TELECOM ADVISORY SERVICES

THE ECONOMIC BENEFIT OF KEEPING THE "E" IN EBS: A COMPARISON OF LICENSING UNASSIGNED EBS TO EDUCATORS AND NONPROFITS VS. COMMERCIAL AUCTIONS

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SHLB
SCHOOLS, HEALTH & LIBRARIES BROADBAND COALITION

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EXECUTIVE SUMMARY

In May 2018, the Federal Communications Commission (FCC) released a Notice of Proposed Rulemaking (WT Docket No. 18-120) that sought comments on potential revisions to the Educational Broadband Service (EBS) rules, including licensing of unassigned EBS spectrum (EBS white space). The EBS white space comprises 4,000+ licenses, [1] mostly in rural markets, covering 50% of the territory and 15% of the population of the United States. This study quantifies and compares the economic and social benefits of two alternative approaches for assigning licenses for the EBS white space. The first would extend and modernize the current licensing of EBS to educational entities and tribal nations by opening application windows for such entities to have priority access to the unassigned spectrum. The second would auction licenses for the EBS white space to commercial carriers. This comparison and its results are specific to the 2.5 GHz EBS spectrum.

In this context, the Schools, Health & Libraries Broadband (SHLB) Coalition has retained Telecom Advisory Services LLC to produce a study that would quantify and compare the social and economic benefits of the options for assigning EBS white space. The study provides compelling evidence in support of a policy that extends and modernizes the current licensing regime, which recognizes a preference for tribes and educational institutions. By rolling out networks in areas without existing wireless broadband service, tribal, educational and nonprofit EBS providers can increase LTE penetration by 3,354,000 new subscribers; additionally, by offering uncapped affordable service in areas served by commercial wireless carriers, they can increase subscribers by 5,002,000. Taken together, this represents a reduction of the digital divide equivalent to 18.28%. The increase in wireless broadband subscriptions would yield positive externalities and a contribution to the U.S. GDP in an amount of $70.93 billion, a large portion of which will be concentrated in rural areas, with a derivative impact on job creation and the mitigation of rural migration. Furthermore, the increase in wireless broadband subscriptions would result in a reduction of the homework gap equivalent to 196,000 children. With 662,000 rural students currently experiencing the homework gap, continuing a modified EBS licensing regime would close the rural homework gap by 29.6%. In comparison, adopting a new policy in favor of auctioning EBS licenses would generate meager economic and social benefits.

The preservation of educational preference in the EBS white spaces through priority windows does not deny auctions as a conventional approach to manage the spectrum. There is a growing consensus among academic research and policy makers that the approaches to spectrum management that maximize welfare comprise a mix of licenses assigned through auctions and the establishment of rules governing portions of the spectrum as a common pool resource or assigned for exclusive use for public good purposes (e.g. unlicensed spectrum, portions of spectrum assigned for free such as EBS, etc.) (Milgrom et al., 2011; Dara, 2016). As a response to the command and control approach that the U.S. government adopted for spectrum management, Ronald Coase originally argued for property rights and a pricing mechanism in spectrum allocation. Although Coase championed the use of auctions,

[1] The 4,000-license figure assumes that the Commission issues new EBS licenses on a county basis instead of retaining the existing circular GSA license areas and retains the current band plan.

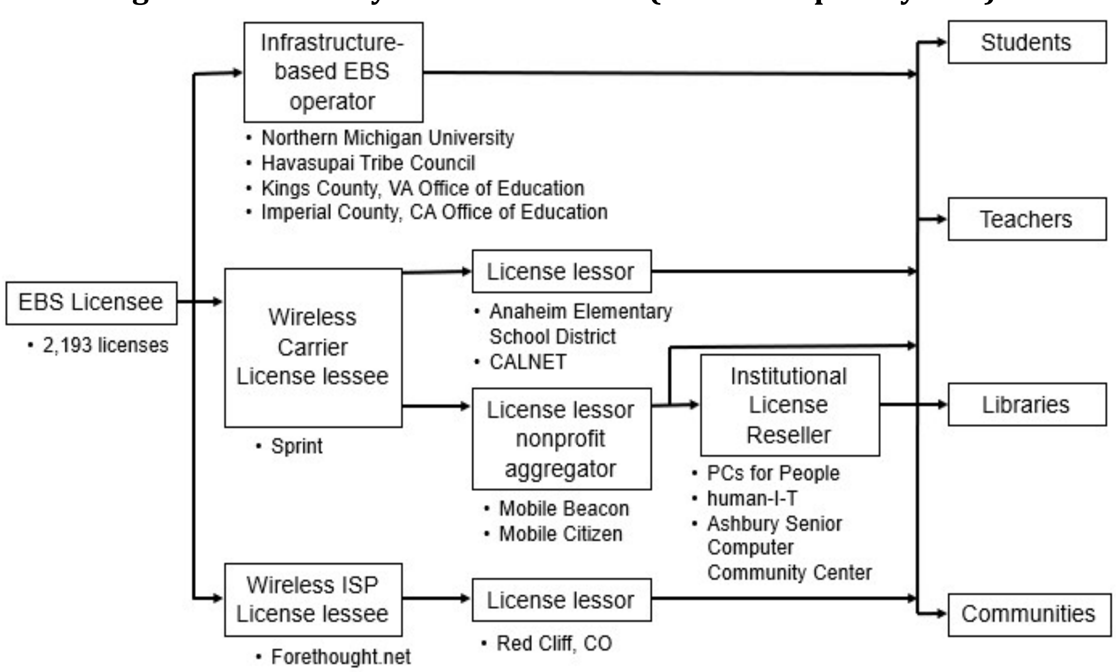
which confer exclusive rights to the auction winners on the assigned frequencies (according to the principle of "highest and best use" basis), his proposal was done in the context of spectrum mainly being used for broadcasting services, with no technology commercially available yet that would allow other ways to use spectrum. Coase's misallocation concern is not all that pressing in the EBS band, because licensees' track record of leasing to commercial providers indicates that transaction costs are fairly low.

Using auctions to assign spectrum licenses may lead to buildout in profitable areas if the economic circumstances provide a return, but it does not always result in spectrum reaching its "highest and best use" in areas that result in a limited return on investment for license holders. Based on this analysis, continuing with a modified EBS licensing regime would provide substantially greater benefits than pursuing an auction of EBS white space, and would not affect the rollout of 5G services. Continuing the EBS licensing scheme would deliver greater broadband deployment and adoption, a stronger positive impact on GDP, a higher reduction in the homework gap, a larger impact on high school attrition and greater consumer and producer surplus.

Current situation

Where licensed, EBS spectrum has been instrumental in advancing both commercial broadband deployment and educational connectivity. EBS is connecting close to ten thousand schools, libraries, nonprofits and anchor institutions across the country and through them millions of students and families not otherwise reached by commercial broadband offers. In those geographies where the FCC has issued EBS licenses, educational institutions and tribal nations serve their communities through two business models: self-deployed infrastructure based and license leasing (see figure A).

Figure A. EBS Ecosystem Value Chain (with examples by role)



Source: Telecom Advisory Services

Under one business model, consistent with FCC regulations, EBS licensees can lease spectrum to wireless operators. Of the approximately 2,193 active EBS licenses that have been assigned so far, 1,909 licenses are leased by educational entities to a national wireless carrier or a wireless internet service provider (ISP). The lessor typically negotiates a credit against the lease payments that can be used for wireless equipment and lines of service, which the licensee uses to provide low-cost connectivity to its community. Lessors are of two types: educational institutions, or nonprofit organizations that serve educational institutions, often through aggregated licenses. Under this "aggregation" model, nonprofit EBS licensees that hold multiple licenses can combine them within a single lease agreement to serve schools, libraries and nonprofits using low-cost accounts on the lessee's network secured under that agreement. In addition, nonprofit organizations can sign distribution agreements with partners that resell EBS service to specific segments of a community.

Under the second business model, EBS licensees can build infrastructure-based networks owned and operated directly by the EBS licensee to provide broadband service to their community. In both cases, EBS licensees that self-deploy and those that lease their spectrum provide educational network access and services that the commercial market is either not supplying or is offering at prices that many community members cannot afford.

Study methodology

This study focuses on the approximately 4,000 pending EBS licenses that have never been assigned by the FCC. Publicly-available data on existing EBS license programs and services were used to support modeling assumptions of the new licenses yet to be assigned. The overarching study framework is based on estimating socio-economic trade-offs of assigning approximately 4,000 county-based 2.5 GHz licenses through priority windows for eligible educational entities and tribes or through an auction to commercial operators. The assessment of economic and social value of both models was conducted for two different situations: (1) geographies currently unserved by wireless service providers and (2) geographies currently covered by commercial wireless service providers, using any spectrum band to offer LTE services. Of the total of 33,112,956 individuals[2] residing in areas where unassigned EBS licenses are available to offer a quality LTE service,[3] 5,782,622 individuals live in an unserved territory, while 27,330,334 live in an area where at least one provider offers service.

The impact of the two alternative spectrum assignment approaches was assessed by means of a set of economic models along six dimensions:

- Which option more effectively reduces the digital divide?

[2] This estimate represents 10% of the total U.S. population. The difference between this and the estimate of 15% served by the unassigned licenses raised in the first paragraph of this executive summary is due to the fact that future licenses will be county-based and that in some of those counties there is not enough unassigned EBS spectrum available to offer quality LTE service. See below.
[3] By "quality LTE" it is assumed that enough spectrum is available to offer download speeds to approximate 25 Mbps.

- Which option generates the larger externalities impacting the GDP?
- Which option has the higher reduction of the homework gap?
- Which option has the higher impact on reducing high school attrition?
- Which option yields the higher consumer and producer (schools, libraries, nonprofit anchor institutions) surplus?
- What is the contribution to the U.S. Treasury of each option?

Economic and social benefits of modernizing the current EBS licensing framework

The economic and social value of assigning the remaining EBS licenses to educational organizations and/or tribal nations is significant:

- By deploying networks in areas without existing service, EBS providers can achieve a penetration of 58% of the unconnected 5,782,622 people in those areas,[4] which would result in 3,353,920 new subscribers (an increase of 1.08% in wireless broadband penetration).[5]

- By offering uncapped LTE service at a prorated average of $15/month, EBS licensees would be targeting the more economically vulnerable population that cannot afford the prorated average of the most affordable commercial plan of $30/month.[6] This would result in up to 5,002,000 additional subscribers (an additional broadband penetration of 1.62%).

- Delivering new and affordable service to these 8,355,920 Americans would close the digital divide by roughly 18.28%.

- The increase in wireless broadband subscriptions would yield positive externalities and a contribution to the U.S. GDP in an amount of $70.93 billion. A large portion of this contribution will be concentrated in rural areas, with a derivative impact on job creation and the mitigation of rural migration.

- The increase in wireless broadband subscriptions would result in a reduction of the homework gap equivalent to 196,000 children, with a majority concentrated in rural areas. With 662,000 rural students currently experiencing the homework gap, continuing a modified EBS licensing regime would close the rural homework gap by 29.6%.

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[4] Source: Pew Research Center. *Internet/Broadband Fact Sheet*, retrieved from: pewinternet.org. Pew states that mobile broadband penetration in rural areas is 58%.

[5] This assumes that EBS licensees would build to cover 100% of the population in unserved counties. The economic model in Appendix B indicated that deployment would be economically unfeasible in only 11 counties, all located in Alaska. Based on the experience of grant support received by infrastructure-based EBS operators in other parts of the country, it is assumed that the remaining Alaskan counties would also be served by EBS licensees by receiving state support.

[6] In a preliminary summary of these findings, the price differential assumed was $10/month versus $20/month. The analysis in this document has refined the initial estimate to capture a more accurate pricing by educational nonprofits and a prorated average of commercial offers.

- Simultaneously, the extension of home broadband access to high school students through either community service provisioning or hotspot lending programs would reduce high school attrition by 22,400 teenagers annually, a majority of them concentrated, again, in rural areas.

- The offering of affordable wireless broadband plans will yield an economic surplus equivalent to $89.52 million in savings for current subscribers switching to a $15.00 per month plan and $98.62 million in savings over five years for schools and libraries in the areas where the 4,000 unassigned licenses are available. This surplus disproportionately acts as an economic stimulus to rural communities, who would now have the opportunity to shift spending to other goods.

Economic and social benefits of auctioning the unassigned EBS frequencies

The economic and social value of assigning the remaining EBS licenses to commercial carriers via an overlay auction—an auction in which unlicensed spectrum would be issued subject to "encumbrances" in cases where new license areas overlap with those of existing users—does not generate comparable economic and social effects:

- Due to intrinsic constraints on the return on investment of commercial network deployment in rural areas, service would only be rolled out in 24 of the 78 totally unserved counties, which would result in 581,562 new subscribers (an increase of 0.19% in wireless broadband penetration).

- No additional impact would be generated in served geographies because affordable offers by commercial carriers are not dependent upon gaining access to the unassigned licenses, which means that there would not be any increase in adoption triggered by price elasticity[7].

- The increase in wireless broadband subscriptions would yield positive externalities and a contribution to the GDP in an amount of $4.21 billion although, as in the case of EBS licenses, the majority of this contribution will be concentrated in rural areas, with a derivative small impact on job creation and the mitigation of rural migration.

- The increase in wireless broadband subscriptions would result in a reduction of the homework gap equivalent to 7,467 children, which amounts to 1.13% of the rural gap.

- Simultaneously, the extension of home broadband access to high school students through either community service provisioning or hotspot lending programs, would reduce high school attrition for 1,394 teenagers, a majority of them concentrated again in rural areas.

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[7] Even if wireless ISPs were to offer more affordable price plans, it would never be under the $30 a month lowest average offering.

- Finally, based on a similar overlay auction of 2.5 GHz Broadband Radio Service (BRS) licenses, the proceeds of an EBS overlay auction are estimated to be $52.25 million. Even assuming 2.5 GHz spectrum has tripled in value since 2009, when the BRS auction used as a benchmark was conducted, total revenue would still be only $156.75 million.

Comparative Assessment

Comparative economic and social value analysis shows that assigning the EBS licenses to educators and nonprofits yields greater benefits than auctioning them to commercial carriers (see table B).

Table B. Comparative Social and Economic Value

		EBS License Windows	Auctioning to commercial carriers
Reduction of the digital divide	Unserved geographies	3,354,000	581,562
	Served geographies	5,002,000	
	Total	**8,356,000**	**581,562**
Contribution to GDP (in million $)	Unserved geographies	$ 28.47	$ 4.21
	Served geographies	$ 42.46	
	Total	**$ 70.93**	**$ 4.21**
Reduction of homework gap (new broadband households with children)	Unserved geographies	122,938	7,467
	Served geographies	73,407	
	Total	**196,345**	**7,467**
Reduction of high school attrition (increase in graduating high school students)	Unserved geographies	21,333	1,394
	Served geographies	1,115	
	Total	**22,448**	**1,394**
Economic surplus (in $ million)	Consumer surplus	$ 89.52	
	Producer surplus (5 years)	$ 98.62	
	Total	**$ 188.14**	**$ 0**
Contribution to Treasury (in $ million)		**$ 0**	**$ 52.25 - $ 156.75**

Source: Analysis by Telecom Advisory Services

There are four reasons why the difference in social and economic value between both options is so significant:

- Wireless broadband deployment economics (not a lack of available commercial spectrum) constrain the deployment of broadband networks in rural, unserved counties. Additional spectrum will not change the economic constraints that disincentivize investment in sparsely populated areas. Commercial carriers already have access to 626 MHz of spectrum below 3 GHz in these same rural areas today;[8] yet, they are uncapable of deploying networks because of the lack of return on investment.[9]

[8] *See* Reply Comments of North American Catholic Educational Programming Foundation and Mobile Beacon at 20, WT Docket No. 18-120 (filed Sept. 7, 2018).

[9] It is important to mention that T-Mobile's pledge to "accelerate deployment of [some] percentage of mid-band sites in rural America within three years of closing" does not state *incremental* rural sites will be

- Commercial wireless carriers do not have an offer focused on increasing adoption by low income population, especially in rural areas. They also do not offer as robust of a data plan or as affordable a price as EBS licensees providing service in those same areas.[10] There is no commercial carrier offer comparable to EBS offers like those available from Mobile Beacon and Mobile Citizen, which focus on affordable service to anchor institutions (schools, libraries, nonprofits) and their users (through the hotspot lending models).

- Commercial-led homework gap offers (e.g. Sprint's 1Million plan) have limitations that comparable EBS offers do not (e.g. stringent data caps and available only to high school students).

- Proceeds of an overlay auction are limited due to significant encumbrances[11] and the fact that the majority of unencumbered spectrum is limited to rural licenses, which generally yield lower proceeds than bids for spectrum in more populated areas.

An overlay auction may also result in dislocation of existing educational users of EBS spectrum, especially among licensees providing service using the leasing model by reducing, perhaps dramatically, the demand for leased EBS spectrum. While this study does not analyze the potential harms of an overlay auction from the evaporation of existing programs and services—particularly those aimed at students, low-income communities, libraries and nonprofits—this could result in a significant negative impact.

On a final note, a potential assignment of the pending 4,000+ licenses to commercial carriers via auction would have no impact on future 5G deployment. As research and ongoing 5G rollout is indicating, the economics of 5G networks are certain to preclude its deployment in rural areas.[12] Any economic gain due to 5G will come in the form of greater speed and capacity in areas already served, not in increased deployment to currently unserved areas. Along these lines, the assignment of upcoming licenses to educational institutions will not preclude 5G deployment.

