Arrow Platform

Comprehensive User Guide

ver. 2024.1 (Release 3.3)

altman solon

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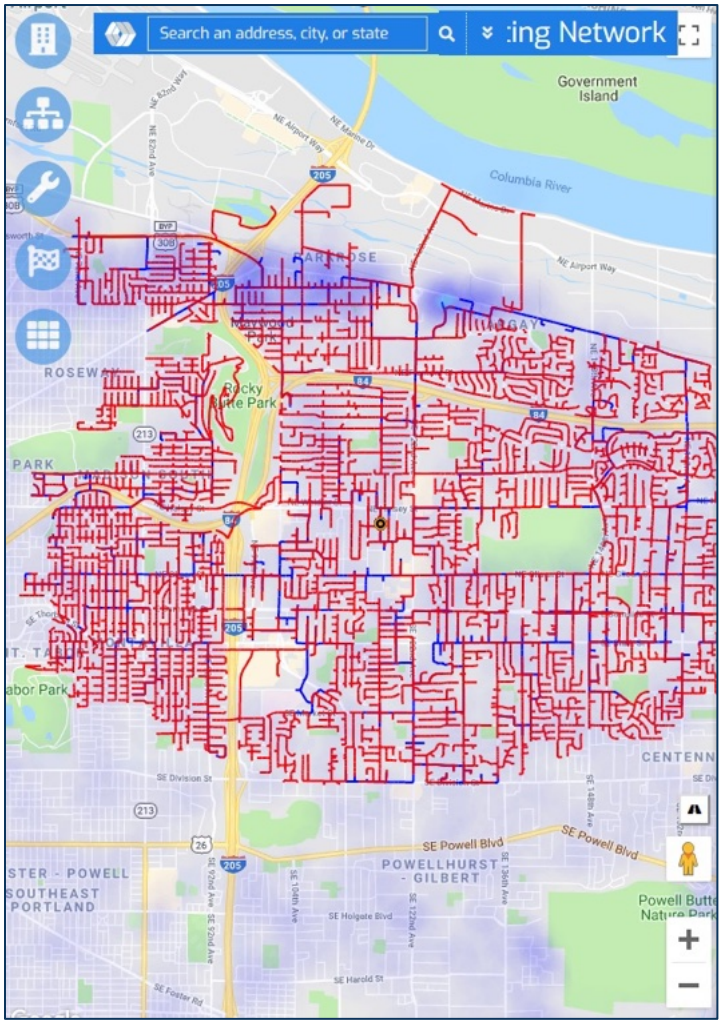
Altman Solon has developed Arrow to comprehensively evaluate different network investment opportunities

Arrow Platform Overview



Overview

- The Arrow Platform has locations of households, businesses and towers
- It can incorporate competitor network information using commercially available fiber route data
- In addition, it has various market-size estimates for households, businesses and towers
- These data are used to optimize end-point network equipment sizing and placement

Algorithms

Optimize – end point sizing and placement by leveraging geo-spatial locations

Network – deploy fiber to businesses, towers and homes

Analyze – Understand the BOM and financial output of optimization

Arrow has been used to help solve each of the operating questions posed by clients

Planning	**Large scale fiber planning**	**Optimized market fiber plans in minutes with full financials**
	Multiple end points and architectures	**Planning for HHs, all business types, towers, small cells, and 5G**
	Acquisition planning	**Rapid, customizable scenario & financial analysis**
Sales & Marketing	**Opportunity targeting**	**Competitive and market opportunity visualization & reporting**
	Channel enablement	**Sales channel enablement**
Detailed Design and Engineering	**Fiber design**	**Detailed fiber route design**
	Field data accuracy	**Update asset meta data**

Arrow differs from other applications in the market in four key areas

Standard Engineering Tools	Arrow Platform	Selected Differentiation Points
Optimize market in **hours**	Optimize market in **minutes**	*Arrow is the only solution which approaches modeling with network planning in mind – giving users ability able to run large optimizations quickly and be able to iterate, running **very fast "What If" scenarios***
Cost-based optimization	**Cost, revenue, and returns-based** optimization	***Bottoms-up demand using Altman Solon's spend data; flexibility of financial goals and assumptions** allows for multiple approaches to network routing (least-cost, IRR, specific budget, coverage)*
Single endpoint-type routing (e.g. households)	**Multiple simultaneous endpoints** (businesses, households, and cell-towers)	*Optimizing for multiple endpoints has **cost-savings of >20%** vs. planning individually*
Single network type (e.g. wireless or FTTH)	**Multiple network types** supported and can run in conjunction (e.g. wireless placement with fiber backhaul)	*By supporting multiple network types, Arrow enables planners to estimate **trade-offs of using each network type** in different areas*

While Arrow was designed to be directionally accurate, it often performs better than most other tools

Baseline Data	Better Data	Best Data
Enables rapid order-of-magnitude cost estimates	**Enables more detailed costing and coverage**	**Enables full business case calculation** *(revenue and costs)*
Roads *for fiber routing*	***Large foliage/clutter tiles*** *(30mx30m squares, e.g. free ones from NASA in US) to allow for ray tracing rather than arbitrary radius*	***Granular foliage/clutter tiles*** *(e.g. 5mx5m tiles) for more detailed ray tracing*
Fixed demand points *(e.g. households, business) with only lat/long information*	***Mobile demand points or polygons***	***Detailed attributes about fixed and mobile*** *demand such as business industry/employees, household attributes, and mobile bandwidth usage*
Existing network elements *(e.g. fiber, splice points) to know where to backhaul fiber*	***Existing / available cell sites*** *to allow Arrow to place nodes on those rather than greenfield*	***Competitive data*** *(e.g. fixed and mobile providers) – to more accurately forecast penetration*

More accurate network design and business case modeling

The Arrow platform is flexible, allowing for activities and analyses ranging from an enterprise-grade planning to competitive wargaming

1 4G Small Cell Deployment	Arrow was used by an operator to model cost avoidance of using other providers for serving its mobile bandwidth needs
2 5G Business Planning	Arrow was used by a consumer operator to build an initial business case for 5G
3 Build Cost Estimation	Helped network planners at a major fiber provider improve their estimation of mileage in a major fiber build – early methodology was underestimating by 50%
4 Competitive Wargaming	Arrow helped a network operator understand which areas of their footprint were most under threat from 5G or FTTH overbuilders
5 Unify Fiber Planning Across Units	Arrow was used to help push a company internally to consider all endpoint types (HHs, SMBs, enterprises) when planning new fiber vs. analyzing each individually

In our experience, Arrow's value is realized across five key dimensions

1 Speed	• Completes city-wide optimizations in <10 minutes • Clients have experience old 2 week processes completed in <2 days
2 Holistic Financial Approach	• Estimates revenues and penetration, taking into account competition, ARPUs and past performance • Produces detailed cost estimates using client's network architecture and costs (full equipment inventory, strand count, etc.) • Estimates value creation from a revenue, cash flow, and returns perspective
3 Optimization Types	• Offers variety of optimization types for different build goals (e.g. coverage, IRR or budget targets) • Optimizations consider marginal costs and returns, including fiber and equipment costs, node count and placement based on coverage objectives and financial returns
4 Little Data Needed Out the Box	• Users can begin to run scenarios by supplying as little as target set of locations, allowing them quickly get a sense for which areas to prioritize for further analysis
5 Scalability	• Initial test deployments (e.g. single market) can be seamlessly scaled up to cover wider geographical areas without any interruptions to end users or loss of data • Arrow's flexible infrastructure and Altman Solon's algorithm experience allows new network technologies to be added relatively easy

Arrow is complementary to detailed RF engineering tools; Arrow is used in advance of final engineering to establish precise budgets and locations that justify detailed plans

	Arrow 5G Fixed Wireless	**Detailed RF Engineering Tools** *(e.g. Atoll)*
Primary Use Case	**Business case modelling and geographic prioritization**	**Wireless engineering**
Accuracy	▪ Uses 30m x30m foliage blocks, building stories, etc.; can be calibrated to line up with ATOLL / OEM tools and parameters	▪ Precise RF tool – factors in elevation, buildings, trees, etc. using LIDAR 1 meter data
Speed	▪ Very fast (10 minutes for a market)	▪ Slow (e.g., 5+ hours for a market)
Fiber backhaul design	▪ Designs greenfield/brownfield fiber routes that minimizes CAPEX	▪ *N/A*
Costs	▪ Calculates costs for nodes and fiber – very flexible, client-customized cost model	▪ *N/A*
Revenue and ROI	▪ Computes full business case, including revenues, cash flows, IRR, etc.	▪ *N/A*
Demand endpoints	▪ Flexible data model allows users to import any type of endpoint (households, businesses, mobile traffic, etc.)	▪ Coverage-based

Arrow comes preloaded with variety of datasets, requiring only target locations to be supplied by end users

	Dataset	Description and Usage	Source
Boundaries	***Census Blocks***	*Used to map each location to competition data*	*Tiger*
	Wirecenters	*Default polygons defining individual areas being analyzed*	*Geotel*
	Zip Codes	*Alternative service area for analysis*	*Tiger*
	States, CBSAs, Counties, etc.	*Reference boundaries used to conveniently select broader areas for large optimization plans*	*varies*
Competition	***FCC Form 477***	*Census-block-level broadband availability data, used to calculate each expected fair share for resi and SMB locations*	*FCC*
	Provider Fiber Routes	*Publicly available provider fiber routes, used to calculate expected fair share for enterprise and tower locations*	*Geotel*
Business Spend	***Altman Solon Telecom Spend Matrix***	*Proprietary estimates of business spend on telecom services, organized by industry, business size and telecom product*	*Altman Solon*
Wireless Signal Impedance	***Clutter***	*Used in fixed wireless optimization, defines signal degradation characteristics of a given area (30mx30m grid)*	*NASA*
Conduits	***Road Segments***	*Proxy conduits used to define which ways new fiber can go*	*OpenStreetMap*
Target Endpoints	***Residential, Business, Towers***	*Latitude and longitude of target locations to use in planning*	*client*
Network Infrastructure	***Network and Equipment Assets***	*Existing fiber and copper network, and equipment infrastructure, as needed (if at all) for accurate modeling*	*client*

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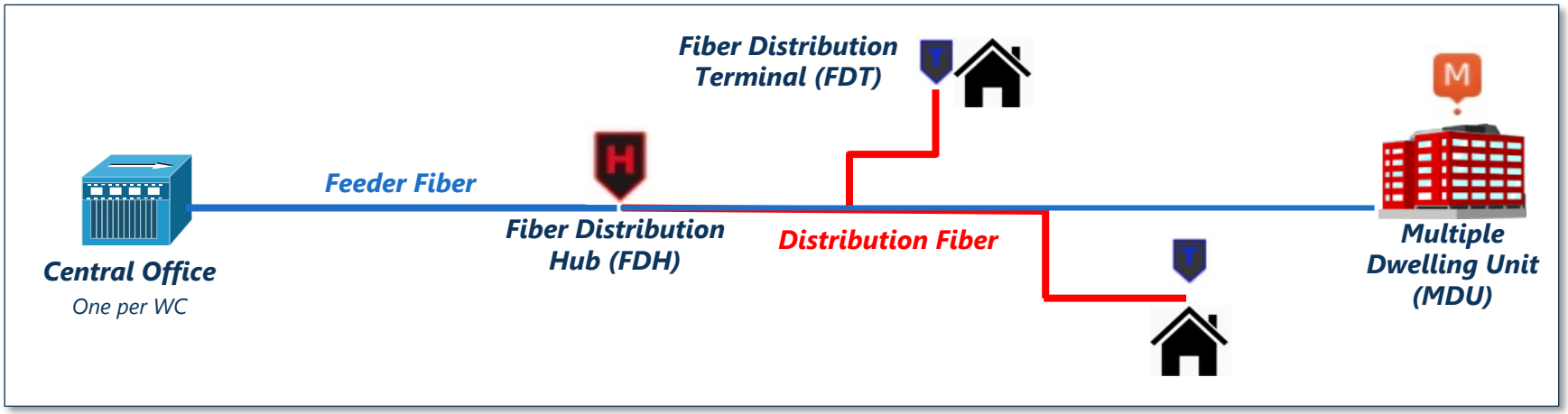
The Arrow platform uses the following network architecture for FTTP deployments

FTTP Network Architecture



Element	Central Office	Fiber	FDH	FDT	MDUs
Description	• Hub which a conglomerate signal is distributed to optical nodes in neighborhoods or prem locations • Carries voice, data, and/or video services to end users	• **Feeder Fiber**: Cable that connects the CO to the FTH splitter • **Distrib. Fiber**: Cable running from the FDH splitter to the customer premise	• Splits the feeder cable into distribution cables to go to customer premises • Includes FDH to hold splitter	• Interconnect between the fiber optic distribution network and drop cables connecting customer prems	• Provides connection from network to MDU • One required per building, generally placed in the basement • Additional equipment required for each prem
Cost Components	• Inter-office facilities • Fiber distribution frame • Power, space, frame • Ops support system	• Materials • Labor	• Splitter materials and labor • Fiber distribution hub materials and labor	• Materials	• Equipment • Installation

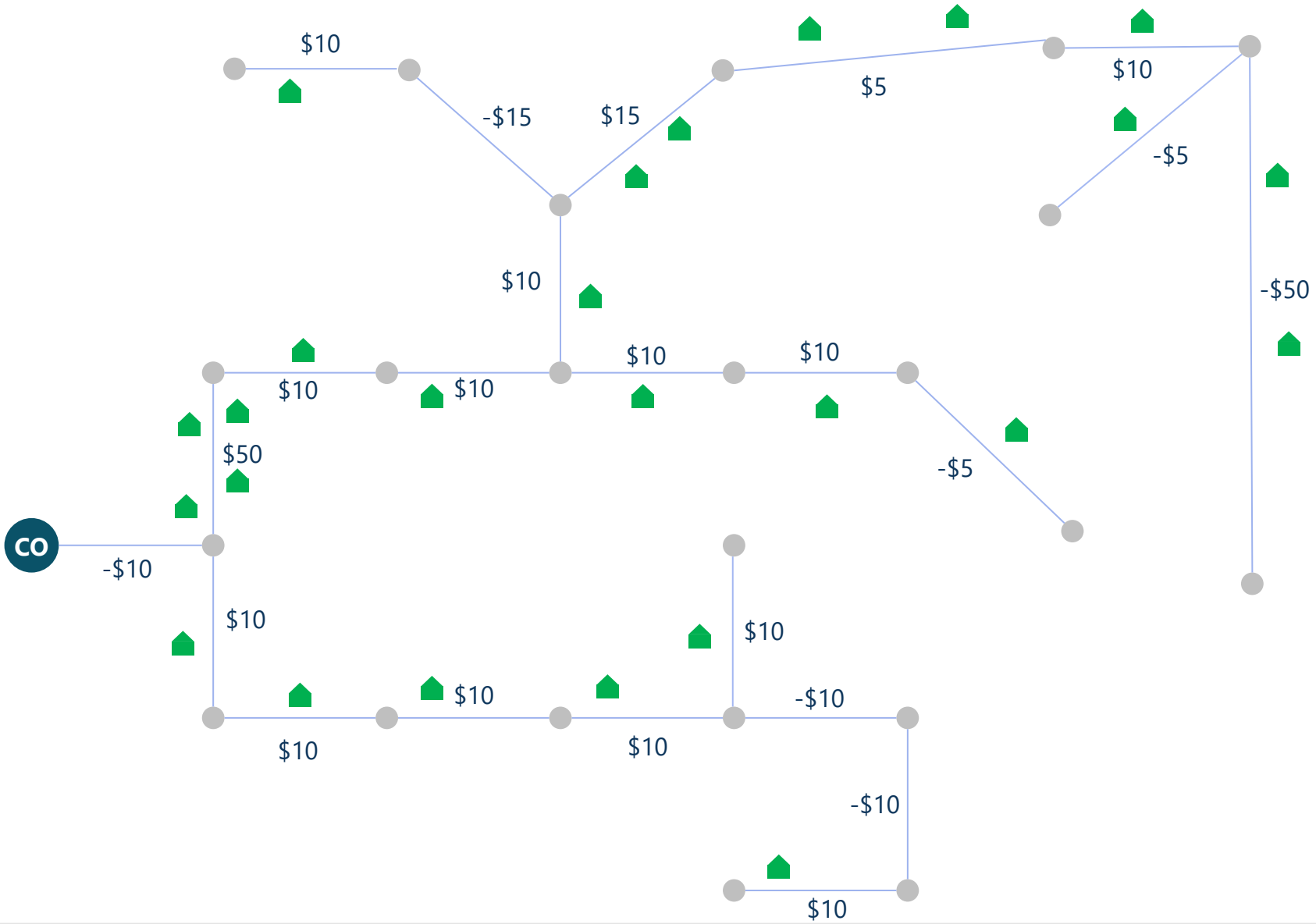
Sources: Altman Solon Research & Analysis

In determining where to build hub and spoke networks, Arrow uses the following optimization process

Initial Network Generation	Pruning	Final Network Generation
Construct minimum cost full network (using Minimum Spanning Tree algorithm)	**Sequentially remove the "worst-scoring" nodes** until all nodes have been removed	**Generate lowest cost network** for the set of resulting target locations selected in the previous step
Score each network node (CO, FDH, etc.), by calculating IRR for each one of them	Determine which pruning step **satisfies optimization criteria** (i.e. which network nodes to keep to meet plan IRR, coverage, or budget target)	
	Use equipment node information from that step to **finalize target locations** (i.e. which locations end up being routed to)	

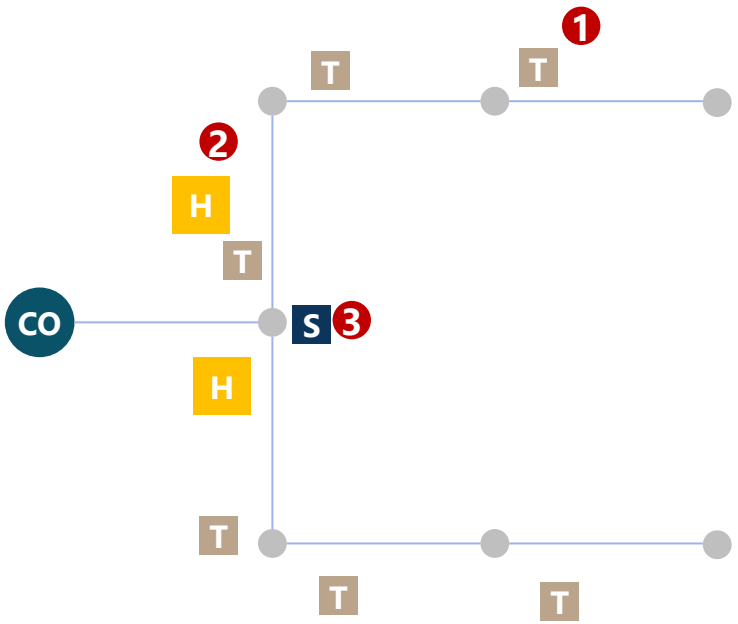
? ***Tip:*** *Detailed explanation of the algorithm can be found in the appendix*

The following layout to illustrates functioning initial network layout and corresponding values of each segment



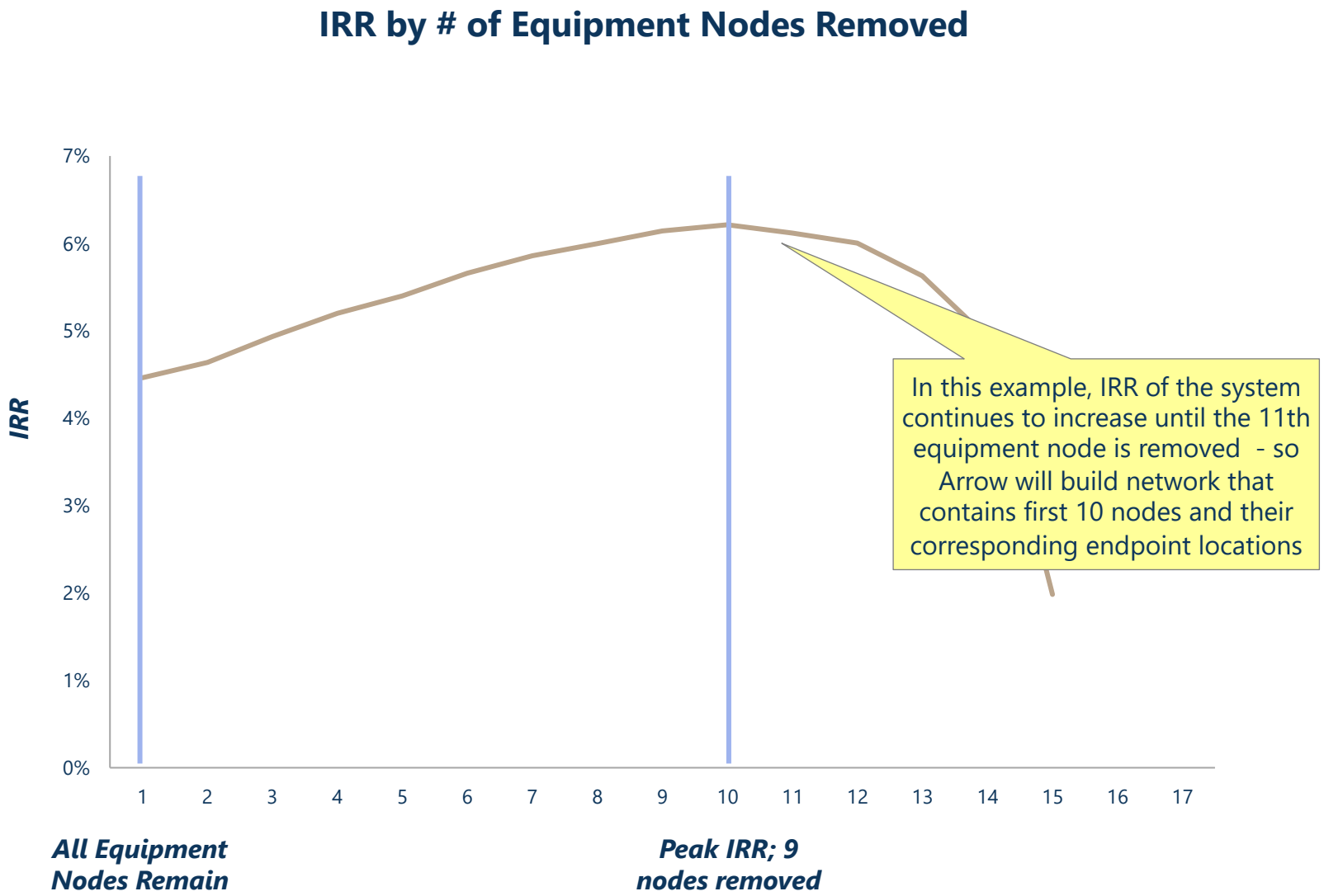
Optimization Logic - Pruning

1. Calculate the marginal IRR of each equipment node in the service area based on marginal CapEx and downstream cash flows
2. Repeat sequentially, by removing lowest IRR nodes and recalculating IRRs of the affected nodes
3. Repeat until stop constraint is hit:
   - For Max IRR <u>without</u> a budget constraint, the stop constraint is the peak system IRR (the next node removed will lower the IRR of the total graph)
   - For Max IRR <u>with</u> a budget constraint, the constraint stops removing nodes once system is under the budget constraint



	Marginal CapEx	Downstream Cash Flow
1 T	• *Cost of placing additional fiber to reach this FDT from the FDT upstream* • *Cost of FDT equipment*	• *All downstream entity cash flows (connect CapEx, revenue and costs)*
2 H	• *Cost of placing additional fiber to reach the FDH* • *Cost of the FDH equipment*	• *All downstream cash flows (from the FDTs and entities downstream)*
3 S	• *Cost of placing additional fiber to reach this splitter* • *Splice point cost*	• *All downstream cash flows (from the FDTs/FDHs downstream)*

In the last step, Arrow will generate lowest cost network for the set of target locations addressed by remaining nodes



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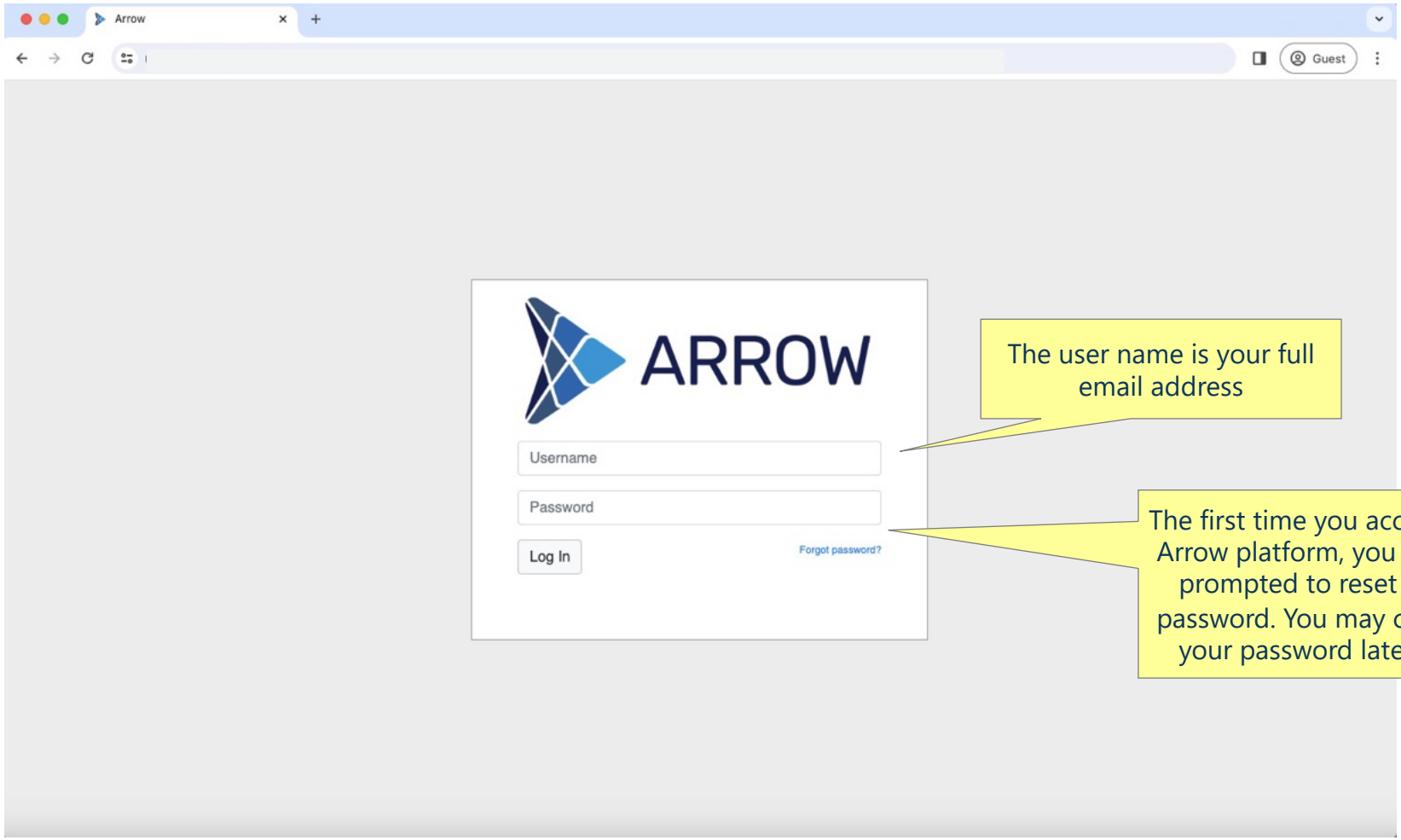
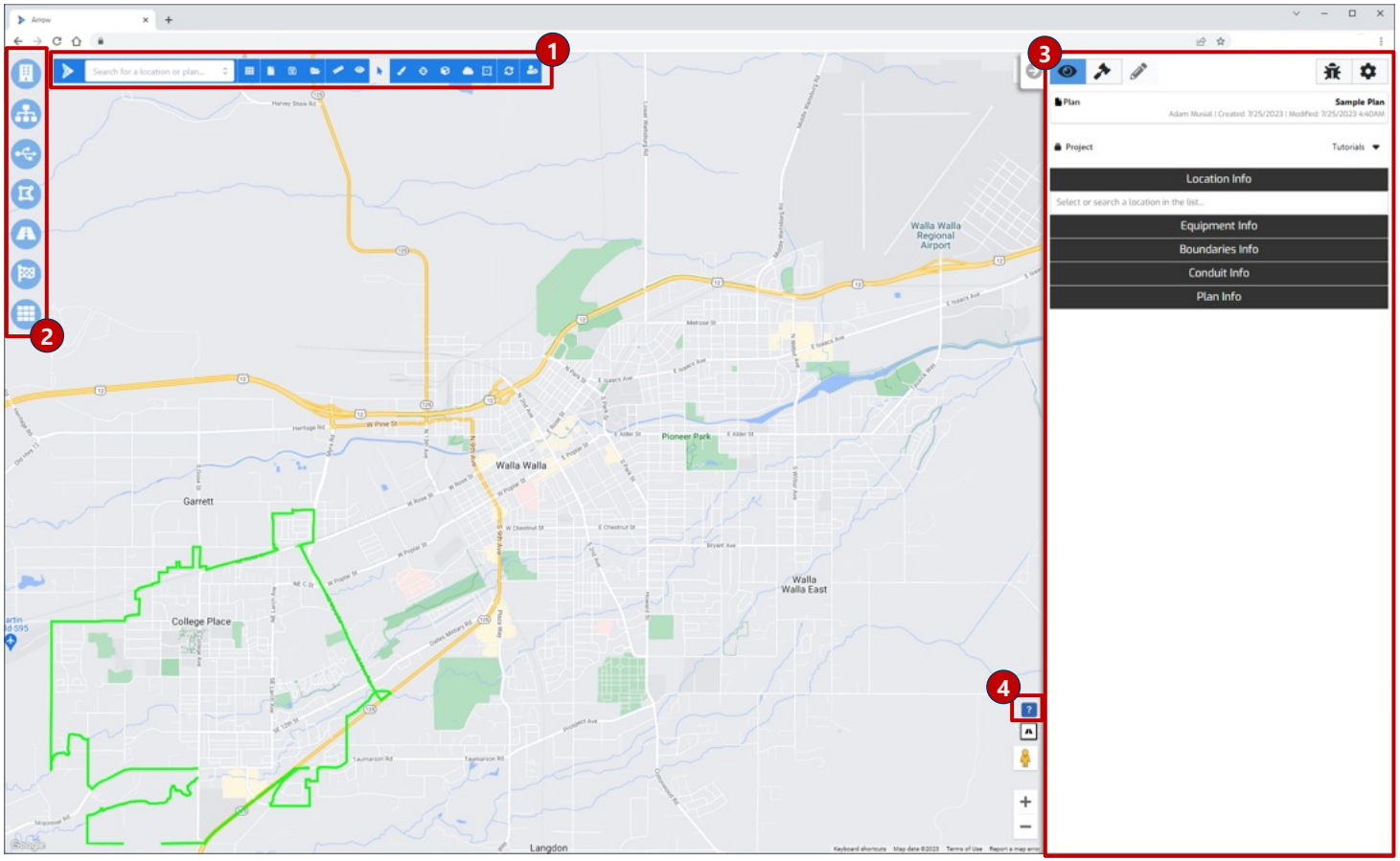
You will receive Arrow access link (password reset) in your inbox



Tip: *For best performance, please use Google Chrome*

Arrow controls are located in three key areas of the screen: Header Bar, Visualizations Modal and the Analysis Panel



1. Header Bar –Displays shortcuts to useful UI tools (e.g., search), plans, and key settings

2. Visualization Modal – Controls which data layers and features are displayed on the map

3. Analysis Panel – Used for:

- Inspecting details of individual data layers (View Mode)
- Setting up new optimizations (*Analysis Mode*)
- Adjusting data and resource selection for individual plans (*Settings*)

4. Help Center – Opens up a panel with links to additional training, troubleshooting and support resources

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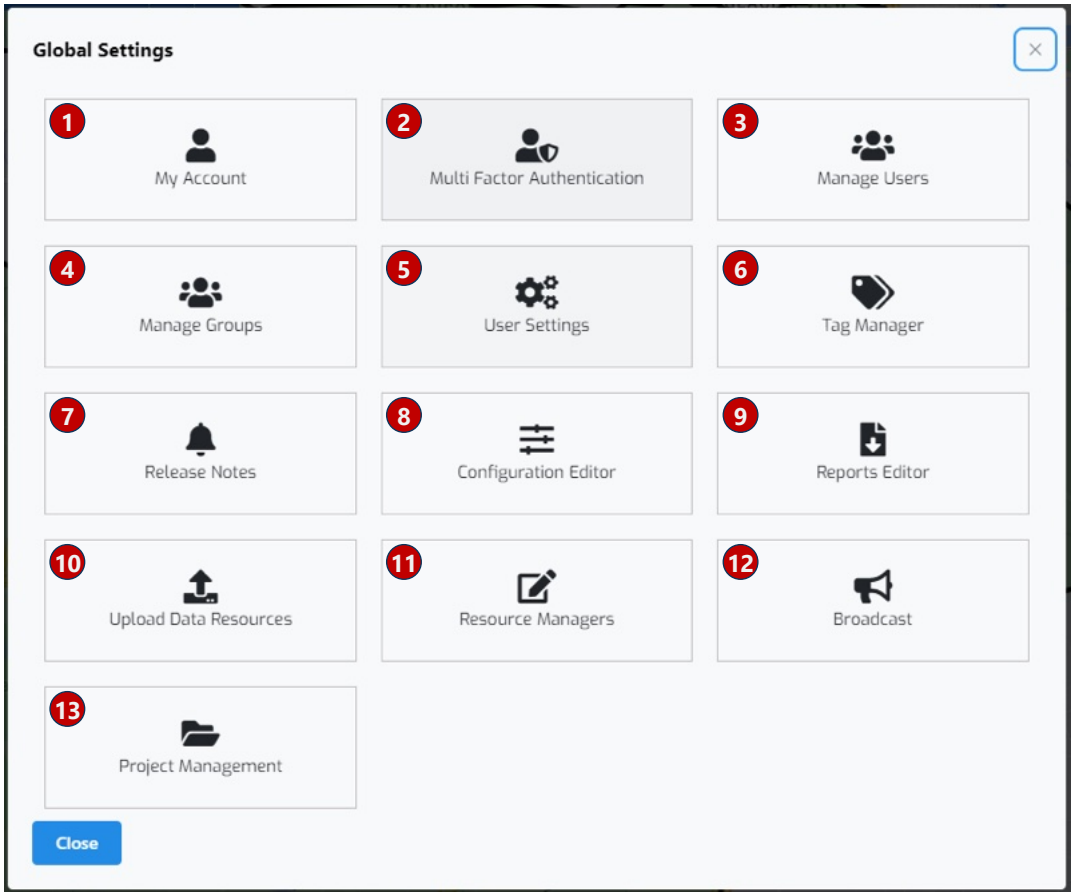
Header Bar displays shortcuts to useful UI tools, plans, and key settings

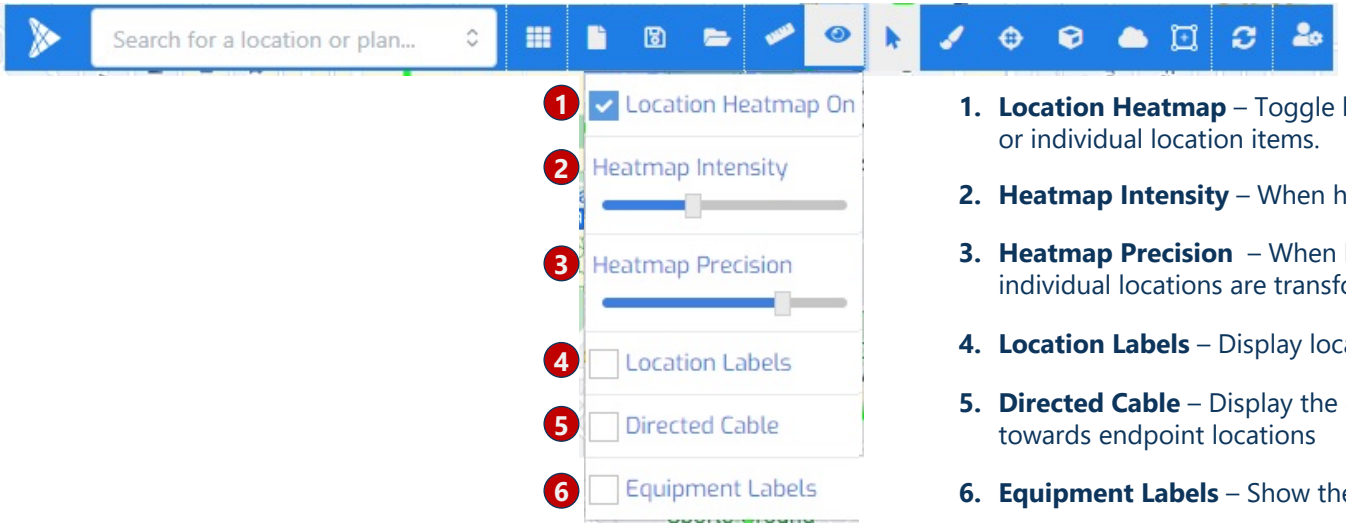
1. **Search** – Global search box where users can search for saved plans, addresses and geographical coordinates. Users can toggle which categories are searched.
2. **Global Settings** – Allows users and platform administrators manage key platform settings and permissions *(details on the following pages)*
3. **Create New Plan**– Shortcut to New plan creation panel
4. **Save Plan** – Saves the plan to make the analysis permanent
5. **Open Existing Plan** – Opens existing plan
6. **Ruler** – Measures distance between points on a map (straight line or along road segments)
7. **View Settings** – Control how certain data features appear on the map *(details on the following pages)*
8. **Selection Tool** – *(visible only inside Analysis Panel)* Locations selection tool
9. **Multi-Selection Tool** – *(visible only in Analysis Mode)* Selects multiple locations or service areas for analysis by drawing a polygon on a map
10. **Annotations** – Draws temporary lines or polygons on the map to track progress or illustrate an analysis
11. **Coverage Boundary Calculator** – *(visible only in View Mode)* Calculates number of locations within specified distance from a point selected on a map. Distance is calculated along the road segments, not straight line.
12. **Boundary Reports** – *(visible only in View Mode)* Opens Boundary Reports modal where user can download custom reports for their coverage boundaries
13. **Copy Locations from Plan –** *(visible only inside a saved plan)* Enables you to copy selected locations from another plan. Note that you must ensure the new plan has the same location data layer selected from which you are copying.
14. **RFP Plans** – Accesses the panel for submitting and retrieving RFP plans and reports (submitted though the panel or Arrow APIs)
15. **Edit Plan Service Area** – *(visible only inside a saved plan)* Temporarily adjust the service area boundary (in the context of a saved plan), for example, to capture additional locations that are originally outside of the serving area
16. **Refresh Tiles** – Refreshes map vector tiles
17. **Account Settings** – Shortcut to user account settings and app logout

Global Settings allow users and platform administrators to manage key platform settings and permissions



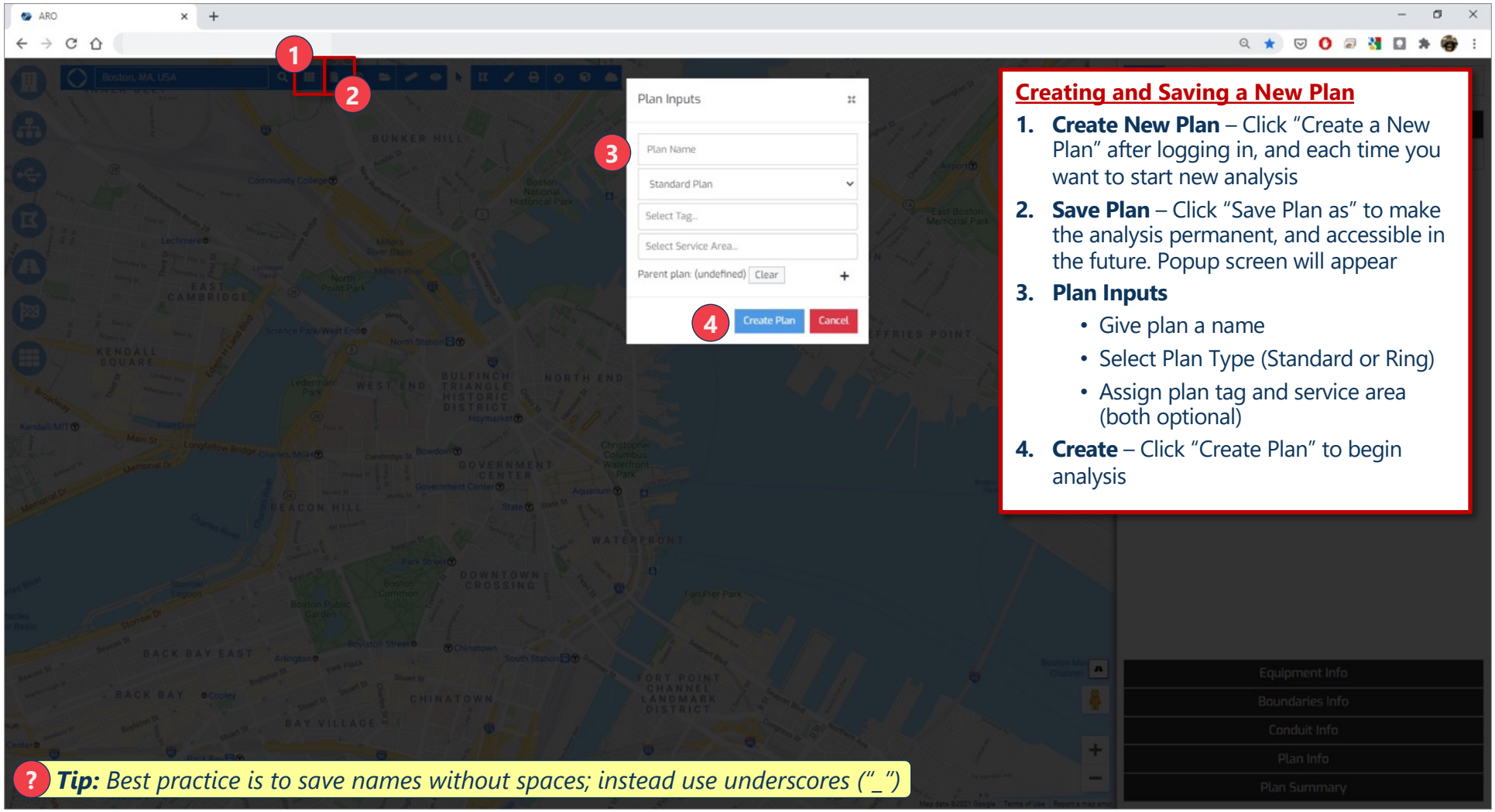
1. **My Account** – Change password
2. **Multi-Factor Authentication** – Manage MFA settings
3. **Manage Users** – [Administrators only] Manage users and their permissions
4. **Manage Groups** – [Administrators only] Manage groups and their permissions
5. **User Settings** – Set default Project template and map start location
6. **Tag Manager** – Manage plan tags
7. **Release Notes** – List recent app upgrades and enhancements
8. **Configuration Editor** – [Administrators only] Manage various aspects of UI display
9. **Reports Editor** – [Admin only] Manage reports available for download after the plan is run
10. **Data Upload** – Shortcut to Data Upload manager
11. **Resource Editor** – Shortcut to Resources manager
12. **Broadcast** – [Administrators only] message other Arrow users logged into the system (e.g., to announce upcoming downtime)
13. **Project Management** – Manage Project templates

View Settings control how certain data features appear on the map

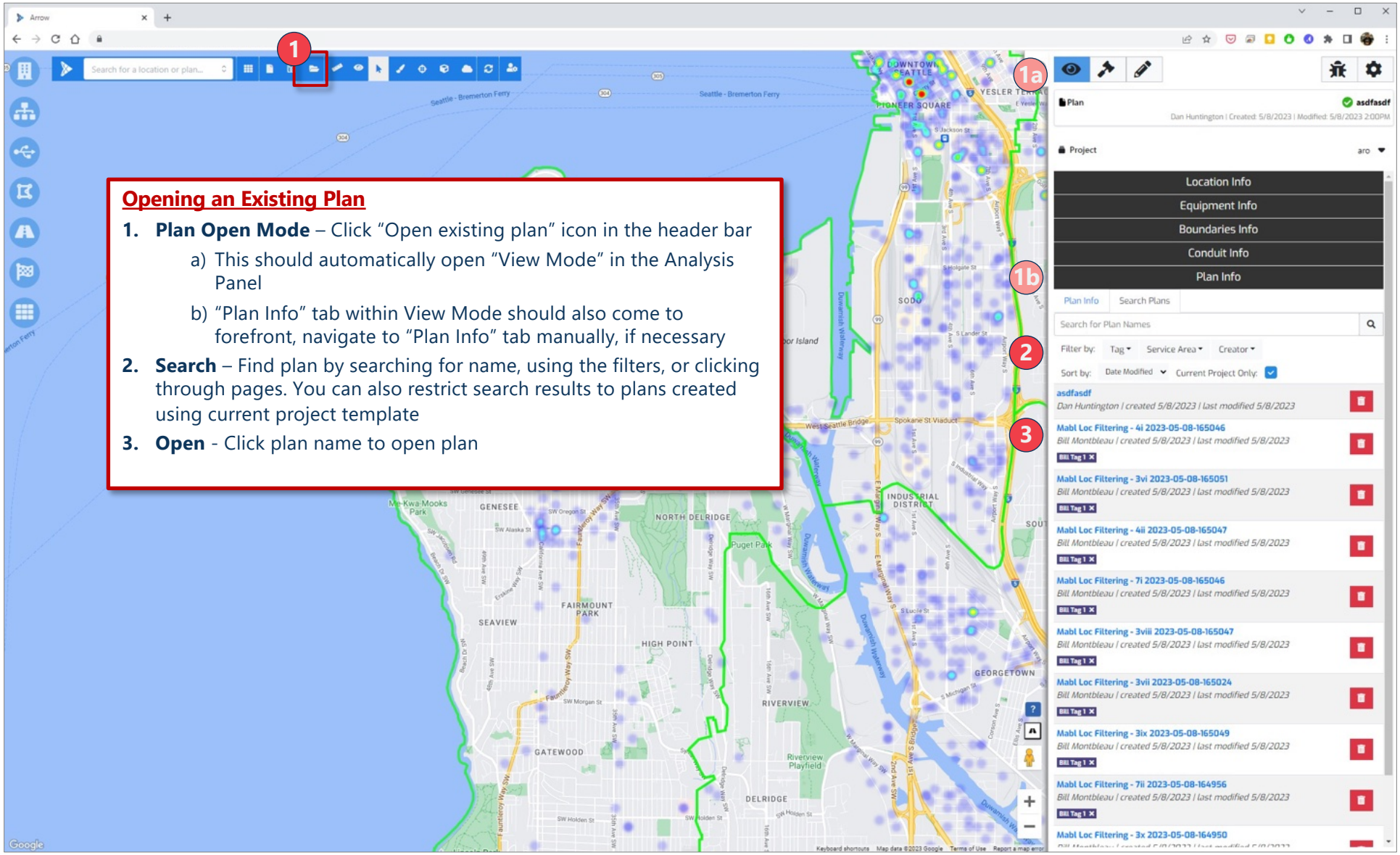


1. **Location Heatmap** – Toggle between displaying location data as a heatmap or individual location items.
2. **Heatmap Intensity** – When heatmap is enabled, it controls its intensity
3. **Heatmap Precision** – When heatmap is enabled, it controls how precisely individual locations are transformed into the heatmap source
4. **Location Labels** – Display location labels on the map
5. **Directed Cable** – Display the direction of the cable, from Central Office towards endpoint locations
6. **Equipment Labels** – Show the site CLLI of each equipment on the map

Creating New Plan is a necessary first step for running plans with



Saved plans can be accessed through Plan Info tab in the View Mode



Opening an Existing Plan

1. **Plan Open Mode** – Click "Open existing plan" icon in the header bar
   a) This should automatically open "View Mode" in the Analysis Panel
   b) "Plan Info" tab within View Mode should also come to forefront, navigate to "Plan Info" tab manually, if necessary
2. **Search** – Find plan by searching for name, using the filters, or clicking through pages. You can also restrict search results to plans created using current project template
3. **Open** - Click plan name to open plan

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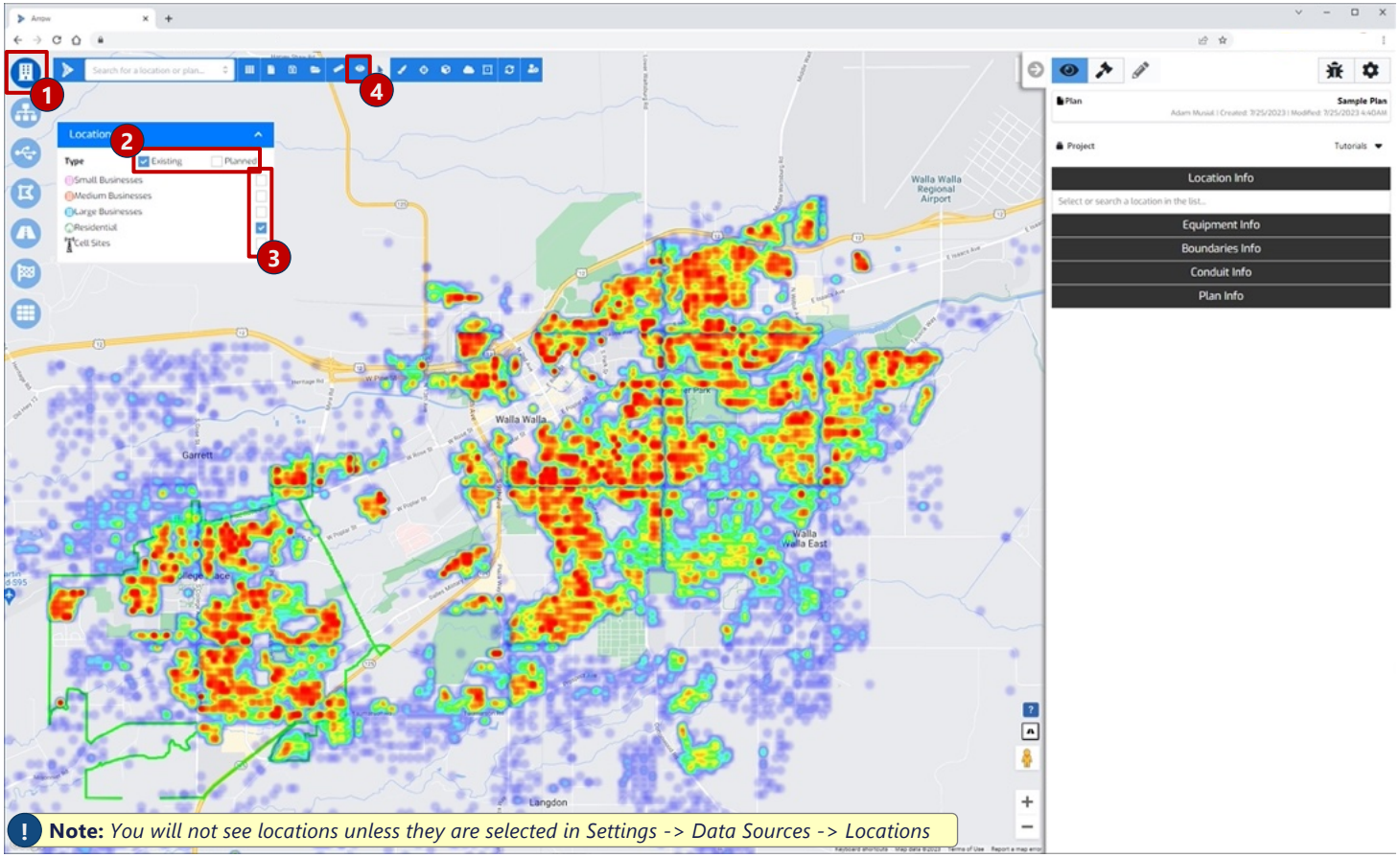
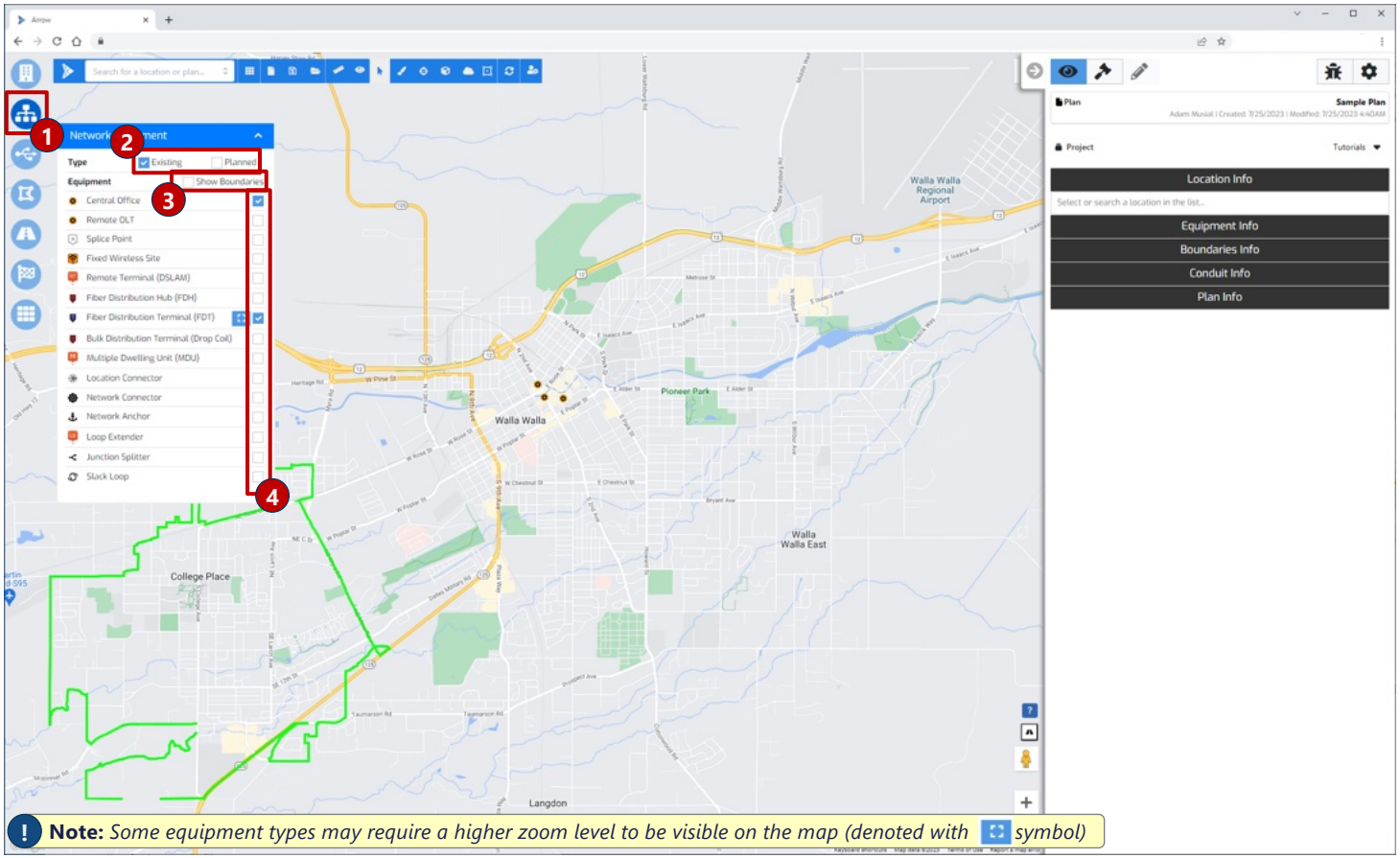
Locations modal is where a user can turn location categories on and off to visualize on the map



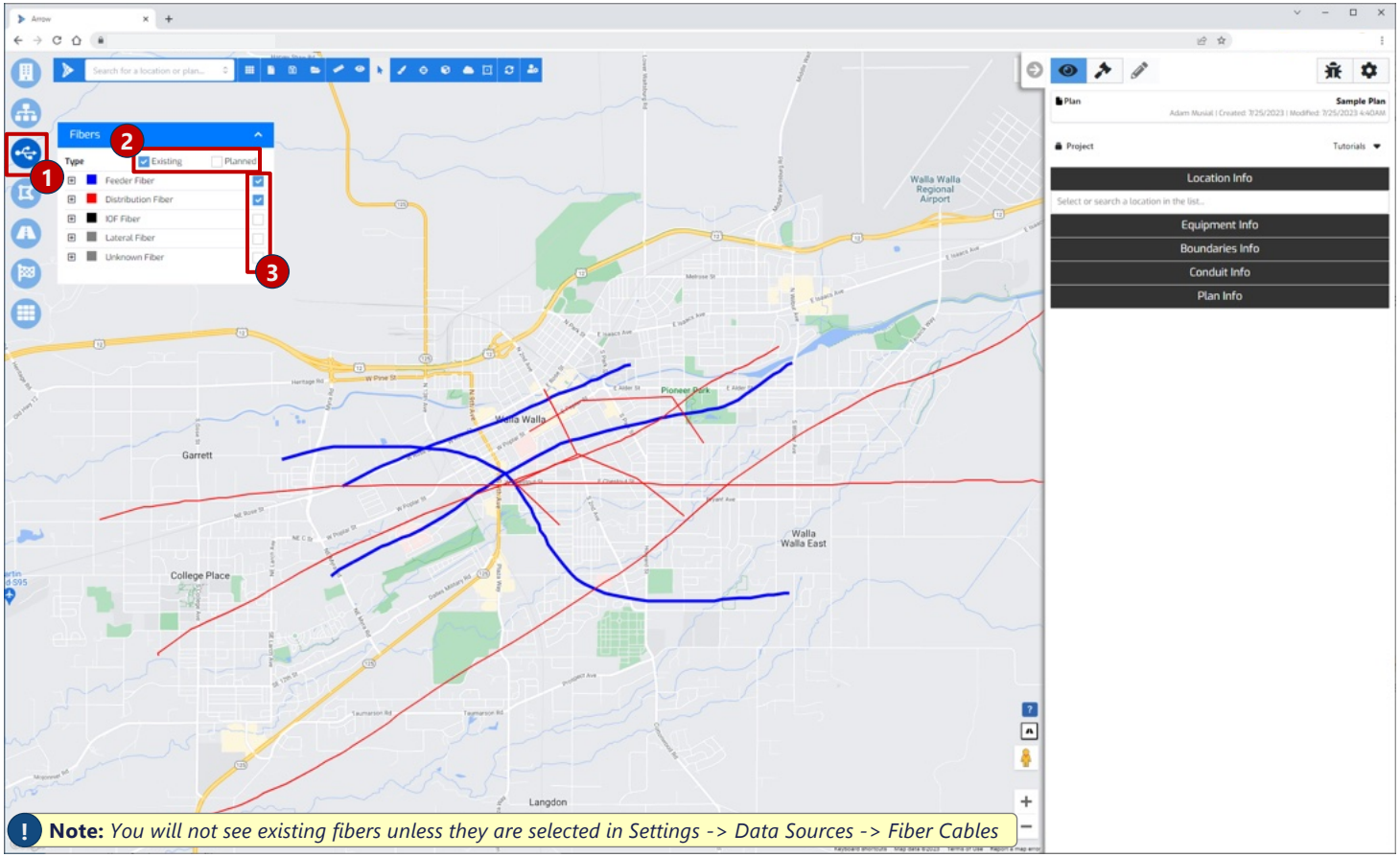
1. **Open Modal** – Select "Locations" button to open the modal
2. **Existing vs. Planned** – Toggle viewing existing and/or planned locations
   Note: Planned locations only show up for RFP plans
3. **Endpoint Selection** – Select the checkbox corresponding to the desired location type(s)
4. **Heatmap** – Toggle location heatmap off/on to see the individual locations or heatmap rendering

Network Equipment modal is where a user can turn on equipment layers to view on the map



