BEAD Threshold Financial Model

Overview and User Guide

August 30, 2023

Extremely High Cost Threshold Model

FBA and Cartesian have partnered to develop a model that evaluates the impact of the Extremely High Cost per Location Threshold ("Threshold") to help states determine, consistent with the NOFO, how to maximize fiber deployments while covering unserved and underserved locations using BEAD and private funding.

Our model illustrates how funding could be allocated and how many locations would likely be served given a particular Threshold and several other constraints.

Objective

Modeling Approach

The model is informed by Cartesian's theoretical fiber route model and several financing and deployment cost inputs, but core to setting the threshold is the state's compliance with the NOFO and its desired goal for how to allocate funding.

As such, this model is a tool designed to help states understand the Threshold and weigh different potential thresholds as a policy lever that helps them deliver broadband to their most in-need locations.

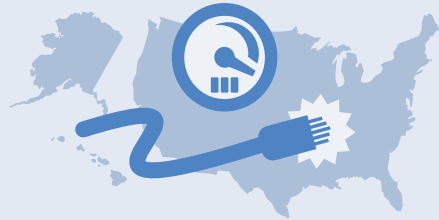Fiber Broadband ASSOCIATION   Cartesian®

Contents

The BEAD Program | Main Objective & Fiber Priority

What is the BEAD Program seeking to achieve?

The provision of robust, reliable broadband service to all unserved and underserved locations in all States and Territories by "prioritizing fiber connectivity directly to the end user"[1]

What is the rationale for the BEAD Program prioritizing fiber connectivity?

"fiber-optic technology...will ensure that the network...can easily scale speeds over time to meet the evolving connectivity needs of households and businesses and support the deployment of 5G, successor wireless technologies, and other advanced services"[2]

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Extremely High Cost Per Location Threshold | Definition & Purpose

What is the Extremely High Cost Per Location Threshold?

The BEAD Program's Notice of Funding Opportunity ("NOFO") defines the Threshold as:

"*a BEAD subsidy cost per location… above which an Eligible Entity may decline to select a proposal [all-fiber project] if use of an alternative technology meeting BEAD's technical requirements would be less expensive*"

▶ **In essence, the Threshold provides a level at which a State or Territory need not prioritize fiber deployments and instead may consider whether other technologies provide an efficient means to reach the highest-cost locations**

▶ **The Threshold is the key mechanism that States/Territories will use to achieve maximum fiber deployment while ensuring as many unserved and underserved locations as possible receive robust, reliable broadband service**

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Extremely High Cost Per Location Threshold | NOFO Directives

A *States/Territories need to submit a proposal to NTIA on setting their Threshold*

- States/Territories (Eligible Entities) must submit a proposal on setting the Threshold when filing their **Initial Proposals** to NTIA
- The proposal can either **identify a Threshold**, or give a **detailed process** for doing so
- Each Entity is **expected to develop its own** reasonable Threshold

B *The Threshold needs to be as high as possible*

- NTIA expects the Threshold to be **as high as possible** to ensure that eligible locations are not left behind and will receive the same fiber connectivity – **the most capable, reliable, durable last-mile technology** – that the most well-served U.S. locations receive
- For locations where the cost is above the threshold, States/Territories may consider, in addition to fiber options, selecting the **next best available technology**

C *The Threshold affects Broadband Service Provider participation[1]*

- Barring special circumstances in high-cost areas, providers must contribute **at least 25% of project costs**
- The Threshold dictates the maximum amount a State/Territory can contribute per location, which in turn **affects ISPs' willingness to participate in financing construction to the higher-cost locations**

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Setting An Economically Rational Threshold | Weighing the Risks

The Threshold should be set to encourage deployment of fiber over less capable alternatives while not deterring providers from participating to build to all eligible locations – a fine line to tread

Fiber Deployment Cost per Unserved Location by Percentile[1]

EXAMPLE THRESHOLD RANGES

⚠ TOO HIGH

✔ OPTIMAL

⚠ TOO LOW

Average Cost per Location

Cost Percentile: 0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
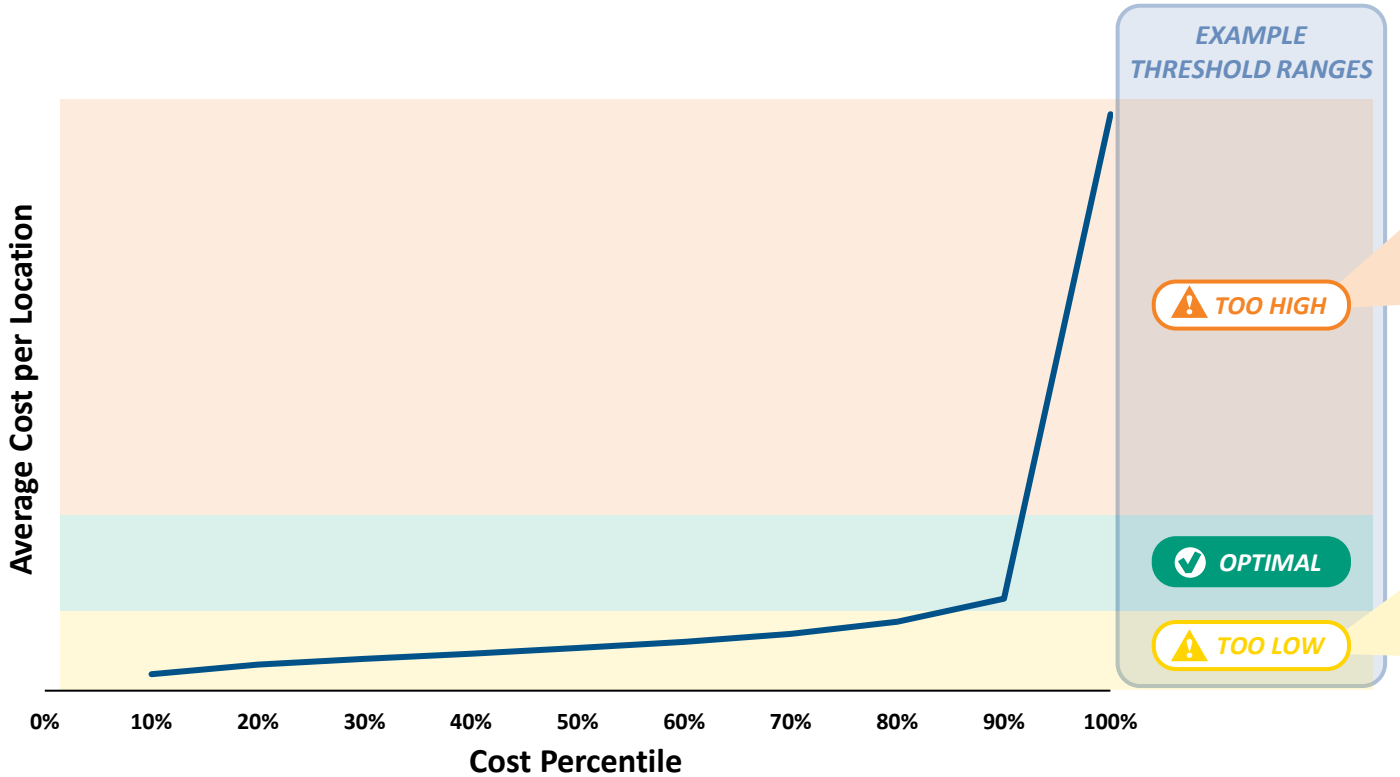
Risks that States/Territories may face:

⚠ **THRESHOLD IS SET TOO HIGH**

LACK OF BIDS OR FUNDS

Eligible locations may completely miss out on getting access through BEAD funding

Many Locations suffer:
- Left with no broadband access, especially costly locations
- Stuck with poor connectivity options

⚠ **THRESHOLD IS SET TOO LOW**

MISSED FIBER COVERAGE

Eligible locations that would have otherwise received fiber miss out
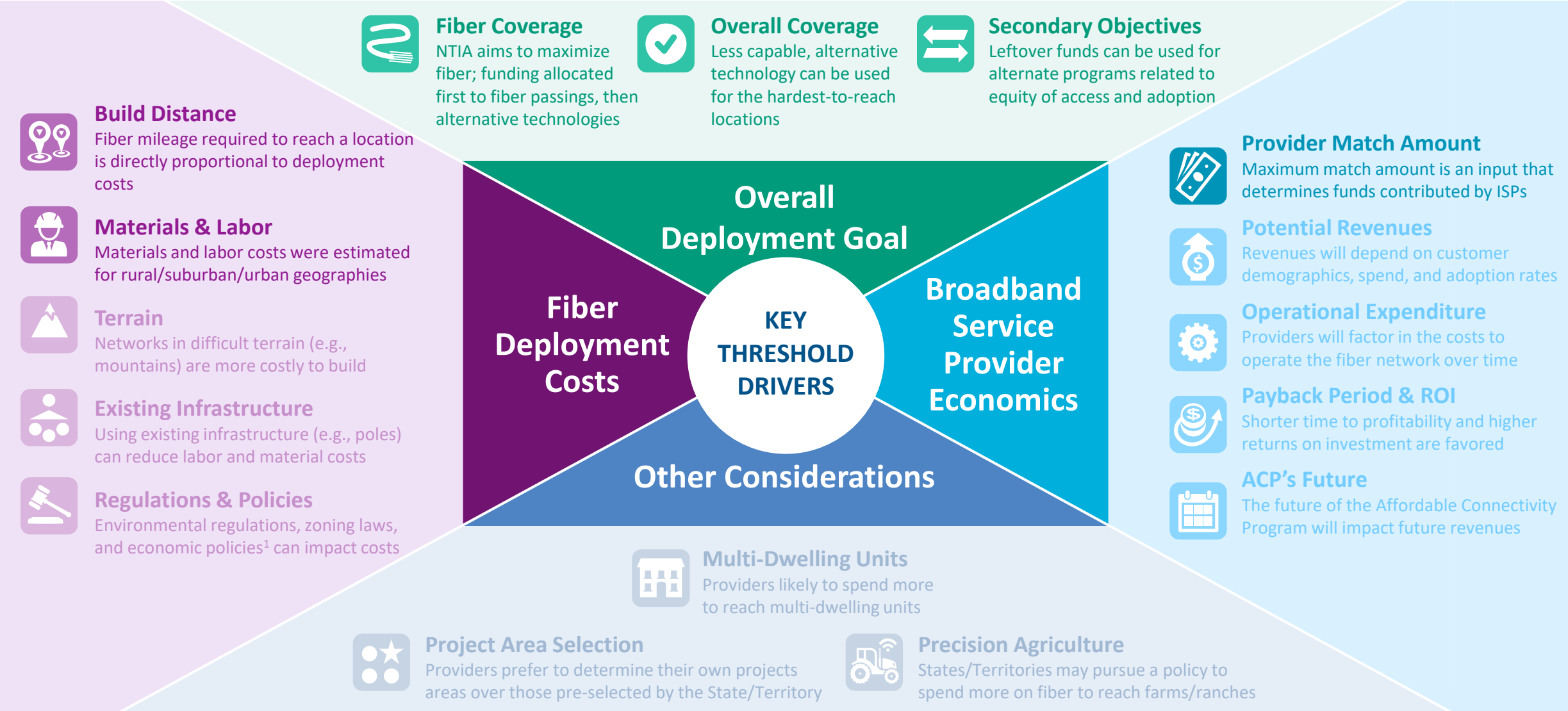
Affordable locations:
- Receive less capable technology
- Require more frequent upgrades
- Incur higher long-term costs

The Threshold signals to providers where they should bid to provide fiber rather than less capable technologies

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Model | Key Factors Considered

Many factors that set the Threshold are addressed by the model; others must be considered by the user

Fiber Coverage
NTIA aims to maximize fiber; funding allocated first to fiber passings, then alternative technologies

Overall Coverage
Less capable, alternative technology can be used for the hardest-to-reach locations

Secondary Objectives
Leftover funds can be used for alternate programs related to equity of access and adoption

Build Distance
Fiber mileage required to reach a location is directly proportional to deployment costs

Materials & Labor
Materials and labor costs were estimated for rural/suburban/urban geographies

Terrain
Networks in difficult terrain (e.g., mountains) are more costly to build

Existing Infrastructure
Using existing infrastructure (e.g., poles) can reduce labor and material costs

Regulations & Policies
Environmental regulations, zoning laws, and economic policies[1] can impact costs

Provider Match Amount
Maximum match amount is an input that determines funds contributed by ISPs

Potential Revenues
Revenues will depend on customer demographics, spend, and adoption rates

Operational Expenditure
Providers will factor in the costs to operate the fiber network over time

Payback Period & ROI
Shorter time to profitability and higher returns on investment are favored

ACP's Future
The future of the Affordable Connectivity Program will impact future revenues

Overall Deployment Goal

Fiber Deployment Costs

KEY THRESHOLD DRIVERS

Broadband Service Provider Economics

Other Considerations

Multi-Dwelling Units
Providers likely to spend more to reach multi-dwelling units

Project Area Selection
Providers prefer to determine their own projects areas over those pre-selected by the State/Territory

Precision Agriculture
States/Territories may pursue a policy to spend more on fiber to reach farms/ranches

1. For example: the Build America, Buy America Act
Source: Cartesian

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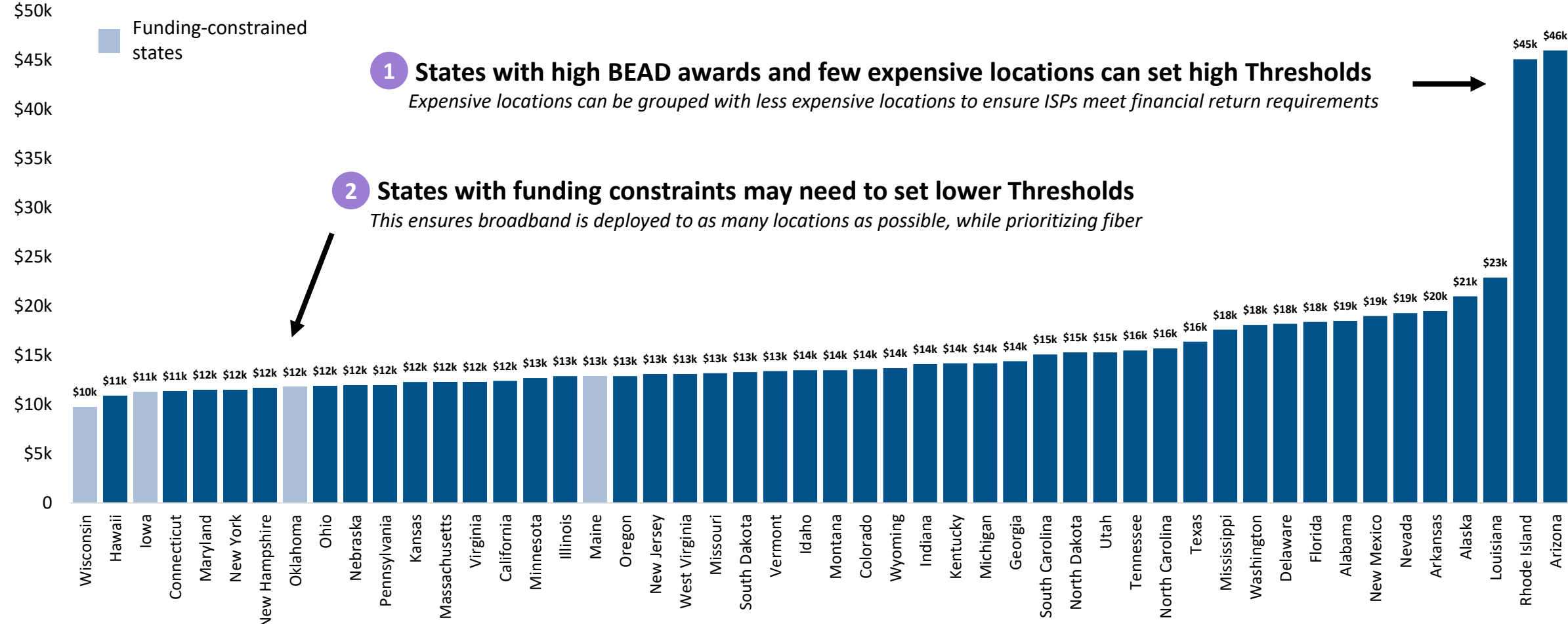
Results