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constructed. T-Mobile has a more extensive coverage footprint than Sprint today, so this pledge can presumably be met (in large part) by adding 2.5 GHz equipment to existing T-Mobile cell sites, which neither increases rural coverage nor addresses affordability.

[10] In terms of the commitment to maintain existing Sprint or T-Mobile prices for three years, this does not affect current non-adopters in the study areas where either carrier claims to have coverage today. It can be assumed this subset of non-adopters do not have broadband because they cannot afford it—not because it is not available. Therefore, a commitment to maintain existing prices will not increase adoption among this population.

[11] Sprint already holds or leases nearly 80% of the licenses for 2.5 GHz EBS and BRS spectrum, according to *Allnet Insights & Analytics*, equating to something north of 100 MHz in the top-100 markets. See https://www.fiercewireless.com/wireless/editor-s-corner-will-sprint-s-treasure-trove-2-5-ghz-spectrum-ever-be-fully-realized.

[12] The most comprehensive research on 5G investments indicates that CAPEX per POP in urban areas is $48.82, while the same number for rural geographies is $4,239.58 (see Oughton, EJ & Frias. Z (2018)."The cost, coverage and rollout implications of 5G infrastructure in Britain," *Telecommunications Policy*, vol. 42, issue 8, pp. 636-652.).

Conclusion

Can the educational organizations and tribal nations deliver on the benefits estimated by this study? We believe this to be the case for three reasons:

- The track record of EBS licensees in the FCC's docket amply demonstrates the ability of these institutions to serve the needs of the unserved, the economically disadvantaged population and students. Mobile Beacon, for example, serves 836 schools, 989 libraries and 4,772 nonprofit institutions by means of a $10/month unlimited data service. A number of educational institutions (e.g., Northern Michigan University, Kings County Schools, Pasadena Independent School District, among others) as well as several tribal nations (e.g., Havasupai Tribal Council, Nisqually Indian Tribe) have deployed or are planning to roll-out LTE infrastructure to serve their students and communities in their territory. Some states (e.g., Nebraska, California, North Carolina, Utah) are planning the development of state-wide educational wireless networks if they can obtain access to EBS.

- Educational organizations and tribal nations benefit from favorable conditions to deploy wireless broadband networks using the 2.5 GHz spectrum. Due to low-cost equipment, use of existing infrastructure, partnerships with local educational institutions and ISPs and the use of open source management software, networks can be deployed for as little as $20,000 per node site. These networks can deliver to end users FCC-defined broadband speeds of 25 Mbps/3 Mbps for roughly 8 miles from a single tower on a single EBS channel group.

- Educational licensees are better suited to deploy wireless broadband in unserved geographies because they face less stringent return on investment constraints than commercial carriers, which are often public companies bound to their shareholders. When considering the 78 counties in the 4,000 unassigned licenses that lack LTE service, educational institutions can cover 67 and could potentially reach the whole universe of those counties through conventional grants, while commercial carriers cannot meet their hurdle rate beyond 24 counties.

The preservation of the EBS white spaces for education through priority windows does not deny auctions as a conventional approach to manage spectrum. Given that (1) the commercial sector has already been licensed 76.5 MHz of 2.5 GHz BRS spectrum, and (2) the FCC has several commercial auctions of other spectrum bands planned or that have recently concluded, commercial entities have had and will have opportunities to obtain both mid-band and high-band spectrum in the near future.[13] Priority windows for educational and

[13] The FCC concluded its auction of 950 MHz of 28 GHz spectrum in January 2019. The FCC also recently-completed its auction of 700 MHz of 24 GHz spectrum across the U.S. in May 2019. The FCC has also proposed steps toward the auction of 37 GHz, 39 GHz and 47 GHz bands—a total of 3,400 MHz of new commercial spectrum. The FCC is planning an upcoming auction in the 3.5 GHz band and approved a Notice of Proposed Rulemaking to allow for flexible use of the 3.7 to 4.2 GHz band in July 2018. See https://www.fcc.gov/document/fcc-proposes-steps-towards-auction-37-ghz-39-ghz-and-47-ghz-bands-0 and https://docs.fcc.gov/public/attachments/DOC-357245A1.pdf.

tribal entities will not take away from commercial deployment. Instead, it will generate additional, targeted programs that have proven to be highly effective at closing the digital divide and homework gap. Furthermore, there is a growing consensus among academic research and policy makers that the approaches to spectrum management that maximize welfare comprise a mix of licenses assigned through auctions and the establishment of rules governing portions of the spectrum as a common pool resource or licenses assigned as public goods.[14]

In this particular case of the 4,000 unassigned EBS licenses, it becomes self-evident that they are not particularly suited to be assigned by an auction. First, there is a vibrant educational EBS ecosystem, which has evolved over the years in order to respond to evolving technology and service needs and is particularly well suited to address critical social needs like a reduction of the digital divide and the homework gap. Furthermore, the current licensing regime carries additional economic benefits, such as a contribution to the nation's GDP, mainly concentrated in rural areas, and enhanced economic surplus, mainly for libraries, schools and nonprofits, which could be assigned to the acquisition of other community services and educational goods. Second, the supply of technology and service enablement services is proof of the educational EBS sector's vibrancy. Third, since there is a lack of any other spectrum identified for educational use, by auctioning the unassigned spectrum the FCC would be completely eliminating the additive educational benefits conveyed by EBS. Fourth, the high patterns of existing use and encumbrance of this spectrum limit its intrinsic commercial interest.

[14] See Milgrom, P., Levin, J., & Eilat, A. (2011). *The case for unlicensed spectrum*. Stanford Institute for Economic Policy Research Discussion paper No. 10-036, p. 2. Retrieved from https://web.stanford.edu/~jdlevin/Papers/UnlicensedSpectrum.pdf. See also Dara, R. "Governing spectrum commons". *TPRC 44: The 44th Research Conference on Communication, Information and Internet Policy 2016*

1. INTRODUCTION

The Educational Broadband Services (EBS) is an educational service generally used for providing high-speed internet access relying on the 2.5 GHz band to support learning by students and other population in the served area. The service is based on the assignment of licenses only to accredited educational institutions, nonprofit educational organizations and tribal nations serving their educational needs. Current FCC rules allow licensees to lease their excess capacity to commercial operators. EBS licensees can provide Wi-Fi based programs at schools and libraries, build county-wide wireless broadband networks for schools and residents, deliver mobile broadband to school or university buses and create public-private partnerships with commercial carriers to extend broadband in unserved areas.

The FCC has assigned 2,193 EBS licenses covering approximately 50% of the U.S. territory, which equates to 85% of the population. In 1995, the FCC stopped issuing new EBS licenses, when there were 800 requests pending.[15] In May 2018, the FCC released a Notice of Proposed Rulemaking (WT Docket No. 18-120), which sought comments on potential revisions to the EBS rules, including licensing of unassigned EBS spectrum (EBS white space). The EBS white space covers primarily rural markets, covering 50% of the territory and 15% of the population of the United States.[16] The proposals under consideration described below include the use of EBS licenses for purposes of closing the digital divide and facilitating 5G deployment:

- A baseline proposal would be to assign the remaining licenses to educational organizations and/or tribal nations through priority application windows, as done before (albeit with some modifications).

- As an alternative, it has been proposed that the remaining EBS white space licenses be auctioned to commercial bidders, allowing them to be held by non-educational entities and removing all requirements that this spectrum is used for educational purposes. Additionally, this recommendation includes the concept that current licensees could sell their licenses to commercial operators.[17]

In this context, the Schools, Health & Libraries Broadband (SHLB) Coalition has retained Telecom Advisory Services LLC to produce a study that would quantify and compare the social and economic benefits of the options for assigning EBS white space. First, the study quantifies the economic and social benefits of assigning EBS white space to educational entities and tribes, recognizing that the current educational use rules may need some

[15] In the past few years, the FCC has granted eight requests for licenses either under waivers of the Commission's rules or under the Commission's Special Temporary Authority framework.
[16] *Ex parte* filing of Catholic Technology Network and National EBS Association, WT Docket No. 18-120 (filed Feb. 26, 2019).
[17] Yet another option would be to allow existing EBS licensees to voluntarily sell their licenses to a private operator through an incentive auction framework, and then use the funds to address some of the gaps in broadband service. The analysis of this option is out of scope of this study because of the numerous legal and regulatory type issues it entails.

modernization (for example, by requiring EBS licensees to provide low-cost wireless service to low-income families in order to reduce the country's digital divide). Second, the study also provides the economic and social trade-offs of following the alternative auction proposal. In sum, the key issues addressed in the following study are:

- What is the economic and social value of extending the current EBS licensing regime to educational institutions and tribal nations?

- What comparable value would be generated if the licenses are auctioned to commercial operators instead?

The following document presents the results of this study. Chapter 2 provides a general view of the current situation in terms of the licenses that have been assigned so far, the business models implemented by educational institutions to offer wireless broadband service and the performance of the current regime. Chapter 3 presents the methodology and assumptions used for quantifying the economic and social value of the two alternative spectrum assignments. On this basis, Chapter 4 presents the results of the analysis of economic and social benefits of extending the current EBS licensing regime to educational institutions and tribal nations. Chapter 5 presents the counterfactual case of economic and social value assessment if the EBS white spaces were to be put up for auction to commercial wireless operators. Finally, Chapter 6 provides a comparison of the results of both cases while Chapter 7 draws the public policy implications. All analyses are supported by data and models included in appendices to the report.

2. THE CURRENT SITUATION

2.1. Current and potential EBS spectrum licenses

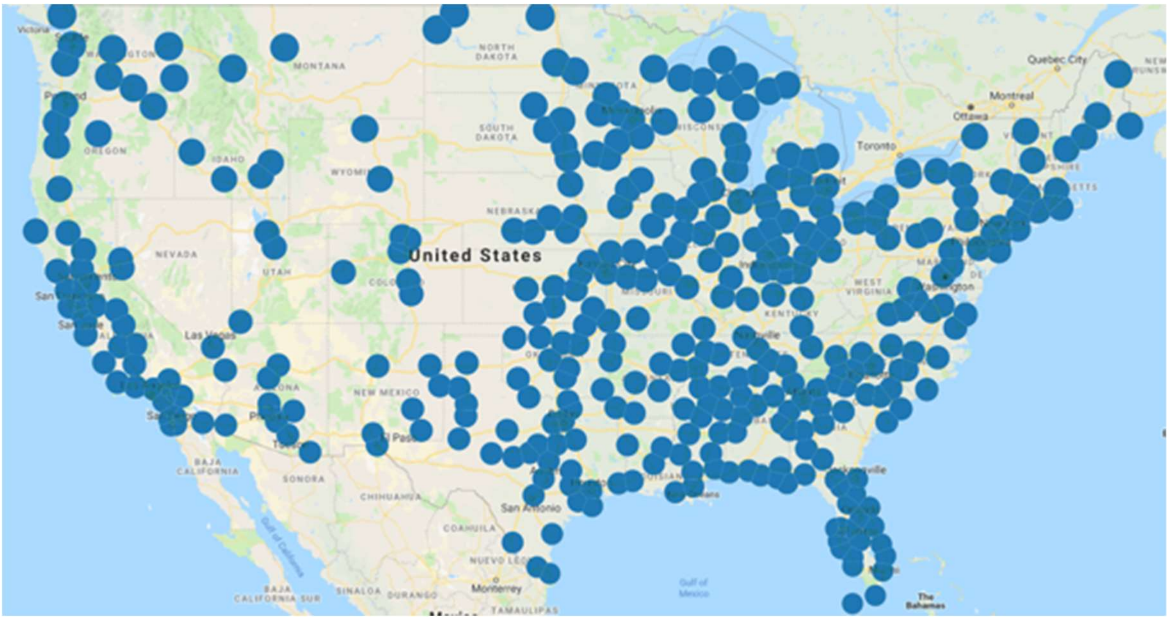
2.1.1. Current licenses

As of today, the FCC has assigned approximately 2,193 EBS licenses[18] in the 2.5 GHz band covering 50% of the U.S. territory and 85% of the population. These licenses were assigned before 1995, when the FCC closed its "window" for accepting new EBS applications.[19] In June 2014, three organizations, representing educational institutions and one commercial wireless operator, submitted a Consensus Proposal to the FCC recommending new procedures to allow schools that missed the initial window to submit applications to license the remaining unused and unassigned areas, known as EBS white space.

Since then, the FCC assigned EBS licenses only through eight waivers by exception. Figure 2-1 depicts the geographic distribution of assigned licenses.

[18] Information in the Universal Licensing System is not complete, in many cases beginning with a renewal application in the 2000s.
[19] The FCC technically instituted the freeze in 1993, when it began a proceeding to change the application procedures for EBS (then ITFS) licenses to use a "window" approach for future applications. However, it never unfroze applications and only opened a single five-day application window in 1995.

Figure 2-1. Current Educational Broadband Service Licenses



Source: FCC Universal Licensing System Data

Figure 2-1 presents the assigned G-1 channel licenses, which generally have the most coverage, although there are some locations where different channels are or are not covered. As is apparent from the map, vast portions of the country, primarily in rural areas, comprise the unassigned EBS white space.

2.1.2. Unassigned licenses

According to the analysis conducted by the Wireless Communication Association International of the FCC Universal Service Licensing system, approximately 4,000 EBS licenses, primarily in rural parts of the country, remain unassigned—assuming that future EBS licenses are licensed on a county basis.[20] The aggregation of spectrum licenses by county provides a perspective of both the breakdown by geography (confirming the importance of rural areas) and spectrum availability[21] (in order to provide LTE service at adequate download/upload speeds) (see table 2-1).

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[20] Comments of Wireless Communications Association International at Attachment A, WT Docket No. 18-120 (filed Sept. 7, 2018).

[21] The EBS band of spectrum lies between 2496 and 2690 MHz. EBS licensees operate in 114 megahertz of the 2.5 GHz band. See FCC. *Transforming the 2.5 GHz Band*. 33 FCC Rcd. 4687 ¶¶ 1 and 4 (2018). That said, the G block licenses also have 1 MHz of non-contiguous spectrum in the K block, which could be used, if leased.

Table 2-1. 2.5 GHz Spectrum Available by County

Spectrum Available (MHz)	Rural Counties	Non-Rural Counties	Total
117.50	384	37	421
111.70	1	0	1
111.50	6	0	6
105.80	1	1	2
94.00	71	24	95
88.20	5	3	8
82.30	1	1	2
82.20	2	1	3
76.50	0	2	2
76.30	2	0	2
76.20	3	0	3
70.50	131	44	175
64.70	1	0	1
58.80	3	2	5
58.70	2	2	4
53.00	0	1	1
47.00	69	45	114
41.30	1	0	1
41.00	4	4	8
35.30	4	2	6
35.20	5	11	16
29.50	0	2	2
29.30	5	0	5
23.50	165	102	267
23.30	1	0	1
17.70	1	6	7
17.50	2	0	2
11.80	1	2	3
11.70	11	10	21
6.00	3	2	5
5.80	7	2	9
Total	892	306	1,198

Source: FCC Universal Licensing System Data; Wireless Communications Association International Reply Comment; Telecom Advisory Services analysis

As indicated in table 2-1, a total of 1,198 counties have considerable spectrum to provide quality LTE service.[22] Of the total of 1,198 counties with available spectrum licenses, 892 (74.46%) are considered to be rural, and the remainder are urban or suburban.[23]

2.2. Potential business models currently used by EBS licensees

There is no single business model followed by EBS licensees to offer service. Figure 2-2 presents a stylized version of the sector value chain with examples by role.

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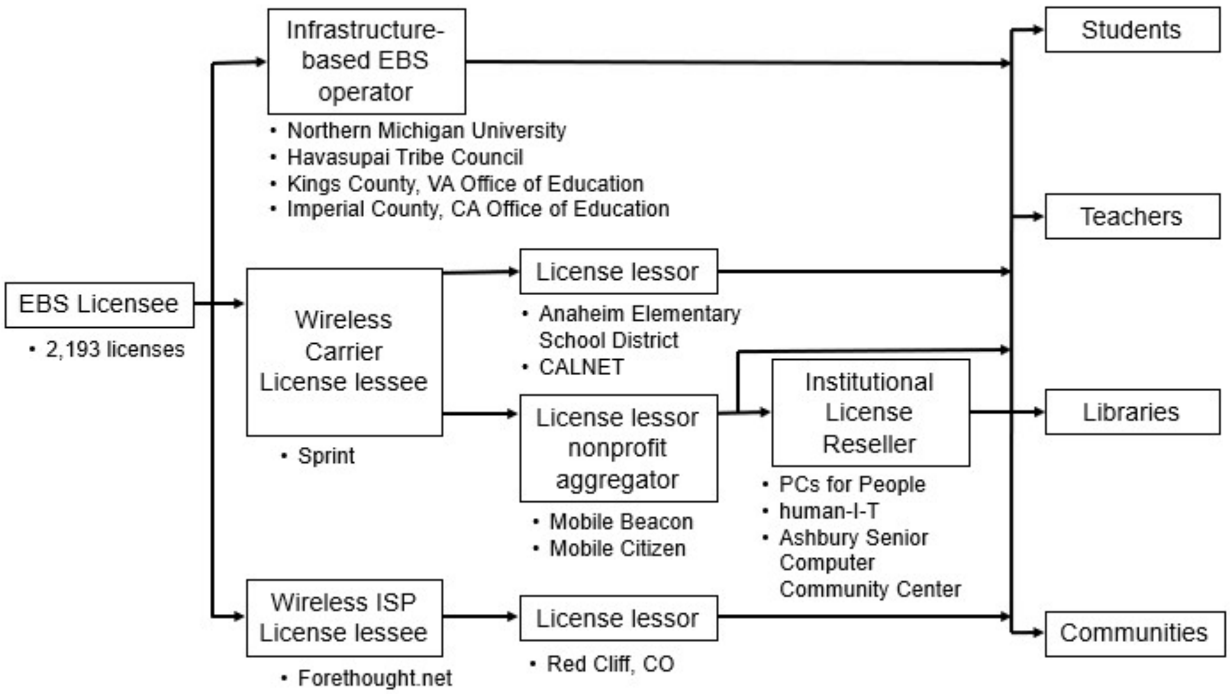
[22] See Comments of Wireless Communications Association International at Attachment A, WT Docket No. 18-120 (filed Sept. 7, 2018).

