrastructure, which requires significant time, expense, and physical disruption to deploy, WISPs can increase their network capacity almost overnight if spectrum policy and governmental action makes it possible. The 5.9 GHz STA shows the flexibility and nimbleness that fixed-wireless broadband operators are capable of achieving.

4 An expanding technology ecosystem gives ISPs more choices.

The fixed-wireless ISP industry started out with consumer and small-enterprise-class technology, deployed on a small scale. But as individual companies and the overall industry have grown, WISPs have come to use a wider array of technologies. This includes LTE, 5G, and carrier-class technologies to reliably carry larger amounts of data traffic.

Thus, an expanding, global ecosystem of wireless equipment suppliers is developing better-performing technologies with greater efficiencies and cost-saving standardization. This in turn delivers ever-improving economies of scale for fixed-wireless-centric ISPs.

For example, LTE technology, which originated in mobile standards bodies, is being deployed by fixed-wireless-centric ISPs to achieve greater speed, capacity, and credibility as service providers. Standards-based technologies also curate a vast ecosystem of interoperable equipment. Many of the advances inherent in mobile 5G apply to fixed 5G, as well.

As another example, there are more wireless design and manufacturing companies working on software-defined capabilities, which result in more efficient use of spectrum. That, in turn, translates into higher-speed performance and lower costs.

The expanding technology ecosystem is showing itself in other ways. For example, The Carmel Group surveyed 26 vendors with trade group affiliations for the 2017 edition of this report, compared to 58 for this updated report. This is a clear reflection of rising tech sector interest in the opportunities and growth of the fixed-wireless industry.

On another front, a growing number of the nation's largest internet stakeholders are making major investments in fixed wireless – a trend that will attract even more competition and choices in fixed-wireless technologies. This group includes traditional, wireline-based broadband companies such as AT&T, Verizon, and Windstream, plus technology providers such as Google and Microsoft.

In summary, the expanding technology ecosystem is driving rapid innovation, spurred by the convergence of heavier market demand, favorable public policy, and large capital investment flows. Ultimately, these advances are leading to wireless broadband offerings that compete favorably even with fiber pure-play services.

Figures 9, 14 and 15 provide a snapshot of the vendor community.

FIGURE 9: U.S. Fixed-Wireless Select Vendors, Key Data Points, 2020-2025

ITEM:	2020 TOTALS: (E) (1)
TOTAL # OF CURRENT VENDORS (2)	575
# OF YEARS IN THE FIXED WIRELESS BUSINESS	11
# OF EMPLOYEES/VENDOR	9
% YOY INCREASE IN 2019-2020 REVENUES	17%
5-YEAR % INCREASE IN REVENUES FROM FIXED WIRELESS BUSINESSES ONLY	27%
1-10 LEVEL OPTIMISM RE: SUBSEQUENT FIVE-YEAR TERM (3)	7
% DEPLOYMENT PER SPECIFIC U.S. AREA	21% in the NE, 23% in the SE, 23% in the NW, 33% in the SW
MAIN FORMS OF CUSTOMER SUPPORT (4)	Email @ 79%, telco CSRs @ 66%, social media @ 54%
DIRECT NEW SUBCRIBER-RELATED REVENUES (MILS. $) (5)	$500

(E) Estimated/Projected.
(1) All datapoints are averages except for # of vendors and revenues.
(2) Vendors category does not include network operators.
(3) 10 = Highest level of optimism.
(4) CSR = Customer Service Representative.
(5) Estimates focus on per-subscriber equipment and other direct charges or fees.
Numbers and estimates by The Carmel Group are from surveys taken during 2020 of specific hardware, software, and services vendors serving the U.S. fixed wireless industry.