Results | Potential Thresholds by State

Under default model inputs, optimal Thresholds are between $10k and $20k for most states

Funding-constrained states

1 **States with high BEAD awards and few expensive locations can set high Thresholds**
Expensive locations can be grouped with less expensive locations to ensure ISPs meet financial return requirements

2 **States with funding constraints may need to set lower Thresholds**
This ensures broadband is deployed to as many locations as possible, while prioritizing fiber

These Thresholds are optimized to provide maximum broadband deployment to both unserved and underserved locations, which meets NOFO requirements. They are a benchmark for states looking to determine their own Threshold.

Results | Potential Thresholds by State

Highly funded states can typically set a high Threshold, while underfunded states may need to set lower values

Two Categories of States

1. Highly Funded

States with high amounts of funding may be able to set higher Thresholds and reach all unserved and underserved locations with primarily fiber technology. Examples include:

NEVADA

NEW MEXICO

2. Underfunded

States with funding constraints typically must forego funds that ISPs would otherwise be willing to contribute, in order to reach as many unserved and underserved locations with broadband as possible. Examples include:

WISCONSIN

OKLAHOMA

Visualizing the Threshold
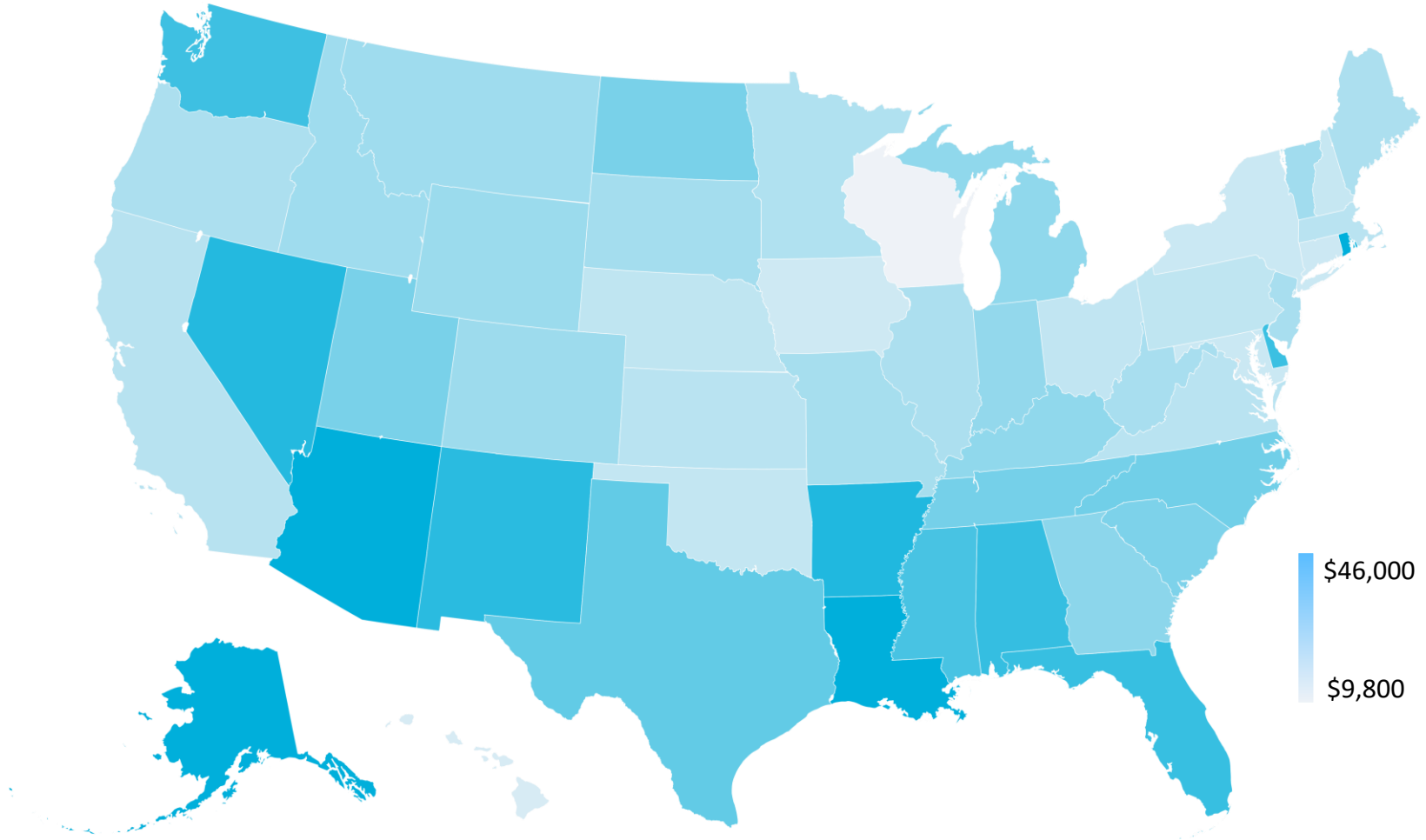
$46,000

$9,800

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Results | Coverage at Example Threshold: Tennessee