[23] Source of county rural, suburban urban classification: Census Bureau (2010). *List of Rural Counties and Designated Eligible Census Tracts in Metropolitan Counties*.

Figure 2-2. EBS Ecosystem Value Chain (with examples by role)



Source: Telecom Advisory Services

Under one business model, consistent with FCC regulations, EBS licensees can lease spectrum to wireless operators. Of the 2,193 active EBS licenses that have been assigned, 1,909 licenses are leased by educational entities to a national wireless carrier or a wireless ISP. The lessor typically negotiates a credit against the lease payments that can be used for wireless equipment and lines of service, which the licensee uses to provide low-cost connectivity to its community. Lessors are of two types of educational entities: educational institutions or not-for-profit organizations that serve educational institutions, often through aggregated licenses. Nonprofit EBS licensees that hold multiple licenses can combine them within a single agreement to serve schools, libraries and nonprofits using low-cost accounts on the lessee's network secured under the lease agreement. In addition, nonprofit organizations can sign distribution agreements with partners that resell EBS service to specific segments of a community. Under the second business model, EBS licenses can build and operate infrastructure-based networks owned and operated directly by the EBS licensee to provide broadband service to their community.

Both EBS licensees that self-deploy and those that lease their spectrum provide educational network access and services that the commercial market is either not supplying or is offering at prices that many community members cannot afford. Whether connecting schools and the surrounding communities[24] or pioneering library hotspot lending programs,[25] EBS licensees are helping to close the digital divide and the homework gap.

2.2.1. Lease agreements

In 1983, the FCC permitted ITFS licensees to lease "excess capacity" on their facilities to commercial entities.[26] In 1995, ITFS licensees were authorized to lease up to 95% of their spectrum capacity for commercial use. Of the 1,909 licenses that are being leased, Sprint has signed a lease agreement for approximately 80%. EBS licensees that lease their excess capacity to Sprint typically receive 15 GB (and in some cases up to 50 GB) plans, which they use in turn to support students in and out of the classroom. On an annual basis, the lease payments to the educational institutions that hold the licenses represent over $300 million.[27]

According to general principles of the lease agreements, the EBS licensee allows the lessee the usage of spectrum against which the lessor receives a wireless credit for acquiring equipment and accounts that the licensee uses to provide educational broadband connections to users anywhere in the lessee's network. One of the key benefits derived from leasing to a national provider is the lessor's end users benefit from the large, national footprint, improving service continuity not only in the licensed EBS area, but throughout the United States. This type of coverage footprint has enabled Wi-Fi on school buses and hotspot lending programs to reach more people. Lease agreements are specific to each license, although multiple national nonprofit organizations have coordinated across licensees to sign common lease agreements. One particular lease agreement of note includes national, nonprofit EBS license aggregators such as the North American Catholic Education Programming Foundation (NACEPF) and Voqal, which operate their own mobile broadband services called Mobile Beacon and Mobile Citizen, respectively.

Mobile Beacon, a wholly-owned subsidiary of NACEPF, leases its EBS licenses in 51 markets to Sprint for its commercial operation needs. In exchange, Mobile Beacon receives

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[24] See, e.g., Comments of the Bad River Band of the Lake Superior Tribe of Chippewa Indians at 3, WT Docket No. 18-120 (filed Aug. 8, 2018); Comments of the Havasupai Tribal Council at 1, WT Docket No. 18-120 (filed July 19, 2018); Comments of Mural Net at 3, WT Docket No. 18-120 (filed Aug. 8, 2018); Comments of North American Catholic Educational Programming Foundation and Mobile Beacon at 22, WT Docket No. 18-120 (filed Aug. 8, 2018); Comments of the Consortium for School Networking at 8, WT Docket No. 18-120 (filed Aug. 8, 2018); Comments of Voqal at 10–13, WT Docket No. 18-120 (filed Aug. 8, 2018); Comments of Northern Arizona University Foundation, Inc. at 2–3 , WT Docket No. 18-120 (filed Aug. 8, 2018); Comments of Northern Michigan University at 3, 5–6, WT Docket No. 18-120 (filed Aug. 8, 2018).

[25] See, e.g., Comments of TechSoup Global at 2, WT Docket No. 18-120 (filed Aug. 8, 2018); Comments of Digital Wish at 2–3, WT Docket No. 18-120 (filed Aug. 8, 2018); Joint Comments of National EBS Association and Catholic Technology Network at 4, WT Docket No. 18-120 (filed Aug. 8, 2018); Joint Comments of South Florida EBS Licensees at 3 n.3, WT Docket No. 18-120 (filed Aug. 8, 2018).

[26] FCC. *Amendment of the Commission's Rules with Regard to the Instructional Television Fixed Service, the Multipoint Distribution Service, and the Private Operational Fixed Microwave Service; and Applications for an Experimental Station and Establishment of Multi-Channel Systems*, 48 Fed. Reg. 33,873, 33,875-76 ¶¶ 114-18 (Jul. 26, 1983) (to be codified at 47 C.F.R. pts. 2, 21, 74).

[27] Source: Select Spectrum (2018). *Your Action is Required: Keep Educational Broadband Spectrum Licenses in the Hands of Educational Institutions and Provide Rural America Internet Access*. Retrieved from: www.selectspectrum.com.

broadband data subscriptions and devices, which in turn are offered to 836 schools, 989 libraries and 4,772 nonprofit institutions for $10/month unlimited data service, with free devices. For example:

- Henderson School in Boca Raton, FL uses Mobile Beacon's devices to allow student athletes to do their homework on buses while they travel to and from games. Now, the program has also been implemented in support of teacher conferences and connects hospitalized students.[28]

- John Stark Regional High School in New Hampshire uses mobile service during the summer to develop teacher curriculum.[29]

In addition to providing service directly to schools, Mobile Beacon partners with entities such as TechSoup Global to distribute hotspot devices to eligible schools, libraries and nonprofits,[30] and Digital Wish to donate hotspot devices to schools, students, teachers and staff across the country.[31] Finally, they also rely on resellers such as PCs for People, which partners with Mobile Beacon to provide refurbished computers and online access to over 11,500 households (36,000 individuals) in 45 states.[32]

Mobile Citizen, a social venture founded by Voqal (a national collaboration of EBS licensees), offers a similar service ($10 per month, unlimited data[33]) for qualifying nonprofits, educational entities and social welfare agencies. Qualifying nonprofits and educational institutions can also receive free uncapped service and loaned hot-spots with a capacity to connect to 10 devices. Mobile Citizen also partners with several resellers, including human-I-T based in Long Beach, CA and Ashbury Senior Computer Community Center based in Cleveland, OH.

Other examples of nonprofit EBS license aggregators include Source for Learning, Views on Learning and the Community Telecommunications Network based in the Detroit, Michigan area.

In addition to national wireless carriers, other EBS leasing partners are wireless ISPs. As an example, the Eagle County School District used its EBS spectrum to partner with a local WISP to provide broadband service in Red Cliff, CO, which built towers in town and on a nearby ski lift.[34] The facility had a significant impact in providing connectivity to a town that had been left completely unserved by commercial operators.

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[28] Comments of NACEPF and Mobile Beacon at 16. Unless otherwise noted all comments cited herein were filed in WT Docket No. 18-120 on August 8, 2018.
[29] Comments of Beth Franke at 1 (filed Aug. 31, 2018).
[30] Comments of TechSoup Global at 2.
[31] Comments of Digital Wish at 1-3.
[32] Comments of PCs for People at 1–2.
[33] Monthly service paid annually upfront plus one-time device fee of approximately $75-$118.
[34] Voqal Comments at 12–13.

2.2.2. Self-operations build out

In addition to potential lease agreements, several EBS licensees chose to offer service through their own infrastructure. Below we highlight nine educational institutions and tribal nations which own and operate their own LTE networks to provide service to students and their communities (see table 2-2).

Table 2-2. Infrastructure-based EBS networks

Institution	Network	Deployment	Users
Northern Michigan University[35]	• LTE (64 base stations)	21,000 sq. miles	9,000
Havasupai Tribal Council	• LTE / Wi-Fi	35 miles radius	800
Nisqually Indian Tribe	• WiMAX/LTE	8 miles radius	100 households
Pasadena Independent School District, TX	• LTE (10 base stations)	- - -	- - -
Houston Independent School District, TX	• WiMAX	- - -	- - -
Kings County Office of Education, CA[36]	• LTE (15 base stations)	1,392 sq. miles	5,200
Albemarle County Public Schools, VA[37]	• LTE (20 base stations)	726 sq, miles	17,000
Imperial County Office of Education, CA[38]	• LTE (14 base stations)	4,482 sq. miles	1,000
Louisa County Public Schools (planned)	• LTE (1 base station)	Areas of Louisa County, VA	- - -

Source: Compiled by Telecom Advisory Services

In addition, to our knowledge there are seven localized tribal pilots and two county boards of education with networks at different stages of development. Finally, of note, there are several state-wide initiatives looking to use and access EBS for educational broadband networks. Four examples are:

- The State of Nebraska is performing a feasibility study regarding combining existing infrastructure with new EBS licenses to develop a statewide network to create equity, close the homework gap and ensure access to digital learning resources. Among other things, it hopes to enable service on school buses so that students can work while "on the road."[39]

- The California K-12 High Speed Network, a program funded by the California Department of Education, is considering building a statewide LTE network that will provide "last mile Internet service to unserved/underserved students at home."[40]

- The Utah Education and Telehealth Network (UETN) connects Utah's K-12 schools, technical colleges, institutions of higher education and public libraries, as well as patients and healthcare providers throughout the state. Its network

[35] Comments of Northern Michigan University at 9.
[36] Comments of the Kings County Superintendent of Schools at 4.
[37] Comments of the Consortium for School Networking at 8.
[38] Comments of the Imperial County Office of Education and California K-12 High Speed Network at 10–11, 18–19.
[39] Comments of Nebraska Department of Education (NDE), Nebraska Educational Television (NET), and the State of Nebraska Office of the Chief Information Officer (OCIO) at 5–6, 7–8.
[40] K12HSN Comments at 4.

facilities comprise a wideband fixed broadband network complemented with an LTE last mile infrastructure under development.[41]

- North Carolina's MCNC, a broadband nonprofit organization, operates the North Carolina Research and Education Network (NCREN) serving all K-12 schools through a combination of fiber optic and wireless access infrastructure.

Business models of self-deployed networks vary by licensee. In some cases, service is provided for free, while in others, a tiered pricing scheme with favorable discounts for students exists (see table 2-3)

Table 2-3. Infrastructure-Based EBS Networks: Business Models

Institution	Service Plans	Operating Expenses	Capital Expenditures
Northern Michigan University	• Community: $34.95 (*) • Affiliate: $ 19.95 (*) • Alumni and veterans: $ 24.95 (*)	- - -	$ 4,000,000
Havasupai Tribal Council	• Free service	• 1 FTE	$ 40,000
Nisqually Indian Tribe	• Free LTE service to all tribal members, whether they are registered students or not	- - -	$ 200,000
Kings County Office of Education, CA	• Originally offered units for either $10/month or $15/month	- - -	- - -
Albemarle County Public Schools, VA	• Free wireless routers and service	- - -	- - -
Imperial County Office of Education, CA	• Initially service provided for free • Considering charging in the future ($100 per unit/year)	• No backhaul or tower expenses • $ 390,000 (network administration budget)	$ 1,800,000
Louisa County Public Schools	• Students, faculty and staff: free LTE service and multi-device hotspots	- - -	- - -

Notes:
(*) Uncapped; Service only
Source: Compiled by Telecom Advisory Services

From a network deployment standpoint, two models coexist: (1) large multi-site networks such as Northern Michigan University and Kings County, with an infrastructure comparable to that of a small regional carrier, and (2) small single site ISPs, whose network replicates that of a small WISP. The economics of both models vary significantly.

* * * * *

As reviewed in chapter 2, EBS spectrum has been instrumental in building, so far, a vibrant ecosystem of infrastructure-based and spectrum leasing operations serving hundreds of thousands of users at schools, libraries, nonprofits and anchor institutions across the country.[42] In those geographies where the FCC has issued EBS licenses, licensees themselves

[41] See www.UEN.org.
[42] Mobile Beacon states that they have more than 450,000 users.

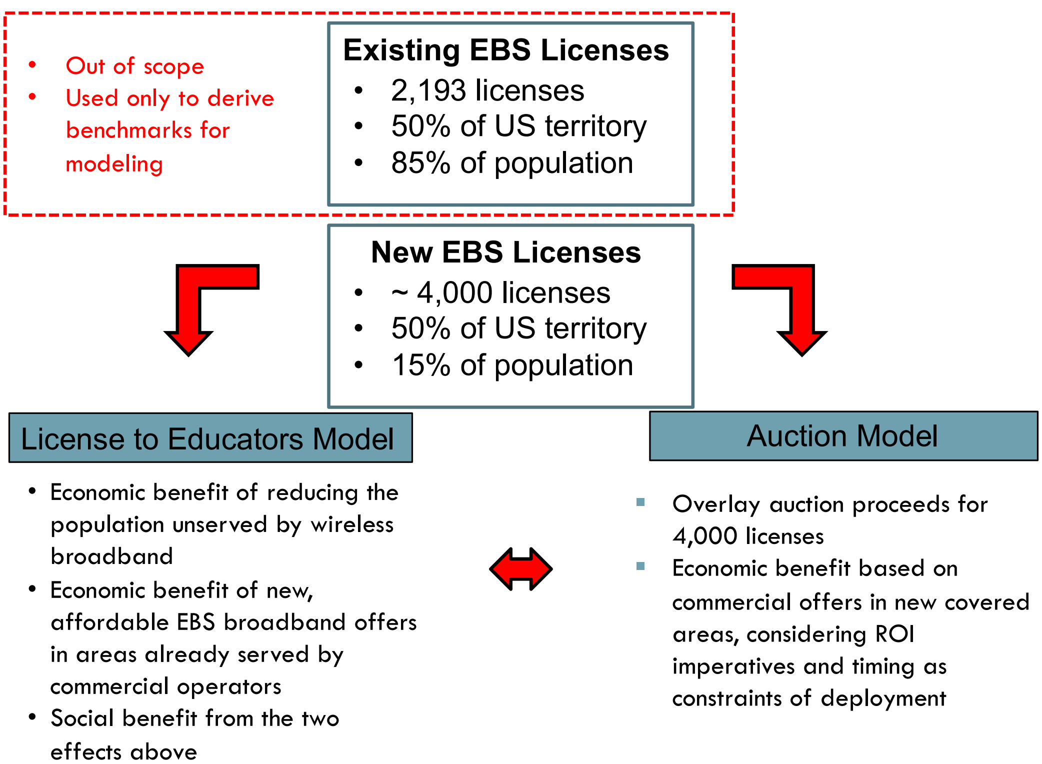
or commercial lessees have provided a full range of LTE wireless services.[43] Furthermore, while 2,193 licenses have already been assigned, an additional 4,000 with potential to allow service in 1,198 counties (74.46% of which are rural) are under consideration by the FCC. The following chapter will present a theoretical framework, methodology and assumptions to assess the economic and social value generated under alternative spectrum assignment approaches.

3. STUDY THEORETICAL FRAMEWORK AND METHODOLOGY

3.1. Scope of analysis

This study focuses on the approximately 4,000 unassigned licenses. Publicly-available data on existing EBS license programs and services were used to support modeling assumptions of the new licenses yet to be assigned. The overarching study framework is based on estimating socio-economic trade-offs of assigning available 2.5 GHz licenses through either licensing to educators through priority windows or an auction to commercial operators (see figure 3-1)

Figure 3-1. Analytical approach



Source: Telecom Advisory Services

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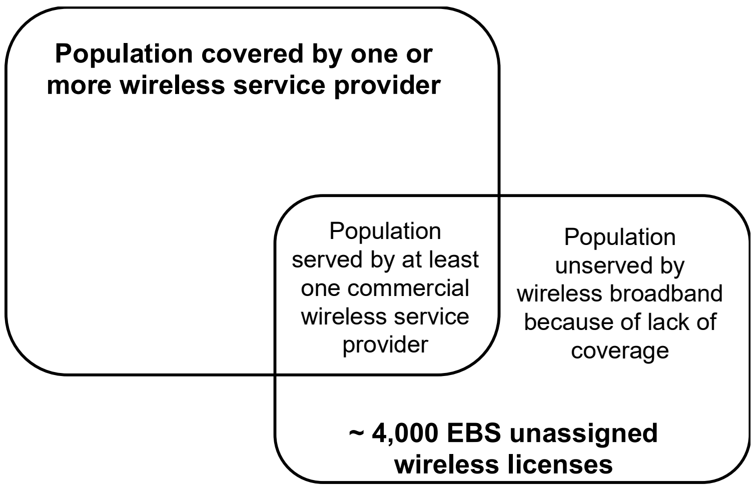
[43] Comments of Sprint Corporation at 3 ("Sprint's 2.5 GHz spectrum is the source of most of the 4G LTE capacity in Sprint's existing commercial wireless network."); Comments of the Wireless Communications Association International at 4; Joint Comments of National EBS Association and Catholic Technology Network at 3–8.

