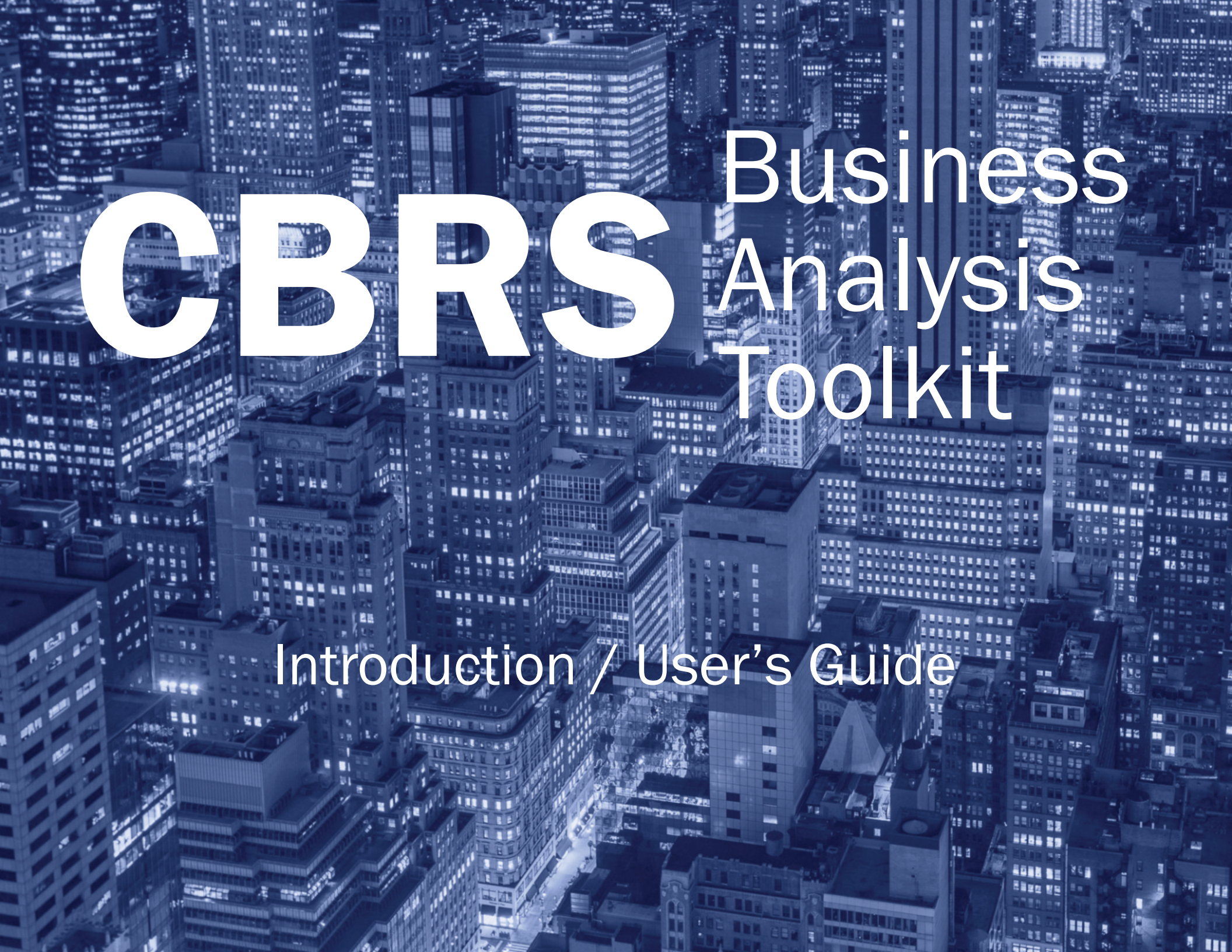

CBRS Business Analysis Toolkit

Introduction / User's Guide

SiGNALS
Analytics, LLC

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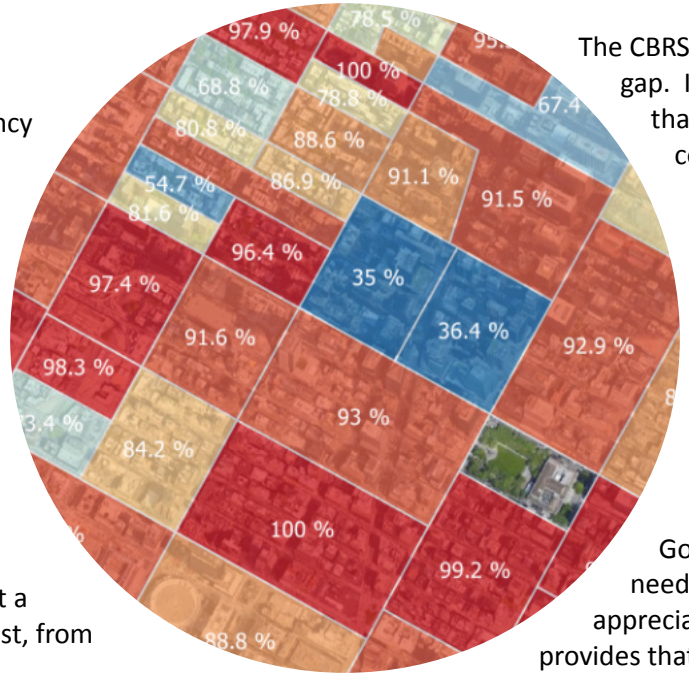
Introduction

CBRS spectrum (3550 - 3700 MHz) is available today to General Authorized Access (GAA) users. On July 23rd, 2020 the FCC will begin an auction of 22,631 priority access licenses (PALs). PAL licenses will be auctioned on a county basis, encouraging small entities (local governments, regional operators, and corporations with private network needs) to participate. A PAL license grants the holder priority access to 10 MHz of spectrum.

The 3.5 GHz frequency band sits between traditional mobile bands and higher frequency bands that have historically been used for wireless broadband access. The 3.5 GHz band is included in 3GPP LTE specifications for 5G (Band 48). The CBRS Alliance, an industry advocacy group, has launched a branded certification program (OnGo) resulting is a sizable ecosystem of ready-to-deploy equipment.



Building the Business Case

Anyone investing in CBRS or any other telecommunications infrastructure will want a robust business case. A number of tools exist, from various parties, that might help:

- An economist's perspective – from 40,000 feet – of the potential value of the CBRS band, including all possible applications.
- Equity analyst views of the associated product markets (network equipment and devices)
- Syndicated reports diving into the technology is great detail and into specific applications.
- "Blank" spreadsheet models that presume to offer a template for business planning.
- Training designed to communicate technology and regulatory frameworks and potentially important cost assumptions.

Many tools are general. Few enable the user to compare adjoining geographic areas, much less study one license area in detail.

The CBRS Business Analysis Toolkit seeks to fill that gap. It is a collection of robust geocoded data that enables the business analyst to study one county in detail or compare the universe of counties or CMAs. It includes a comprehensive suite of market sizing data and competitive data in both a visual and spreadsheet form.

The Toolkit is available in 55 different versions addressing the needs of those with various geographic interests and budgets.

Government entities seeking to identify local needs and/or encourage investment, will appreciate the wealth of information the toolkit provides that identifies unmet needs.

Decision-Oriented Information

The CBRS Business Analysis Toolkit includes the following categories of information:

Figure 1: Demographic and Economic Data, Multiple Resolutions

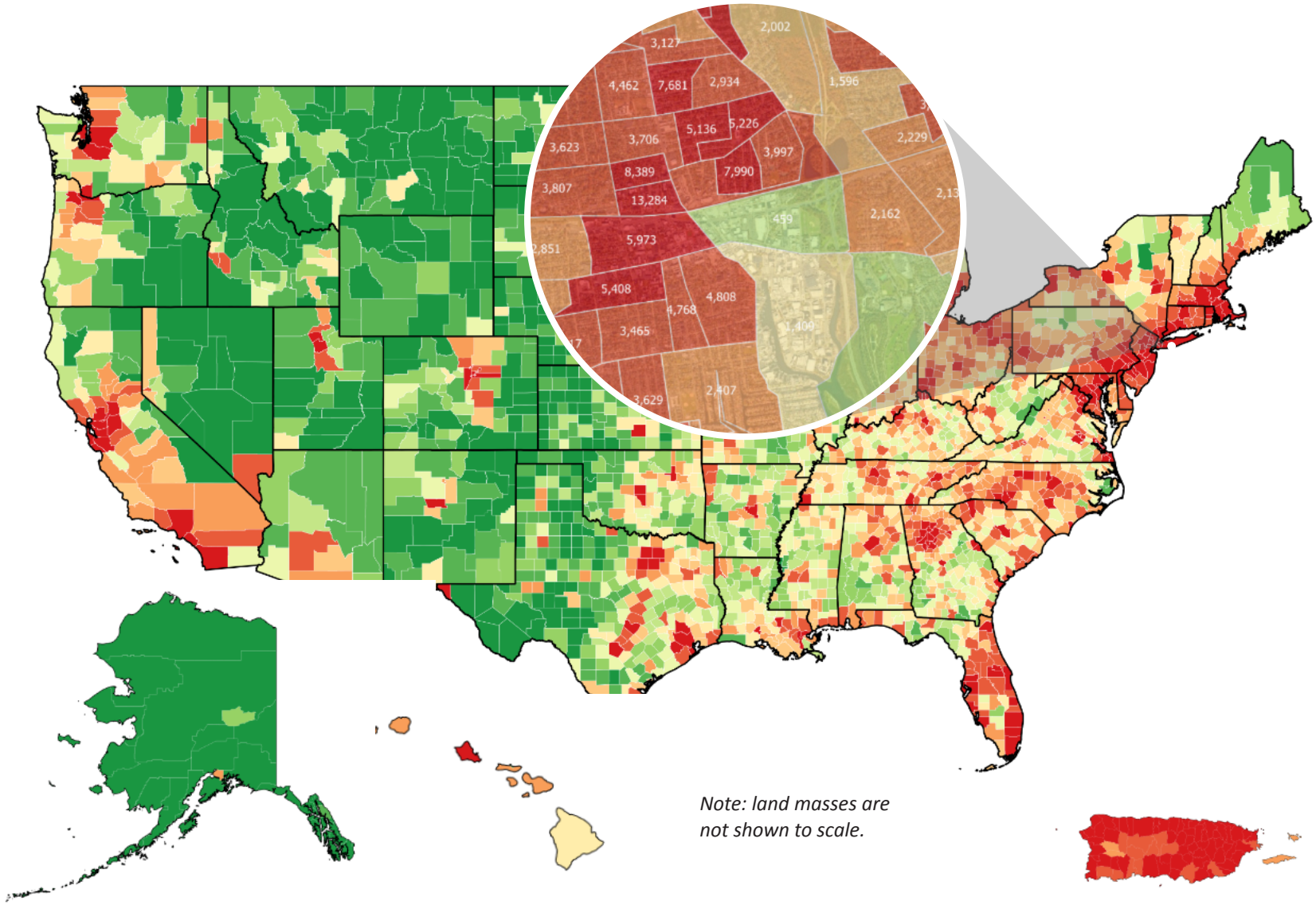


Figure 2: GIS Data in an Excel Spreadsheet

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Indexing Information (Data Locator Code below in Blue)														
Priority	State	Geography ID	Geography Name	State FIPs Code (2 digits)	Congressional District Code	County FIPs Code (5 digits)	Tract FIPs Code (11 digits)	Block Group FIPs Code (12 digits)	Zip Code Tabulation Area (ZCTA)	Population Density (POPs per sq km)	Household Density (HHs per sq km)	Income per Capita (Income per year per POP)	Income per Household (Income per year per HH)	Participation in SNAP (a.k.a. food stamps, % of HHs)
A	B	C	D	E	F	G	H	I	J	1	2	3	4	5
5	PA	15000US420792107002	Block Group 2, Census Tract 2107, Luzerne County, Pennsylvania	42		42079	42079210700	420792107002		1,121.6	489.5	$ 20,362	$ 44,033	37.1%
5	PA	15000US420792108001	Block Group 1, Census Tract 2108, Luzerne County, Pennsylvania	42		42079	42079210800	420792108001		2,485.2	1,266.3	$ 39,667	$ 77,533	13.3%
5	PA	15000US420792108002	Block Group 2, Census Tract 2108, Luzerne County, Pennsylvania	42		42079	42079210800	420792108002		2,767.7	1,254.5	$ 22,010	$ 46,768	20.9%
5	PA	15000US420792108003	Block Group 3, Census Tract 2108, Luzerne County, Pennsylvania	42		42079	42079210800	420792108003		3,204.6	1,258.3	$ 16,434	$ 39,674	42.6%
5	PA	15000US420792108004	Block Group 4, Census Tract 2108, Luzerne County, Pennsylvania	42		42079	42079210800	420792108004		2,529.1	1,081.3	$ 15,942	$ 36,492	35.8%
5	PA	15000US420792109001	Block Group 1, Census Tract 2109, Luzerne County, Pennsylvania	42		42079	42079210900	420792109001		3,149.8	1,281.9	$ 20,138	$ 47,553	22.6%
5	PA	15000US420792109002	Block Group 2, Census Tract 2109, Luzerne County, Pennsylvania	42		42079	42079210900	420792109002		2,458.5	905.4	$ 17,414	$ 45,579	43.1%
5	PA	15000US420792110001	Block Group 1, Census Tract 2110, Luzerne County, Pennsylvania	42		42079	42079211000	420792110001		1,809.8	984.0	$ 25,811	$ 46,874	36.1%
5	PA	15000US420792110002	Block Group 2, Census Tract 2110, Luzerne County, Pennsylvania	42		42079	42079211000	420792110002		2,618.2	956.1	$ 31,089	$ 84,260	20.3%
5	PA	15000US420792110003	Block Group 3, Census Tract 2110, Luzerne County, Pennsylvania	42		42079	42079211000	420792110003		5,113.8	2,046.6	$ 29,036	$ 72,911	24.7%
5	PA	15000US420792110004	Block Group 4, Census Tract 2110, Luzerne County, Pennsylvania	42		42079	42079211000	420792110004		1,229.1	432.7	$ 30,709	$ 85,811	20.7%
5	PA	15000US420792110005	Block Group 5, Census Tract 2110, Luzerne County, Pennsylvania	42		42079	42079211000	420792110005		2,574.3	1,275.5	$ 28,292	$ 55,267	17.9%
5	PA	15000US420792111011	Block Group 1, Census Tract 2111.01, Luzerne County, Pennsylvania	42		42079	42079211101	420792111011		931.2	386.4	$ 24,315	$ 58,198	14.2%
5	PA	15000US420792111012	Block Group 2, Census Tract 2111.01, Luzerne County, Pennsylvania	42		42079	42079211101	420792111012		2,461.9	1,098.7	$ 26,843	$ 59,010	3.5%
5	PA	15000US420792111013	Block Group 3, Census Tract 2111.01, Luzerne County, Pennsylvania	42		42079	42079211101	420792111013		603.8	304.9	$ 29,961	$ 59,249	0.0%
5	PA	15000US420792111014	Block Group 4, Census Tract 2111.01, Luzerne County, Pennsylvania	42		42079	42079211101	420792111014		1,234.1	409.0	$ 27,144	$ 78,625	20.2%
5	PA	15000US420792111015	Block Group 5, Census Tract 2111.01, Luzerne County, Pennsylvania	42		42079	42079211101	420792111015		118.8	45.2	$ 42,488	$ 105,926	11.8%
5	PA	15000US420792111021	Block Group 1, Census Tract 2111.02, Luzerne County, Pennsylvania	42		42079	42079211102	420792111021		79.6	29.5	$ 36,053	$ 95,497	3.6%
5	PA	15000US420792111022	Block Group 2, Census Tract 2111.02, Luzerne County, Pennsylvania	42		42079	42079211102	420792111022		49.3	21.4	$ 40,800	$ 93,143	1.8%
5	PA	15000US420792112011	Block Group 1, Census Tract 2112.01, Luzerne County, Pennsylvania	42		42079	42079211201	420792112011		673.6	285.3	$ 32,655	$ 75,861	6.5%
5	PA	15000US420792112012	Block Group 2, Census Tract 2112.01, Luzerne County, Pennsylvania	42		42079	42079211201	420792112012		837.4	391.1	$ 42,249	$ 88,896	0.9%
5	PA	15000US420792112013	Block Group 3, Census Tract 2112.01, Luzerne County, Pennsylvania	42		42079	42079211201	420792112013		305.2	113.2	$ 44,102	$ 118,196	0.9%
5	PA	15000US420792112031	Block Group 1, Census Tract 2112.03, Luzerne County, Pennsylvania	42		42079	42079211203	420792112031		53.2	21.0	$ 43,129	$ 108,629	8.2%
5	PA	15000US420792112041	Block Group 1, Census Tract 2112.04, Luzerne County, Pennsylvania	42		42079	42079211204	420792112041		447.2	182.3	$ 34,165	$ 84,178	7.9%
5	PA	15000US420792112042	Block Group 2, Census Tract 2112.04, Luzerne County, Pennsylvania	42		42079	42079211204	420792112042		344.5	113.8	$ 49,436	$ 147,420	3.4%
5	PA	15000US420792112043	Block Group 3, Census Tract 2112.04, Luzerne County, Pennsylvania	42		42079	42079211204	420792112043		697.6	199.7	$ 16,916	$ 45,746	0.0%
5	PA	15000US420792112044	Block Group 4, Census Tract 2112.04, Luzerne County, Pennsylvania	42		42079	42079211204	420792112044		95.5	34.8	$ 26,127	$ 70,453	7.9%
5	PA	15000US420792112045	Block Group 5, Census Tract 2112.04, Luzerne County, Pennsylvania	42		42079	42079211204	420792112045		704.8	261.6	$ 35,122	$ 92,862	4.8%
5	PA	15000US420792112051	Block Group 1, Census Tract 2112.05, Luzerne County, Pennsylvania	42		42079	42079211205	420792112051		51.3	19.5	$ 36,655	$ 94,477	9.8%
5	PA	15000US420792112052	Block Group 2, Census Tract 2112.05, Luzerne County, Pennsylvania	42		42079	42079211205	420792112052		665.2	272.4	$ 45,555	$ 106,023	6.0%
5	PA	15000US420792113011	Block Group 1, Census Tract 2113.01, Luzerne County, Pennsylvania	42		42079	42079211301	420792113011		119.8	46.2	$ 48,718	$ 124,860	3.7%
5	PA	15000US420792113012	Block Group 2, Census Tract 2113.01, Luzerne County, Pennsylvania	42		42079	42079211301	420792113012		146.1	10.1	$ 7,641	$ 95,389	6.5%
5	PA	15000US420792113021	Block Group 1, Census Tract 2113.02, Luzerne County, Pennsylvania	42		42079	42079211302	420792113021		84.9	33.0	$ 31,788	$ 81,228	5.9%
5	PA	15000US420792113022	Block Group 2, Census Tract 2113.02, Luzerne County, Pennsylvania	42		42079	42079211302	420792113022		42.7	16.1	$ 43,101	$ 113,092	11.9%
5	PA	15000US420792113023	Block Group 3, Census Tract 2113.02, Luzerne County, Pennsylvania	42		42079	42079211302	420792113023		91.3	39.5	$ 36,081	$ 82,395	2.5%
5	PA	15000US420792113031	Block Group 1, Census Tract 2113.03, Luzerne County, Pennsylvania	42		42079	42079211303	420792113031		180.0	83.9	$ 47,119	$ 100,453	2.0%
5	PA	15000US420792113032	Block Group 2, Census Tract 2113.03, Luzerne County, Pennsylvania	42		42079	42079211303	420792113032		235.7	112.0	$ 35,977	$ 73,232	8.1%
5	PA	15000US420792113041	Block Group 1, Census Tract 2113.04, Luzerne County, Pennsylvania	42		42079	42079211304	420792113041		25.1	8.6	$ 28,537	$ 80,330	11.5%
5	PA	15000US420792113042	Block Group 2, Census Tract 2113.04, Luzerne County, Pennsylvania	42		42079	42079211304	420792113042		54.3	18.4	$ 29,845	$ 88,320	14.5%
5	PA	15000US420792114001	Block Group 1, Census Tract 2114, Luzerne County, Pennsylvania	42		42079	42079211400	420792114001		343.9	134.8	$ 49,080	$ 123,399	0.0%
5	PA	15000US420792114002	Block Group 2, Census Tract 2114, Luzerne County, Pennsylvania	42		42079	42079211400	420792114002		347.5	137.2	$ 34,480	$ 85,479	11.4%
5	PA	15000US420792114003	Block Group 3, Census Tract 2114, Luzerne County, Pennsylvania	42		42079	42079211400	420792114003		493.7	209.4	$ 34,874	$ 81,968	12.0%
5	PA	15000US420792114004	Block Group 4, Census Tract 2114, Luzerne County, Pennsylvania	42		42079	42079211400	420792114004		230.6	96.8	$ 44,330	$ 106,621	11.8%
5	PA	15000US420792114005	Block Group 5, Census Tract 2114, Luzerne County, Pennsylvania	42		42079	42079211400	420792114005		1,247.1	553.5	$ 25,148	$ 55,270	12.8%
5	PA	15000US420792114006	Block Group 6, Census Tract 2114, Luzerne County, Pennsylvania	42		42079	42079211400	420792114006		67.9	24.2	$ 55,347	$ 153,121	2.8%
5	PA	15000US420792115001	Block Group 1, Census Tract 2115, Luzerne County, Pennsylvania	42		42079	42079211500	420792115001		1,240.7	447.5	$ 26,997	$ 72,618	23.1%
5	PA	15000US420792115002	Block Group 2, Census Tract 2115, Luzerne County, Pennsylvania	42		42079	42079211500	420792115002		109.9	49.4	$ 32,995	$ 71,557	7.6%
5	PA	15000US420792115003	Block Group 3, Census Tract 2115, Luzerne County, Pennsylvania	42		42079	42079211500	420792115003		610.0	268.8	$ 33,428	$ 75,704	4.8%
5	PA	15000US420792116001	Block Group 1, Census Tract 2116, Luzerne County, Pennsylvania	42		42079	42079211600	420792116001		2,204.2	1,169.1	$ 27,951	$ 51,567	12.8%
5	PA	15000US420792116002	Block Group 2, Census Tract 2116, Luzerne County, Pennsylvania	42		42079	42079211600	420792116002		1,503.8	719.0	$ 25,729	$ 53,557	31.6%
5	PA	15000US420792116003	Block Group 3, Census Tract 2116, Luzerne County, Pennsylvania	42		42079	42079211600	420792116003		494.2	222.9	$ 30,361	$ 66,328	9.3%
5	PA	15000US420792117011	Block Group 1, Census Tract 2117.01, Luzerne County, Pennsylvania	42		42079	42079211701	420792117011		31.1	12.7	$ 33,320	$ 81,035	11.1%