Threshold: $15.5K

SUMMARY OF MODELED COVERAGE

Unserved (71%) | Underserved (29%)

| Fiber | Alternative Technology | Not Passed |
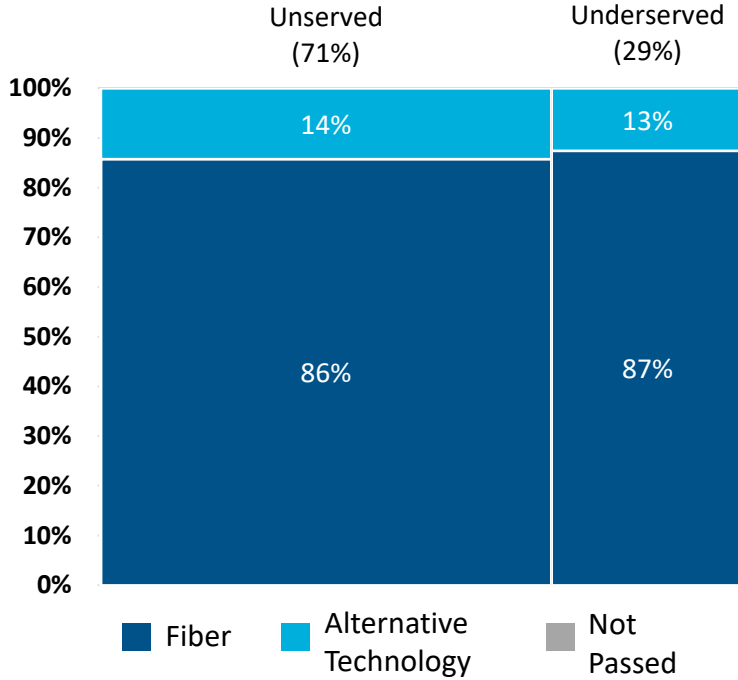
Goal: Maximize Broadband

The recommended Threshold aims to maximize fiber, while ensuring there is enough funding to pass all unserved and underserved locations

Visualizing the Threshold

— Cumulative Average Cost per Location[1]   — Cost per Location[2]

Threshold: the Threshold is set where the Cost per Location curve reaches the $12K business case maximum

$15.5K Threshold

$12K: business case maximum

Eligible Location Percentile

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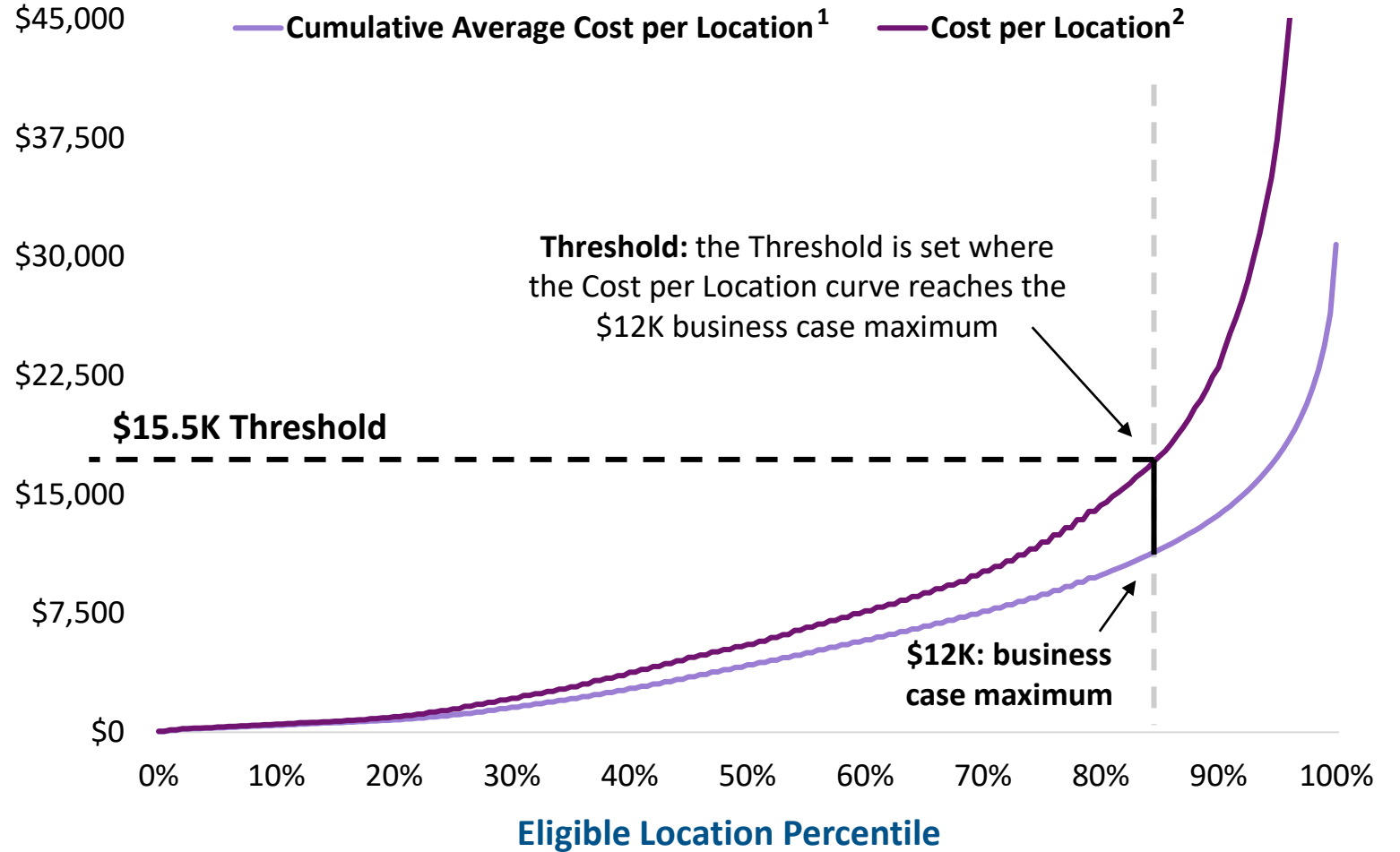
1. Charted average is of the top 25% least-dense, most-costly-to-pass locations. See slide 22 "Cost per Location" for more information.
2. Represents the maximum cost to pass locations at the percentile. See slide 22 "Maximum Cost per Location" for more information.

Source: Cartesian

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Quick Start Guide

Quick Start Guide | Model Content

The model uses a target Threshold input to estimate BEAD build costs and locations passed for a selected state
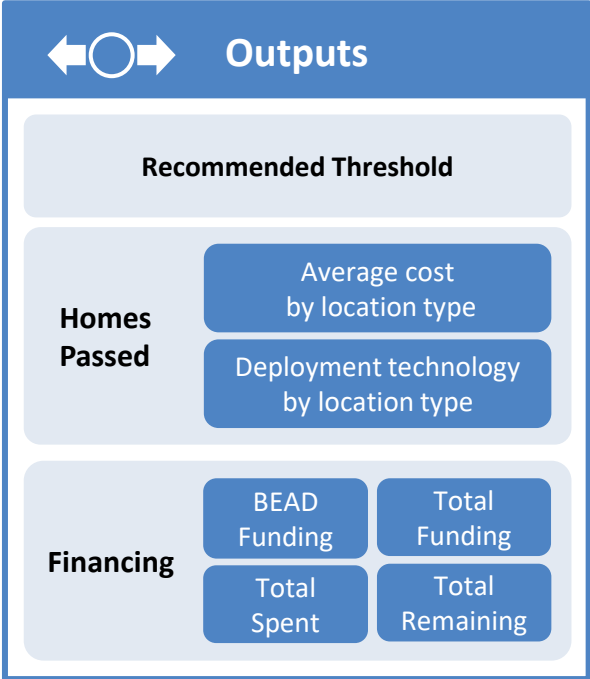
How to Run the Model

Press F9 to run, or Formulas -> Calculate

On the right of the Formulas tab, set Excel to calculate manually. It takes about two minutes to calculate and update outputs after a new state is selected.