The new EBS licenses that represent the core of the analysis can be deployed in either areas currently unserved by wireless service providers or in geographies currently covered using other spectrum bands. Along those lines, the assessment of economic and social value of both models will be conducted for these two different situations (as depicted conceptually in figure 3-2).

Figure 3-2. Scope of Analysis



Source: Telecom Advisory Services

The estimation of the population benefitting from either license assignment model followed a four-step process conducted at the county level:

- **Step 1:** Identify the counties with available 2.5 GHz spectrum to offer quality LTE service. As mentioned in section 2.3.2. above, of the 3,115 surveyed counties comprising a total population of 309,707,751,[44] 1,198 counties contain enough unassigned 2.5 GHz spectrum through one or more licenses to offer LTE service. The data used for compiling this database was extracted from Reply Comments submitted by the Wireless Communications Association.[45] Each county where a 2.5 GHz license would be available was analyzed in terms of MHz availability in the low, medium and upper band segments.

- **Step 2:** Split the 1,198 counties identified in step 1 between those that have at least one commercial 4G service provider and those that are unserved. By relying on the FCC Form 477 for December 2017, 78 completely unserved counties were identified (primarily located in Alaska, Washington, North Dakota, Montana, Idaho, West Virginia and Colorado), while 141 counties were located at the border of an unserved area (primary clusters in Arizona, Colorado, Idaho, Kentucky, Minnesota, Montana, North Dakota, Nevada). The remaining 979 counties already had at least one wireless provider offering LTE service.

[44] Some counties were not analyzed due to data omission.
[45] Reply Comments of Wireless Communications Association, WT Docket No. 18-120 (filed Sep. 7, 2018).

- **Step 3:** The FCC reports that, as of December 2016, 100% of the non-rural population was covered by at least one LTE carrier, while the equivalent number for rural POPs was 98.8%.[46] However, the FCC also mentions that the fact that a service provider reports coverage in a particular census block does not necessarily mean that it provides coverage everywhere in that block. In the past, the authors of this study have used OpenSignal crowdsourced data[47] to determine true coverage. According to our analysis of the OpenSignal coverage report, which addresses only main metros and corridors, the year end 2017 nationwide 4G U.S. coverage is 95.78%. This again likely overstates coverage, particularly in rural areas. With this background, the coverage assessment assumptions considered four cases:

    - Form 477 states county is totally unserved (78 counties);
    - Form 477 states county is covered but is located at the border of an unserved area (141 counties): coverage is only 50% of total county;
    - Form 477states county is served but county is classified by the Census Bureau as rural (716 counties): coverage is 75% of county;
    - Form 477 states county is served and is classified as urban-suburban (263 counties): coverage is 100% of the county.

- **Step 4:** Based on the analysis conducted in steps 1 through 3, the population benefitting from the 2.5 GHz licenses under consideration would be as follows (see table 3-1).

Table 3-1. Counties and Population Benefitting from 2.5 GHz Licenses

		Counties	Population	Observations
Areas with no EBS spectrum licenses available to offer LTE service in 2.5 GHz (*)		1,917	276,594,795	Out of scope
Areas with spectrum available to offer LTE service in 2.5 GHz	Areas unserved by commercial carriers	78	1,404,887	In-scope
	Areas partially served by commercial carriers	857 (**)	13,974,282	
	Areas totally served by commercial carriers	263	17,733,787	
	Total	1,198	33,112,956	

(*) This comprises counties where licenses have already been assigned before 1995 and counties with very limited MHz licenses, which precludes the offering of LTE service.
(**) This is the sum of counties which Form 477 states are covered but are located at the border of an unserved area (141 counties) and counties which Form 477 states are served but are classified by the Census Bureau as rural (716 counties)
Source: Analysis by Telecom Advisory Services (see Appendix A)

As indicated in table 3-1, of the total of 33,112,956 individuals residing in counties where licenses are available to offer a quality LTE service,[48] 5,782,622 individuals live in LTE commercially unserved territory (that is to say 1,404,887 in totally unserved counties and 4,377,735 in counties that are partially unserved), while 27,330,334 live in covered areas

[46] FCC. *Annual Report and Analysis of Competitive Market Conditions with Respect to Mobile Wireless, Including Commercial Mobile Services*, FCC-CIRC1709-08, Twentieth Report, Page 59.
[47] OpenSignal. *State of Mobile Networks* (February 2016 through January 2018).
[48] By "quality LTE" it is assumed that enough spectrum is available to offer download speeds to approximate 25 Mbps.

(the sum of 17,733,787 residing in totally served counties and 9,596,547 living in partially served counties). The analysis of the economic contribution of alternative spectrum assignment approaches will differ by these two groups.

3.2. Dimensions of economic and social contribution of unassigned 2.5 GHz licenses

Having estimated the counties and population that would be impacted by licenses representing sufficient spectrum to offer LTE service in 2.5 GHz, we then formalized the dimensions of economic and social impact resulting from the two alternative models. Six dimensions were identified:

- Reduction of the digital divide: Which option more effectively reduces the digital divide?
- Increase in GDP: Which option generates larger externalities impacting the GDP?
- Reduction of the homework gap: Which option has the higher reduction of the homework gap?
- Reduction of high-school attrition: Which option has the higher impact on reduction of high school attrition?
- Economic surplus: Which option yields the higher consumer and producer (schools, libraries, nonprofit anchor institutions) surplus?
- Contribution to the U.S. Treasury: What is the contribution to the U.S. Treasury of each option?

The remaining portion of this section describes the approach used to estimate value and provides an assessment of the current situation (in other words, what are the conditions either model is attempting to remedy?).

3.2.1. Reduction of the digital divide

The digital divide is defined in the study as the population that does not use broadband services. In prior studies by this author, lack of access to broadband is explained by three factors[49]:

- Lack of service coverage: individuals do not access broadband service because it is not being offered in the area where they live;
- Affordability gap: even if service is offered in the area where individuals live, some of them cannot purchase the service because it remains too expensive given their monthly income;
- Cultural/educational gap: even if broadband service is offered in the area, some individuals lack digital literacy to manipulate the technology or they consider the content offered through the Internet to lack cultural or linguistic relevance.

[49] See Katz, R. and Berry, T. (2014). *Driving demand of broadband networks and services*. London: Springer.

The assessment of the potential contribution of either license assignment model focused on the first two dimensions: coverage and affordability.[50] Under the coverage analysis, the focus was to estimate what the impact on the 5,783,000 unserved population would be under each model (in other words, could either model contribute to network deployment?).

On the other hand, under the affordability gap, the focus was the impact the license assignment model could have on the introduction of offers that could meet the reduced income of the non-adopting population. In this case, while recognizing that the national wireless broadband penetration is 85%,[51] the analysis of affordability would be focused only on the non-adopting population in the served areas. Our assumption in this case is that, considering that these geographies are in large part rural, current penetration is 58%[52] (or 15,852,000 people): the remaining 42% (or 11,478,000) remains non-adopting, primarily due to limited affordability.

Having defined the two target populations (the unserved and the one that cannot acquire service due to affordability), the study then estimated what the impact of the two alternative approaches to assigning the 2.5 GHz spectrum would be on wireless broadband penetration. They will be reviewed in detail in sections 4.1 and 5.1.

3.2.2. Increase in GDP

Research on the impact of broadband penetration on GDP has been conducted over the past 30 years.[53] State-of-the-art econometric models, such as the one applied in this study, aim to control for the reverse causality that afflicted some of the earlier single equation regressions. Originally developed by Roller and Waverman (2001) and implemented by Koutroumpis (2009), Katz and Koutroumpis (2012a; 2012b) and Katz and Callorda (2014; 2016; 2018), these structural models consist of four equations: an aggregate production function modeling the economy and, subsequently, three functions: demand, supply and output. In the case of mobile telecommunications, for example, the last three functions model the mobile market operation and, controlling for the reverse effects, the actual impact of the infrastructure is estimated. In the production function (1), GDP is linked to the fixed stock of capital, labor and the mobile infrastructure proxied by mobile penetration. The demand function (2) links mobile penetration to the average consumption propensity of individuals proxied by GDP per capita, the price of a mobile service proxied by ARPU (Average Revenue per User), the percent rural population and the level of competitive intensity in the mobile market measured by the HHI (Herfindahl Hirschman) index. The supply function (3) links aggregate mobile revenues to mobile price levels proxied by ARPU, the industry concentration index of the mobile market (HHI) and GDP per capita. The output equation links annual change in mobile penetration to mobile revenues, used as a proxy of the capital invested in a country in the same year.

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[50] Pew Research has stated that, based on its latest research, "relevance" is no longer a dominant factor precluding adoption.
[51] Source: GSMA Intelligence.
[52] Source: Pew Research Center. *Internet/Broadband Fact Sheet*, retrieved from: pewinternet.org.
[53] For a review, see Katz, R. *The impact of broadband: on the economy: research to date and policy issues*. Geneva: International Telecommunications Union, 2012.

The econometric specification of the model is as follows:

Aggregate Production function:

$$GDP_{it}=a_1K_{it}+a_2L_{it}+a_3Mob\_Pen_{it}+ e_{it} \quad (1)$$

Demand function:

$$Mob\_Pen_{it}=b_1Rural_{it}+b_2Mob\_Price_{it}+b_3GDPC_{it}+b_4HHI_{it}+e_{it} \quad (2)$$

Supply function:

$$Mob\_Rev_{it}=c_1MobPr_{it}+c_2GDPC_{it}+c_3HHI_{it}+\varepsilon_{3it} \quad (3)$$

Output function:

$$\Delta Mob\_Pen_{it} = d_1 Mob\_Rev_{it} + \varepsilon_{4it} \quad (4)$$

In this study, the authors have relied on such a model developed for the Americas region, which includes the United States and Canada[54] (see table 3-2).

Table 3-2. Americas: Economic Impact of Mobile Broadband

GDP per Capita (PPP)	
Mobile Broadband Unique Subscribers Penetration	0.11556 ***
Capital	0.02984
Education	0.62879 ***
Mobile Broadband Unique Subscribers Penetration	
Mobile Unique Subscribers Penetration	1.81434 ***
Rural Population	-0.11386 ***
GDP per capita	-0.12194 *
Mobile Broadband price	-0.09555 *
HHI Mobile Broadband	-1.02608 ***
Revenue Mobile Broadband	
GDP per capita	2.32425 ***
Mobile Broadband price	-0.79913 ***
HHI Mobile Broadband	-3.55965 ***
Mobile Broadband Adoption Growth	
Revenue Mobile Broadband	-0.36353 ***
Observations	565
Number of countries	18
Country Fixed Effects	Yes
Year and quarter Fixed Effects	Yes
Years	2010-2017
R-Squared first model	0.9767

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

According to the mobile broadband model for the Americas, an increase of 1% in mobile broadband penetration yields an increase in 0.1156% in GDP. This is the coefficient used to estimate the GDP contribution of the increase in wireless broadband penetration resulting for the two alternative 2.5 GHz spectrum licensing approaches; licensing EBS to educational

[54] Katz, R. and Callorda, F. *The economic contribution of broadband, digitization and ICT regulation: econometric modelling for the Americas*. Geneva: International Telecommunications Union, 2019.

entities and an auction. The results of this analysis will be presented in detail in sections 4.2 and 5.2.

3.2.3. Reduction of the homework gap

The 2017 American Community Survey prepared by the U.S. Census Bureau estimates that 5,013,242 children under 18 years old reside in a household with a computer but no broadband subscription, while 2,036,753 children under 18 years old reside in a household without a computer. Thus, per the 2017 survey, the homework gap is 7,049,995. Of this amount, considering only those counties where 2.5 GHz is available for licensing, 144,226 children reside in counties unserved by LTE and 87,450 live in areas where there is at least one commercial carrier offering LTE service, but there is no broadband in the household due to affordability barriers.

The methodology used to assess the impact of either spectrum licensing approach would have on reducing the homework gap mirrors the one used for estimating the decrease in the digital divide. In other words, the analysis focuses on how each approach would contribute to either the deployment of wireless broadband where 144,226 children reside or how it would increase affordability in areas where 87,450 do not have access to broadband because of economic barriers. The analysis of the impact on the homework gap of both alternatives for assigning the EBS spectrum will be presented in sections 4.3 and 5.3.

3.2.4. Reduction of high school attrition

The impact of home broadband access on student performance is also an area of research that has garnered considerable attention in past years.[55] However, it is fair to stipulate that research conducted on the impact of home computers and broadband access on educational outcomes is not totally conclusive, although at times results are affected by the omitted variables effect. Among the more robust assessments, the following has been determined:

- Having a computer at home increases school enrollment by 1.4 percentage points, after socio-demographic controls;[56]
- Teenagers who have access to home computers are 6 to 8 percentage points more likely to graduate from high school than teenagers that do not have access, controlling for socio-demographics;[57]
- High school students with home computer access have a strong positive relationship with academic performance;[58]

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[55] For survey of the research literature, see Bulman, G. and Fairlie, R. *Technology and Education: Computers, Software, and the Internet*. National Bureau of Economic Research Working Paper 22237, Cambridge, Massachusetts, 2016, retrieved from: http://www.nber.org/papers/w22237.
[56] Fairlie, Robert W. 2005. "The Effects of Home Computers on School Enrollment," *Economics of Education Review* 24(5): 533-547.
[57] Beltran, Daniel O., Kuntal K. Das, and Robert W. Fairlie. 2010. "Home Computers and Educational Outcomes: Evidence from the NLSY97 and CPS," *Economic Inquiry* 48(3): 771- 792.
[58] Ibid.

- However, in a quasi-experimental approach, no evidence on educational outcomes such as grades and test scores was identified in a grade 6-10 group in California;[59]
- One important study in North Carolina found mild negative effects between home computer and broadband access and math and reading test scores using panel data and fixed effects, although the broadband access variable is not clearly defined in this study;[60]
- Access to broadband among junior high school students increases their SAT scores, range of college applications and admissibility;[61]
- A study among college students in California found that educational performance tends to improve over time (after two years);[62]
- College graduation: Minority students are more likely to graduate from community college if they have access to a computer at home.[63]

Among the most important impacts that have been measured is that broadband access at home increases the probability of high school graduation: teenagers with broadband home access are 6-8 percentage points more likely to graduate from high school than teenagers that do not have access. While positive effects have also been found in college application probability, the coefficients are not statistically significant. Consequently, we decided to rely on the high school retention coefficient to estimate the impact of alternative 2.5 GHz license assignments in providing wireless broadband access to children in school. The National Center of Education Statistics estimates that, while it has been decreasing, the national high school dropout rate in 2016 was 6.1%, although it reached 8.6% among Hispanic teenagers.[64] Considering that there are 11.5 million enrolled high school students in the nation, we estimate that 971,000 are enrolled in rural counties, of which 59,227 will drop out before high school graduation.[65] In terms of the counties where there is 2.5 GHz spectrum to be licensed for offering LTE service, 907,639 students reside in served geographies, while 187,171 live in unserved areas. This is the population that will be positively impacted by gaining access to wireless broadband. The analysis of the impact of both spectrum assignment strategies will be presented in sections 4.4 and 5.4.

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[59] Fairlie, Robert W., and Jonathan Robinson. 2013. "Experimental Evidence on the Effects of Home Computers on Academic Achievement among Schoolchildren," *American Economic Journal: Applied Economics* 5(3): 211-240.
[60] Vigdor, Jacob L., Helen F. Ladd, and Erika Martinez. 2014. "Scaling the Digital Divide: Home Computer Technology and Student Achievement," Economic Inquiry. 52(3): 1103–1119.
[61] Dettling, L., Goodman, S. and Smith, J. (2012). *Every little bit counts: the impact of high-speed internet on the transition to college.*
[62] Fairlie, Robert W., and Rebecca A. London. 2012. "The Effects of Home Computers on Educational Outcomes: Evidence from a Field Experiment with Community College Students," *Economic Journal* 122(561): 727-753.
[63] Fairlie, Robert W. 2012. "Academic Achievement, Technology and Race: Experimental Evidence," *Economics of Education Review* 31(5): 663-679.
[64] U.S. Department of Education, National Center for Education Statistics 92018. *The condition of education 2018*. NCES 2018-144
[65] This estimate is conservative since dropout rate is expected to be higher in rural counties than the national average.

3.2.5. Economic surplus

The concept of economic surplus is based on the difference between the value of units consumed and produced up to the equilibrium price and quantity, allowing for the estimation of consumer surplus and producer surplus. Consumer surplus measures the total amount consumers would be willing to pay to have the service compared to what they actually pay while producer surplus measures the analogous quantity for producers, which is essentially the economic profit they earn from providing the service.

The approach relied upon for this study measures the total reduction in consumer spending for acquiring wireless broadband under the two options for assigning the 2.5 GHz licenses. Under this premise, the analysis focuses only on those individuals currently purchasing wireless broadband services at the market value (or the least expensive offer available in the market). For example, if the assignment of licenses to educational institutions results in the introduction of an offer less expensive than the one currently existing in the marketplace and a consumer changes operator to acquire the educational offer, the resulting savings are considered to be consumer surplus. In a similar vein, if a library substitutes the broadband offer it purchases from a commercial operator for one less expensive offered by an educational institution, the net savings (which can be dedicated for acquiring other goods) are considered to be producer surplus.