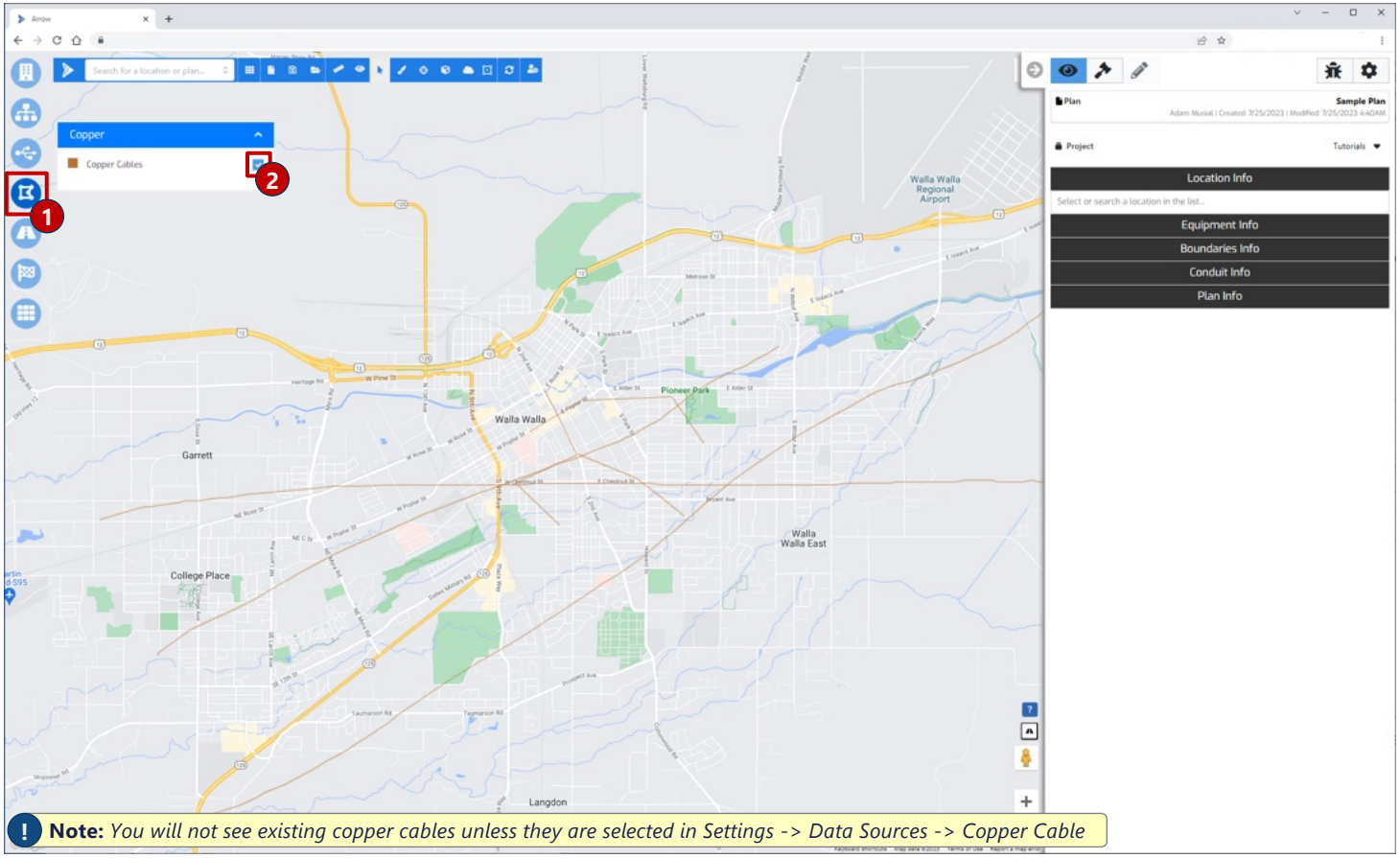
1. **Open Modal** – Select "Network Equipment" button to open the modal
2. **Existing vs. Planned** – Toggle viewing existing and/or planned network equipment
3. **Show Boundaries** – Display site boundaries on the map
4. **Equipment Selection** – Toggle specific equipment types to bring into the view

Fibers modal is where a user can turn on cable layers to view on the map



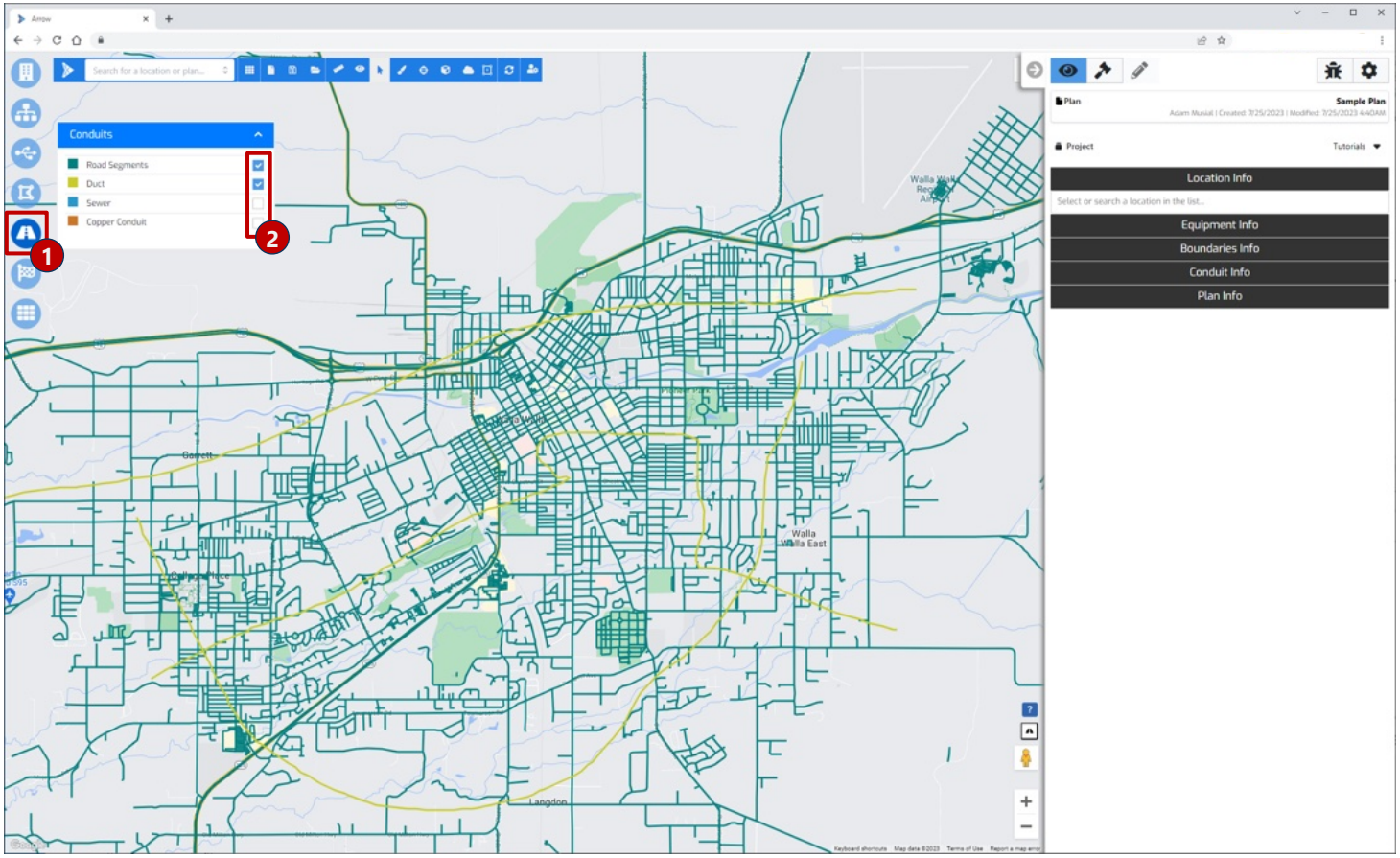
1. **Open Modal** – Select "Fibers" button to open the modal
2. **Existing vs. Planned** – Toggle viewing existing and/or planned fibers
3. **Fiber Selection** – Toggle specific fiber types to bring into the view

Copper modal is where a user can turn on existing copper layers to view on the map for reference



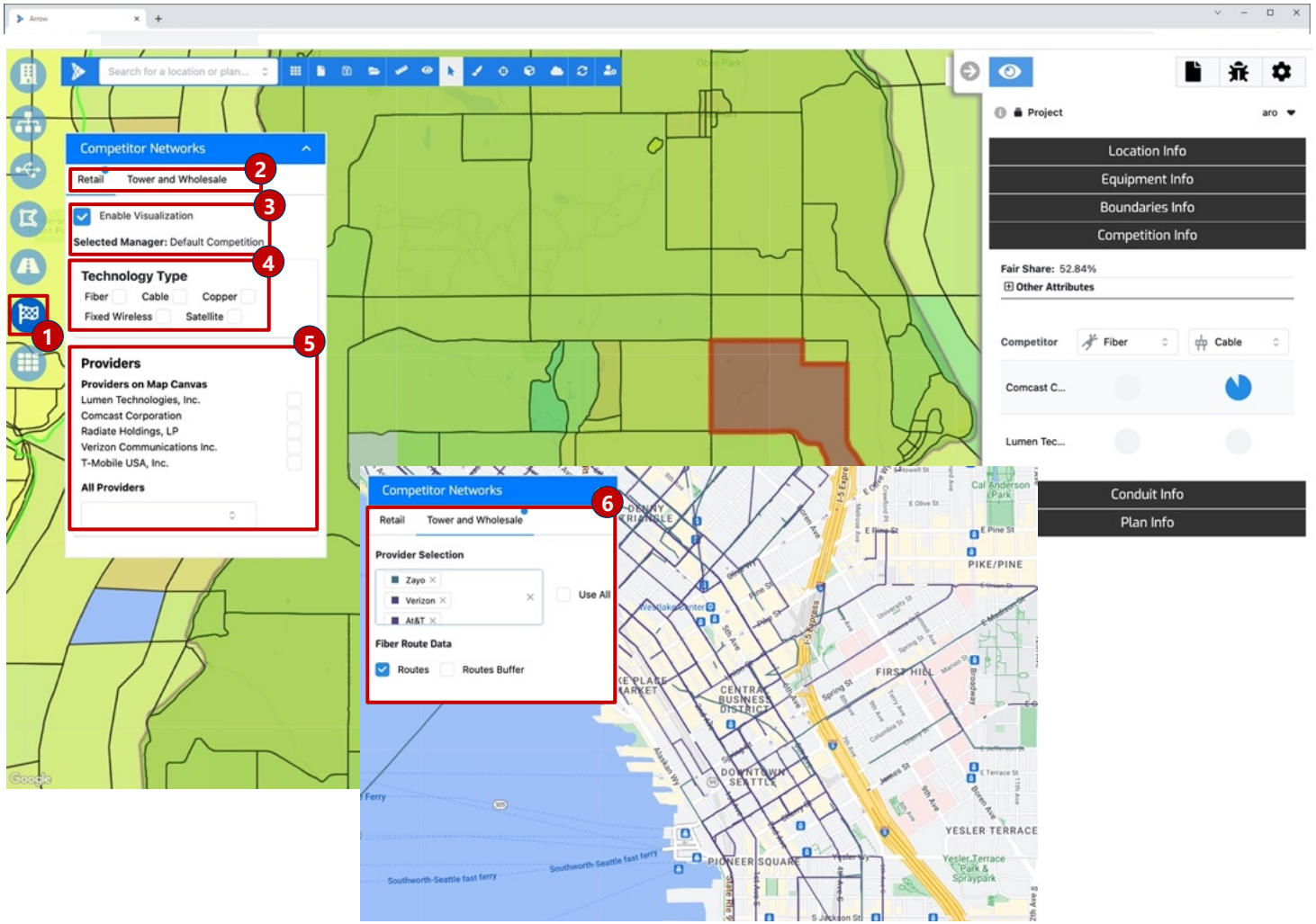
1. **Open Modal** – Select "Copper" button to open the modal
2. **Copper Selection** – Toggle cable visualization on/ off

Conduits modal is where a user can visualize road segments and other conduit types, along which new network can be planned



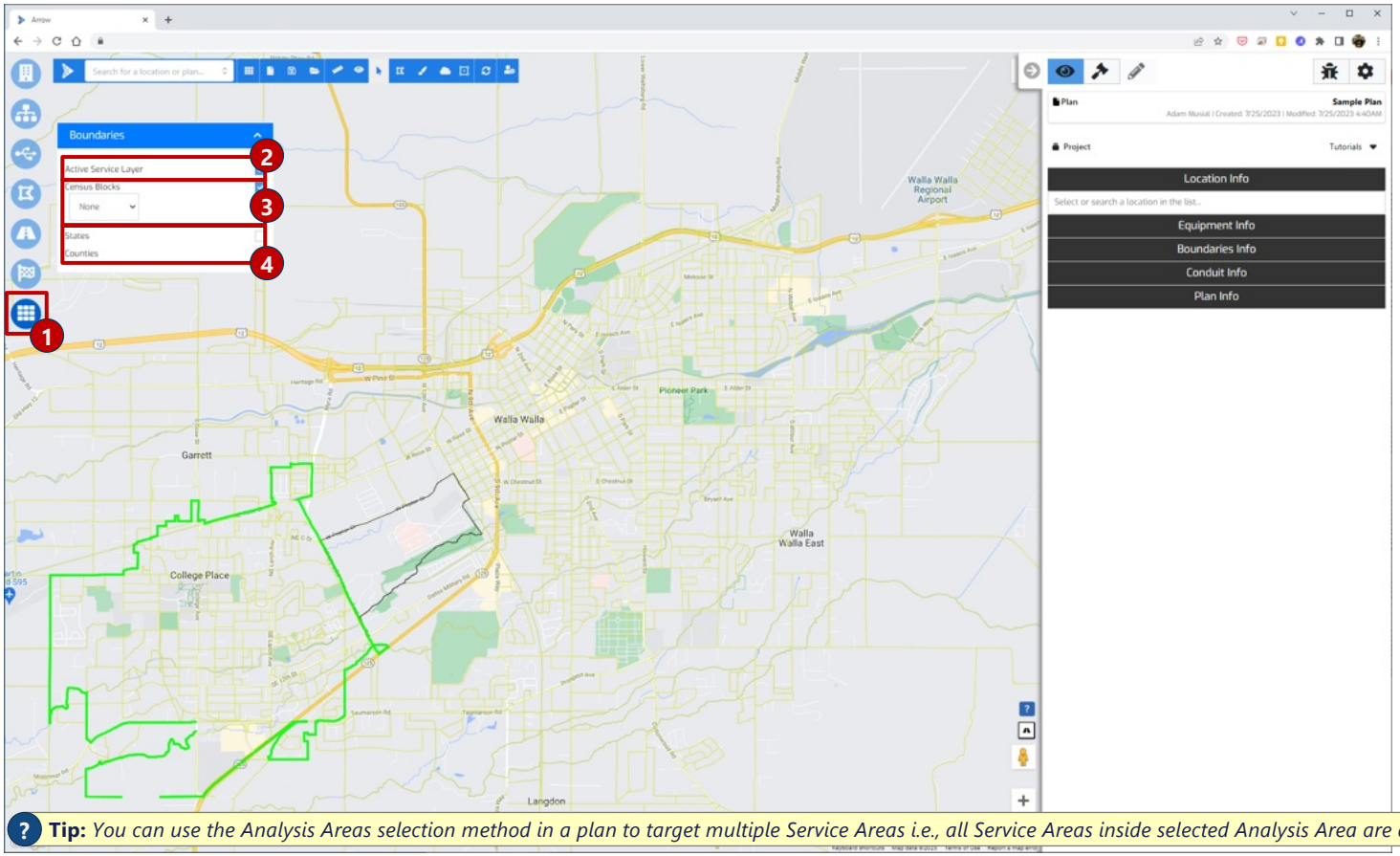
1. **Open Modal** – Select "Conduits" button to open the modal
2. **Cable Selection** – Toggle specific conduits layers to bring into the view

Competition modal visualizes FCC BDC and GeoTel provider data that comes preloaded with Arrow



1. **Open Modal** – Select "Competition Networks" button to open the modal
2. **Competitor Type** – Select between Retail or Tower and Wholesale. Retail is based on FCC BDC data and Tower and Wholesale is based on GeoTel data.
3. **Enable Visualization** – Turn on the heat map based on the Competition Resource Manager that is currently selected. The color gradient varies from green for limited competition and high fair share to red for intense competition and low fair share.
4. **Technology Type**– Filter based on the provided technology
5. **Providers** – Filter based on specific providers
6. **Tower and Wholesale**– Visualize Fiber Routes for all or select providers in the area

Service Areas and reference boundaries (Analysis Areas) can be toggled on and off from the Boundaries modal



1. **Open Modal** – Select "Boundaries" button to open the modal
2. **Active Service Layer** – Toggles on/off rendering of service area boundaries selected in Service Layer data selection
3. **Census Blocks** – Renders 2020 Census Blocks, for reference
4. **Analysis Areas** – States, Counties and any other boundaries loaded below can be visualized and used in plan target selection as Analysis Area

Note: Having a boundary switched on is necessary for running plans targeting "Service" and "Analysis" Areas, but not when targeting individual locations

Tip: *You can use the Analysis Areas selection method in a plan to target multiple Service Areas i.e., all Service Areas inside selected Analysis Area are automatically selected.*

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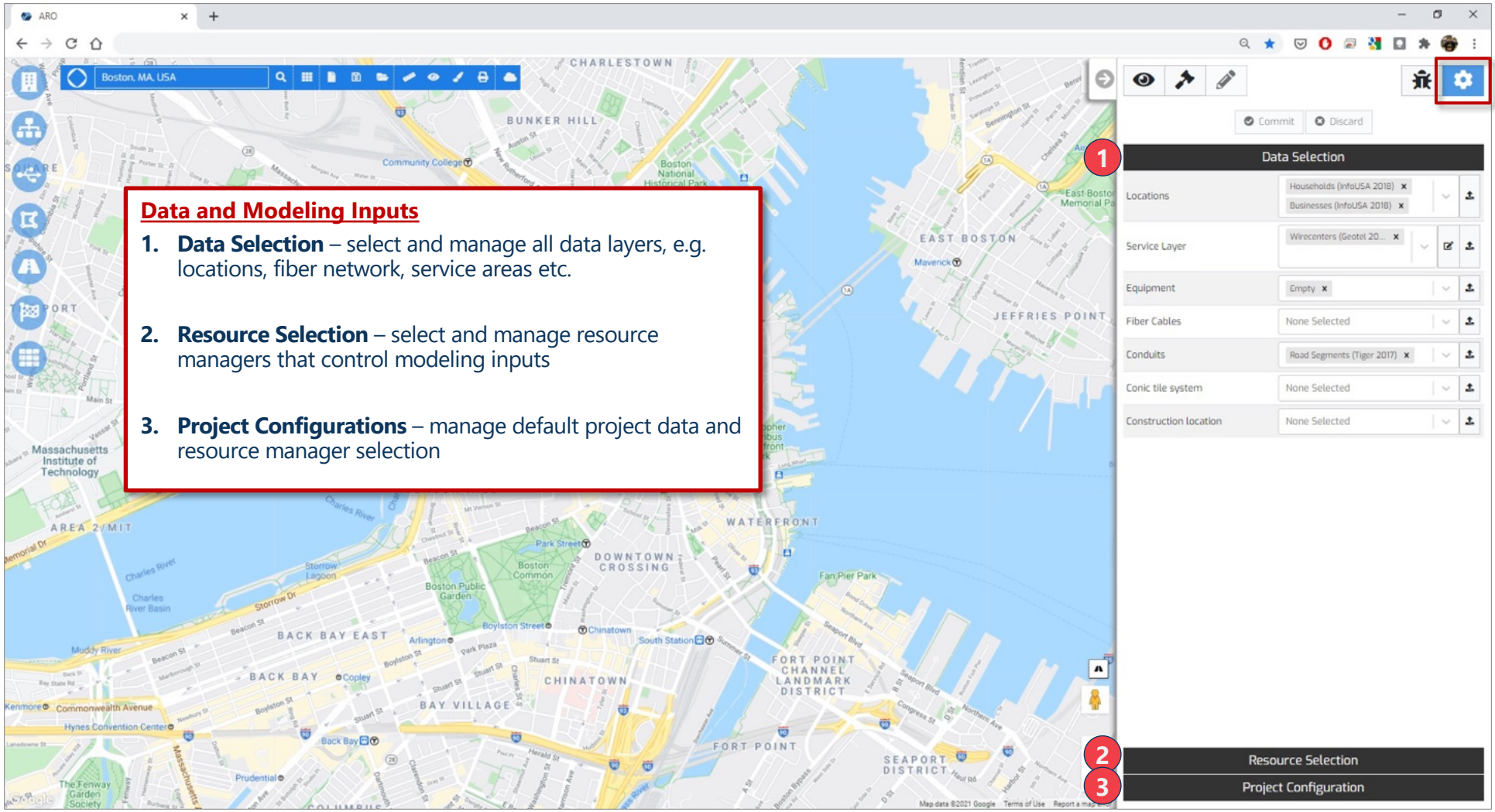
Data and Resources selected in Setting section of the Analysis Pane determine is available for Arrow to use during optimization runs



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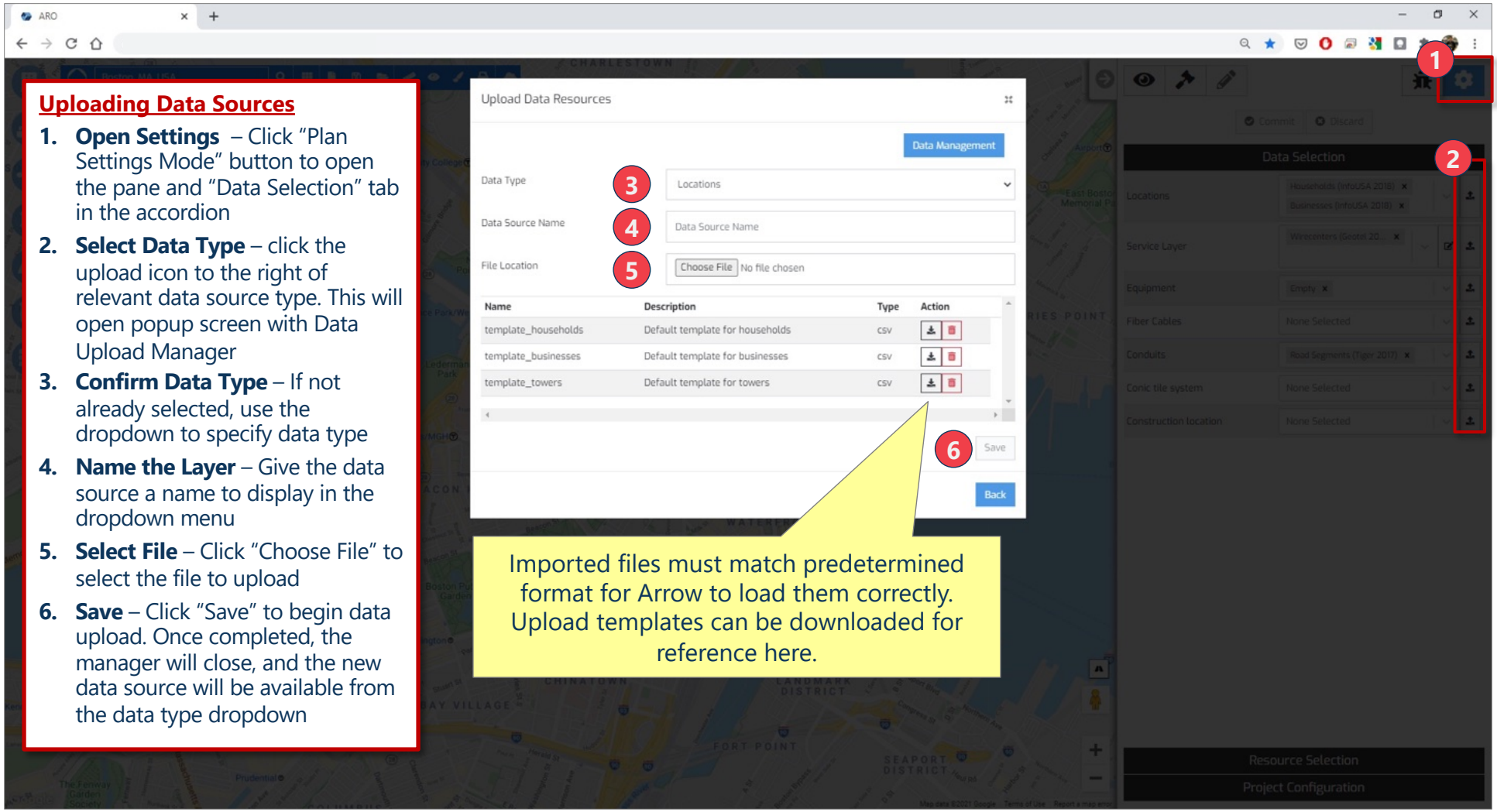
User data can be imported to Arrow via upload templates

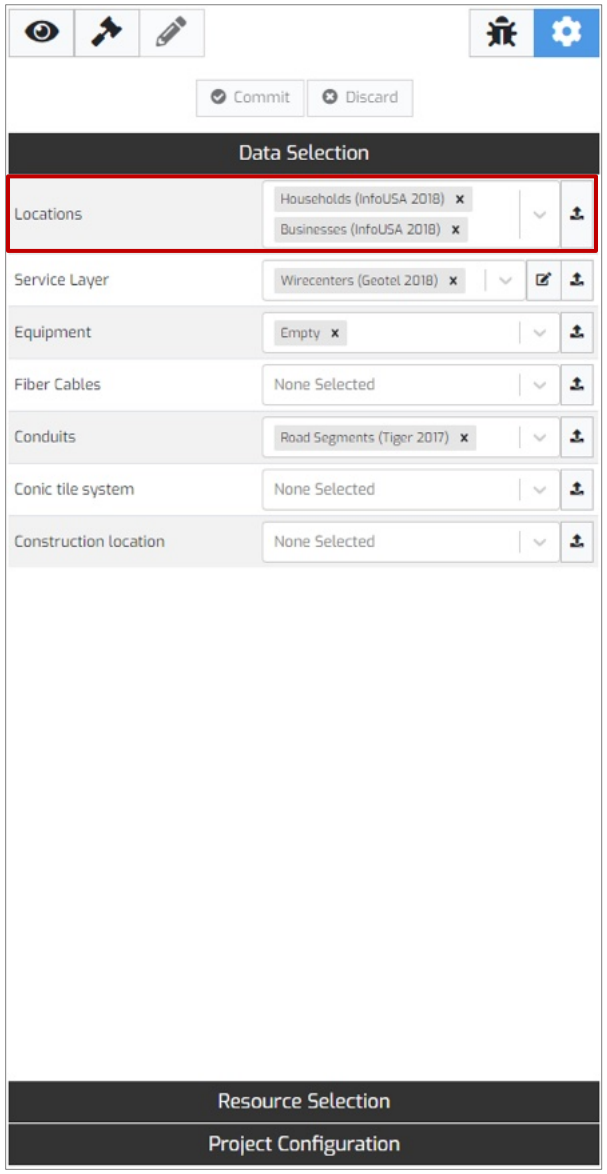


Uploading Data Sources

1. **Open Settings** – Click "Plan Settings Mode" button to open the pane and "Data Selection" tab in the accordion
2. **Select Data Type** – click the upload icon to the right of relevant data source type. This will open popup screen with Data Upload Manager
3. **Confirm Data Type** – If not already selected, use the dropdown to specify data type
4. **Name the Layer** – Give the data source a name to display in the dropdown menu
5. **Select File** – Click "Choose File" to select the file to upload
6. **Save** – Click "Save" to begin data upload. Once completed, the manager will close, and the new data source will be available from the data type dropdown

Imported files must match predetermined format for Arrow to load them correctly. Upload templates can be downloaded for reference here.

Users can upload three types of locations: Households, Businesses and Towers



Location Type	Field	Required?	Type	Value
Households	entity_category_id	✓	String	• household
	lat	✓	Float	
	longitude	✓	Float	
	number_of_households	✓	Integer	• <12 for SFUs • 12+ for MDUs
Businesses	entity_category_id	✓	String	• business
	lat	✓	Float	
	longitude	✓	Float	
	number_of_employees	✓	Integer	
	industry_id	✓	Integer	• SIC4 Code • Use 5099 where unknown
Towers	entity_category_id	✓	String	• celltower
	lat	✓	Float	
	longitude	✓	Float	

MDU threshold can be adjusted in Network Architecture Manager

Additional location attributes can be stored by including their values immediately to the right of the required columns. Column header will be used as attribute name

Furthermore, when uploading locations, users have the ability to override global ROIC and ARPU Resource Managers settings with values specific to individual locations, e.g. different BAU or Plan ARPU for each location

Complete list of override fields is available in the upload template accessible from the locations upload window

Number of optional fields can be provided to override global location settings and provide users with granular control over settings

BAU Case Settings:

ROIC.BAU.START_PENETRATION – Current subscriber penetration of legacy product (0.00 – 1.00 value range)

ROIC.BAU.MONTHLY_ARPU – ARPU for legacy product (0.0001+ value range)

ROIC.BAU.FAIR_SHARE – Used to prescribe terminal fair share value of legacy product (0.0001 – 1.00 value range)

Plan Case Settings

ROIC.PLAN.MONTHLY_ARPU – ARPU for the new fiber product (0.0001+ value range) *(Note: Revenue fields are only used when ARPU manager is set to 'Location Layer' strategy)*

ROIC.PLAN.FAIR_SHARE – Used to prescribe fair share value of planned fiber network (0.0001 – 1.00 value range)

ROIC.PLAN.SUBSIDY – Known one-time subsidy amount to be received by connecting given location

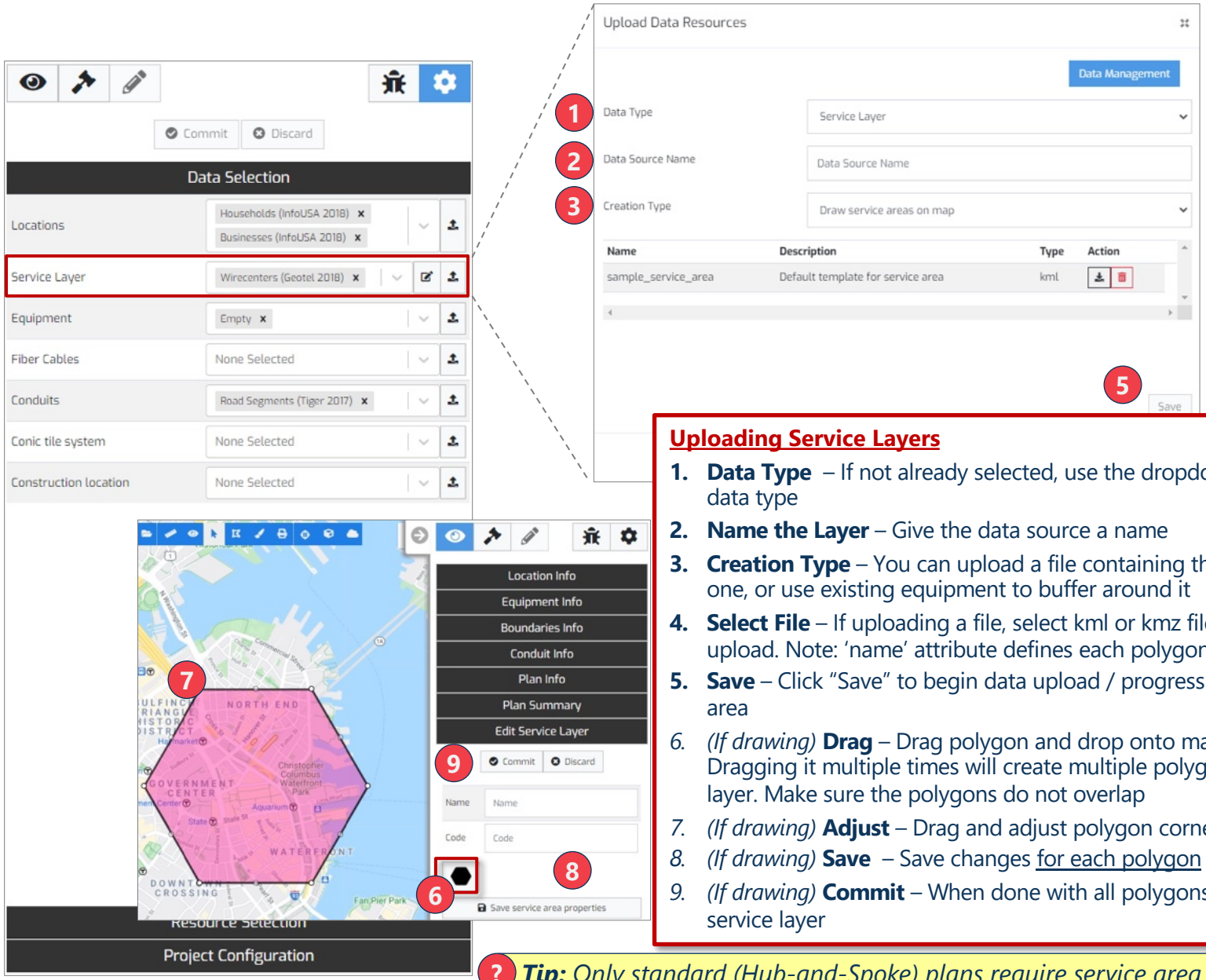
grant_eligible – 0 or 1 *(binary)*, to specify whether location is eligible for subsidies *(when using Subsidy feature)*

comp_object_id – location id from BDC/FCC/CostQuest to enable location-level competition evaluation

Note:

- Include only the overrides you wish to use *(i.e. do not upload files with column headers containing no content below)*
- When using any of the above overrides, do not leave any cells blank or otherwise invalid *(i.e. every column needs to be fully populated)*
- Do not apply any custom formatting to values in these fields *(e.g. $ or , signs will prevent Arrow from converting these text strings to usable numeric inputs)*

Users can define their own service layers to match their exchange

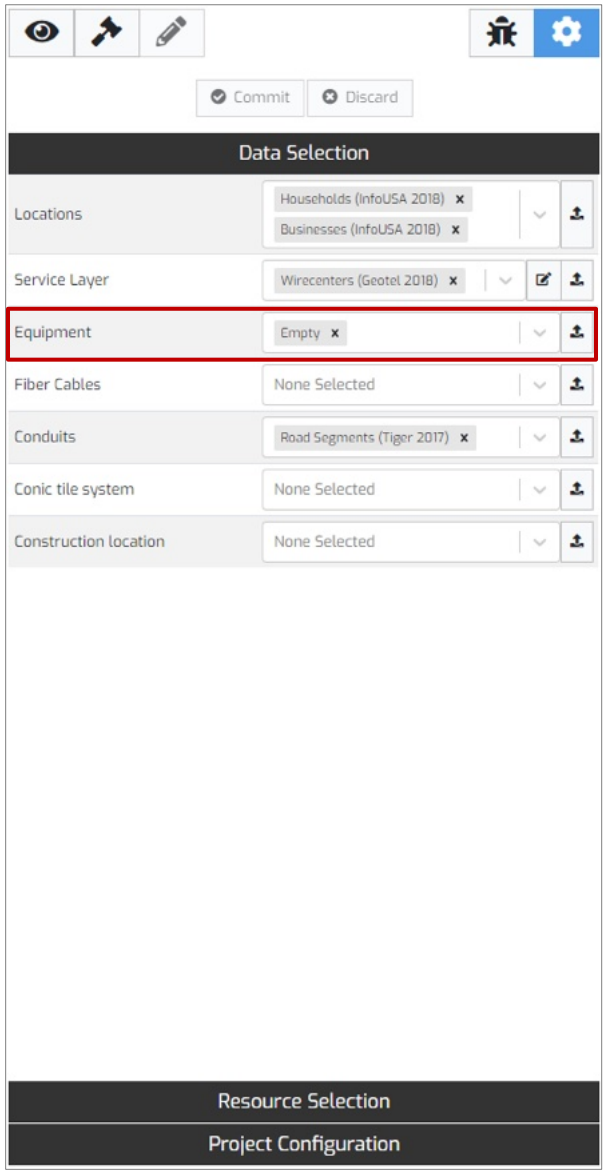


Uploading Service Layers

1. **Data Type** – If not already selected, use the dropdown to specify "Service Layer" data type
2. **Name the Layer** – Give the data source a name
3. **Creation Type** – You can upload a file containing the boundaries, manually draw one, or use existing equipment to buffer around it
4. **Select File** – If uploading a file, select kml or kmz file with polygon features for upload. Note: 'name' attribute defines each polygon / area's name.
5. **Save** – Click "Save" to begin data upload / progress to drawing your own service area
6. *(If drawing)* **Drag** – Drag polygon and drop onto map to create new service area. Dragging it multiple times will create multiple polygons for the same service layer. Make sure the polygons do not overlap
7. *(If drawing)* **Adjust** – Drag and adjust polygon corners to shape the area
8. *(If drawing)* **Save** – Save changes for each polygon
9. *(If drawing)* **Commit** – When done with all polygons, commit changes to the service layer

? ***Tip:*** *Only standard (Hub-and-Spoke) plans require service area layers*

Various kinds of network equipment can be uploaded through standard upload template



Most common equipment upload types:

- **Central Offices / Exchanges** – Places COs at user-specified location

  Upload file (csv) requires 3 columns:
  - entity_category_id (use "central_office" for all records)
  - lat
  - longitude

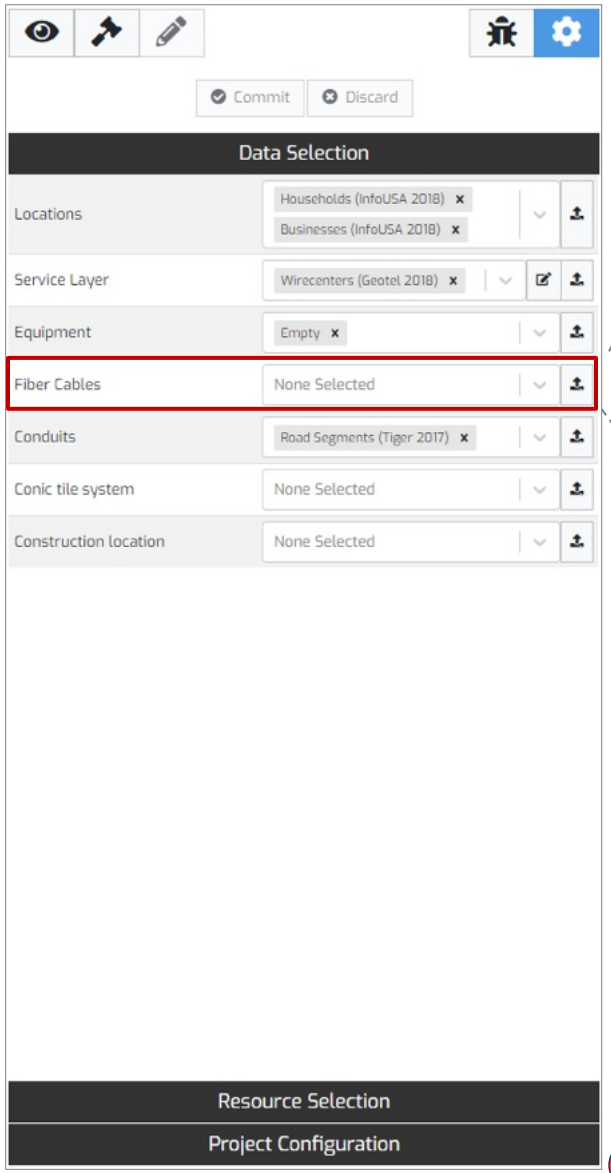
- **Splice Points** – Indicates where planned fiber can be spliced into the existing network if the routing from existing fiber option is selected

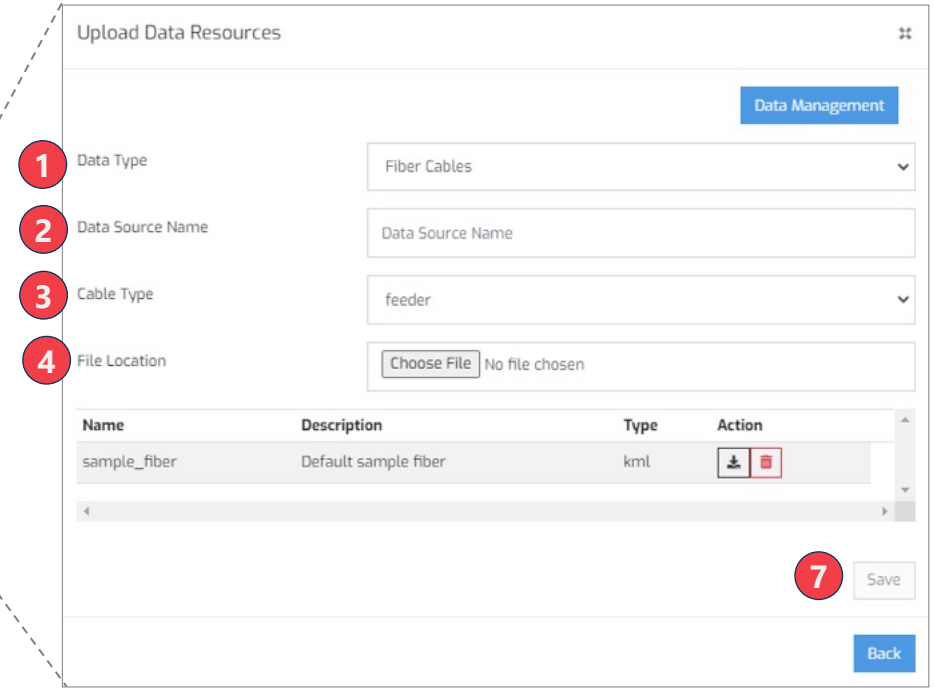
  If no splice points are uploaded and selected and the plan requires routing from existing network, Arrow will assume splicing is permitted anywhere along the existing fiber routes

  Upload file (csv) requires 3 columns:
  - entity_category_id (use "splice_point" for all records)
  - lat
  - longitude

Complete list of network equipment types is available in the upload template accessible from the data upload window

To upload existing fiber network or conduit data, users should utilize Fiber data import feature



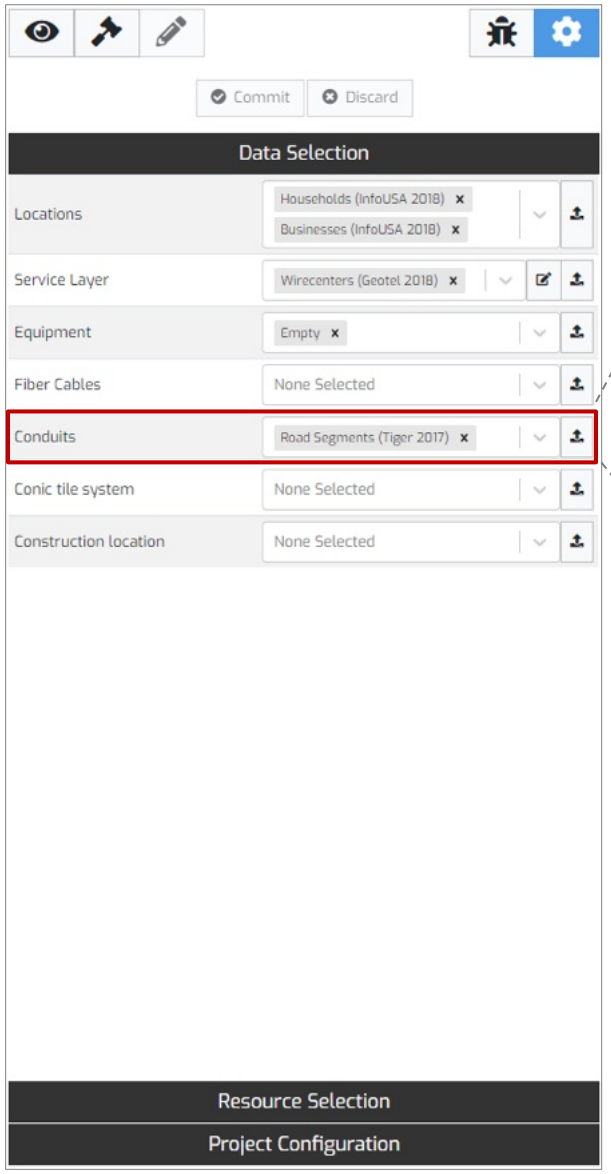


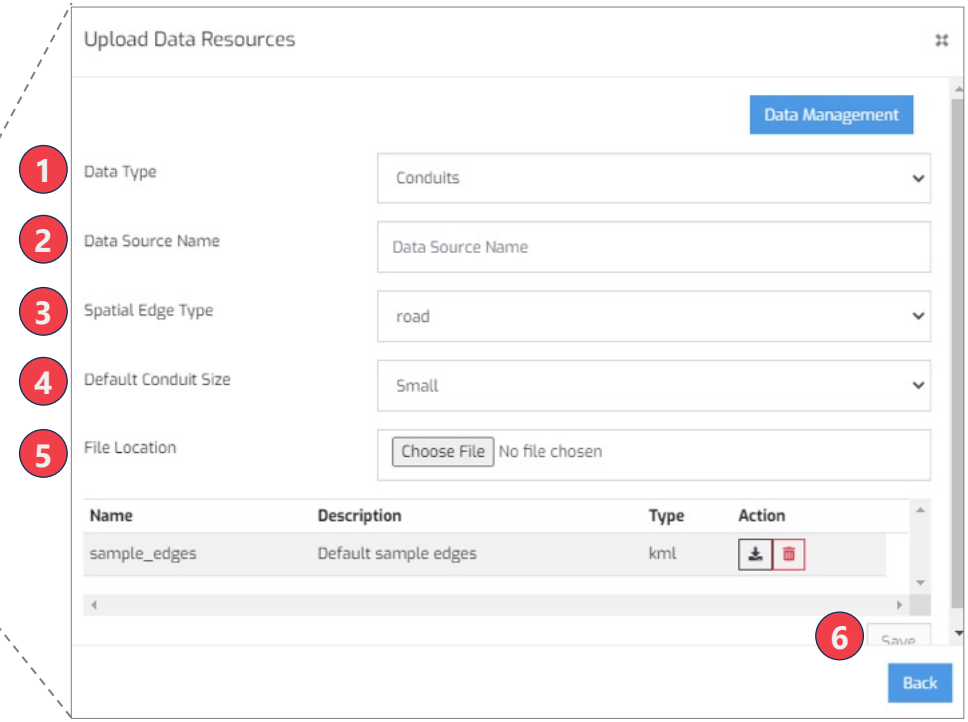
Uploading Fiber

1. **Data Type** – If not already selected, use the dropdown to specify "Fiber Cables" data type
2. **Name the Source** – Give the data source a name to display in the dropdown menu
3. **Cable Type** – Specify cable type (e.g. Feeder, Distribution) Note, only feeder and distribution fiber types can be used to splice from (when running plans that route from existing fiber)
4. **Select File** – Click "Choose File" to select a kml or kmz file for upload
5. **Save** – Click "Save" to begin data upload. Once completed, the manager will close, and the new data source will be available from the data type dropdown

? ***Tip:*** *Only a subset of layers is needed, edit the file in QGIS or Google Earth prior to uploading*

Conduits define paths along which Arrow can place its fiber routes

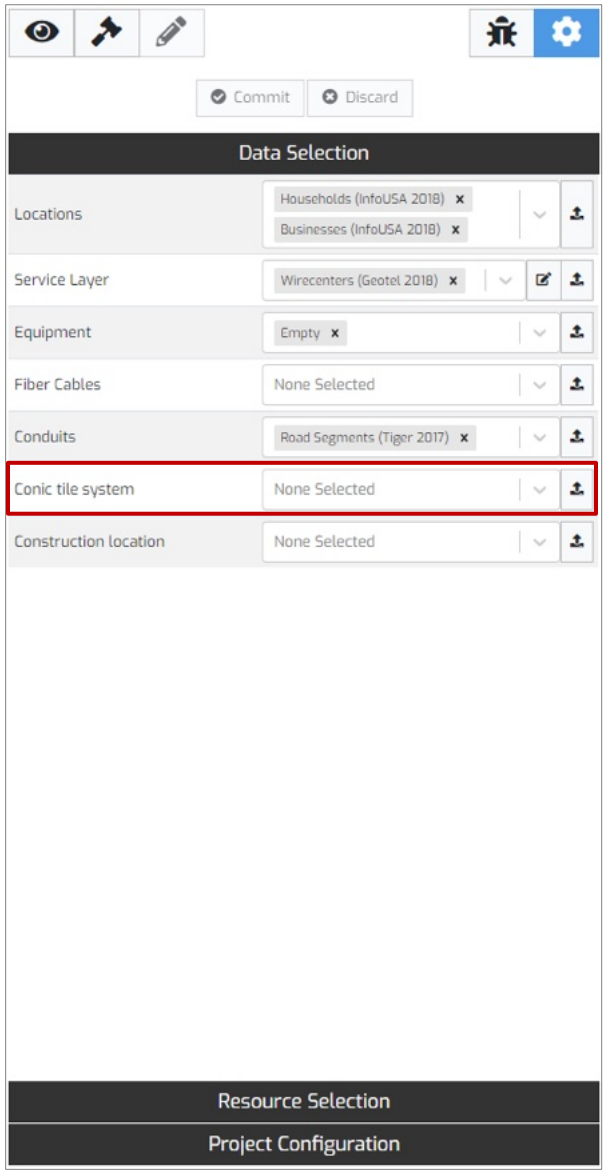




Uploading Fiber

1. **Data Type** – If not already selected, use the dropdown to specify "Conduits" data type
2. **Name the Source** – Give the data source a name to display in the dropdown menu
3. **Spatial Edge Type** – Use the dropdown to specify edge type (road, duct, sewer, etc.)
4. **Default Conduit Size** – If uploading ducts/sewers users can specify their size (S/M/L)
5. **Select File** – Click "Choose File" to select a kml or kmz file for upload
6. **Save** – Click "Save" to begin data upload. Once completed, the manager will close, and the new data source will be available from the data type dropdown

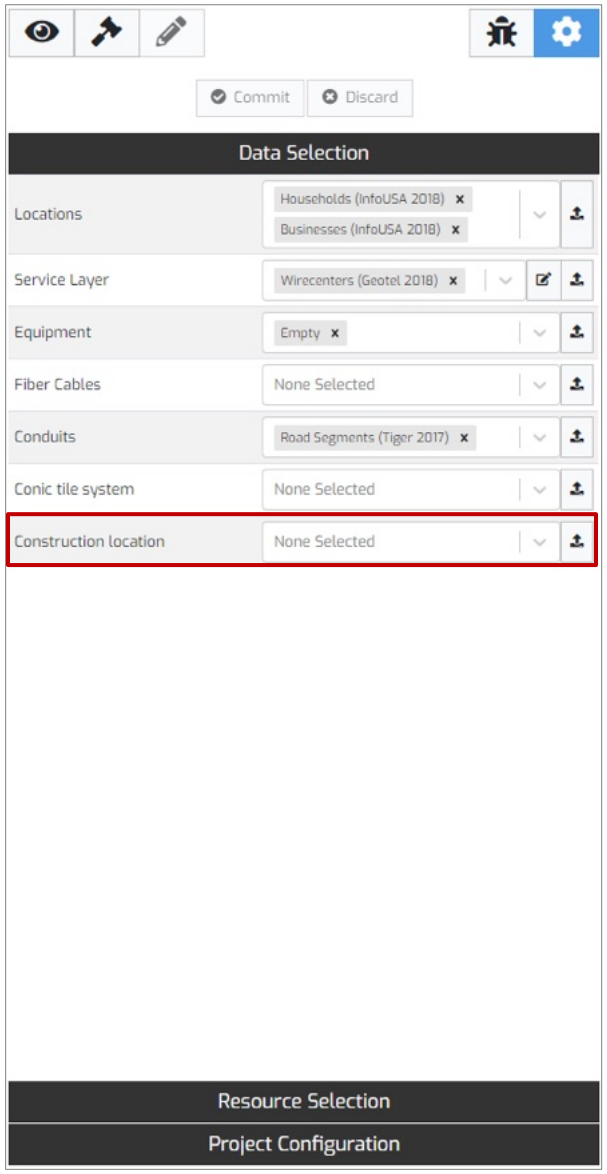
In Fixed Wireless optimizations, Conic Tiles supply topographic characteristic of a given area (e.g., density of foliage, etc.)



Conic Tiles are used in conjunction with Impedance Resource Manager to determine how far from its source wireless signal can reach

If you are planning on running 5G / Fixed wireless optimizations, please contact Arrow team members to assist you with data loading

Construction locations define areas where Arrow can place equipment at different cost e.g., reuse existing towers, rather than build new ones



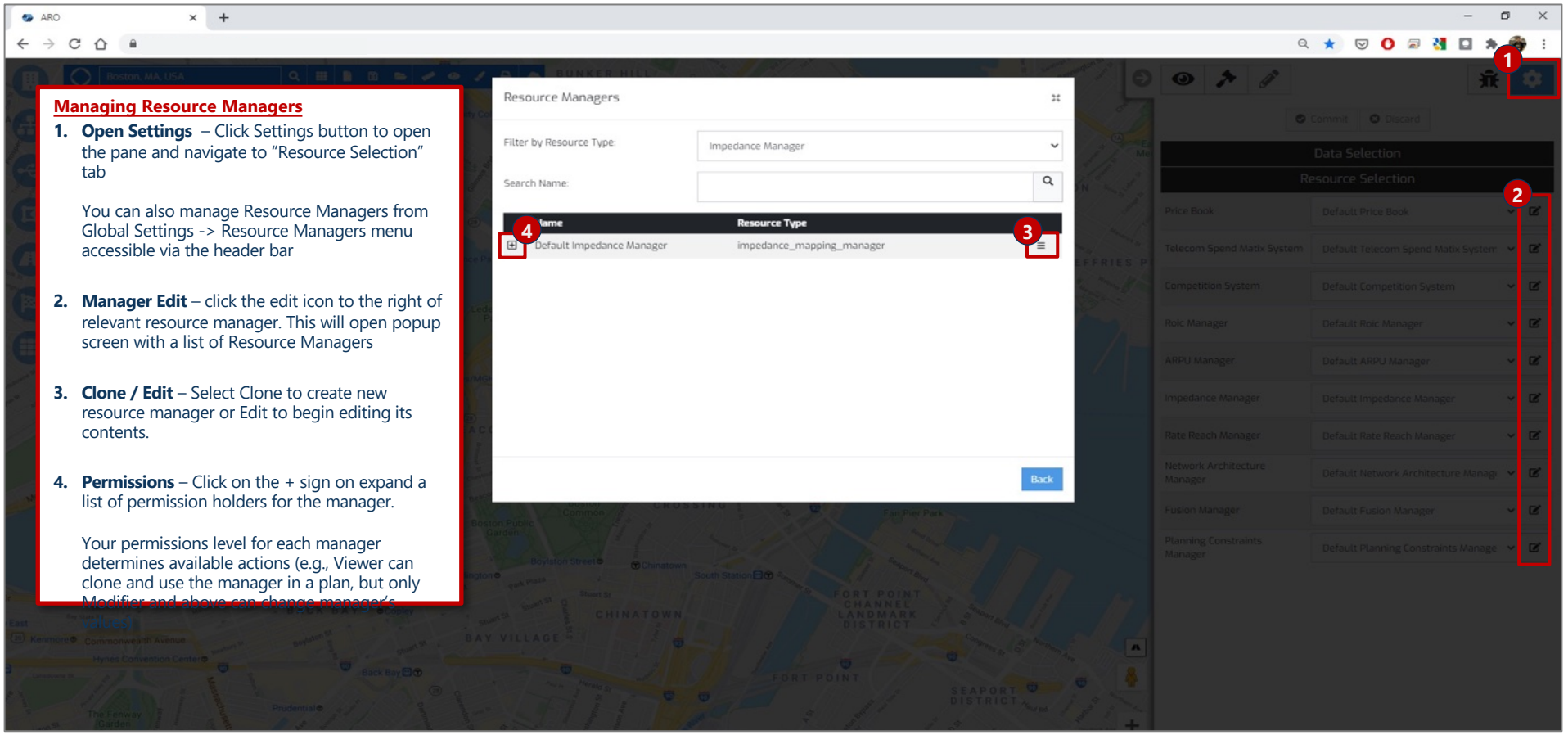
By default, all data layers imported as locations can be used as construction locations, and show up in the dropdown menu

Contents

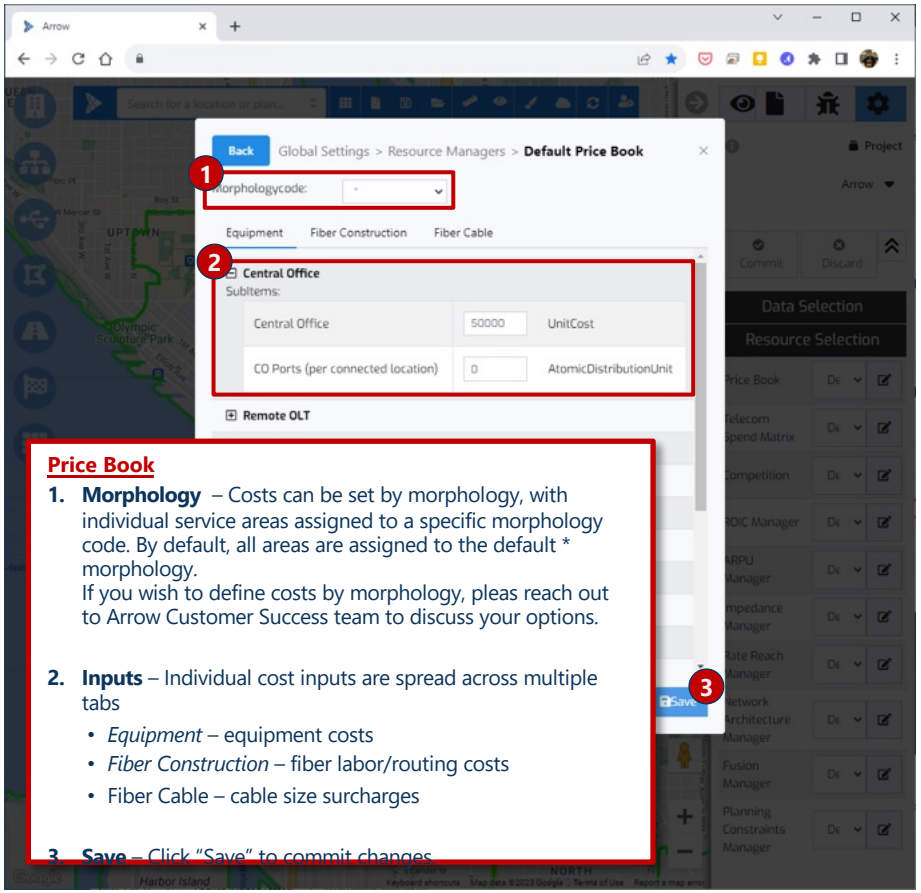
Resource Managers define the modeling inputs and assumptions that Arrow uses when performing an optimization

Resource Selection		What does it define / What is it used for?	When to adjust from defaults?
Price Book	Default Price Book	All network build costs *(e.g., equipment, fiber labor and cable cost)*	When accurate network cost is needed
Telecom Spend Matrix	Default Telecom Spenc	How to calculate Enterprise revenues	When Enterprise revenue is estimated using A|S' Telecom Spend Matrix approach
Competition	Default Competition	How to translate available competition information into target endpoints' fair share	When Arrow is used to determine fair share of target endpoints *(and revenue-side business case calculation is needed)*
ROIC Manager	Default ROIC Manager	Revenue-side business case inputs	When revenue-side business case calculation is needed *(e.g., IRR targets or NPV-maximizations)*
ARPU Manager	Default ARPU Manager	ARPU assumptions	When revenue-side business case calculation is needed *(e.g., IRR targets or NPV-maximizations)*
Impedance Manager	Default Impedance Ma	Wireless signal loss characteristics	Only when planning Fixed Wireless networks that factor in clutter information
Rate Reach Manager	Default Rate Reach Ma	Addressability thresholds for FTTN/DSL equipment	Only when planning FTTN/DSL networks
Network Architecture Manager	Default Network Archit	Equipment properties for each network architecture *(e.g., max cabinet size)*	When additional information on equipment sizes and fiber length constraints is available *(To further improve network cost estimation)*
Fusion Manager	Default Fusion Manage	Interaction rules between conduit networks *(e.g., where can a route jump from a road to a ducts)*	Only when intricate interactions between conduit types are required
Planning Constraints Manager	Default Planning Const	Optimization constraints, reporting settings, and technology-specific parameters	Generally, only when directed by the Customer Success team, based on specific project or configuration needs

Resource Managers are managed via their respective management windows



Price Book is used to define all network build costs



Price Book

1. **Morphology** – Costs can be set by morphology, with individual service areas assigned to a specific morphology code. By default, all areas are assigned to the default * morphology.
   If you wish to define costs by morphology, pleas reach out to Arrow Customer Success team to discuss your options.