- *Demographics*. Population and household densities. These provide precise indications of where people / customers live. Most telecommunications providers derive a large percentage of their customers from a small percentage of their coverage area. At the same time, they are likely to face fewer competitors in less dense areas. Finally, there is a population density / household density threshold at which they can no longer profitably conduct business. It is important to understand each of these dividing lines.

- *Income / Income Distribution*. Income per capita, mean and median household income, and GINI index calculations (visualizing income inequality). Pricing and price sensitivity is a critical input in sizing a market. It is important to understand not only mean household income, but also median household income (representing affordability to the masses) in defining coverage areas and product mixes. Low broadband penetration is often a function of affordability, not a lack of technology.

- *Indications of Need*. Households participating in SNAP (a.k.a. food stamps), households participating in SSI (supplemental security income), households receiving public assistance (a.k.a. welfare), and the portion of the population determined to be living in poverty. These indicators are collectively important because they identify populations in need. They also qualify households to participate in federally subsidized Lifeline services. Providing Lifeline services is an attractive opportunity for telecommunications providers. Local governments will almost certain want areas with high Lifeline eligibility and low telecommunications adoption to be covered with high quality affordable telecommunications offerings.

- *Opportunity Zones*. Opportunity Zones were created by the 2017 Tax Cuts and Jobs Act to spur economic development and job creation in distressed communities. Opportunity zones have been designated in all 50 states and in every inhabited US territory (American Samoa, Guam, Northern Mariana Island, Puerto Rico, and the US Virgin Islands). Investors benefit from deferral or exclusion of capital gains. The community benefits from financial investment. They are designed to encourage investment in areas with high socioeconomic needs. The statute excludes specific luxury investments (e.g. golf courses) and specific “sin industries”, but is otherwise applicable to any business.

  The Toolkit visualizes Opportunity Zones either as bright green polygons (if one wishes to find them on a map) or as clear tiles in an ocean of whited out space. Understanding the location of Opportunity Zones relative to other measurable metrics – particularly indications of need – is extremely powerful. It enables a business to deploy capital in locations that are likely to have a favorable social impact while offering investors unique tax incentives. Local governments (urban and rural) may wish to encourage outside investment based on the juxtaposition of Opportunity Zones with important needs identified by other layers of data.

- *Business / Employee / Payroll Density*. Detailed data on the number of businesses, the number of employees and payroll density are critical inputs in selling to business and in locating retail operations. Payroll density and household income density are two complementary views. The first shows