The most affordable wireless broadband offer provided by a commercial carrier at this time was found to be Verizon's Connected Device Ellipsis Hotspot service at $20 monthly. This offer for receiving service at LTE speeds is capped at 2 GB (which is estimated to accommodate 6 hours of streaming video, or 6,000 webpages or 26,000 emails). Once the user reaches this threshold, the download speed is reduced to 600 kbps for the remainder of the billing cycle. If the consumer is willing to resume the original LTE speed, the overage cost is $15 per 1 GB. In addition, other national carriers offer services that are more expensive, although less restrictive. AT&T, for example, offers a 50 GB capped plan at $40/month (the subscriber can purchase additional 1 GB increments for $25 each). While recognizing this service is not comparable with some of the uncapped plans offered by EBS licensees as described in chapter 2, the purpose in this case is to test savings against a prorated plan at $30 per month.[66]

The analysis of the impact of the affordable educational nonprofit offers on consumer and producer surplus will be presented in sections 4.5 and 5.5.

3.2.6. Contribution to the U.S. Treasury

The methodology for quantifying proceeds generated from an auction of the unassigned EBS licenses started by identifying the counties where 2.5 GHz spectrum is available (see table 2-1 above). The MHz available was then multiplied by county population to estimate the total MHz/POP available (see table 3-3).

[66] For reference and comparability to EBS offerings, we note that unlimited plans offered by commercial operators are priced at $80/month for 15 GB (Verizon Beyond Unlimited).

Table 3-3. 2.5 GHz Available MHz/POP by county

MHz per POP	Rural Counties	Non-rural counties	Total
Higher than 10 million	2	13	15
9,999,999 – 5,000,000	22	43	65
4,999,999 – 3,000,000	41	41	82
2,999,999 – 2,000,000	67	45	112
1,999,999 – 1,000,000	173	70	243
999,999 – 800,000	65	20	85
799,999 – 600,000	103	18	121
599,999 – 400,000	111	20	131
399,999 – 200,000	165	20	185
199,999 – 100,000	86	9	95
99,999 – 50,000	46	5	51
49,999 – 30,000	7	0	7
29,999 – 20,000	3	0	3
19,999 – 10,000	1	1	2
9,999 – 5,000	0	1	1
Lower than 4,999	0	0	0
Total	892	306	1,198

Source: FCC Universal Licensing System Data; analysis by the author

The total estimate of 1,935,336,866 MHz-POP was then multiplied by the price per MHz-POP for a comparable auction. This will be discussed in section 5.7 below.

3.3. EBS license windows

The methodology for estimating the economic and social value of the EBS license windows is based on the assumption that if enough spectrum is available for offering LTE service, the educational institution being assigned the license would launch service, as discussed in section 4.6 below.

3.4. Spectrum assigned through auction

The assessment of economic and social value of the 2.5 GHz licenses if they were to be assigned through an auction was predicated on two key assumptions:

- Wireless broadband deployment by commercial service providers acquiring spectrum licenses will only take place in selected currently unserved geographies;
- A potential 2.5 GHz auction will not affect the economic and social impact on already served geographies.

The rationales for these two assumptions are reviewed in turn.

3.4.1. Wireless broadband deployment of commercial providers acquiring unassigned licenses

A stand-alone financial model was developed to estimate the Net Present Value and Internal Rate of Return of a wireless broadband network deployed in a given county (model included in appendix B).[67] The model is driven by two primary variables, county population and sq. miles to calculate population density. The other factors are considered constant:

- Monthly ARPU: $35.00
- Wireless broadband penetration: 58%
- Annual cost of service: (over a nine-year period with scale effect): $42.62 per sub
- Annual SG&A: $35.68
- CAPEX: estimated based on a curve between $1,000 and $100,000 per sq. mile (the total amount is ramped up over a five-year period to match subscriber growth)
- Taxes: 10%
- WACC: 10% (Sprint)
- Annual growth: 2%

The model was applied to the 78 counties that are currently unserved with the following results (see table 3-4).

Table 3-4. Financial Ratios for Unserved Counties-Commercial Carriers

	County	State	Population	Sq. miles	Pop/sq. miles	NPV w/o terminal value	IRR
1	Lawrence County	OH	61,057	457	134	$30,657,120	53.09%
2	Marshall County	WV	32006	312	103	$12,856,324	33.96%
3	Wayne County	WV	41063	512	80	$12,798,336	28.86%
4	Logan County	WV	34428	456	76	$9,561,757	25.41%
5	Mingo County	WV	25150	424	59	$3,358,384	16.03%
6	Lewis County	WA	76,012	2,436	31	$4,007,702	12.71%
7	McKinley County	NM	72,849	5,456	13	$3,789,349	12.66%
8	Grays Harbor County	WA	71,454	2,224	32	$3,693,047	12.64%
9	Lewis and Clark County	MT	66,290	3,498	19	$3,336,559	12.54%
10	Klamath County	OR	66,018	6,136	11	$3,317,781	12.54%
11	Herkimer County	NY	62,943	1,458	43	$3,105,504	12.48%
12	Franklin County	NY	51054	1,697	30	$2,284,765	12.17%
13	Nye County	NV	43296	18,159	2	$1,749,203	11.91%
14	Clatsop County	OR	38021	1,084	35	$1,385,052	11.68%
15	Greenbrier County	WV	35523	1,025	35	$1,212,606	11.55%
16	Coos County	NH	32119	1,830	18	$977,616	11.35%
17	Malheur County	OR	30421	9,930	3	$860,397	11.24%
18	Randolph County	WV	29152	1,040	28	$772,794	11.15%
19	Del Norte County	CA	27442	1,006	27	$654,747	11.02%
20	Curry County	OR	22377	1,988	11	$305,092	10.55%
21	Wyoming County	WV	22130	502	44	$288,041	10.52%
22	Lincoln County	WV	21241	439	48	$226,670	10.42%
23	Pacific County	WA	20940	1,223	17	$205,891	10.39%
24	McDowell County	WV	19707	535	37	$120,773	10.24%
25	Polk County	TN	16722	435	38	($85,292)	9.81%
26	Crawford County	WI	16313	571	29	($113,527)	9.75%
27	Idaho County	ID	16275	8,503	2	($116,150)	9.74%
28	Gunnison County	CO	16215	3,260	5	($120,292)	9.73%
29	Wetzel County	WV	15793	361	44	($149,424)	9.66%
30	Kodiak Island Borough	AK	13773	12,022	1	($288,872)	9.28%
31	Ketchikan Gateway Borough	AK	13745	6,654	2	($290,804)	9.27%
32	Millard County	UT	12651	6,828	2	($366,327)	9.04%

[67] The return on an investment can be measured with a variety of methods (net present value, payback, breakeven, internal rate of return). In this case, the combination of NPV in conjunction of IRR provides a fairly close view of the financial return of the project.

	County	State	Population	Sq. miles	Pop/sq. miles	NPV w/o terminal value	IRR
33	Shoshone County	ID	12490	2,635	5	($377,441)	9.00%
34	Custer County	MT	11895	3,793	3	($418,516)	8.86%
35	Grant County	WV	11673	480	24	($443,842)	8.80%
36	Jackson County	TN	11573	308	38	($440,745)	8.78%
37	Sanders County	MT	11414	2,790	4	($451,721)	8.74%
38	Ritchie County	WV	10005	454	22	($584,990)	8.35%
39	Deer Lodge County	MT	9131	741	12	($609,325)	8.07%
40	Tyler County	WV	8949	261	34	($621,889)	8.01%
41	Webster County	WV	8637	556	16	($643,427)	7.90%
42	Pocahontas County	WV	8574	942	9	($647,777)	7.88%
43	Clearwater County	ID	8533	2,488	3	($650,607)	7.86%
44	San Miguel County	CO	7804	1,289	6	($700,932)	7.59%
45	Ferry County	WA	7568	2,257	3	($717,224)	7.50%
46	Calhoun County	WV	7450	281	27	($725,370)	7.45%
47	Presidio County	TX	7191	3,856	2	($743,250)	7.34%
48	Wallowa County	OR	6864	3,152	2	($765,824)	7.20%
49	Powell County	MT	6852	2,333	3	($766,652)	7.19%
50	Saguache County	CO	6338	3,170	2	($802,135)	6.95%
51	Wirt County	WV	5800	235	25	($839,275)	6.68%
52	Cherry County	NE	5792	6,009	1	($839,828)	6.67%
53	Sheridan County	NE	5241	2,470	2	($877,865)	6.36%
54	Bristol Bay Borough	AK	917	888	1	($621,626)	6.12%
55	Hamilton County	NY	4646	1,808	3	($918,940)	6.00%
56	Menominee County	WI	4506	358	13	($928,605)	5.90%
57	Wahkiakum County	WA	4105	287	14	($956,287)	5.63%
58	Sheridan County	MT	3568	1,706	2	($993,358)	5.21%
59	Catron County	NM	3547	6,929	1	($994,808)	5.20%
60	Mineral County	CO	834	878	0	($895,909)	3.96%
61	Jeff Davis County	TX	2236	2,265	1	($1,085,311)	3.94%
62	Logan County	ND	1932	1,011	2	($1,106,297)	3.58%
63	Bethel Census Area	AK	17957	45,504	0	($3,474,119)	3.43%
64	Dolores County	CO	1736	1,068	2	($1,119,827)	3.33%
65	Hinsdale County	CO	820	1,123	0	($995,773)	3.24%
66	Aleutians West Census Area	AK	5784	14,116	0	($1,763,421)	3.18%
67	Kalawao County	HI	86	53	0	($1,190,623)	0.62%
68	Nome Census Area	AK	9869	28,278	0	($3,652,087)	0.03%
69	Terrell County	TX	721	2,358	0	($1,521,727)	-0.80%
70	Dillingham Census Area	AK	4974	20,915	0	($4,869,214)	-8.10%
71	Aleutians East Borough	AK	3338	15,010	0	($4,028,319)	-8.49%
72	Hoonah-Angoon Census Area	AK	2146	10,914	0	($3,490,416)	-9.35%
73	Denali Borough	AK	2303	12,751	0	($4,031,301)	-11.43%
74	Northwest Arctic Borough	AK	7715	40,749	0	($9,879,163)	-14.29%
75	Yakutat City and Borough	AK	682	9,463	0	($4,126,541)	-22.69%
76	Lake and Peninsula Borough	AK	1301	32,922	0	($12,133,611)	-39.66%
77	Yukon-Koyukuk Census Area	AK	5453	147,805	0	($50,456,402)	-42.18%
78	North Slope Borough	AK	9757	94,796	0	($27,837,844)	-43.00%

Source: Analysis by the author

As is indicated in table 3-4, network deployment in only 24 counties would yield an IRR in excess of a minimum hurdle rate of 10% (conventionally defined for commercial carriers). For purposes of determining the economic and social impact of commercial carriers acquiring 2.5 GHz spectrum in unserved counties, it was assumed that network deployment would be conducted only in 24 of the total 78 unserved counties.

3.4.2. Economic and social impact of an auction on already served geographies

This assumption is driven by two considerations:

- If the carrier acquiring the 2.5 GHz license is already offering service in a given county, the purchasing of additional spectrum would potentially improve the quality of service but have no impact on low-cost offerings. While they could add high-end plans, the low-cost data plans offered before the acquisition of the license would not change; therefore, no changes in affordability would result. In addition, a potential assignment of the pending 4,000+ licenses to commercial carriers would have no impact on future rural 5G deployment. As research and ongoing roll-out is indicating, the economics of 5G networks are certain to preclude its deployment in rural areas.[68] Therefore, any economic gain due to 5G will come in the form of greater speed and capacity in areas already served, not in increased deployment to currently unserved areas.[69]

- If the carrier acquiring the license is not present in the county, a potential license acquisition would have a positive effect (e.g. additional penetration) only if that carrier would offer a plan that is significantly less expensive than the ones available from other competitors before the auction. Given the pricing spread among commercial carriers, we expect this effect to be minimal.

In sum, it is assumed that the auction would not have any significant economic and social effects in already served geographies.

* * * * *

Having completed the review of the theoretical framework, methodologies and assumptions, we will now move to present the impact of both options: (a) preserving the EBS license windows and (b) holding a 2.5 GHz auction.

4. ECONOMIC AND SOCIAL VALUE OF EBS LICENSE WINDOWS

4.1. Reduction of the digital divide

As reviewed in section 3.2.1, in those counties where there is 2.5 GHz spectrum available, the preservation of EBS license windows would have two types of contribution to the reduction of the digital divide. First, it would result in wireless service being offered in the previously unserved areas with a total population of 5,782,622. This will have the first contribution to a reduction of the digital divide. Second, educational institutions would launch an affordable offer in counties already served by at least one commercial carrier, which would primarily

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[68] The most comprehensive research on 5G investments indicates that CAPEX per POP in urban areas is $48.82, while the same number for rural geographies is $4,239.58. See Oughton, EJ & Frias, Z (2018). "The cost, coverage and rollout implications of 5G infrastructure in Britain," *Telecommunications Policy*, vol. 42, issue 8, pp. 636-652.

[69] There may be geographies where assigning the licenses allows aggregation of enough contiguous spectrum for a provider to offer 5G in a place where they otherwise would not be able to do so. *However*, this does not change the fact that they are unlikely to deploy in rural areas—much less rural areas that currently lack *4G* service.

benefit the 11,478,000 non-adopting population. This will result in a contribution to reducing the affordability gap.

The first effect will result in an increase of 3,354,000, estimated on the basis that service will be adopted by 58% of the population, reflecting the percent adoption currently reported by Pew Research in rural areas.

The second effect is predicated on two assumptions and an assessment of wireless broadband price elasticity:

- As mentioned in section 3.2.5, the least expensive plan available in the market is offered by Verizon Connected Device Ellipsis Hotspot service at $20 monthly; however, considering that this carrier is not present in all counties and that other carriers offer a less restrictive product that is more expensive,[70] a prorated average commercial price of $30 per month was assumed.

- Educational institutions entering the market would be offering an uncapped service at a price of $10 per month, as that enabled by Mobile Beacon and Mobile Citizen currently offer.[71] However, as stipulated in the SHLB proposal, "to ensure that the service is available to more than just a handful of customers, the FCC could require that at least 20% of a licensee's customers subscribe to an affordable plan." Considering that resellers of Mobile Citizen service often price their offering at approximately $15 per month, the price of educational institutions targeting the served market is assumed to be $15 monthly.[72]

- The elasticity model quantifies the impact of a reduction in subscription prices on service penetration, recognizing that broadband price elasticity is a function of service adoption. At lower levels of service adoption, broadband is price inelastic. This means that early adopters are not sensitive to price declines. Beyond a threshold point of approximately 2-5% adoption, price elasticity increases significantly and persists at high levels up to 20% penetration, when it starts declining again (see example in graphic 4-1).

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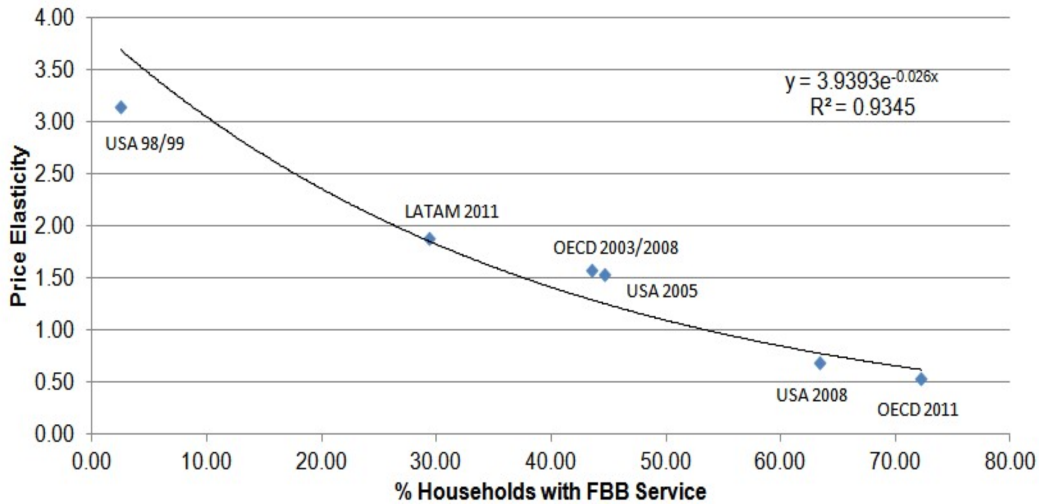
[70] ATT offers a $40/month for 50 GB plan (subscriber can purchase additional 1 GB increments for $25/each).
[71] See Comments of the Schools, Health and Libraries Broadband (SHLB) Coalition at 5.
[72] Mobile Citizen estimates that 2/3 of its users purchase service at between $10 and $15 per month. Mobile Beacon estimates that 2/3 of its users pay $10 per month, while the remainder pay between $10 and $15 per month.

Graphic 4-1. Correlation between Fixed Broadband Penetration and Price Elasticity



Source: Estimates by Telecom Advisory Services based on research literature

While the elasticity data in graphic 4-1 is presented in absolute values, the price elasticity coefficient is always negative, indicating the indirect relationship between price and demand. Thus, the relationship between both variables indicates that a change in the price level would have a positive impact on the level of broadband penetration.

Under this assumption, the increase in penetration resulting from the affordable offer by educational institutions in already served areas would be as follows (see table 4-1).

