Reimagine NY Commission
Connectivity Working Group – Background Research

I. Executive summary

The COVID-19 crisis has heightened focus on both the necessity of affordable, high-speed internet connection and the connectivity disparities that exist in New York State and across the United States. Governor Andrew Cuomo has charged the Reimagine New York Commission with helping to ensure that all New Yorkers have access to affordable, high-speed internet, as well as the knowledge and technical support to use it. This document reviews the current state of connectivity in New York in order to inform the Commission's forward-looking work.

Compared to other states, New York ranks highly across broadband access metrics, largely due to the success of the State's $500 million program to increase broadband coverage statewide. Nonetheless, critical work remains to be done. Two million households in New York do not subscribe to at-home broadband, and millions more do not have the devices and skills needed to perform basic online tasks such as job hunting or enrolling in unemployment benefits.

On a global scale, data suggest the broadband market in the U.S. underperforms those of other developed nations due to an insufficient regulatory framework that has failed to create competitive broadband markets that serve all consumers.[i]

In assessing connectivity in New York State, the Commission is mindful that there are barriers posed to New Yorkers, as well as market-level coordination and deployment challenges. There are three primary barriers to connectivity that New Yorkers may face:

1. **Lack of coverage at adequate speeds,** where questions include: Are internet options available at the place of residence? Do those options offer the speeds needed by that household?
2. **Affordability, where questions include:** Are the personal devices and monthly subscription costs needed to connect to the internet at home reasonably affordable?
3. **Digital literacy, where questions include:** Does every New Yorker have the tools and capabilities to use the internet to its fullest capacity?

The substantial up-front investment required for broadband deployment results in two challenges for broadband markets as they exist under current regulatory frameworks: (1) markets tend toward local concentration, limited consumer choice, and prices above what could be sustained in a competitive market (supra-competitive prices), and (2) it is difficult for private providers to justify rural deployment based on monetary return alone.

A number of innovative business models have emerged to connect communities, increase market competition, and secure access for underserved groups. These include open-access networks, municipal networks, cooperative networks, public-private partnerships, and wireless community-led networks. The new models are significant because they have the potential to address the underlying economic challenges that leave certain markets underserved and perpetuate the digital divide.

In order to inform the Commission's work, this memo provides background information on the state of connectivity, current market dynamics, and how New York ranks in connectivity. It analyzes existing limitations to connectivity and emerging models that might be deployed to ensure all New Yorkers have access to affordable, at-home broadband and the best digital skills. Finally, Appendices include definitions, coverage and adoption rates, as well as a recap of the Commission's work to date.

II. Digital equity and the digital divide

Internet connectivity is increasingly viewed by the public as a utility, essential for social, economic, and

democratic prosperity—for learning, working, accessing healthcare, and connecting with loved ones.[ii] Many jobs only accept online applications.[iii] Students without at-home internet access struggle to complete homework and fall behind in school. Government services and information are increasingly administered online.

The necessity of at-home broadband has become all the more apparent as the COVID-19 pandemic has closed public access facilities and local businesses. It has also brought to light both the necessity of affordable, high-speed internet connection and the substantial connectivity disparities that exist in New York State and across the U.S.

To achieve full digital equity, New York will need to bridge "the digital divide," which exists across the following axes:

1. **Population density:** Because of the economic challenges of deploying capital-intensive broadband infrastructure in rural areas, these parts of the state are more likely to lack high-speed internet coverage.
2. **Income:** Many Americans cannot afford at-home broadband, which is only widening the digital divide based on income. Further, new technologies such as fiber are less likely to be deployed in lower-income communities, creating further divisions in quality of connection.[iv]
3. **Race:** In New York, Black and Hispanic households are respectively 1.35x and 1.14x more likely to be without a broadband subscription than non-Hispanic White households.[v] In studying the U.S. as a whole, researchers have found that these racial disparities, driven by structural inequities, continue to persist even after controlling for income and employment.[vi, vii]
4. **Historically underserved populations:** The digital divide crosses other socioeconomic demographics as well. Often left behind are the elderly, individuals with disabilities, the homeless, and undocumented immigrants, among others. Some of these groups face additional, structural barriers to getting connected, such as lack of access to a credit card.

III. The market for connectivity

Mobile and fixed telecommunications markets and the regulatory environments in which they operate are complex. This section surveys these markets, highlights the economic challenges faced by both customers and new market entrants, and addresses the historical lack of federal regulation that has enabled market concentration to persist. These market dynamics provide important context to evaluating the barriers to universal connectivity in New York State today.

Two distinct but interconnected connectivity markets exist: the fixed broadband market and the mobile wireless market. Fixed broadband is delivered to a stationary point, while mobile networks enable connection with a portable device. Mobile broadband, delivered through wireless technologies, is generally slower and less reliable than fixed offerings.

Mobile wireless access

Three major mobile network operators (MNOs) operate in the United States: Verizon, AT&T, and T-Mobile.[viii] In addition, a handful of mobile virtual network operators (MVNOs) (e.g., Cricket Wireless, Virgin Mobile, Boost Mobile) lease service wholesale from the MNOs and resell to subscribers as a retail provider.
Mobile network infrastructure is distinct from fixed infrastructure and is delivered through a network of cell towers, antennas, and small cells connected to the internet predominantly via backhaul fiber. Most towers in the United States are now owned by independent tower companies (e.g., Crown Castle, American Tower, SBA Communications).

Cellular delivery also requires spectrum—the right to use certain radio frequencies to deliver wireless

communication. In the United States, spectrum is allocated by the Federal Communications Commission (FCC) to minimize interference. Some spectrum bands are licensed for exclusive commercial use via auction while other spectrum bands are designated for unlicensed use (i.e., Wi-Fi). New spectrum bands are also being considered for allocation to facilitate additional wireless and fixed wireless deployment, including Citizens Broadband Radio Service (CBRS) and TV White Space (TVWS).