Figure 3: County vs. Zip Code (ZCTA), Northeastern United States

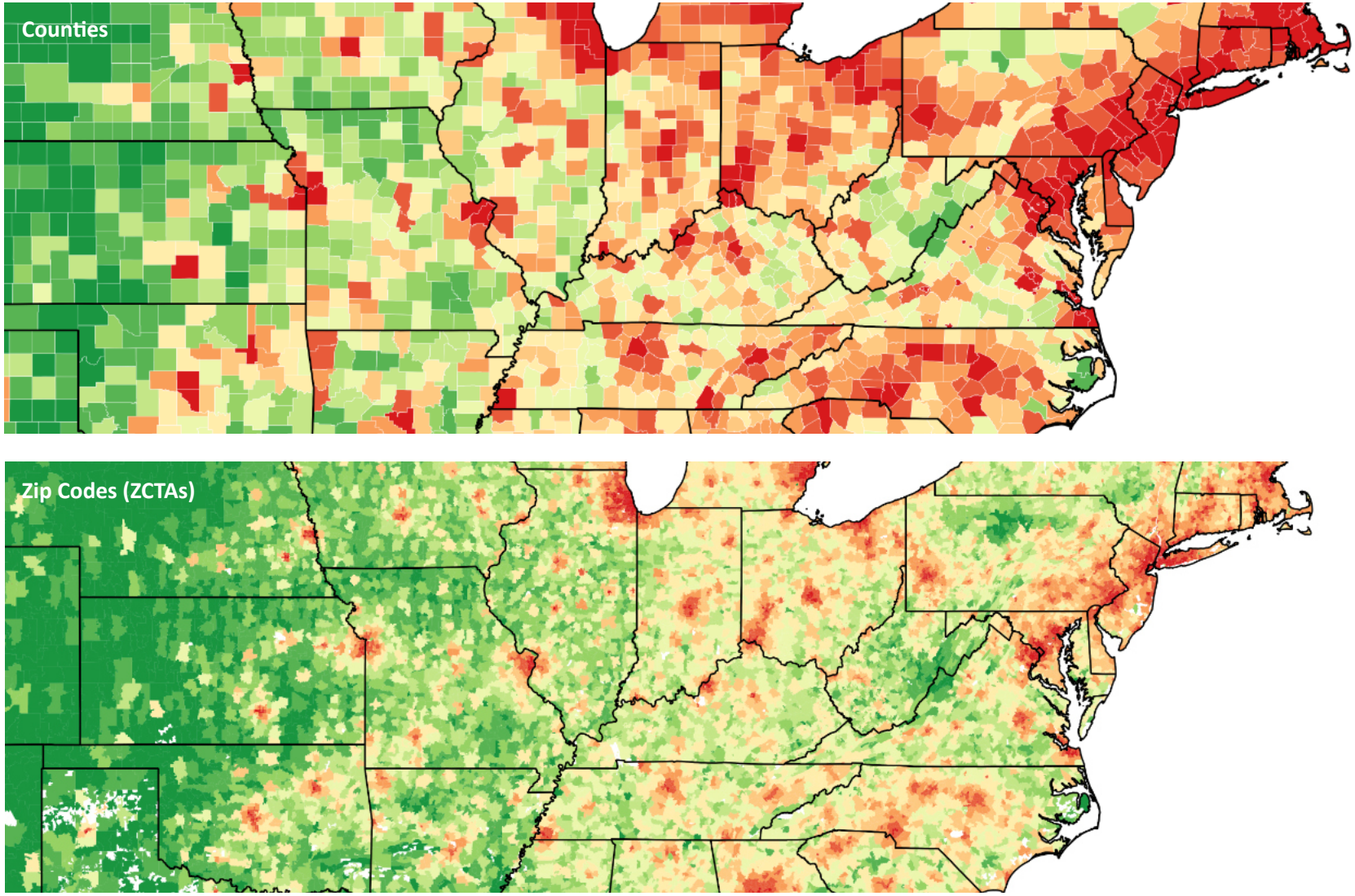


Figure 4: Zip Code (ZCTA) vs. Tract, Washington DC

Figure 5: Tract vs. Block Group, Washington DC

geographically where income is earned. The second shows where those earning income live. Ideally, an operator will want to have a presence in each set of locations. Business-oriented offerings will be directly driven by the presence of businesses and their size.

- *Housing Market*. The occupancy rate of all available housing units (single family homes, duplexes, multi-tenant dwellings, mobile homes, trailers, etc.), the percentage of households that rent, the percentage of households that own, the number of units in buildings with 2+, 10+, and 25+ units, and the percentage of units built in the 21st century. Occupancy rates are a critical input in estimating demand. Owning vs. renting has implications for how some services are sold. Buildings with a large number of units are attractive to telecommunications providers who connect wirelessly (e.g. with multi-gigabit millimeter wave) or with fiber. The age of a building is important because it provides a strong hint as to whether modern Cat5e wiring is likely to exist or whether legacy wiring exists, in which case G.Fast or another "last 100 meter" access technology is needed.

- *Behavior – Devices*. What types of computing devices (desktops / laptops, smart phones) do members of the household own? Someone who does not own a computing device is unlikely to pay for broadband connectivity.

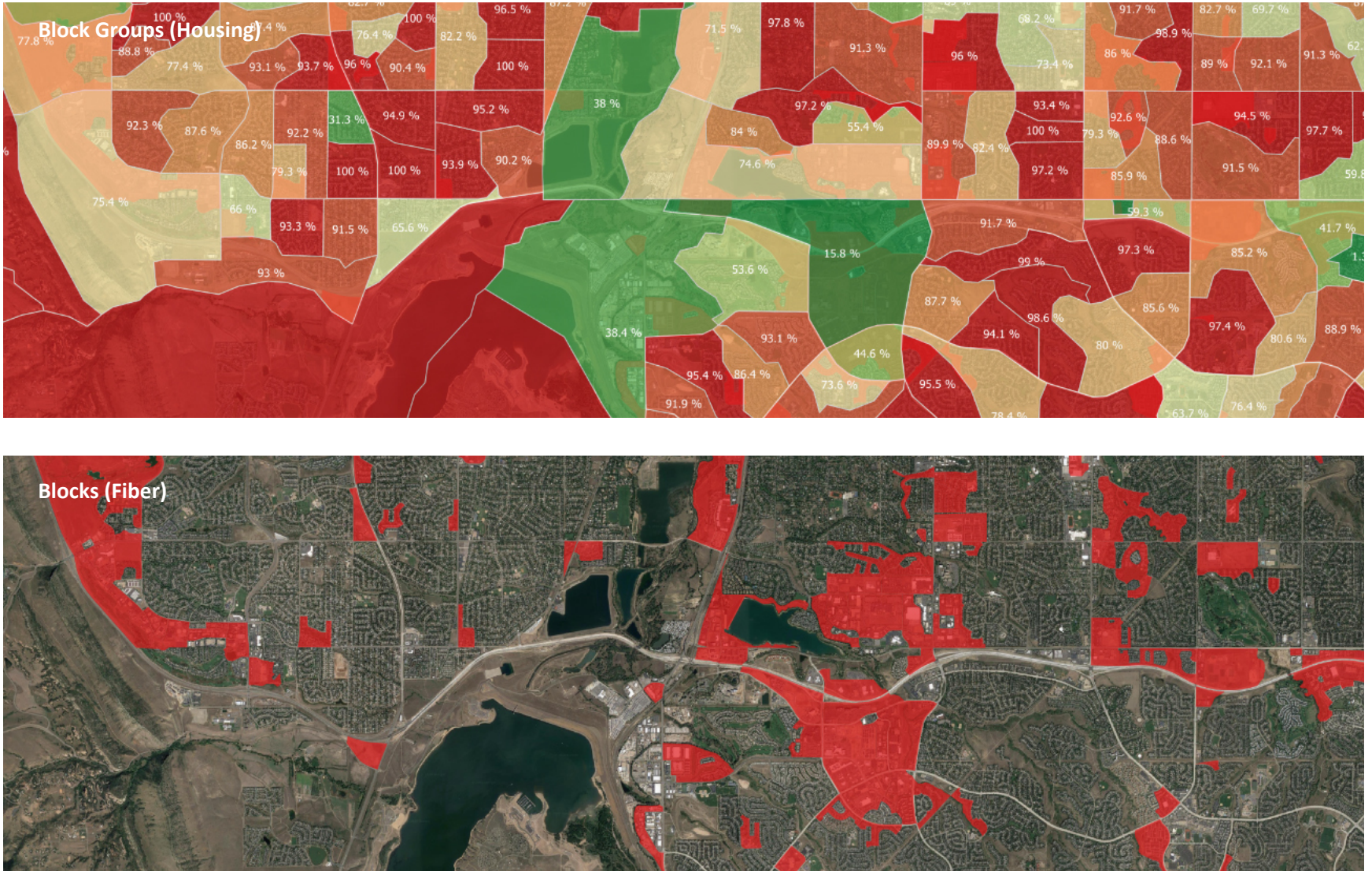
- *Behavior – Broadband Connectivity*. Does the household enjoy broadband connectivity via fiber / cable / DSL? Does the family have satellite broadband? How about mobile broadband from a cellular operator? Does the household have internet connectivity at all? This behavioral view is an important complement to the infrastructure-oriented view below showing reported service availability. High satellite service adoption is an indication that an area has disposable income but is underserved by traditional wired infrastructure. It arguably tests operator assertions that they serve an area with fiber or hybrid-fiber-coax, as an example.

- *Incumbent Access Users*. The value of any particular CBRS priority access license (PAL) may be influenced by nearby incumbent access users. The Toolkit includes a recent geolocated list of earth stations and grandfathered 3,650 links, categorized by their license expiration dates. The Toolkit also includes a list of Navy installations, where the use of naval radar (a primary user of the band) is particularly likely.

  Earth stations and 3,650 MHz links are identified by their call signs. A WISP or other user that has an expired 3,650 Part 90 license may have converted it to Part 96 operation and may be using nearby spectrum in the CBRS band today under GAA rules. That party may plan to bid for a PAL license. Knowing that a link previously existed in a location provides insight to others who might wish to participate in the auction. It indicates that there are other likely users in the license area and provides technical information (location, antenna gain, direction) about the previous application.

  Finally, some of the expiration dates may change. Individual license holders have petitioned the FCC for extensions, asking for additional time to transition. The FCC has granted a broad extension for licenses originally due to expire on April 17th. Those licensees, who would otherwise needed to transition during the peak of the Covid-19 crisis will have until October 17th, 2020 to transition (link). The situation is therefore fluid.

Figure 6: Block Group (Housing Occupancy) vs. Block (Fiber Coverage), Denver and Surrounding Suburbs



- *Fixed Coverage* (fiber, cable, DSL, wireless)*. This layer of data reports available fixed infrastructure (fiber, cable, DSL, wireless, satellite) and performance (Mbps) on a very granular (block level) basis. It is essential information for anyone planning to deploy new infrastructure.

- *Mobile Coverage* (national and regional mobile operators)*. This layer of data reports available mobile infrastructure (specifically LTE) on a very granular (block level) basis. With the advent of 5G, mobile operators will increasingly compete with fixed operators.

- *Rural Subsidy Programs (geographic coverage of each)*. The federal government has put in place a number of programs to subsidize the deployment of rural infrastructure, both fixed and mobile. This layer of data describes two of the most important programs. It is important to recognize that federal subsidies and reverse auctions paint a picture of future infrastructure deployments. If someone has just been awarded a federal contract to provide subsidized service in an area then anyone planning to serve that area needs to know that these subsidy arrangements exist. Even though no infrastructure may be present today, it will be deployed in the near future. The terms of the award normally indicate the minimum service specifications.