2. **Inputs** – Individual cost inputs are spread across multiple tabs
   - *Equipment* – equipment costs
   - *Fiber Construction* – fiber labor/routing costs
   - Fiber Cable – cable size surcharges

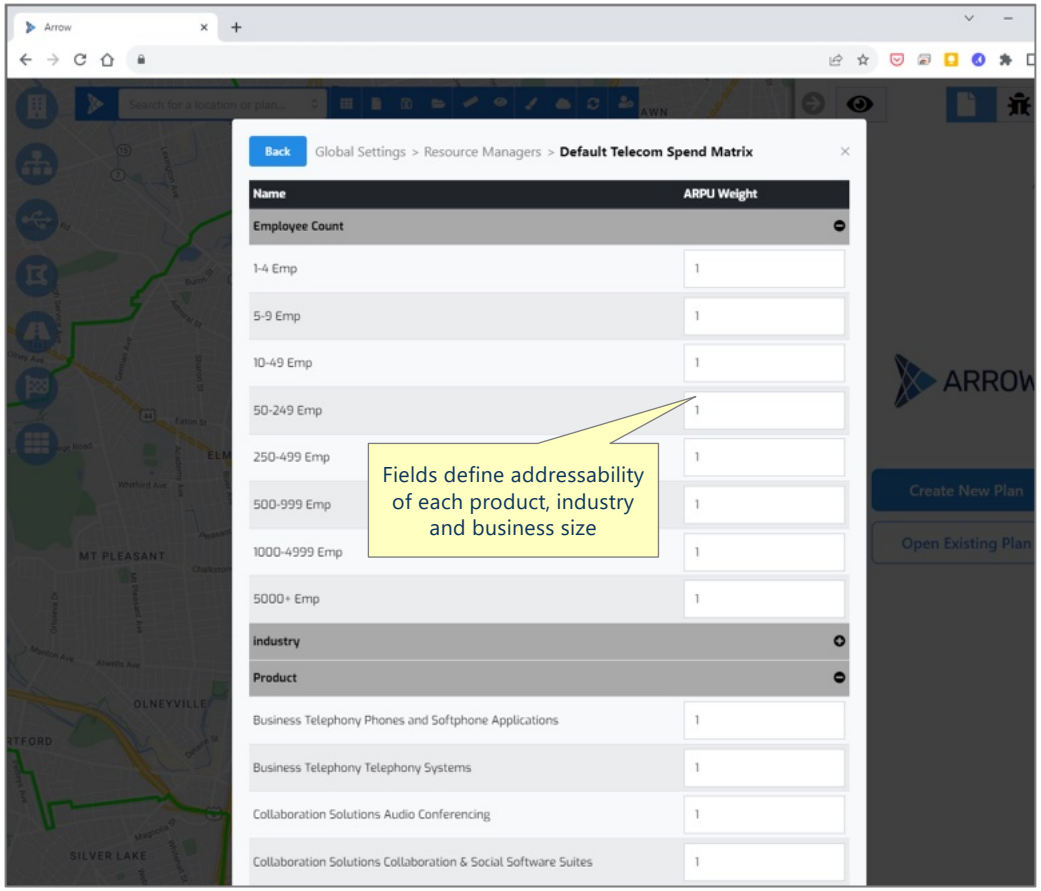
3. **Save** – Click "Save" to commit changes

The Following Costs can be set in the Price Book:

Input Field	Units
Central Office	Unit Cost and/or per Premise Passed
Remote OLT	Unit Cost and/or per Premise Passed
Splice Point	Unit Cost and/or per Premise Passed
Fiber Distribution Hub	Unit Cost and/or per Premise Passed
FDT Terminal 1x12	Unit Cost and/or per Premise Passed
MDU ONT	Unit Cost and/or per Premise Passed
Drop Coil / Bulk Distribution Terminal	Unit Cost
FW Cell Node (New Tower)	Unit Cost
FW Cell Node (Use Existing Tower)	Unit Cost
Remote Terminal (DSLAM)	Unit Cost
(Junction) Splitter	Unit Cost
Location Connector	Unit Cost
Network Anchor	Unit Cost
Slack Loop	Unit Cost
Network Connector	Unit Cost
Subnet node	Unit Cost
Install [by conduit type] - [by placement type]	Cost Per Meter
Fiber Cable [by size]	Cost Per Meter

Placement type cost is only used when road segments have explicitly assigned placement type. Otherwise, average cost, computed from assigned percentages, will be used

The TSM Manager is used to determine enterprise spend of target businesses when the Telecom Spend Matrix strategy is enabled in the ARPU Manager



Using Telecom Spend Matrix it is possible to calculate precise telecom expenditure for each target business

Planners can define their target industries, addressable business sizes and products. By doing so Arrow only consider each business' addressable revenues and provides a realistic representation of each location's revenue potential.

Industries, business size and products that are not in current scope can be zeroed out and will result in prospective targets within those industries or sizes registering zero revenues.

Revenue potential is determined via a set of coefficients defining the magnitude of addressability of each item/category contained within:

- **ARPU Weight** – Coefficient defining the addressability *(1.0 = fully addressable)*. Fractional values can also be used to reflect partial addressability
- **Employee Count, Industry, Product** – Available addressability categories

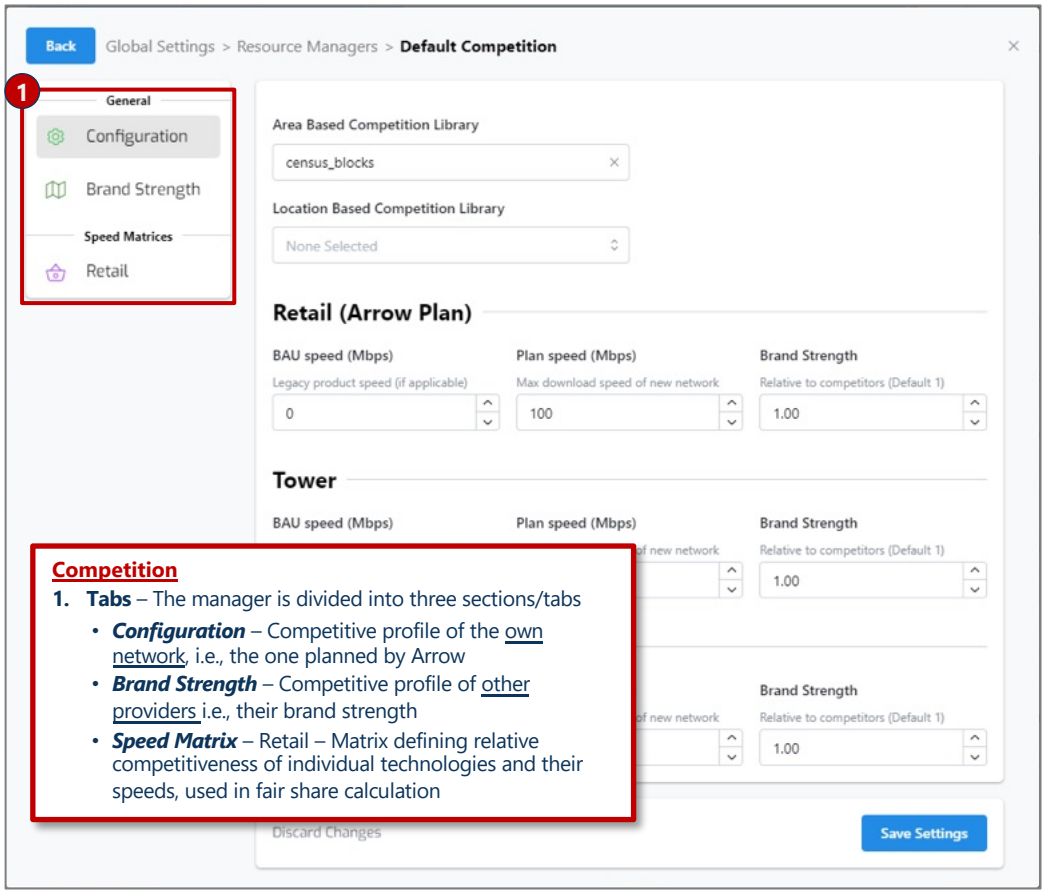
Each location's revenue is calculated by cross multiplying each Product, Industry and Size coefficient with the estimated expenditure on said products.

Individual Product spend estimates are a specific to the market tier the business is in, its size bracket and the industry the business operates in.

This resource manager is only used then TSM ARPU strategy is selected in the ARPU resource manager.

Telecom Spend Matrix is a proprietary Altman Solon dataset available in the tool at no extra cost to Arrow subscribers.

Competition Manager defines how factors such as available technology, service speed and brand recognition translate into fair share for the planned network



Competition

1. **Tabs** – The manager is divided into three sections/tabs
   - ***Configuration*** – Competitive profile of the own network, i.e., the one planned by Arrow
   - ***Brand Strength*** – Competitive profile of other providers i.e., their brand strength
   - ***Speed Matrix*** – Retail – Matrix defining relative competitiveness of individual technologies and their speeds, used in fair share calculation

Area Based Competition Library – Identifies which library contains competitive information stored for individual geographical areas – Census Blocks by default – to use when calculating individual locations' fair share. Note if left blank, the default census_blocks library is used.

Location Based Competition Library – *Only for use in conjunction with the CostQuest locations data* – Identifies which Arrow library contains location-level competition data that can be matched to target endpoints purchased from CostQuest, to evaluate fair share for each location individually.

Please reach out to Arrow Customer Success team for help with setting up custom, or location-level competition systems.

Retail – Tower - Wholesale – Settings defining competitive profile of the network planned by Arrow

BAU Speed (Mbps) – Implied service speed of the legacy network / the network that Arrow is going to overbuild. This value is only relevant when running an overbuild scenario *(configured in ROIC Manager).*

Plan Speed (Mbps) – Maximum service speed of the planned networks.

Brand Strength – Go-to-market strength factor for own brand (default = 1.00 = 100%) , i.e., technology and speed being equal, how well is the provider planning the network recognized, regarded and positioned to win new customers relative to its competitors.

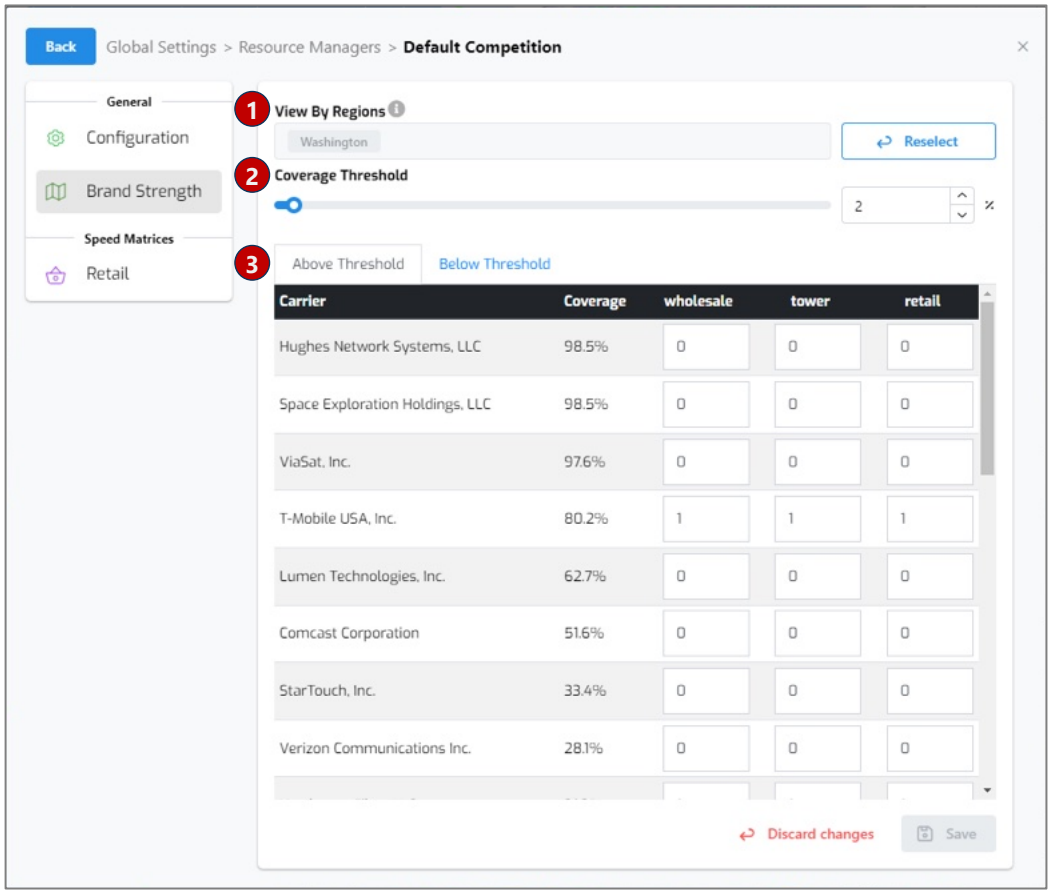
Retail = Residential and Small Business endpoints

Wholesale = Medium and Large Businesses

Tower = Tower endpoints

Tip: *Target Fair Share can be directly specified for each location by supplying "ROIC.BAU.FAIR_SHARE" and "ROIC.PLAN.FAIR_SHARE" parameters during location upload. Values at the location level* ***override*** *the Competition Resource Manager settings.*

Brand Strength tab of the Competition Manager defines competitive go-to-market strength of providers that the planned network is competing against



1. **View By Regions** – Users can filter provider list by the state(s) in this they operate

2. **Coverage Threshold** – Coverage threshold slider can be used to display only the providers that report sufficient presence in the preselected states

3. **Above/Below Threshold** – Prioritized list of providers to define their individual brand strengths. Providers with coverage below the target threshold are reported on the separate tab

   Carrier – Provider name

   Coverage – Fraction of census blocks in the selected region(s) in which the carrier reports service

   Wholesale – Brand Strength inputs for Medium and Large Businesses

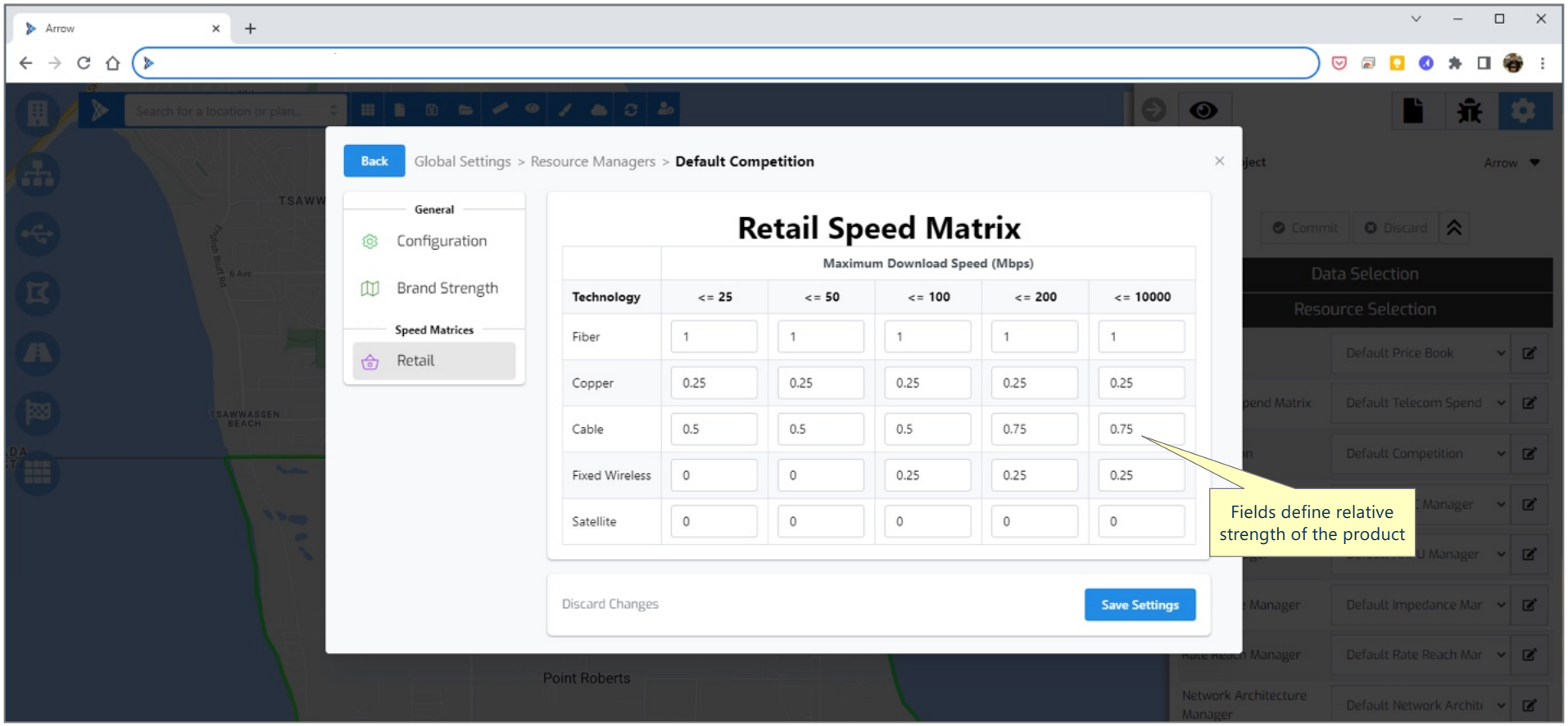
   Tower – Brand Strength inputs for Tower endpoints

   Retail – Brand Strength inputs for Residential and Small Business endpoints

   Strength of 1 implies regular competition level from the given provider, while 0 means that they do not compete at all.

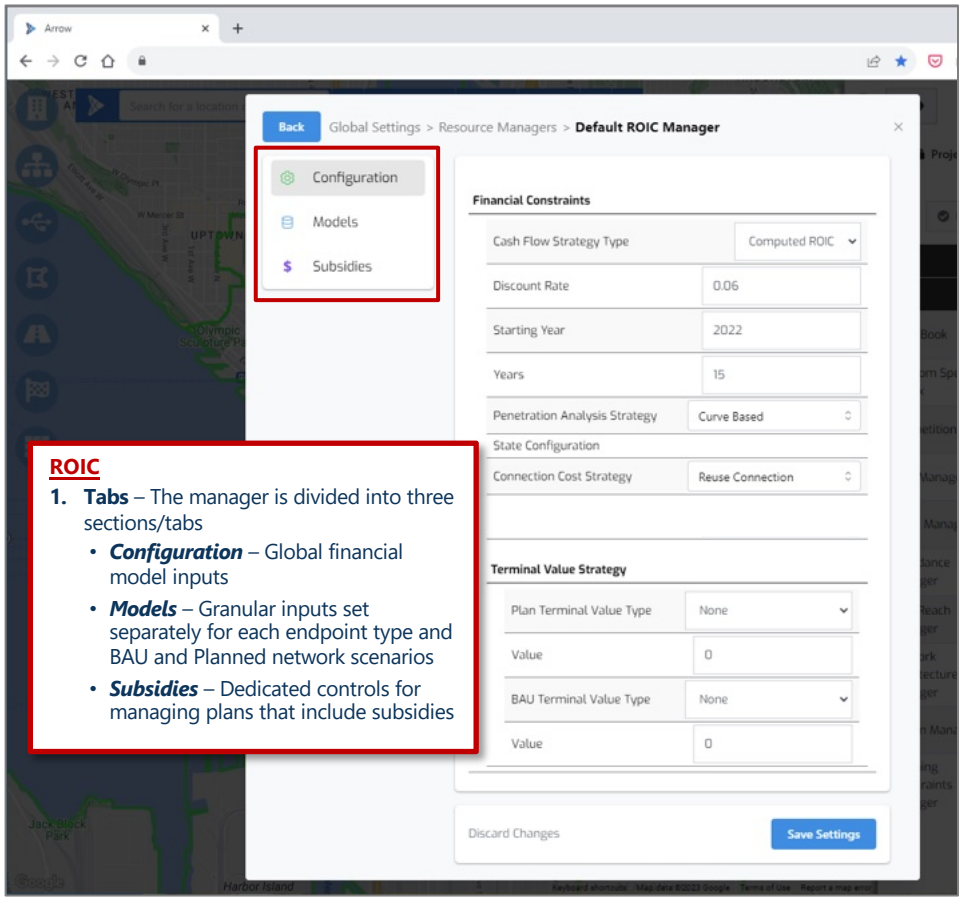
Network operators should set their own competitive weight to 0 here to avoid simulating competing with themselves.

Retail Speed Matrix tab of Competition Manager defines the relative competitiveness of individual technologies and speeds used in fair share calculations



Tip: *See appendix for fair share (penetration) calculation methodology*

ROIC Manager defines the YoY financial profile of each plan analyzed in Arrow



Financial Constraints – Global business case inputs

Cash Flow Strategy Type – use Computed ROIC for all plans

Discount Rate – Cost of capital / WACC to use for NPV calculation

Starting Year – Which year the plan starts *(only relevant when TSM ARPU strategy is used)*

Years – How many years to project the cash flows for and use in NPV/IRR calculations

Penetration Analysis Strategy – Specifies the method to determine customer penetration over time

- **Curve Based** – Penetration follows a predefined adoption curve *(defined by the penetrationRate parameter on the Models tab)*
- **Flow Share** – Uses granular flow-share modeling to determine each period's subscribers *(using churn and locations growth settings from the Models tab)*

Connection Cost Strategy – Specifies how to handle individual location's re-connect costs

- **New Connection** – Charges full new connection cost every time location (re)subscribes *(cost set by ConnectCost field in the Models tab)*
- **Reuse Connection** – Probabilistically model what fraction on new subscribers had connected in the prior periods and only charge for the net new locations

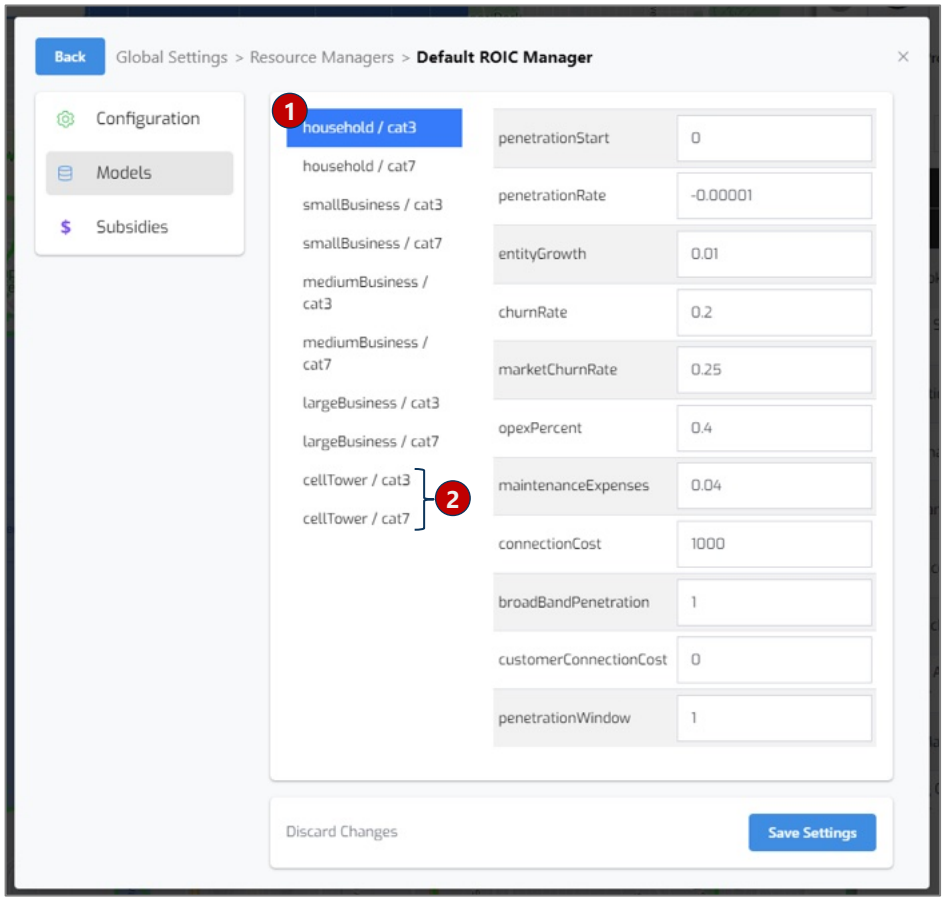
Terminal Value Strategy – Set separately for Planned and BAU scenarios

Terminal Value Type – Defines what method of TV calculation to use

- **None** – No terminal value applied
- **Net Cash Flow Multiple** – Last year's net cash flow multiplied by the value and added to the last period
- **EBITDA Multiple** – Similar to Net Cash Flow, but maintenance and new build costs are excluded
- **Perpetual Growth** – Assumes that a business will generate cash flows at a constant rate (from the last period) forever

Value – Multiplier to use for the given strategy type (fraction for Perpetual Growth)

ROIC Manager defines the YoY financial profile of each plan analyzed in Arrow



1 **Inputs are set independently for each endpoint type** – Residential (households), Towers and Small, Medium and Large Businesses

2 **For each endpoint type, users can set BAU (cat3) and Planned (cat7) network inputs** – This allows Arrow to account for revenue cannibalization in network overbuild scenarios

- **Legacy / BAU** – Sets up the cash flow profile of locations served by the legacy network / the network that Arrow is going to overbuild. These values need only be adjusted when running an overbuild scenario.
- **Planned** – Cash flow inputs for locations that will be connecting to the planned network

penetrationStart – starting penetration of passed locations (at year 0)

penetrationRate – when Curve-Based penetration strategy is used (set on the Configuration tab), it determines the pace of subscriber ramp to the fair share value

entityGrowth – annual growth percent of passed locations

churnRate – own annual churn rate *(used to calculate new connects in each period)*

marketChurnRate – market annual churn rate *(only used with Flow Share penetration strategy)*

opexPercent – fraction of the total revenue spent on operating expenses

maintenanceExpense – fraction of the total revenue spent on maintenance expenses

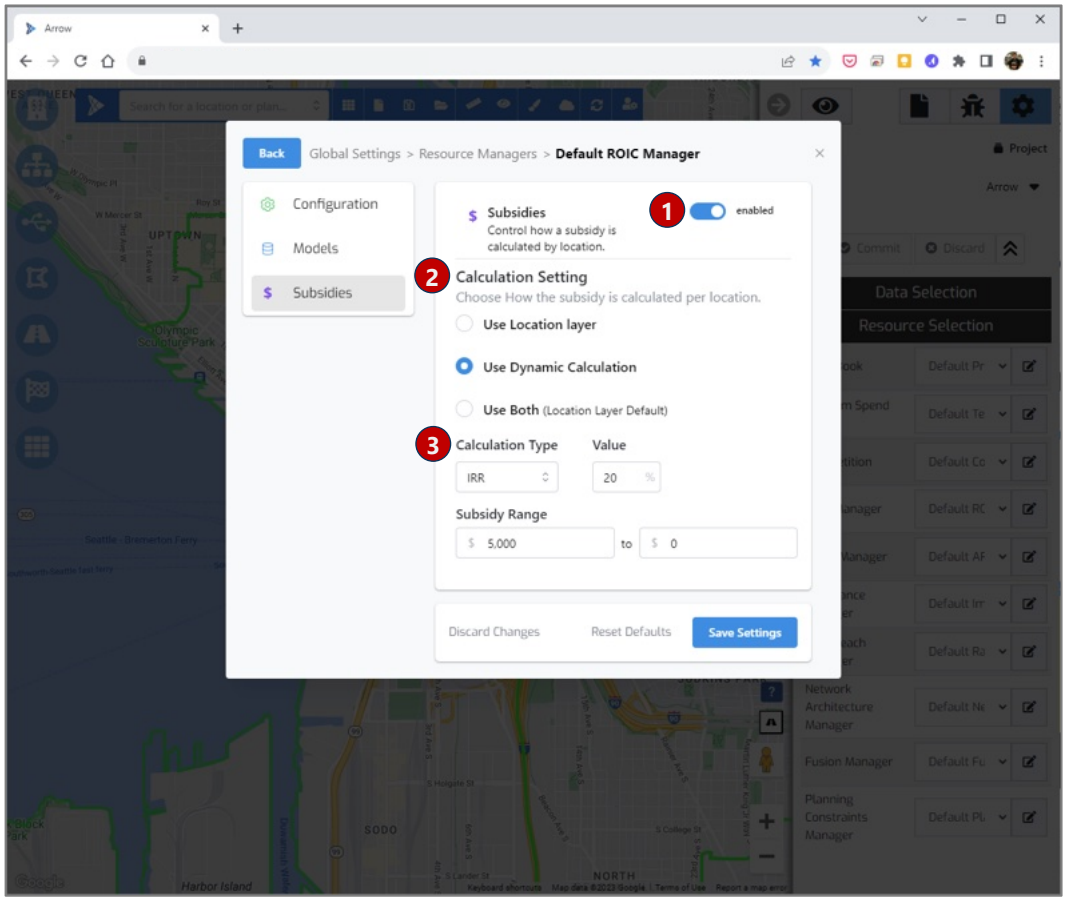
connectionCost – one-time success-based CapEx, incurred when given location subscribes to the new network

broadBandPenetration – broadband adoption ratio, effectively adjusting total number of premises passed in the plan (and correspondingly scaling down revenues and cash flows)

customerConnectCost – The cost to connect a new customer, regardless of connection strategy. It is applied per-customer, not per-connection.

penetrationWindow – The number of periods over which to average the penetration (best to leave set to 1)

Dedicated tab in the ROIC Manager is used to define how subsidies are used in a plan



1 **Enable subsidy calculation** – Toggles location-level subsidy calculations. Subsidy amounts are then used to offset the cost of the new network build. The subsidy can be predefined or calculated by Arrow (configured below)

Note that **individual locations must be flagged as subsidy-eligible** to be included in subsidy calculations via "grant_eligible" attribute. Please refer to the Data Preparation guide for information how to prepare these inputs.

2 **Calculation Setting** – Determines how the subsidy is used / determined

- **Use Location Layer** – Uses the predefined subsidy amount assigned to each location i.e., the user defines the amount of subsidy each location is receiving. *("ROIC.PLAN.SUBSIDY" location attribute is used to define the subsidy amount)*
- **Use Dynamic Calculation** – Determine the amount of subsidy required to meet the target threshold (as defined by Calculation Type setting below)
- **Use Both** – First look for predefined subsidy amount stored with the location layer. If no values are present, the Dynamic Calculation is used for locations marked as grant eligible

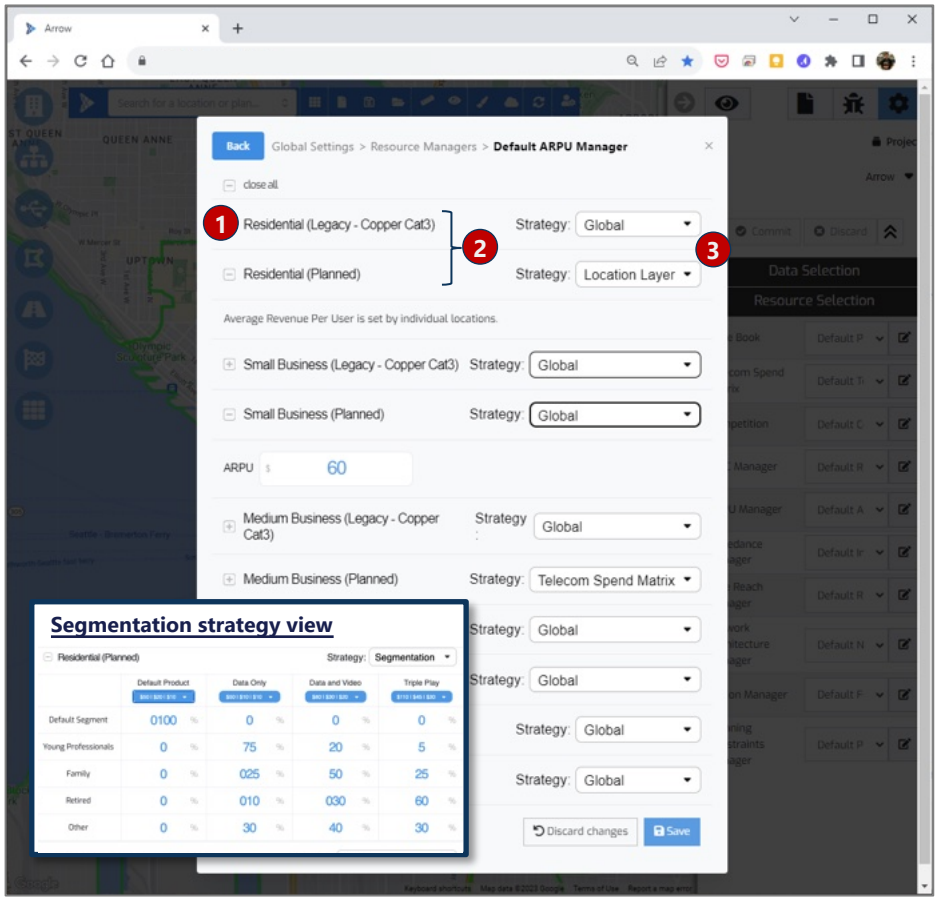
3 **Calculation Type** – Defines how to calculate the required subsidy amount

- **IRR** – determines the necessary amount to achieve target IRR value for locations marked as grant eligible (leach location on a proportional cost basis)
- **Fixed** – applies a fixed $ amount to all locations marked as grant eligible
- **Percentage** – applies a percentage value of the proportional cost required to reach locations marked as grant eligible

Value – Target value for Dynamic Calculation Type *(percentage or $ amount)*

Subsidy Range – Apply upper and lower bound on acceptable subsidy amounts to avoid extreme results. Minimum and Maximum values are used when calculated about is outside of the range.

ARPU Manager is used to define monthly revenue assumptions for target endpoints

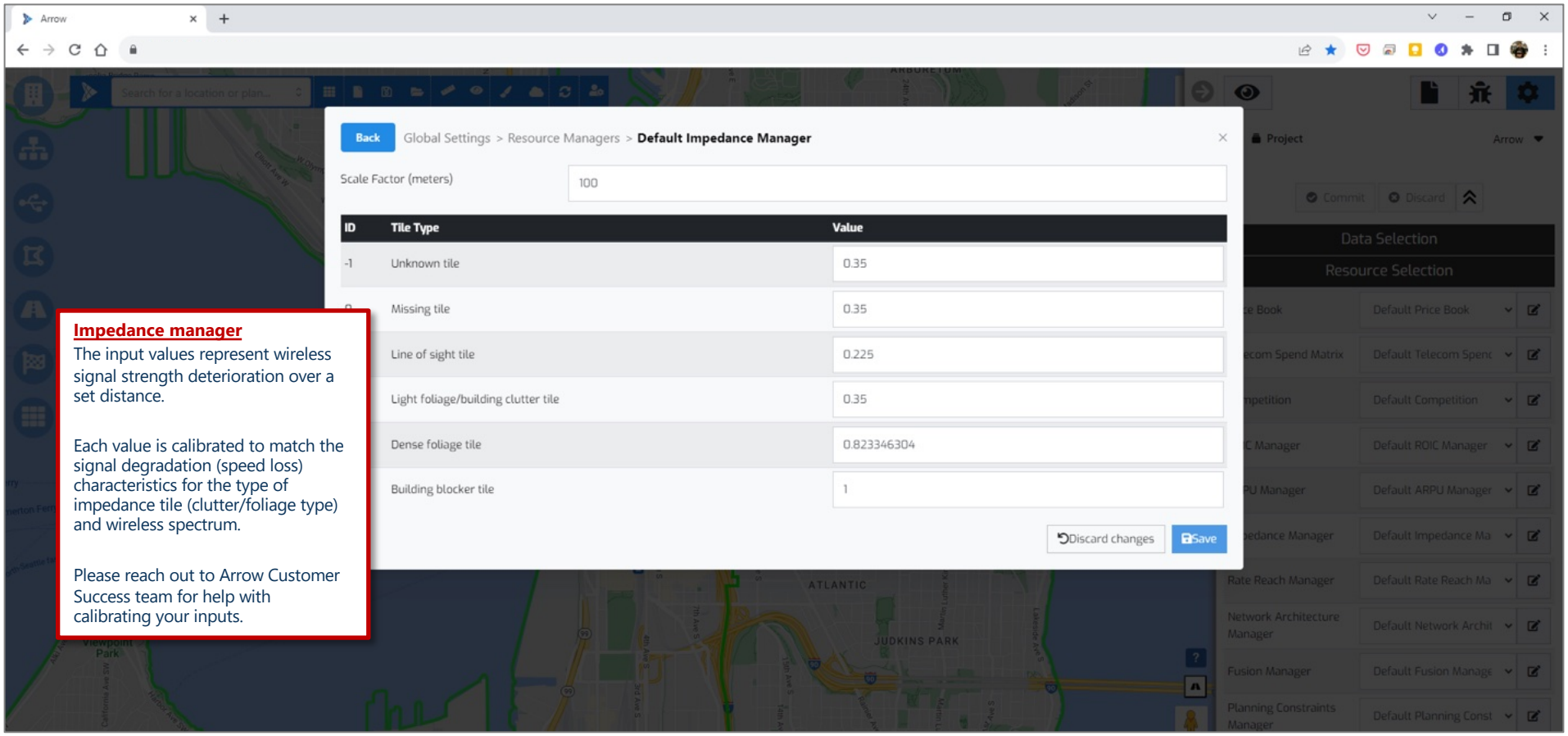


1. **ARPU strategy is set independently for each endpoint type** – Residential, Towers and Small, Medium and Large Businesses

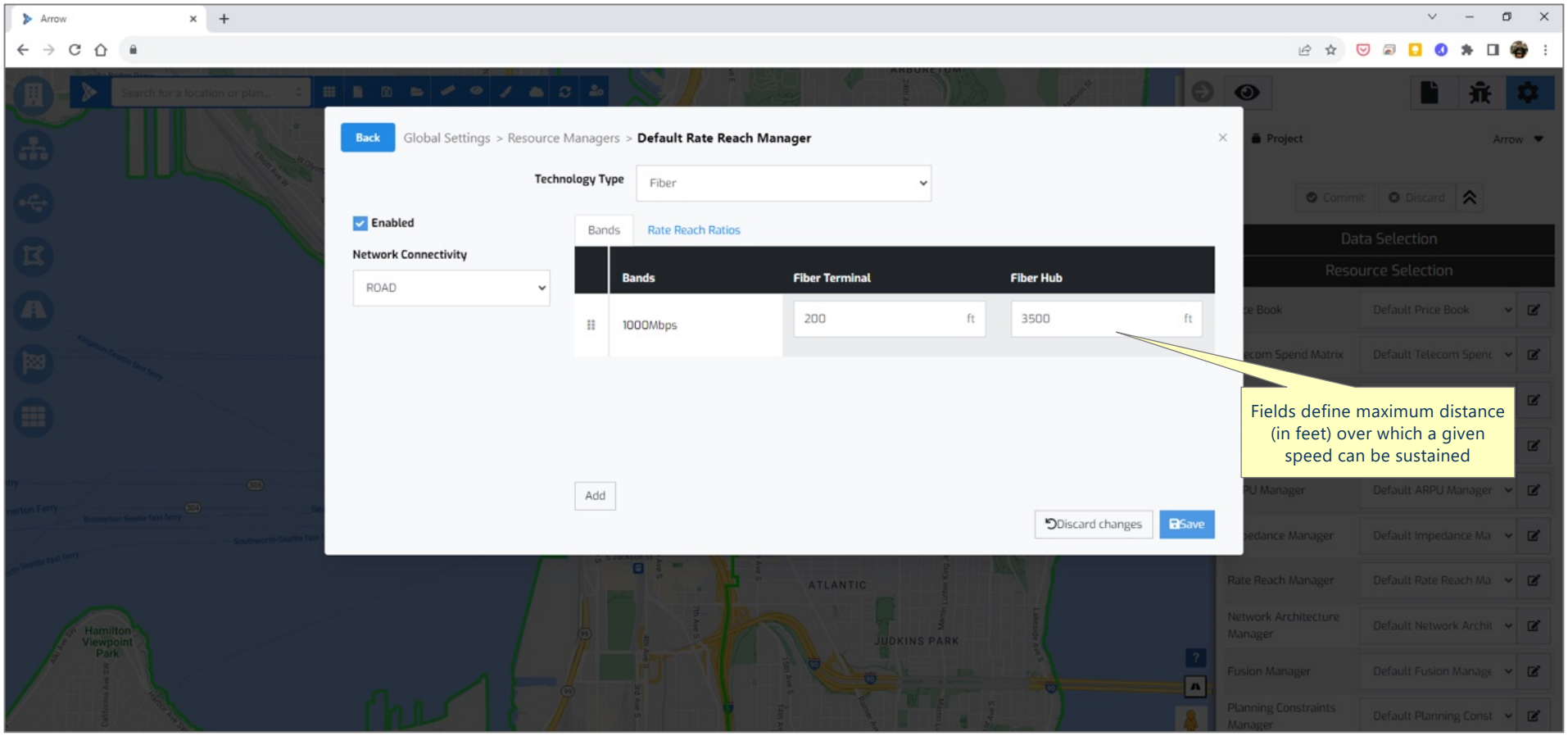
2. **For each endpoint type, users can set BAU and Planned ARPU inputs** – This allows Arrow to account for revenue cannibalization in network overbuild scenarios
   - **Legacy / BAU** – ARPU of current subscribers served by the legacy network / the network that Arrow is going to overbuild. These values need only be adjusted when the financial model (in the ROIC Manger) is being set up to account for existing network's current cash flows.
   - **Planned** – Expected revenue of locations that will be connecting to the planned network

3. **Users can select from the following strategies:**
   - **Global** – The specified value is used for all locations of the given type
   - **Location Layer** – Each location uses the ARPU value that is assigned to it in the data layer.
     Note, this strategy only works in conjunction with locations layers that explicitly assign ARPU to each record via attributes ("ROIC.PLAN.MONTHLY_ARPU" / "ROIC.BAU.MONTHLY_ARPU" [case sensitive]). Please refer to Arrow Data Preparation Guide to learn how to assign ARPU to each location.
   - **Telecom Spend Matrix** – *For Business endpoints only*, each location is computed its own revenue based on the combination of the business' size, industry, market, and addressable products defined in Telecom Spend Matrix resource manager. For most accurate results, each business should have a 4-digit industry SIC code assigned to it, as outlined in the Data Preparation guide.
   - **Segmentation** – *For Residential endpoints only*, the Segmentation strategy uses the values based on the product mix specified in the UI across pre-defined segments. It also allows you to adjust OpEx and Acquisition cost at the individual product level.
     Note, segmentation strategy only works in conjunction with locations layers that explicitly assign segments to each location. Please contact Arrow Customer Success team to discuss setting it up in your instance of Arrow.

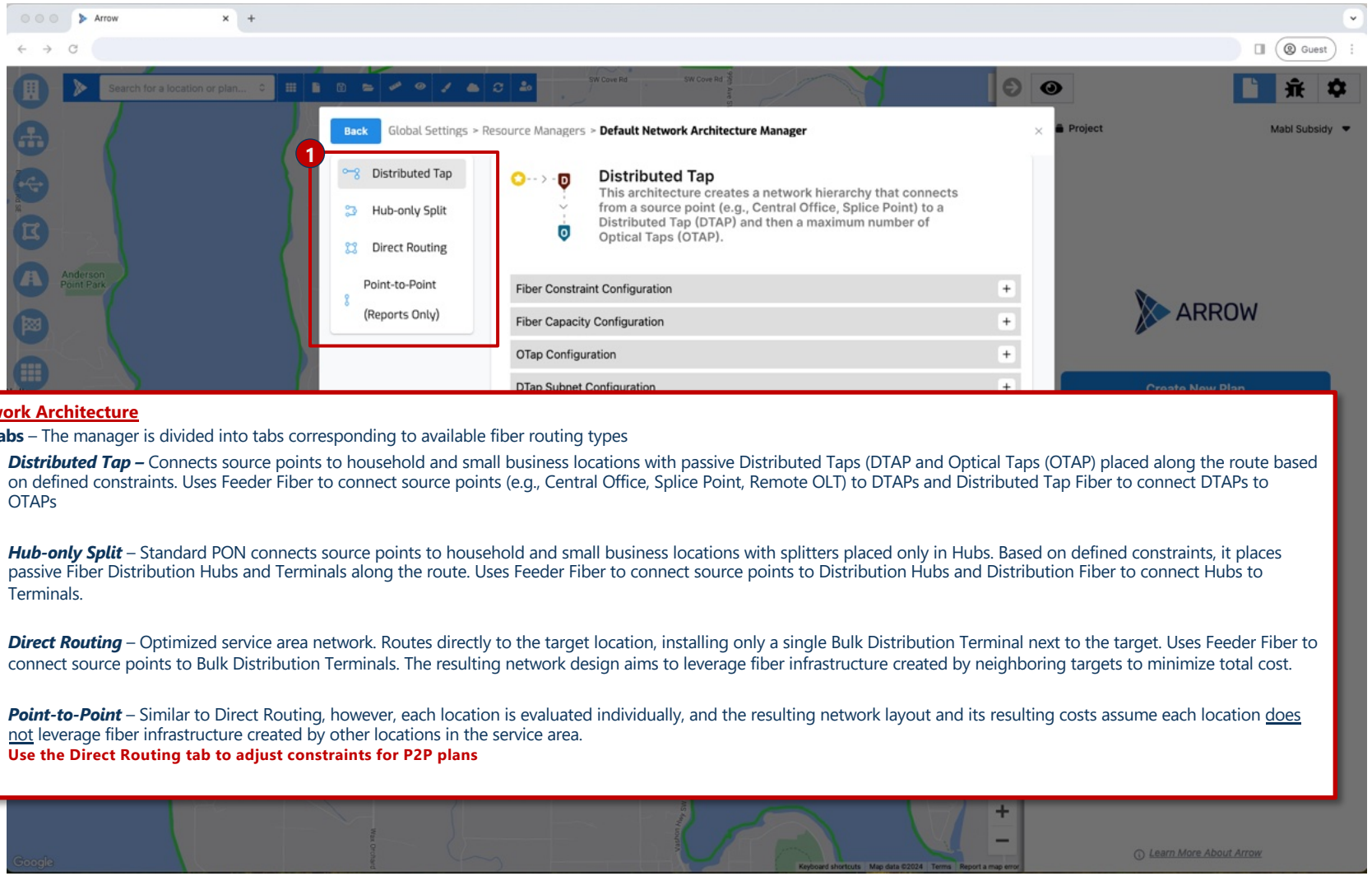
Impedance Manager controls wireless signal loss characteristics as a function of distance and topography in fixed wireless plans



Rate Reach Manager is used to define distance thresholds for placing FTTN/DSL equipment to serve target locations



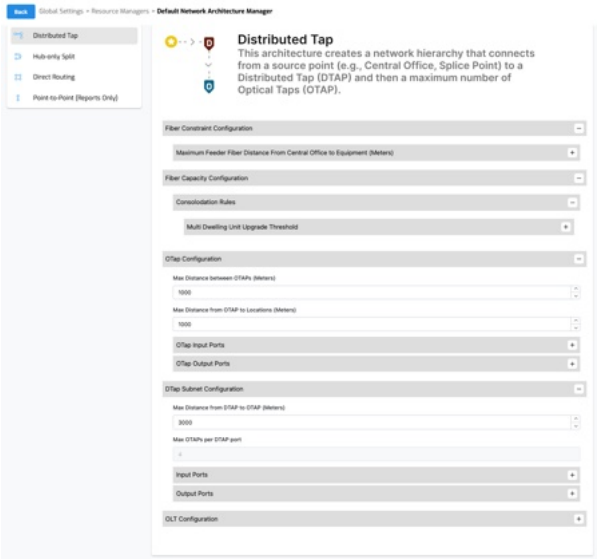
Network Architecture Manager is used to define key equipment properties for each of the available network architecture types



Network Architecture

1. **Tabs** – The manager is divided into tabs corresponding to available fiber routing types
   - ***Distributed Tap –*** Connects source points to household and small business locations with passive Distributed Taps (DTAP and Optical Taps (OTAP) placed along the route based on defined constraints. Uses Feeder Fiber to connect source points (e.g., Central Office, Splice Point, Remote OLT) to DTAPs and Distributed Tap Fiber to connect DTAPs to OTAPs
   - ***Hub-only Split*** – Standard PON connects source points to household and small business locations with splitters placed only in Hubs. Based on defined constraints, it places passive Fiber Distribution Hubs and Terminals along the route. Uses Feeder Fiber to connect source points to Distribution Hubs and Distribution Fiber to connect Hubs to Terminals.
   - ***Direct Routing*** – Optimized service area network. Routes directly to the target location, installing only a single Bulk Distribution Terminal next to the target. Uses Feeder Fiber to connect source points to Bulk Distribution Terminals. The resulting network design aims to leverage fiber infrastructure created by neighboring targets to minimize total cost.
   - ***Point-to-Point*** – Similar to Direct Routing, however, each location is evaluated individually, and the resulting network layout and its resulting costs assume each location does not leverage fiber infrastructure created by other locations in the service area.
     Use the Direct Routing tab to adjust constraints for P2P plans

Distributed Tap settings are in effect for plans ran using Distributed Tap network construction option



Fiber Constraint Configuration – Feeder fiber length maximums

Maximum Feeder Fiber Distance to Equipment (Meters) – Thresholds for the maximum length of buildable feeder fiber per service area, set separately for each target equipment type used in a plan (e.g., DTAP Subnet, Remote OLT)

Fiber Capacity Configuration – Defines how individual locations types connect to the planned network and their bandwidth requirements.

Consolidation Rules

- **Multi Dwelling Unit Upgrade Threshold** – The threshold determining how many locations on the exact latitude and longitude should be treated as an MDU location. For example, setting this to 5 means that any location with more than 5 units is treated as an MDU (connects with MDU terminal) rather than five households connecting through one or more OTAPs. **Note, ensure that this setting is above the maximum connections in OTap Configurations.**

OTap Configuration – OTap-specific equipment settings

Max Distance between OTaps (Meters) – Maximum distance between OTaps connected to the same DTap port

Max Distance between OTaps to Locations (Meters) – The maximum length of the drop cable connecting individual locations. Note that locations further than this distance from the conduit available for routing (e.g., distance from road layer) will not be connected.

OTaps Input and Output ports are currently not configurable through the UI.

DTap Subnet Configuration – Terminal-specific equipment settings

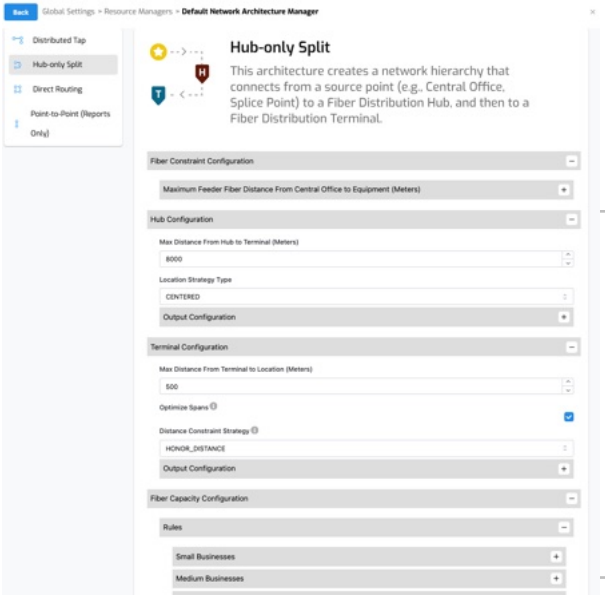
Max Distance from DTap to OTap (Meters) – Maximum length of buildable Distributed Tap fiber between a DTap and OTap

Output Ports – Target and maximum number of Ports available on each DTap for Distributed Tap fiber. Note that multiplying this number by the fiber size (e.g. , FS_1X32) provides you with the location capacity the DTap can support.

OLT Configuration – Defines capacity constraints for Remote OLTs

Output Ports – Sets minimum, target, and maximum number of Ports available for Feeder Fiber connectivity in each Remote OLT. **Note, this functionality for Distributed Tap is currently in Early Access as we continue to refine it.**

Hub-only Split settings are in effect for plans ran using Hub-only Split network construction option



Fiber Constraint Configuration – Feeder fiber length maximums

Maximum Feeder Fiber Distance to Equipment (Meters) – Thresholds for the maximum length of buildable feeder fiber per service area, set separately for each target equipment type used in a plan (e.g., Fiber Distribution Hub, Remote OLT)

Hub Configuration – Hub-specific equipment settings

Max Distance from Hub to Terminal (Meters) – Maximum length of buildable distribution fiber between Hubs and Terminals

Location Strategy Type – Determines how the Hub is placed in the context of its serving cluster

- **Centered** – Hub is placed in the center of the location cluster
- **Optimized** – Hub is optimally placed, closer to the boundary of its serving area, towards the CO, to reduce Feeder fiber length
- **Fiber Optimized** – Extension of "optimized" strategy, where the hub is placed on top of other planned feeder fiber, closer to center of target locations, minimizing distribution fiber requirement

Output Configuration – used with K-Means hub clustering (Planning Constraints Manager setting)

- **Target Connections** –- Target number of connections per Hub
- **Maximum Connections** – Upper bound of how many connections each hub can support

Terminal Configuration – Terminal-specific equipment settings

Max Distance from Terminal to Location (Meters) – The maximum length of the drop cable connecting individual locations

Optimize Spans – Control if Terminals can traverse road intersections to serve locations. With Optimized Spans unchecked, the Terminal will not cross intersections and reduce the likelihood of path overlap

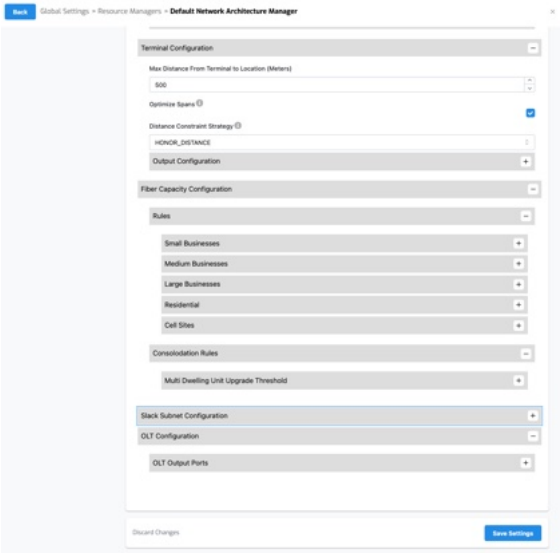
Distance Constraint Strategy – Defines how to treat locations that are beyond the drop cable distance threshold

- **Honor Distance** – Location is dropped. Only locations that are within the maximum distance are connected.
- **Always Connect** – Location is connected. The Terminal is placed as close to the location as possible (a longer drop cable is required)

Output Configuration

- **Maximum Connections** – the maximum number of connections each Terminal can support.