MNOs are now building their next-generation 5G networks. 5G offers the potential of faster mobile speeds (>1 Gbps) and low-latency connections for smart devices and smart city infrastructure. Optimal deployment of 5G will require both mid-band (< 6 GHz) and high-band (mmWave) spectrum. Because high-band frequencies cannot travel long distances, 5G networks will require greater cell site density. A majority of these cell sites must be connected to fiber backhaul, so 5G will require significant fiber buildout and densification in metropolitan areas. 5G is likely to be expensive for both providers and users, with low-income households likely to be the last to receive service.

A convergence is now occurring between mobile and fixed markets. As MNOs continue to densify their wireless networks and fixed wireless technologies advance, MNOs are beginning to launch fixed offerings (e.g., T-Mobile Home, Verizon LTE Home Internet). At the same time, fixed providers are entering the mobile market with retail MVNO offerings (e.g., Altice Mobile).

The remainder of this report focuses primarily on fixed, residential broadband delivery.

Fixed internet delivery technologies

Fixed internet connection can be delivered via a set of wired and wireless technologies. These technologies differ in the download and upload speeds they are able to offer. Historically, upload speeds have lagged behind download speeds—the speeds are said to be "asymmetric." However, because video conferencing requires two-way data transfer, it needs fast download and upload speeds, or a "symmetric" connection. As video conferencing and other two-way data transfers have increased in importance—especially during the COVID-19 crisis—many have emphasized the necessity of symmetric speeds.[ix]

Wired delivery technologies include fiber to the home (FTTH), coaxial cable, and DSL. Wireless delivery technologies include terrestrial fixed wireless and satellite internet. Details on each delivery technology and associated speeds can be found in Appendix 1.

Challenging market dynamics

Fixed broadband markets face two structural challenges, which result from the substantial upfront investment required to build an end-to-end broadband network:

1. **Unregulated broadband markets tend toward local concentration, limited consumer choice, and supra-competitive prices.** Upfront capital costs create large economies of scale and high barriers to entry. This dynamic has resulted in local markets being divided among the major internet service providers (ISPs) in the United States. Any given home will typically have one cable offering (e.g., Comcast's Xfinity, Charter's Spectrum, Altice's Optimum), one DSL offering, and potentially a new FTTH offering (e.g., Verizon Fios, Google Fiber). Most households across New York State have only one or two high-speed internet offerings from which to choose (Figure 1). Limited consumer choice alongside high barriers to entry have the potential to result in supra-competitive prices.

2. **In the country's most rural areas, profit-maximizing firms choose not to invest in infrastructure in the absence of government intervention, subsidies, or cooperative action.** In these areas, fiber must cover greater distances to connect a single household. The cost of deployment per household is inversely proportional to population density. In the most rural areas, the capital investment needed per household exceeds the net present value of revenues generated by that household. If the monetary return on

investment is negative, a profit-maximizing firm will choose to not build infrastructure.

Figure 1. Weighted average number of fixed internet providers, by county
(excl. DSL, satellite) (download speeds >100 Mbps).

Source: FCC Form 477, Reimagine NYS Analysis

Federal regulation is limited

In the United States, utilities such as roads and electric power are heavily regulated due to their status as both essential services and natural monopolies.[x] These two conditions are held to justify government intervention to ameliorate market failures and increase consumer welfare. The same argument is increasingly being made for the internet. However, at present, federal regulation of internet service providers is limited.

ISPs in the United States have historically faced limited federal regulation. In 2015, the FCC's Open Internet Order reclassified ISPs as "common carriers" for the purpose of passing net neutrality requirements. "Common carriers" (as opposed to "information services") are subject to greater federal regulation under the Communications Act of 1934. However, this decision was repealed in 2018. ISPs are currently lightly regulated as "information services." Cable operators are not required to share access to their broadband infrastructure with competitors, a practice known as "interconnection" or "common carriage." Though telephone companies (i.e., DSL providers) were initially bound by common carriage laws, the FCC dropped these regulations in 2005 to avoid asymmetric penalization across cable providers and telecommunication providers. Regulation of ISPs today is done in the context of merger approvals and conditions on federal and state funding.

Historically, bipartisan consensus in the United States, bolstered by ISP lobbying, argued that light-touch regulation of internet service provision would facilitate innovation and fast expansion by enabling providers to reap the rewards of their capital investments.
Proponents of increased federal regulation hold that internet delivery, such as roads and power, is both an essential service and a natural monopoly. As former President Barack Obama said in his 2014 advocacy to the FCC on net neutrality, "In plain English, I'm asking [the FCC] to recognize that for most Americans, the internet has become an essential part of everyday communication and everyday life." President Obama's statement was in the particular context of net neutrality regulation. However, other proponents of increased regulation would take it a step further and argue that common carriage requirements and/or price controls would lead to a more efficient market outcome and increased consumer welfare.

The FCC has historically argued that its decision not to regulate ISPs under Title I of the Communications Act of 1934 preempts states from regulating ISPs on their own accord, and circuit courts have traditionally held that state regulation of ISPs is preempted by federal authority. However, the DC Appeals Court Mozilla v. FCC decision in 2019 may open the door to state regulation of ISPs, particularly state net neutrality laws, so long as ISPs remain regulated as information services by the FCC.

IV. The state of connectivity in New York State

An ambitious standard for what it means to be "connected"

Internet connection today is a necessity. Connectivity is omnipresent—individuals require access in their homes, places of work, schools, and on the go. As such, ISPs offer a multitude of services targeted toward different market segments: large enterprises, small to mid-sized businesses (SMBs), and individual consumers. This document focuses on the consumer market segment and the barriers to connecting New Yorkers in their homes.