Inputs

State	Target Threshold

Alternative Technology Cost	Cost per Location	ISP %

ISP Match	Max ($)	Max (%)

Deployment Costs per Mile

Unserved Rural	Underserved Rural
Unserved Suburban	Underserved Suburban
Unserved Urban	Underserved Urban
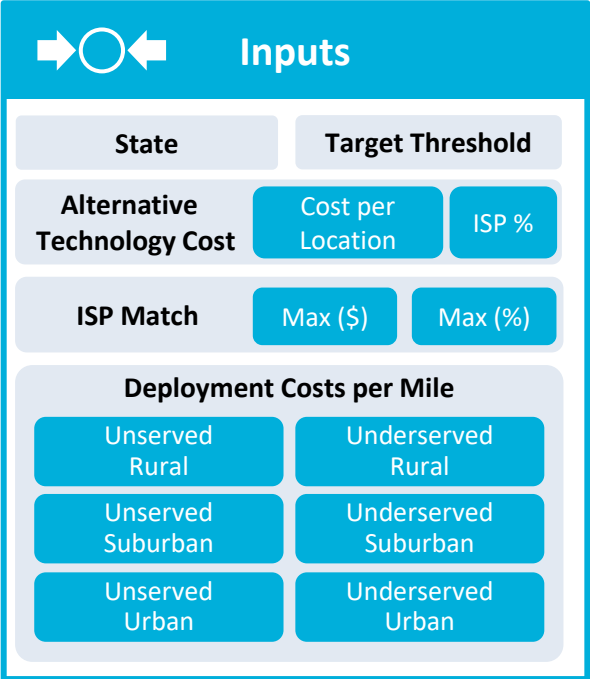
How to Read the Model

The model returns locations passed in both a table and chart, estimated deployment costs, and remaining BEAD funding given the model inputs. It will provide feedback if the Threshold is higher or lower than it could be.

Outputs

Recommended Threshold

Homes Passed	Average cost by location type
	Deployment technology by location type

Financing	BEAD Funding	Total Funding
	Total Spent	Total Remaining

Threshold Cap

If the Threshold is set too high for providers to meet the average 25% match required by the NOFO, the model will select the highest Threshold that meets NOFO criteria and display warning text

Locations Passed

The "Locations Passed" table reports average cost per unserved or underserved location as well as how many unserved and underserved locations are served by fiber or alternative technologies

Financing

Total Funding sums BEAD funding and total ISP contribution. Total Spent can be expanded to detail deployment costs by deployment technology and location type. Remaining funding for other applications of BEAD funding is also an output

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Quick Start Guide | Model Use

There are three steps to using the model effectively, and several caveats that should be recognized

Using the Default Model Successfully

1 **Have a Clear Objective**

The Threshold level reflects a state's **compliance with the NOFO and its funding priorities** for BEAD. Examples include, but are not limited to, maximizing fiber coverage, passing all unserved and underserved locations with any broadband technology, and/or ensuring funds remain for other policy goals. The recommended Threshold meets the goal of passing all unserved and underserved locations while maximizing fiber.

2 **Determine Inputs**

While the model comes with default inputs, which are explained in this document, users are encouraged to **set their own inputs and build upon the model** as is useful.

3 **Iterate Through Possible Values; Set the Threshold**

The model allows the user to try different Threshold values and see the resulting output. To find an appropriate threshold, check the locations passed and cost outputs and assess whether the state's goals have been met.

Important Considerations and Caveats

Project Boundaries

In practice, the **economics of individual projects will vary widely**. Project boundaries are not currently known, so the model assumes states will typically establish grants for multi-location projects that have a mix of cost profiles. In setting the Threshold, the model takes a conservative stance by assuming a mix of locations above state-wide average costs are included in projects.

State-Level Funding

State-specific broadband funding could be added into the model to complement the federal funding programs already accounted for to **prevent the "double funding"** of locations

Deployment Costs

Deployment costs can be customized to **reflect local terrain, preferred deployment types, and regional labor costs** for additional precision
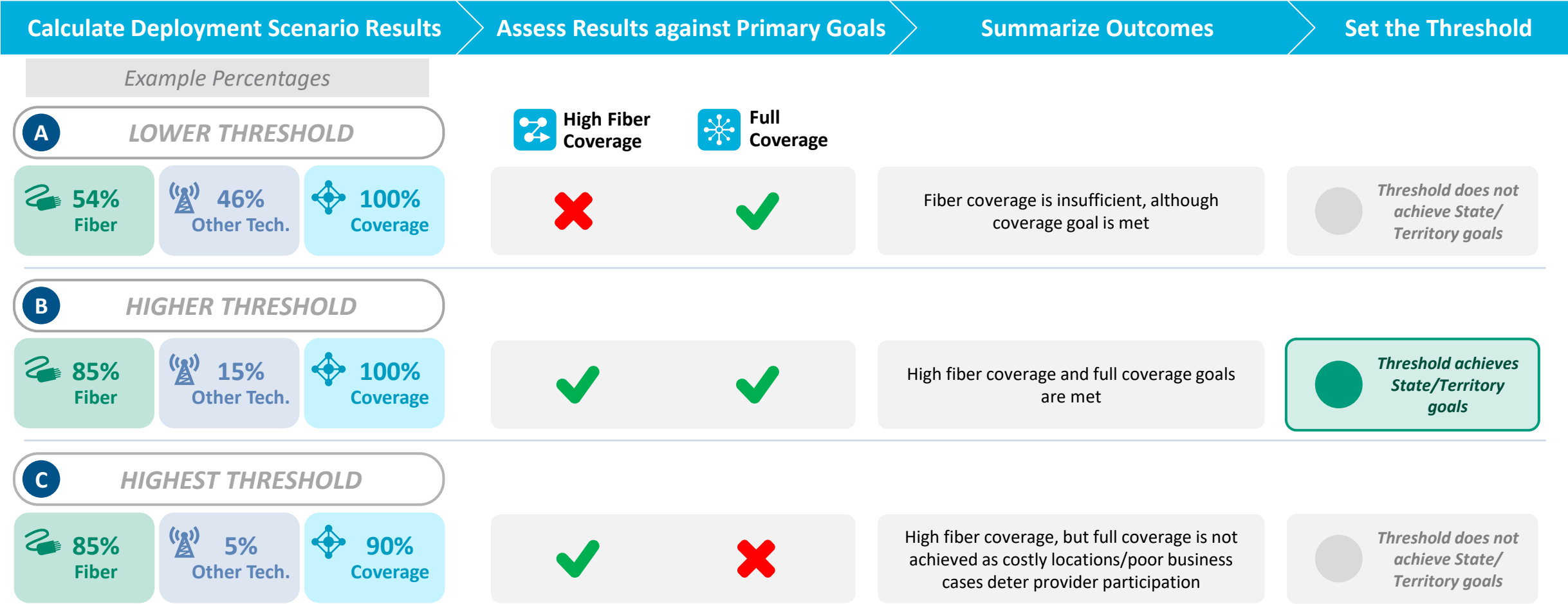
Location Data

The model uses fiber route lengths calculated by Cartesian using **open mapping data**. Locations in that data may vary from the FCC Data Map fabric, which is not publicly available. The fiber routing methodology described on slide 27 does not consider the precise location of existing providers' infrastructure. Better location data would improve the model's accuracy

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Quick Start Guide | Assessing the Results of an Evaluated Threshold

The modeled cost and coverage for a given Threshold can be assessed against NOFO compliance and state goals

Calculate Deployment Scenario Results	Assess Results against Primary Goals	Summarize Outcomes	Set the Threshold

Example Percentages

	High Fiber Coverage	Full Coverage		

A — *LOWER THRESHOLD*

| 54% Fiber | 46% Other Tech. | 100% Coverage | ✘ | ✔ | Fiber coverage is insufficient, although coverage goal is met | Threshold does not achieve State/Territory goals |