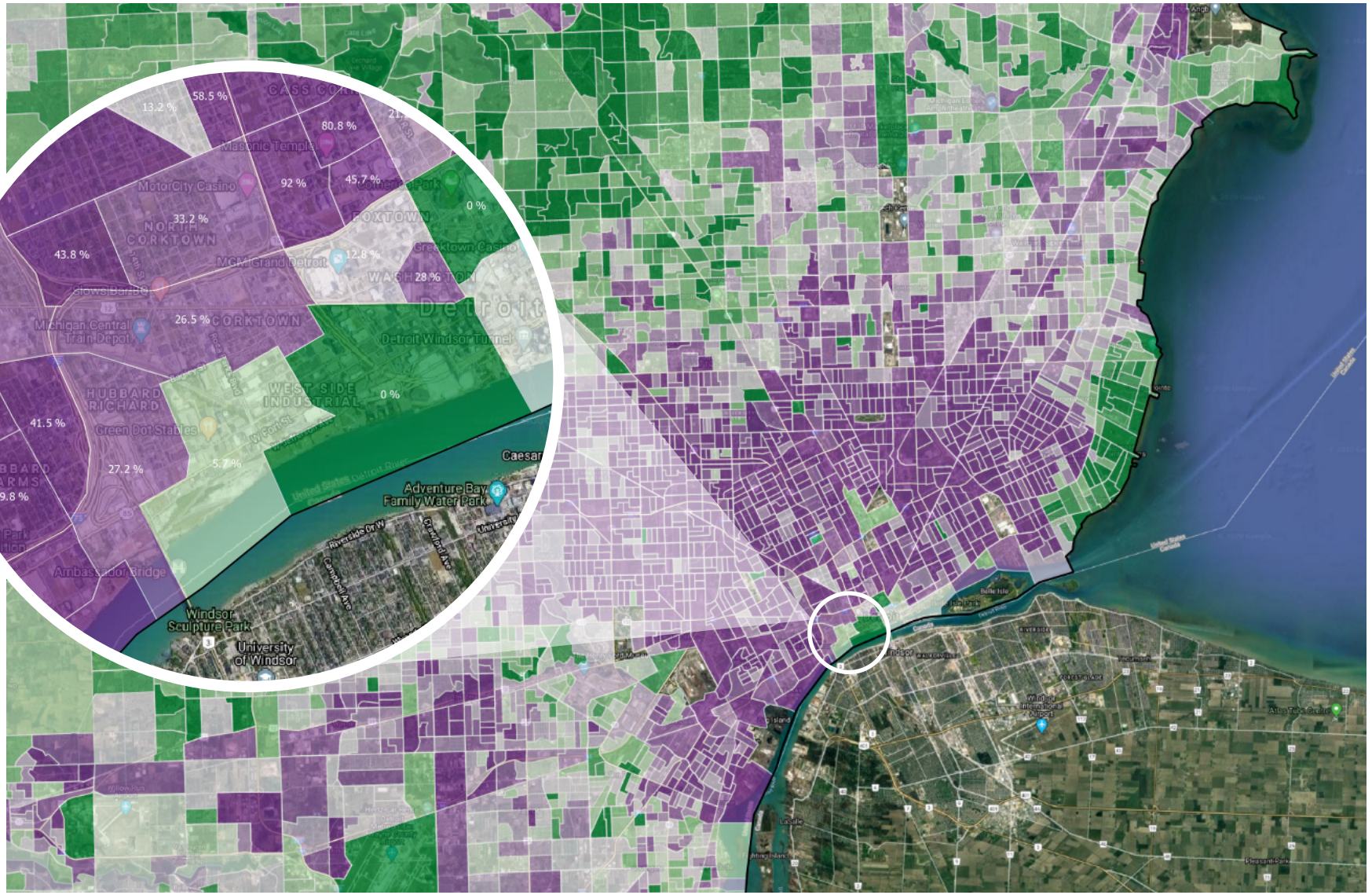
    - Fixed Rural (CAF II). The Connect America Fund, II is a program that awarded 103 bidders $1.49 Billion in subsidies over a ten-year period of time. This data layer shows the speed, latency, and awarded / unawarded status of each auctioned block.

    - Mobile Rural (MF II)*. The Mobility Fund Phase II is an auction that has yet to occur. The FCC has provided a set of eligible areas in each state. This data layer visualizes those eligible areas, along with single provider areas, which have mobile coverage from only one provider. The eligible areas have been identified as a result of a crowd sourced challenge-response process. Some are identified as "covered" on official mobile operator FCC submissions. The diversity of data sets is beneficial to existing operators, future operators, municipalities, and other stakeholders in objectively determining what coverage is available.

- References
    - *Streaming Maps*. The toolkit comes with several layers of streaming maps. These include: Google Satellite, Google Hybrid, Google Road, Bing Aerial, Bing Maps, and OpenStreet Map. In each case content is provided by a third party. The availability of any particular streaming service may change, or its terms of use may change. These links are provided on an "as is" basis to users. Maps with recognizable geographic features provide valuable context . Each map is tiled, which means that its resolution automatically adjusts as the user zooms in or zooms out. For streaming maps to work the user does need an internet connection.

    - *Solid Backgrounds*. In some instances it is easier to see content by replacing the streaming map with a solid background. The Toolkit has built-in white, gray, and black backgrounds. If a solid background is enabled it hides the map.

Figure 7: SNAP (a.k.a. food stamps) household participation rates, Block Group level, Detroit and Suburbs



- Geographic boundary overlays.
- License area overlays.

Some data sets (*) are only included in state-level products, because of the high resolution and large size of the underlying data.

Visualizing Geocoded Data

The Visual Toolkit includes a number of important features:

- *Scrollable / pannable user interface*. A user can easily zoom in for a closer view or zoom out for a more distant view using the mouse's wheel. Similarly, a user can grab the image and drag it in any direction. One can start in Florida, zoom out then fly to Hawaii or Alaska (with the national tool) then zoom in again for a detailed view. As the user manipulates the screen all of the underlying data scrolls and pans accordingly.

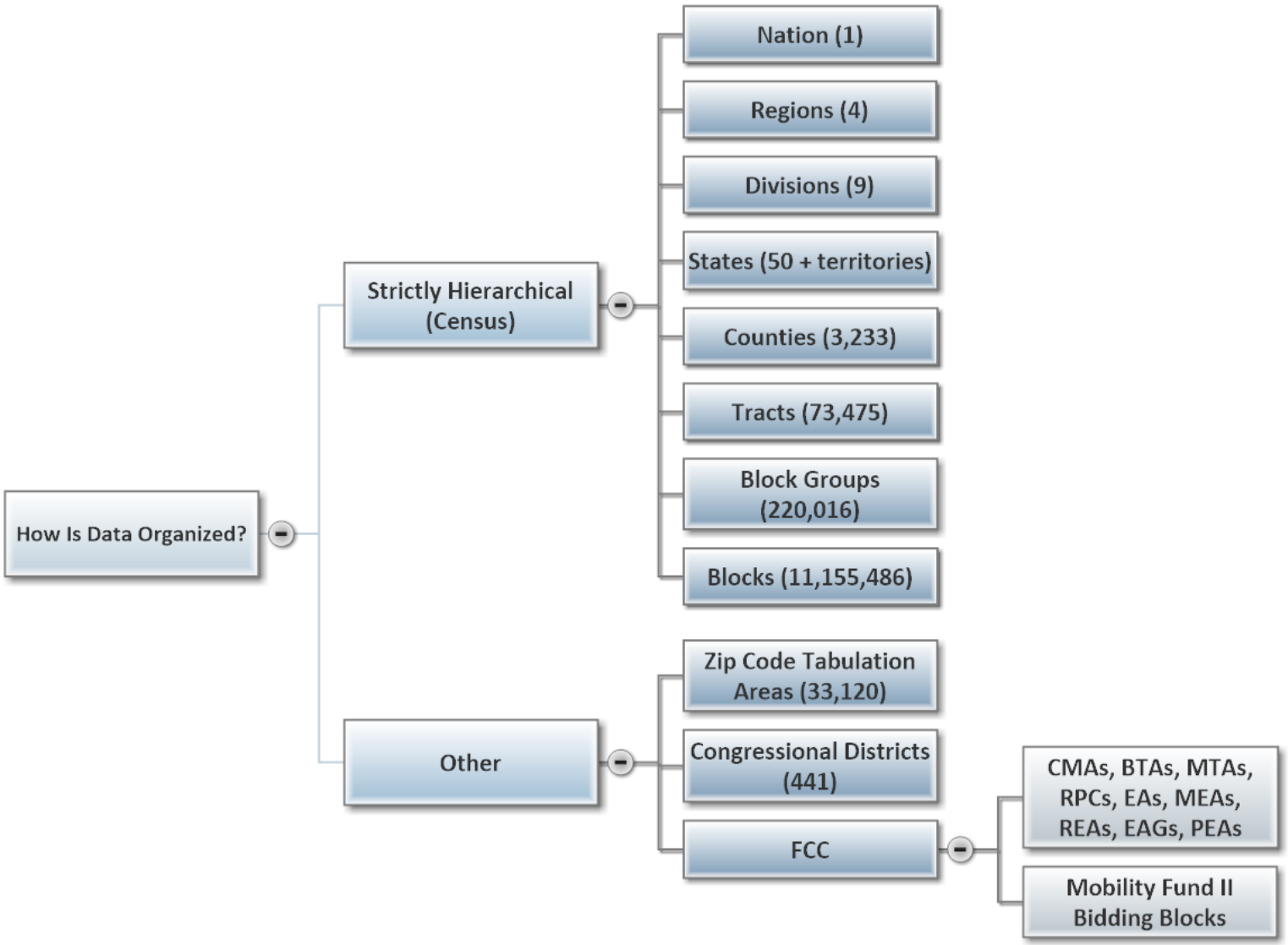
- *Many layers*. The visual toolkit includes, depending upon the version, dozens of layers of data that can be individually toggled on or off. The Visual Toolkit is designed to show one graphical layer at a time. Each layer is translucent, so that the underlying map is visible.