To achieve true digital equity, New Yorkers need both mobile and fixed connections. This section focuses on home internet connection, given the limitations of mobile for activities such as filling out job applications, working from home via video conferencing, completing online homework assignments, and accessing digital government services—all tasks which require a laptop or tablet device and fixed connection at adequate speeds. An ambitious standard of at-home connectivity requires:

1. **Fixed, at-home connection:** A truly equitable solution would ensure all New Yorkers have at-home broadband access in addition to free access at anchor sites (e.g., libraries). During the course of the COVID-19 pandemic, some libraries have extended Wi-Fi access to their parking lots. Students completing homework in parking lots is a novel concept, but not equitable or sustainable.[xi] Students without at-home connection risk falling behind academically.[xii] Further, though cellular service may be an effective interim solution, fixed service is faster and more reliable than cellular.

2. **Laptop/tablet devices:** Mobile device connection alone is insufficient for many of the basic tasks New Yorkers must complete online today.[xiii] Many entry-level jobs require online applications, which are challenging to fill out on a small smartphone screen.[xiv] Ultimately, the ideal outcome would be for all New Yorkers to have both mobile and fixed access.

3. **Speeds in excess of 100 Mbps:** New Yorkers require different internet speeds depending on their online activities; at a household level, required speeds also depend on the number of users online simultaneously (Figure 2). For example, four users simultaneously on video conferencing will require 40–80 Mbps connection. The current threshold of 100 Mbps to be considered to be "served" in New York State,[xv] is therefore sufficient. However, activities such as video conferencing require symmetric (download and upload) speeds as data is transferred in two directions. Some states and the FCC still consider 25 Mbps to be "covered," while New York has it as "underserved."

(See next page for Figure 2)

Figure 2. Download speeds needed by activity and users per household

Source: https://broadbandnow.com/guides/how-much-internet-speed-do-i-need, https://www.highspeedinternet.com/how-much-internet-speed-do-i-need
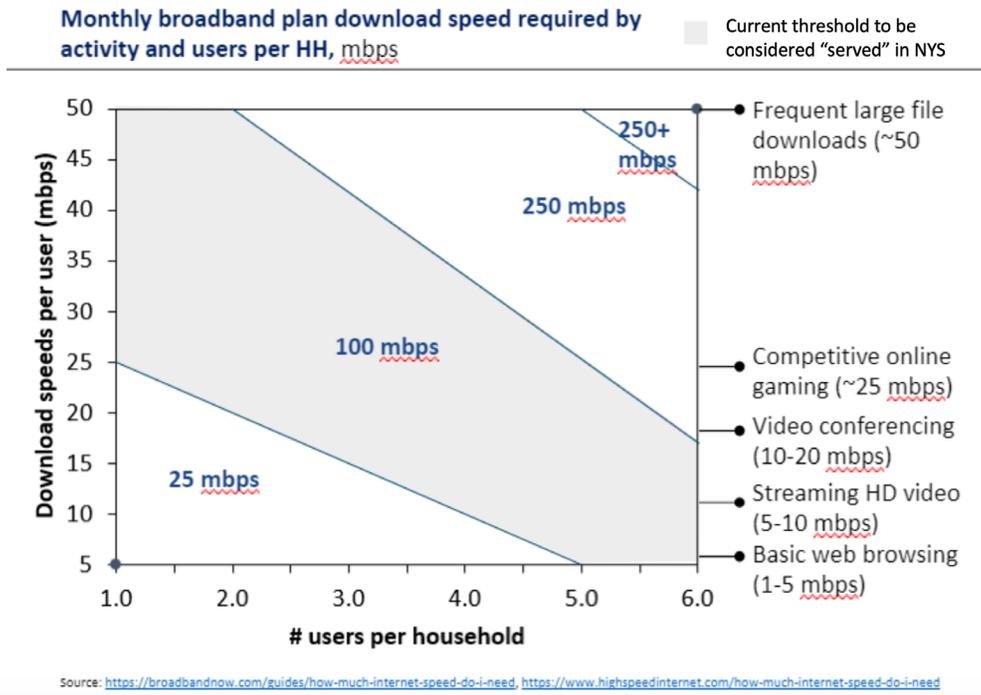
The scale of barriers today

Keeping this ambitious standard in mind, there are three common barriers to connectivity a New Yorker may face: Lack of coverage at adequate speeds, affordability, and digital literacy. Affordability represents the largest barrier to bringing New Yorkers online.

(A) Availability: According to FCC Form 477 data, 98.8 percent of households in New York State are covered by >100 Mbps fiber, cable, or terrestrial fixed wireless.[xvi] This suggests ~100,000 households are still not covered by 100 Mbps broadband.[xvii, xviii] If a household lacks coverage, it means that the household could not purchase 100 Mbps service at-home access even if it tried.

Additional deployment catalyzed by the New York State Broadband Program Office grants under the New NY Broadband Program will bring the percentage of households covered by >100 Mbps fiber, cable, or terrestrial fixed wireless up to at least 99.3 percent (~51,000 households without coverage), placing New York State second nationally in broadband access rankings.[xix]