Hub-only Split settings are in effect for plans ran using Hub-only Split network construction option



Fiber Capacity Configuration – Defines how individual locations types connect to the planned network and their bandwidth requirements

Rules

- **Fiber Capacity Type** – Defines what equipment is used to connect each target endpoint type ("SingleConnection" = FDTs/MDUs, "DropCoil" = Drop Coil / BDT)
- **Atomic Units** – The number of distribution strands that are required to enable each location category, e.g., at 32 strands connection has sufficient feeder fiber to enable a tower, medium or large business

Consolidation Rules

- **Multi Dwelling Unit Upgrade Threshold** – The threshold determining how many locations on the exact latitude and longitude should be treated as an MDU location. For example, setting this to 5 means that any location with more than 5 units is treated as an MDU (connects with MDU terminal) rather than five households connecting through one or more terminals. **Note, ensure that this setting is above the maximum connections in Terminal Configurations.**

Slack Subnet Configuration – Defines slack loop cluster constraints. Relevant only when Slack Clustering is enabled in the Planning Constraints Manager

Boundary Generator Strategy – Defines how the slack loop boundary polygon is created

- **Spatial Buffer** – Generates a spatial buffer around the centroid of the target locations
- **Spatial Concave** – Generates concave buffer around target the target locations
- **Centroid Distance** – Snaps centroid of target locations to the nearest road edge, and then builds a polygon based on the maximum roads distance from that point
- **Optimized Polygon** – Generates a polygon based on road distance for every target location and then takes the spatial intersection of all the polygons. The resulting polygon defines the area that guarantees that all targets are at most N meters from the subnet parent

Max Distance (Meters) – Defines the maximum radius of a slack loop cluster

Location Strategy Type – Determines how the slack loop is placed in context of a cluster

- **Centered** – Slack loop is placed in the center of the location cluster
- **Optimized** – Slack loop is optimally placed to reduce Feeder fiber length
- **Fiber Optimized** – Extension of the "optimized" strategy, where the loop is placed on top of other planned fiber, if it exists, closer to the target locations, minimizing future lateral fiber requirement

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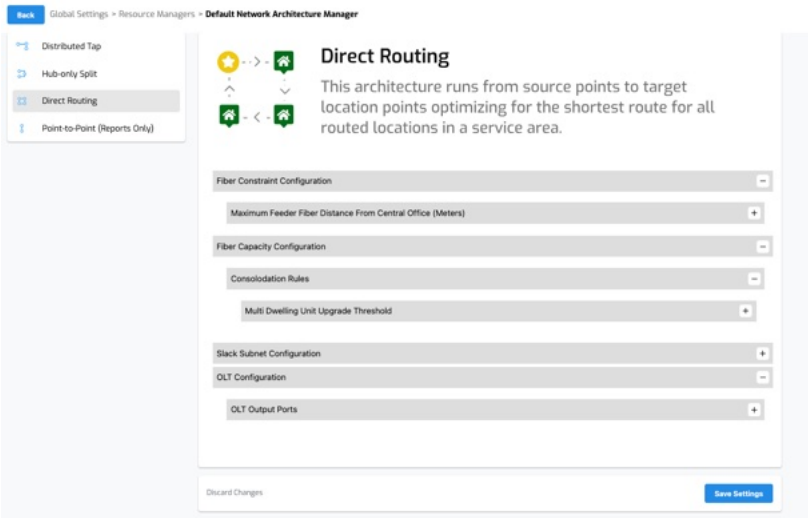
OLT Configuration – Defines capacity constraints for Remote OLTs

Output Ports – Sets minimum, target, and maximum Ports available for Feeder Fiber connectivity in each Remote OLT. **Note that the minimum number of ports multiplied by Fiber cable size should be equal to or greater than the maximum Hub connections set under the Hub Output Configuration.**

Direct Routing settings are in effect for plans ran using Direct Routing and Point-to-Point network construction option



Fiber Constraint Configuration – Feeder fiber length maximums

Maximum Feeder Fiber Distance from Central Office (Meters) – Thresholds for the maximum length of buildable feeder fiber per service area, set separately for each target location type (e.g., Large Business, Cell Tower, Remote OLT)

Fiber Capacity Configuration – Defines how individual locations types connect to the planned network

Multi Dwelling Unit Upgrade Threshold – Threshold that determines how many locations on the same latitude and longitude should be treated as an MDU location.
For example, setting this to 5 means that any location with more than 5 units is treated as an MDU (connects with MDU terminal) rather than five individual households that connect through a BDT

Slack Subnet Configuration – Defines slack loop cluster constraints. Relevant only when Slack Clustering is enabled in the Planning Constraints Manager

Boundary Generator Strategy – Defines how the slack loop boundary polygon is created

- **Spatial Buffer** – Generates a spatial buffer around the centroid of the target locations
- **Spatial Concave** – Generates concave buffer around target the target locations
- **Centroid Distance** – Snaps centroid of target locations to the nearest road edge, and then builds a polygon based on the maximum roads distance from that point
- **Optimized Polygon** – Generates a polygon based on road distance for every target location and then takes the spatial intersection of all the polygons. The resulting polygon defines the area that guarantees that all targets are at most N meters from the subnet parent

Max Distance (Meters) – Defines the maximum radius of a slack loop cluster

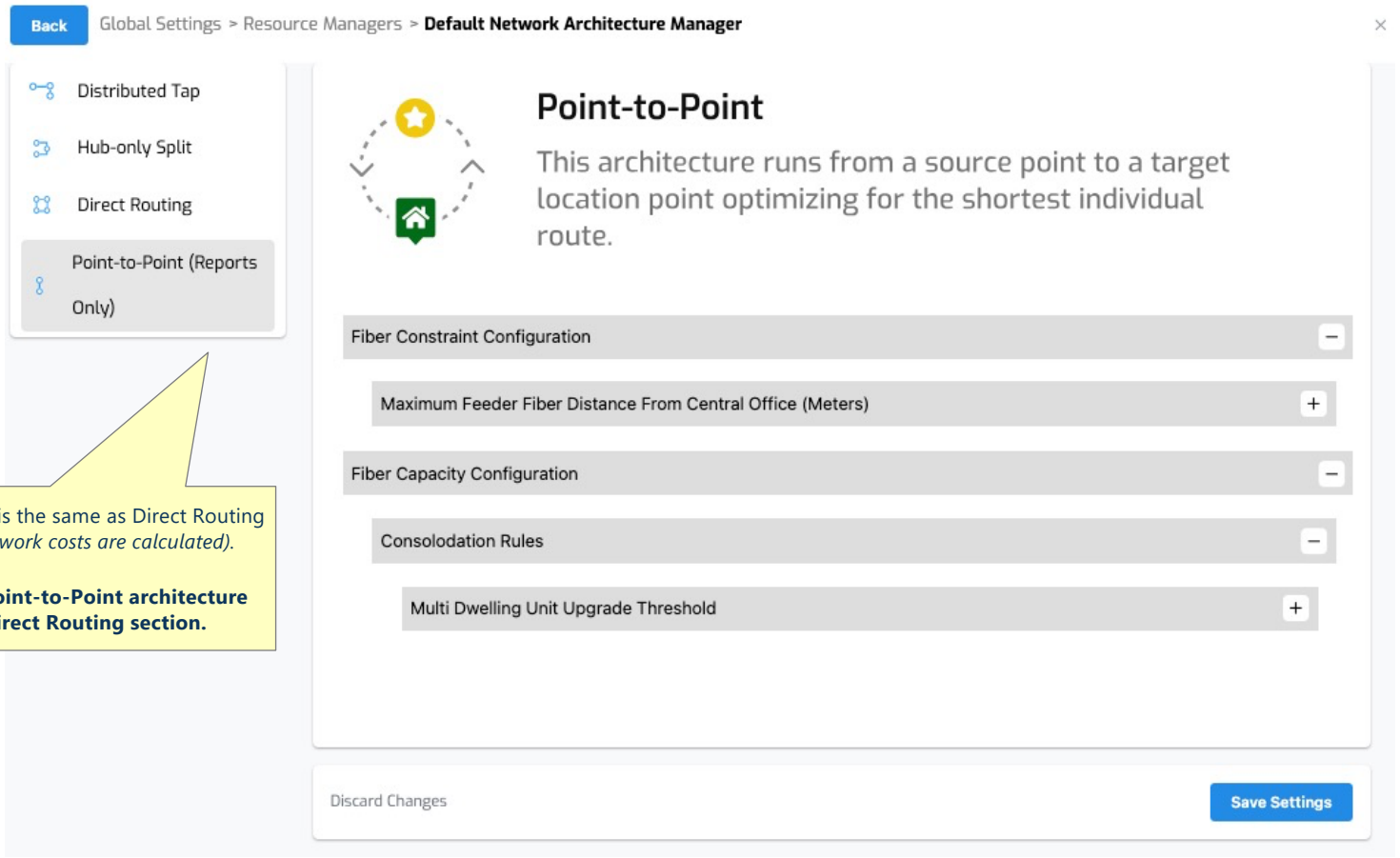
Location Strategy Type – Determines how the slack loop is placed in context of a cluster

- **Centered** – Slack loop is placed in the center of the location cluster
- **Optimized** – Slack loop is optimally placed to reduce Feeder fiber length
- **Fiber Optimized** – Extension of the "optimized" strategy, where the loop is placed on top of other planned fiber, if it exists, closer to the target locations, minimizing future lateral fiber requirement

OLT Configuration – Defines capacity constraints for Remote OLTs

Output Ports – Sets minimum, target, and maximum number of Ports available for Feeder Fiber connectivity in each Remote OLT. **Note, this functionality for Direct Routing is currently in Early Access as we continue to refine it.**

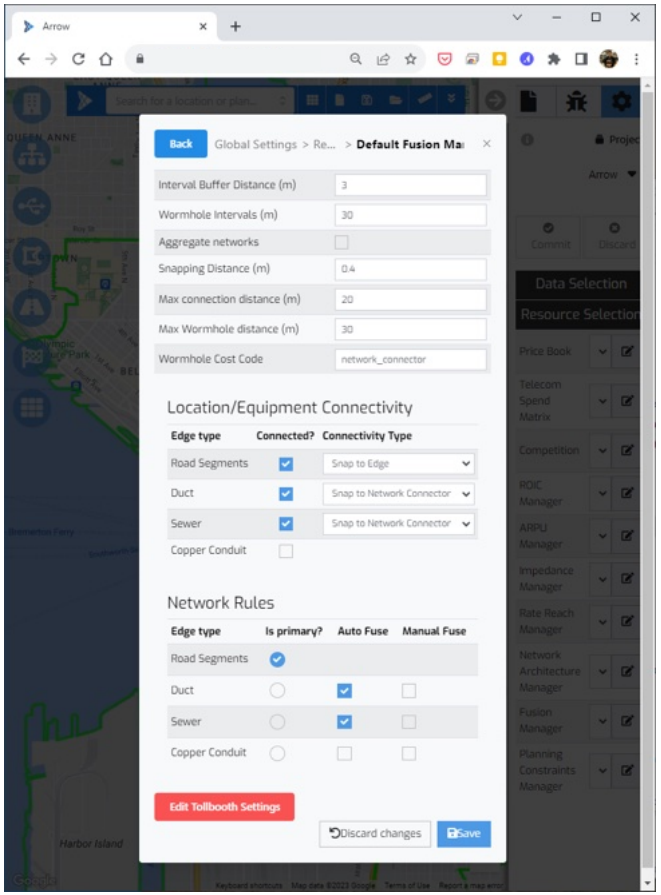
Point-to-Point settings are currently only used for reporting purposes, and do not need to be changed



Point-to-Point architecture is the same as Direct Routing *(it only differs in how network costs are calculated).*

You should **adjust the Point-to-Point architecture constraints in the Direct Routing section.**

Fusion Manager enables users to define precise interaction rules between conduit networks for plans that leverage multiple conduit types



Interval Buffer Distance – Interval for putting synthetic splice points on the primary conduit edge (i.e., how frequently to consider a new splice point locations when routing from existing fiber)

Wormhole Intervals – Distance between auto-generated potential connection points (wormholes) along each network

Aggregate networks – If selected, networks of the same type and different size can be treated as equal (e.g., treat small and large ducts as equivalent)

Snapping Distance - the distance over which networks of the same type and size can be snapped together i.e., the proximity between two conduit segments to be considered intersecting with one another (e.g., small sewer to a nearby small sewer line)

Max connection distance – the distance over which networks of the same type but different size can be snapped together (e.g., small sewer to a large sewer)

Max Wormhole distance – the distance over which networks of different types can be snapped together (i.e., the distance between sewer/manhole and sewer/road)

Wormhole cost code – specifies which price book item represents wormhole cost (connections between conduit types)

Location/Equipment Connectivity – Determines how target locations connect to the planned network

- **Connected?** – toggle to select which conduit types target locations can connect to
- **Connectivity Type** – defines how the connection occurs (directly [Snap to Edge], or via a dedicated Network Connector)

Network Rules – Defines rules around jumps between conduit types

- **Is primary** – Tells Arrow which layer should be treated as the primary/default conduit layer (generally, Road Segments as they are most complete)
- **Auto Fuse** – when enabled, allows Arrow to autogenerate connection points between different conduit types, i.e., it allows the planned routes to switch between conduits in any place (e.g., places manholes to connect roads with sewers),
- **Manual Fuse** – tells Arrow to only use the predefined network connection points, which must be uploaded ahead of time and selected from the equipment data layer to include in a plan

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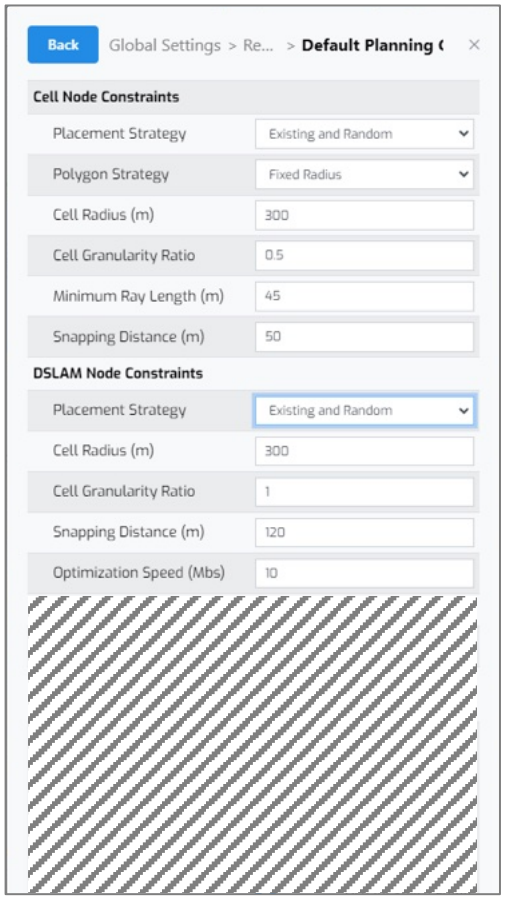
Tollbooth Settings – Defines exact rules use of tollbooths in a plan (one-time costs associated with switching between which conduit the planned route goes through). Please contact Arrow Customer Success team if think tollbooths might be needed in your plans.

Settings at the top of the Planning Constraints Manager define placement behavior of fixed wireless and FTTN/DSL nodes



Cell Node Constraints – Fixed Wireless Cell Node / equipment behavior settings

Placement Strategy – Defines how to chose initial placement of network nodes

- **Existing Locations** – Places initial set of coverage nodes using user specified latitude and longitude data
- **Random** – In areas with no specified node data or areas with coverage gaps due to limited existing data, random strategy enables Arrow to place additional nodes to meet coverage or IRR targets
- **Existing and Random** – Combination of the two above

Polygon Strategy – Defines how the coverage area of the cell node is defined

- **Fixed Radius** – Circular coverage areas with set radii *(e.g., 500 meters)*
- **Average Radius** – Circular coverage areas with set radii based on assumed average coverage distance
- **Ray Tracing** – Variable octagonal coverage areas determined by impedance clutter data between polygon centroid and shape points. Requires Clutter data (Conic tile system) is selected in plan's data selection, and the Impedance Manager defines wireless signal propagation characteristics

Cell Radius (Meters) – Constant coverage radius assumption for Fixed and Average radius polygon strategies above

Cell Granularity Ratio – The interval along conduit edge segments that cell towers are placed when searching for optimal placement

Minimum Ray Length (Meters) – *Used only when Ray Tracing is selected* - Minimum ray length used when computing diagonal rays

Snapping Distance (Meters) – Determines the cell radii overlap with each other during the initial cell node placement.

DSLAM Node Constraints – FTTN/DSL equipment behavior settings

Placement Strategy – *Same functionality and options as for Cell Node Placement Strategy*

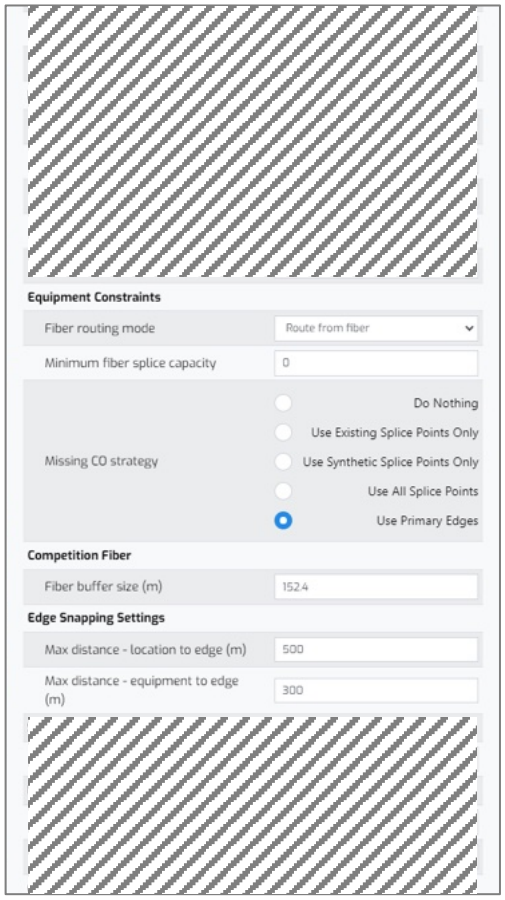
Cell Radius (Meters) – Currently not used

Cell Granularity Ratio – The interval along conduit edge segments that the terminals are placed when searching for optimal placement

Snapping Distance (Meters) – Determines the radii overlap with each other during the initial node placement

Optimization Speed (Mbps) – The minimum service speed that each connected location is required to achieve. The setting is used in conjunction with Rate Reach Manager to calculate the maximum distance between a location and its serving DSLAM/FTTN node to deliver the minimum speed.

Planning Constraints Manager defines various optimization constraints, reporting settings, and technology-specific parameters



Equipment Constraints – Fiber route starting point(s) settings

Fiber Routing Mode – Determines where to originate/splice from when designing the new fiber paths.

- **Route From Fiber** – Routes start at splice points that are automatically placed on top of existing fiber. Interval Buffer Distance setting in Fusion Manager defines how densely those synthetic splice points can be placed
- **Route From Nodes** – Routes originate from Central Office or existing splice points (i.e., layer containing splice points data that is selected in the Equipment data selection dropdown)

Minimum Fiber Splice Capacity – Defines the minimum splice point capacity required to be usable in the plan, i.e., only splice points with spare capacity set above this threshold are used in a plan. Note that splice point capacity must be defined on the equipment layer for this setting to take effect.

Missing CO Strategy – Defines what to do when a Central Office is not present in the selected service area(s), i.e., how to go about placing a new CO required for a network in the area:

- **Do Nothing** – Do not place a new Central Office. As a result, there will be no planned fiber in areas with no existing COs
- **Use Existing Splice Points Only** – Place a new CO on top of existing Splice Points *(when splice point data layer is selected)*
- **Use Synthetic Splice Point Only** – Place a new CO on top of auto-generated splice points from a selected existing fiber layer, i.e., place CO on top of existing fiber
- **Use All Splice Points** – Use a combination of existing and synthetic splice points for optimal CO placement
- **Use Primary Edges** – *Preferred* - Place a new CO anywhere along the primary Conduit layer (typically roads)

Competition Fiber – Wholesale & Tower competition threshold

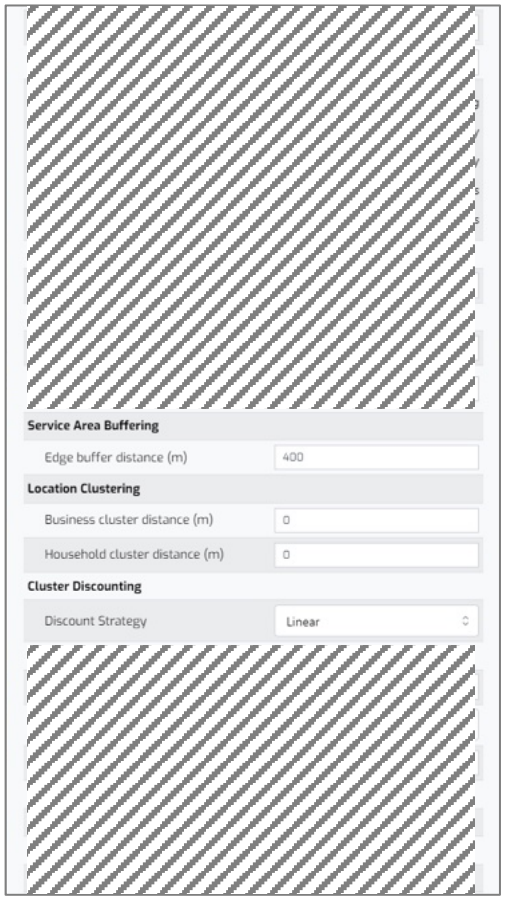
Fiber Buffer Size (Meters) – Defines the radius used to determine the competitive presence of other service providers from the target location, used in its fair share calculation

Edge Snapping Settings – Defines maximum distances from conduit to location-supporting equipment

Max Distance – Location to Edge (Meters) – Maximum distance from the conduit edge for the target to be considered routable

Max Distance – Equipment to Edge (Meters) – Maximum distance from the conduit edge for the equipment to snap to a fiber network

Planning Constraints Manager defines various optimization constraints, reporting settings, and technology-specific parameters



Service Area Buffering – Service Area conduits inclusion settings

Edge Buffer Distance (Meters) – Maximum buffer distance outside of the selected service area(s) to allow the planned fiber to go through. This allows the planned fiber to temporarily leave the service area to reach locations inside of it that would otherwise be unreachable though the conduit networks restricted to the service area boundary, e.g., reach the other side of the lake, or take more direct / cheaper path in service areas that are oddly shaped.

Location Clustering – Automatic location clustering/merging settings

Business Cluster Distance (Meters) – Defines the maximum cluster width for business endpoints. Inside each cluster, the business are aggregated together into a single latitude and longitude, and the planned fiber and equipment reach only this single point rather than each location individually. Revenues and financial potential of each locations are not impacted preserving the integrity of the business case.

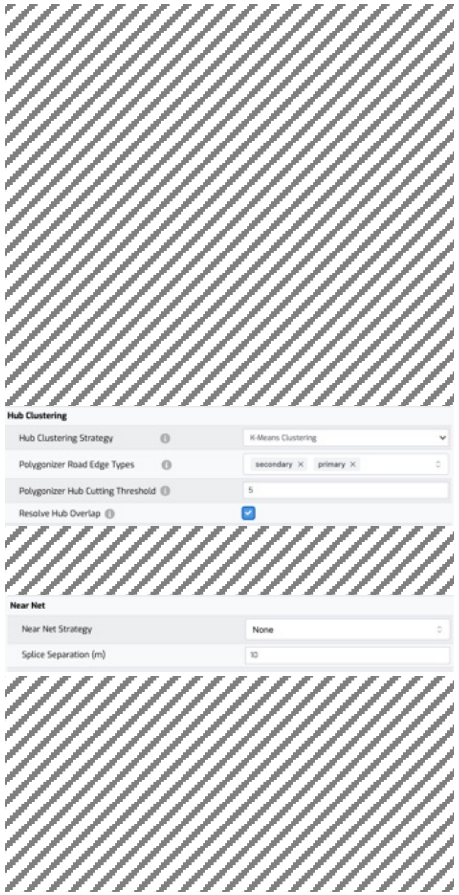
Household Cluster Distance (Meters) – Defines the maximum cluster width for residential endpoints. Inside each cluster, the households are aggregated together into a single latitude and longitude, and the planned fiber and equipment reach only this single point rather than each location individually. Revenues and financial potential of each locations are not impacted, preserving the integrity of the business case.

Cluster Discounting – *Used for Integrated Build planning only* – defines how to discount future revenues of location clusters. *It is only applicable when Slack Cluster Rule Type is set to Cluster, i.e., when Integrated Build module is engaged.*

Discount Strategy – Defines the discounting strategy for location clusters

- **None** – Do not discount revenues
- **Linear** – Turns on the discount strategy for Integrated Builds. Linear option helps when a slack cluster has a small number of locations with a significant variance in potential revenue. When selected, the expected revenue is discounted based on a factor that is derived from a ratio of the Expected Revenue and the Median Revenue from a distribution of the locations in the cluster.

Planning Constraints Manager defines various optimization constraints, reporting settings, and technology-specific parameters



Hub Clustering – Settings defining how to generate hub-service areas and where to place the network equipment

Hub Cluster Strategy – Specifies an approaches for deciding on where to place Fiber Distribution Hubs

- **DAG (Directed Acyclic Graph)** – *Legacy* – The algorithm places hubs "downstream" from the CO, prioritizing filling the hub with as many locations as possible (within the maximum locations per hub constraint).
  It is a very fast algorithm but may result in oddly shaped hub serving areas.
  It should only be used to reproduce legacy Arrow results *(pre-2021)*
- **Minimum Spanning Tree** – Similar to DAG, however, prior to doing the hub placement, the algorithm uses a minimum spanning tree to eliminate redundant conduits from the route, e.g., if there are multiple road edges connecting the same point it removes the longer ones.
  This is also a fast algorithm, that produces slightly more realistic hub serving areas.
- **K-Means Clustering** – *Default* – The algorithm uses a clustering approach to first cluster locations based on the road distance, and then places hubs in relation to these clusters, while ensuring the maximum locations per hub (or cluster) and the maximum distance from locations to the hub settings are honored.
  This approach results in the most realistic output, i.e., like what a network engineer would plan by hand, but is slightly slower than the other two. Nevertheless, any analysis (short of high-level *relative* comparison of attractiveness of different markets) should be using this approach.

Polygonizer Road Edge Types – *Used only with K-means clustering strategy* – Defines which road edge types to use when dividing the whole service area into smaller polygons, that are then used in K-means analysis to determine final hub serving areas. Using the Polygonizer results in hub boundaries that are closer to what a network engineer would design. It also improves overall plan runtime.

Polygonizer Hub Cutting Threshold – *Used only with K-means clustering strategy* – Threshold at which additional road edge types are considered. For example, with Primary and Secondary entered and Hub Cutting Threshold set to 5, if any of the polygons created using Primary roads have 5 or more Hubs Secondary roads will also be used to further divide the polygons.
Note that this value may need to be carefully calibrated to match your exact preferences and current planning practices.

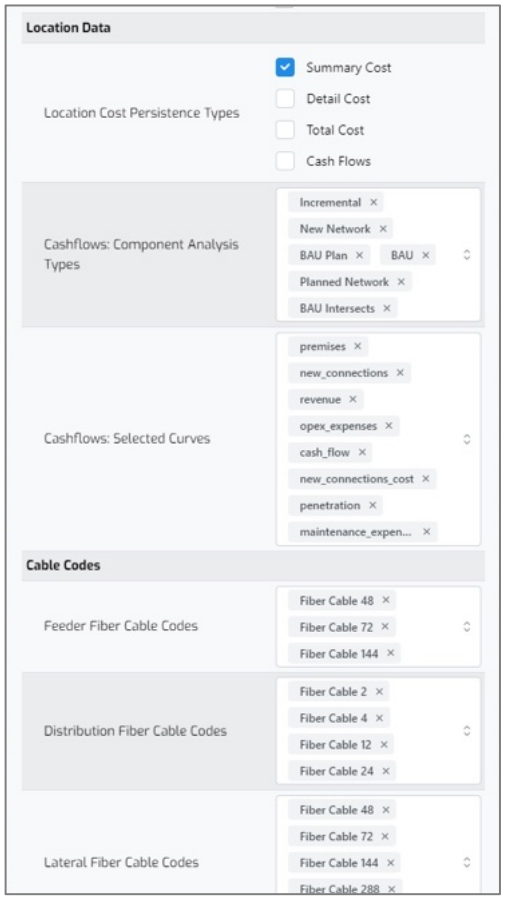
Resolve Hub Overlap – *Used only with K-means clustering strategy* – In areas with sparse road network, it is possible to encounter two hubs leveraging the same road segments to connect their respective locations. When this occurs, hub boundaries may overlap. This setting detects such scenarios and places a third hub to ensure all three polygon boundaries do not overlap with each other. The approach effectively reduces the size of the two original hubs and forces the third one to be placed.

Near Net – Near-Net module settings

Near Net Strategy – Enables leveraging the Slack Loop clusters along routes targeting specific locations. The Slack Cluster Rule Type needs to be enabled, and the Business Cluster distance should be set to 0. For example, Slack Loops will be placed along the path when a plan is run for selected Cell Tower locations and Slack Cluster Rule Type is enabled for Medium Businesses. In addition, routed lateral fiber distances are calculated for each Medium Business included in a cluster.

Splice Separation – Determines the distance interval along the Fiber route evaluated for placing Slack Loops.

Planning Constraints Manager defines various optimization constraints, reporting settings, and technology-specific parameters



Location Data – Location-level reporting settings

Location Cost Persistence Types – Defines the level of detail to preserve when saving location-level attribution of plan's costs. Note that this writes significant amount of data into the database, and should only be used when necessary

- **Summary Cost** – Total attributed cost (fiber + equipment) as a single entry
- **Detail Cost** – Detailed cost attribution by equipment and fiber type
- **Total Cost** – *only for RFP plans* – Minimum cost needed to connect the location. (This ignores fiber route sharing benefits with other targets included in the plan)
- **Cash Flows** – Year-over-year financial model components, as selected in the settings below

Cash Flows: Component Analysis – When locations-level cash flows are enabled in Location Cost Persistence above, it defines which components of the business model to save for each location:

- **BAU** – BAU for all locations in the service area – *generally redundant*
- **BAU Plan** – BAU for all locations passed by the planned network
- **BAU Remaining** – BAU for locations not passed by the planned network – *generally redundant*
- **BAU Intersects** – All passed locations that are still subscribers of the legacy technology
- **New Network** – All passed locations that already migrated to the new technology
- **Planned Network** – All passed locations (New Network + BAU Intersects)
- **Incremental** – Incremental impact of the new network, i.e., Planned Network – BAU Plan

Cash Flows: Selected Curves – When locations-level cash flows are enabled in Location Cost Persistence above, it defines which line items of the business model to save for each location

Cable Codes – Defines available cable sizes, by fiber cable type. Cables are rounded up from their exact strand count (based on the downstream locations demand) to the next available size. Cable surcharges for each size can are defined in the Price Book and are added on top of fiber install costs.

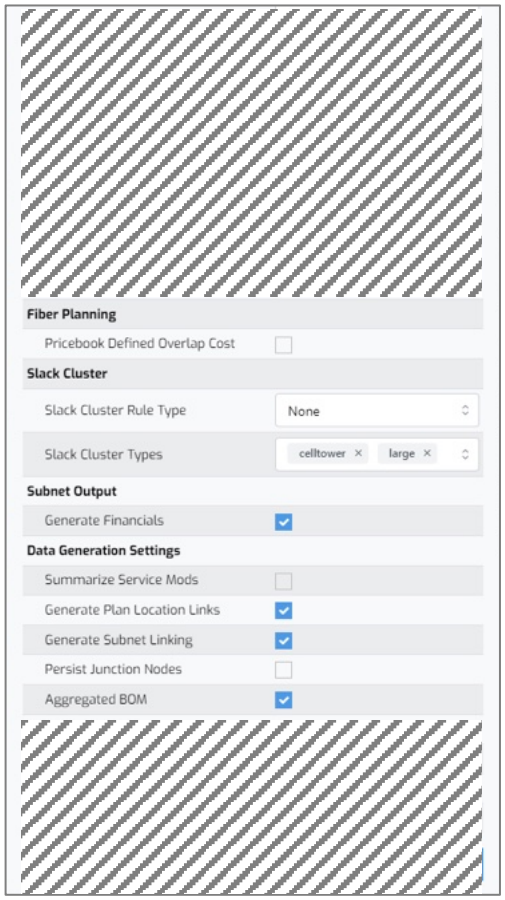
Feeder Fiber Cable Codes – List of eligible Feeder fiber sizes

Distribution Fiber Cable Codes – List of eligible Distribution fiber sizes

Distributed Tap Fiber Cable Codes – List of eligible Distributed Tap fiber sizes

Lateral Fiber Cable Codes – List of eligible Lateral fiber sizes

Planning Constraints Manager defines various optimization constraints, reporting settings, and technology-specific parameters



Fiber Planning – Defines how to treat/cost instances of feeder and distribution fiber overlapping with one another

Pricebook Defined Overlap Cost – When selected, all instances of overlapping fiber will be separately itemized in the bill of materials, and a separate Price Book cost code is used when costing the overlapping distance. You can set the "Planned Overlap" fiber cost in Price Book to $0/m to completely eliminate double counting of the overlap portion of the network, or to any number lower than actual fiber cost to represent the reduced cost of such double routes. Total route mileage is unaffected by this setting

Slack Cluster – *Used to engage the Integrated Build planning functionality* – Defines the behavior of slack loop location clusters

Slack Cluster Rule – Turns the slack loop location clustering on/off

- **None** – No clustering, *i.e., the Integrated Build functionality is off*
- **Cluster** – Turns the slack loop clustering on for the Integrated Builds

Slack Cluster Types – Defines which location types are aggregated into slack loop clusters. Note that running plans with slack clustering enabled but no eligible endpoint types selected is equivalent to running the plan without the Integrated Build functionality enabled.

Subnet Output – Sub-service area financial reporting settings

Generate Financials – Directs the tool to saves financial details at a subnet level, e.g., by hub, enabling more granular cost reporting

Data Generation Settings – Settings defining how much detailed data to saved with each plan

Summarize Service Mods – Summarizes all equipment, fiber, and coverage for a plan as it is modified

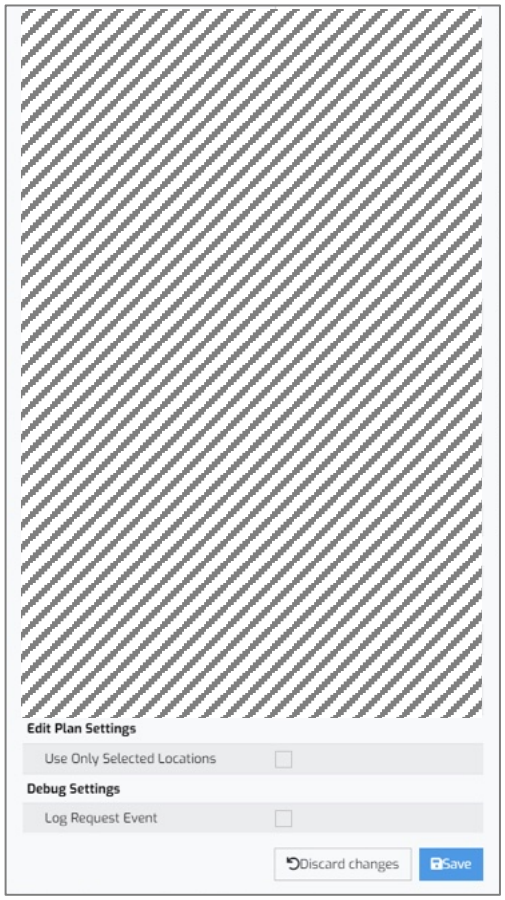
Generate Plan Location Links – *Required to retrieve routed locations reports* – Directs the tool to save the linking between each target endpoint and the equipment it connects to, enabling detailed reporting of each connected locations in a plan – *Keep selected*

Generate Subnet Linking – *Required for Plan Editing* – Directs the tool to establishes tracing between equipment, fiber, and endpoints which enables generation of network topologies – *Keep selected*

Persist Junction Nodes – When selected, the includes Junction Nodes in its detailed equipment output and cost breakdown

Aggregated BOM – When selected, the tool produces breakdown of equipment and fiber costs, vs. just the total cost – *Keep selected*

Planning Constraints Manager defines various optimization constraints, reporting settings, and technology-specific parameters



Edit Plan Setting – Defines UI behavior in Plan Edit mode

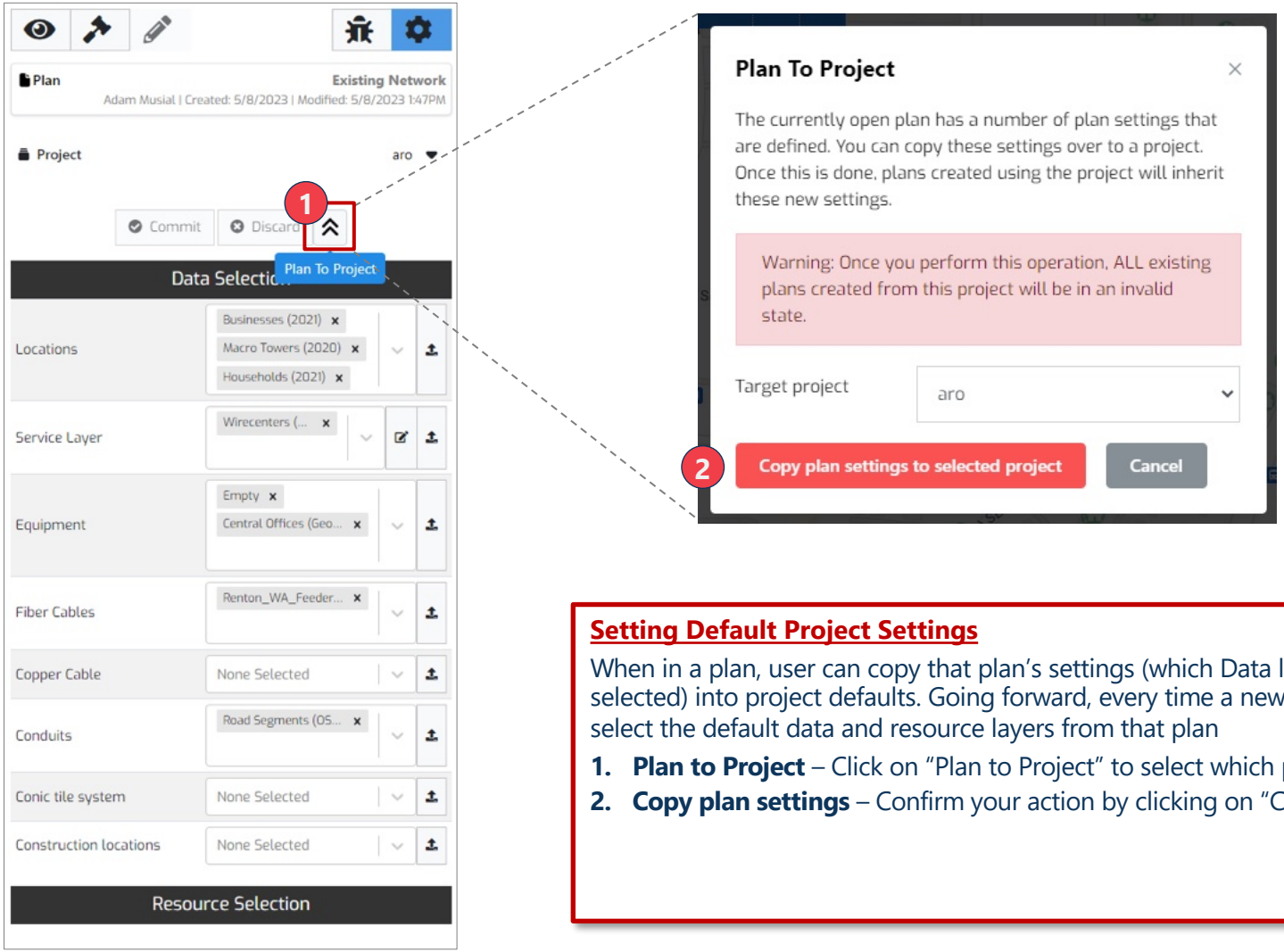
Use Only Selected Locations – When selected, only the originally selected target locations will be displayed in the Edit Mode. This makes it easy to, e.g., inspect that all targets have been connected (or view the ones that were not), but eliminates the possibility of expanding the list of plan targets from inside the Edit Mode, e.g., by manually adding a new hub

Debug Setting– Debugging settings

Log Request Event – *Do not enable unless directed by the Customer Success team* – Saves detailed debugging data in the database

Contents

Users can set their project defaults (data and resources that are enabled by default) and create new Projects directly above Data Selection panel



Setting Default Project Settings

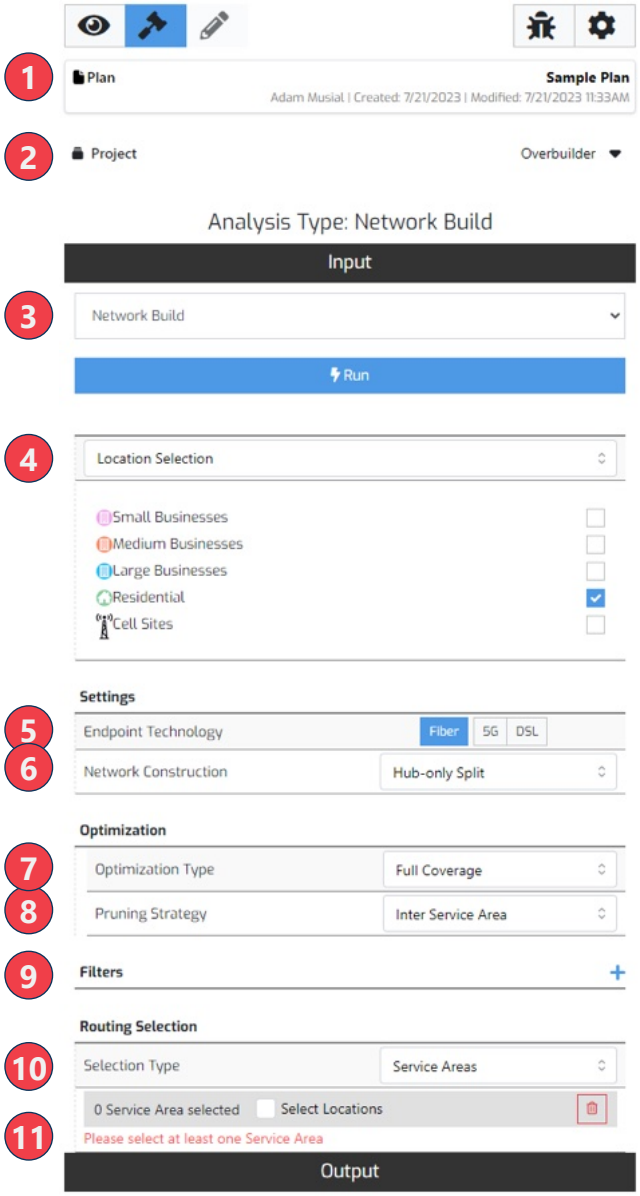
When in a plan, user can copy that plan's settings (which Data layers and Resource Managers are selected) into project defaults. Going forward, every time a new plan is created, it will automatically select the default data and resource layers from that plan

1. **Plan to Project** – Click on "Plan to Project" to select which project you wish to update
2. **Copy plan settings** – Confirm your action by clicking on "Copy plan settings..." button

? ***Tip:*** *Users, and groups of users, can utilize multiple project templates. Go to User Settings to choose which one is in use by default*

Contents

Analysis Settings define all the aspects of optimization plan to be run



1. **Plan Information**
2. **Project** – Defines which project template (defaults for data and resource selection) should be used as a starting point
3. **Analysis Type**
   - *Network Build:* runs an optimization and places equipment as part of plan
   - *Network Analysis*: runs the pruning analysis and shows high level financials for all levels of build
4. **Location Selection** Defines which endpoint types to target in the optimization
5. **Endpoint Technology** – Defines which technology to use for the optimization
6. **Network Construction** – Defines the network architecture - *Details on the next page*
7. **Optimization type** – 5 target optimization types available, e.g. full build, coverage target - *Details on the following pages*
8. **Pruning Strategy** – Indicates where the budget constraint is to be applied: to all selected geographies ("Inter Service Area") or to each ("Intra Service Area")
9. **Filters –** Adds filters to the locations analyzed based on preconfigured attributes. Note, once a filter is added and service areas are selected the locations that match the filter can be previewed on the map.
10. **Selection Type** – Defines whether the selection mode will be service areas (selecting polygons) or location selection (individual locations)
11. **Selected Areas/Locations** – Lists areas/locations selected for the analysis

? ***Tip:*** *Please contact Arrow team member to configure filters for your environment*

Users can select between three different hub and spoke network architectures to generate their plans

1 Direct Routing

Direct Routing **–** Does not place any equipment along the way

- Routes from source point directly to target location, installing a single Bulk Distribution Terminal (representing a coil) at a point on the road nearest to target(s)
- Generally used to connect Towers, Medium/Large Businesses and Fixed Wireless locations (feeder fiber)

2 Point-to-Point

Point-to-Point **–** Does not place equipment along the way

- Similar to Direct Routing, but each target endpoint is evaluated individually, The resulting network layout, and costs, assume each target does not leverage fiber infrastructure created by neighboring targets (e.g. shared fiber route between two targets will be costed twice)

3 Hub-Only Split

Standard PON **–** Splitters are placed only in Hubs (1x32)

- Places equipment along the way – Fiber Distribution Hubs and Terminals
- Feeder Fiber connects the source point to Hubs and Distribution Fiber connects Hubs to Terminals
- Drop distance constraints determine Terminal placement in relation to household and small business locations

4 Distributed Tap

Distributed Tap **–** Limits number of Terminal placed per Fiber cable

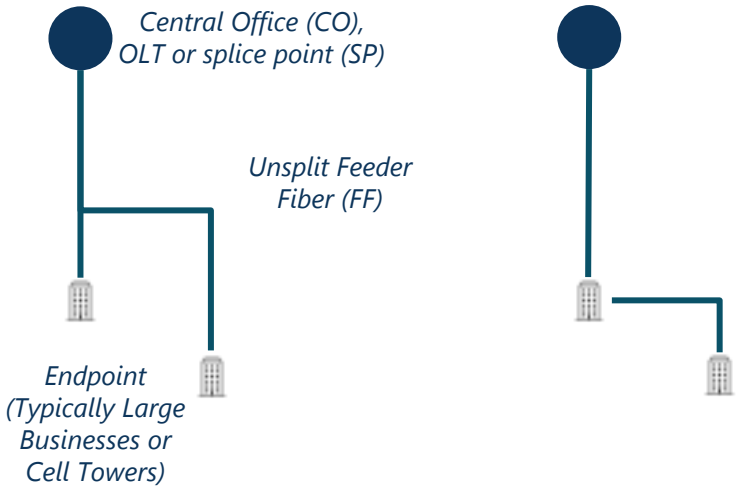
- Places equipment along the way – Distributed Taps (DTap) and Optical Taps (OTaps)
- Feeder Fiber connects the source point to DTaps, and Distributed Tap Fiber connects DTaps to OTaps
- Drop distance and maximum OTaps per DTap port constraints determine OTap placement in relation to household and small business locations

The four different hub and spoke network architectures can be illustrated by the following fiber architectures

Point-to-Point *(Individual)*

Direct Routing *(Optimized)*

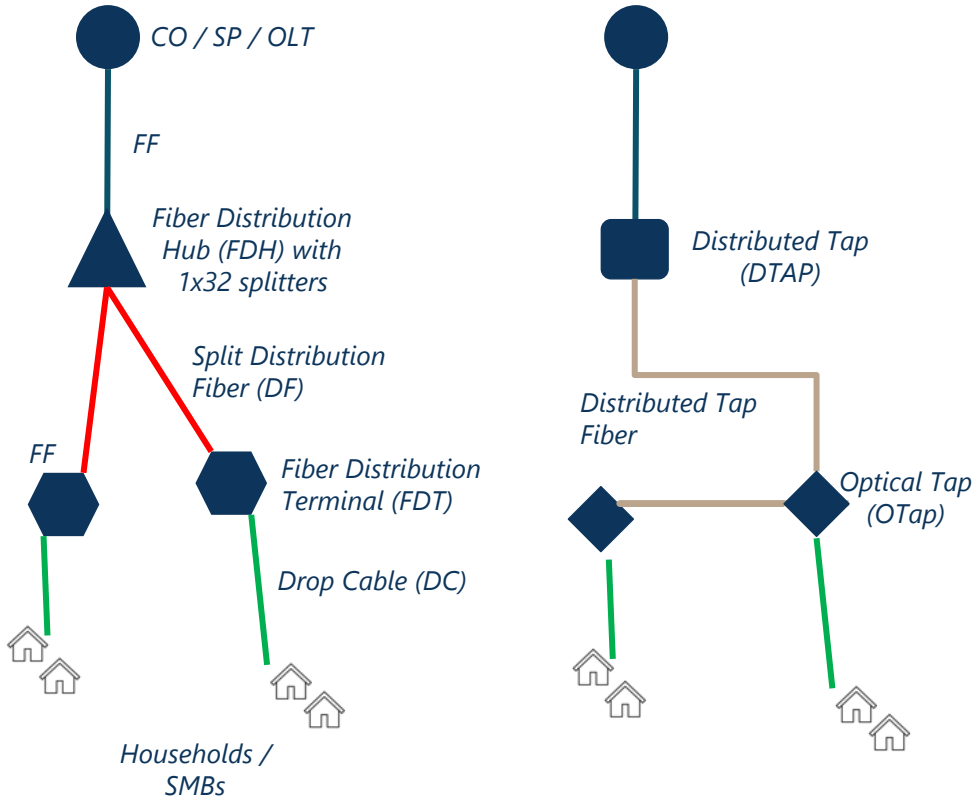
Single-level architecture with no passive optical equipment placed along route



Hub-Only Split

Distributed Tap

Two-level architecture with with passive optical equipment placed along route

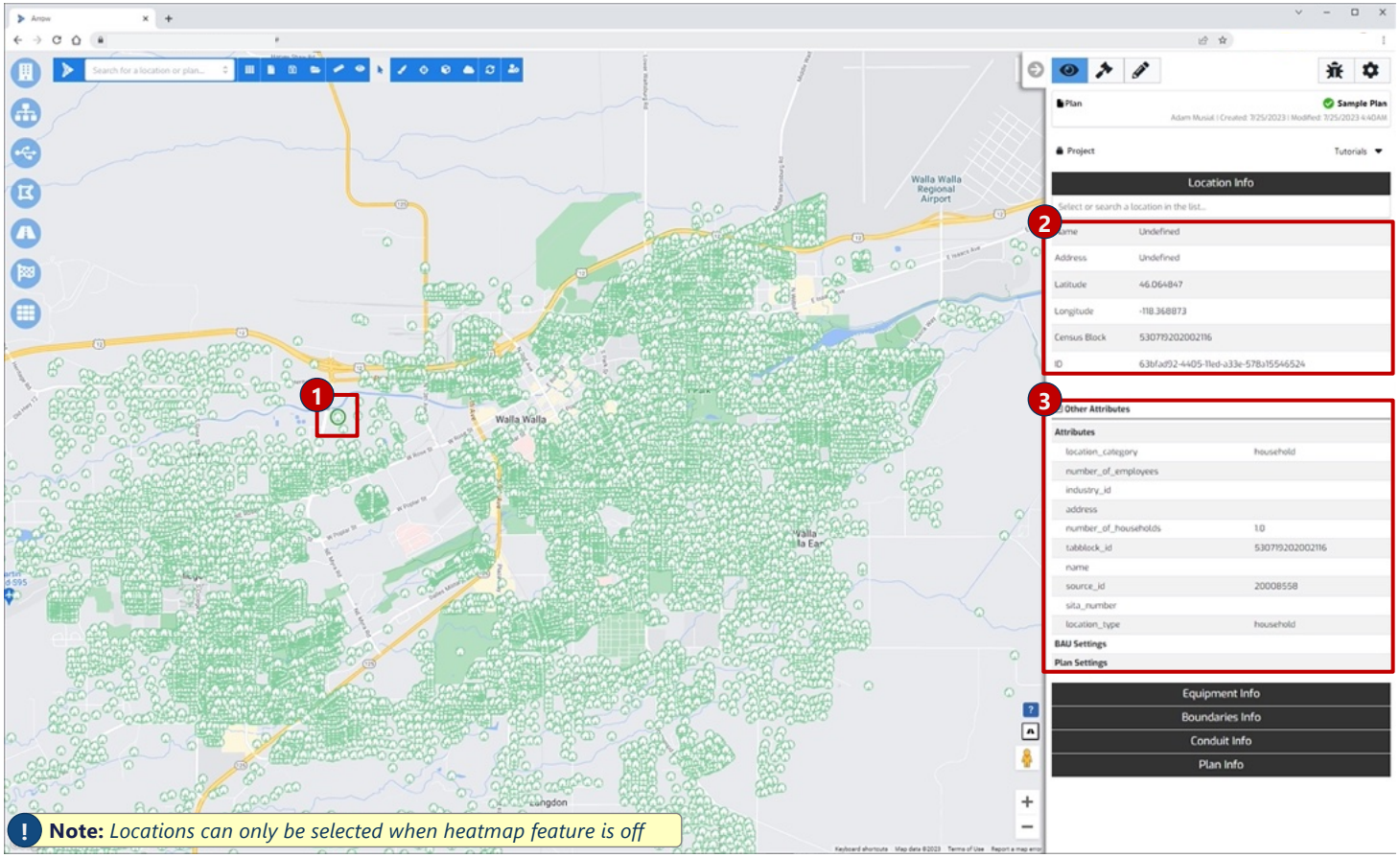


In Network Build, Arrow allows users to run five main types of optimizations

Full Coverage	***Design network that covers every location in target service area(s)*** **–** Coverage provided by fiber or fixed wireless technology, as specified by the user
Budget	***Build most financially attractive network for a fixed budget amount*** **–** Route to highest-opportunity locations first (IRR-based), until construction budget runs out
Coverage Target	***Design NPV-maximizing network that achieves desired coverage level*** **–** Route to most attractive locations first, until coverage target is reached
Plan IRR Floor	***Within a given budget, build until plan IRR is reached*** **–** Continue expanding until plan IRR falls to target IRR, or budget runs out, whichever comes first. Resulting plan IRR will be no less than target IRR
Segment IRR Floor	***Build to all locations that exceed target IRR*** **–** Every location above target IRR will be routed to. Resulting plan IRR will be above target IRR

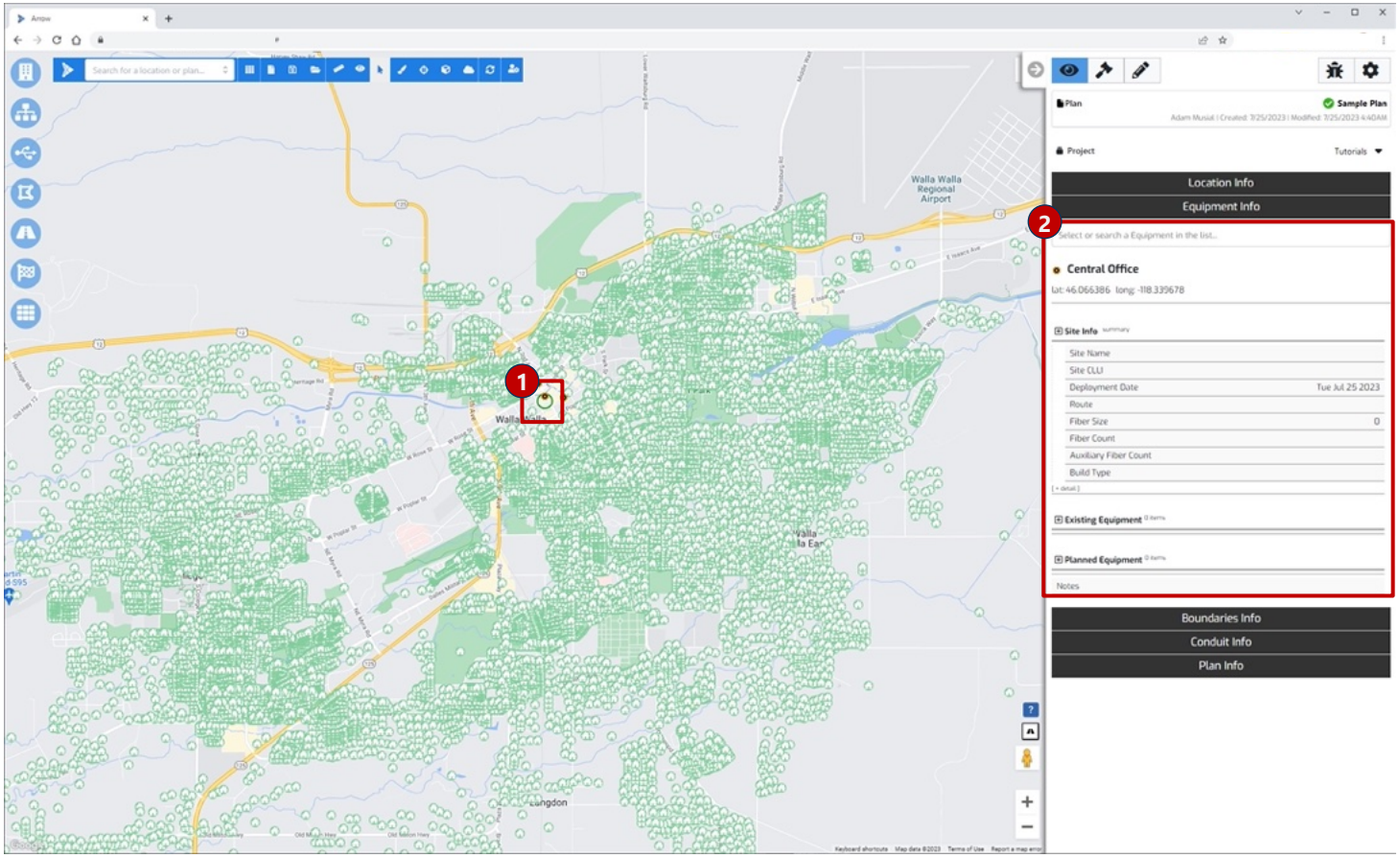
Contents

Location Info tab allows users to inspect details of individual locations



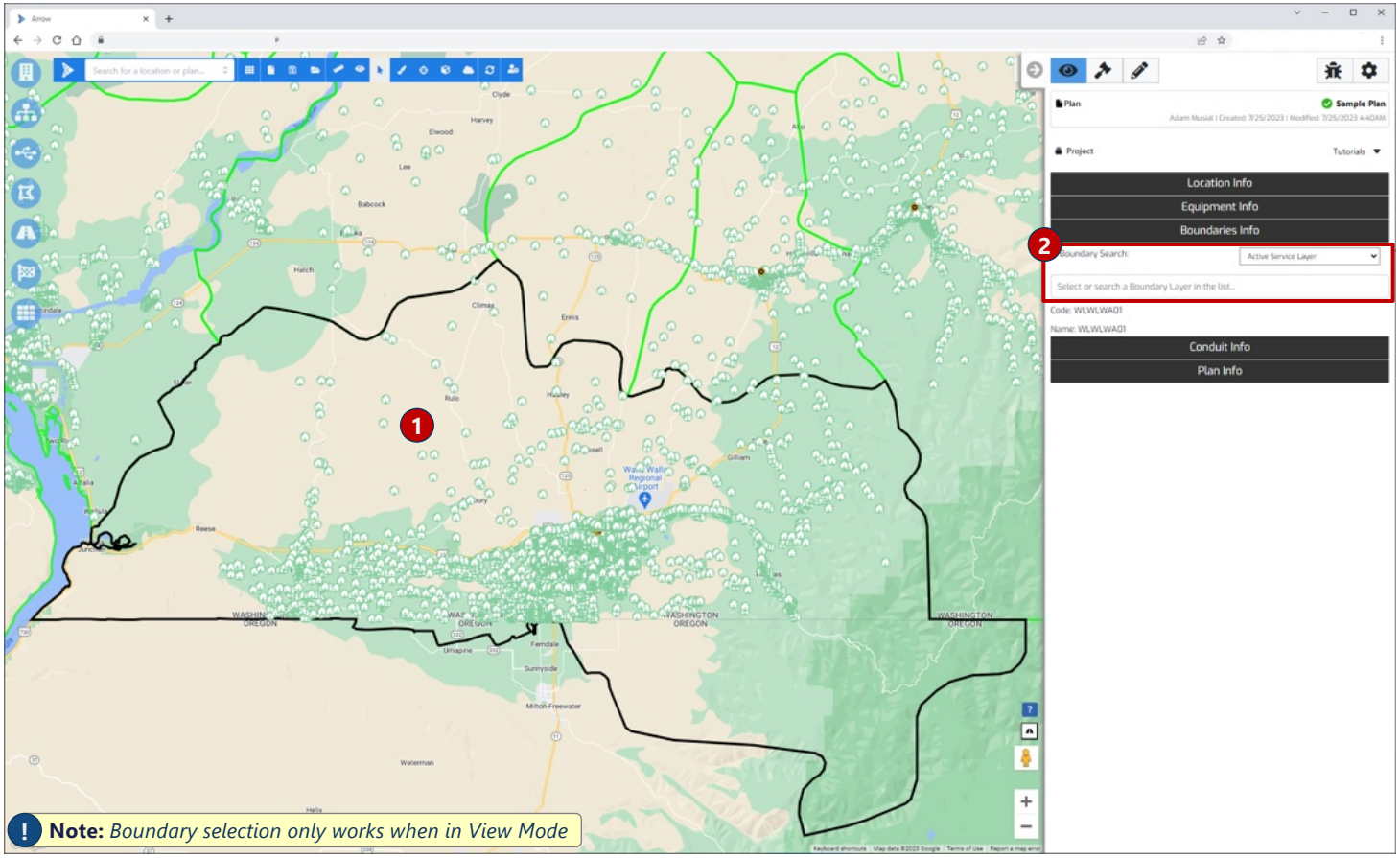
1. **Select Location** – Click on individual location on a map to bring up the Location Info tab
2. **Location Information** – Key location information displays at the top of the panel
3. **Additional Information** – Displays all additional attributes assigned to the location during the upload process (from the upload template)

Equipment Info tab allows users to inspect the details of existing and planned network equipment



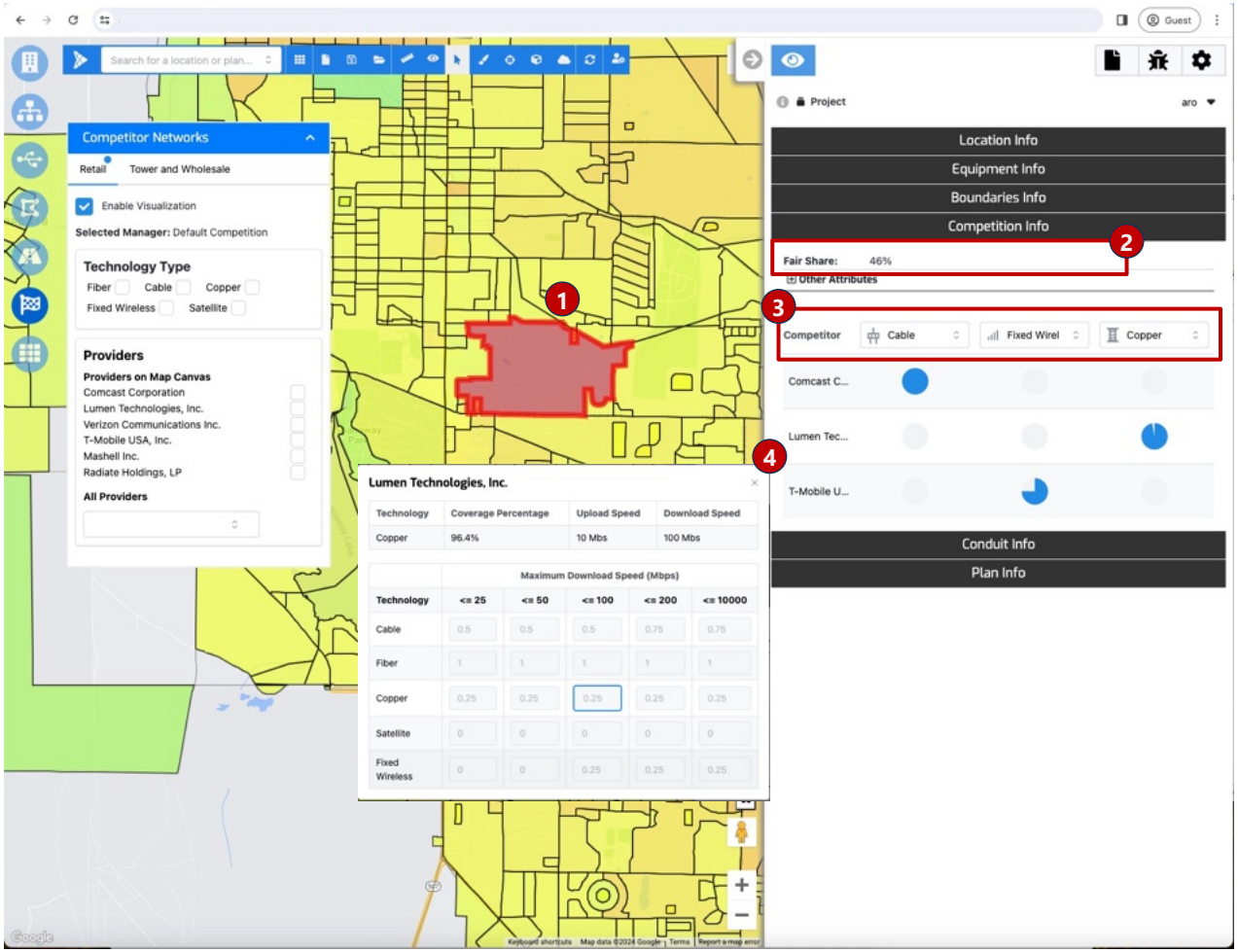
1. **Select Equipment**– Click on individual equipment element on a map to bring up the Equipment Info tab
2. **Location Information** – Equipment details, if set by the user (existing equipment), or placed in the plan (planned equipment), display in the panel