- *Meaningful colors*. Numerical data is displayed using a range of colors. In most cases the scale runs from green (low values) to red (high values). Indications of need (SNAP, SSI, public assistance, and poverty) and some abstract measures (GINI) run from green (low values) to purple (high values). Behavioral metrics (device ownership and broadband adoption) run from blue (low values to red (high values). The color scheme provides a hint as to the type of data. In each case there are ten color thresholds that represent quantiles (an equal number of data points). There is no absolute meaning to "red" or "green" across data elements, since the color scheme changes with each data element to reflect the underlying range of the data. The colors are designed to provide a visual cue to help the user see patterns and identify outlying values within any particular data set. Each data set has a legend that the user can see by clicking the "expand" triangular icon next to the "Visual" label for the data set. The legend displays the exact range of values associated with each color.

- *Numerical overlays*. Most of the data sets (all of demographic and economic data) display not only colors, but also numbers. The exception to this is high resolution coverage data where an area is either covered or not and performance data where each performance threshold (e.g. 1000 Mbps, 500 Mbps, etc.) is represented by a color that can be enabled or not. With demographic and economic data it is desirable to turn on the numerical overlay to see the exact value of each underlying region, especially when zoomed in to a small geographic area. If the user zooms out it is generally desirable to turn off the numerical display and enjoy a rich mosaic of color. If numerical text continues to be displayed when zoomed out the text associated with adjacent regions starts to overlap and quickly becomes unreadable.

- *Multiple levels of resolution*. The most comprehensive national products ship with data at multiple resolutions, each of which can be visualized. One might view the nation at a county level then zoom in to a tract or block group level.

Figure 8: Hierarchy of Geographic Boundaries



Each level of detail includes a comprehensive set of polygons and an associated set of displayed values (the numerical overlays) and an associated set of spreadsheet data (more on that later).

- *Geographic Boundaries*. The Visual Toolkit includes a long list of boundaries that can be turned on or off. These include state lines, county lines, congressional districts, zip code (ZCTA) boundaries, census tracts, census block groups, and census blocks.

- *License Areas*. The FCC has licensed spectrum over the years using different geographic boundaries. Many users of the Toolkit may already own mobile spectrum. It is important to think about the business case for new spectrum in the context of one's existing inventory of spectrum. The toolkit therefore includes boundaries for the most widely use license areas. These include: Cellular Market Areas (CMAs), Basic Trading Areas (BTAs), Major Trading Areas (MTAs), Regional PCS Areas (RPCs), Economic Areas (EAs or BEAs), Major Economic Areas (MEAs), Regional Economic Areas (REAs), Economic Areas Groupings (EAGs), and Partial Economic Areas (PEAs).

- *Boundary names and other data*. In most cases the name of the boundary (e.g. the state or county) can be displayed. Alternatively a code may be displayed. The Census Bureau has a hierarchical numbering scheme called FIPS that begins at the state level (2 digits) then goes to the county level (2+3 = 5 digits) then to the tract level (2 + 3 + 6 = 11 digits) then to the block group level (2 + 3 + 6 + 1 = 12 digits) then to the block level (2+ 3+ 6 +1 +3 = 15 digits). If a user wishes to pull up spreadsheet data that corresponds to a visualize image it is helpful to turn on the numerical display for FIPS, take a screen shot, then look for the corresponding data set of spreadsheet data. Since everything is hierarchical one can select a county (the first 5 digits of the FIPS) by selecting all the block group data with the desired county code in the first 5 digits, as an example.

- *Roads*. The national versions of the Toolkit include primary roads, with or without name labels. The state-level versions include both primary and second roads. Road layers may be turned on or off. Alternatively, one might choose an underlying map that includes road and place labels. Google, Bing, and OpenStreets, in the Maps folder, each include this option.

Graphical Versus Tabular Data

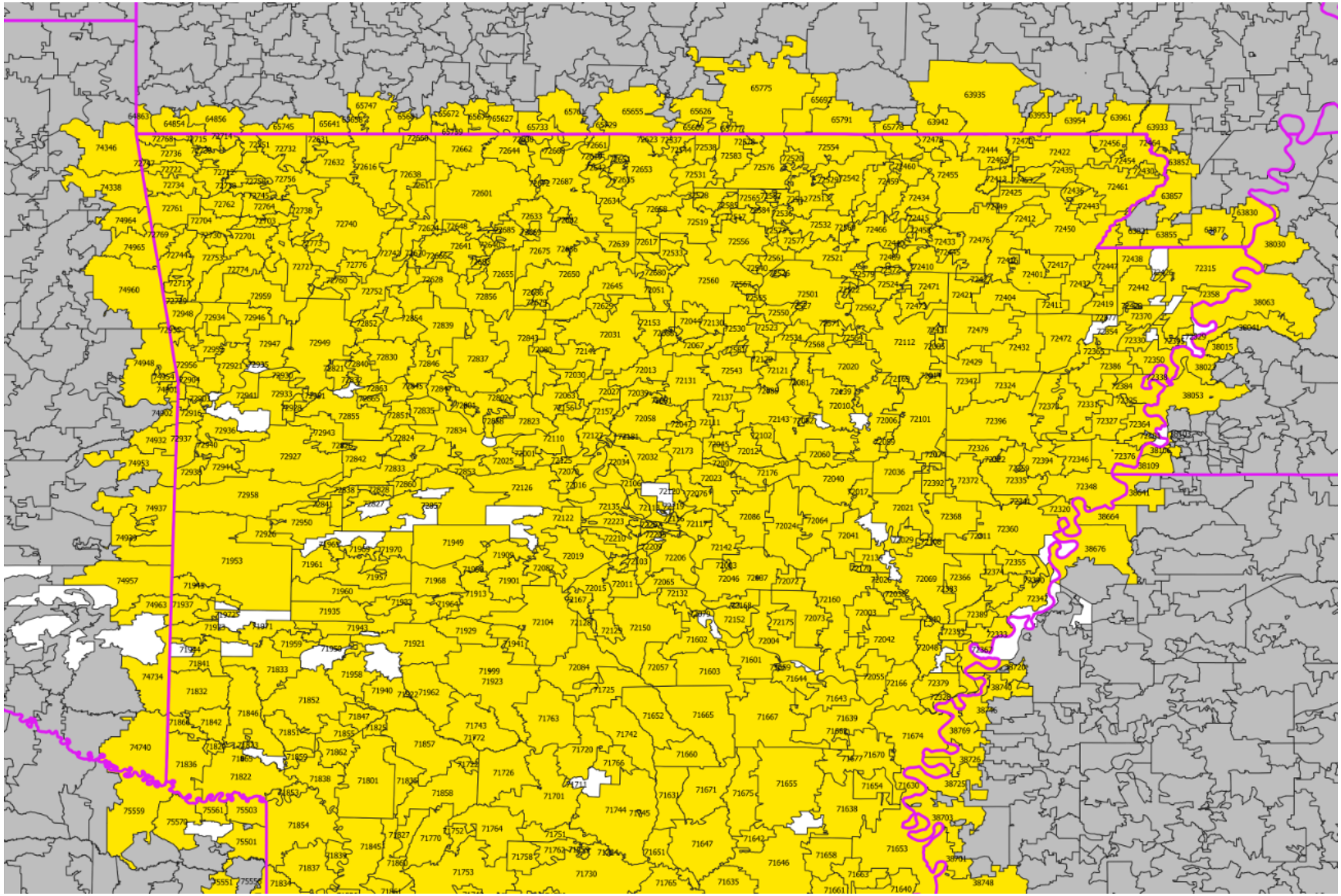
To build a business case one needs real data, not just a pretty picture. The Toolkit includes a comprehensive set of geocoded spreadsheet data that matches the demographic and economic data sets in the visual tool. Each data set includes:

- *Numerical Code*. A numerical identifier for the region (typically a FIPS code)

- *Name of Region*. The name of the region (e.g. a state or county or Congressional district or a region of the United States)

- *Numerical Data for KPIs*. Each of the KPIs visualized in the Visual Toolkit (typically represented as real numbers, with appropriate formatting)

Figure 9: Zip Code Tabulation Area (ZCTA) Boundaries vs. State Boundaries



- *Raw "Counter" Data*. Component elements, typically as counters. For instance, to calculate "Occupancy rate" one would divide the number of households (which by definition include people) in an area by the number of housing units. Counters are flexible in that they enable a user to add up a collection of unrelated geographic areas then do a simple calculation (e.g. dividing two sums) to arrive at an accurate result for a particular KPI for a newly defined area (e.g. the geographic area that the user wishes to cover with a new network). Counters underlie most of the visual data.