The coverage improvements achieved through the New NY Broadband Program are impressive. However, FCC data is known to overestimate the number of covered households because coverage is reported at the census-block level, and a census block is marked as served even if only one household in that census block can receive service. In February 2020, BroadbandNow, a consumer guide for ISP plans, pricing, and coverage, published a report using sampling methods to estimate the true number of households without coverage. BroadbandNow's analysis suggests that, as of 2019, 96.8 percent of NYS households are covered by >100 Mbps broadband (~241,000 households remain without coverage); this number is expected to rise as New York's broadband program continues to be implemented.
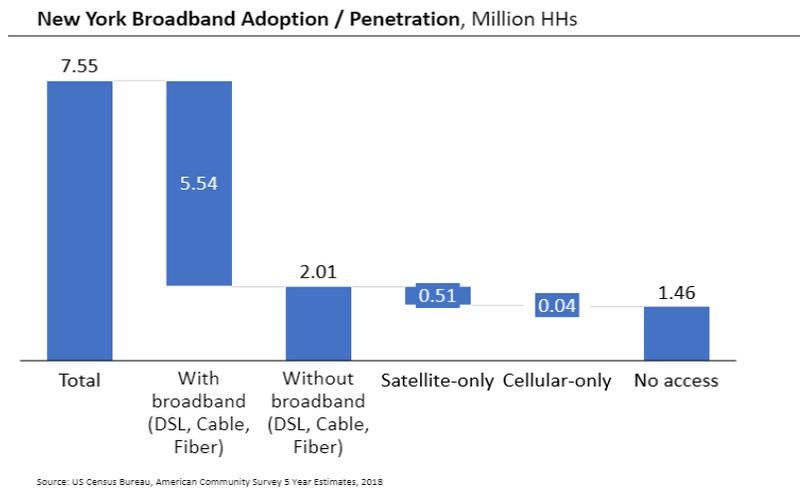
As mandated by the March 2020 federal Broadband DATA Act, the FCC's Digital Opportunity Data Collection (DODC) efforts put forth a plan to (1) develop a nationwide building-level location "Fabric," (2) require mobile

and fixed service providers to submit collect granular coverage shapefiles, and (3) develop a process to challenge and validate these maps through crowdsourcing methods and third parties.[xx] The FCC's ongoing efforts to improve map accuracy, including lot-level coverage data, will be critical to identifying and serving the households that remain without adequate service today. Congress appropriated the necessary funds to implement DODC through its COVID-19 relief and stimulus package in December 2020.

Taken together, these findings suggest that the number of households remaining without fixed coverage in New York State is relatively small, particularly compared to other connectivity barriers addressed below (e.g., affordability, digital literacy). However, the State must be aware of the flaws in current FCC data and remain diligent in closing remaining gaps in fixed connectivity.

(B) Affordability: About two million households in NYS (approximately 5.2 million individuals) do not subscribe to at-home broadband (Figure 3).[xxi] Given this definition of at-home broadband includes DSL connections, that means an even higher number of households do not subscribe to at-home broadband with download speeds >100 Mbps.

Figure 3. Broadband adoption in New York State

New York Broadband Adoption / Penetration, Million HHs

7.55	5.54	2.01	0.51	0.04	1.46
Total	With broadband (DSL, Cable, Fiber)	Without broadband (DSL, Cable, Fiber)	Satellite-only	Cellular-only	No access

Source: US Census Bureau, American Community Survey 5 Year Estimates, 2018

Source: US Census Bureau, American Community Survey 1 Year Estimates, 2018.
Census Bureau adoption estimates scaled up to match FCC estimates of the total households in New York State.

Adoption is principally an issue of affordability. Improving service affordability is arguably the most significant lever for bringing more New Yorkers online. Note that broadband prices differ across New York State (Figure 4). The lowest priced 100 Mbps broadband plan ranges from $40 to $70 across the state. Fewer low-cost offerings exist upstate, driven largely by the fact that fewer providers offer service there.

(See next page for Figure 4)

Figure 4. Lowest priced 100 Mbps terrestrial plan, by county
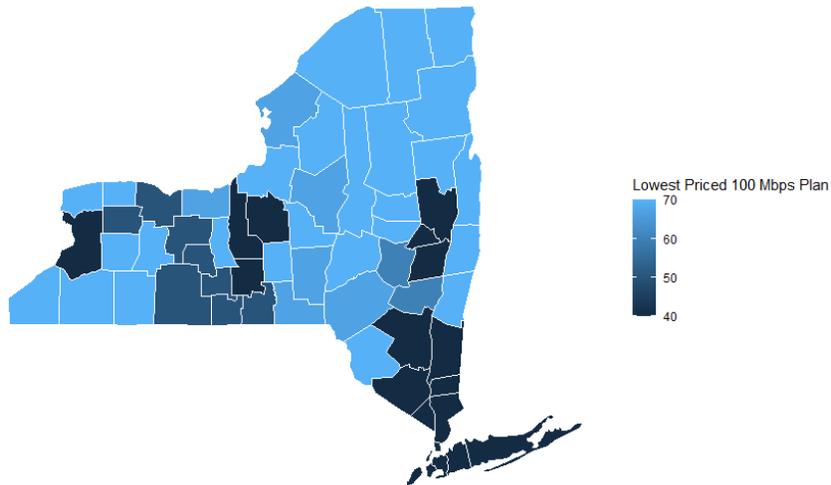
Source: BroadbandNow pricing data, Reimagine NYS Analysis

At the individual level, affordability is a function of both price of available plans and income (Figure 5). The figure below examines affordability as a function of these two variables, plotting by county the percentage of households for which 100 Mbps broadband would cost greater than 2.5 percent of monthly household income. One to two million households statewide would have to spend more than 1.5 to 2.5 percent of monthly household income on at-home 100 Mbps broadband.[xxii]