5 Capital availability and government support are growing.

The fixed-wireless-centric ISP industry has a proven business model and is attracting unprecedented levels of financial support from several sources:

- Strong growth in organic revenues, e.g., predictable recurring monthly revenues;
- Owners and other investors interested in mergers and acquisitions;
- Lending sources, including traditional banks, "angel," private equity, and venture-capital (VC) investors;
- Large incumbents that now recognize the favorable economics;
- Public-private partnership opportunities; and
- Expanding Congressional, regulatory agency, state, and municipal government connectivity programs, e.g., Universal Service Reform, which include multi-billion-dollar subsidies.

Three key factors are pushing more investment funding to the U.S. fixed-wireless industry:

- **Improved organic funding and consolidation.** Executive interviews and surveys revealed that typical monthly cash flow for well-run fixed-wireless and hybrid fiber-wireless operators is strong and trending higher. Whether they are serving a steady plateau of customers or expanding, by all reports, these ISPs are typically healthy and going concerns, with low failure rates. This, in turn, permits investment from internally generated cash flows into their own networks, and funding of mergers and acquisitions of adjacent or complementary networks and staff. Some of the consolidators are determined to bring large-scale innovation to what they view as a stale competitive dynamic in the regions they serve. Merger activity appears to be growing in markets where regional operators choose to acquire teams and networks, rather than to over-build.

- **Improved private funding.** As fixed wireless has become more recognized for its cost advantages, its rapid ROI, its ability to expand rapidly in under-served markets, and the loyalty of its customer base, industry leaders report that private lenders are expressing growing interest in the sector. These lenders include angels, VCs, investment companies, and private equity firms, together with small-, medium- and large-sized banks.

- **Expanding government support and influence.** Few policy issues enjoy as much strong, bipartisan support as building and improving broadband networks for rural Americans. At the federal level, two FCC programs – the Connect America Fund (CAF) and the Rural Digital Opportunity Fund (RDOF) – are currently making available more than $23 billion for investment in under-served areas. Fixed-wireless ISPs were among the top winners of government support in these auctions and are leveraging that support to obtain access to co-investment capital. The industry enjoys rising visibility and credibility in Congress and federal agencies, and it is well positioned to secure favorable legislative and regulatory outcomes during the Biden Administration.

Other federal agencies are also creating funding opportunities for fixed-wireless-centric providers.[8] The USDA is reorienting broadband subsidy programs to be more technology neutral and focused on cost-effectiveness and prompt deployment. The U.S. Department of Commerce (DOC), through the National Telecommunications & Information Administration (NTIA), administers grant programs for fixed broadband connectivity. The U.S. Small Business Administration (SBA) is also engaging with WISPs.

Added to this, an increasing number of state and local governments offer grants, tax breaks, and access to government properties such as schools, parks, and vertical structures where fixed-wireless transmitters can be located.

Private capital is attracted to public capital investment activities. In today's U.S. broadband arena, this co-leveraging of public and private capital provides a boost to rapid industry expansion. Unprecedented levels of government support have drawn investors and innovators who understand local markets. Bankers, equity investors, and entrepreneurs are seeking favorable returns while solving the nation's broadband crisis.

[8] Craig Settles, "Bullish on Broadband: New Fiscal Year Means Replenished Grant Funds For Many Programs," Daily Yonder, October 8, 2020, https://dailyyonder.com/bhttps://dailyyonder.com/bullish-on-broadband-new-fiscal-year-means-replenished-grant-funds-for-many-programs/2020/10/08/llish-on-broadband-new-fiscal-year-means-replenished-grant-funds-for-many-programs/2020/10/08/; and "Bullish on Broadband: Time to Get Your Grant Proposals Ready," Daily Yonder, October 9, 2020, https://dailyyonder.com/bullish-on-broadband-time-to-get-your-grant-proposals-ready/2020/10/09/?utm_source=Center+for+Rural+Strategies&utm_medium=e-mail&utm_campaign=10-9-2020&utm_medium=email&mc_cid=879b44bdb4&mc_eid=5ad9df9db4.

Significant Challenges Remain

Despite the numerous positive forces driving dramatic growth in the fixed-wireless and hybrid fiber-wireless ISP industry, several significant challenges remain.