Boundaries Info tab enables users to look up active service area name, or search for it on a map using its name



1. **Select Boundary** – Click inside the boundary to bring up its details
2. **Boundary Search** – Search for boundaries using individual service area's names or codes

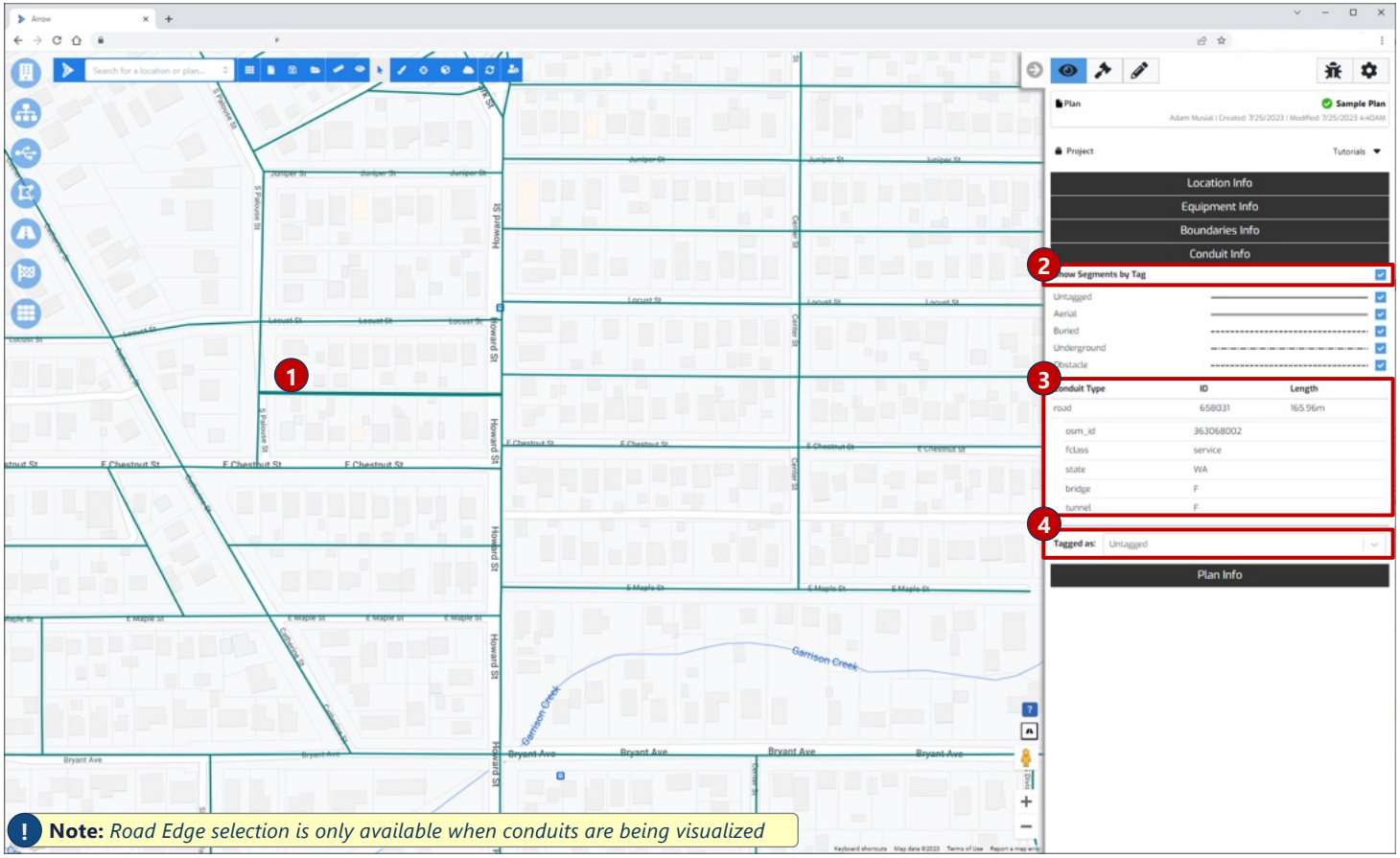
Competition Info tab enables users to understand the providers present in a specific boundary



Note: *Boundary selection only works when in View Mode*

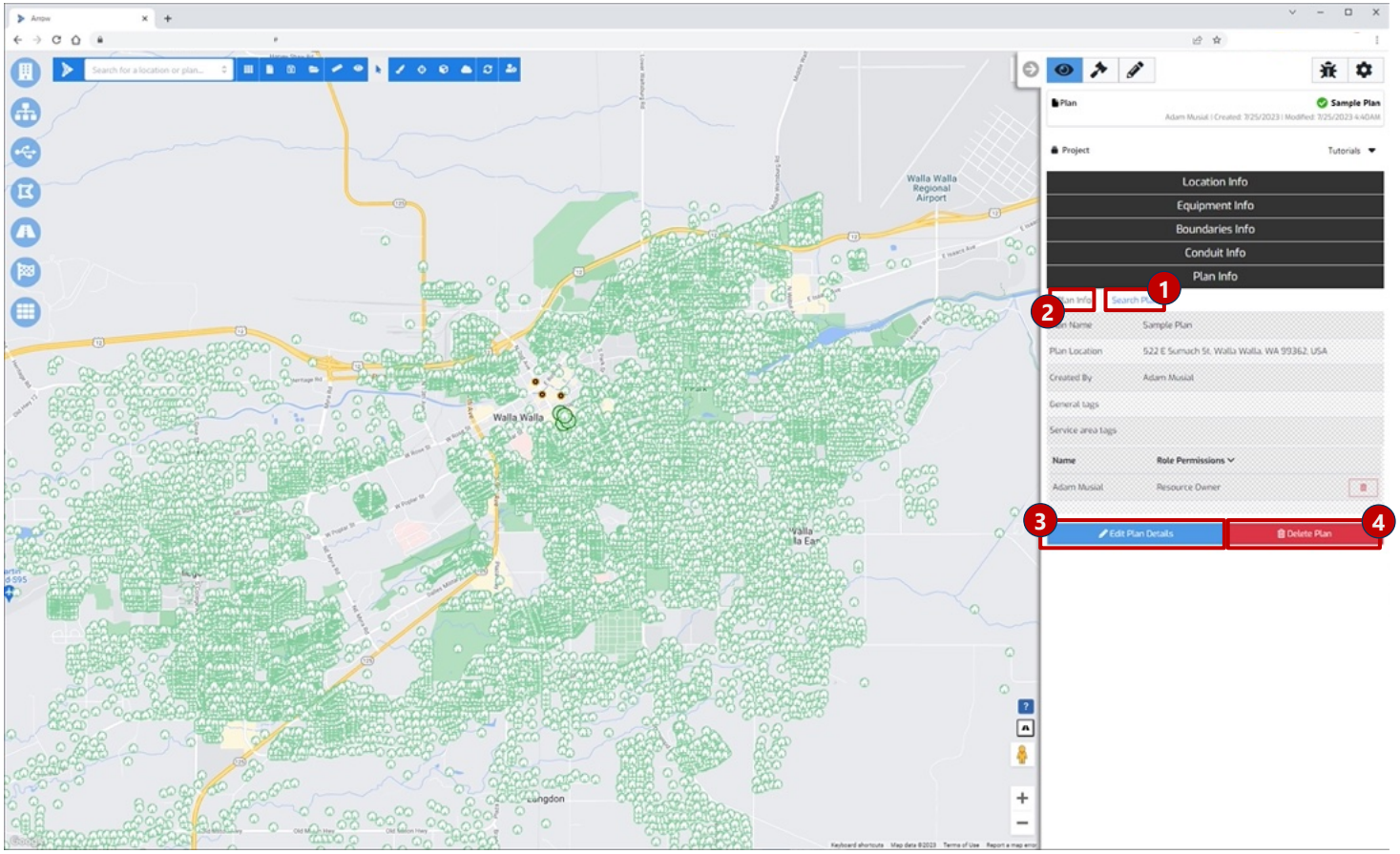
1. **Select Boundary** – With Retail competition enabled, click inside the boundary to bring up its details
2. **Fair Share** – This calculation is based on the provider's present in the selected boundary and settings in the currently selected Competition Resource Manager (see Penetration Rate Calculation in the appendix for additional detail)
3. **Competitive Technology** – You can change the order of which technologies to display
4. **Competitor Detail** – Click on an individual provider to see additional detail

Conduit Info panel displays information about the conduits and enables users to change placement type of individual road segments



1. **Select Conduit** – Select individual segment by clicking it on a map
2. **Show Segments by Tag** – Displays placement tags of road segments, if available
3. **Conduit Info** – Displays available segment attributes
4. **Tagged As** – Users with modify permissions and above can change placement tag of the selected segment(s). Use the Shift key to select multiple segments

Plan Info tab allows users to search, open, delete, rename and update permissions to existing plans



1. **Search Plans** – Opens up plan search utility
2. **Plan Info** – Brings up info panel with key information about the plan
3. **Edit Plan Details** – Unlocks the greyed-out area above, and allows the user to rename the plan, update start location, tags and user permissions
4. **Delete Plan** – Deletes current plan

Contents

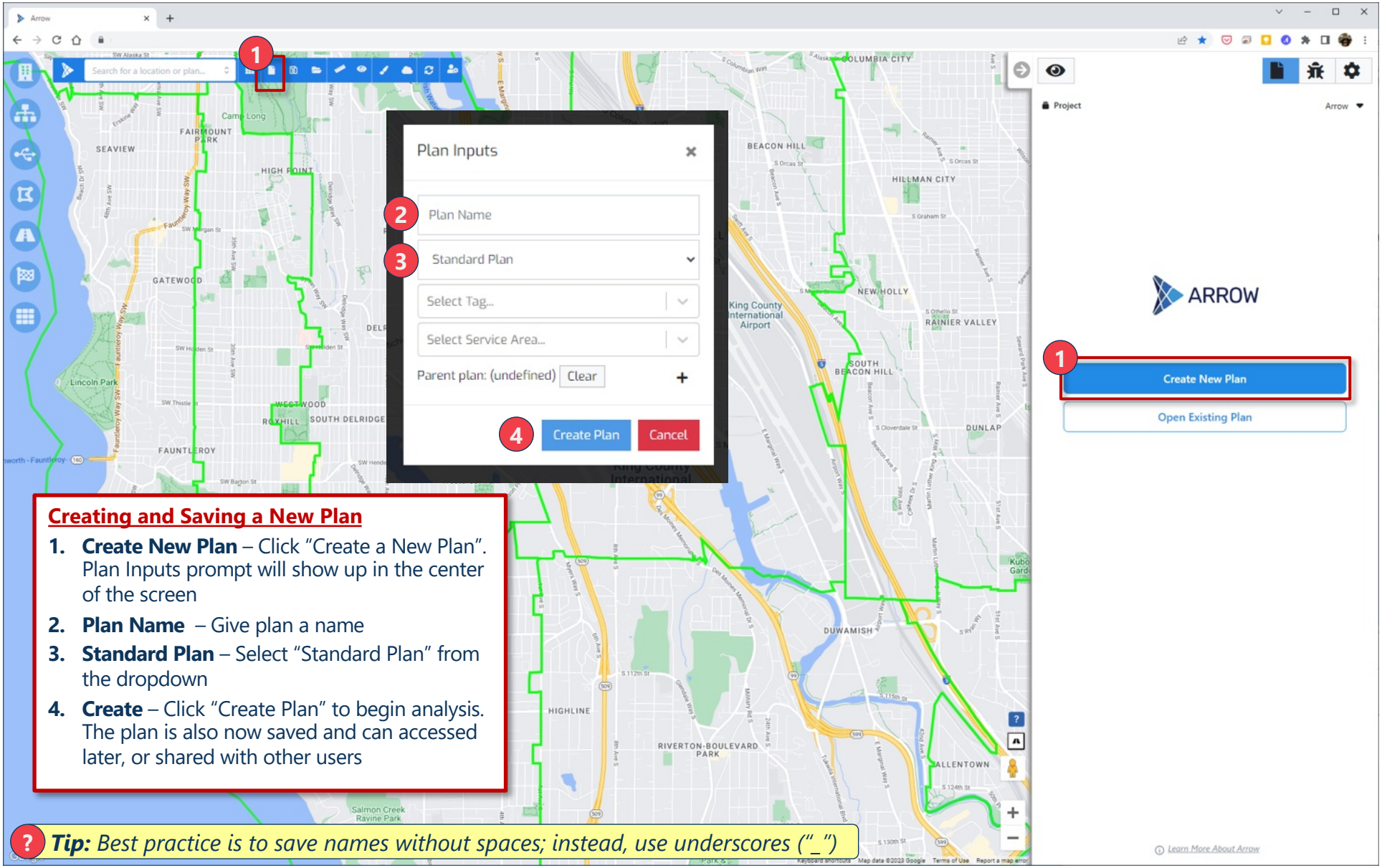
We recommend the following order of operations for running optimizations

Order of Operations		Description
Set-Up	New Plan	**Create a New Plan** • Before adjusting any settings or running simulations, please create a plan to store results for later reference
	Settings	**Adjust Data Sources and Plan Settings** • To ensure plans run with correct / most recent data, circuit locations, fiber routes, analysis areas, and build costs should be adjusted here
	Locations	**Select Location Types to be Used in the Run** • Users can turn on location layers to be used in simulations and to view on the map • A plan will not run without a selection here
	Input	**Adjust Analysis Settings** • Configure build type and parameters, and financial assumption to best suit analysis goals
	Equipment	**Select Equipment to View on Map** • Users can turn on equipment layers to view on the map • If existing fiber is loaded into the application, this layer can be turned on for viewing; it does not need to be turned on in order to be used in optimizations
Results	Output	**View Build and Financial Results** • Build (fiber miles, CapEx, locations connected) and financial (NPV, IRR, revenue, cash flow) outputs are easily accessible once a run is complete

Notes: Before planning to use Arrow, make sure you have active log in credentials. If a setting is not mentioned, keep default.

Contents

Create a new plan and select ‘Standard Plan’ in plan type dropdown

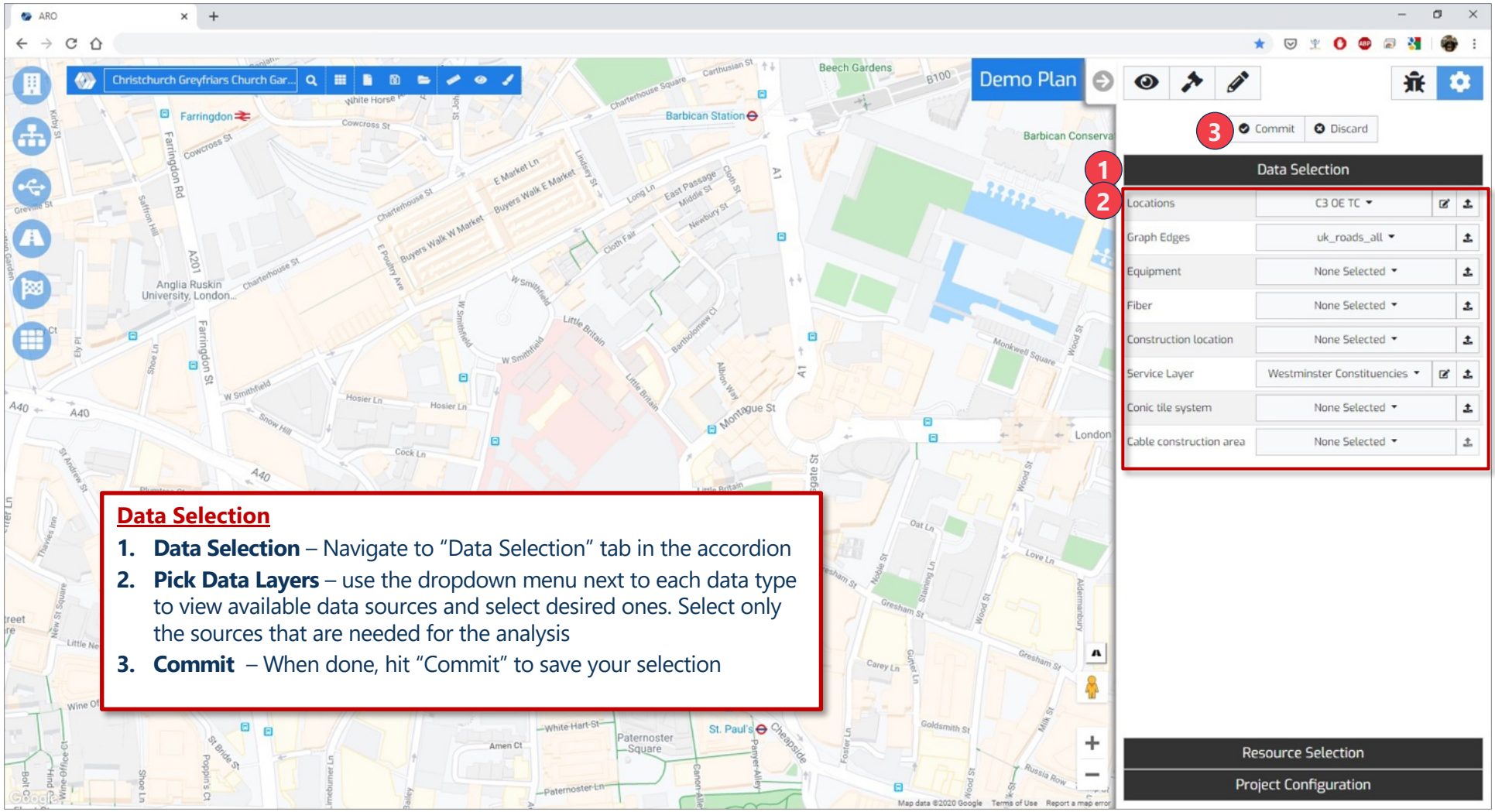


Creating and Saving a New Plan

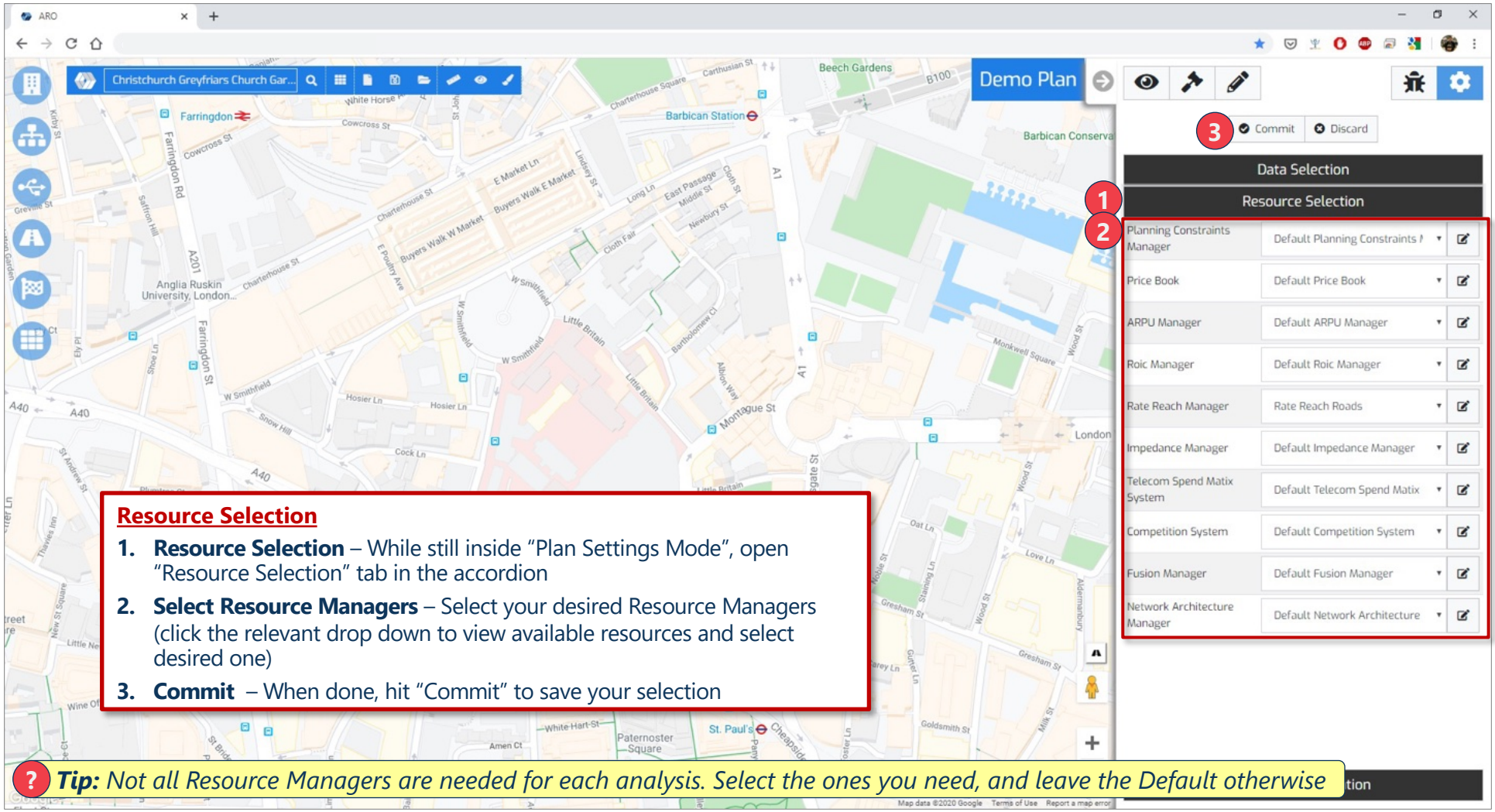
1. **Create New Plan** – Click “Create a New Plan”. Plan Inputs prompt will show up in the center of the screen
2. **Plan Name** – Give plan a name
3. **Standard Plan** – Select “Standard Plan” from the dropdown
4. **Create** – Click “Create Plan” to begin analysis. The plan is also now saved and can accessed later, or shared with other users

? ***Tip:*** *Best practice is to save names without spaces; instead, use underscores (“_”)*

Select data layers to include in the analysis



Select Resource Managers to use in the analysis

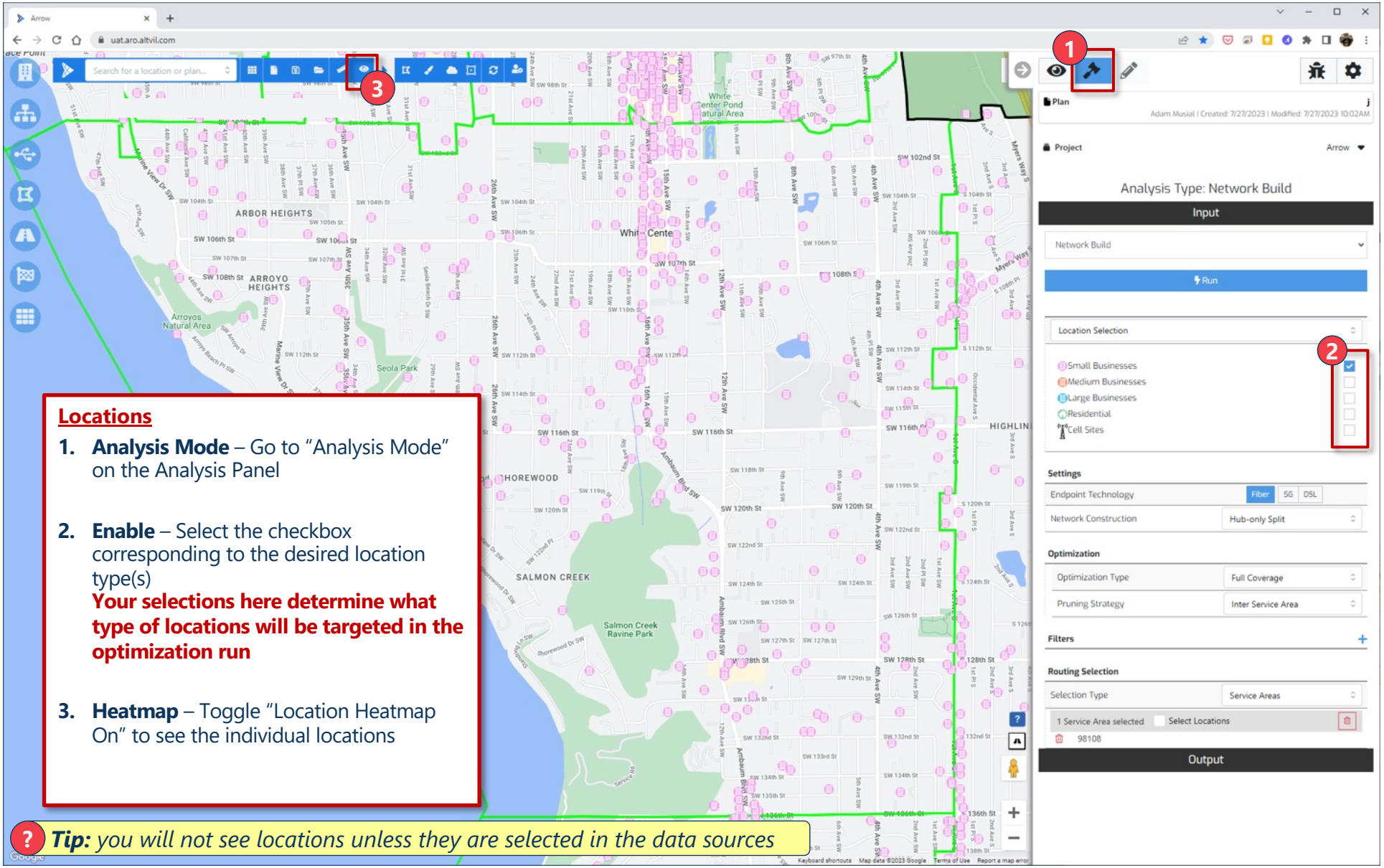


Resource Selection

1. **Resource Selection** – While still inside "Plan Settings Mode", open "Resource Selection" tab in the accordion
2. **Select Resource Managers** – Select your desired Resource Managers (click the relevant drop down to view available resources and select desired one)
3. **Commit** – When done, hit "Commit" to save your selection

Tip: *Not all Resource Managers are needed for each analysis. Select the ones you need, and leave the Default otherwise*

Turn on location layers to be used in simulations, and to view on the map



Locations

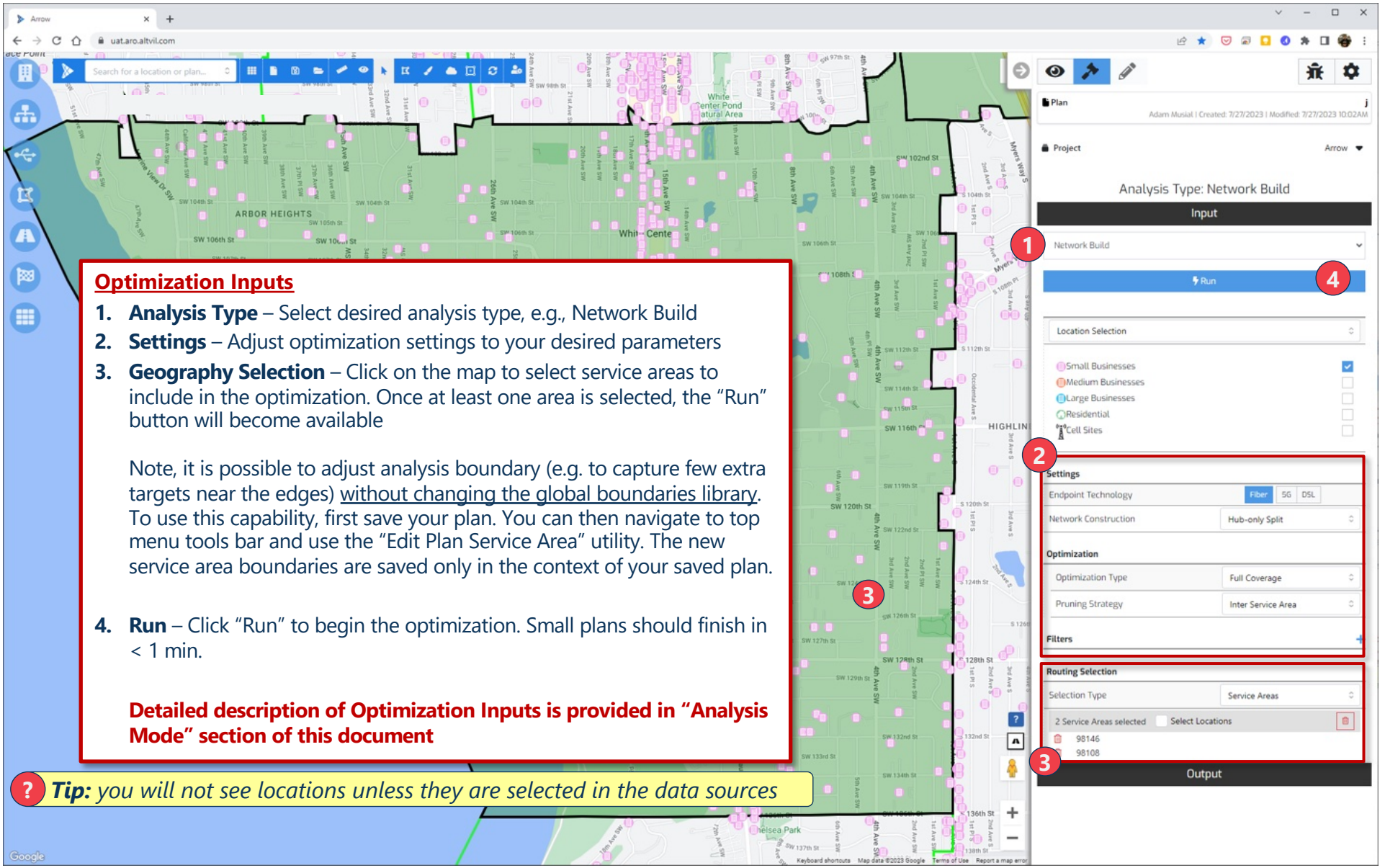
1. **Analysis Mode** – Go to "Analysis Mode" on the Analysis Panel

2. **Enable** – Select the checkbox corresponding to the desired location type(s)
   Your selections here determine what type of locations will be targeted in the optimization run

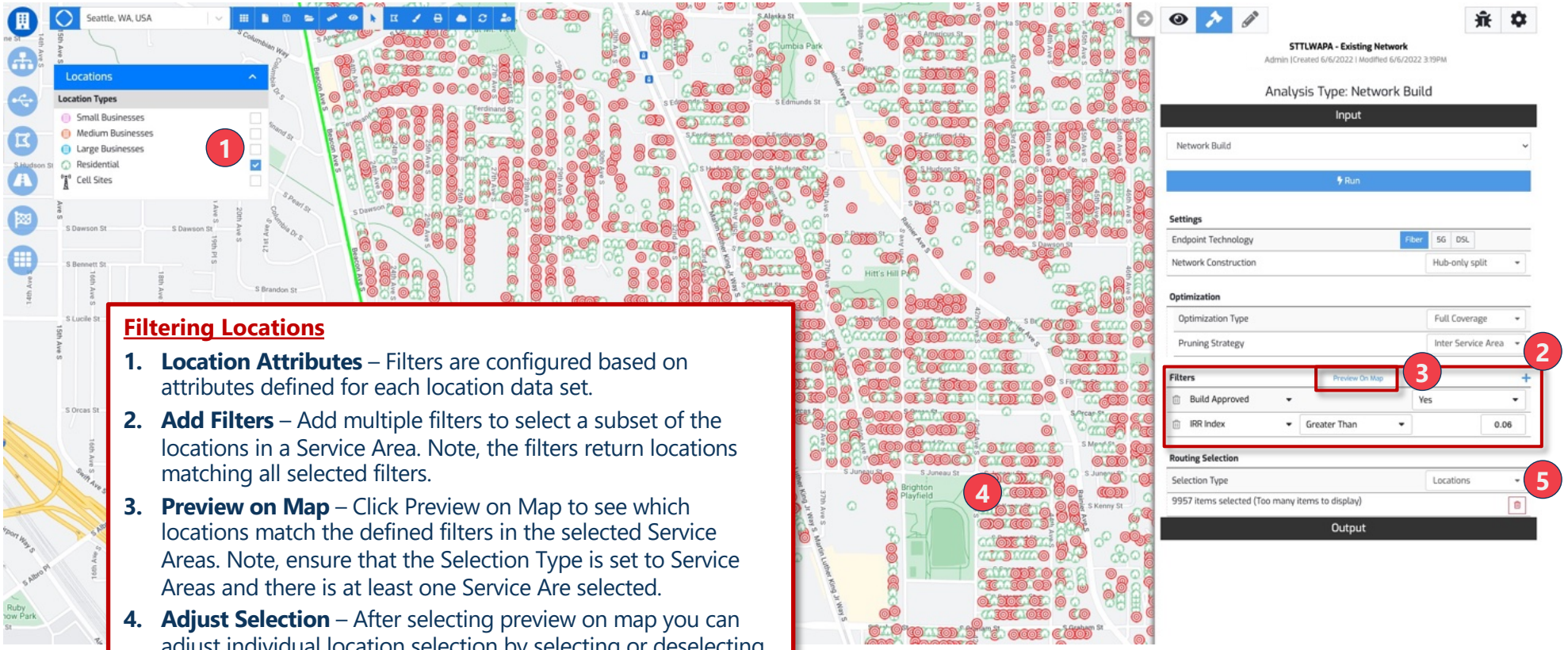
3. **Heatmap** – Toggle "Location Heatmap On" to see the individual locations

Tip: *you will not see locations unless they are selected in the data sources*

Adjust optimization settings, and run a plan



Filter locations in Service Areas based on multiple criteria

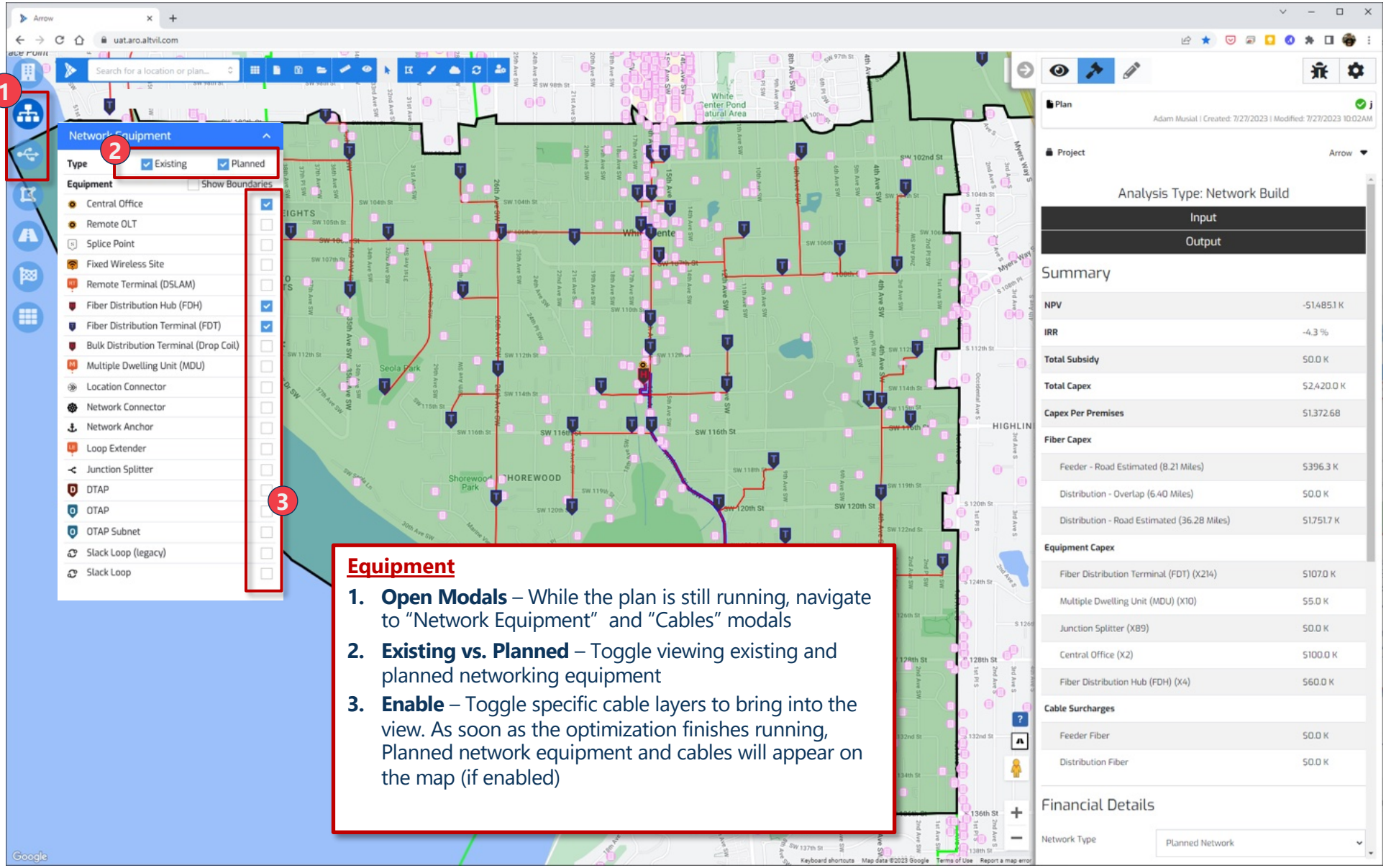


Filtering Locations

1. **Location Attributes** – Filters are configured based on attributes defined for each location data set.
2. **Add Filters** – Add multiple filters to select a subset of the locations in a Service Area. Note, the filters return locations matching all selected filters.
3. **Preview on Map** – Click Preview on Map to see which locations match the defined filters in the selected Service Areas. Note, ensure that the Selection Type is set to Service Areas and there is at least one Service Are selected.
4. **Adjust Selection** – After selecting preview on map you can adjust individual location selection by selecting or deselecting locations with a red target.
5. **Service Area vs. Locations** – Clicking Preview on Map changes the Selection Type from Service Areas to Locations. Note to first define filters or adjust the filters used in a plan make sure Selection Type is set to Service Areas.

? ***Tip:*** *Please contact Arrow team member to configure filters for your environment*

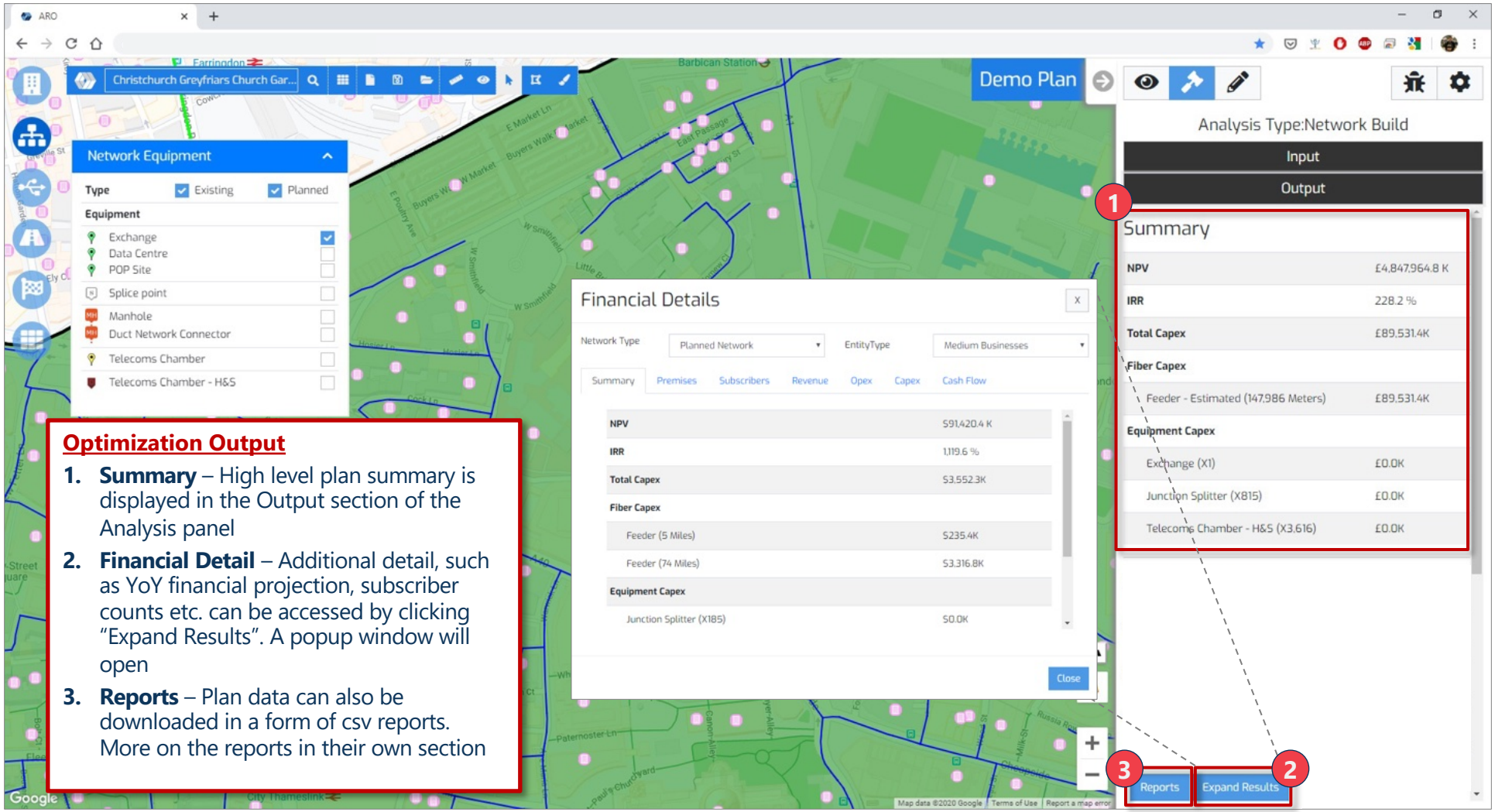
Turn on equipment and cable layers to view on the map



Equipment

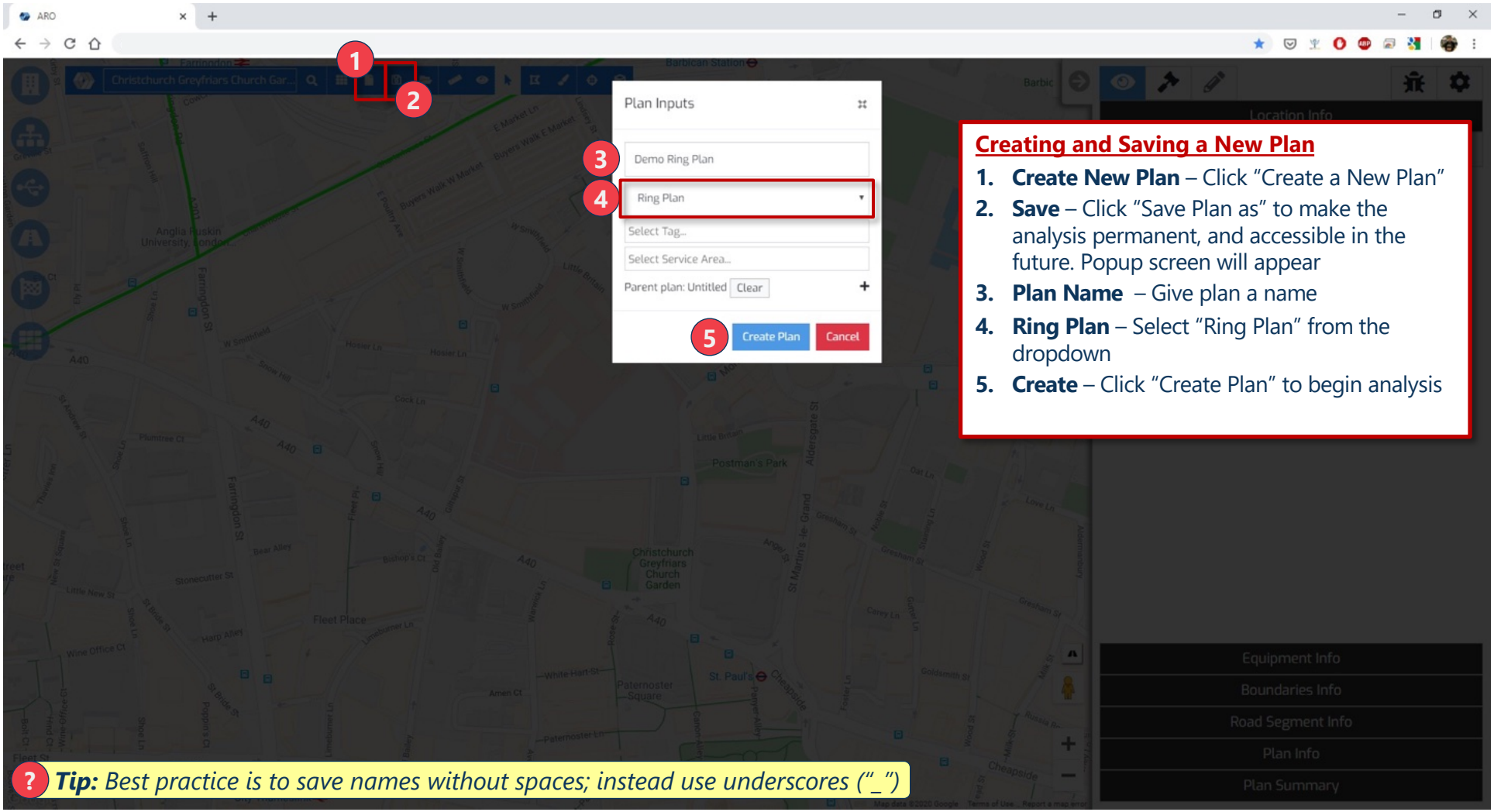
1. **Open Modals** – While the plan is still running, navigate to "Network Equipment" and "Cables" modals
2. **Existing vs. Planned** – Toggle viewing existing and planned networking equipment
3. **Enable** – Toggle specific cable layers to bring into the view. As soon as the optimization finishes running, Planned network equipment and cables will appear on the map (if enabled)

After running a plan, a number of outputs can be extracted from Arrow, including financial projections and new fiber routes

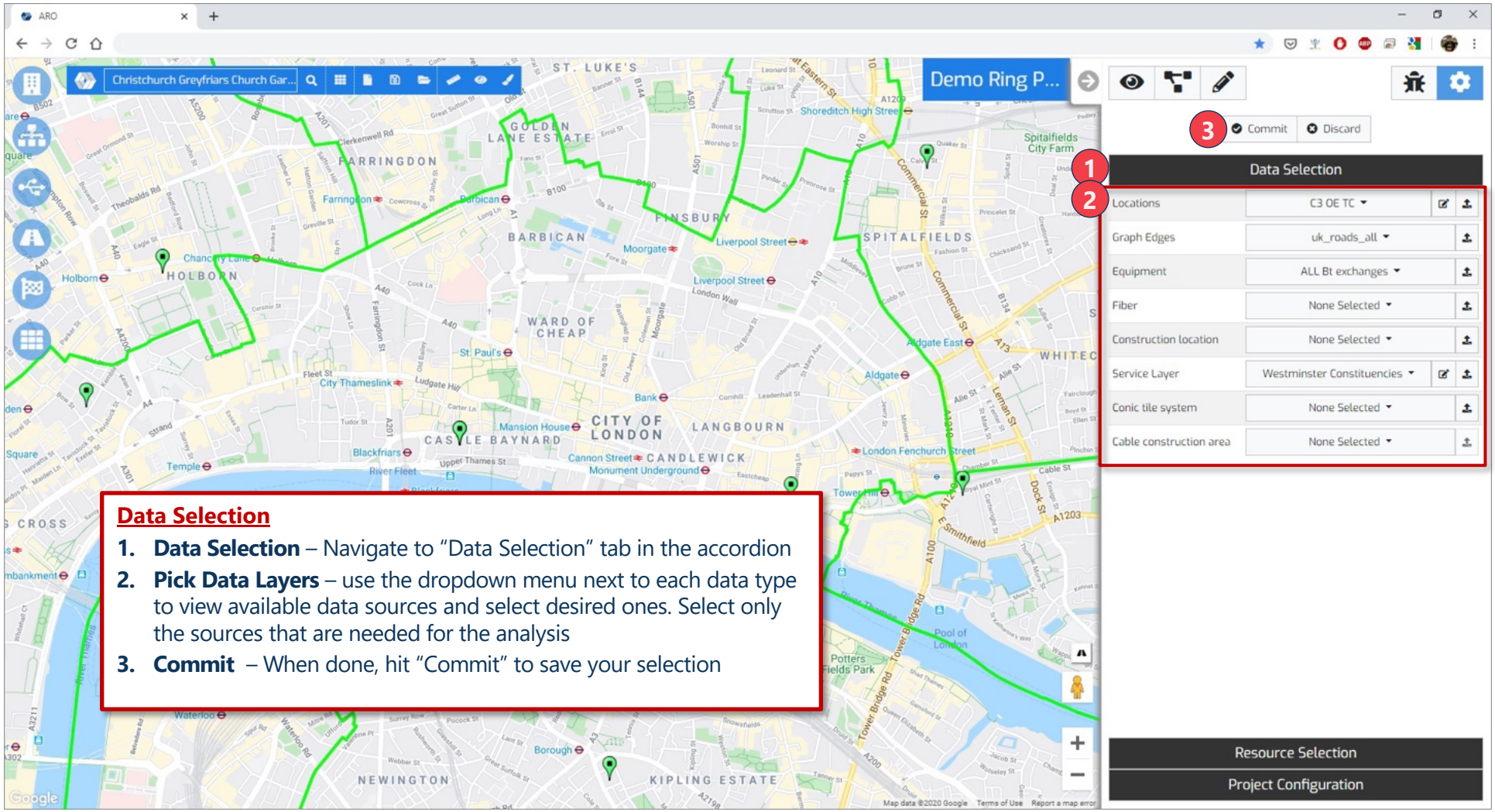


Contents

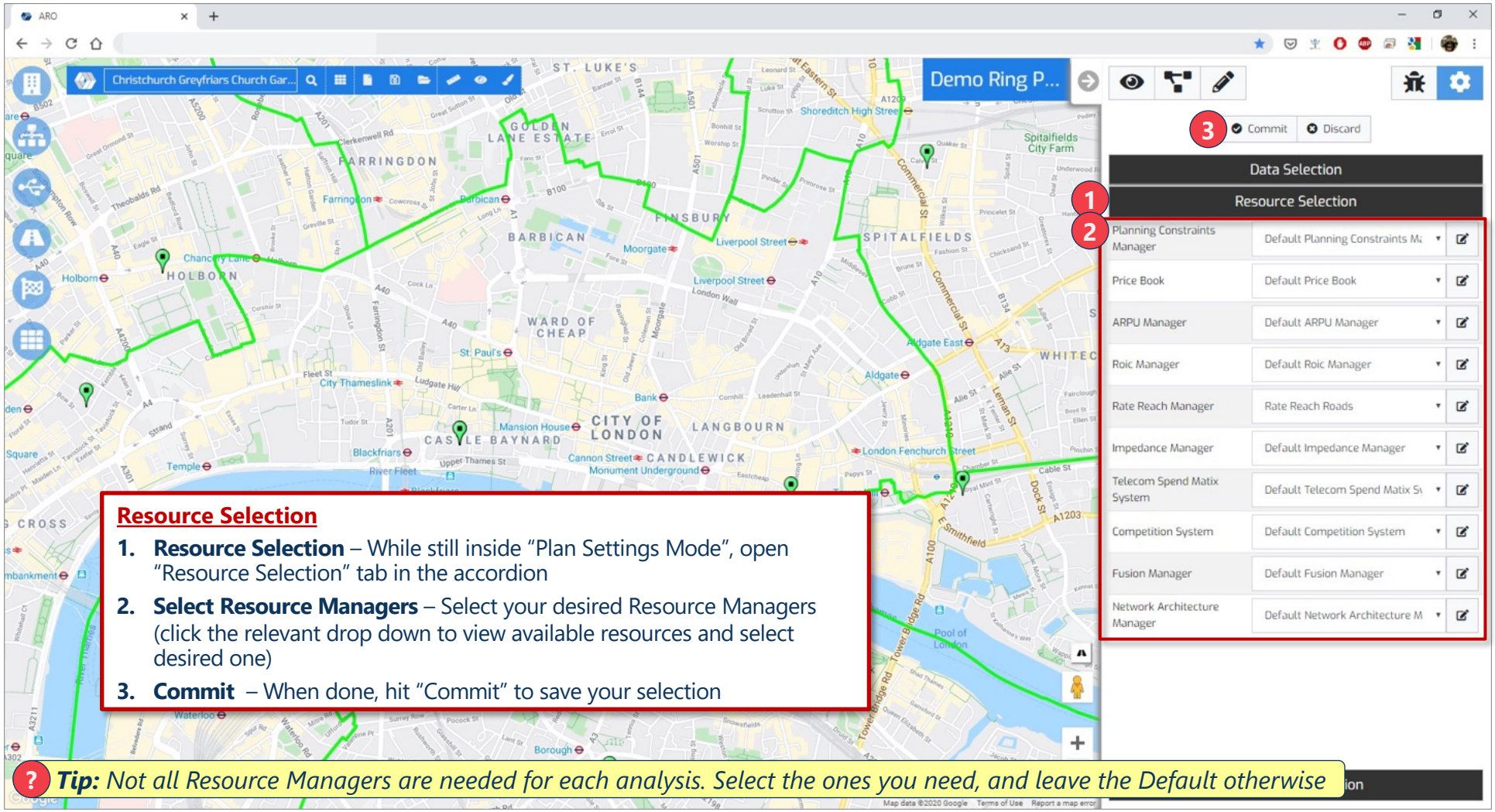
Create a new plan and select ‘Ring Plan’ in plan type dropdown



Select data layers to include in the analysis



Select Resource Managers to use in the analysis

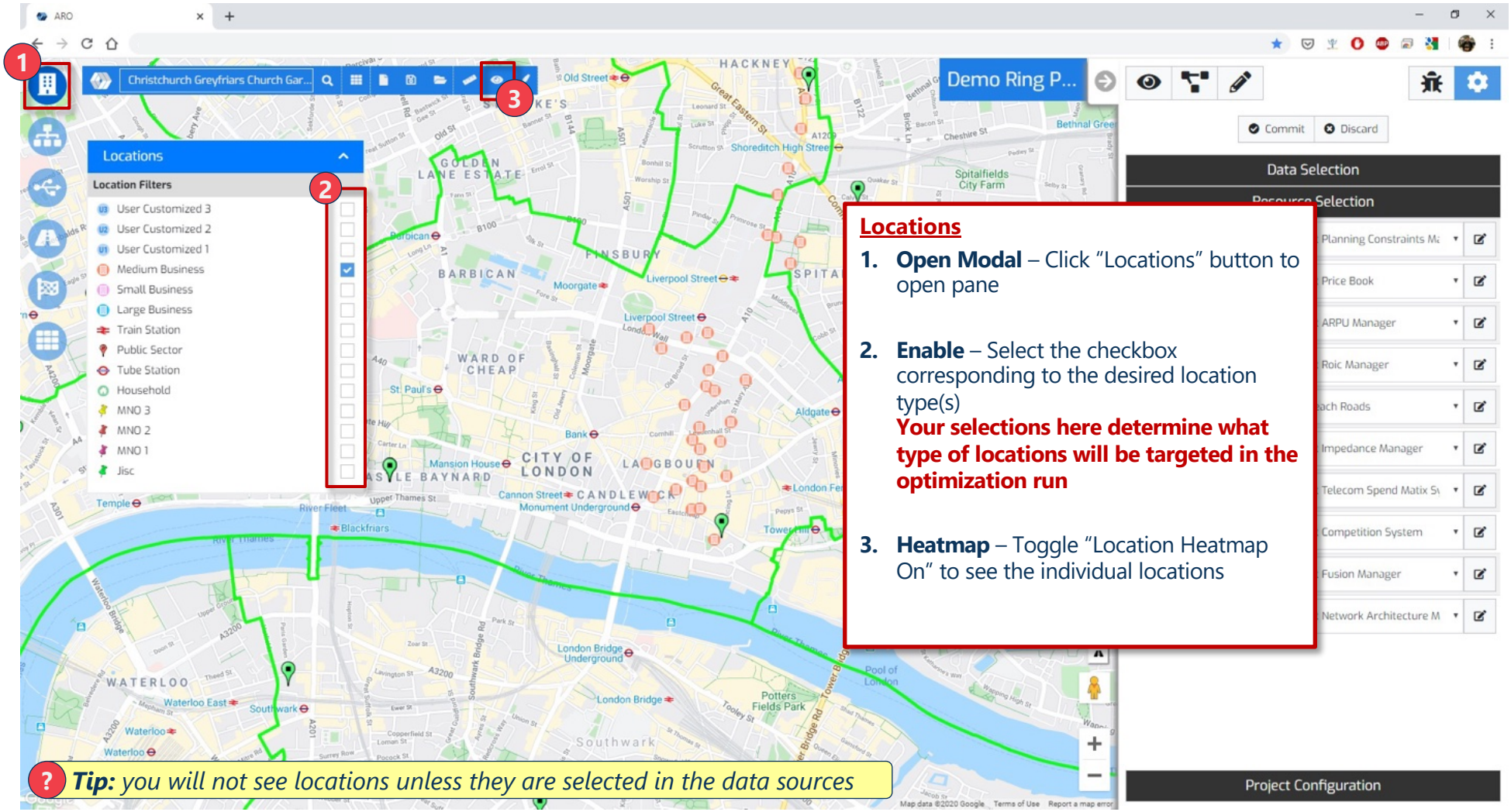


Resource Selection

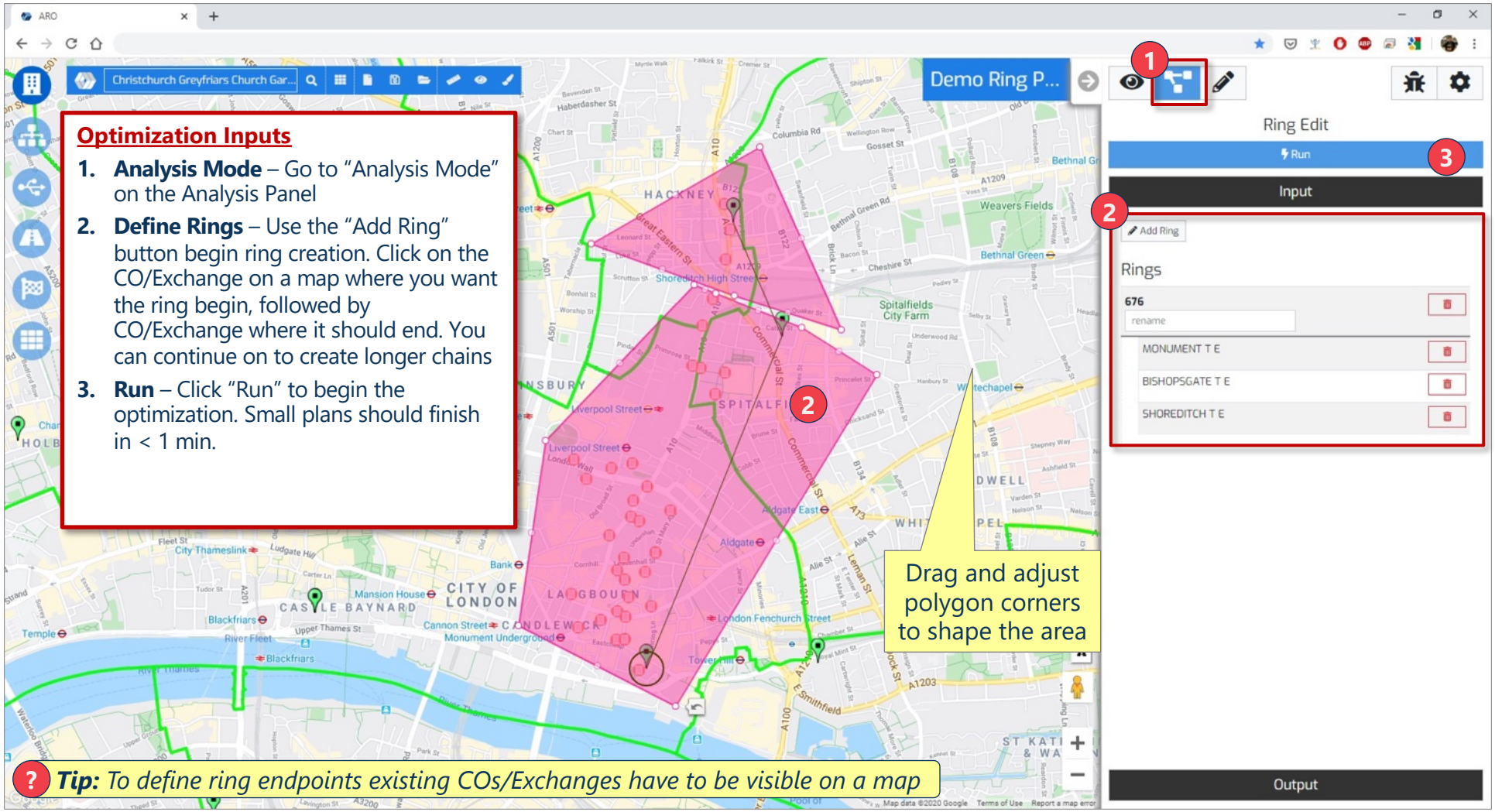
1. **Resource Selection** – While still inside "Plan Settings Mode", open "Resource Selection" tab in the accordion
2. **Select Resource Managers** – Select your desired Resource Managers (click the relevant drop down to view available resources and select desired one)
3. **Commit** – When done, hit "Commit" to save your selection