Figure 5. Proportion of households for which 100 Mbps broadband would cost >2.5% of household income
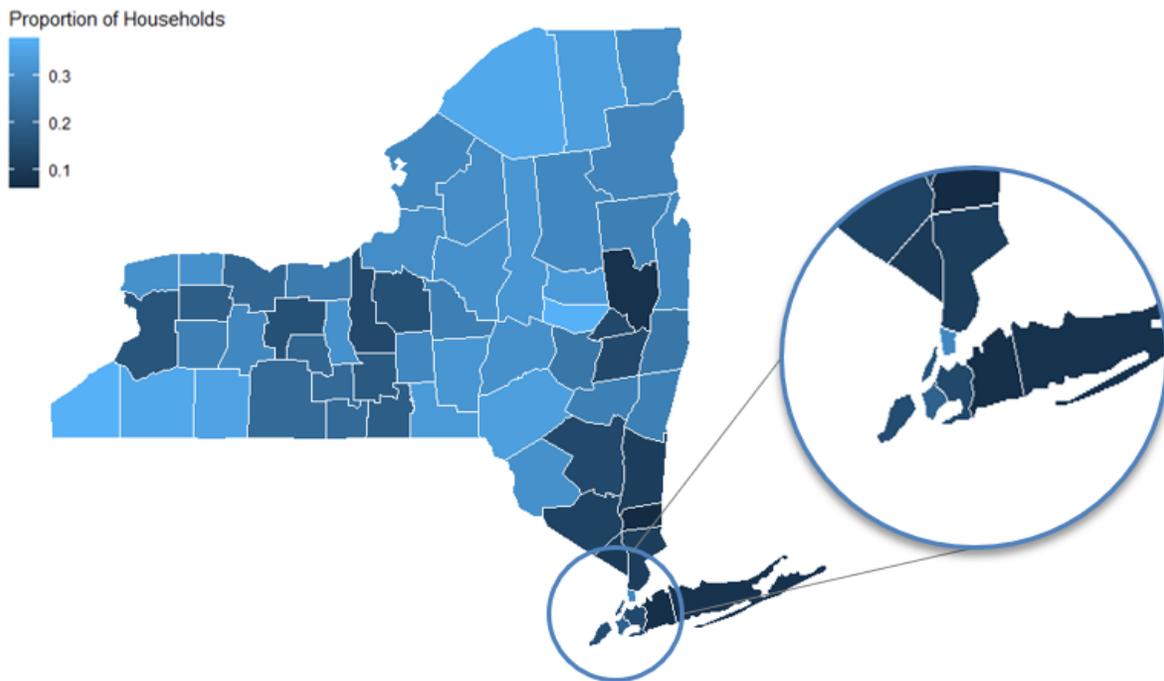
Source: BroadbandNow pricing data, US Census Bureau income data, Reimagine NYS Analysis

As an additional component for understanding affordability, each county and municipality faces differing needs. Appendix 2 provides details on coverage, adoption, prices, and income by county.

Further, price transparency in broadband markets is clouded by bundling, limited time discounts, and hidden fees.[xxiii] Lack of price transparency may inhibit consumers from making informed choices and purchasing decisions in broadband markets.

(C) Digital literacy: Studies suggest that ~15 percent of adults in the U.S. lack the digital skills and confidence needed to use the internet to its fullest capacity.[xxiv,xxv] This equates to 2.9 million individuals in New York State. Digital literacy is the ability to use technology and the internet to acquire and share information with others. Basic digital skills involve being able to troubleshoot access equipment (e.g., modems, routers), log on to devices, browse the internet safely, and locate and upload necessary online information. Research from the U.S. Department of Education reveals strong inverse correlations between digital literacy and existing social and economic inequities.[xxvi]

How New York State ranks in the United States and globally

Within the United States, New York State ranks among the top across broadband metrics. According to BroadbandNow, New York State ranks third for terrestrial broadband coverage, sixth for access to low-priced broadband plans, and third for fastest average download speeds. When taken together, New York ranks second nationally among states.[xxvii]

However, the U.S. broadband market as a whole is known to underperform relative to that of other developed nations—and has some of the highest broadband prices.[xxviii] The Open Technology Institute's 2020 Cost of Connectivity Report finds that the United States consistently has higher average monthly prices than other markets in North America, Europe, and Asia.

According to the FCC's 2018 Sixth International Broadband Data Report, out of 29 examined OECD countries, the United States ranks:
- 10th for fixed broadband coverage,
- 10th for average experienced fixed broadband speed,
- 21st for "fixed broadband price index" aggregating across both fixed and standalone broadband plans, and
- 7th for the "fixed hedonic price index" adjusting price for demographic and quality differences across countries.[xxix]

According to Akamai's 2017 State of the Internet Report, a widely cited report based on data from the company's Intelligent Edge Platform, New York State ranks as the 16th region globally for average peak connection speed, with Singapore, Macau, and Mongolia topping the chart.[xxx]

V. Existing connectivity programs and their limitations for New Yorkers

Federal connectivity programs

The federal Universal Service Fund, administered by the Universal Service Administration Company (USAC) at the direction of the FCC, administers four relevant connectivity programs:
1. **The "high-cost" program addresses the coverage barrier,** providing funding for infrastructure deployment in unserved rural areas of the United States. The high-cost program consists of multiple funds including the Connect America Fund (CAF) reverse auctions and the subsequent Rural Digital Opportunity Fund (RDOF), which has a budget of $20.4 billion to spend over the next 10 years, with Phase I launched in October 2020.

2. **The Lifeline program addresses the affordability barrier,** providing a $9.25 per month discount per qualifying household on telephone or internet connection (mobile or fixed). Households qualify if they participate in the Supplemental Nutrition Aid Program (SNAP) or Medicaid, or if their income is 135 percent or less than federal poverty guidelines. In New York State, 771,000 of the 2.6 million households eligible for Lifeline participate in the program—a 29 percent participation rate.[xxxi] This participation rate, while low, is in line with that of other states. Low participation rates likely result from flaws in program eligibility rules that limit its impact: the ability to utilize Lifeline for fixed access is limited as it covers only mobile or landline connections, not cable or other standalone broadband connections.[xxxii]

3. **The E-rate program addresses connectivity for schools and libraries,** providing connectivity funding for K-12 schools and libraries on eligible services (e.g., access, leased fiber, self-provisioned networks, internal connection equipment). However, the FCC currently argues that E-rate funds cannot be used to procure access for students outside of school and library campuses. Since the COVID-19 crisis began, many groups have advocated for a waiver to allow E-rate funds to be used to extend access to students at home.[xxxiii]

4. **The rural healthcare program addresses connectivity for healthcare providers,** subsidizing the difference in access costs between rural and urban areas.[xxxiv]

State programs

Addressing coverage barriers, particularly upstate, has been a particular focus of New York State government since 2015, when Governor Cuomo launched the New NY Broadband Program with a goal of achieving 100 percent broadband coverage in New York State.[xxxv] At the time, only 70 percent of households were covered with high-speed broadband. This $500 million in state funding—allocated through a reverse-auction process—is the largest investment by any state to date to support projects delivering high-speed internet access to both unserved and underserved areas. The program expanded coverage to approximately 2.4 million locations statewide, catalyzing almost $1 billion in private investment. According to FCC Form 477 data from June 2019, 98.8 percent of households are covered by 100 Mbps speeds (excluding DSL and satellite providers) with additional areas to be covered through planned BPO grants.