- *Population Estimates / Forecast.* In addition, the Toolkit includes separate population estimates / forecasts for every county in the 50 United States plus for the District of Columbia and Puerto Rico, based on the most recent yearly data from the Census Bureau. Recent county-level growth rates are used to produce near-term forecasts through the date of the auction (July 1, 2020). The populations of other island territories with 2010 census data (American Samoa, Guam, Northern Mariana Islands,, and the US Virgin Islands) are similarly estimated/forecast through July 1, 2020, using data from the Census Bureau's International Database, with slightly less resolution. These separate estimates / forecasts are helpful in anticipating how economic, demographic, and behavioral metrics translate into absolute numbers that would drive a business case. Finally, they are helpful in providing a comparative view of license areas that is more current than the 2010 census data included in a lot of the auction documentation.

Optimizing Performance

Geographical Information Systems, such as the QGIS browser, are data crunching machines and miraculous pieces of software in that they seek to visualize overwhelmingly large amount of data elegantly. The Visual Toolkit, as an application, has been highly optimized for performance, using as few computer resources as possible to achieve its objectives. Even so, it is helpful for every user to be aware of factors that impact performance:

- *Computer Hardware*. Every GIS application demands significant hardware resources. Ideally, one would run the Toolkit on a computer with a 64-bit operating system, lots of RAM, reasonable processing power, and fast disk access (ideally SSD). The current version of QGIS and the current highly optimized version of the Toolkit will both run with modest resources.

- *Light Versions of the Visual Toolkit*. State-level versions that include high resolution coverage data, especially for large states, are likely to be the most resource intensive. In each case one or more "light" version of the Visual Toolkit is included. It will load quickly without the bulkiest state-level data sets, but will be suitable for the vast majority of analyses. These "light" options are described in the Getting Started Guide that ships with every Toolkit.

- *Application Loading Time*. Expect any GIS application to take a few minutes to load. Think of it as an opportunity to get a fresh cup of coffee. During the load process it connects to all of the linked data sets and prepares to load the associated data on demand. It doesn't work like Microsoft Word, where one clicks on a document and, an instant later, the document

appears. Once loaded, though, the application is designed to be responsive, with a few caveats.

- *First Time Loading a Layer*. The first time a user loads a layer (e.g. mean household income) after launching the application in QGIS the application may pause for a few seconds as it finds the desired data. Afterwards, one can select and deselect that data layer and expect the text and graphics to appear and disappear almost instantaneously, because it has been cached by the application. One can then generally zoom in and out and pan without any visible delay.

- *Streaming Maps*. In theory, streaming maps can cause the user interface to be slow because map data must be retrieved from a remote server. In practice, with the current version of QGIS and with a fast internet connection, the delay is negligible. Do be careful not to enable multiple maps at the same time. Doing so will multiply the volume of data that must be downloaded. Also, the user will see only one map at a time, so most of the effort will be wasted. If the user is in an airplane or has a slow internet connection or no connection at all then the user should disable the map by unchecking the map layer. If one is unsure about the impact of the map it is easy to disable it and to enable, instead, a solid color background (gray, black, white) to see if the application becomes visibly more responsive. Dark solid backgrounds, while not as pretty as a map, are wonderful for reading detailed overlaid data.

- *Text Overlays*. A text overlay can sometime slow the display. This is generally the case when text is enabled with a high resolution data set and the user is zoomed out. Imagine, for instance, looking at the continental United States, viewing data at the block group level, with text enabled. QGIS would attempt to write 200,000 numerical values on the screen, one number for each polygon visualized. The user interface would be slow and the resulting image would be a mess. It is best to turn off text overlays before you zoom out then decide what text is appropriate at the new zoom level. Up close, one might be interested in block group FIPS codes, but zoomed out one might be interested in state boundaries and state names, as an example. High resolution boundaries (e.g. block group boundaries) when zoomed out can also slow the user interface and flood the resulting image with a single color of ink (reflecting the color of the boundaries). The implications of most of these decisions will become obvious the first time one uses the application.

Video Tutorials

In the near future the Toolkit will have a collection of video tutorials to help new users get started, understand the included functionality, enable and disable options, and effectively use the visual toolkit and the spreadsheet data to assess geographic markets.

Data Sources

The Toolkit derives its data from a small number of high quality government sources. The US Census Bureau is best known for its decennial census, conducted in fulfillment of Article 1, Section 2 of the US Constitution. The Census Bureau also conducts 120 other surveys, often in collaboration with other agencies. The FCC requires fixed and mobile operators to report geographic coverage by technology along with other metrics. Furthermore, the FCC engages

the public in crowd sourced data collection and challenge-response initiatives. Finally, the federal government has used reverse auctions to allocate rural broadband subsidies to areas with acute need. The pubic has visibility, based on the auction results, into the future service commitments of the winning bidders.

The Toolkit leverages several important sources. In general, these are the latest available sources as of May 1, 2020:

- US Census Bureau, American Community Survey. The ACS surveys 3.5 million households + 185,000 persons in group quarters per year on subjects ranging from household income to demographics to physical space and amenities to devices and connectivity to monthly household expenditures. These are converted into single-year and 5-year estimates and other data products. The Toolkit uses the 2018 5-year estimates, which were published on December 19th, 2019.

- US Census Bureau, Population and Housing Estimates (PEP), The International Data Base, County Business Patterns, and a wide rage of geographic boundary products and definitions. Extremely important are well-documented processes, which give the numerical data important context and meaning.

- The Federal Communications Commission. The FCC surveys fixed and mobile operators to understand their geographic coverage by technology, as well as other service KPIs, via Form 477. These data sets are visualized in the state versions of the Toolkit. The FCC also provides databases of incumbent access users in the 3,650 MHz band. Finally, the FCC initiates inquiries that ultimately result in rule-makings that provide a framework for each category of users within a band.

- The Universal Service Administrative Company (USAC) and the FCC provide a framework for Lifeline subsidies, forward-looking data on planned auctions (e.g. the Mobility Fund Phase II) and historical data on past auctions (e.g. the Connect America Fund II). When a reverse auction finishes the winning bidders have committed to a specific set of service obligations. The Connect America Fund Phase II results are included in both the state and national versions of the Toolkit. The Mobility Fund Phase II specifications are included in the state versions of the Toolkit.

- The US Department of the Treasury and the Internal Revenue Service articulate the rules defining Opportunity Zones and provide a set of geocoded data identifying designated areas in each US state, district, and populated territory.

- The Department of Defense publishes a comprehensive list of all US military installations, ranges, and training areas. The DoD database further identifies facilities associated with the US Navy.

One might ask “If the analytics are derived from public data, can I simply download the data myself from the original government sources?” The answer is yes, with a few caveats. Government agencies are exceptional at assembling high quality data. However, they do not necessarily release it in a format that is prepackaged for the needs of the average user.

Developing the Toolkit involved:

- Identifying the most relevant and timely data sources, out of 100+ candidate sources
- Downloading, decompressing, and extracting the relevant data (many tens of GBs)
- Identifying and interacting with subject matter experts to

understand the data, especially key definitions.
- Identifying anomalies in the data and developing methodologies to deal with these exceptions
- Developing KPIs to visually represent the data
- Joining data sets with different field types
- Optimizing databases for size and performance
- Optimizing the Visual Toolkit to cache data effectively so that the visual tool will run in a minimal memory footprint.

A broadly skilled team with several months of free time could probably replicate the effort. Our hope is that many prospective users will appreciate the value of a ready-to-use tool.

Case Study: CBRS Auction Participants

A CBRS bidder seeking to construct a regional or national footprint must consider the comparative value of various county-level licenses:

- *Population Estimates.* First, adjust the 2010 population numbers provided by the FCC to reflect 2020 numbers. This is particularly important in markets that have grown or shrunk significantly in the past decade. National versions of the Toolkit include a county-level forecast based on the latest vintage of Census population estimates.

- *Urban vs. Rural Differences*. Spectrum differs widely in value ($ per POP per MHz) depending upon whether a market is urban or rural. Here are some factors to consider:

    - *Network Cost of Deployment*. Most wide-area networks (whether mobile or fixed) have cost curves that are fairly flat relative to population density in urban and suburban areas then deteriorate rapidly as population density decreases. If a bidder knows the cost curve for his intended application he can easily filter the data for each market to exclude demonstrably unprofitable areas.

    - *Competition*. The number of competitors varies widely by location, especially as one moves from an urban to a rural area. Rural areas have few competitors. The likely increase in network cost will be offset – to some extent – by an increase in market share and reduced price competition. The Toolkit characterizes the competitive environment using a range of coverage and performance metrics.

- *Income Effects*. A key factor limiting broadband adoption is income. There are urban neighborhoods with deployed fiber but poor broadband adoption due to limited household income. The Toolkit includes a rich set of income metrics (per capita, mean household, median household, GINI, etc.) as well as broadband adoption metrics.

- *No-Bid / Joint-Bid Options*. One may conclude that the demand for CBRS spectrum will be so low in some markets that there is no point in bidding, because GAA users will have everything they need. Alternatively, some markets are likely to be pricey, squeezing out many interested parties.