Table 4-1. EBS License Windows: Increase in wireless broadband penetration of affordable $15/month offer in already served areas

	Data	Source
Population in served counties	27,330,334	Calculated from licenses available and census data
Adopting population	15,852,000	Pew Research (58% rural penetration)
Non-adopting population*	11,478,000	
Average of more affordable plans	$ 30.00	Prorated average of commercial offers
Planned offer	$ 15.00	Prorated of price defined in Comments of SHLB on WT Docket No. 18-120, p. 5. and reseller interviews
Price reduction	50 %	Calculated
Increased broadband adoption at national level (309,700,000)	1.62 %	Elasticity model
Additional subscribers	5,002,000	Calculated

(*) This number is presented as reference, but is not a variable in the calculation of the additional subscribers.
Source: analysis by Telecom Advisory Services

In rural counties with existing commercial wireless service, where there is no limit to the number of accounts that an educational operator could provide at $15/month, our price elasticity model predicts that 5,002,000 subscribers that could not afford broadband at the previously prevailing minimum rate of $30/month would subscribe to this new low-cost offer. However, there may be questions about whether all educational providers will be able to offer a sufficient number of accounts at $15/month in each county. In the case of licensees that self-deploy through their own facilities, the cost of doing so may present financial challenges to offering so many accounts at a very low cost. In the case of licensees that offer service through leased spectrum, it would be feasible to offer service at this price point, however there may be limits to the number of accounts that they can secure through negotiations with a commercial lessee.

In the latter case, the number of low-cost accounts will likely be driven by Commission rules requiring a certain level of educational use. The FCC has proposed to require licensees that acquire licenses through priority filing windows to reserve 20% of the capacity of their EBS network for educational use. Such a rule would make it likely that negotiations between EBS licensees and their lessees would result in a quantity of low-cost educational offers that account for 20% of the lessee's EBS network capacity—in other words, assuming that each subscriber requires approximately the same network capacity, that 20% of users would be able to subscribe to the $15/month plan, allowing the licensee to satisfy the 20% educational reservation requirement.

Because we have assumed that, in rural counties, commercial operators cover approximately 50% of the population, one could estimate the total network capacity for a lessee serving rural counties with some existing service in terms of number of subscribers—approximately 13.7 million users (50% of the total population of these counties). Under this approach, 20% of these subscribers, 2.7 million, would therefore be able to subscribe to a $15/month plan. Therefore, even if 5,002,000 is taken to be the outer limit of the number of previously unserved subscribers that could gain service through a low-cost offer in these counties, the number who could benefit would remain very substantial.

To sum up, the additional lines derived from increased coverage (3,354,000) and enhanced affordability (5,002,000) result in a total increase in subscribers of 8,356,000, which amounts to an 18.28% reduction of the digital divide.

4.2. Contribution to GDP

As discussed in section 3.2.2, the contribution to the GDP is a function of the increase in wireless broadband penetration. The assignment of 2.5 GHz licenses to educational institutions and tribal entities will result in two effects:

- New subscribers in previously unserved counties;
- Non-adopting population in served counties that can now acquire more affordable service plans.

The resulting calculation of impact of both effects would be as follows (see table 4-2).

Table 4-2. EBS License Windows: Contribution to GDP

		Data	Source
Broadband adoption in unserved areas	Current wireless broadband adoption	0%	
	Adoption of wireless broadband after EBS network roll-out	58%	Pew Research: rural penetration
	New wireless broadband subscribers	3,354,000	Calculated
	Incremental broadband adoption	1.08 %	Calculated
	Coefficient of GDP impact of wireless broadband adoption	11.56%	Katz, R. and Callorda, F. (2019)
	Contribution to GDP	0.15%	Calculated
	Impact on GDP ($ billion)	$ 28.468	Calculated
Broadband adoption in served areas	Current wireless broadband penetration	85%	GSMA
	Planned offer	$ 15.00	Comments of SHLB on WT Docket No. 18-120, p. 5.
	Price reduction	50 %	Calculated
	Additional wireless broadband penetration	1.62%	From Table 3-5
	Coefficient of GDP impact of wireless broadband adoption	11.56%	Katz, R. and Callorda, F. (2019);
	Contribution to GDP	0.22%	Calculated
	Impact on GDP ($ billion)	$ 42.460	Calculated
TOTAL IMPACT ON GDP ($ billion)		**$ 70.928**	

NOTE: The U.S. GDP was reduced by $3.279 billion due to lower wireless broadband prices as a result of new offer.

Source: Analysis by Telecom Advisory Services

The new 8,356,000 subscribers would add $70.928 billion to the U.S. GDP. It is important to note that a large part of the incremental GDP would be concentrated in rural areas which could have a derivative impact on job creation and a mitigation of rural migration.

4.3. Reduction of the homework gap

As stated in section 3.2.3, the homework gap affects 7,049,995 children, of which 662,000 are concentrated in rural areas. Of these, in those areas where 2.5 GHz is available for licensing, 144,226 reside in counties unserved by LTE and 87,450 live in areas where there is at least one commercial carrier offering LTE service, but there is no broadband in the household due to affordability barriers (thus a total of 231,676).

Once educational institutions begin offering uncapped service at $15 per month, it is expected that adoption among this population will reach 85% (a higher penetration than assumed in the assessment of digital divide reduction in 4.1 because the broadband need in a household with children is more significant than in a household with no children). The resulting calculation would be as follows (see table 4-3).

Table 4-3. EBS License Windows: Reduction of Homework Gap

		Data	Source
Broadband adoption in unserved areas	Children in households with no broadband	144,226	Calculated based on ACS 2017
	Adoption of wireless broadband after EBS network roll-out	85.24 %	National penetration (GSMA)
	Children in households with new broadband	122,938	Calculated
Broadband adoption in served areas	Children in households with no broadband	87,450	Calculated based on ACS 2017
	Adoption of wireless broadband after EBS network roll-out	85.24 %	National penetration (GSMA)
	Children in households with new broadband	73,407	Calculated
TOTAL IMPACT ON HOMEWORK GAP REDUCTION		**196,346**	

Source: Analysis by Telecom Advisory Services

Considering that the homework gap in rural areas amounts to 662,000, and that a large majority of the available 2.5 GHz licenses are concentrated in rural counties, the reduction in homework gap of 196,346 children amounts to 29.6% of the rural gap.

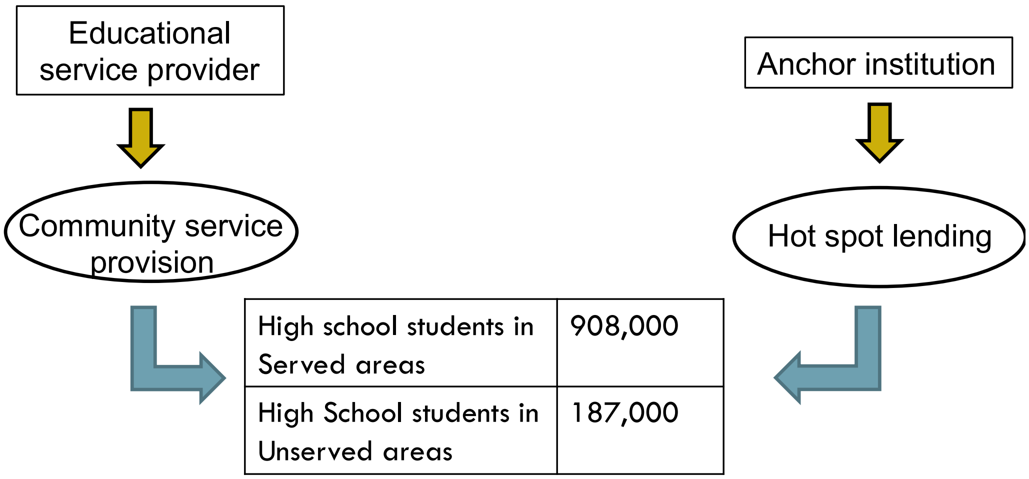
4.4. Reduction of high school attrition

As stated in section 3.2.4, of the 11.5 million enrolled high school students in the nation, we estimate that 971,000 are enrolled in rural counties, of which 59,227 will drop out before high school graduation.[73] In terms of the counties where there is 2.5 GHz spectrum to be licensed for offering LTE service, 907,639 high school students reside in served geographies, while 187,171 live in unserved areas. Further, as highlighted in the research literature, teenagers with broadband home access are 6 to 8 percentage points more likely to graduate from high school than teenagers that do not have access.

A reduction in high school attrition will be triggered by two simultaneous effects caused by educational institutions' wireless broadband provision. First, by offering wireless broadband to their communities, non-adopting households with high school children in served areas could benefit from a less expensive offering (an effect similar to that generated by the Sprint 1Million program), while households with high school children in unserved areas could gain access to broadband service. Second, anchor institutions, such as schools, could offer service through their hot spot lending program similar to the ones enabled by Mobile Beacon and Mobile Citizen, benefitting non-adopting households in served and unserved areas (see figure 4-1).

[73] This estimate is conservative since the dropout rate is expected to be higher in rural counties than the national average.

Figure 4-1. EBS License Windows: Home service provisioning effects on high school students



Source: Telecom Advisory Services

The calculation of high school students that would not be dropping out as a result of these two effects proceeds as follows (see table 4-4).

Table 4-4. EBS License Windows: Reduction of High School Attrition

Effect	Geography		Data	Source
Educational Service Provider	Unserved geographies	Current high school enrollment	205,986	Estimated based on Dept. of Education and FCC licenses
		Adoption of wireless broadband after EBS network roll-out	58%	Pew Research: rural penetration
		High school students benefitting from wireless broadband adoption	119,472	Calculated
		Retention coefficient	7 %	Beltran et al. (2010)
		High school attrition reduction	8,363	Calculated
	Served geographies	Current high school enrollment	983,241	Estimated based on Dept. of Education and FCC licenses
		Increased broadband adoption	1.62 %	Elasticity model
		High school students benefitting from wireless broadband adoption	15,928	Calculated
		Retention coefficient	7 %	Beltran et al. (2010)
		High school attrition reduction	1,115	Calculated
Anchor institution	Unserved geographies	Total number of K-12 schools	3,676	Estimated based on Dept. of Education and FCC licenses
		Average number of high school students per school	120	Estimation based on national averages
		Adoption of wireless broadband after EBS network roll-out	42%	Pew Research: rural penetration
		High school students benefitting from wireless broadband adoption	185,270	Calculated
		Retention coefficient	7 %	Beltran et al. (2010)
		High school attrition reduction	12,970	Calculated
TOTAL REDUCTION IN ATTRITION			**22,448**	

NOTE: There is no effect on anchor institutions in served geographies because schools already have access to broadband

Source: Analysis by Telecom Advisory Services

In sum, the combination of both effects on high school attrition yields a total reduction of 22,448 students, a significant impact in rural areas.

4.5. Economic surplus

As stated in section 3.2.5, the calculation of economic surplus comprises the consumer and producer benefit generated by the offer of educational institutions operating with 2.5 GHz licenses.

4.5.1. Consumer surplus

This calculation is based on the savings a household might accumulate by switching from a commercial offering to one provided by an educational institution relying on EBS spectrum. As stated above, the average of more affordable offers identified as of today is $30 per month capped. When compared with the prorated $15 per month, it generates a $15 saving. This benefit would only be realized by current subscribers in the served geographies, where service adoption is 85% (see table 4-5).

Table 4-5. EBS License Windows: Consumer surplus

	Data	Source
Broadband households in served areas	583,457	Calculated based on ACS 2017
Average of more affordable plans	$30.00	Prorated commercial offer
Planned offer	$15.00	Prorated between Comments of SHLB on WT Docket No. 18-120, p. 5. and market pricing
Percentage of switching households	85%	
Switching households	495,938	Calculated
Annual savings (million)	$89.52	Calculated

Source: Analysis by Telecom Advisory Services

It should be noted, however, that this number could be reduced if the FCC or licensees impose conditions on the low-cost plan restricting eligibility.

4.5.2. Producer surplus

The producer surplus is calculated on the basis of the savings reported by anchor institutions when they switch from a commercial broadband provider to an operator such as Mobile Beacon or Mobile Citizen. Data was collected on schools and libraries per county that would benefit from an educational institution providing broadband service through the 2.5 GHz license. As stated above, this was calculated only for those institutions that are within a served geography[74]:

[74] The sources for total institutions by county were compiled from National Center for Education Statistics: School locations and geo assignments: https://nces.ed.gov/programs/edge/Geographic/SchoolLocations and Institute of Museum and Library Services: Public Libraries Survey: https://www.imls.gov/research-evaluation/data-collection/public-libraries-survey/explore-pls-data/pls-data. Institutions were screened for served counties where there was enough EBS spectrum to offer quality LTE service.

- K-12 schools: 12,114
- Post-secondary schools: 720
- Libraries: 2,785

Savings per institution were calculated by prorating annual savings as reported by Schartman-Cyck, S. and Messier, K. (2018), which resulted in savings of $1,263. By multiplying these savings by the total of 15,619 institutions from the figures above over five years, we estimate the producer surplus to reach $ 98,615,134.

4.6. EBS licensees' ability to deliver on the estimated economic and social contribution

The assessment of economic and social benefits derived from preserving the EBS license regime is not speculative. It is based not only on a track record of accomplishments in bridging the digital divide but also on an analysis of the intrinsic economics of managing spectrum licenses with a perspective of maximizing the public good. This section provides evidence in support of the prior assessment.

4.6.1. Track record

The track record amply demonstrates the ability of these institutions to serve the needs of the unserved, the economically disadvantaged population and students. Mobile Beacon serves 836 schools, 989 libraries and 4,772 nonprofit institutions by means of a $10/month unlimited data service. A number of educational institutions (Northern Michigan University, Kings County Schools, Pasadena Independent School District, among others) as well as several tribal nations (Havasupai Tribal Council, Nisqually Indian Tribe) have deployed or are planning to roll out LTE infrastructure to serve their students and communities in their territory. Some states (Nebraska, California, Utah and North Carolina) are planning the development of state-wide educational networks. As a side note, of all these initiatives occurred under the existing spectrum assignment rules, which the FCC could choose to strengthen significantly.

4.6.2. Close relationship to the unserved consumer base

EBS licensees are better equipped to close the digital divide than the commercial sector when it comes to closeness with unserved users. Commercial carriers do not typically come in contact with people that they do not serve in the normal course. For example, if an operator does not serve certain counties, it is not going to have retail stores in those areas, which, by definition, limits its interaction with those people. Furthermore, if an unserved individual cannot afford purchasing a commercial broadband service, she is not going to be online trying to purchase service since she lacks internet access. In other words, purely commercial entities are not interacting with the unserved people.

On the other hand, an EBS licensee (directly or through its relationship with anchor institutions) have 1:1 contact with the unserved. A student who tells her teacher she cannot complete an assignment because she does not have a computer or internet will prompt the school to address the problem. Similarly, librarians that see people waiting in line for a computer can tell them they can also check out a hotspot and connect to the internet at home. In other words, the EBS licensee institutions are better at closing the digital divide because they know who the unserved are: their names, what they need, etc.

4.6.3. Favorable conditions to deploy wireless broadband networks

The EBS licensee sector has been instrumental in developing a robust eco-system of equipment, administrator training, engineering support and legal services to deliver high-speed wireless internet access to student homes. Due to low equipment costs, use of existing infrastructure, partnerships with local educational institutions and ISPs and the use of open-source management software, networks can be erected for as little as $20,000 per node site.[75]

4.6.4. Advantageous conditions for investment in unserved geographies

The most appropriate approach to understand why educational institutions are better suited to launch wireless broadband in unserved geographies is to quantify the effect changes on the financial profile of a stand-alone project could have on the likelihood of deployment. For this purpose, the model used in section 3.4.1 to estimate the deployment likelihood of commercial carriers in the 78 unserved counties is recalculated with changes in the assumption set that are relevant to educational institutions (all other variables are held constant)[76]:

- Taxation: while commercial carriers are assumed to be taxed at 10%, educational institutions as 501(c)(3) or governmental entities benefit from no tax burden.

- CAPEX: educational institutions are likely to benefit from grant contributions from state and local governments which reduce the amount of capital to be invested in the project. As an example, the Northern Michigan University LTE network received financial assistance from the Michigan Economic Development Corporation.[77] While it is not an educational institution, the municipality of Red Cliff, Colorado benefitted from grants provided from the Colorado Department of Local Affairs covering tower construction, a portion of the land and part of the trenching to install fiber, and a second grant from the Colorado General Assembly.[78] In total, the town contributed $133,484 (37%), while the state grants represented $214,203 (63%). While it is not expected that educational institutions would benefit from such a large state grant for what are significantly larger projects such as the ones under consideration here, it is reasonable to assume that 20% of CAPEX would be contributed through state grants.