B — *HIGHER THRESHOLD*

| 85% Fiber | 15% Other Tech. | 100% Coverage | ✔ | ✔ | High fiber coverage and full coverage goals are met | Threshold achieves State/Territory goals |

C — *HIGHEST THRESHOLD*

| 85% Fiber | 5% Other Tech. | 90% Coverage | ✔ | ✘ | High fiber coverage, but full coverage is not achieved as costly locations/poor business cases deter provider participation | Threshold does not achieve State/Territory goals |

**According to the NTIA, states and territories should aim to cover
all eligible locations while maximizing fiber connectivity**

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1 | Background on BEAD and the Threshold

2 | Results and Quick Start Guide

3 | Approach

4 | Methodology

Approach | Tying Locations to the Fiber Mileage Required to Serve Them

Census blocks are sorted into percentiles based on fiber mileage per location, which translates into total costs

Methodology of Model Components

A — ***Census blocks are sorted from low-to-high***
Census blocks are sorted from low to high based on the average fiber mileage required to reach locations in that census block

B — ***Percentiles are calculated based on the total number of unserved or underserved locations in each state***
Census blocks align with percentiles based on the unserved and underserved locations in each relative to the total number of unserved or underserved locations in the state. The highest percentiles comprise the census blocks with the highest average required fiber mileage per location – the costliest to serve

C — ***Sorting is done first for unserved, then underserved***
Percentiles are calculated for census blocks with unserved locations (regardless of whether underserved locations are in the same census blocks) and then for census blocks with only underserved locations. This approach is consistent with NOFO's deployment priority, where unserved locations must be served in lieu of underserved locations if both cannot be

Determining the Threshold

Average mileage per location

State

Threshold

Threshold cost value correlates with miles of fiber

Each "step" of the chart represents a different Census Block with a higher average mileage per location than the previous

Miles of Fiber per Location (y-axis)

Percent of locations passed at the Threshold

EXAMPLE

50%   80%   100%

Percentile of Location
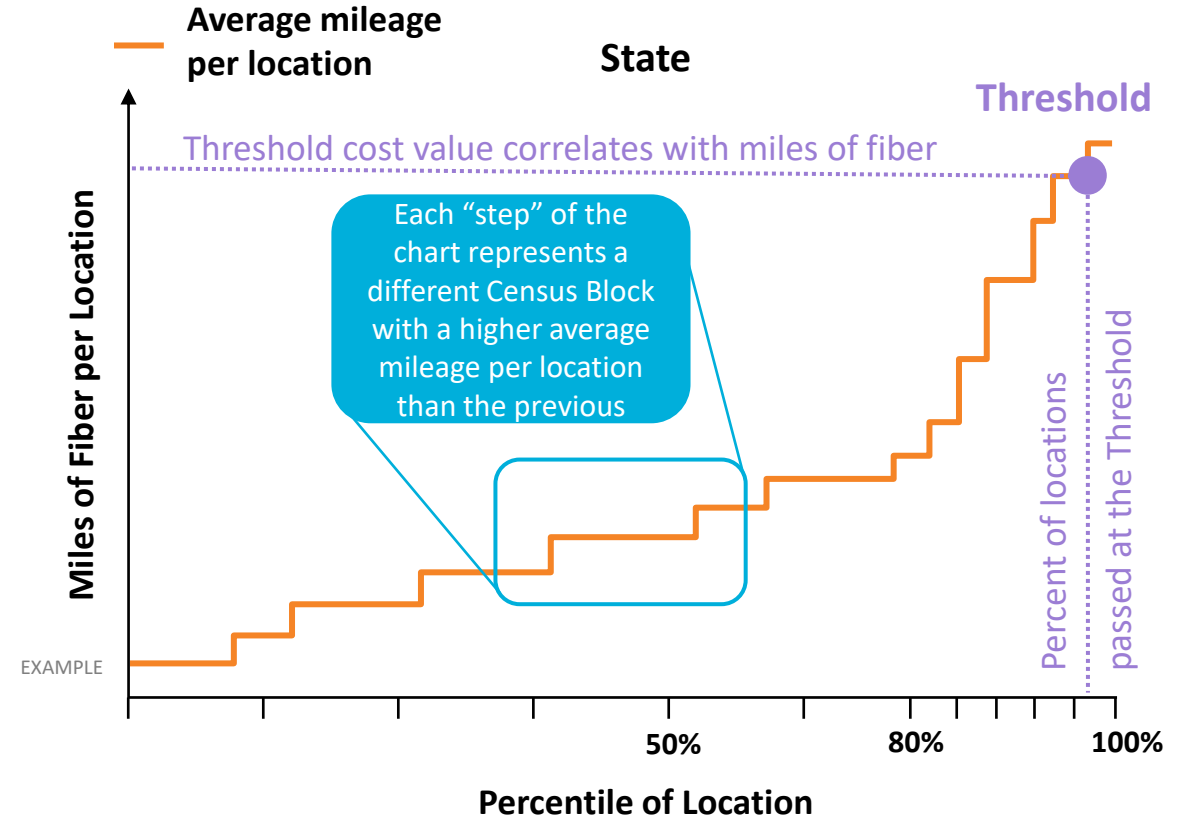
The model uses miles per location to determine total costs:

Configured by the model user

| Miles per Location | × | Total Locations | × | Avg. Cost per Mile | = | Total Costs |

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Approach | Funding and Cost Flow Chart

The model, like BEAD funding, prioritizes unserved locations over underserved, and fiber over alternative tech

BEAD Funding

State-Specific
Source: FCC

Private Financing

Max ISP Match ($) — $3.0K[1]

Max ISP Match (%) — 75%[1]

Alternative Technology Cost

Cost per Passing — $4.8K[1]

Provider Match (%) — 40%[1]

The model follows a "waterfall" approach to allocating funding

1 **Unserved Locations Passed with Fiber**
Is there enough funding for fiber coverage up to the Threshold in areas with unserved locations?

2 **Unserved Locations Passed with Alternative Technology**
Is there enough funding for fixed wireless coverage for the locations over the Threshold in areas with unserved locations?

Coverage required by BEAD

3 **Underserved Locations Passed with Fiber**
Is there enough funding for fiber coverage up to the Threshold in areas with underserved locations?

4 **Underserved Locations Passed with Alternative Technology**
Is there enough funding for fixed wireless coverage for locations over the Threshold in areas with underserved locations?