COMPETITION. Significant competition faces nearly every size and type of fixed-wireless operator. The rivals include the large incumbent telephone, cable, and satellite providers; emerging Low Earth Orbit (LEO) satellite systems such as Starlink, being built by SpaceX; rural cooperatives; municipal internet providers; and mobile/cellular alternatives.

VERTICAL CONTENT. Nearly every one of the large incumbent video and broadband operators now owns and controls highly valuable vertical assets, including huge content properties. For example, AT&T owns Warner Media, including Home Box Office (HBO), and it packages HBO services into its internet service packages. Similarly, Comcast owns the NBCUniversal family of TV and film properties, as well as other complementary businesses. The control of such assets by these companies provides a competitive advantage over others that lack them.

SPECTRUM CHALLENGES. Spectrum degradation and interference remain concerns for fixed-wireless providers that rely primarily on unlicensed spectrum bands. Because radio signals traveling through the air may be affected by both natural and manmade obstacles, ready-made Quality of Service (QoS) signal improvements remain elusive and sometimes inadequate.

GOVERNMENT PROCESS. One of the industry's perennial characteristics – its comparatively small size at both the local and national level – has affected its ability to educate and win over key audiences. Regulators are much more familiar with the incumbent ISPs, and the regulatory system has been tilted toward those larger providers for decades. For the industry to maximize all the positives described in this report – and minimize the negatives – industry leaders must continue to be persistent and creative in educating policy makers and advocating for their current and would-be customers.

Government authorities at all levels have come a long way in recognizing the need to boost their support of fixed-wireless internet access. But a deeper mindset is needed to achieve optimal broadband connectivity.

FUNDING. Much of the funding flowing into the fixed-wireless industry is unavailable to operators that are relatively new and lack a track record of success, or that lack collateral assets to support loans. In addition, most fixed-wireless operators we interviewed preferred independence from government funding and were concerned about subsidies going to less efficient network operators, such as electric and telephone cooperatives and municipalities, which also tend to have long build schedules. Nonetheless, public funding for all types of broadband providers, including less efficient ones, appears to be headed toward significant increases, which could create ongoing competitive challenges for some fixed-wireless-centric operators.

Conclusion

The data and trends contained in this second study of the U.S. fixed-wireless ISP industry, as well as the real-world anecdotes, continue to speak for themselves. The technology and business model are tested and compelling. Revenues and subscribers continue to rise; customer churn remains low. The onward march of technology is spawning lower costs and enhanced capabilities. Governments around the world are enhancing public and private access to spectrum and seed funding. The "no brainer" aspects of fixed-wireless and hybrid fiber-wireless networks are becoming more evident to – and supportable by – stakeholders of every kind.

For the five-year outlook, this alignment of favorable factors seems likely to continue. For the industry as a whole, we see relatively few and generally modest and manageable obstacles affecting the future.

Appendices

As part of its extensive research conducted for this report, in Q3 of 2020, The Carmel Group received survey results from 244 fixed-wireless operator respondents, and 58 fixed-wireless vendor respondents with trade-group affiliations. This compares with a Q4 2016 result of 169 operators and 26 vendor operators, also with trade-group affiliations. The response rate was above 30% for every survey sample, which is far above the national norm for external surveys. Additionally, even measured against our estimate of 2,800 total U.S. WISPs, the 244 operator responses in 2020 approaches a respectable response rate of nearly 10 percent.

Furthermore, in every one of the four surveys, at least 73 survey questions were presented. Plus, as was done in 2016 and again in Q2 2020, 30 executive interviews of approximately 90 minutes each delivered additional feedback and foundation.