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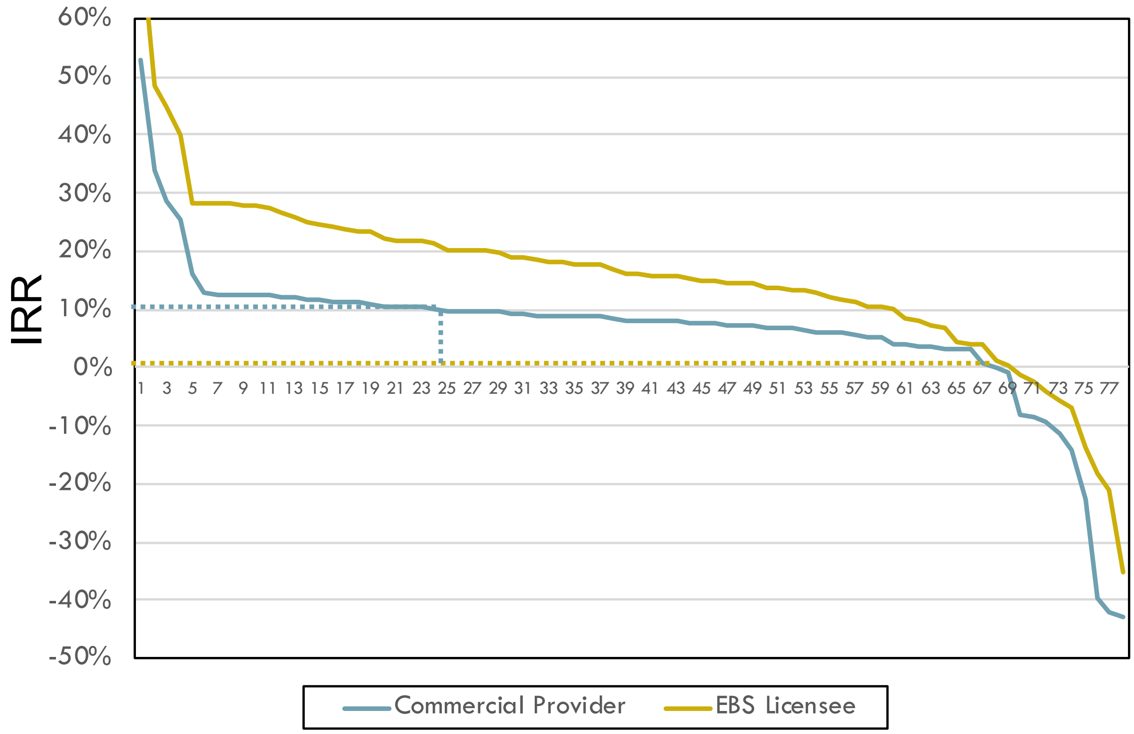
[75] Comments of MuralNet.
[76] A similar approach was used in Katz, R. (2008). "Ultrabroadband investment models," *Communications & Strategies*, November, pp. 99-115.
[77] Northern Michigan University. *2017-2018 Financial Report*.
[78] See Colwell, M., Schumann, A. and Shakfa, A. (2018). *The social impact of broadband: A case study of Red Cliff, Colorado*. April 9.

- Hurdle rate: the conventional hurdle rate used for commercial providers in the analysis in chapter 3.4.1 is 10%. Research indicates that the average hurdle rate among nonprofit foundations and endowments is 6.95%.[79] However, the broadband projects under consideration cannot be considered a long-term portfolio return objective. Thus, we assume that the hurdle rate for educational institutions and tribal nations should approximate the return of a treasury bill (approximately 2.30%).

While other variables, such as the WACC (Weighted Average Cost of Capital), might also change for an educational institution, we decided to keep the one for commercial carriers as a proxy.[80] It is important to note as well that the ARPU has held at $35.00.[81]

Graphic 4-2 presents the distribution of the internal rate of return for stand-alone investments in each of the 78 unserved counties.

Graphic 4-2. EBS Licensee vs. Commercial Service Provider: Comparison of Internal Rate of Return of a stand-alone investment



Source: Analysis by Telecom Advisory Services

As indicated in graphic 4-2, under commercial investment assumptions, stand-alone investments could only meet the 10% hurdle rate in 24 counties. On the other hand, under

[79] Pollard, T. (2013). "SEI paper: Average hurdle rate among non-profit foundations and endowments stands at 6.95%," June 26.
[80] WACC calculations are based on the cost of debt and equity. While the cost of debt is straight-forward, the cost of equity for a non-profit refers to capital from retained earnings, contributions, and/or grants, which require an assessment of the opportunity cost of making the right investment from a donor perspective.
[81] Contrary to the case of service offered in served areas, in the case of unserved geographies, it is assumed that EBS licensees would offer service at a higher price.

educational institution investment assumptions, 67 counties exhibit an internal rate of return higher than the Treasury Bill (the hurdle rate assumed in this case). The remaining 11 counties are all located in Alaska, a geography with very specific demographic characteristics, which would require a more tailored approach to reach appropriate broadband coverage. That said, since these counties represent only 2.8% of the total population of the unserved counties, we assume that coverage under the scenario of educational institutions and tribal nations retaining the EBS license would be for all 78 counties. Based on the experience of grant support received by infrastructure-based EBS operators in other parts of the country, it is assumed that the remaining Alaskan counties would also be served by EBS licensees by receiving state support.

4.7. Conclusion

To conclude, the economic and social value of assigning the remaining EBS licenses to educational organizations and/or tribal nations is significant:

- A reduction of the digital divide by launching wireless broadband service in unserved geographies: by rolling out networks in areas that concentrate 5,783,000 population, EBS providers can achieve a penetration of 58%, which would result in 3,354,000 new subscribers.

- By offering uncapped LTE service at a prorated average of $15/month, as the one enabled by Mobile Beacon and Mobile Citizen, EBS licensees would be targeting the more economically vulnerable population that cannot afford the prorated average of a commercial plan of $30/month. This would result in 5,002,000 additional subscribers.

- The increase in wireless broadband subscriptions would yield positive externalities and a contribution to the U.S. GDP in an amount of $70.93 billion. A large portion of this contribution will be concentrated in rural areas, with a derivative impact on job creation and the mitigation of rural migration.

- The increase in wireless broadband subscriptions would result in a reduction of the homework gap equivalent to 196,000 children, with a majority concentrated in rural areas.

- Simultaneously, the extension of home broadband access to high school students through either community service provisioning or hot spot lending programs, would reduce high school attrition for 22,400 teenagers, a majority of them concentrated again in rural areas.

- The offering of affordable wireless broadband plans will yield an economic surplus equivalent to $89.52 million in savings for current subscribers switching to $15 per month and $98.62 million in savings over five years for schools and libraries in the areas where the 4,000 unassigned licenses are available.

Can the educational organizations and tribal nations deliver on these benefits? We believe this to be the case for three reasons:

- The track record amply demonstrates the ability of these institutions to serve the needs of the unserved, the economically disadvantaged population and students. Mobile Beacon serves 836 schools, 989 libraries and 4,772 nonprofit institutions by means of a $10/month unlimited data service. A number of educational institutions (Northern Michigan University, Kings County Schools, Monterrey County Schools and Louisa County Public Schools) as well as tribal nations (Havasupai Tribal Council, Nisqually Indian Tribe) have deployed LTE infrastructure to serve their students and communities in their territory.

- Educational organizations and tribal nations benefit from favorable conditions to deploy wireless broadband networks: due to low equipment costs, use of existing infrastructure, partnerships with local educational institutions and ISPs and the use of open source management software, networks can be erected for as little as $20,000 per node site.

- EBS licensees are better suited to deploy wireless broadband in unserved geographies because they face less stringent return on investment constraints than commercial carriers. When considering the 78 counties that lack service, educational institutions can cover up to 67 counties, while commercial carriers cannot meet their hurdle rate beyond 24 counties.

However, the study would not be complete if a counterfactual assessment was not done. In other words, what would a comparable value of the said licenses be if, as an alternative, they are auctioned to commercial providers, while simultaneously eliminating all requirements that this spectrum is used for educational purposes? This analysis is presented in the next chapter of the study.

5. ECONOMIC AND SOCIAL VALUE OF AUCTIONING UNASSIGNED 2.5 GHZ LICENSES

5.1. Reduction of the digital divide

As reviewed in section 3.2.1, in those counties where there is 2.5 GHz spectrum available, assigning the licenses to commercial carriers through an auction would yield a contribution to the reduction of the digital divide in unserved areas. Commercial carriers would launch wireless service in some of the previously unserved geographies which account for 5,782,622 population. However, when it comes to bridging the affordability gap in the served population, there would be no effect. If a carrier is already present in the geography, it would not need additional spectrum to launch a more affordable offer.

In the case of unserved areas, the geographies to be deployed are restricted to those where building networks makes financial sense.[82] As indicated in section 3.4.1, network deployment in only 24 of 78 totally unserved counties presents a positive NPV and an IRR in excess of a minimum hurdle rate of 10%. Assuming a 58% final penetration in deployment of EBS licensees, it would result in 581,562 new subscribers (see table 5-1).

Table 5-1. Unserved Counties: New subscribers from commercial deployment

	County	State	Population	Sq. miles	Pop/sq. miles	NPV w/o terminal value	IRR	New Users
1	Lawrence County	OH	61,057	457	134	$30,657,120	53.09%	35,413
2	Marshall County	WV	32006	312	103	$12,856,324	33.96%	18,563
3	Wayne County	WV	41063	512	80	$12,798,336	28.86%	23,817
4	Logan County	WV	34428	456	76	$9,561,757	25.41%	19,968
5	Mingo County	WV	25150	424	59	$3,358,384	16.03%	14,587
6	Lewis County	WA	76,012	2,436	31	$4,007,702	12.71%	44,087
7	McKinley County	NM	72,849	5,456	13	$3,789,349	12.66%	42,252
8	Grays Harbor County	WA	71,454	2,224	32	$3,693,047	12.64%	41,443
9	Lewis and Clark County	MT	66,290	3,498	19	$3,336,559	12.54%	38,448
10	Klamath County	OR	66,018	6,136	11	$3,317,781	12.54%	38,290
11	Herkimer County	NY	62,943	1,458	43	$3,105,504	12.48%	36,507
12	Franklin County	NY	51,054	1,697	30	$2,284,765	12.17%	29,611
13	Nye County	NV	43,296	18,159	2	$1,749,203	11.91%	25,112
14	Clatsop County	OR	38,021	1,084	35	$1,385,052	11.68%	22,052
15	Greenbrier County	WV	35,523	1,025	35	$1,212,606	11.55%	20,603
16	Coos County	NH	32,119	1,830	18	$977,616	11.35%	18,629
17	Malheur County	OR	30,421	9,930	3	$860,397	11.24%	17,644
18	Randolph County	WV	29,152	1,040	28	$772,794	11.15%	16,908
19	Del Norte County	CA	27,442	1,006	27	$654,747	11.02%	15,916
20	Curry County	OR	22,377	1,988	11	$305,092	10.55%	12,979
21	Wyoming County	WV	22,130	502	44	$288,041	10.52%	12,835
22	Lincoln County	WV	21,241	439	48	$226,670	10.42%	12,320
23	Pacific County	WA	20,940	1,223	17	$205,891	10.39%	12,145
24	McDowell County	WV	19,707	535	37	$120,773	10.24%	11,430
	TOTAL		1,002,693					581,562

Source: Analysis by Telecom Advisory Services

It is assumed that additional penetration derived from those counties partially covered by commercial carriers will not yield additional subscribers since the licenses derived from the overlay auction would not change the nature of offers, while coverage would still be limited as it is today (in other words, an additional spectrum license in a given county will not change the economics of wireless network deployment). Similarly, as stated above, gaining spectrum through an overlay auction would not result in launching a more affordable plan.

In sum, making the unassigned 2.5 GHz licenses available to commercial carriers through an auction would result in 581,562 new subscribers of the 1,002,693 population (which is

[82] A build-out requirement in excess of what is assumed here could actually make the case for auctions worse by reducing the number of counties for which it would be economical to acquire a license in the first place. Thus, assuming a stronger build-out rule would not necessarily improve the case for an auction as much as one might think.

equivalent to a 0.19% increase in penetration in wireless broadband). The remaining 402,194 population residing in unserved counties would not receive the service, while the 4,377,735 living in in counties that are partially unserved would never benefit from service coverage, as well.

5.2. Contribution to GDP

As discussed in section 3.2.2, the contribution to the GDP is a function of the increase in wireless broadband penetration. The assignment of 2.5 GHz licenses to commercial carriers through an auction will result in new subscribers in previously unserved counties

The resulting calculation of impact would be as follows (see table 5-2).

Table 5-2. Auction: Contribution to GDP

		Data	Source
Broadband adoption in unserved areas	Current wireless broadband adoption	0%	
	Population in 24 counties where wireless networks will be deployed	1,002,693	Calculated based on model in Appendix B
	Adoption of wireless broadband after EBS network roll-out	58%	Pew Research: rural penetration
	New wireless broadband subscribers	581,562	Calculated
	Incremental broadband adoption	0.19 %	Calculated
	Coefficient of GDP impact of wireless broadband adoption	11.56%	Katz, R. and Callorda, F. (2019)
	Contribution to GDP	0.02%	Calculated
TOTAL IMPACT ON GDP ($ billion)		**$ 4.208**	

Source: Analysis by Telecom Advisory Services

The new 581,562 subscribers would add $4.21 billion to the U.S. GDP. As in the case of EBS licenses, a large part of the incremental GDP would be concentrated in rural areas which could have a derivative impact on job creation and a mitigation of rural migration.

5.3. Reduction of homework gap

As stated in section 3.2.3, the homework gap affects 7,049,995 children, of which 662,000 are concentrated in rural areas. Of these, in those areas where 2.5 GHz is available for licensing, 144,226 reside in counties unserved by LTE and 87,450 live in areas where there is at least one commercial carrier offering LTE service but there is no broadband in the household due to affordability barriers (thus a total of 231,676).

We modelled the impact on the homework gap of commercial carriers that gain access to the remaining 2.5 GHz licenses via auction on the basis of the Sprint 1Million program. In the same as way as in the reduction of the digital divide, which assumed that the effect from commercial carriers will emerge only on unserved geographies, the contribution of Sprint 1Million will materialize in the counties where network roll-out yields a rate of return in excess of 10%: 24 out of the 78 counties. Further, considering that the 1Million program provides free wireless broadband access only to high school students (assumed to be 25%), we optimistically expect that adoption will reach 100% of the targeted population. The resulting calculation would be as follows (see table 5-3).

Table 5-3. Auction: Reduction of Homework Gap

		Data	Source
Broadband adoption in unserved areas	Children in households with no broadband (78 counties)	144,226	Calculated based on ACS 2017
	Children in households with no broadband (24 counties)	29,869	Calculated based on model in appendix B
	High school children in households with no broadband (24 counties)	7,467	
	Adoption of wireless broadband after commercial carrier network roll-out	100 %	National penetration (GSMA)
TOTAL IMPACT ON HOMEWORK GAP REDUCTION		**7,467**	

Source: Analysis by Telecom Advisory Services

Considering that the homework gap in rural areas amounts to 662,000, and that a large majority of the available 2.5 GHz licenses are concentrated in rural counties, the reduction in homework gap of 7,467 children amounts to 1.13 % of the rural gap.

5.4. Reduction of high school attrition

As stated in section 3.2.4, of the 11.5 million enrolled high school students in the nation, we estimate that 971,000 are enrolled in rural counties, of which 59,227 will drop out before high school graduation.[83] In counties where there is 2.5 GHz spectrum to be licensed for offering LTE service 907,639 high school students reside in served geographies, while 187,171 live in unserved areas. In addition, as highlighted in the research literature, teenagers with broadband home access are 6 to 8 percentage points more likely to graduate from high school than teenagers that do not have access.

A reduction in high school attrition will be only triggered by commercial carriers gaining access to 2.5 GHz licenses in unserved areas. By offering wireless broadband to households with high school children in unserved areas (an effect similar to that generated by Sprint 1Million), commercial carriers could have a contribution to high school attrition. No additional effect in served areas could materialize since gaining access to 2.5 GHz spectrum in served areas is no pre-condition to offer a plan similar to Sprint 1Million. The calculation of high school students that would not be dropping out as a result of these two effects proceeds as follows (see table 5-4).

[83] This estimate is conservative since the dropout rate is expected to be higher in rural counties than the national average.

Table 5-4. EBS License Windows: Reduction of High School Attrition

	Geography	Data	Source
Unserved geographies	Current high school enrollment (78 counties)	205,986	Estimated based on Dept. of Education and FCC licenses
	Current high school enrollment (24 counties)	34,335	Calculated based on model in Appendix B
	Adoption of wireless broadband after commercial network roll-out	58%	Pew Research: rural penetration
	High school students benefitting from wireless broadband adoption	19,914	Calculated
	Retention coefficient	7 %	Beltran et al. (2010)
	TOTAL IMPACT ON HIGH SCHOOL ATTRITION	**1,394**	

Source: Analysis by Telecom Advisory Services

In sum, the combination of both effects on high school attrition yields a total reduction of 1,394 students.

5.5. Economic surplus

Considering that gaining access to the EBS licenses through auction would not allow commercial carriers to launch more affordable offerings, economic surplus in this case equals zero.

5.6. Contribution to U.S. Treasury

In section 3.2.6, it was estimated that the unassigned 2.5 GHz licenses represented 1,935,336,866 MHz-POP. The starting point to estimate auction proceeds is determined from comparable MHz-POP prices from prior auctions: we have chosen the Broadband Radio Service (auction 86) conducted in October 2009.[84] Auction 86 is the most recent overlay auction of spectrum with similar characteristics and levels of license encumbrance to a potential 2.5 GHz auction. Total gross bids equaled $20,701,000 and net bids equaled $19,426,000 for 77 small to medium sized BTAs within the BRS band (the commercial counterpart to EBS licenses.[85] The five most valuable licenses sold in that auction were those covering, in descending order of price, Burlington, VT ($2,556,000), Gulf of Mexico Zone A ($1,053,000), San Juan, PR ($1,023,000), Santa Fe, MN ($982,000) and Albuquerque, NM ($912,000).[86]

As to a determination of the price per MHz-POP, the FCC did not publish them in the case of Auction 86. Goldman Sachs published an estimated price of $0.28 per MHZ-POP, but their

[84] This was the upper part of 2.5 GHz band overlay auction. The auction only lasted three days. It should be noted that this auction was around the time carriers started complaining about the “spectrum crunch” so demand was hypothetically very high for spectrum.

[85] FCC. *Auction 86: Broadband Radio Service*, https://www.fcc.gov/auction/86.