1. These are the default values for the model, and should be changed to reflect local conditions.
Source: Cartesian

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Approach | The Interplay of Average Costs and Extremely High Costs

ISPs consider average costs to determine match; the Threshold depends upon the most-expensive locations

Existing Network	Census Block A	Census Block B
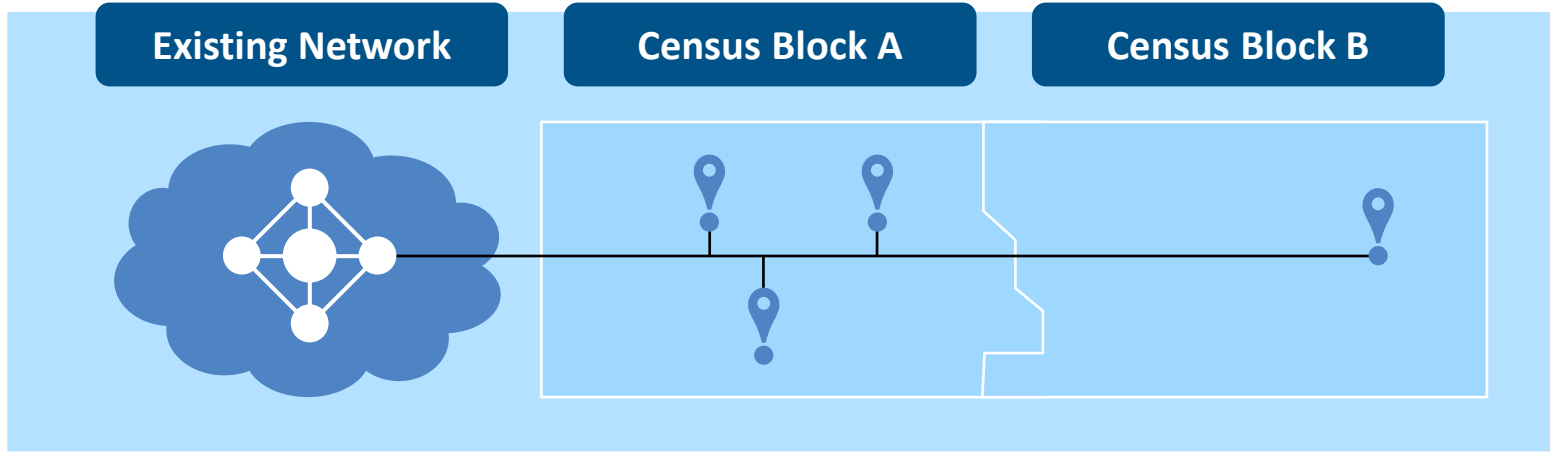
Census Block A:
- Clustered locations
- Close to existing network

Census Block B:
- Few locations
- Far from existing network

Per location, Census Block A is less expensive to serve than Census Block B. Let's assume that both are bundled together for a project won by an ISP

Average cost per location
Census Block A

Average cost per location
Census Block B

$8.0K

$24.0K

Average cost of locations within a project

$12K

$3K
ISP Match
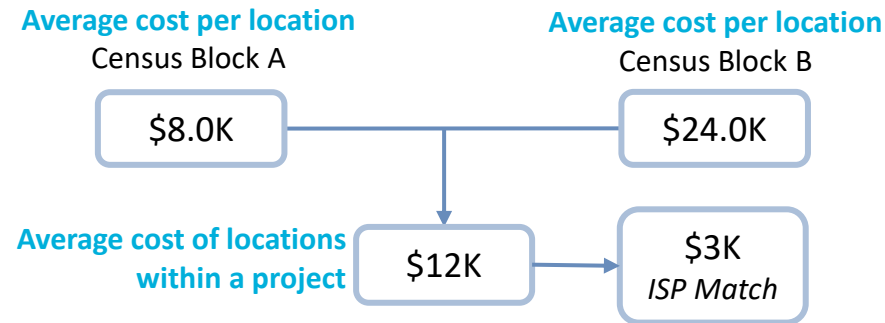
Example Threshold = $24k
With a Threshold of $24k, these locations can be included in the project and passed with fiber. A lower Threshold would mean these locations would receive an alternative technology for service. **In the model, the maximum location cost for each percentile factors into the Threshold**

Reasonable Provider Match Bounds

Lower Limit: 25% ISP Match Floor
Fiber internet service providers must contribute at least 25% of the costs for projects under the Threshold according to the NOFO. States may set a higher, but not lower, contribution floor if they wish under normal circumstances.

Upper Limit: Provider Business Case
Eligible locations within a project will range in deployment cost. The ISP will look at the average costs for the project as a whole when considering its match amount. If the Threshold is set high enough to reach the most expensive locations in a state, it's possible that the 25% match required of the ISP no longer supports a viable business case. In this situation, few or no ISPs would bid on the project because the average project cost is too high. The default ISP match maximum is set at $3k.

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Approach | Average Project Costs and Threshold-Setting Costs

Costs per location are estimated differently to calculate total state cost, average project cost, and threshold cost

Simulating Average Project Costs

- Project boundaries are not yet known, so there is uncertainty surrounding the range of deployment costs that will occur in each project
- The model takes a balanced view by looking at the average costs of the 25% most expensive locations under the Threshold
- Projects will likely include locations with similar required fiber mileage per passing, and ISPs will look at the project as a whole to determine their match amount

Cost Type	Cumulative Average Cost per Location		Threshold-Setting Costs
Explanation	The model uses cumulative average cost per location to determine how much the state spends on fiber and alternative technologies, and how much funding remains	The model takes the average of the 25% most expensive locations at the modeled coverage level to approximate the cost of the most expensive project in a state, which is used to calculate the ISP match	The Threshold, according to the NOFO, relies on the cost of the most expensive location in a project. If the maximum location cost of a project exceeds the Threshold, that project is not required to use fiber service
Calculation	**A1** *Cumulative average cost per location*	**A2** *Cumulative average cost per location, top 25%[1]*	**B** *Maximum cost per location*
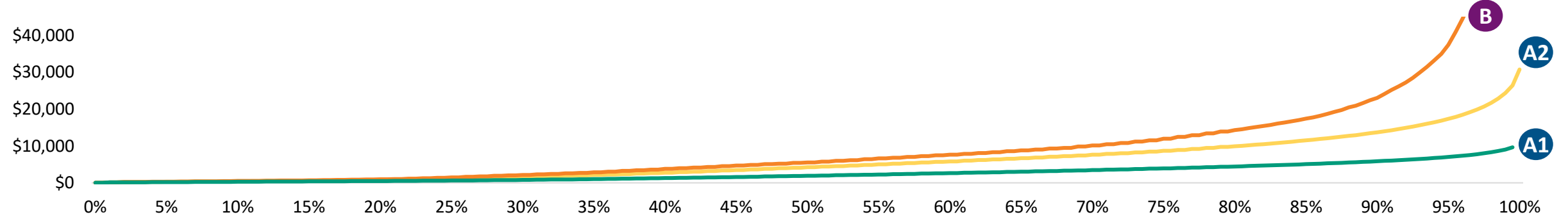
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Approach | Default Inputs

Provider match, alternative technology costs, and build cost default inputs can be adjusted by the end user

Input	Model Default	Rationale
Provider Match	**Max ISP Match (%)**: 75% **Max ISP Match ($)**: $3.0K	• The highest provider match dollar amount is based on the maximum a typical ISP would spend to deploy fiber to a typical location while meeting financial return requirements • This in turn varies based upon an ISP's operating metrics and return requirements • Ultimately, this match maximum is based on projects that contain more than one revenue generating household or business
Alternative Technology Cost	**Cost per Passing**: $4.8K **Provider Match (%)**: 40%	• $4.8K cost per passing is a fixed wireless benchmark, and fixed wireless may be an alternative to fiber broadband in low-density areas • While it can be slower and less reliable than fiber, it will likely be the most common alternative technology used for locations above the Threshold
Fiber Cost Benchmarks	Blended deployment type costs for each morphology	• The model's deployment cost estimates are set at a national scale • Aerial, buried, and underground deployment cost benchmarks are blended for each morphology (rural, suburban, and urban)

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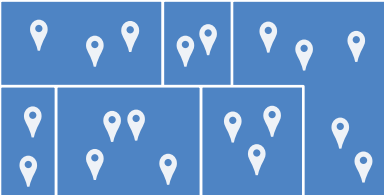
Methodology | Locations

The model uses the latest FCC Data Map counts of unserved and underserved locations at the census block level

Census Block

EXAMPLE

Census Blocks are the smallest unit of geographic area used by the Census Bureau to map and measure the United States. In this model, census blocks are used to aggregate locations and fiber mileage.