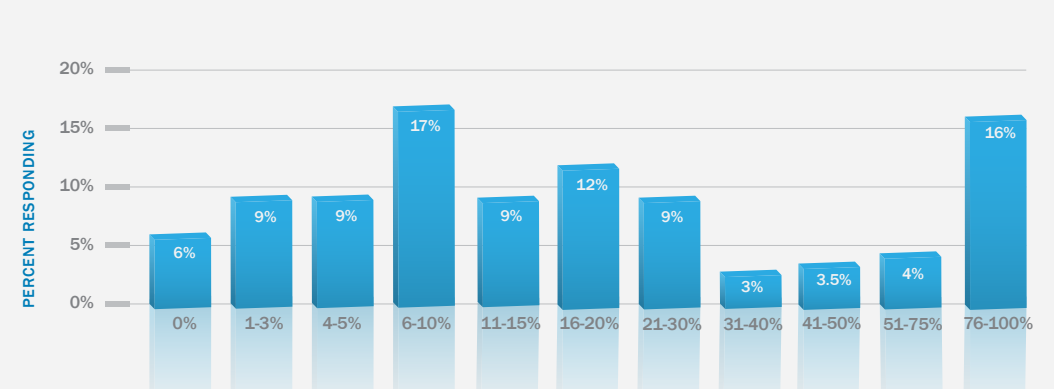
Topic areas of the 2020 Operator Survey included Subscribers, Future Subscribers, Customer Service, Policy, Equipment, Services, Competition, and Business.

Topic areas of the 2020 Vendor Survey were General Data, Hardware, Software, and Service.

OPERATOR SURVEY ANSWERS[9]

Residential Subscribers: Almost 75% of respondents claimed double-digit year-over-year (YOY) growth in residential subscribers from 2019 to 2020; 16% stated a whopping YOY growth of 76% to 100%. Especially compared to recent subscriber losses of both cellular/mobile operators and of pay TV operators, these represent admirable telecom growth percentages.

FIGURE 10: U.S. Fixed-Wireless and Hybrid ISP Residential Subscriber Growth, 2019-2020

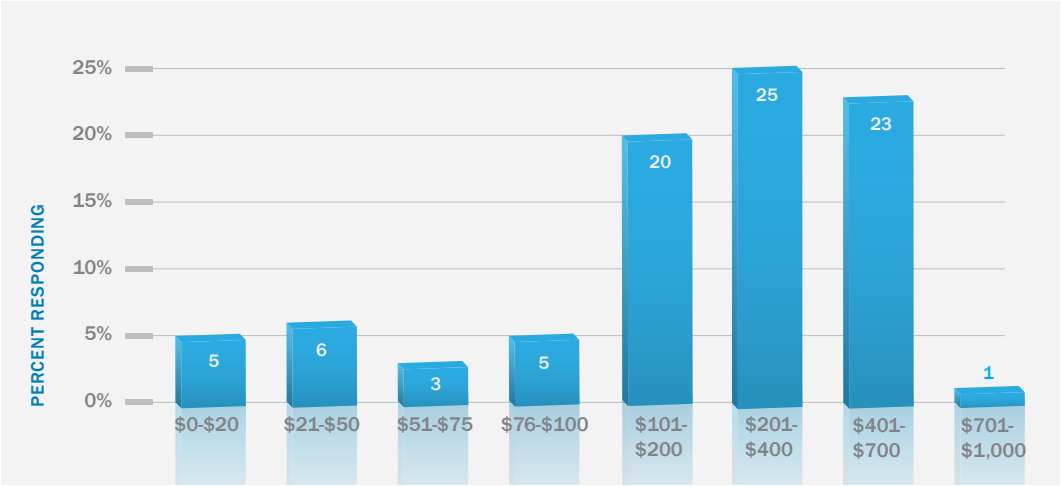


Source: Surveys and Analysis by The Carmel Group from an in-depth survey of U.S. Fixed wireless operators and vendors during June-July 2020.

[9] The data shown in this Appendices section are for residential subscribers. The Carmel Group has data on non-residential subscribers, as well.

RESIDENTIAL SAC: Subscriber acquisition costs (SAC) for residential subscribers were between $101 and $700 for 68% of the operator respondents. A quarter of respondents identified SAC in the range of $201 to $400. This compares favorably with the SAC for every national competitive broadband provider.