[86] Encumbered spectrum does not generate much revenue relative to greenfield spectrum (see Auction 102). This auction of two 425 MHz wide channels was limited in generating revenue because much of this spectrum was already licensed (This is analogous to EBS if there were to be a white space auction). Total proceeds were $702 million.

estimation is based on the various transactions between AT&T, Clearwire and Sprint, and therefore probably reflects a far higher valuation than one would see in an overlay auction since the transactions would have disproportionately included desirable urban areas (see table 5-5).

Table 5-5. Auction 86: Price per MHz-POP (according to Goldman Sachs)

Transaction	Value ($ million)	POPs	MHz	MHz-POP	$/MHz/POP
Sprint acquisition of Clearwire	$14,000	307 (nationwide)	152	46,667	$0.30
Sprint contribution to Clearwire	$7,400			29,000	$0.26
Clearwire purchase from ATT	$300			1,700	$0.18
					$0.28

Source: Goldman Sachs (2018). Spectrum auction applicant list reveals few surprises, p. 4

As an alternative, the following methodology was used. In the BRS auction, the Commission adopted encumbrance rates for each of the BTAs (which it used, in conjunction with MHz and total POPs) to calculate bidding units and starting bids for each, which represent roughly the percentage of people in the BTA that are within existing license areas and therefore not covered by the newly auctioned overlay spectrum. We calculated a representative, "unencumbered" $/MHz*POPs by multiplying total POPs (as of 2009) in each BTA by the complement of the encumbrance rate (i.e., 1-encumberence rate) for each BTA to yield an unencumbered population, and then proceeded with the usual $/MHz*POPs calculation for the BRS auction using that as the value for POPs rather than total value.[87]

Using the methodology described above, the 2009 BRS auction yielded an average $/MHz*POPs (counting only unencumbered POPs) of $0.027. Based on this value and unencumbered MHz-POP available by county for EBS, total overlay auction proceeds would amount to $52,254,000. Even if 2.5 GHz spectrum has tripled in value since 2009, total revenue would still be only $156.75 million.

5.7. Conclusion

To conclude, the economic and social value of assigning the remaining 2.5 GHz licenses to commercial carriers via an overlay auction does not generate significant economic and social effects:

- A reduction of the digital divide by launching wireless broadband service in unserved geographies: rolling out commercial networks in areas that concentrate 5,783,000 population can achieve a penetration of 58% and would result in 581,562 new subscribers because service would be rolled out only in 24 of the 78 counties (an increase of 0.22% in wireless broadband penetration).

[87] The typical 2.5 GHz license would be heavily encumbered in any potential overlay auction, which would result in artificially depressed prices due to bidding advantages for existing incumbent operators.

- No additional impact would be generated in served geographies because affordable offers by commercial carriers are not dependent upon gaining access to the unassigned licenses.
- The increase in wireless broadband subscriptions would yield positive externalities and a contribution to the U.S. GDP in an amount of $4.21 billion. As in the case of EBS licenses, a large portion of this contribution will be concentrated in rural areas, with a derivative impact on job creation and the mitigation of rural migration.
- The increase in wireless broadband subscriptions would result in a reduction of the homework gap equivalent to 7,467 children, which amounts to 1.13% of the rural gap.
- Simultaneously, the extension of home broadband access to high school students through either community service provisioning or hot spot lending programs would reduce high school attrition for 1,394 teenagers, a majority of them concentrated again in rural areas.
- Finally, the proceeds of an overlay auction are estimated at $52.25 million, although even if 2.5 GHz spectrum has tripled in value since 2009, total revenue would still be only $156.75 million.

8. FACTUAL VERSUS COUNTERFACTUAL CASES COMPARATIVE ASSESSMENT

Having completed the two assessments, it is possible to present the results in a comparative manner in order to draw conclusions and implications. Comparative economic and social value analysis shows that assigning the EBS licenses to educators and nonprofits yields greater benefits than auctioning to commercial carriers (see table 8-1).

Table 8-1. Comparative Social and Economic Value

		EBS License Windows	Auctioning to commercial carriers
Reduction of the digital divide	Unserved geographies	3,354,000	581,562
	Served geographies	5,002,000	
	Total	8,356,000	581,562
Contribution to GDP (in million $)	Unserved geographies	$ 28.47	$ 4.21
	Served geographies	$ 42.46	
	Total	$ 70.93	$ 4.21
Reduction of homework gap (New broadband households with children	Unserved geographies	122,938	7,467
	Served geographies	73,407	
	Total	196,345	7,467
Reduction of high school attrition (increase in graduating high school students)	Unserved geographies	21,333	1,394
	Served geographies	1,115	
	Total	22,448	1,394
Economic surplus (in $ million)	Consumer surplus	$ 89.52	
	Producer surplus (5 years)	$ 98.62	
	Total	$ 188.14	$ 0
Contribution to Treasury (in $ million)		$ 0	$ 52.25 - $ 156.75

Source: Analysis by Telecom Advisory Services

There are five reasons why the difference in social and economic value between options is so significant:

- Wireless broadband deployment economics (not a lack of available commercial spectrum) constrain the development of commercial networks in rural, unserved counties. Additional spectrum will not change the economic constraints that disincentivize investment in sparsely populated areas.

- Outside of the lifeline program, commercial wireless carriers do not have an offer focused on increasing adoption by low income population (especially in rural areas).

- Commercial-led homework gap offers (e.g. Sprint's 1Million plan) have limitations that comparable EBS offers do not (e.g. data caps and available only to high school students).

- There is no commercial carrier offer comparable to EBS offers like those available from Mobile Beacon and Mobile Citizen, which focus on affordable service to anchor institutions (schools, libraries, nonprofits) and their users (such as hotspot lending models).

- Proceeds of an overlay auction are limited due to significant encumbrances and the majority of unencumbered spectrum is limited to rural licenses, which generally yield lower proceeds than bids for spectrum in more populated areas.

9. CONCLUSION AND PUBLIC POLICY IMPLICATIONS

The EBS licensing regime, which has evolved over the years in order to respond to the evolving technology and service needs, represents an appropriate approach to address critical social needs like a reduction of the digital divide and the homework gap. In doing so, the EBS licensing regime is also conducive to addressing other social needs such as reducing high school attrition. Furthermore, the licensing regime represents additional economic benefits such as a contribution to the nation's GDP, mainly concentrated in rural areas, and enhanced economic surplus, mainly for libraries, schools and nonprofits, which could be assigned to the acquisition of other community services and educational goods. Each of these benefits is greater than the comparable benefits produced by an overlay auction of EBS spectrum.

The preservation of education in the EBS white spaces through priority windows does not deny auctions as a conventional approach to manage the spectrum. There is a growing consensus among academic research and policy makers that the approaches to spectrum management that maximize welfare comprise a mix of licenses assigned through auctions and the establishment of rules governing portions of the spectrum as a common pool resource (e.g. unlicensed spectrum, portions of spectrum assigned for free such as EBS, etc.) (Milgrom et al., 2011). As a response to the command and control approach that the U.S. government adopted for spectrum management, Ronald Coase originally argued for property rights and a pricing mechanism in spectrum allocation. Although Coase championed the use of auctions, which confer exclusive rights to the auction winners on the assigned frequencies (according to the principle of "highest and best use" basis), his proposal was done in the context of spectrum mainly being used for broadcasting services with no technology commercially available yet that would allow other ways of spectrum usage.

The mere assignment of spectrum licenses with property rights may lead to buildout in profitable areas if the economic circumstances provide a return, but it does not always result in spectrum reaching its "highest and best use" in areas that result in a limited return on investment for license holders. The FCC has attempted to address this concern by implementing buildout requirements on licenses, but often the most stringent requirements only obligate a licensee to serve just 75% of the population over a 10-year period. Coase's theory does not account for the socio-economic benefits of providing new and affordable service to the unserved in these unprofitable, predominantly rural areas and the consequential impact of the various areas examined in this study.

In an era when sharing the spectrum is not only technically feasible but economically desirable, Coase's theorem gets a renewed perspective by which the focus shifts from whether all spectrum should be allocated on an auction basis, with corresponding counter arguments for spectrum allocation on a different basis, to rather questioning what is the optimal mix for the co-existence of the two regimes. The underlying argument of this study is that the reservation of a portion of the spectrum, specifically the EBS portion of the 2.5 GHz band, to be assigned and managed through a set of specific regulations is particularly attractive in terms of reducing the cost of setting up and deploying networks for local wireless transmission in view of meeting socio-economic objectives.

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APPENDICES

Appendix A: General county-based model

(Under separate cover)

Appendix B. Financial Model to assess profitability of commercial wireless deployment

County	State	Population	Sq. miles	Pop/Sq miles	CAPEX	NPV	IRR	NPV	IRR
Lewis County	WA	76,012	2,436	31	62,407	$ 4,007,702	12.71%	$183,243,665	29.58%

		2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	
Revenues			$ 9,258,262	$ 12,961,566	$ 14,813,219	$ 18,516,523	$ 18,516,523	$18,516,523	$ 18,516,523	$ 18,516,523	$ 18,516,523	
Cost of Service			$ 1,512,704	$ 2,610,373	$ 1,891,811	$ 1,716,382	$ 1,440,965	$ 1,243,826	$ 1,172,644	$ 1,125,543	$ 1,090,594	
SG&A			$ 214,699	$ 982,786	$ 1,289,370	$ 1,769,443	$ 1,759,320	$ 1,784,491	$ 1,794,316	$ 1,799,824	$ 1,806,238	
EBITDA		$ -	$ 7,530,859	$ 9,368,408	$ 11,632,038	$ 15,030,698	$ 15,316,238	$15,488,206	$ 15,549,563	$ 15,591,157	$ 15,619,692	
Depreciation												
EBIT		$ -	$ 7,530,859	$ 9,368,408	$ 11,632,038	$ 15,030,698	$ 15,316,238	$15,488,206	$ 15,549,563	$ 15,591,157	$ 15,619,692	
Taxes	10%		$ 753,086	$ 936,841	$ 1,163,204	$ 1,503,070	$ 1,531,624	$ 1,548,821	$ 1,554,956	$ 1,559,116	$ 1,561,969	TOTAL CAPEX
CAPEX	2,436	$ 15,000,000	$ 745,343	$ 30,404,800	$ 10,858,857	$ 19,003,000	$ -	$ -	$ -	$ -	$ -	$ 76,012,000
Change in Working Capital			$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	
FCF		$(15,000,000)	$ 6,032,430	$(21,973,233)	$ (390,023)	$ (5,475,372)	$ 13,784,614	$13,939,386	$ 13,994,607	$ 14,032,041	$ 14,057,723	$ 179,235,963

WACC	10.0%
g	2%
NPV withou terminal value	$ 4,007,701.82
NPV with terminal value	$ 183,243,664.69
IRR	12.71%
IRR	29.58%

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Cost of Service		16%	20%	13%	9%	8%	7%	7%	7%	7%
SG&A		2%	8%	9%	10%	10%	10%	10%	10%	10%
EBITDA		81%	72%	79%	81%	83%	84%	84%	84%	84%

Population	Adoption
76,012	58.00%

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	
Subscribers		22,043	30,861	35,270	44,087	44,087	44,087	44,087	44,087	44,087	Achieving 58% penet
ARPU	$ 35.00	$ 35.00	$ 35.00	$ 35.00	$ 35.00	$ 35.00	$ 35.00	$ 35.00	$ 35.00	$ 35.00	Internet Essentials
Cost of service		$ 2,120,636	$ 20,273,917	$ 23,849,445	$ 25,176,207	$ 27,351,192	$27,923,392	$ 30,166,385	$ 32,637,595	$ 35,025,117	
Subscribers		30,902	239,686	444,632	646,676	836,822	989,734	1,134,142	1,278,399	1,415,881	
		$ 68.62	$ 84.59	$ 53.64	$ 38.93	$ 32.68	$ 28.21	$ 26.60	$ 25.53	$ 24.74	$ 42.62
SG&A											
Staff cost		$ 179,400	$ 2,558,400	$ 3,432,000	$ 5,553,600	$ 5,647,200	$ 5,616,000	$ 5,678,400	$ 5,834,400	$ 5,928,000	
Market and distribution		$ 65,134	$ 3,075,502	$ 7,771,311	$ 12,364,196	$ 16,816,210	$20,875,818	$ 24,533,681	$ 28,094,219	$ 31,563,931	
Customer operations		$ 34,738	$ 1,230,201	$ 3,108,524	$ 4,945,678	$ 6,726,484	$ 8,350,327	$ 9,813,472	$ 11,237,688	$ 12,625,573	
G&A		$ 21,711	$ 768,875	$ 1,942,828	$ 3,091,049	$ 4,204,053	$ 5,218,955	$ 6,133,420	$ 7,023,555	$ 7,890,983	
Total		$ 300,983	$ 7,632,978	$ 16,254,662	$ 25,954,523	$ 33,393,947	$40,061,100	$ 46,158,973	$ 52,189,861	$ 58,008,487	
Total per sub		$ 9.74	$ 31.85	$ 36.56	$ 40.14	$ 39.91	$ 40.48	$ 40.70	$ 40.82	$ 40.97	$ 35.68

Appendix C. Financial Model to assess profitability of educational institution network deployment

County	State	Population	Sq. miles	Pop/Sq miles	CAPEX	NPV	IRR	NPV	IRR
Lewis County	WA	76,012	2,436	31	62,407	$ 21,972,303	28.34%	$ 221,123,373	41.88%

			2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	
Revenues				$ 9,258,262	$ 12,961,566	$ 14,813,219	$ 18,516,523	$ 18,516,523	$ 18,516,523	$ 18,516,523	$ 18,516,523	$ 18,516,523	
Cost of Service				$ 1,512,704	$ 2,610,373	$ 1,891,811	$ 1,716,382	$ 1,440,965	$ 1,243,826	$ 1,172,644	$ 1,125,543	$ 1,090,594	
SG&A				$ 214,699	$ 982,786	$ 1,289,370	$ 1,769,443	$ 1,759,320	$ 1,784,491	$ 1,794,316	$ 1,799,824	$ 1,806,238	
EBITDA			$ -	$ 7,530,859	$ 9,368,408	$ 11,632,038	$ 15,030,698	$ 15,316,238	$ 15,488,206	$ 15,549,563	$ 15,591,157	$ 15,619,692	
Depreciation													
EBIT			$ -	$ 7,530,859	$ 9,368,408	$ 11,632,038	$ 15,030,698	$ 15,316,238	$ 15,488,206	$ 15,549,563	$ 15,591,157	$ 15,619,692	
Taxes		0%		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	TOTAL CAPEX
CAPEX		2,436	$ 12,000,000	$ 596,274	$ 24,323,840	$ 8,687,086	$ 15,202,400	$ -	$ -	$ -	$ -	$ -	$ 60,809,600
Change in Working Capital				$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	
FCF			$ (12,000,000)	$ 6,934,584	$ (14,955,432)	$ 2,944,952	$ (171,702)	$ 15,316,238	$ 15,488,206	$ 15,549,563	$ 15,591,157	$ 15,619,692	$ 199,151,070
WACC	10.0%	Sprint	$ 15,000,000	$ 745,343	$ 30,404,800	$ 10,858,857	$ 19,003,000						$ 76,012,000
g	2%												
NPV withou terminal value		$ 21,972,303.09											
NPV with terminal value		$ 221,123,372.95											
IRR	28.34%												
IRR	41.88%												

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Cost of Service		16%	20%	13%	9%	8%	7%	7%	7%	7%
SG&A		2%	8%	9%	10%	10%	10%	10%	10%	10%
EBITDA		81%	72%	79%	81%	83%	84%	84%	84%	84%

Population	Adoption
76,012	58.00%

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	
Subscribers		22,043	30,861	35,270	44,087	44,087	44,087	44,087	44,087	44,087	Achieving 58% penet
ARPU	$ 35.00	$ 35.00	$ 35.00	$ 35.00	$ 35.00	$ 35.00	$ 35.00	$ 35.00	$ 35.00	$ 35.00	
Cost of service		$ 2,120,636	$ 20,273,917	$ 23,849,445	$ 25,176,207	$ 27,351,192	$ 27,923,392	$ 30,166,385	$ 32,637,595	$ 35,025,117	
Subscribers		30,902	239,686	444,632	646,676	836,822	989,734	1,134,142	1,278,399	1,415,881	
		$ 68.62	$ 84.59	$ 53.64	$ 38.93	$ 32.68	$ 28.21	$ 26.60	$ 25.53	$ 24.74	$ 42.62
SG&A											
Staff cost		$ 179,400	$ 2,558,400	$ 3,432,000	$ 5,553,600	$ 5,647,200	$ 5,616,000	$ 5,678,400	$ 5,834,400	$ 5,928,000	
Market and distribution		$ 65,134	$ 3,075,502	$ 7,771,311	$ 12,364,196	$ 16,816,210	$ 20,875,818	$ 24,533,681	$ 28,094,219	$ 31,563,931	
Customer operations		$ 34,738	$ 1,230,201	$ 3,108,524	$ 4,945,678	$ 6,726,484	$ 8,350,327	$ 9,813,472	$ 11,237,688	$ 12,625,573	
G&A		$ 21,711	$ 768,875	$ 1,942,828	$ 3,091,049	$ 4,204,053	$ 5,218,955	$ 6,133,420	$ 7,023,555	$ 7,890,983	
Total		$ 300,983	$ 7,632,978	$ 16,254,662	$ 25,954,523	$ 33,393,947	$ 40,061,100	$ 46,158,973	$ 52,189,861	$ 58,008,487	
Total per sub		$ 9.74	$ 31.85	$ 36.56	$ 40.14	$ 39.91	$ 40.48	$ 40.70	$ 40.82	$ 40.97	$ 35.68