? ***Tip:*** *Not all Resource Managers are needed for each analysis. Select the ones you need, and leave the Default otherwise*

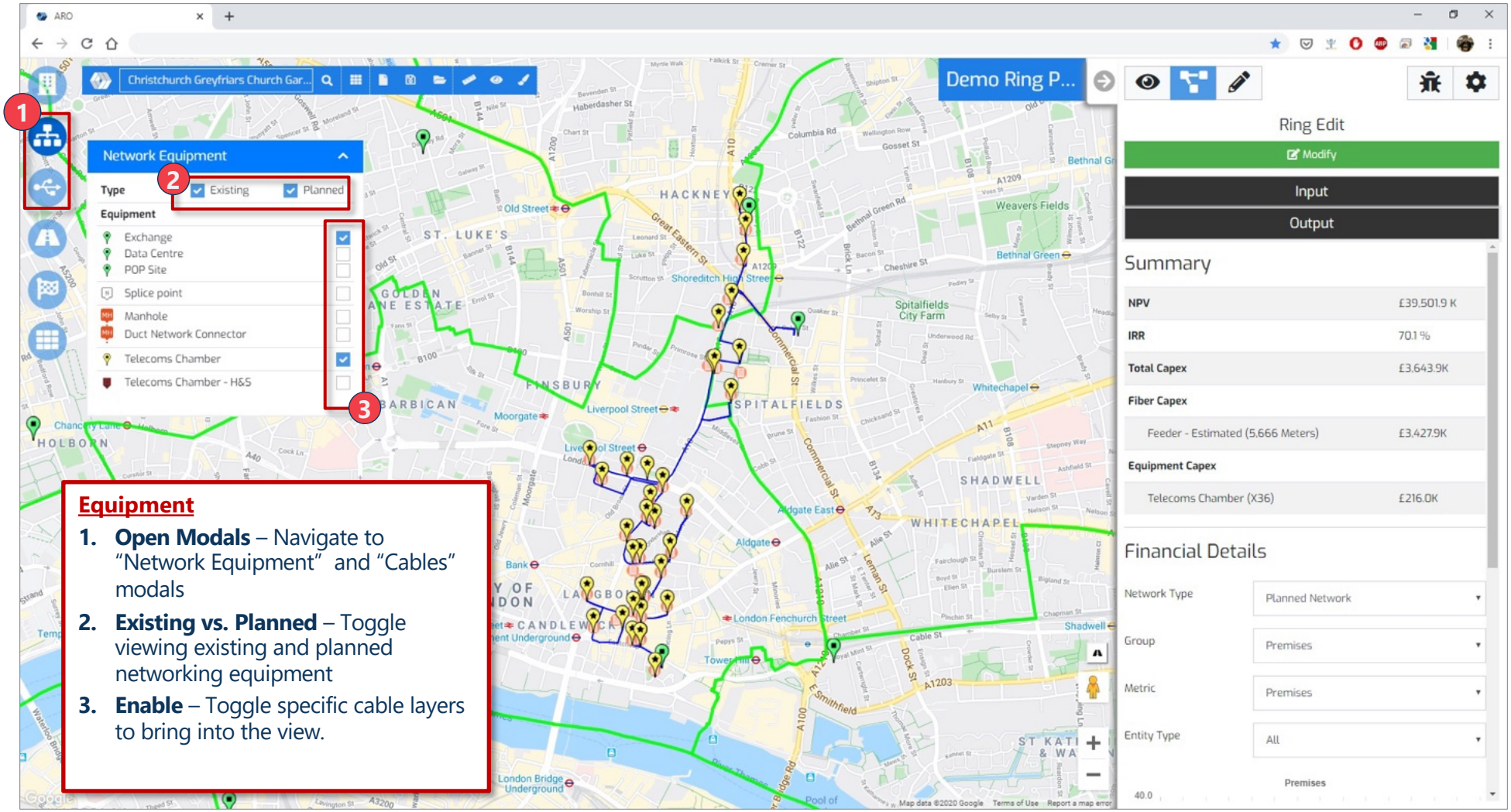
Turn on location layers to be used in simulations, and to view on the map



Specify ring endpoints, optimization settings, and run the analysis



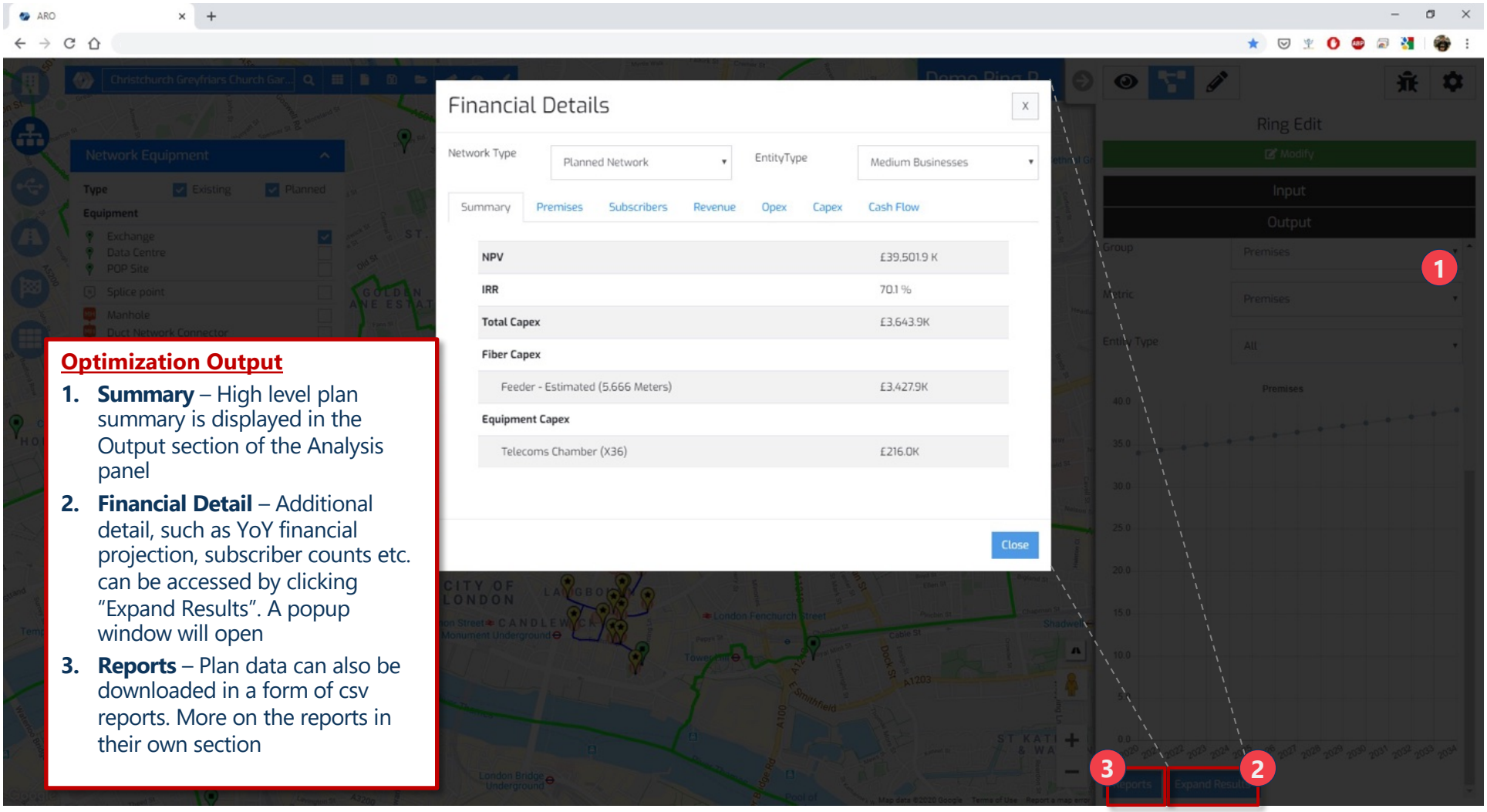
Turn on equipment and cable layers to view on the map



Equipment

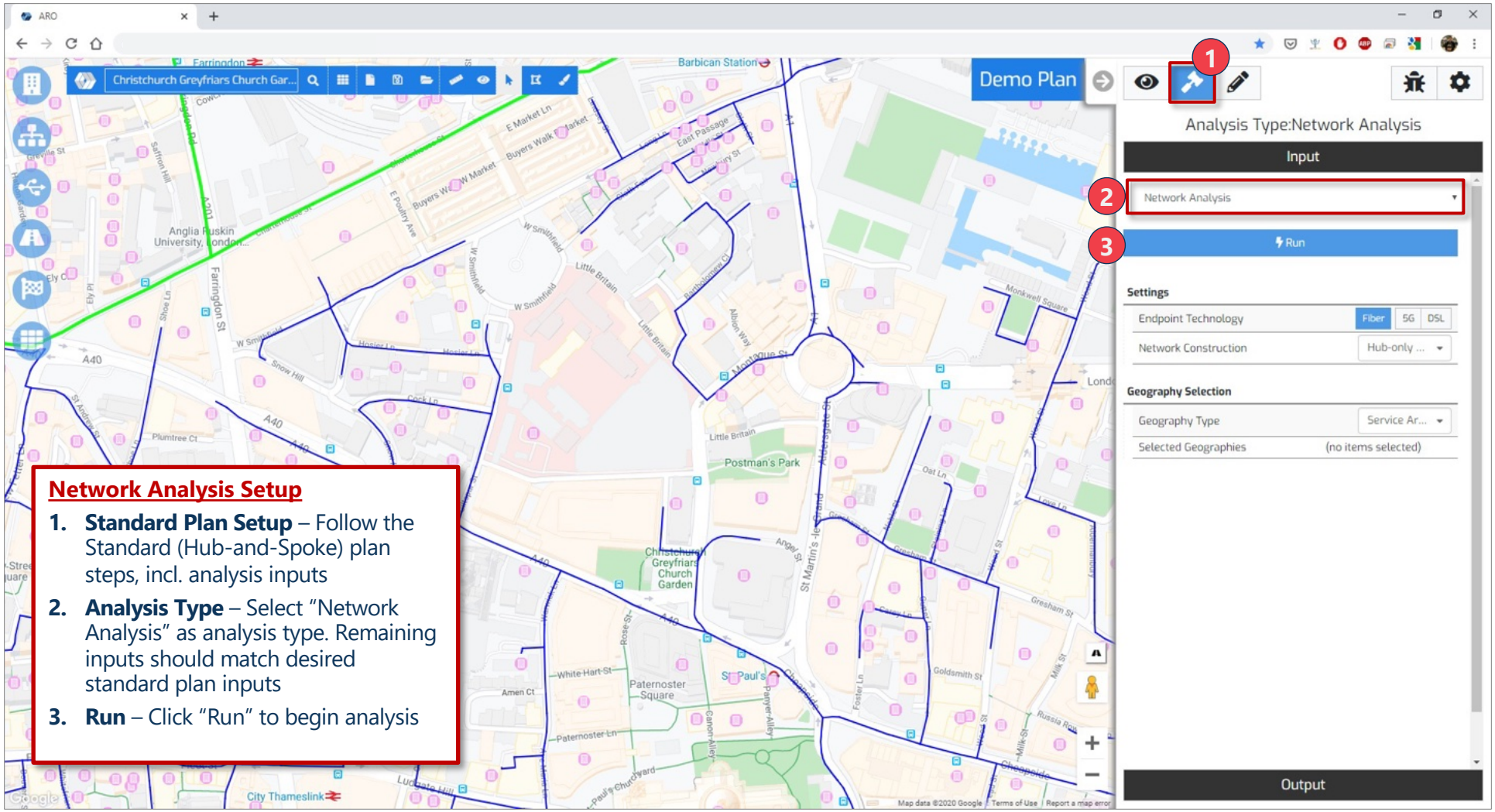
1. **Open Modals** – Navigate to "Network Equipment" and "Cables" modals
2. **Existing vs. Planned** – Toggle viewing existing and planned networking equipment
3. **Enable** – Toggle specific cable layers to bring into the view.

After running a plan, a number of outputs can be extracted from Arrow, including financial projections and new fiber routes

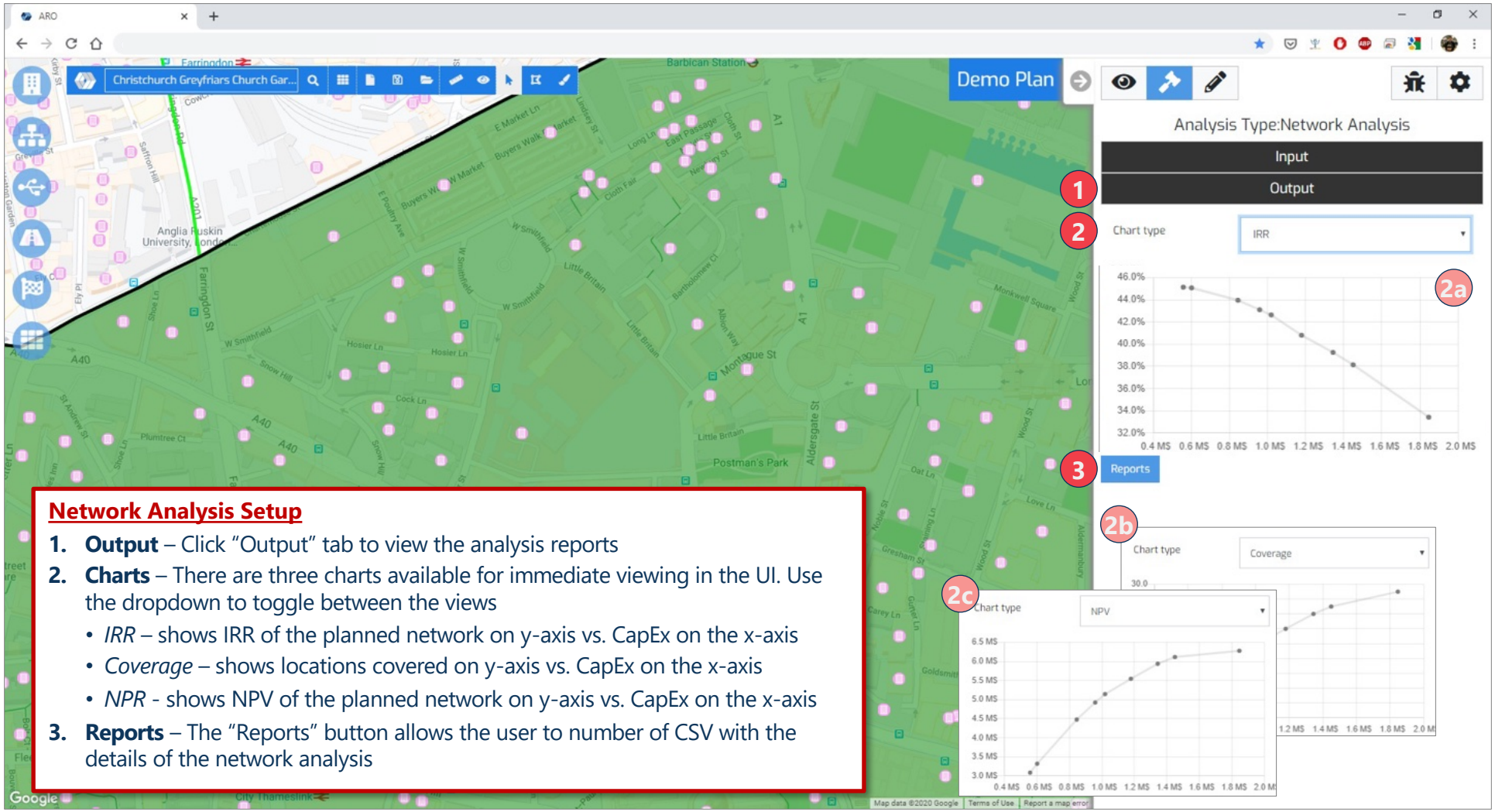


Contents

Network Analysis plan setup should mimic that of a standard plan, with analysis type set to *Network Analysis*

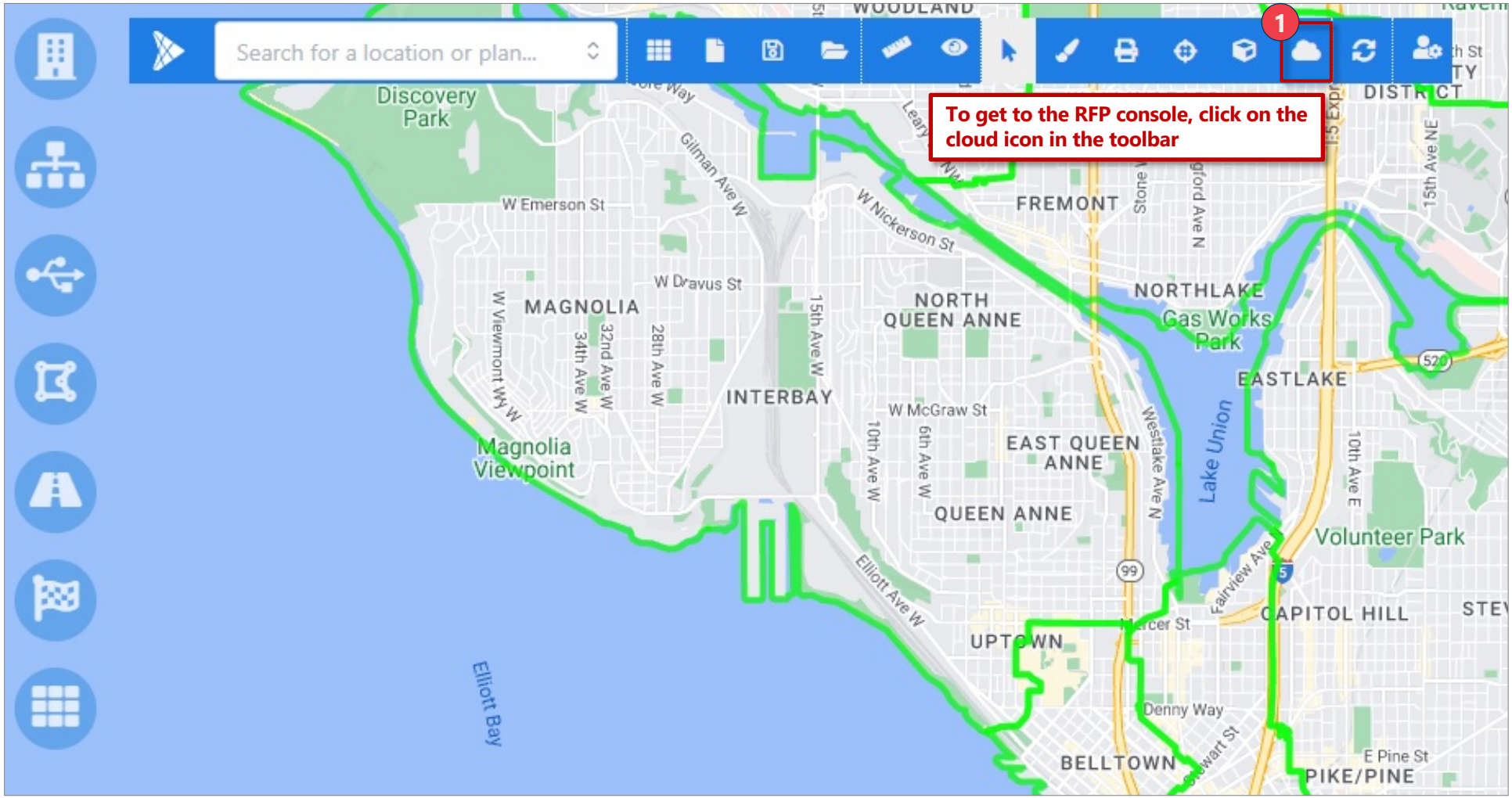


After running a network analysis, there are 3 views of the output in the UI

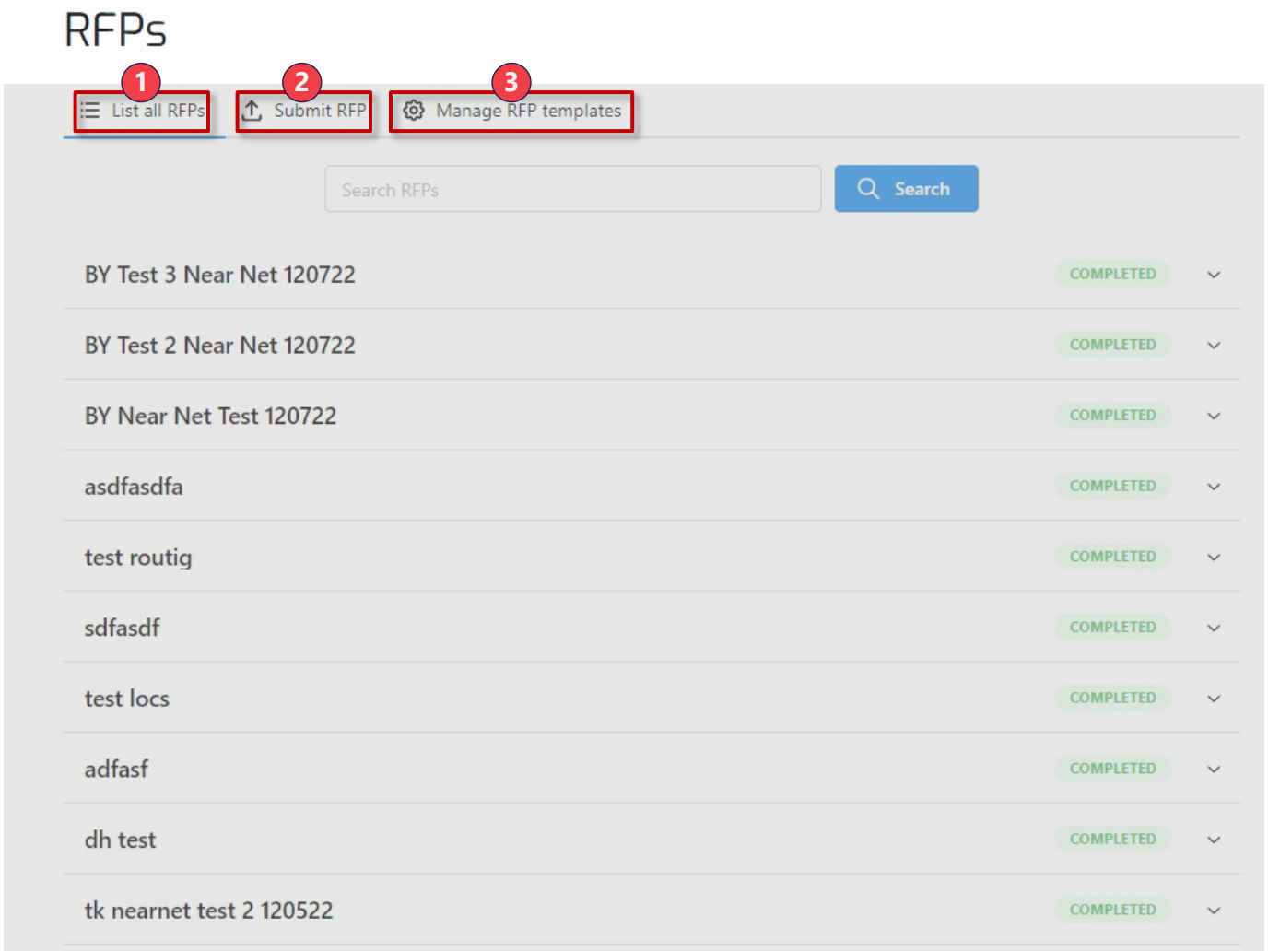


Contents

Navigate to the RFP Console using the cloud icon in the toolbar

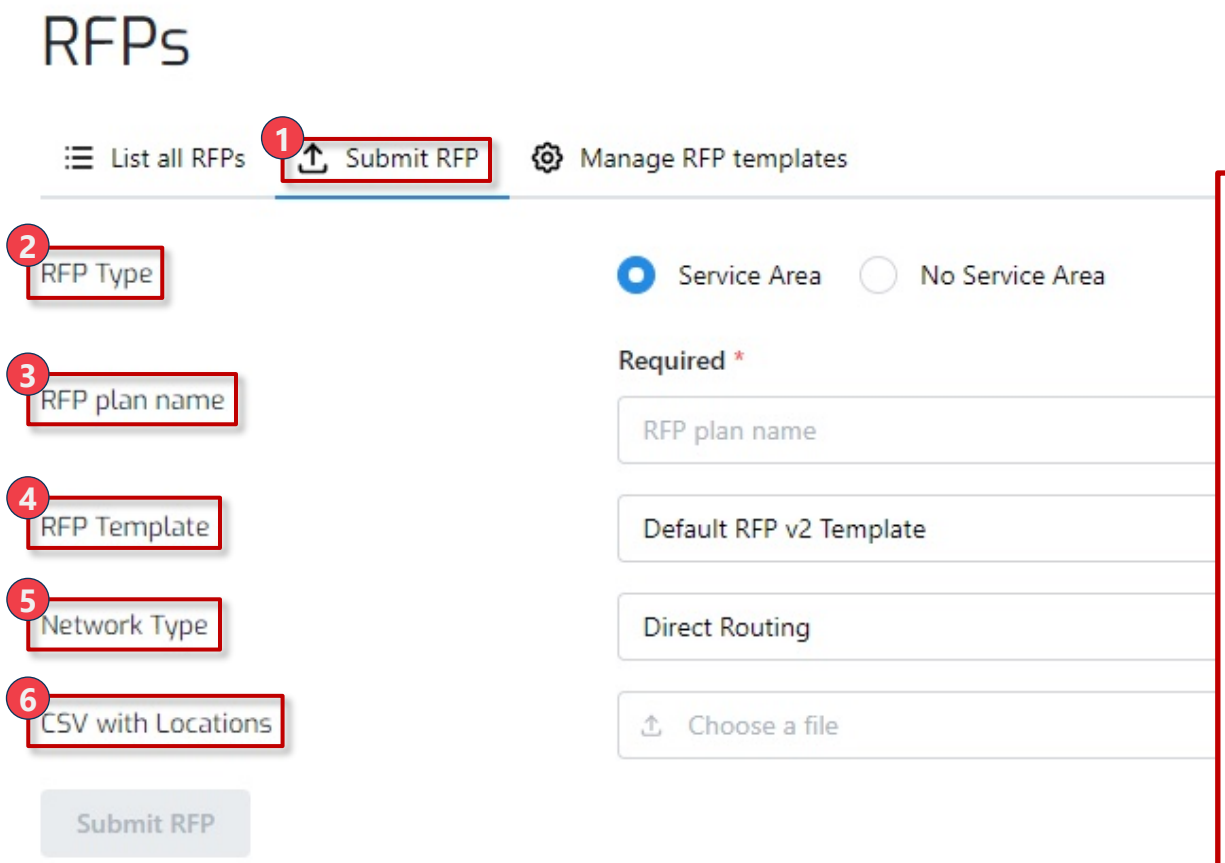


RFP Console list 3 tabs used for submitting and opening existing plans



1. **List All RFPs** – This tab shows all the RFPs which have been run and allows users to go into the plans or download reports
2. **Submit RFP** – This tab is where new RFPs are created
3. **Manage RFP Templates** – This tab is where templates are controlled; templates define the settings that are used when running RFPs

To submit a RFP plan, navigate to the Submit RFP tab



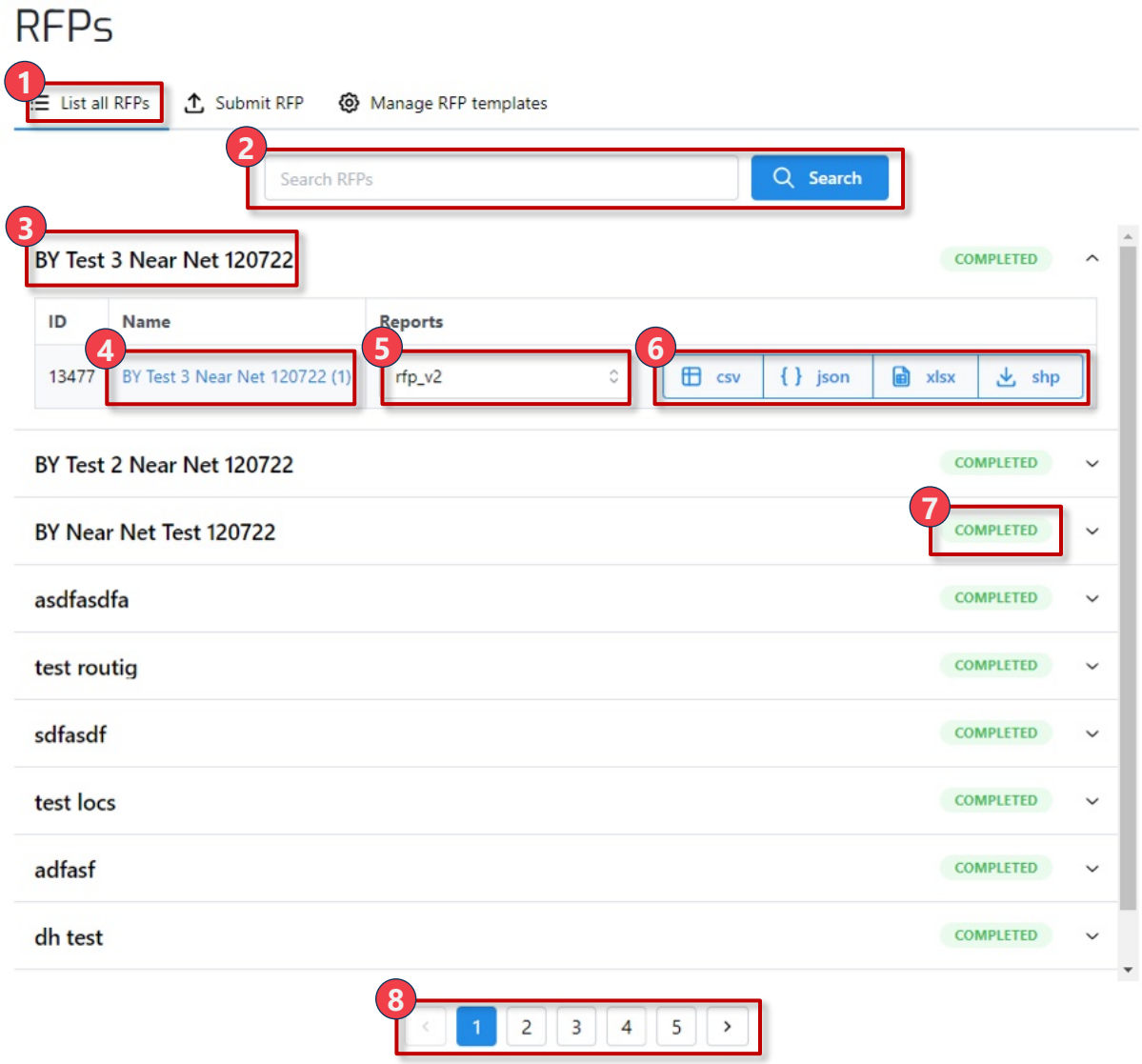
1. **Navigate to the Submit RFP tab**
2. **RFP Type** – Choose which type of RFP you want to run. "Service Area" RFPs operate on top of the service areas like normal Arrow plans, while "No Service Area" plans can be without have service areas
3. **RFP plan name** – Give the plan a name
4. **RFP Template** – Choose from the list of templates. Based on which template you choose the plan will be executed on different set of data sources and resource managers
5. **Network Type** – Choose the optimization type. "Direct Routing" optimizes across all locations in the plan. "Point to Point" optimizes each location individually
6. **CSV with Locations** – Upload the CSV file that has the locations to run in the RFP. See next page for structure of this CSV.

Target locations csv file should have the following structure

	A (1)	B (2)	C (3)	D (4)
1	id	latitude	longitude	
2	14296258	47.45033	-122.446	
3	13025784	47.45048	-122.46	
4	1	47.45292	-122.436	
5	2	47.45907	-122.437	
6	3	47.45664	-122.441	
7	4	47.45269	-122.44	
8	5	47.45391	-122.439	
9	6	47.47361	-122.462	
10	7	47.47214	-122.489	
11	8	47.41534	-122.459	
12				
13				
14				
15				

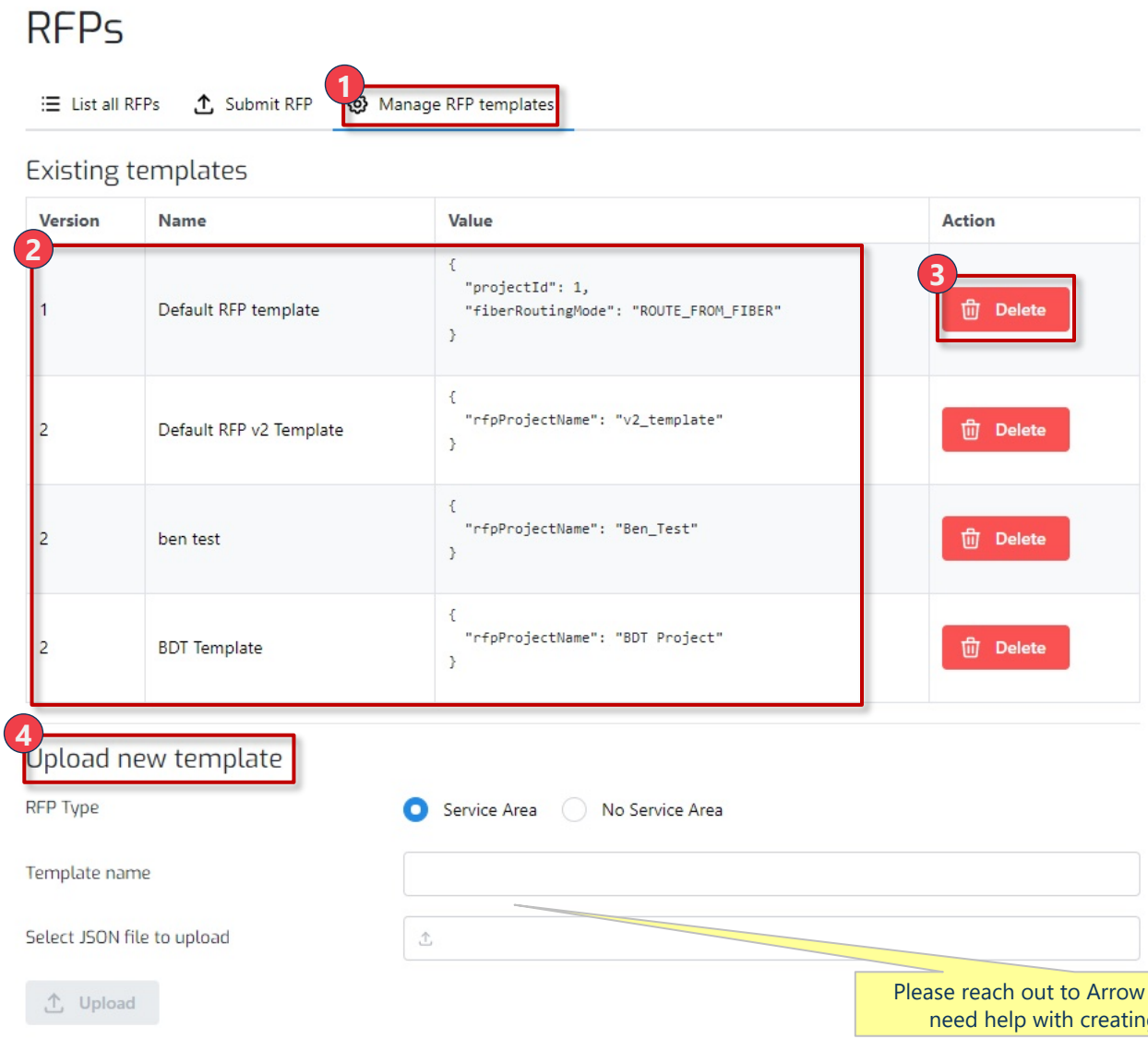
1. **Id** – This column should contain a unique id for each location
2. **Latitude** – Latitude of the site
3. **Longitude** – Longitude of the site
4. **Other** – Any other number of columns, including location-specific financial inputs, can be added after the first three, and these will be passed through

To view all the RFPs which have previously been submitted go to the “List all RFPs” tab



1. **Navigate to the List all RFPs tab**
2. **Search** – You can search for RFPs based on the name
3. **Click on RFP to expand** – User can click on any of the RFPs in the list to expand down the additional information
4. **Enter Plan** – User can click on the hyperlink plan name to jump into the plan where the plan can then be viewed or edited
5. **Report Selection** – This dropdown shows all the various reports available for the plan. Reports can be added to RFPs just like reports are added to other parts of the system
6. **Download Report** – Depending on what report is selected in the prior step, there are various report types available to download the report
7. **Plan State** – Each plan displays the state of the plan
8. **Pages** – User can view multiple pages of plans at the bottom

Users can add or remove RFP templates in Manage RFP Templates section



1. **Navigate to the Manage RFP templates tab**
2. **View Templates** – The table shows all current templates in the system
3. **Delete Template** – Using the delete buttons on the right of the existing templates you can delete them
4. **Upload new template** – In this section you can upload new templates. You have to choose if it is a "service area" or "no service area" type. Give the template a name. Then upload a json file with the template value (see next page for the structure of templates)

RFP Template has the following structure

“No Service Area” template:

```
{
  "projectId": 1,
  "fiberRoutingMode": "ROUTE_FROM_FIBER"
}
```

Name of the project that should be used by the template

Available options:
- ROUTE_FROM_FIBER
- ROUTE_FROM_NODES

“Service Area” template:

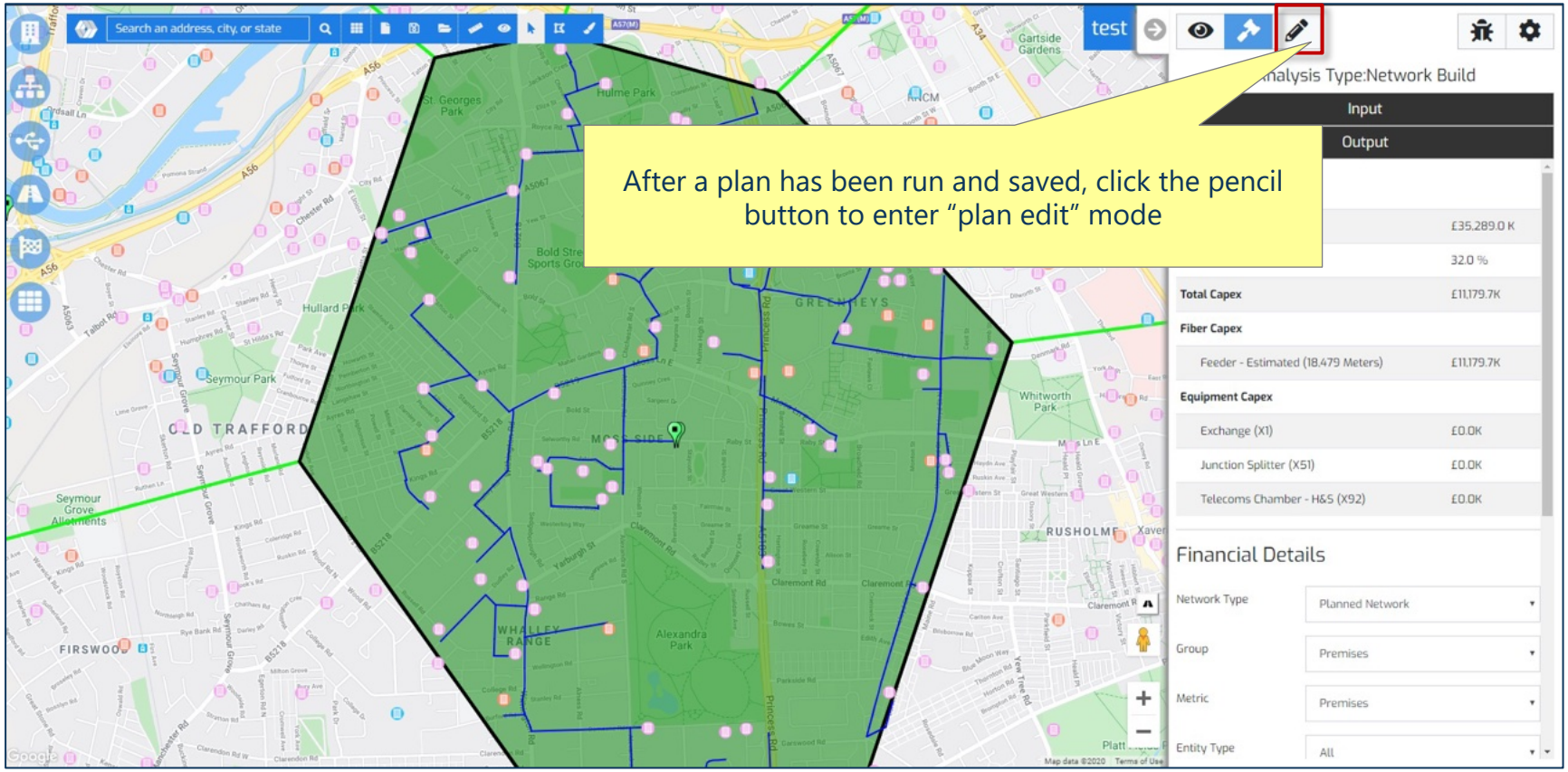
```
{
  "rfpProjectName": "BDT Project“
}
```

Name of the project that should be used by the template

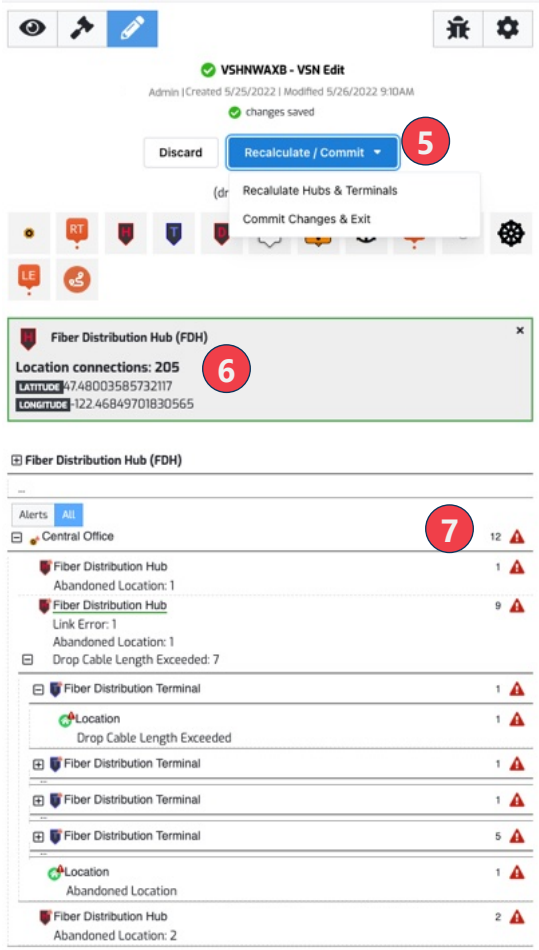
When a plan completes running, you can enter manual edit mode

Editing Functionality

- **Equipment** – you can edit equipment location, location to equipment assignment, add or delete equipment, adjust Fiber Distribution Hub and Remote Terminal coverage boundaries, and add notes to equipment
- **Routes** – you can adjust fiber routes by using Route Adjusters to avoid or prefer a specific path, you can add Anchors to ensure Feeder Fiber passes through a specific point and add notes on Feeder Fiber path segments. Note, feeder and distribution fiber routes are recalculated after adjusting equipment locations and boundaries and clicking Recalculate or Commit.
- **Plan Types** – you can edit Hub and Spoke plans (both Hub only split and Direct Routing) and Ring plans, in addition you can create an empty Hub and Spoke plan and manually add equipment to cover locations.



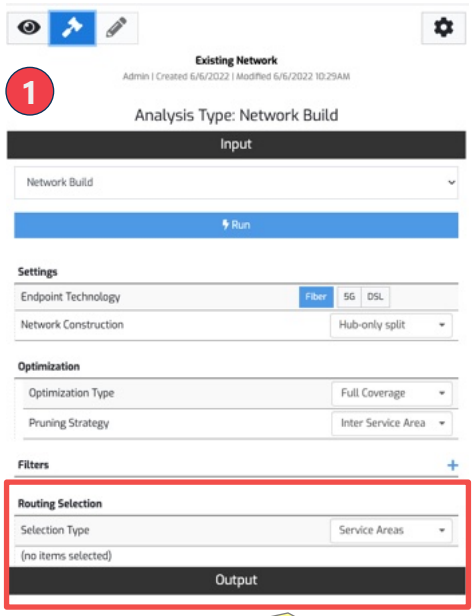
Editing is supported for Hub and Spoke plans run using Direct Routing and Hub Only Split Network Construction



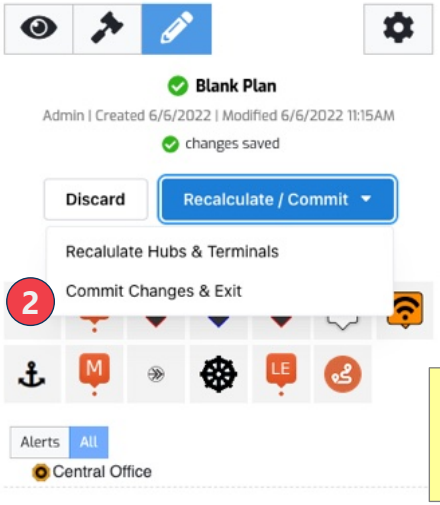
Hub and Spoke Edits

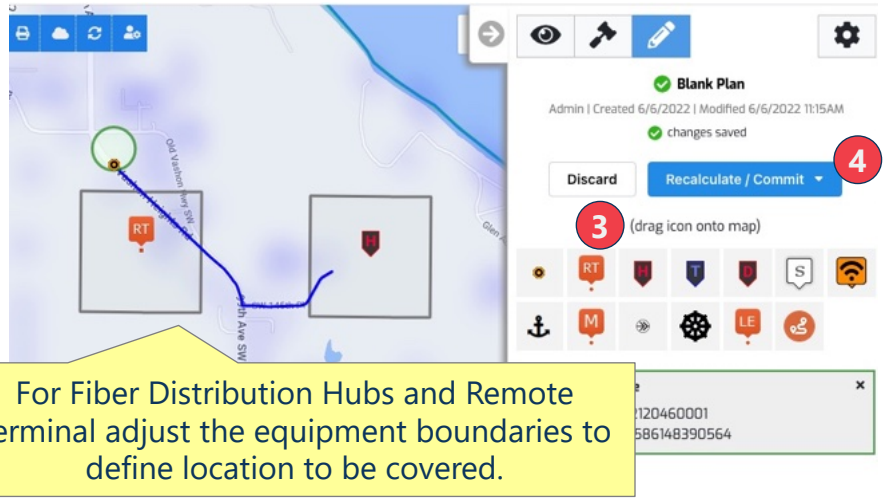
1. **Equipment Location** – move equipment to a new location by selecting it and dragging it (note, CO locations are not editable in edit mode)
2. **Location Assignment** – assign or unassign locations from Fiber Distribution Terminal or Bulk Distribution Terminals
3. **Fiber Distribution Hub Boundary** – adjust the boundary to exclude or include locations served. Note, Fiber Distribution Terminals and Distribution fiber will be re-optimizing after recalculating or committing boundary edits.
4. **Merge Bulk Distribution Terminals** – merge Bulk Distribution Terminals that are in proximity into one and all locations will connect to it
5. **Recalculate / Commit –** after making edits Recalculate Hubs & Terminals re-optimizes fiber routes based on equipment and boundary changes. Commit will recalculate, update the plan outputs including reports and exit edit mode.
6. **Location Connections** – you can view the number of locations served by a Fiber Distribution Hub or Terminal
7. **Alerts –** highlight abandoned locations and violations of network architecture rules (e.g., max locations served, drop cable length)

Creating and editing blank Hub and Spoke plans



Ensure that under Routing Selection the Selection Type is Service Areas and no items are selected



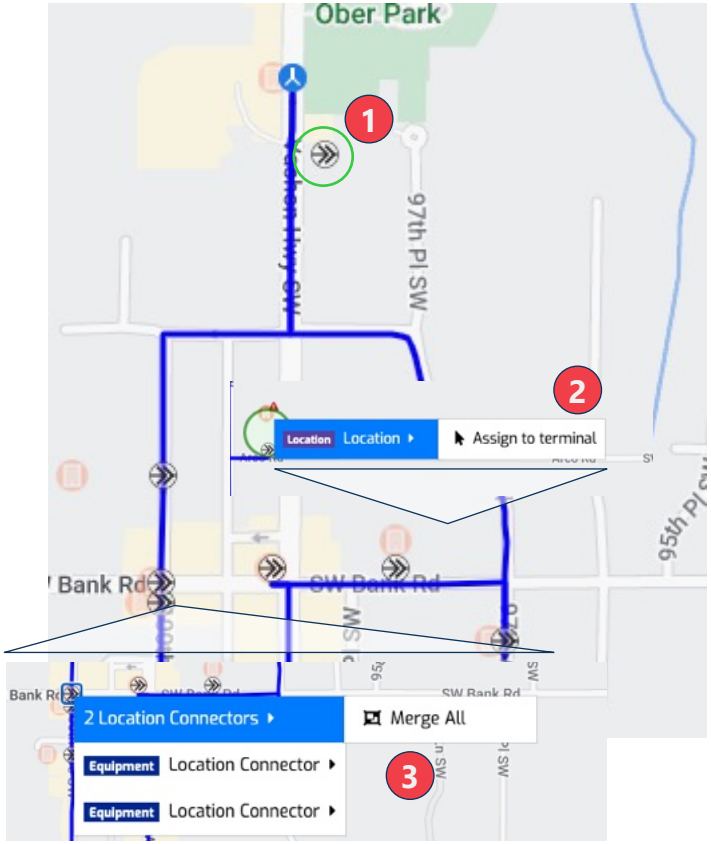


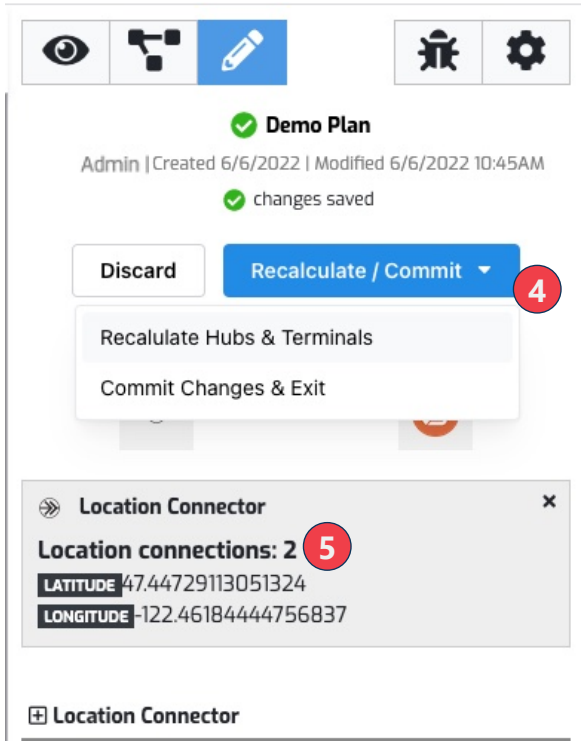
For Fiber Distribution Hubs and Remote Terminal adjust the equipment boundaries to define location to be covered.

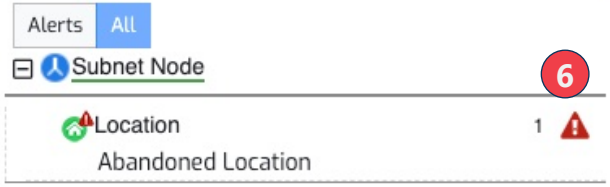
Steps for Editing Blank Hun and Spoke Plans

1. **Network Build Plan** – Run a Network Build plan selecting Location Types, Selection Type as Service Areas and **NO** Service Areas selected.
2. **Edit Plan** – In edit mode, place a Central Office on the map and select Commit Changes & Exit (this associates an underlying Service Area with the plan). Note, this step is not required if there is an existing CO in the Service Area you are planning for.
3. **Place Equipment** – Add Fiber Distribution Hubs, Remote Terminals or Bulk Distribution terminals by dragging and dropping them onto the map. You can define the locations covered by adjusting boundaries or associating locations with individual terminals.
4. **Recalculate /Commit** – after making edits Recalculate Hubs & Terminals optimizes fiber routes based on equipment locations and boundaries. Commit will recalculate, update the plan outputs including reports and exit edit mode.

Editing Ring Plans



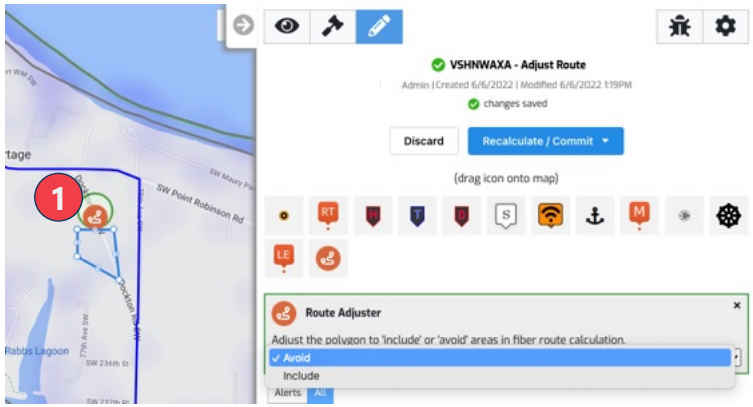




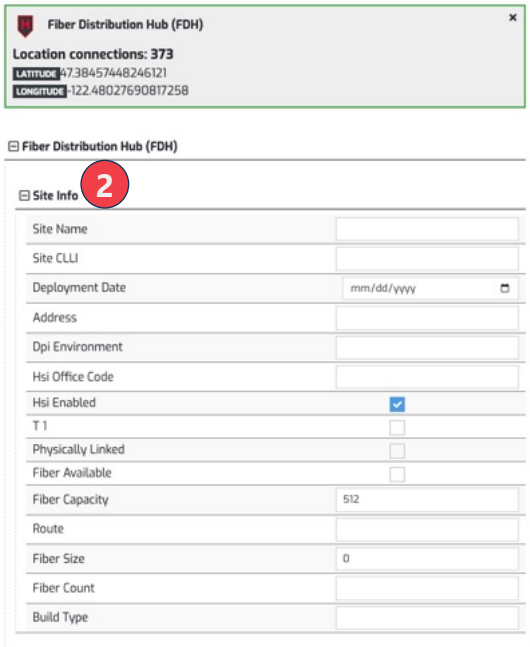
Ring Plan Edits

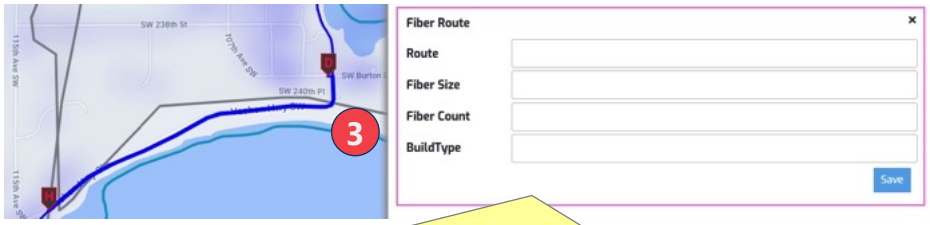
1. **Equipment Location** – move Location Connectors or Route Adjusters to a new location (note, Subnet Node locations are not editable in Edit mode)
2. **Location Assignment** – assign or unassign locations from Location Connector
3. **Merge Location Connectors**–merge Location Connectors that are in proximity into one and all locations will connect to it
4. **Recalculate / Commit –** after making edits Recalculate Hubs & Terminals will re-optimize fiber routes based on equipment and boundary changes. Commit will recalculate, update the plan outputs including reports and exit edit mode.
5. **Location Connections** – you can view the number of locations served by a Location Connector (aka Terminal)
6. **Alerts –** highlight abandoned locations and violations of network architecture rules (e.g., max locations served, drop cable length)

Adjust the fiber route and add additional detail on equipment and route segments



Avoid or Include apply a multiplier to the cost of underlying conduit making it financially more or less expensive





To avoid losing Feeder Fiber annotations, make edits only after equipment locations and FDH boundaries and Fiber routes have been finalized

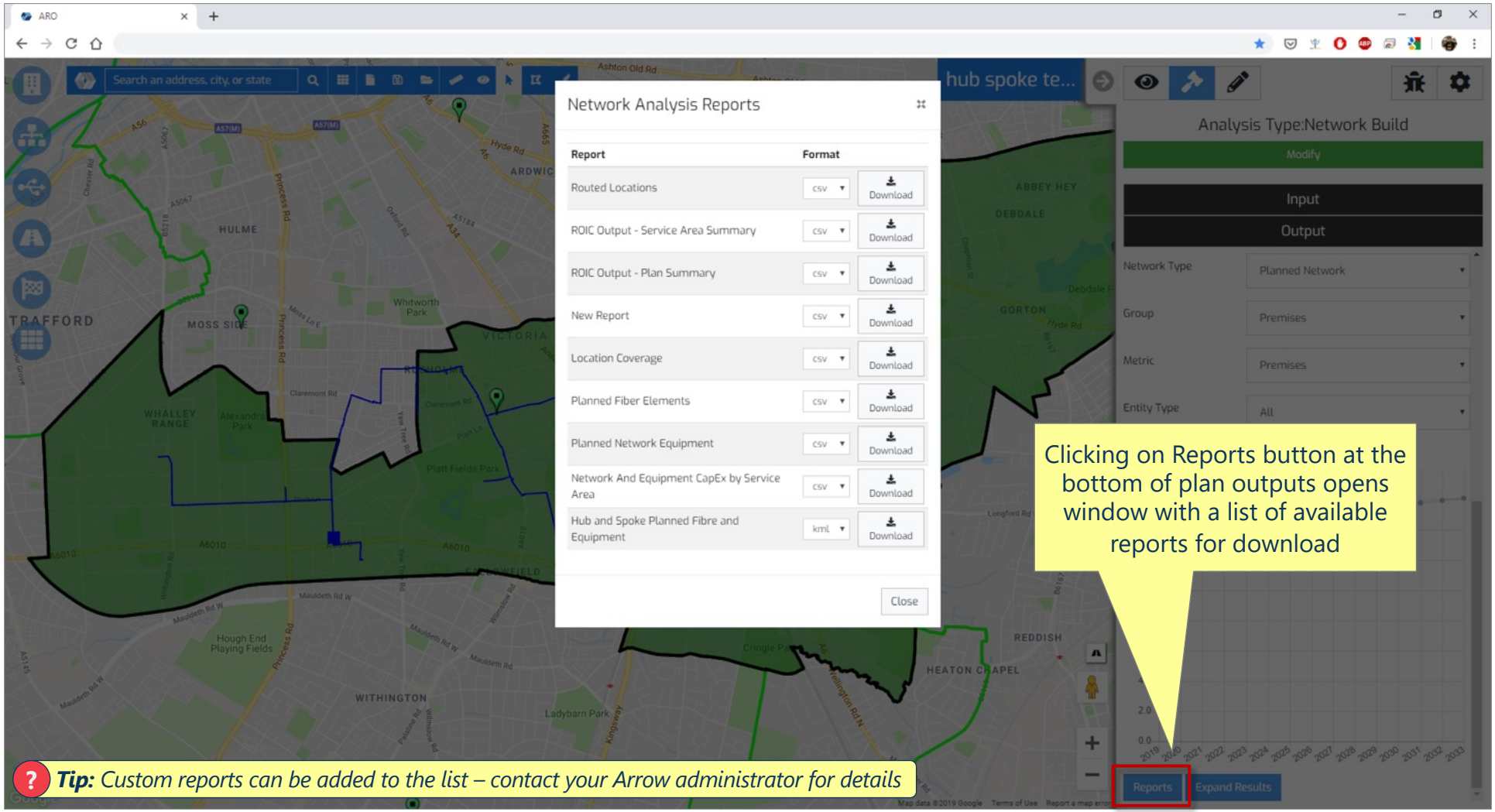
Plan Edits

1. **Route Adjusters** – route adjusters enable you to change the fiber route by placing them over an area and selecting avoid or include. Clicking Recalculate Hubs & Terminal after placing a Route Adjuster reoptimizes the fiber route
2. **Equipment Annotation** – Add additional detail to equipment (e.g., Fiber Distribution Hub, Splice Points)
3. **Feeder Fiber Annotation** –Add additional detail to Feeder Fiber route segments. Note, when Arrow recalculates routes in Edit mode or by Modifying a plan the Feeder Fiber segments are reconstituted and all annotations are lost.