Beyond investments in coverage, NYS has also heavily prioritized closing the digital divide at schools via its 2014 Smart Schools Bond Act. The $2 billion program has made funding available to school districts across the state for technology-enabled devices and classroom enhancements that improve in-person learning and school connectivity.

However, members of the public and community advocates have testified to the Commission about remaining gaps in coverage, limited consumer choice, and, most notably, affordability.[xxxvi] The discrepancy between coverage data and on-the-ground testimony is likely driven by the lack of granularity in FCC Form 477 data and discrepancies between advertised speeds and experienced speeds. Being covered does not mean that New Yorkers can afford or have access to high-speed internet.

ISP programs

Many internet service providers advertise affordable access options for qualifying subscribers (Figure 6). Some of these affordable programs are the result of state or federal regulation through merger conditions.[xxxvii] Eligibility requirements are broadly similar to those for the Lifeline program but differ by provider. Further, many providers limit offerings for individuals with existing overdue balances. Lifeline discounts cannot be used on top of the plans listed below because these providers are not eligible for Lifeline participation (except for Verizon). Advocates continue to call for expansion of affordability programs to make them more accessible and higher quality.[xxxviii]

Figure 6. ISP affordable access plans (availability varies)[xxxix]

Provider	Affordable plan
Comcast Internet Essentials	+ $9.95 per month for 25 Mbps. + No installation or modem fee. + Option to purchase a low-cost computer.
Spectrum Internet Assist (Charter)	+ $14.99 per month for 30 Mbps. + No installation or modem fee.
Altice Advantage	+ $14.99 per month up to 30 Mbps. + Free modem. Discounted installation.
Verizon	+ $19.99 per month for 200 Mbps FIOS service. *($20 per month discount on $39.99 per month service)* + $99 installation fee. $15 / mo router fee. + DSL offerings excluded.
AT&T Access[1]	+ $10 per month for up to 25 Mbps. + No installation or modem fee.
Starry Connect	+ $15 per month for 30 Mbps. + No installation or modem fee.

[1] Not available in New York State.

VI. Emerging models for connectivity

There are a number of emerging business models to connect communities, increase competition and consumer choice, and secure access for underserved groups. These business models differ based on design choices along the value chain:

1. Scope of network: middle-mile, last-mile, both

2. Backbone and backhaul infrastructure: owned or leased

3. Network ownership: public, private for-profit, private non-profit, public-private partnership, collective community ownership

4. Last-mile technology used: fiber, fixed-wireless

5. Revenue model: wholesale/open access, retail service provision

These business models for ISPs are increasingly adopted by niche, start-up, and minority and women-owned business enterprises (M/WBE). We highlight five emerging archetypes below.[xl, xli]

(1) Open-access networks lease shared, physical infrastructure to multiple retail providers that offer internet services to the internet user. One of the principal challenges across the United States is that internet users lack a real choice when choosing a broadband provider. Local incumbents can charge supra-competitive prices with little incentive to innovate. By shouldering the initial capital investment, open-access networks are able to drive retail competition, reduce prices, and increase consumer choice. Open-access networks have been successful outside the United States in Sweden, Singapore, and New Zealand.

Open-access networks may be publicly or privately owned. Ammon, Idaho's publicly-owned, open-access,

FTTH network offers service through four retail providers with gigabit service ranging from $10–$50 per month. Privately-owned, open-access FTTH networks include Albuquerque's CityLink Fiber and SiFi Networks' Fullerton FiberCityTM in California.[xlii, xliii]

(2) Municipal networks are owned end to end by the local government, which may contract a private firm to handle network operations. An archetypal example is that of the Electric Power Board of Chattanooga, TN, a city-owned authority that built out the FTTH network that made Chattanooga a magnet for start-ups and tech talent and gave it the name "gig city."

A 2018 study through Harvard's Berkman Klein Center for Internet & Society finds that among "community networks" (publicly owned or cooperative owned FTTH networks), 23 out of 27 networks studied provided the cheapest 25/3 Mbps service in their localities, offering three percent to 50 percent discounts compared to private providers in their respective markets.[xliv]

(3) Cooperative networks are non-profit, member-owned entities that self-finance, own, and often operate the network. Most cooperative broadband networks are telephone or electric cooperatives that expanded into broadband services. RS Fiber in Minnesota was one of the first successful FTTH cooperatives built solely for broadband. RS Fiber is owned and controlled by its membership.

(4) Public-private partnerships are when governments and private firms partner to share the risks and rewards of a network deployment. These agreements may involve revenue-sharing models and temporary exclusivity periods for the private provider. Successful examples include partnerships between Westminster, Maryland and Ting, and West Des Moines, Iowa and Google Fiber.

(5) Wireless community-based networks are supported by and responsive to community-based organizations and volunteers. In New York State, NYC Mesh and the Red Hook Initiative are non-profit mesh networks that provide connection free of charge, operating as a system of wirelessly interconnected routers. The challenge with wireless mesh networks is connection is unpredictable and subject to interference.

Broadband markets today are controlled by a small handful of incumbents. These new business models are significant because they have the potential to address the underlying economic challenges that leave certain markets underserved and perpetuate the digital divide. They have the potential to change that dynamic in a way that results in lower prices, higher-quality service, and deployment in rural areas that would otherwise be unserved by traditional ISPs.