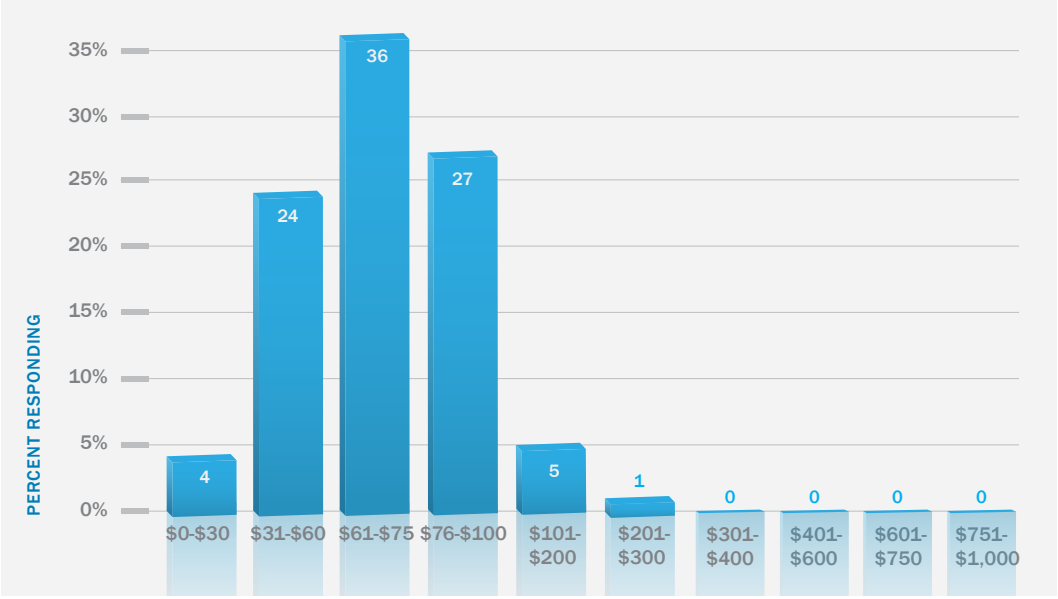
FIGURE 11: U.S. Fixed-Wireless and Hybrid ISP Residential SAC, 2019-2020



Source: Surveys and Analysis by The Carmel Group from an in-depth survey of U.S. Fixed wireless operators and vendors during June-July 2020.

Residential ARPU: YOY average revenue per unit has increased incrementally from 2016-17, rising from an estimated $51 per month then to an estimated $57 per month today.

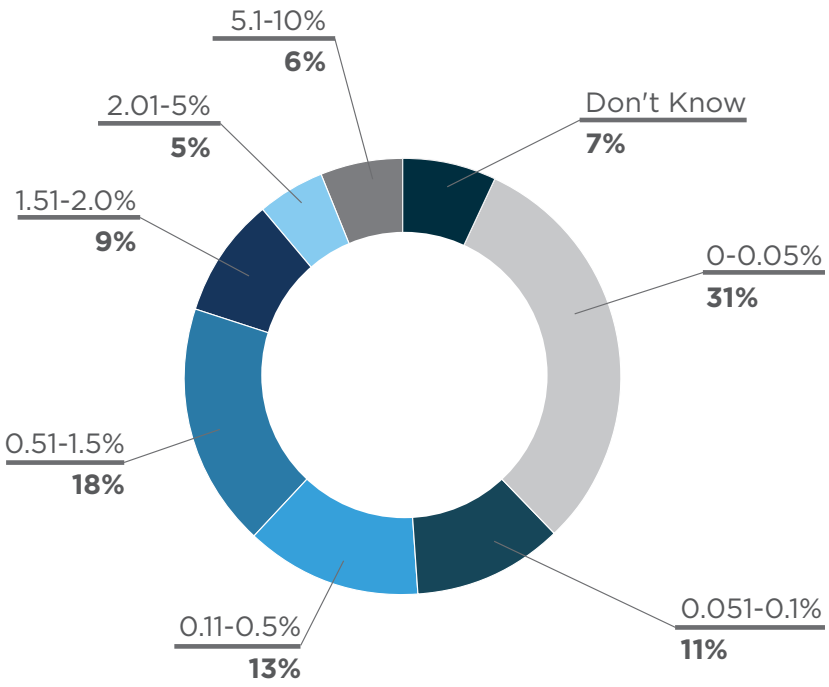
FIGURE 12: U.S. Fixed-Wireless and Hybrid ISP Residential ARPU, 2019-20