Case Study: Mobile Operators

Mobile operators are likely to be influential bidders in the auction. They will be highly motivated to purchase spectrum at an attractive price. Mobile data demand continues to grow at an impressive compound annual rate. Operators need to invest in spectrum and/or network densification to continue to meet demand. The concerns of

the operator are therefore the concerns of any auction participant, qualified by an understanding of the operator's existing footprint and incremental spectrum needs.

The Toolkit also displays most historical FCC license boundaries, enabling the user to asses existing spectrum holdings.

A mobile operator may be interested in CBRS for several different applications:

- Incremental macro cellular network capacity
- Incremental outdoor small cell capacity
- Public venue small cell coverage and capacity
- Indoor small cell capacity and coverage (leveraging GAA spectrum)

Anticipating sources of traffic in any frequency band:

- In second tier cities and small towns a single macro cellular site might cover a significant area.
- In such a scenario high resolution population and business data might provide insight into the location of consumer and business demand.
- The vast majority of data traffic (80% to 85%) originates indoors. If an operator knows where people live and where they work then a lot of traffic can be anticipated.
- Residential and business heat maps might serve as useful planning tools.

Retail operations:

- Network coverage is essential for an operator to compete. Every consumer knows this.
- Retail coverage (the presence of company-owned *stores*) is also extremely important. A mobile operator can quickly review its retail footprint by using the Toolkit to compare the location of company-owned stores to the areas of maximum demand based on population density and business employee density.

Most mobile operators are likely to become fixed operators with the advent of 5G. If they are new to providing fixed services, or are deploying 5G outside of their existing fixed footprint, the Toolkit provides valuable market sizing and competitive data.

Case Study: Fixed Operators

The business case is slightly different for each category of fixed broadband operator.

Wireless ISPs:

- The model includes a set of KPIs designed to help Wireless ISPs model future deployments.
- One set of KPIs shows the percentage of housing units that are in buildings with 2+ units per building, 10+ units per building, and 25+ units per building.
- If an operator places a CBRS radio or a millimeter wave radio on a roof then there are significant economies of scale in serving an MTU versus a single home or business.
- One can therefore choose sections of a city with a high percentage of households in qualifying MTUs (e.g. 2+, 10+, or 25+). Alternatively, one could bid on county-level markets that excel in that metric.

Fiber / G.Fast ISPs

- Every state-level version of the Toolkit has the latest block-level map of infrastructure deployments. It shows:
  - Deployment by technology (fiber, cable, DSL, etc.)
  - Deployment by fastest available downlink speed (1000

Mbps, 500 Mbps, etc.)

- A separate set of integrated maps show the performance commitments of the winners of the CAF II reverse auction. These awards represent 10-year federal subsidies to operators that have committed to deliver a specific level of performance in each designated area. The maps show the awarded regions and the associated performance requirements.

- Finally, the toolkit includes a KPI showing the age of the building (specifically the percentage of housing units built in 2000 or later). The premise is that those built in the 21st century were built during the age of the internet and are likely to have Cat5e or later wiring. Those built before that threshold date are more likely to have phone-oriented wiring. The latter can be used to deliver broadband. Technologies such as G.Fast maximize performance given the physical constraints of any media. This metric is designed to set expectations for the complexity of the in-building environment.

The Role of Broadband Satellites

- An option for a consumer who has money and is unable to purchase a compelling terrestrial solution is to purchase broadband satellite service.
- The toolkit shows broadband satellite adoption by block group (a very small area).
- A high level of satellite adoption is a likely indication of a lack of terrestrial alternatives.
- In some cases a broadband operator will claim to cover a large remote area with fiber. Widespread broadband satellite adoption, in such a situation, suggests the possibility of an overstated coverage claim.
- Geosynchronous satellite service is fast, but high in latency (due to the limitations of the speed of light and the distance to geosynchronous orbit) and expensive for medium to heavy users relative to most terrestrial alternatives.

Case Study: State, County, and Local Governments

Government officials have a unique role. Their mission includes understanding the needs of society. In particular:

- How does income influence broadband adoption and participation in modern society (Hint: it is actually quite influential)?
- How does network coverage (wired and wireless) and network quality impact the lives and businesses of those in rural areas?
- Is the public fully aware of all the federal programs designed to facilitate access?

The state-level Toolkit is designed to be affordable to all state, county, and local governments. It provides a robust set of tools for identifying unmet needs.

Lifeline eligibility / indicators of financial need:

- SNAP (a.k.a. food stamps) % household participation.
- SSI (supplemental security income) % household participation.
- Public Assistance (a.k.a. welfare) % household participation.
- Determination of Poverty Status % of population.

Participation in the information economy:

- Ownership of a desktop / laptop computer
- Ownership of a smartphone

- Fixed broadband connectivity
- Wireless data connectivity
- Broadband satellite connectivity

Availability of fixed broadband infrastructure:

- Access technologies available by block (fiber, cable, DSL, WISP, etc.)
- Data speeds available by block
- CAF II buildout commitments, including quality of service

Availability of mobile broadband infrastructure:

- LTE coverage footprint of the big four providers
- LTE coverage footprint of others
- MF II eligible areas and single-provider areas

Case Study: WISPs

Most WISPs believe they know their market. Even so, we live in an age where investors and other stakeholders expect a data-driven story.

The state-level Toolkit allows a WISP to analyze:

- A detailed map / data set of population density and household density
- A detailed map / data set of income density
- A detailed map / data set of median incomes (suggesting areas where adoption should be strong or weak, based on differences in income).
- A detailed map / data set showing areas of high satellite adoption (indicating the presence of eager consumers with no terrestrial fixed broadband options).
- A detail coverage map of fiber, cable, DSL, and wireless coverage (each as separable layers)
- A detailed coverage map of mobile broadband providers

The very affordable state version of the toolkit is likely to meet the needs of a WISP whose business resides a single state.

Case Study: Private LTE Solutions

The owner of a private LTE system who plans to bid will ask "who else needs spectrum in this location?" One could bid on a PAL license then split the license with another large entity in the license area.

If a corporation has important in-building or campus-wide applications (perhaps a mission-critical system requiring dedicated spectrum, but operating indoors) there is a high likelihood that other business entities could share the same spectrum in different locations without interfering:

- A corporation could use the data in the Toolkit to identify its share of the "business market" within a license area or – even better – within a small section of the license area.
- Business density metrics might help two parties arrive at a fair arrangement for sharing a license.
- A corporation might bid for a license, prior to identifying other prospective users. Knowing the business density and employee density within a city, using Toolkit data, might give the corporation confidence to commit funds to a PAL license, in the absence of finding specific complementary users.
- A corporation with a national footprint might estimate its share of employees or payroll within each geographic market area then bid in markets likely to be affordable.

Case Study: Strategy Consultants

The limiting factor in most strategy consulting engagement is access to high quality data. With the right data and a team of bright consultants it is not hard to "wow" the client. On the other hand, a brilliant team of consultants with no data will find it hard to deliver value.

The Toolkit includes everything a consultant might need to develop a broad range of telecommunication business cases. Large mobile operators, enthused with the idea of doing complex data analyses, might lack the resources internally or the expertise. That's where a data-enabled consultant enters the picture.

One might conclude that these data sets are relevant beyond CBRS and beyond telecommunications. Do other businesses care about demographics and economics? Yes, of course. Do you need to help a national sandwich franchise identify future franchise locations, based on employee densities (hungry workers at lunchtime) and residential population centers? Are you trying to help a local government assess the beneficial impact of recruiting a Fortune 500 corporate headquarters to its city? If so, the Toolkit is likely to include relevant data.

Finally, data is presented in a consultant-friendly format. It appear visually, but also appears in tabular form, where one can extract relevant portions of the data and use it as key inputs to large complex analyses.

In the national versions of the tool the data sets are national and exceptionally detailed. Would it be helpful to have 200,000 data points for your linear regression or advanced multivariate estimation technique? If so, the data can be used in that way – providing compelling data-driven answers.

Next Steps

A fully functional version of the Toolkit is available for prospective users. It includes every category of data found in the national and state Toolkits. It is limited only in its geography and in some of the included spreadsheet data.

An interested individual can download it from:

http://cbrstoolkit.com

The CBRS Business Analysis Toolkit team will be happy to answer your questions / discuss your needs by phone or video conference.

You can reach us at **support@cbrstoolkit.com**.

Figure 10: Feature Comparison

Product	Scope	Information	County	Zip (ZCTA)**	Tract	Block Group	Block
Everything Analyzer	$14,995 National (A bundle including every other product)	Demographic, Business, Fixed and Mobile Broadband Competition	Yes	Yes	Yes	Yes	Yes
Block Group Analyzer	$9,995 National	Demographic, Business	Yes	Yes	Yes	Yes	
Tract / Zip Analyzer	$6,995 National	Demographic, Business	Yes	Yes	Yes		
County Analyzer	$2,995 National	Demographic, Business	Yes				
State Analyzer	$495* Single state	Demographic, Business, Fixed and Mobile Broadband Competition	Yes	Yes	Yes	Yes	Yes

* CA, FL, NY, and TX are $795 each. ** ZCTA boundaries, spreadsheet data, and visualized ZCTA data when ZCTAs are superior to other available resolutions.