VII. Conclusion

Now more than ever, internet connectivity is a key driver of social and economic equity. The Reimagine New York Commission therefore envisions a future wherein all New Yorkers have at-home access to affordable broadband at high speeds >100 Mbps as well as the skills to use that connection to meet their individual needs. To achieve this goal, the Commission seeks to implement solutions to overcome the barriers identified here: lack of coverage, choice, reliability, and literacy; prohibitive device and service costs; and slow speeds. Building on its impressive progress to date, and in concert with federal and local governments, New York State can be a global leader in advancing next-generation broadband technologies—and promoting equity for all New Yorkers.

Appendix 1. Definitions

The internet

The internet is a network of networks, transferring data via an array of connected technologies. The core of the internet, its "backbone," is made up of a series of long-distance fiber networks that peer with each other at internet exchange points (IXPs). The networks that comprise the backbone are owned by what are referred to as "Tier 1" internet service providers (ISPs), which agree to interconnect their networks free of charge through settlement-free peering.

Residential broadband subscribers typically interact with a local network provider that connects to the regional (Tier 2) or national (Tier 1) networks through both peering and transit purchase. The connection between the consumer-facing ISP and the internet backbone is often referred to as backhaul. Local access providers may lease backhaul from other network operators.

As such, there are four segments of the market for fixed connectivity: (1) backbone network operator, (2) middle-mile network operator, (3) last-mile network operator, and (4) retail service provider.

Wired technologies:
- **Fiber to the home (FTTH)** is considered the gold standard for fixed internet connectivity.[xlv] Data is transferred through tiny, glass, optical fibers that carry data through light particles. Most of the internet backbone and middle mile is composed of fiber. FTTH is uniquely powerful because fiber is used as the "last-mile" technology, all the way to the internet user's home. FTTH can achieve symmetric speeds in excess of 1 GB (1000 Mbps).
- **Coaxial cable** delivers internet over existing cable television wires using the DOCSIS standard, which enables cables originally intended for video transmission to transfer data and provide internet. Today, hybrid fiber-coaxial cables can reach nearly 1 GB download speeds. However, cable speeds are asymmetric, favoring download over upload speeds.
- **DSL** delivers internet over existing telephone lines, consisting of twisted copper pair wires. DSL is generally slower than other last-mile delivery technologies, typically delivering download speeds less than 25 Mbps, though some DSL providers can deliver up to 100 Mbps.

Wireless technologies:
- **Terrestrial fixed wireless** delivers last-mile connection to a stationary point via wireless technology. An antenna connected to fiber backhaul projects out radio waves to a rooftop antenna at the subscriber's residence. Most fixed wireless solutions today have limited speeds (5–50 Mbps) and are subject to interference due to line-of-sight requirements between central and home antennas.[xlvi] Though today's fixed wireless access (FWA) service is limited, improved equipment and higher spectrum bands may eventually enable fixed wireless to deliver gigabit speeds.[xlvii] For example, **mmWave fixed wireless** is transmitted over the same high frequency bands (24–100 GHz) being used to deploy 5G. These wavelengths offer high speeds but can only travel short distances and are susceptible to interference (e.g., buildings, walls, trees, people). Mobile operators (e.g., Verizon, AT&T, T-mobile) are likely to use their licensed mmWave bands to deploy both mobile and fixed wireless. Unlicensed bands may be useful for further residential deployment. Verizon has begun 5G home internet rollout with expansion expected in Q4 2020; T-Mobile aims to have over 9 million home internet customers by 2024.[xlviii]
- **Satellite internet** transmits data via satellites in space to a dish located on Earth. **Geostationary (GEO) satellites** orbit far from Earth's surface (~22K miles) parallel to Earth's rotation and thus cover a specific area of Earth's surface. **Low Earth orbit (LEO) satellites** orbit closer to Earth's surface (~1K miles). A constellation of LEO satellites can be used to cover the entirety of the Earth's surface. GEO satellites have high latency and slow speeds because the information must travel great distances between the satellite and Earth.

Thus, satellite broadband today offers limited speeds (typically less than 25 Mbps, though some providers may offer up to 100 Mbps). However, there is a potential that in the future LEO satellites (i.e., SpaceX's Starlink) will be able to deliver high-speed broadband.[xlix]

Appendix 2. Coverage and adoption rates by county in New York State

Classification	County	Coverage Rate[i]	Adoption Rate[ii]	Lowest Priced 100 Mbps Plan	Median Income	% of HHs broadband burdened at 1.5%[iii]	% of HHs broadband burdened at 2.5%[iii]
High Coverage, High Adoption	Albany County	99%	76%	$39.99	$64,535	25%	14%
High Coverage, High Adoption	Broome County	99%	73%	$66.95	$50,859	52%	33%
High Coverage, High Adoption	Chemung County	98%	67%	$50.00	$53,299	38%	22%
High Coverage, High Adoption	Chenango County	91%	70%	$66.95	$50,595	52%	32%
High Coverage, High Adoption	Clinton County	93%	70%	$69.99	$55,178	50%	30%
High Coverage, High Adoption	Columbia County	98%	68%	$69.99	$63,032	45%	27%
High Coverage, High Adoption	Delaware County	92%	66%	$66.95	$48,827	54%	34%
High Coverage, High Adoption	Dutchess County	100%	81%	$39.99	$78,028	20%	11%
High Coverage, High Adoption	Erie County	100%	70%	$39.99	$55,673	30%	17%
High Coverage, High Adoption	Essex County	91%	70%	$69.99	$56,196	48%	28%
High Coverage, High Adoption	Fulton County	93%	67%	$69.99	$50,248	54%	33%
High Coverage, High Adoption	Genesee County	95%	69%	$50.00	$59,338	33%	19%
High Coverage, High Adoption	Herkimer County	91%	66%	$69.99	$51,862	53%	32%
High Coverage, High Adoption	Jefferson County	96%	71%	$66.95	$52,268	51%	29%
High Coverage, High Adoption	Kings County	100%	70%	$39.99	$56,015	32%	20%
High Coverage, High Adoption	Livingston County	90%	73%	$69.99	$56,071	49%	29%
High Coverage, High Adoption	Madison County	94%	70%	$69.99	$60,228	46%	27%
High Coverage, High Adoption	Monroe County	100%	74%	$50.00	$57,479	36%	21%
High Coverage, High Adoption	Nassau County	100%	84%	$39.99	$111,240	13%	7%
High Coverage, High Adoption	New York County	100%	77%	$39.99	$82,459	26%	17%
High Coverage, High Adoption	Niagara County	99%	68%	$69.99	$54,085	51%	31%
High Coverage, High Adoption	Oneida County	97%	69%	$66.95	$53,844	49%	31%
High Coverage, High Adoption	Onondaga County	100%	73%	$39.99	$59,225	27%	16%
High Coverage, High Adoption	Ontario County	97%	76%	$50.00	$63,359	31%	16%