Excluded Locations

Served Locations

Locations that currently receive broadband service at speeds of 100/20 Mbps or above.

Locations Funded by Other Programs

Rural Digital Opportunity Fund   *3.4M locations*
An FCC program that provides support to connect rural homes and small businesses to high-speed, low-latency networks.

Connect American Fund (CAF)   *393K locations*
An FCC program that provides funds to five service providers to connect rural areas likely to remain unconnected otherwise.

Tribal Broadband Connectivity Program   *93K locations*
An NTIA program that provides funds to connect households, businesses, and community anchor institutions on tribal lands.

Other Federal Programs   *2.1M locations*
Other federal programs modeled include the Broadband Infrastructure Program, the Rural EConnectivity Program, the Telephone Loan Program, and the Capital Projects Fund.[1]

The model considers three types of census blocks:

Unserved Only	Unserved and Underserved	Underserved Only
These census blocks include only unserved locations	These census blocks have a combination of unserved and underserved locations; public FCC data does distinguish which are which	These census blocks include only underserved locations
These categories are considered jointly in the analysis, since unserved locations receive funding first and our smallest unit of analysis is the census block, not location.[2]		Underserved-only census blocks are considered last.

Unserved Locations

4.7M
Locations considered

Unserved locations have internet speeds below 25/3 Mbps

Underserved Locations

2.4M
Locations considered

Underserved locations have internet speeds above 25/3 Mbps but below 100/20 Mbps

1. Locations served by ARPA or ACAM funding are included in this analysis. 2. Providers would not skip underserved locations in the same CB as unserved location they are contracted to pass.
Source: Cartesian, FCC Broadband Funding Map Funding Summary

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Methodology | Fiber Cost per Mile

Fiber cost per mile is a product of geography, location type, deployment type, and other factors

Blended Cost per Mile		
Geography	**Unserved** Greenfield	**Underserved** Brownfield
Rural	$46.3K per mile	$38.3K per mile
Suburban	$60.8K per mile	$48.3K per mile
Urban	$71.0K per mile	$51.5K per mile

Deployment type is blended differently by morphology in the cost per mile calculation

AERIAL **BURIED** **UNDERGROUND**

Driving Factors

Location Type

The model considers unserved locations *greenfield*, where no provider has previously built out reusable infrastructure to the area, and underserved locations *brownfield*, where providers may be in the area but do not have high-speed access lines to particular locations. Unserved locations are thus assumed to be more expensive to reach than underserved locations.
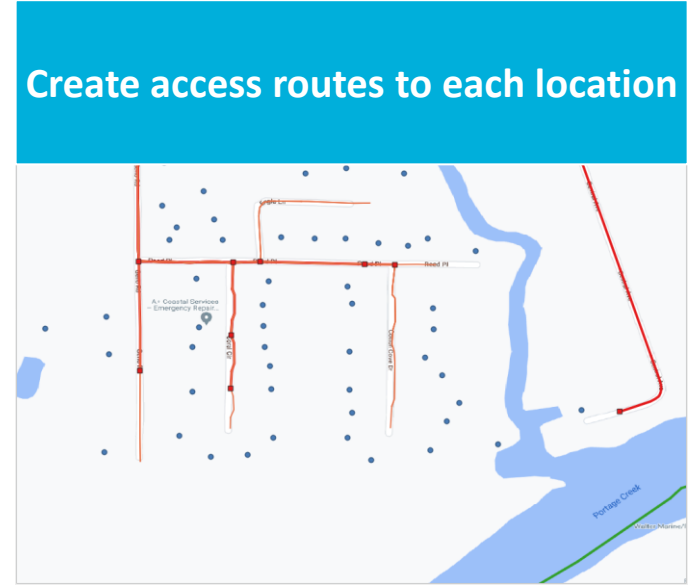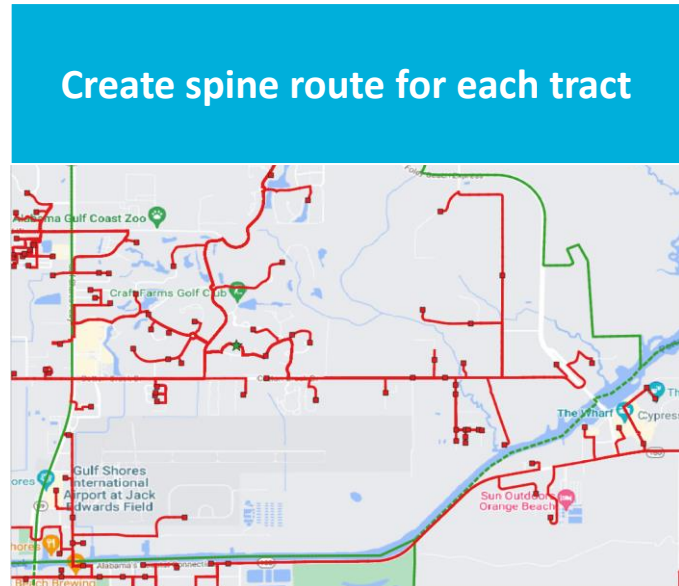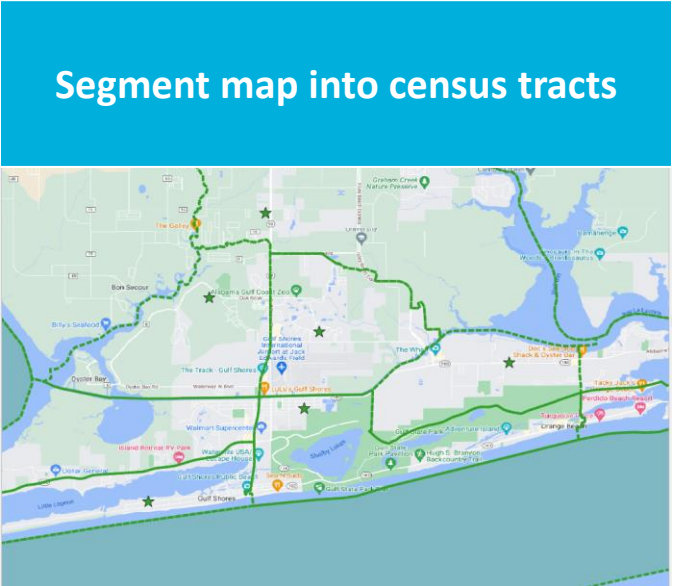
Terrain Variation

Terrain varies dramatically by state, and impacts build costs; tunneling through granite is more expensive than through dirt. Users should substitute their own build costs per mile that best represent the unique terrains in their state of interest.

States are encouraged to use their own deployment costs that accurately reflect their local conditions

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Methodology | Fiber Routing Model

Fiber routing lengths are determined using open mapping data

Fiber Routing	Average Mileage per Location
▶ A dataset of US locations acts as the basis of our fiber routing methodology ▶ Each structure in the data is marked with a point at its center, and access routes are drawn from each location to the nearest road ▶ Spine routes are estimated for each census tract and then allocated proportionally to the census blocks in each tract ▶ Access and spine fiber mileage are summed, resulting in one mileage metric per census block	▶ Fiber mileage and BEAD eligible location counts are aggregated by Census Block ▶ Fiber mileage is then assigned proportionally to each location ▶ Fiber miles are converted to cost estimates, and locations can then be sorted from least expensive to most expensive

Segment map into census tracts

Create spine route for each tract

Create access routes to each location

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