Source: Surveys and Analysis by The Carmel Group from an in-depth survey of U.S. Fixed wireless operators and vendors during June-July 2020.

Residential Churn: Relative monthly subscriber turnover continues to be an objectively positive benchmark of the U.S. fixed-wireless-centric ISP industry. The local nature of the networks tends to improve QoS, in turn making customers more loyal, long-term, and accretive. Importantly, loyal subscribers enable operators to avoid the drag of both ARPU losses and the SAC of trying to replace that lost customer. Frequent, incremental investments in infrastructure, especially tower and CPE, further reduce the likelihood of significant customer loss.

FIGURE 13: U.S. Fixed-Wireless and Hybrid ISP Residential Subscriber Churn

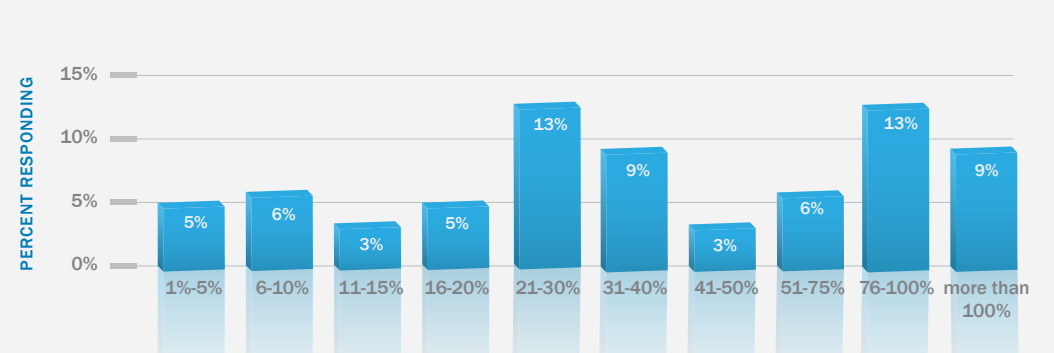


Source: Surveys and Analysis by The Carmel Group from an in-depth survey of U.S. Fixed wireless operators and vendors during June-July 2020.

VENDOR SURVEY ANSWERS

Revenues: From 2019 to 2020, overall sales of fixed-wireless-related hardware, software, and services rose in the range of 76%-100% YOY for 13% of the vendors surveyed. An equally large percentage, 13%, claimed their 2019-2020 growth was 21%-30%, while an impressive 9% listed YOY growth at "more than 100%." Indeed, well over 50% of surveyed vendors estimated 2019-2020 growth above 21%. Perhaps more importantly, almost 20% said they believe that by year-end 2025, their company's fixed-wireless-related revenues will increase by 51% to 75%. Asked to rate their optimism about the five-year outlook on a scale of 1 to 10, where 10 is the most optimistic, 20% said 7; 31% said 8; 22% said 9; and 15% said 10. This results in a grand total of 88% of vendor respondents who were moderately to highly optimistic.

FIGURE 14: U.S. Fixed-Wireless Vendors' Revenue Growth, 2019-2020



Industry Makeup: To better understand the composition of fixed-wireless-centric industry vendors, sales makeup was queried. This data answers the question: What do they make? Thirty percent said they were hardware-only vendors; 6% said software-only; and 18% said service-only, e.g., legal, accounting, PR, marketing, and sales. Three percent sell hardware and software; 12% sell hardware and services; and 18% sell all three.

FIGURE 15: U.S. Fixed-Wireless Vendors' Product/Service Makeup, 2020