High Coverage, High Adoption	Orange County	100%	72%	$39.99	$76,716	21%	12%
High Coverage, High Adoption	Orleans County	98%	68%	$69.99	$51,843	53%	31%
High Coverage, High Adoption	Oswego County	99%	73%	$69.99	$53,597	51%	30%
High Coverage, High Adoption	Putnam County	99%	84%	$39.99	$102,186	13%	6%
High Coverage, High Adoption	Queens County	100%	73%	$39.99	$64,987	25%	14%
High Coverage, High Adoption	Rensselaer County	100%	75%	$69.99	$65,851	43%	25%
High Coverage, High Adoption	Richmond County	100%	76%	$39.99	$79,267	23%	15%
High Coverage, High Adoption	Rockland County	100%	75%	$39.99	$91,108	19%	10%
High Coverage, High Adoption	St. Lawrence County	93%	67%	$69.99	$49,305	55%	36%
High Coverage, High Adoption	Saratoga County	100%	82%	$39.99	$80,839	17%	8%
High Coverage, High Adoption	Schenectady County	100%	77%	$39.99	$63,785	26%	14%
High Coverage, High Adoption	Seneca County	85%	66%	$69.99	$54,695	51%	31%
High Coverage, High Adoption	Suffolk County	100%	82%	$39.99	$96,675	15%	8%
High Coverage, High Adoption	Sullivan County	99%	71%	$69.99	$56,256	50%	31%
High Coverage, High Adoption	Tioga County	96%	72%	$50.00	$60,736	34%	19%
High Coverage, High Adoption	Tompkins County	98%	77%	$39.99	$58,743	30%	18%
High Coverage, High Adoption	Ulster County	100%	78%	$39.99	$63,348	26%	14%
High Coverage, High Adoption	Warren County	96%	75%	$69.99	$59,813	46%	27%
High Coverage, High Adoption	Wayne County	94%	67%	$66.95	$55,765	47%	26%
High Coverage, High Adoption	Westchester County	100%	80%	$39.99	$92,758	19%	11%
High Coverage, Low Adoption	Bronx County	100%	63%	$39.99	$38,085	44%	29%
High Coverage, Low Adoption	Cattaraugus County	82%	51%	$69.99	$47,240	57%	36%
High Coverage, Low Adoption	Cayuga County	89%	63%	$39.99	$56,579	27%	14%
High Coverage, Low Adoption	Chautauqua County	97%	64%	$69.99	$45,332	59%	38%
High Coverage, Low Adoption	Cortland County	94%	64%	$69.99	$54,489	50%	29%
High Coverage, Low Adoption	Franklin County	94%	59%	$69.99	$51,696	53%	34%
High Coverage, Low Adoption	Greene County	94%	58%	$59.99	$53,617	45%	27%

High Coverage, Low Adoption	Lewis County	84%	65%	$69.99	$52,380	52%	30%
High Coverage, Low Adoption	Montgomery County	96%	65%	$69.99	$45,837	58%	38%
High Coverage, Low Adoption	Schoharie County	98%	55%	$59.95	$53,989	44%	25%
High Coverage, Low Adoption	Schuyler County	89%	64%	$50.00	$51,479	38%	22%
High Coverage, Low Adoption	Steuben County	85%	64%	$50.00	$51,789	39%	22%
High Coverage, Low Adoption	Washington County	89%	60%	$69.99	$54,114	51%	29%
High Coverage, Low Adoption	Wyoming County	85%	62%	$69.99	$57,914	48%	27%
Low Coverage, High Adoption	Hamilton County	67%	67%	$69.99	$57,552	50%	29%
Low Coverage, Low Adoption	Allegany County	74%	57%	$69.99	$47,033	58%	35%
Low Coverage, Low Adoption	Otsego County	80%	64%	$69.99	$53,121	52%	31%
Low Coverage, Low Adoption	Yates County	75%	62%	$50.00	$54,343	38%	21%

Appendix 3. Commission work to date

As the Commission began its work, with a focus on equity, it sought to identify the groups most affected by barriers to connectivity. Among these are K-12 students, the elderly, low-income individuals, those facing housing insecurity or living in public housing, and individuals residing on tribal lands.

In our work to date, we have heard from local and municipal leaders, as well as community-based organizations that represent these groups, including Older Adults Technology Services (OATS), the Bronx Defenders, members of the National Digital Inclusion Alliance (NDIA), and librarians across the state.

We also sought input from leading thinkers in this space, including academics, federal advocacy groups, national and regional education networks, major ISPs, challenger ISPs, leaders of best-in-class community networks from across the United States, firms that provide financing for community broadband networks, and consumer protection advocates.

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lii Percentage of households that would have to spend > X% of income to access 100 Mbps broadband.