? ***Tip:*** *Please contact Arrow team member to configure financial multipliers for Route Adjusters*

Contents

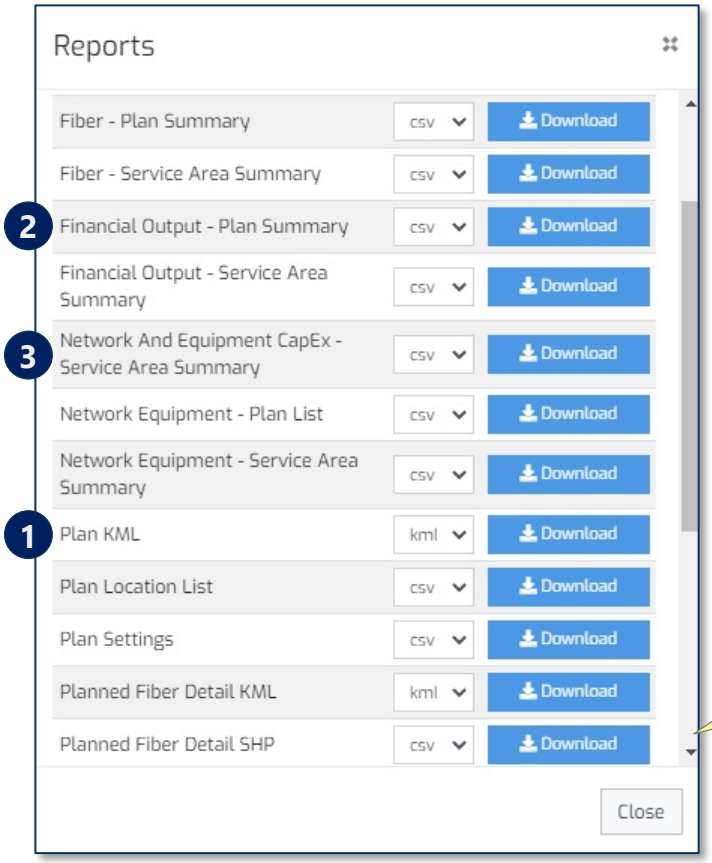
After a plan is run, a number of outputs can be extracted from Arrow, including financial projections and new fiber routes



The reports section contains downloadable reports from the plan, specific to the plan type which was just run

Hub-and-Spoke Plan Reports

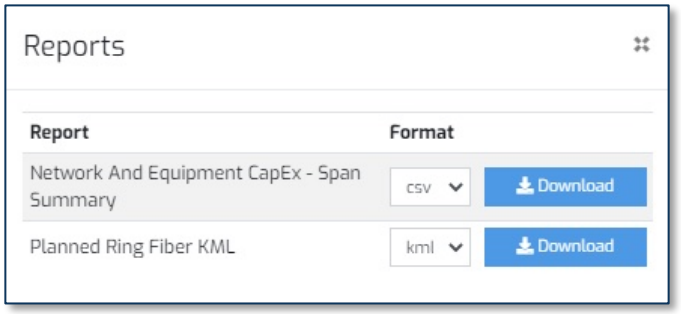
Default list. More reports can be created as needed



There are ~30 different reports available for download. Custom reports can be easily added in

Ring Plan Reports

Default list. More reports can be created as needed



Details on the following page

Arrow comes preloaded with a number of standard reports; main ones include the following

1. ***Plan KML (.kml) –*** Generates KML file containing planned fiber and key network elements

2. ***Financial Summary (.csv) –*** Comprehensive financial modeling results, from number of locations passed and subscribers to individual cash flow components for each analysis year

location_type	item	year_0	year_1	year_2	year_3	year_4	year_5	year_6
All locations	Build Cost	$25,852,508	0	0	0	0	0	0
All locations	Customer Penetration	36%	49%	55%	59%	61%	62%	62%
All locations	Customers	8,531	11,711	13,459	14,454	15,052	15,442	15,722
All locations	Maintence Expenses	$343,638	$584,754	$715,921	$789,157	$831,889	$858,578	$876,850
All locations	Net Cash Flows	($22,470,575)	$2,439,059	$6,563,145	$8,790,407	$10,018,066	$10,719,201	$11,143,256
All locations	New Connection Cost	$137,895	$5,066,733	$3,100,811	$2,068,539	$1,528,593	$1,248,277	$1,104,899
All locations	New Connections	689	4,126	2,836	2,162	1,814	1,637	1,550
All locations	New Customers	689	4,126	2,836	2,162	1,814	1,637	1,550
All locations	Operating Expenses	$4,727,492	$6,528,294	$7,518,152	$8,080,831	$8,418,681	$8,638,396	$8,796,240
All locations	Penetration	15%	25%	30%	33%	35%	35%	36%
All locations	Premisies	23,826	24,065	24,305	24,548	24,794	25,042	25,292
All locations	Revenue	$8,590,959	$14,618,840	$17,898,029	$19,728,935	$20,797,229	$21,464,452	$21,921,245
All locations	TAM	$57,531,506	$58,106,821	$58,687,889	$59,274,768	$59,867,516	$60,466,191	$61,070,853

3. ***Network And Equipment CapEx (.csv) –*** Summary of fiber and network equipment elements placed in a plan, incl. costs for each item

plan_name	service_area	type	equipment	build_type	count_or_meters	capex_dollars
XXX	ZZZ	Equipment	Bulk Distribution Terminal	Planned	87	$0
XXX	ZZZ	Equipment	Bulk Distribution Terminal	Planned	42	$0
XXX	ZZZ	Equipment	Central Office	Planned	1	$0
XXX	ZZZ	Equipment	Junction Splitter	Planned	2	$0
XXX	ZZZ	Equipment	Junction Splitter	Planned	21	$0
XXX	ZZZ	Equipment	Multiple Dwelling Unit	Planned	3	$600
XXX	ZZZ	Equipment	Splice Point	Planned	31	$0
XXX	ZZZ	Equipment	Splice Point	Planned	35	$0
XXX	ZZZ	Fiber	Feeder Fiber	Overbuilt	379	$10,588
XXX	ZZZ	Fiber	Feeder Fiber	Overbuilt	388	$10,863
XXX	ZZZ	Fiber	Feeder Fiber	Planned	1,884	$52,690
XXX	ZZZ	Fiber	Feeder Fiber	Planned	815	$22,784

4. ***Near-Net Coverage (.csv) –*** List of locations with corresponding demand, fair share and proximity to fiber data

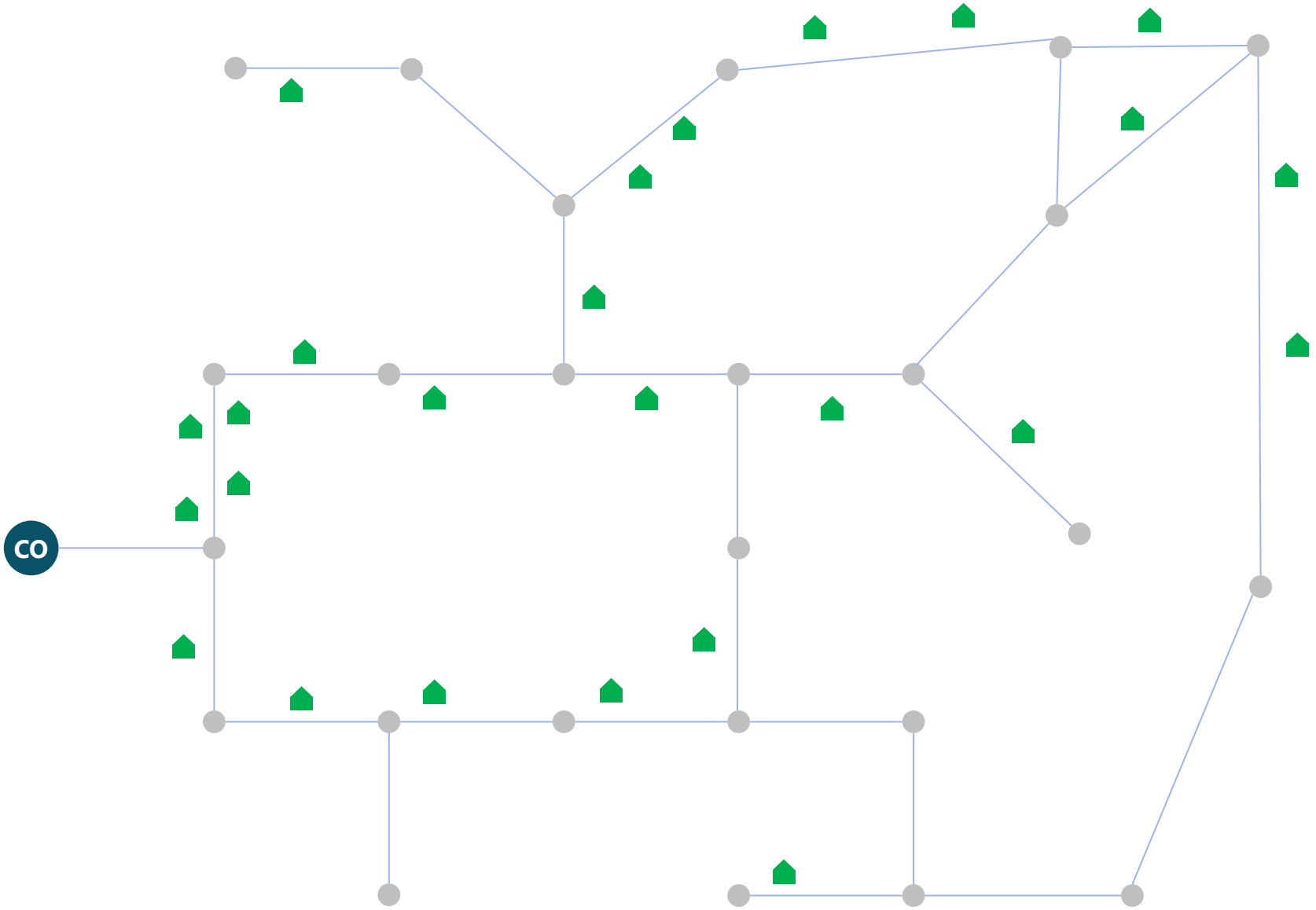
number_of_households	lat	long	service_area	state	distance_meters	distance_ft
1	38.81	-92.77	BU-01	MO	1,814	5,948
1	38.80	-92.78	BU-01	MO	1,017	3,336
1	38.81	-92.77	BU-01	MO	1,660	5,443
1	38.81	-92.76	BU-01	MO	2,172	7,123
1	38.81	-92.78	BU-01	MO	250	821
1	38.81	-92.76	BU-01	MO	2,073	6,800
1	38.81	-92.76	BU-01	MO	2,657	8,714
1	38.81	-92.70	BU-05	MO	1,093	3,587
1	38.81	-92.67	BU-05	MO	901	2,956
1	38.81	-92.69	BU-05	MO	314	1,030
1	38.81	-92.71	BU-05	MO	2,574	8,442

Custom reports can be added based on team's specific needs

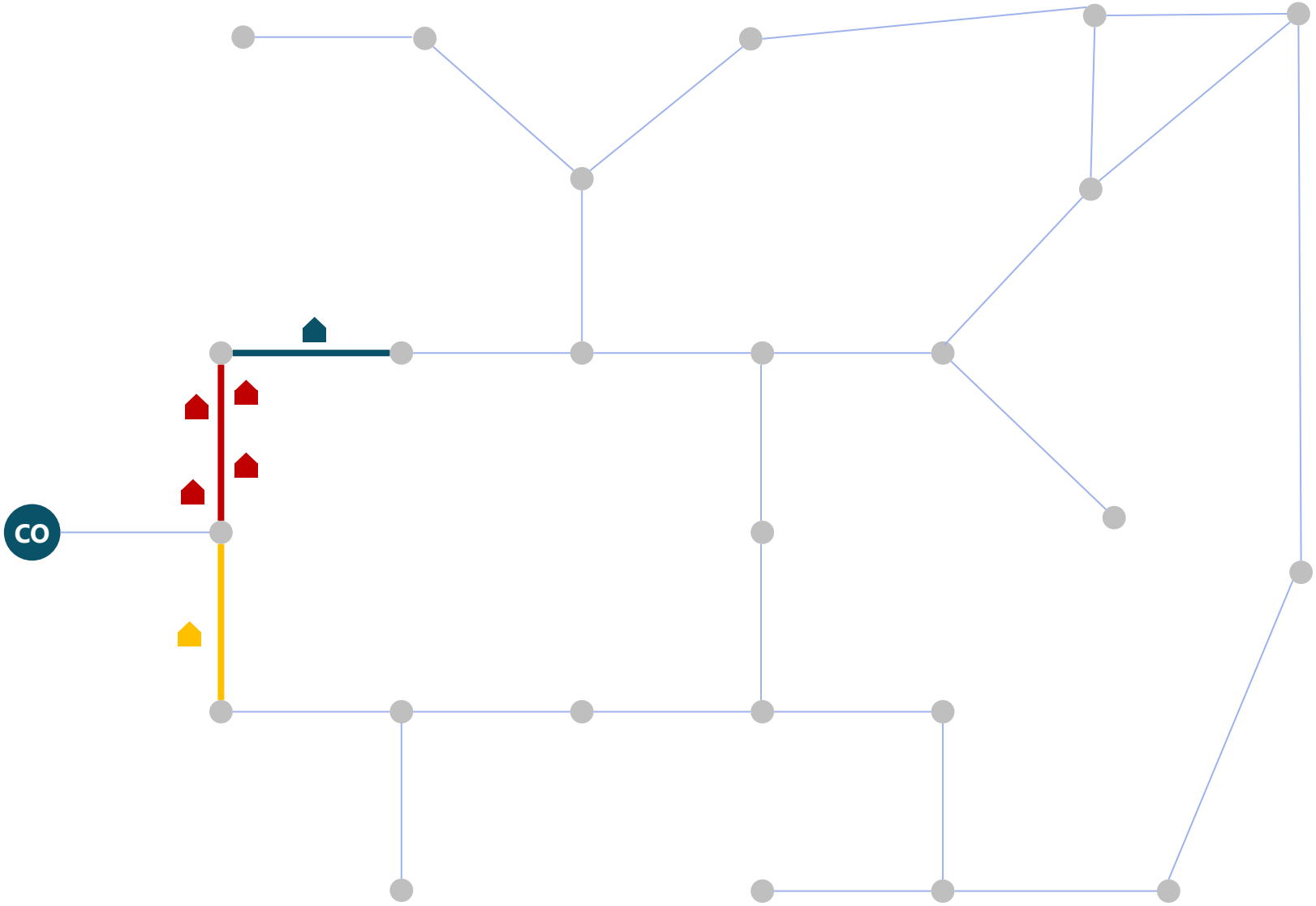
All network optimizations undertake the same major steps, with inputs at each step varying depending on what the user is solving for

1	2	3	4	5
Graph Reduction	**Equipment Placement**	**Initial Network Generation**	**Pruning**	**Final Network Generation**
Map locations to road edges **Remove unnecessary road segments** (reduce the graph)	**Build initial path towards CO** (create directed graph) **Place equipment** along the initial path (agglomeration)	**Construct minimum cost full network** using Minimum Spanning Tree (MST) algorithm	**Sequentially remove the "worst-scoring" nodes** (IRR-based) until all nodes have been removed Determine which pruning step **satisfies optimization criteria** Use equipment node information from that step to **finalize target locations**	**Generate lowest cost network** for the set of locations selected in the previous step (MST algorithm)

We'll us the following wirecenter layout to illustrate functioning of key algorithms



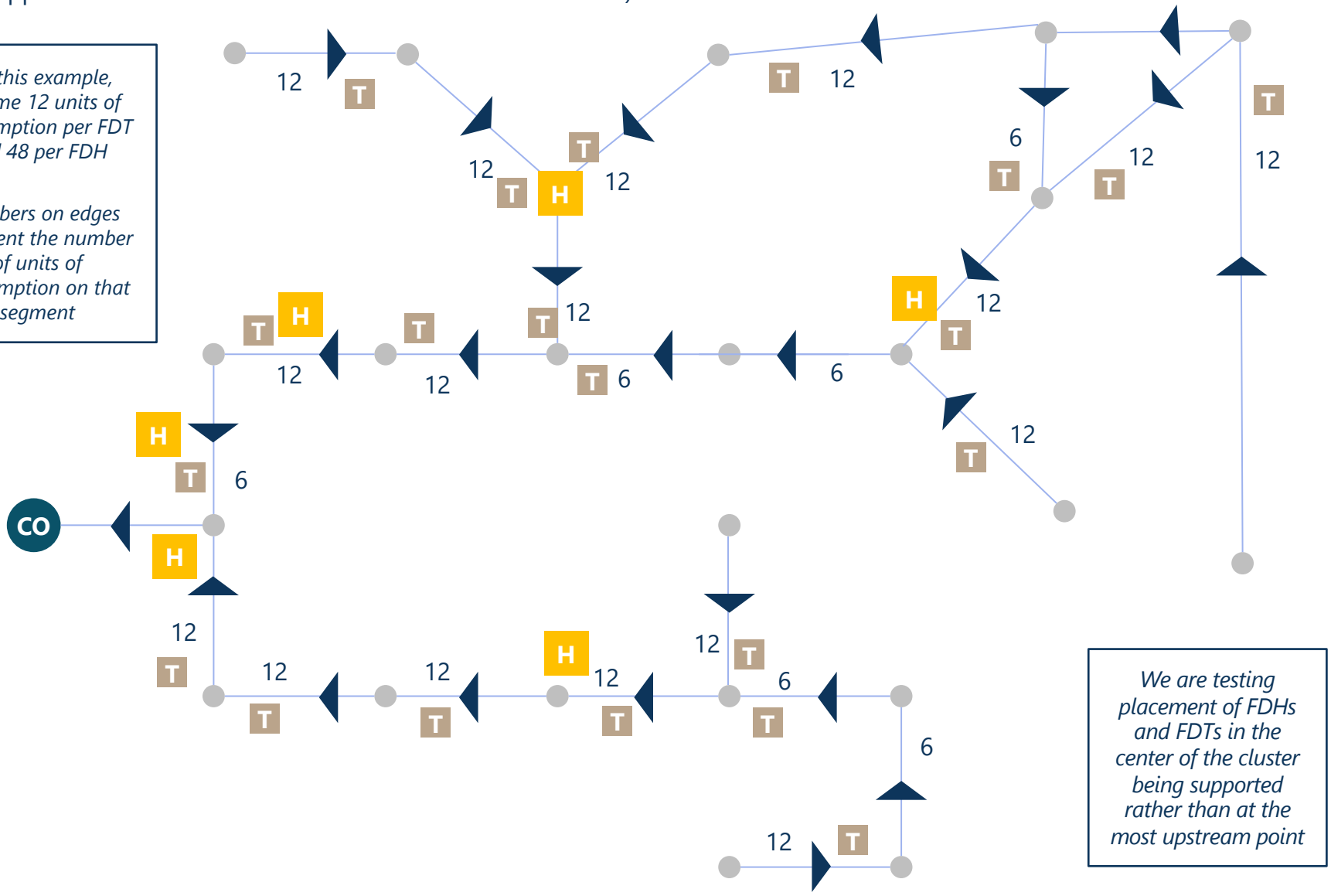
1. Map all locations to the nearest road segment
2. Record the point where the location maps to the road, and the corresponding distance between road edge and the location



1. The algorithm walks up the graph from the furthest-away edges and places FDTs and FDHs as needed to support the downstream units of consumption
2. Maximum distance thresholds are also applied (e.g. if there have only been 6 HHs but the next one is a mile away, an FDT will be dropped as the next one is outside of the distance threshold)

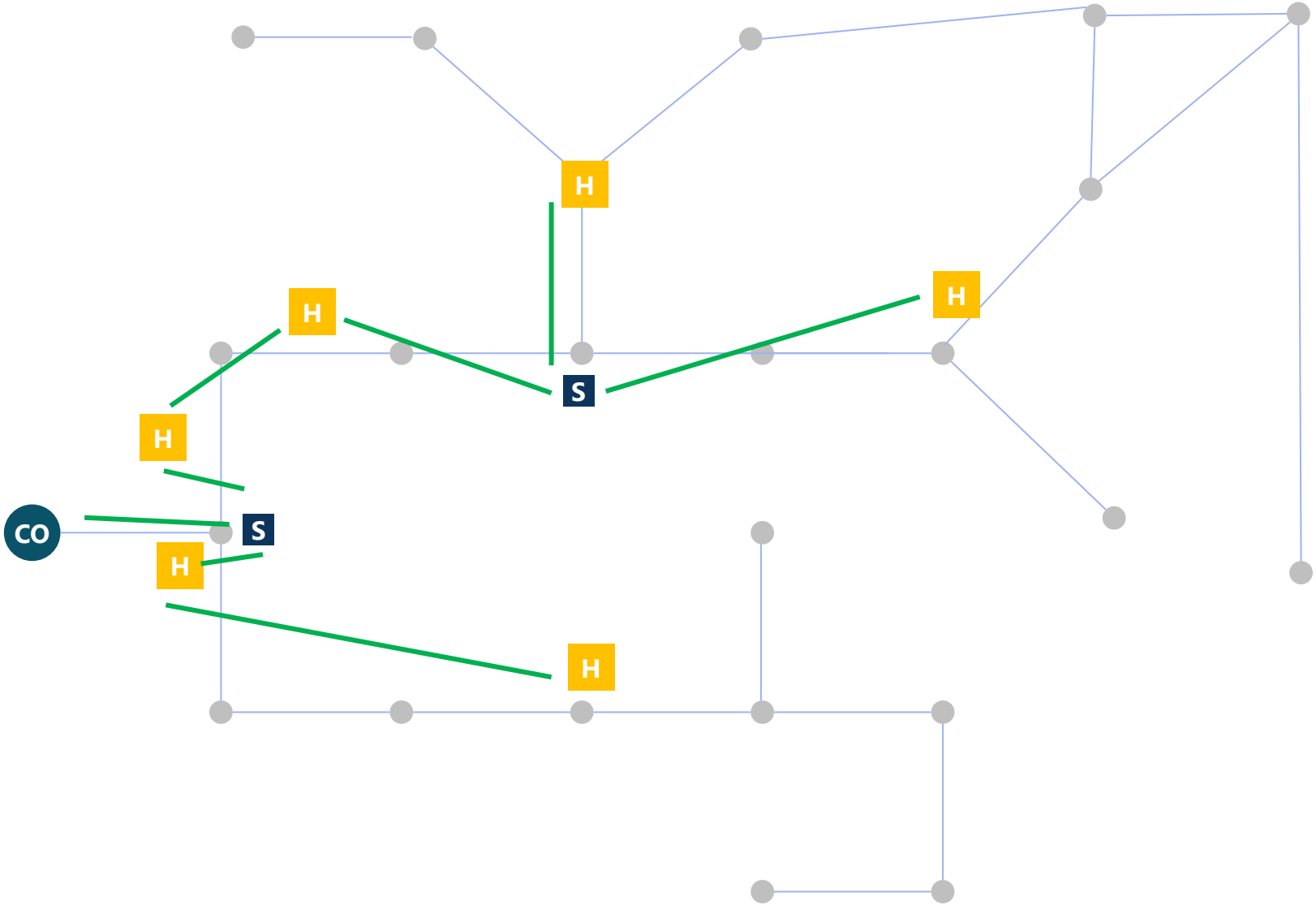
For this example, assume 12 units of consumption per FDT and 48 per FDH

Numbers on edges represent the number of units of consumption on that segment

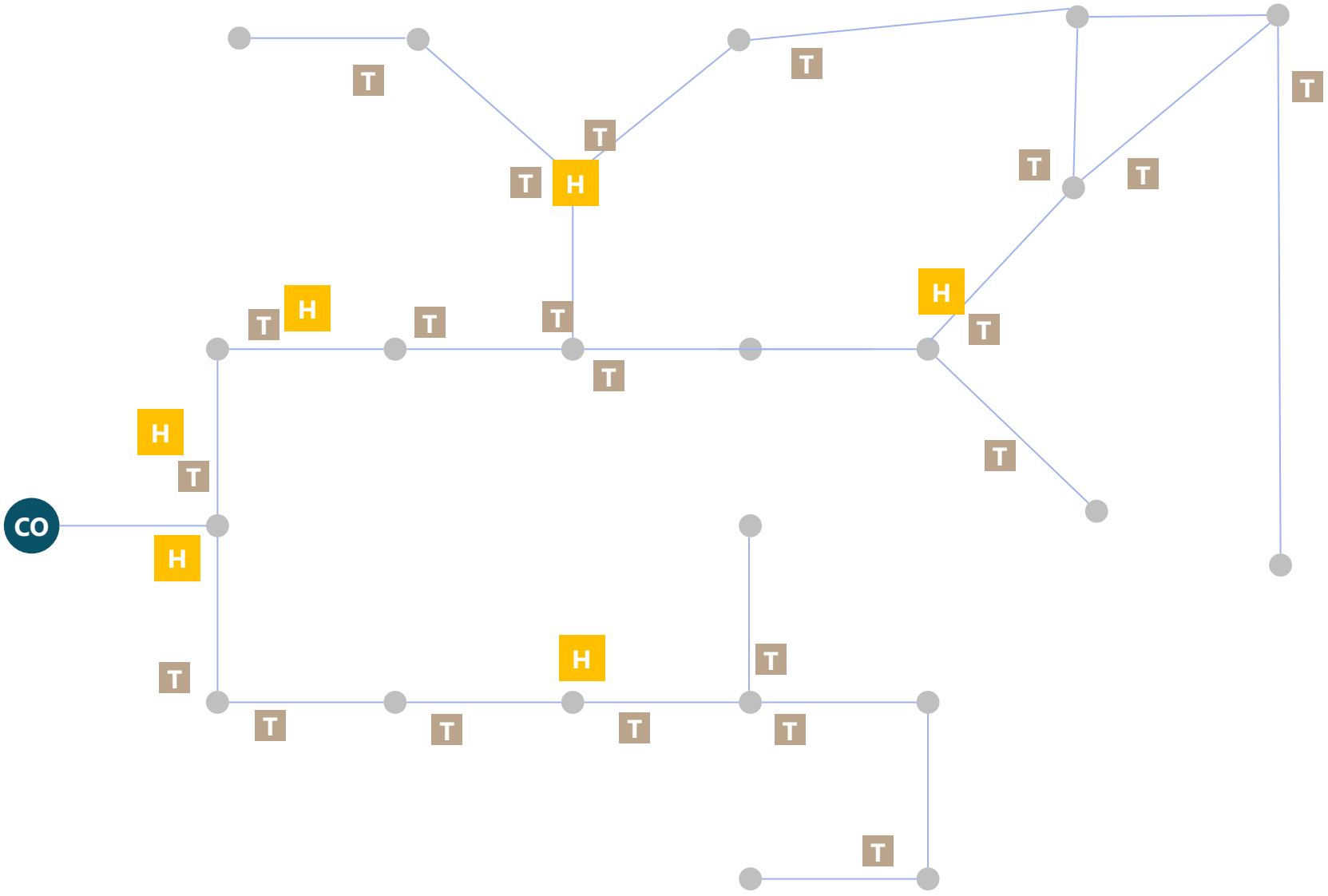


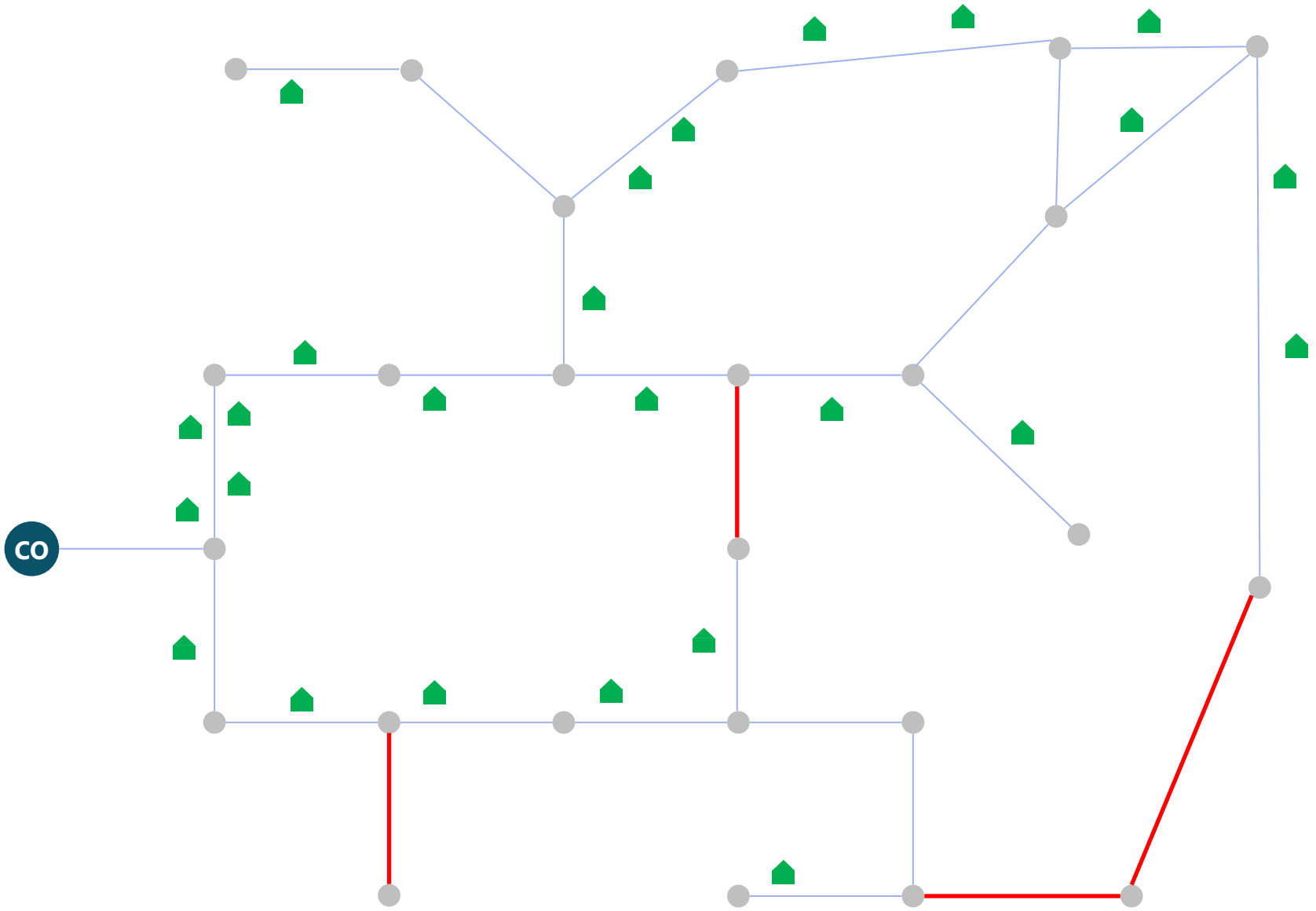
We are testing placement of FDHs and FDTs in the center of the cluster being supported rather than at the most upstream point

1. Nodes on graph are FDHs and sources (e.g. CO)
2. Algorithm finds nearest unconnected nodes and connects them; continues this until all nodes are connected
3. Splice points are inserted where needed

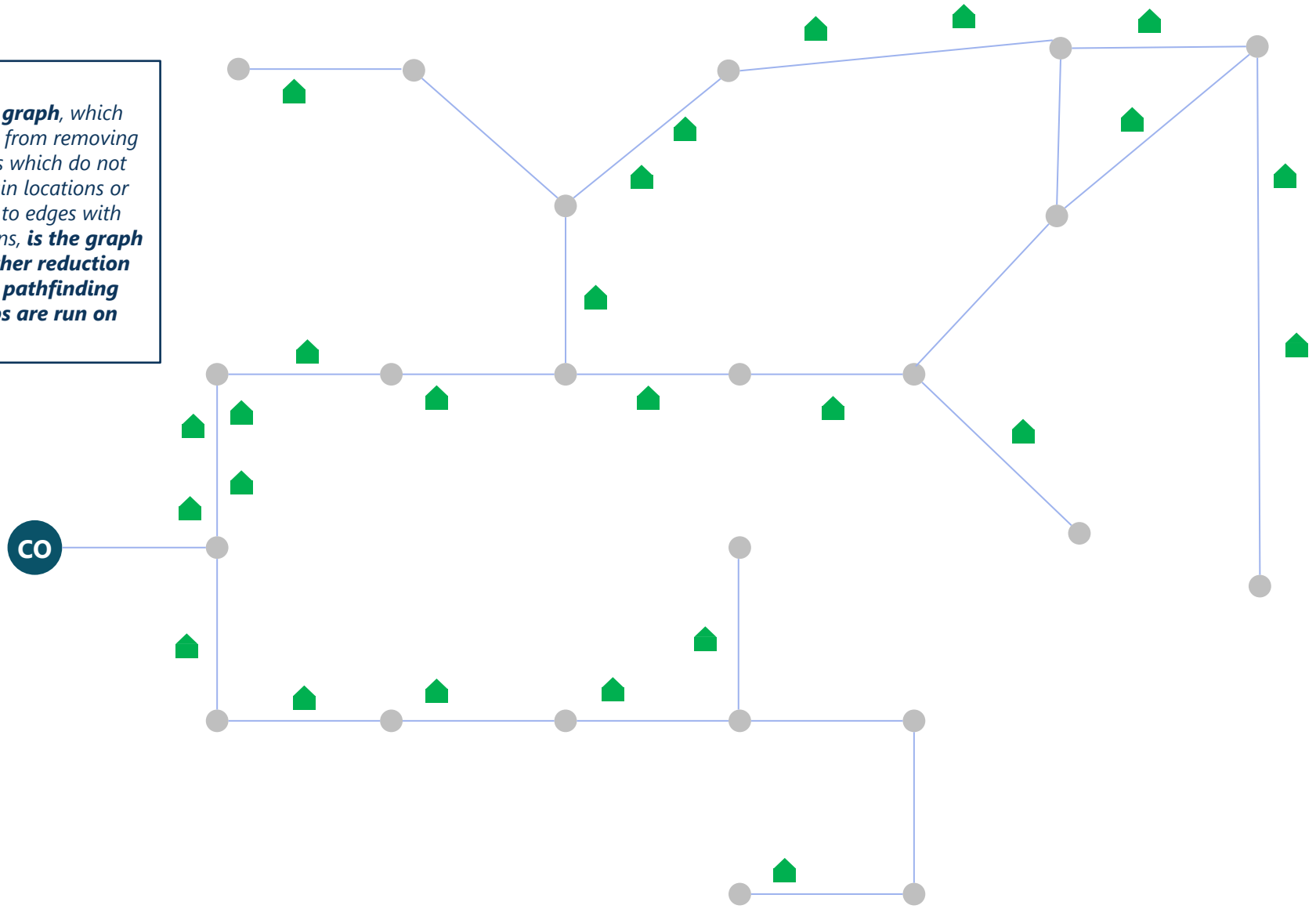


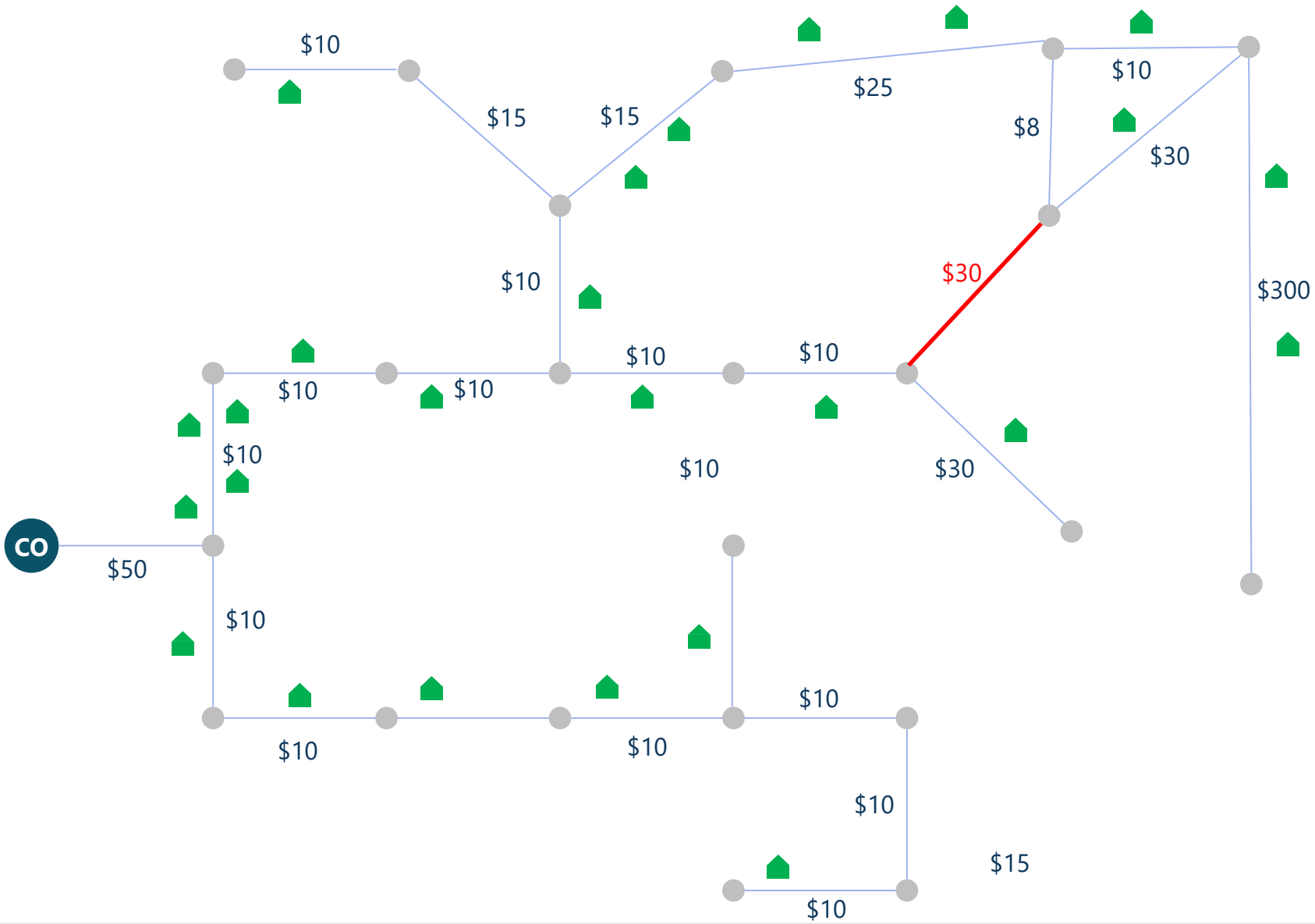
1. Similar to feeder fiber, distribution fiber is placed to link FDTs within the same FDH to minimize distance
2. Splice points are placed where needed




CO

This graph**, which results from removing edges which do not contain locations or lead to edges with locations, **is the graph all other reduction and pathfinding steps are run on




$10
$15
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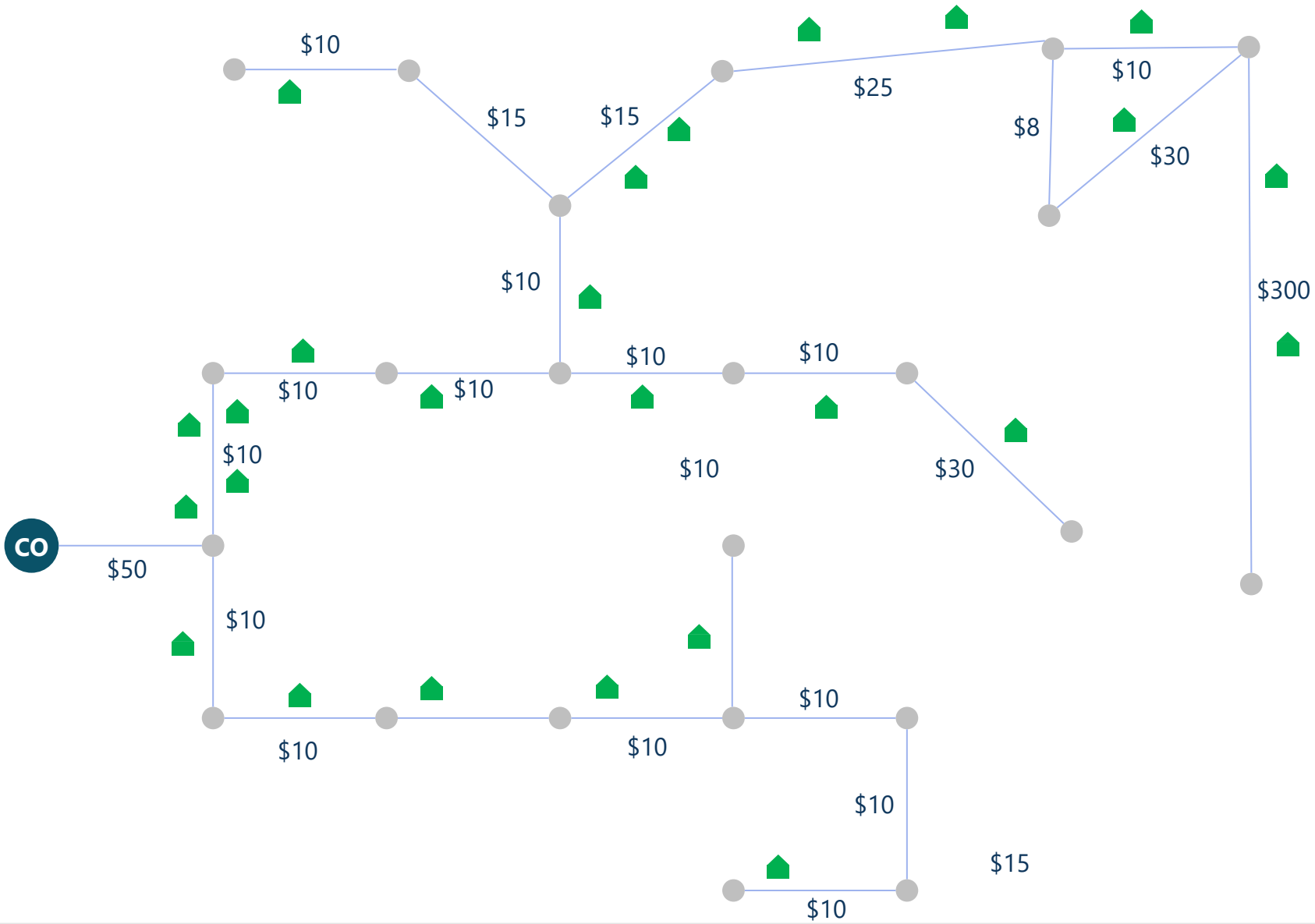
$10
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CO
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$10
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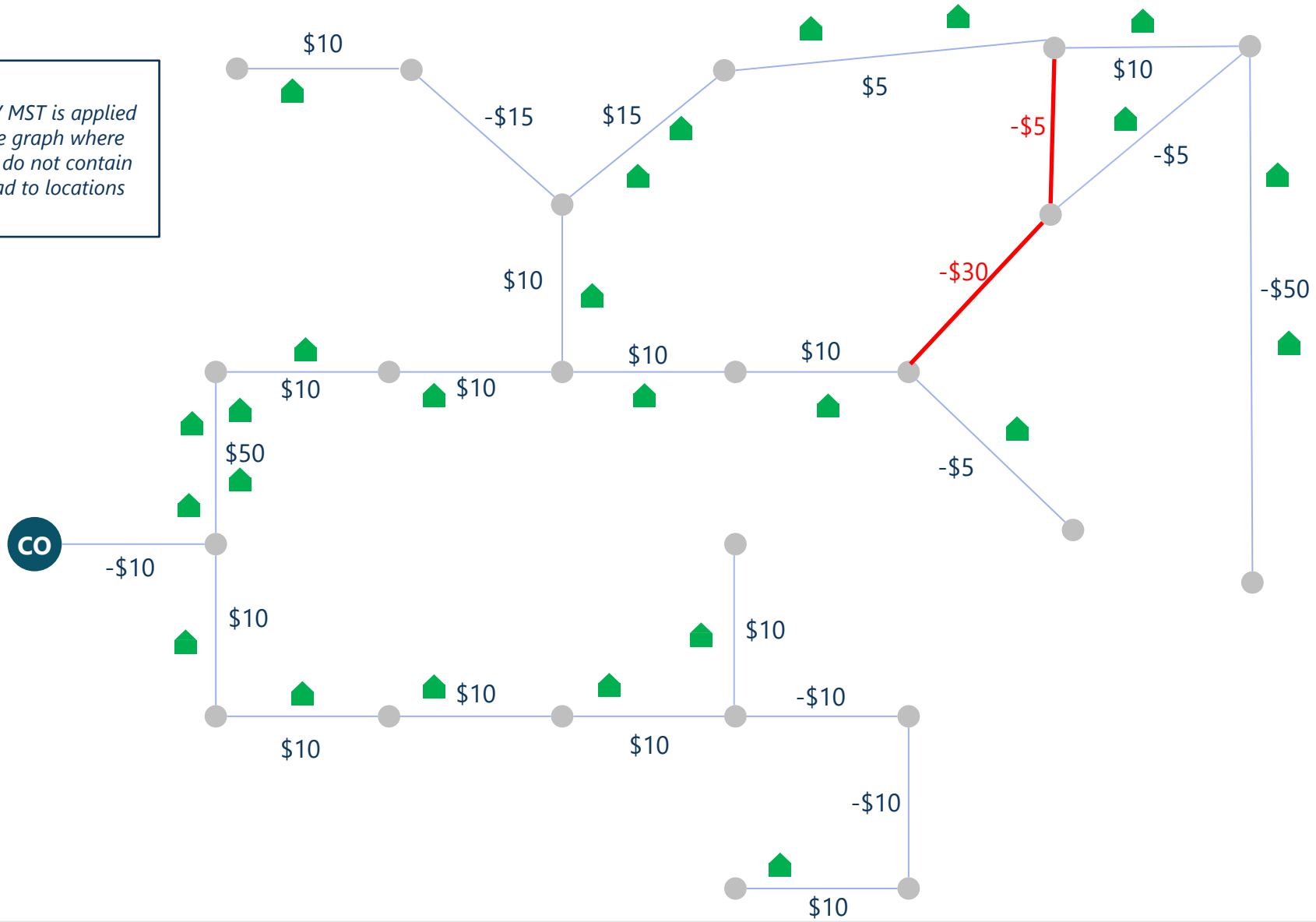
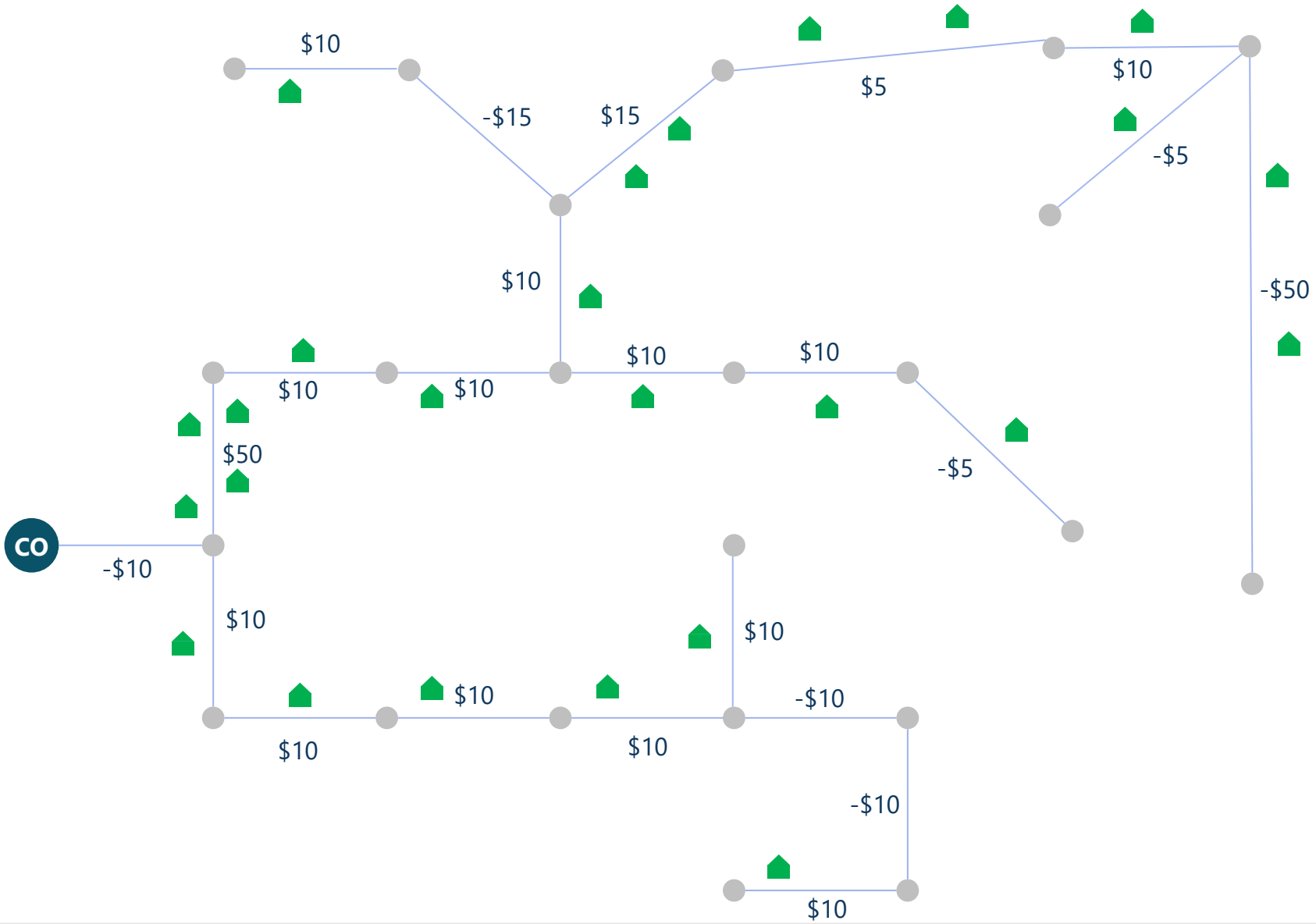
$10

[50, 15…15, 10…10, -10..-10, -15…-15, -30, -50, -200]

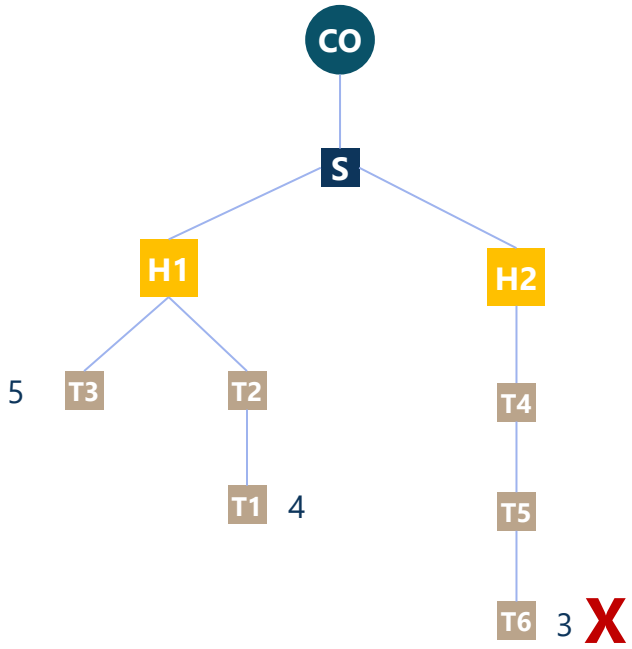
1/NPV MST is applied to the graph where edges do not contain or lead to locations



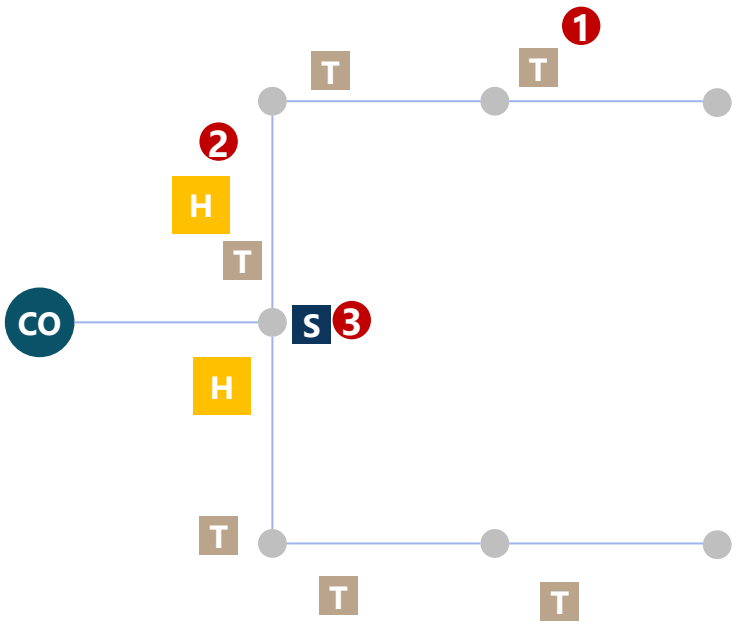
[50, 15…15, 10…10, -10..-10, -15…-15, -30, -50, -200]



1. Equipment nodes are given score based on IRR
2. Pruning removes the lowest-scoring node, recalculates all affected nodes and then repeats
3. It continues to remove lowest-scoring node until a stop-condition is met (e.g. IRR is at peak)



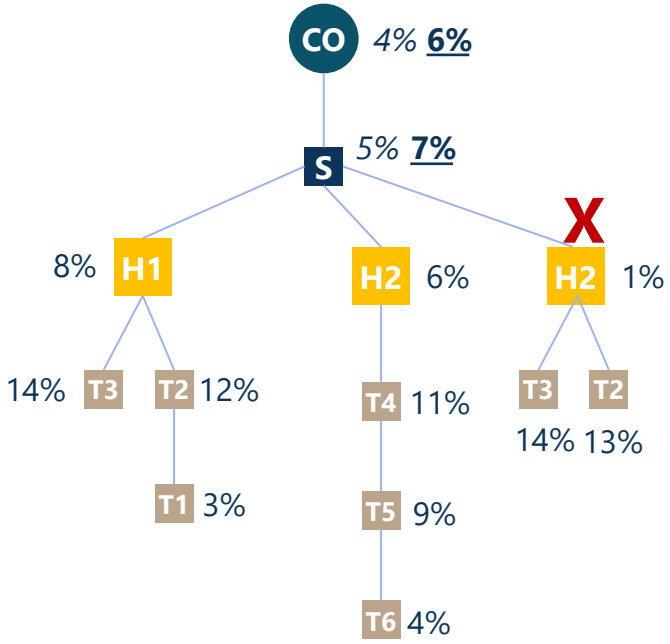
1. Calculate the marginal IRR of each equipment node in the wirecenter
2. Marginal CapEx for the equipment is the marginal cost for connecting and placing that piece of equipment
3. Downstream cash flow for the equipment is the revenue and cost of all the downstream entities



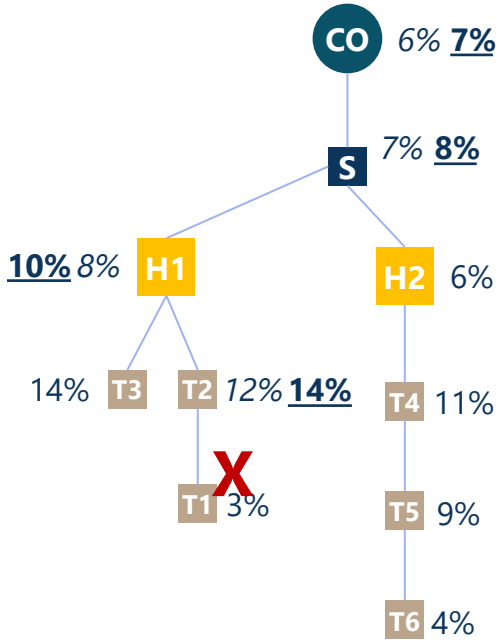
	Marginal CapEx	Downstream Cash Flow
1 T	• *Cost of placing additional fiber to reach this FDT from the FDT upstream* • *Cost of FDT equipment*	• *All downstream entity cash flows (connect CapEx, revenue and costs)*
2 H	• *Cost of placing additional fiber to reach the FDH* • *Cost of the FDH equipment*	• *All downstream cash flows (from the FDTs and entities downstream)*
3 S	• *Cost of placing additional fiber to reach this splitter* • *Splice point cost*	• *All downstream cash flows (from the FDTs/FDHs downstream)*

1. Sequentially, remove lowest IRR node and recalculate IRRs of affected nodes; calculate IRR of the complete graph
2. Repeat until stop constraint is hit:
   - For Max IRR without a budget constraint, the stop constraint is the peak system IRR (the next node removed will lower the IRR of the total graph)
   - For Max IRR with a budget constraint, the constraint stops removing nodes once system is under the budget constraint

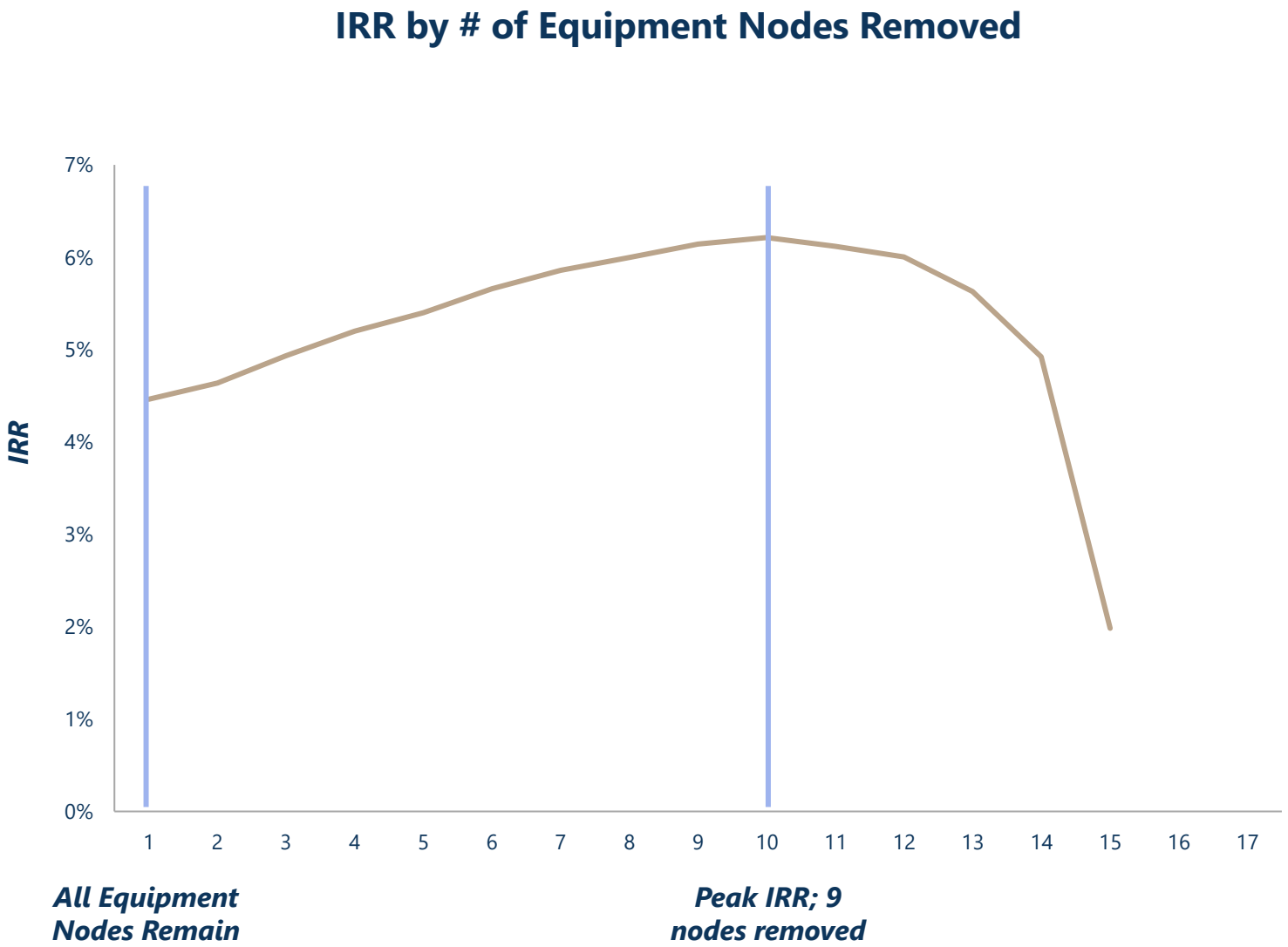
Remove lowest-IRR equipment node and re-calculate affected nodes' IRRs



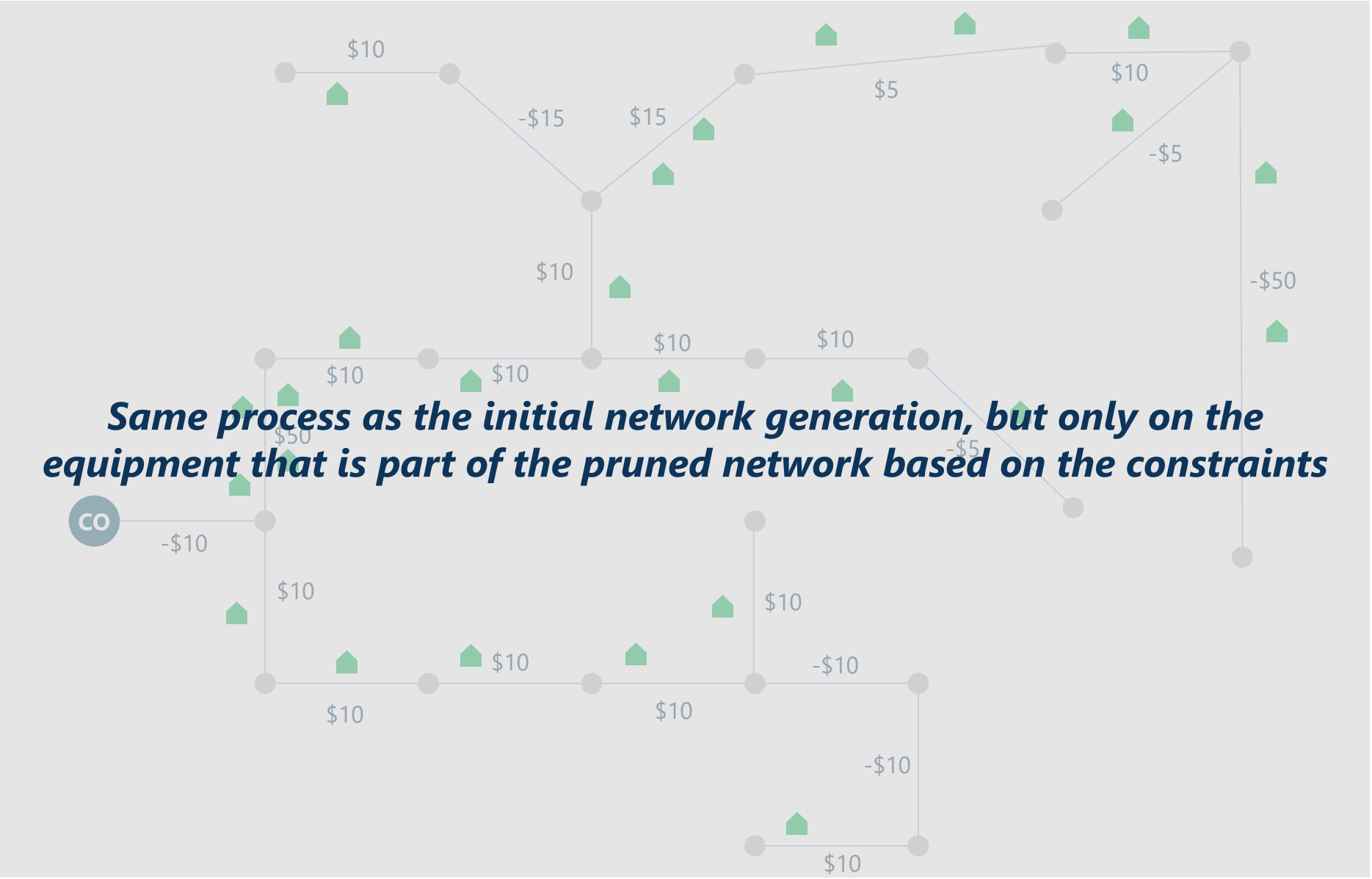
Repeat until system-wide IRR has peaked (next removal decreases IRR)



1. In this example, IRR of the system continues to increase until the 11th equipment node is removed – so the peak IRR is after the removal of equipment node 10



1. Final network generation hooks up equipment with fiber using the same algorithms as initial network generation, but only on the equipment which is part of the pruned network



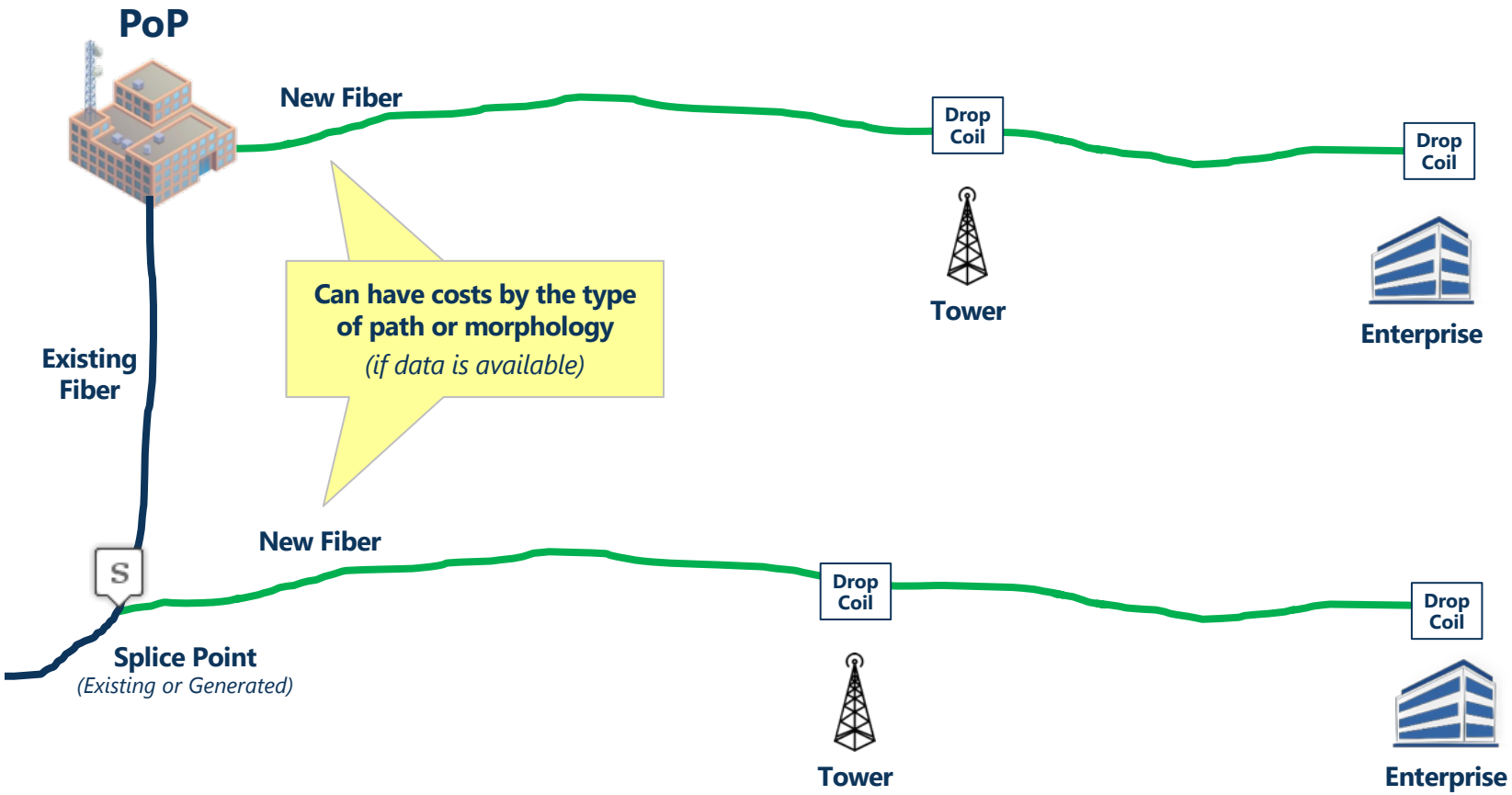
Same process as the initial network generation, but only on the equipment that is part of the pruned network based on the constraints

Contents

In planning routes to target locations, Arrow factors in a number of necessary network equipment elements and their costs

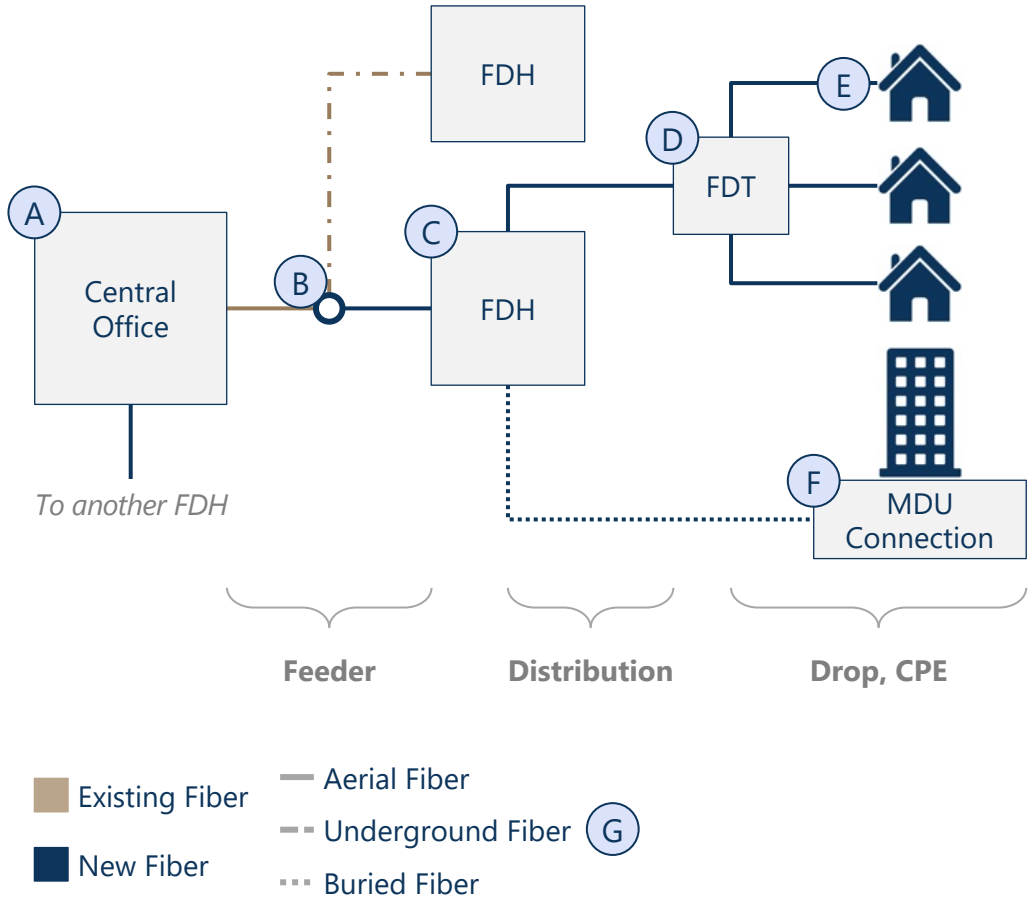
Typical Arrow Enterprise / Tower Build Plan Components

Illustrative



Arrow models costs associated with building FTTP networks

Arrow FTTP Network Model Topology



(A) **Central Office** – Hub of local loop connections

(B) **Splice Point** – Location where possible to splice new fiber off of existing fiber strands

(C) **Fiber Distribution Hub** – Splits fiber at the junction between "feeder" and "distribution"

(D) **Fiber Distribution Terminal** – Splits fiber at the junction between "distribution" and "customer drop"

(E) **Success-Based Capex** – Equipment and labor costs associated with connecting a customer; includes drop, ONT, and other hardware and installation at the customer premises

(F) **Multi-Dwelling Unit** – Variable equipment and labor costs associated with connecting units in a MDU

(G) **Fiber** – Fiber costs can be assigned by location: aerial, underground *(usually located in urban conduit)*, and buried *(dug in shallow trench)*

Input values may be varied by morphology/location

Sources: Altman Solon Research & Analysis

Fiber costs drive the largest capex deployed in a plan; splice points and success-based capex are also important factors

Ordered by model impact

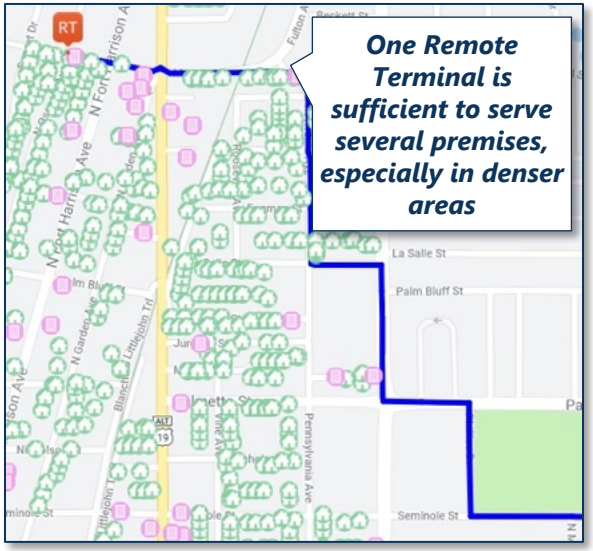
	Arrow Input	Description	Received	Impact on Plan Financials
G	Fiber Costs	Fiber costs can be assigned by morphology and by location: aerial, underground *(usually located in urban conduit)*, and buried *(dug in shallow trench)*; includes materials and labor		
B	Splice Points	Location where possible to splice new fiber off of existing fiber strands; splice point locations have a **significant effect on fiber routing**		
E	Success-Based Capex	Equipment and labor costs associated with connecting a customer; includes drop, ONT, and other hardware and installation at the customer premises		
C	Fiber Distribution Hub	Splits fiber at the junction between "feeder" and "distribution"		
D	Fiber Distribution Terminal	Splits fiber at the junction between "distribution" and "customer drop"		
A	CO Upgrade Cost	Hub of local loop connections; upgrade costs include installing and upgrading equipment for GPON		
F	MDU	Variable equipment and labor costs associated with connecting units in a MDU		

In past Arrow analysis, **fiber costs** have accounted for **the majority of plan capex**

Sources: Altman Solon Knowledgebase

Low → High

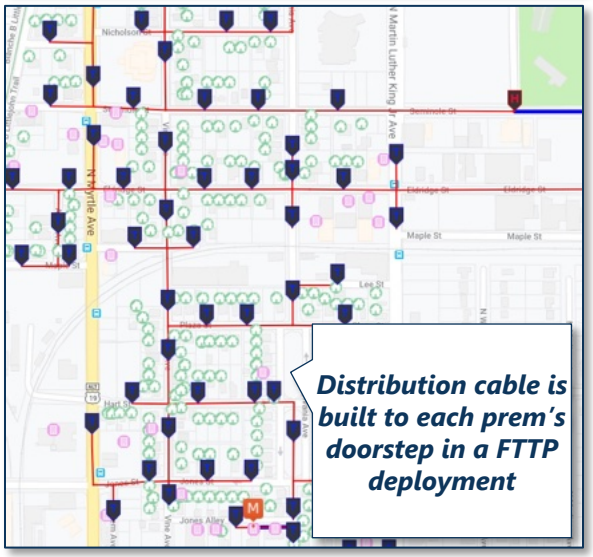
While FTTP and FTTN network deployments use similar general architectures, there are a few key differences around connecting prems



FTTN Deployment

(assumes node is in range of prems to guarantee 25Mbps target speed)

- A FTTN network deployment lays fiber from the CO to remote terminals in sufficient range to guarantee a 25Mbps target speed for each connected prem
- The network uses Remote Terminal (RT) equipment at network end nodes
- When a prem subscribes, connect cost is assumed to cover both equipment and installation



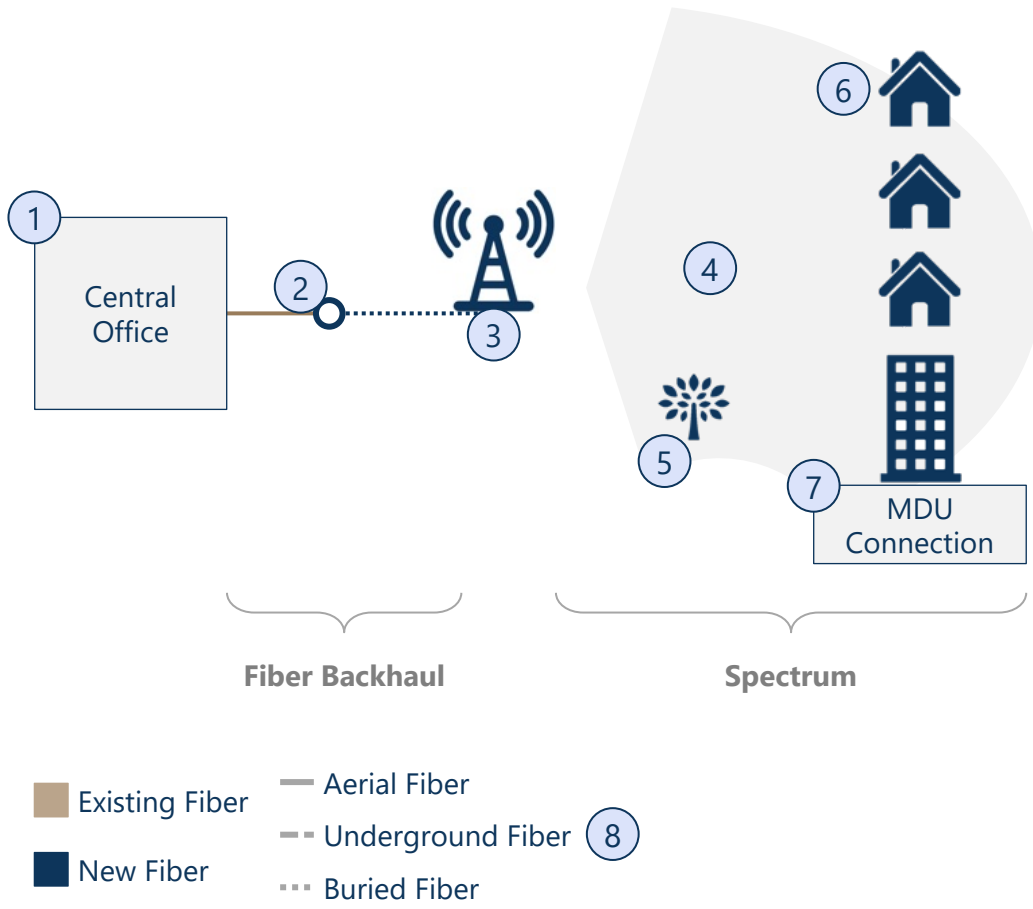
FTTP Deployment

(fiber is built to the prem doorstep and can offer 100Mbps+ speeds)

- A FTTP network deployment lays fiber from the CO all the way to the doorstep, guaranteeing speeds over 100Mbps for each connected prem
- The network uses FDHs and FHTs / MDU equipment to pass all prems
- This is a more capex intensive deployment compared to FTTH since it requires additional fiber miles and equipment
- When a prem subscribes, higher connect cost in assumed, given the different CPE required

Arrow models costs associated with the following FW network topology

Arrow FW Network Model Topology



1. **Central Office** – Hub of local loop connections
2. **Splice Point** – Location where possible to splice new fiber off of existing fiber strands
3. **5G Fixed Wireless Node** – Access Node and tower for 5G signal; associated costs include equipment, labor
4. **Spectrum** – Bands of frequencies for propagating wireless information; radius (propagation distance) can be a model input

   No costs associated with spectrum in Arrow
5. **Obstacles** – Foliage and buildings can impede the propagation of high-frequency wireless signals
6. **Success-Based Capex** – Equipment and labor costs associated with connecting a customer; includes hardware and installation at the customer premises
7. **Multi-Dwelling Unit** – Variable equipment and labor costs associated with connecting units in a MDU
8. **Fiber** – Fiber costs can be assigned by location: aerial, underground *(usually located in urban conduit)*, and buried *(dug in shallow trench)*

Input values may be varied by morphology/location

Sources: Altman Solon Research & Analysis

Spectrum propagation and fiber costs drive most capex in a fixed wireless build plan; splice points and success-based capex also important factors

Ordered by model impact

Arrow Input	Description	Received	Impact on Plan Financials
4 5 Spectrum Radius, Obstacles	Propagation distance of wireless signal		
8 Fiber Costs	Fiber costs can be assigned by morphology and by location: aerial, underground *(usually located in urban conduit)*, and buried *(dug in shallow trench)*		
3 5G Fixed Wireless Node Cost	Access Node and tower for 5G signal; associated costs include equipment, labor		
2 Splice Points	Location where possible to splice new fiber off of existing fiber strands; splice point locations have a **significant effect on fiber routing**		
6 Success-Based Capex	Equipment and labor costs associated with connecting a customer; includes hardware and installation at the customer premises; based on % prems requiring truck roll		
1 CO Upgrade Cost	Hub of local loop connections; upgrade costs include installing and upgrading equipment for GPON		
7 MDU	Variable equipment and labor costs associated with connecting units in a MDU; can MDUs be served with FW?		

Sources: Altman Solon Knowledgebase

Low → High

Residential opportunity fair share is estimated by combining the Competition Manager inputs and the competitive intelligence data available for each location

Identify providers serving given Census Block

List all providers serving the census block in which the location is situated using FCC's BDC fabric data (for US-based implementations)

Look up reported maximum download speed for each provider and technology (for a given census block)

Translate available speed, technology and provider 'brand' into offer strength

Convert download speeds to Speed Strength values (0-1 scale)

Multiply each provider's strength score by 'Brand Strength' to arrive at final competitive strength for a provider (e.g., superior brand recognition in consumers' minds results in more competitive offer even when speeds and technologies may be the same)

Aggregate across all providers and calculate implied fair share

Sum up competitive strengths of all providers in a given census block, add expected offer strength from Arrow's plan, to determine resulting fair share

Calculated by Altman Solon based on the available FCC data

Lookup from Speed Matrix section of Competition Resource Manager (using technology and maximum download speed)

Lookup from Competition Resource Manager. Set 1 one by default for all providers and self.

When running overbuild plans from a provider perspective, ensure that own strength is set to zero to avoid treating legacy assets as a competitor.

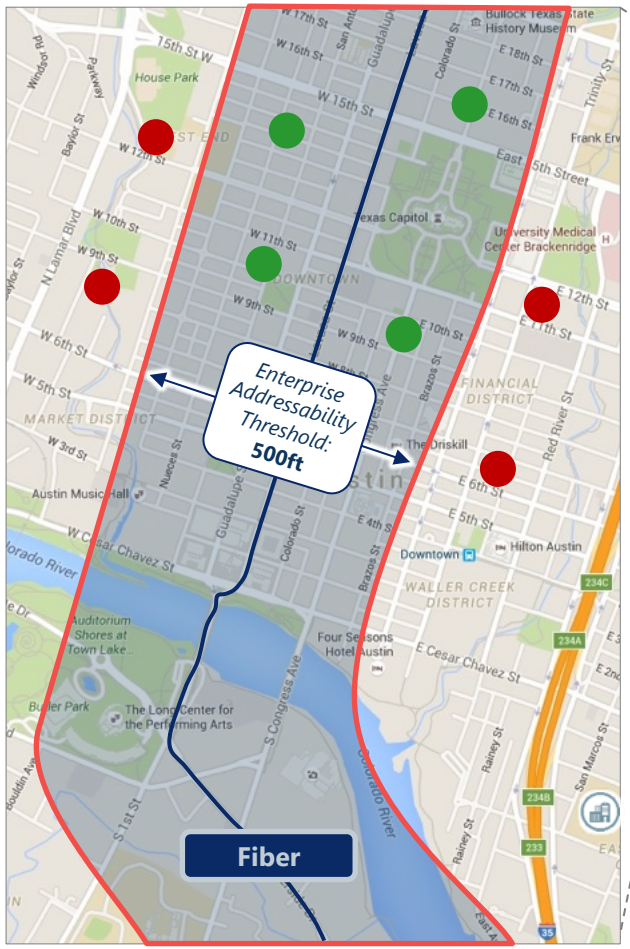
Provider total strength / Sum of all provider's total strength

ILLUSTRATIVE

Provider	Technology	Max Speed	Area Coverage	x	Technology Strength	x	Brand Strength	=	Total Strength	->	Implied Fair Share
Provider A	Cable	75	100%		0.50		1.00		0.50		17.39%
Provider A	Fiber	150	75%		1.00		1.00		0.75		26.09%
Provider B	Fiber	500	50%		1.00		0.75		0.38		13.04%
Provider C	Satellite	30	100%		0.00		1.00		0.00		0.00%
Provider D	Fixed Wireless	125	100%		0.25		1.00		0.25		8.70%
Arrow Planned Network	Fiber	1,000	100%		1.00		1.00		1.00		**34.78%**

? ***Tip:*** *Target Fair Share can be directly specified for each location by supplying "ROIC.BAU.FAIR_SHARE" and "ROIC.PLAN.FAIR_SHARE" parameters during location upload*

Tower and Business opportunity fair share is estimated for each location by determining the number of competitors within a specified distance

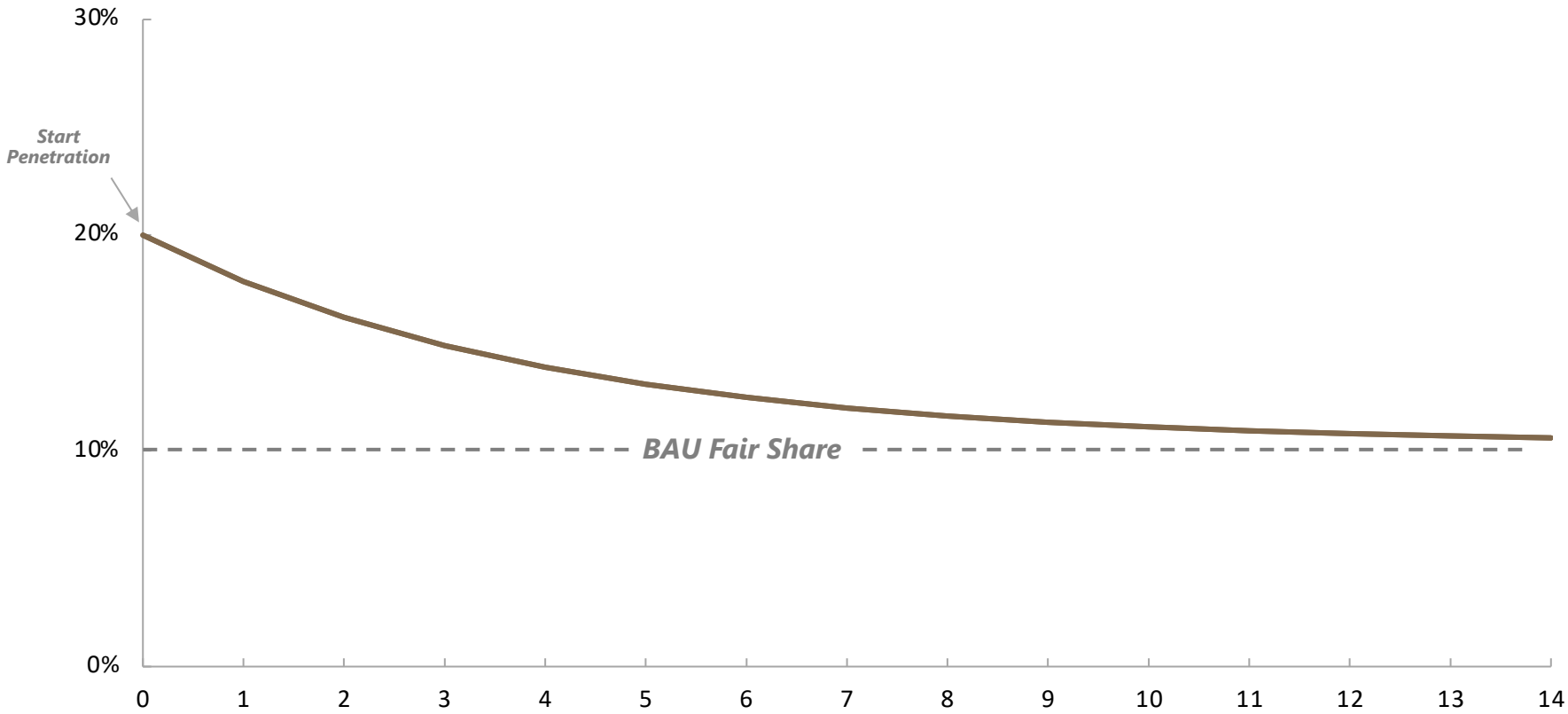


1. Put a buffer of around all the competitive fiber routes from the Geotel dataset (buffer radius adjustable in Planning Constraints Manager)
2. For each location, calculate how many competitive fiber route buffers it is contained within, and their respective brand strengths
3. Fair share is calculated as:

   1 / (1 + (number of competitors* respective brand strength))

? ***Tip:*** *Target Fair Share can be directly specified for each location by supplying "ROIC.BAU.FAIR_SHARE" and "ROIC.PLAN.FAIR_SHARE" parameters during location upload*

BAU penetration curves are based on decay towards estimated BAU fair share penetration, with rate of change determining decay rate

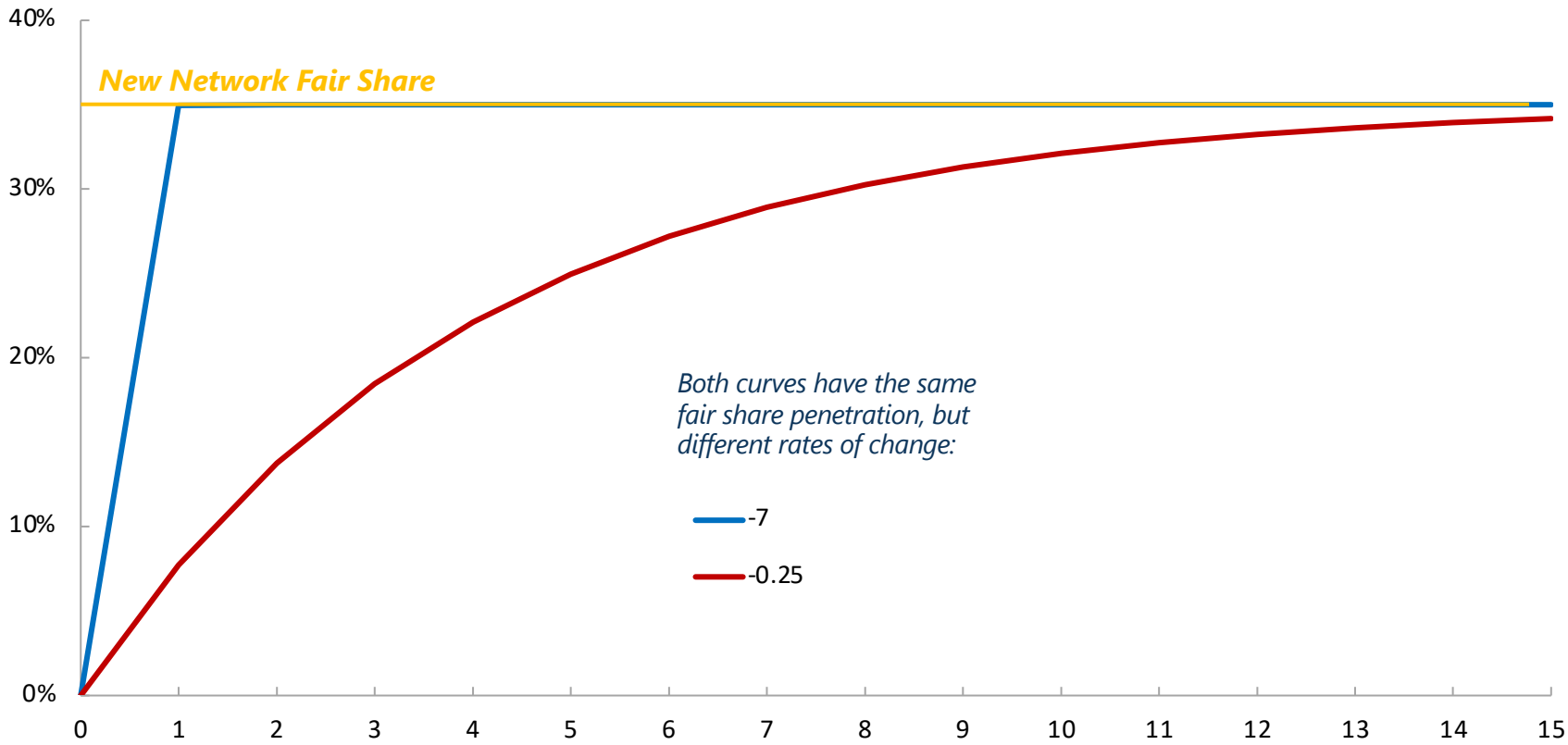


Penetration (at time t) = (fairShare - startPenetration) * (1 – e ^ (rateChange * t)) + startPenetration

rateChange: Set by user to represent historical rate of decay for legacy technology
-0.00001 to -7.0 value range, with -0.25 being representative of recent market trends

? ***Tip:*** *Set BAU start penetration = 0 and rateChange = -0.00001 to model greenfield network builds*

New Network penetration curves are based on target fair share and a rate of change factor which determines how steep the curve is

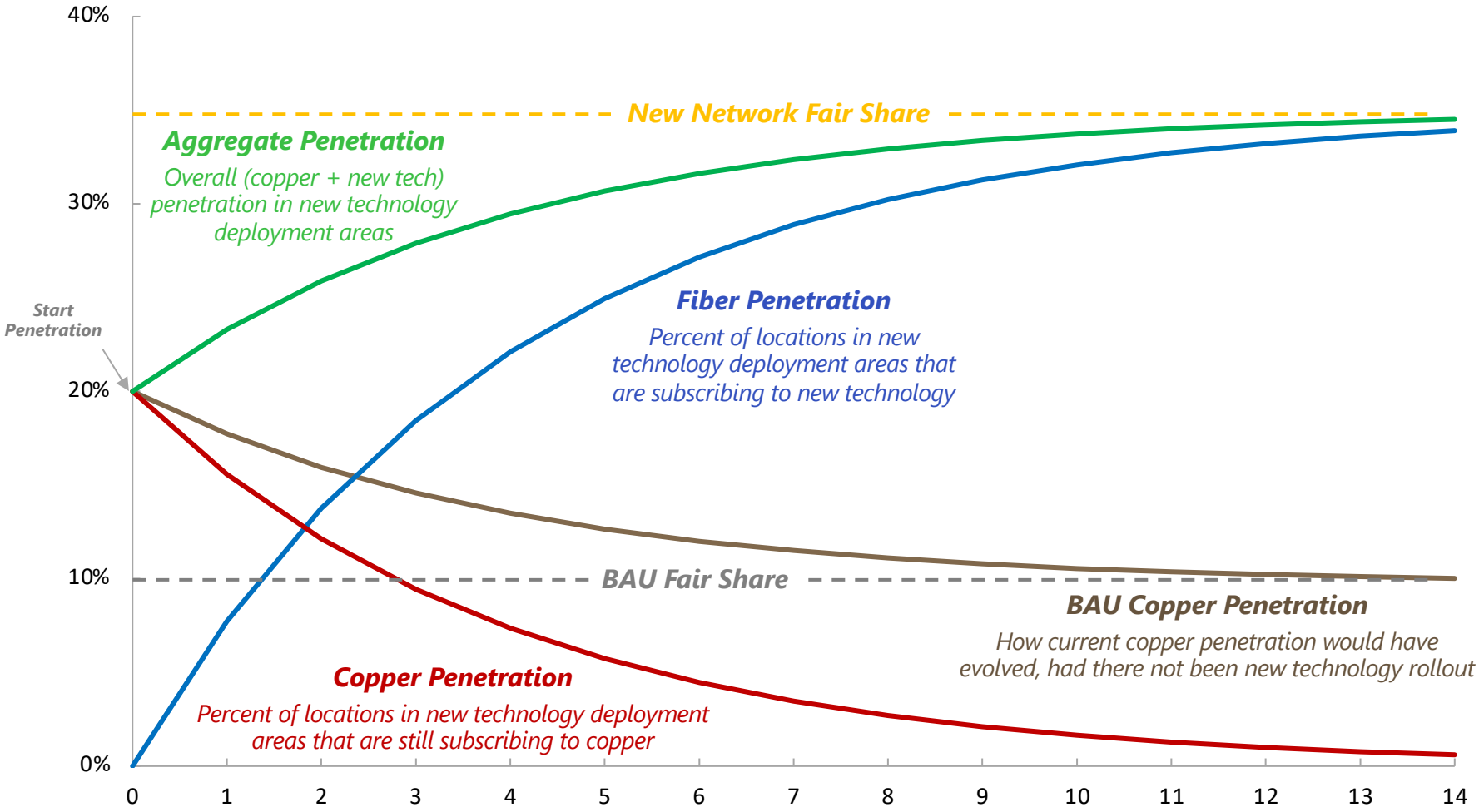


Penetration (at time t) = fairShare * (1 – e ^ (rateChange * t))

rateChange: Set by user to represent historical rate of penetration for new technology
-0.00001 to -7.0 value range, with -0.25 being representative of recent market trends

? ***Tip:*** *Set to 7.0 to reach fair share penetration within one time period (e.g. when modeling building out to contract customers)*

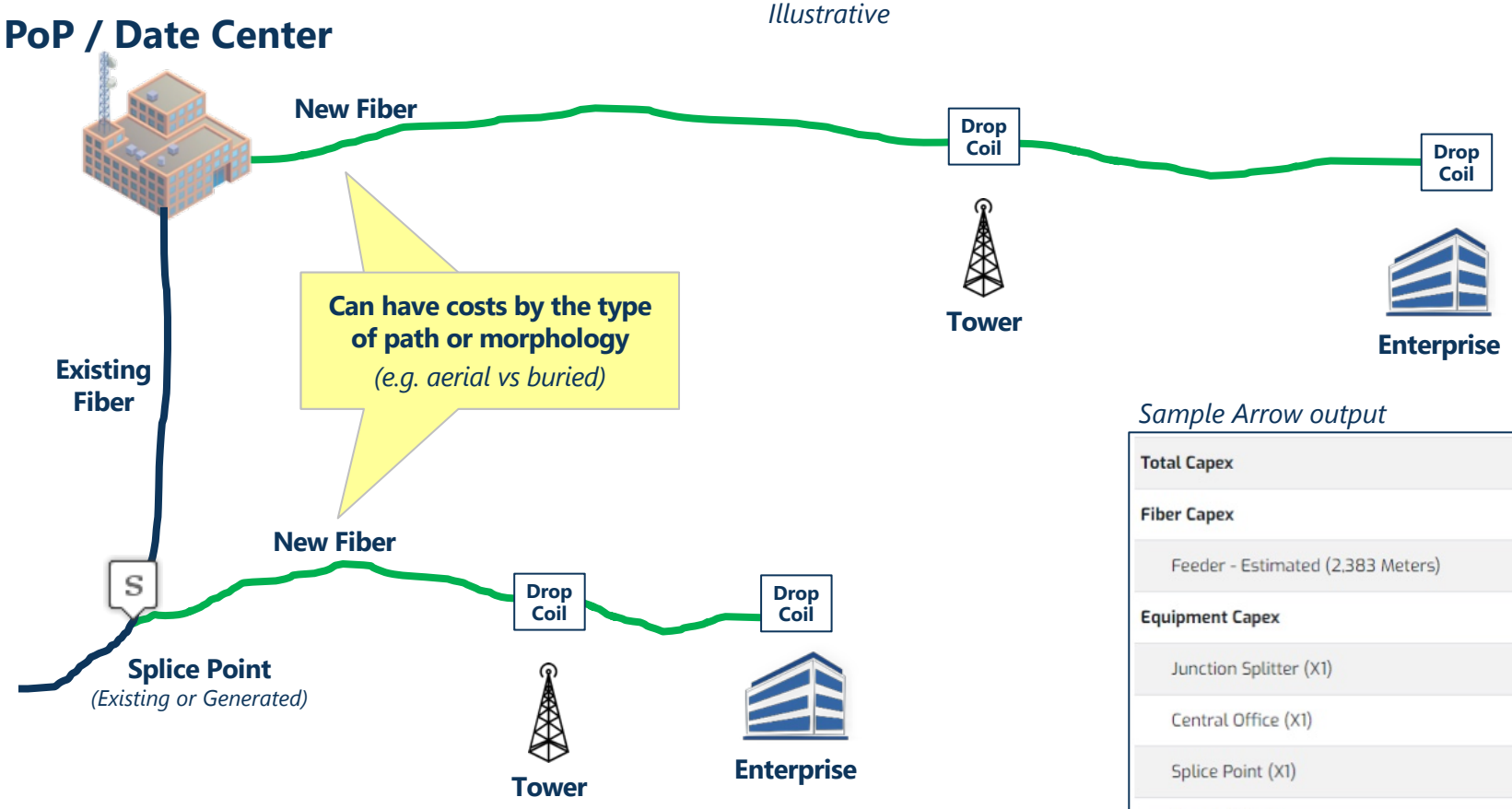
In the case when fiber is launched in a current copper market, the curve for copper decline is based on the fiber rate of change rather than historical



In planning routes to target locations, Arrow factors in a number of necessary network equipment elements and their costs

Typical Arrow Enterprise / Tower Build Plan Components

Illustrative



Sample Arrow output

Total Capex	$23.4K
Fiber Capex	
Feeder - Estimated (2,383 Meters)	$21.8K
Equipment Capex	
Junction Splitter (X1)	$0.0K
Central Office (X1)	$0.3K
Splice Point (X1)	$0.3K
Drop Coil (X1)	$1.0K

All equipment and fiber capex is considered one-time upfront expense

ARPU, operating expenses and ramp up to fair share are all considered in projecting revenue for each location

Typical Arrow Individual Location Financial Evaluation

Illustrative

Time Period / Year	0	1	2	3	4	5	6	7	8	9
Number of Locations	1	1	1	1	1	1	1	1	1	1
Location ARPU [annual]	$5,100	$5,100	$5,100	$5,100	$5,100	$5,100	$5,100	$5,100	$5,100	$5,100
Number of Customers	0.00	0.11	0.18	0.23	0.27	0.29	0.30	0.31	0.32	0.32
Penetration	0.0%	11%	18%	23%	27%	29%	30%	31%	32%	32%
Location Revenue	**$0**	**$560**	**$936**	**$1,188**	**$1,357**	**$1,470**	**$1,546**	**$1,597**	**$1,631**	**$1,654**
Operating Expenses	$0	$118	$197	$249	$285	$309	$325	$335	$342	$347
Maintenance Expenses	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Location Expenses	**$0**	**$118**	**$197**	**$249**	**$285**	**$309**	**$325**	**$335**	**$342**	**$347**
Location Net Cash Flow	**$0**	**$443**	**$740**	**$938**	**$1,072**	**$1,161**	**$1,221**	**$1,261**	**$1,288**	**$1,306**
Discounted Cash Flow	$0	$403	$611	$705	$732	$721	$689	$647	$601	$554

Total annual location ARPU *(input directly via ARPU manager, or pulled from Telecom Spend Matrix)*

Ramp up to fair share penetration value *(fair share determined by competitive area of the location, or direct user input)*

Total Location Revenue x Penetration

Fraction of revenue spent on OpEx and Maintenance

Location Revenue – Location Expenses

Present value of future cash flow

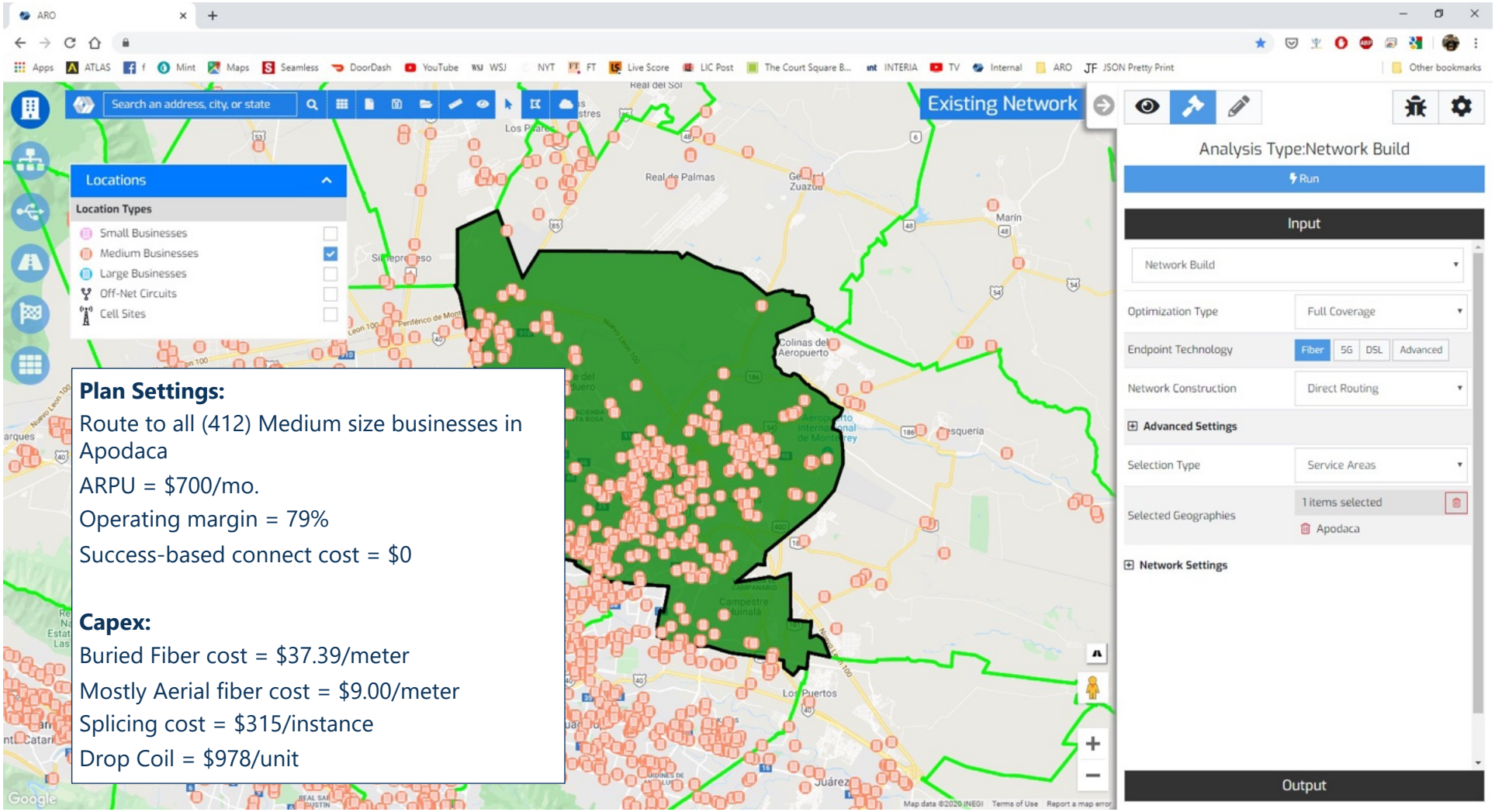
Present Value of Future Cash Flows **$5,664**

Total expected current value of location's revenue streams. This value gets compared to network build cost to determine overall profitability

All above assumptions can be changed using ARPU and ROIC resource managers

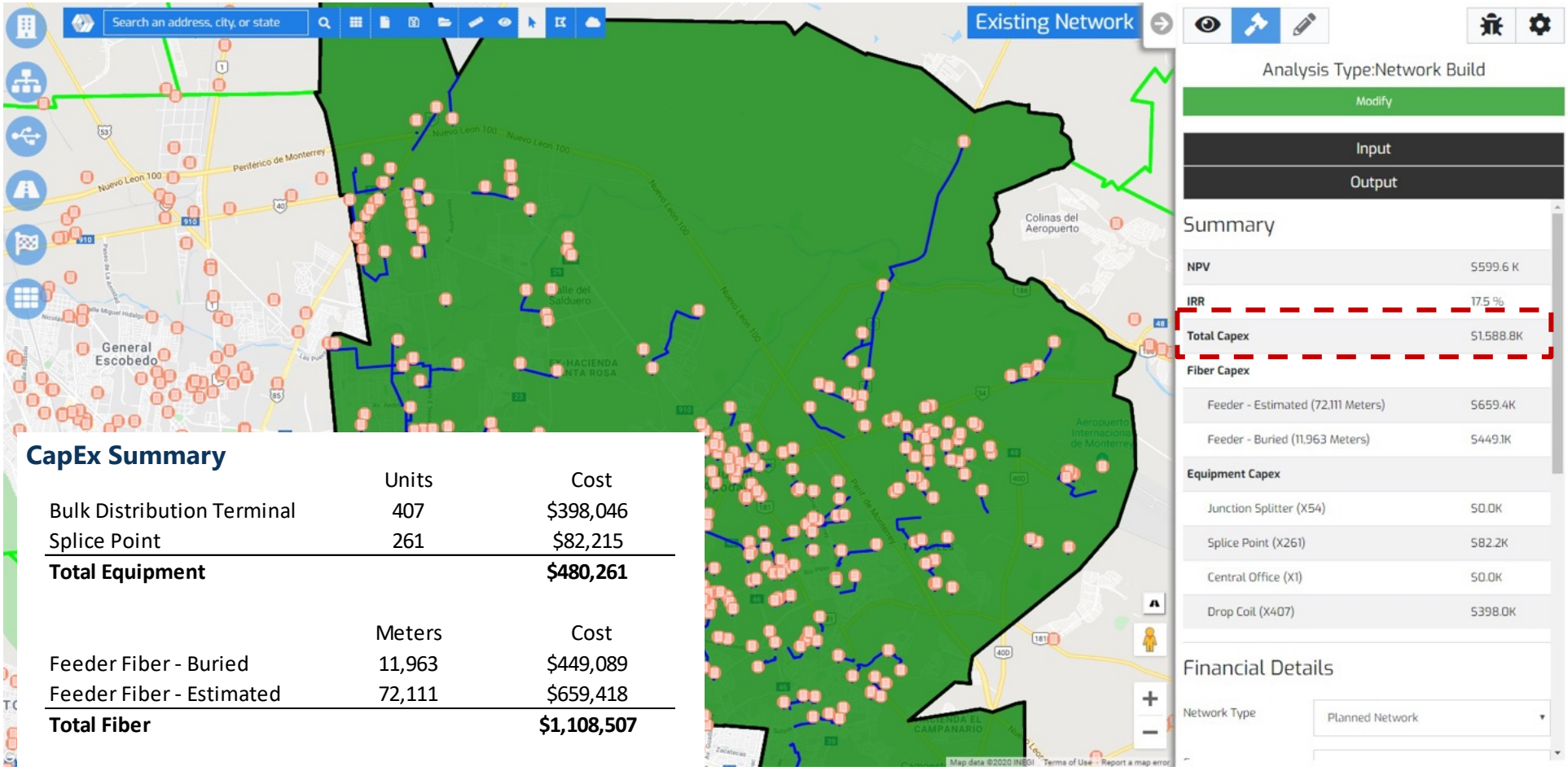
To visualize how cost and revenue models come together, we will run a sample full coverage plan in one area

Arrow Build – Sample Scenario



Routing to 412 medium businesses using current assumptions will require $1.59M, all of which will be spent upfront

Arrow Build – Sample Scenario – CapEx



CapEx Summary

	Units	Cost
Bulk Distribution Terminal	407	$398,046
Splice Point	261	$82,215
Total Equipment		**$480,261**

	Meters	Cost
Feeder Fiber - Buried	11,963	$449,089
Feeder Fiber - Estimated	72,111	$659,418
Total Fiber		**$1,108,507**

Total Build Cost **$1,588,768**

Those 412 locations, however, are expected to turn into 76 customers, by year 10, resulting in plan's overall NPV of $0.6M, with 17.5% IRR

Arrow Build – Sample Scenario – Cash Flow

Time Period / Year	0	1	2	3	4	5	6	7	8	9
Number of Locations	412	412	412	412	412	412	412	412	412	412
Total Available Revenue	$3,460,800	$3,460,800	$3,460,800	$3,460,800	$3,460,800	$3,460,800	$3,460,800	$3,460,800	$3,460,800	$3,460,800
Number of Customers	0	26	43	55	62					76
New Customers	0	30	24	20	17					12
Penetration	0%	6%	10%	13%	15%	16%	17%	18%	18%	18%
Revenue	**$0**	**$216,556**	**$361,718**	**$459,022**	**$524,248**	**$567,970**	**$597,277**	**$616,923**	**$630,092**	**$638,919**
Network Build Cost	$1,588,768	$0	$0	$0	$0	$0	$0	$0	$0	$0
New Connection Cost	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Operating Expenses	$0	$45,477	$75,961	$96,395	$110,092	$119,274	$125,428	$129,554	$132,319	$134,173
Maintenance Expenses	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Expenses	**$1,588,768**	**$45,477**	**$75,961**	**$96,395**	**$110,092**	**$119,274**	**$125,428**	**$129,554**	**$132,319**	**$134,173**
Net Cash Flow	-$1,588,768	$171,079	$285,757	$362,628	$414,156	$448,696	$471,849	$487,369	$497,772	$504,746
Discounted Cash Flow	**-$1,588,768**	**$155,526**	**$236,163**	**$272,448**	**$282,874**	**$278,605**	**$266,347**	**$250,097**	**$232,215**	**$214,062**
NPV	**$599,568**									
IRR	**17.5%**									

Number of new customers is greater than customer difference between time periods because it factors in customer churn

Total build CapEx from prior page

New Customers x Success-based CapEx per customer

Plan NPV and IRR matching Arrow UI output

Above cash flow projections are available in "Financial Output" reports

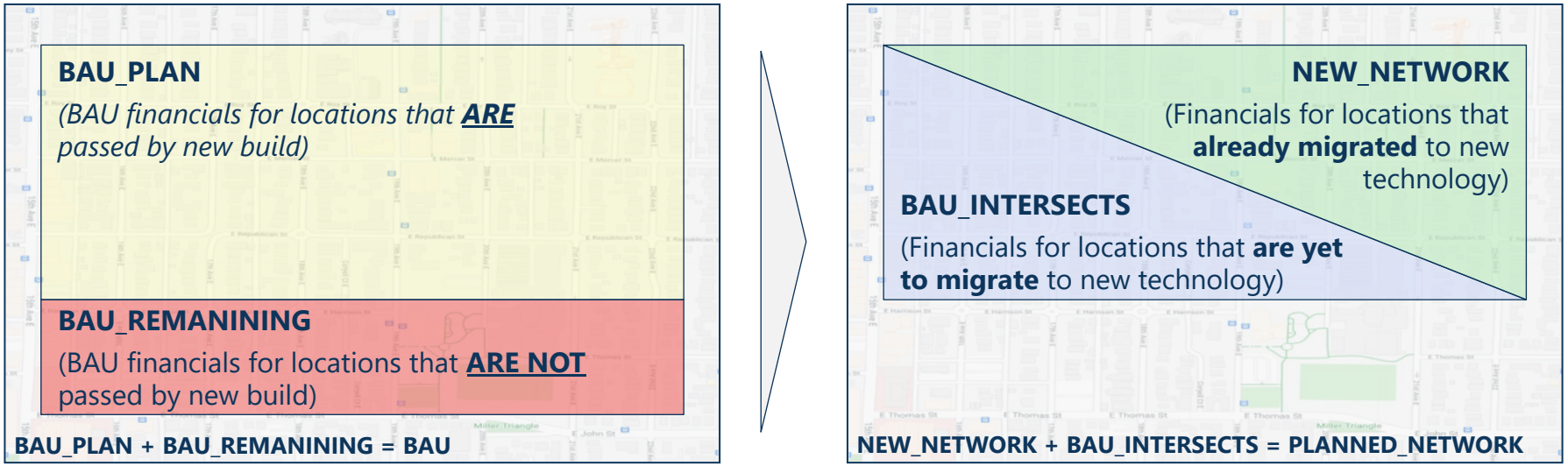
Arrow Financial Output Reports allow in-depth analysis of financial net impact of the proposed build

BAU

What the financials would have looked like without any new build

PLANNED_NETWORK

What the financials will look like after accounting for the new build, for passed locations only?



INCREMENTAL = PLANNED_NETWORK – BAU_PLAN

*What is the **net** impact of the new build*

Example:

Customers		Year	0	1	2	3	4	5
BAU	BAU for all locations		30.0	36.7	42.7	48.1	53.1	57.5
BAU_PLAN	BAU for passed locations		21.3	26.0	30.3	34.2	37.7	40.9
BAU_REMANINING	BAU for locations not passed		8.7	10.6	12.4	14.0	15.4	16.7
PLANNED_NETWORK	Passed locations		21.3	32.3	40.9	47.5	52.7	56.8
NEW_NETWORK	Passed, already migrated		0.0	15.7	27.9	37.5	44.9	50.7
BAU_INTERSECTS	Passed, not yet migrated		21.3	16.6	12.9	10.1	7.8	6.1
INCREMENTAL	Net impact of the new build		0.0	6.3	10.5	13.3	15.0	15.9

30 existing legacy (DSL) customers, 21.3 of which got passed by the planned build. Baseline customer count expected to go up to 40.9 in year 5 in areas passed by new network

21.3 customers in year 0, turn into 56.8 in year 5, split between new and legacy technology subscribers

*In areas covered by new network, 40.9 customers in the baseline case become 56.8 customers, **for a net gain of 15.9***

Arrow is set up to enable automatic, machine-to-machine, plan submission and result retrieval via REST APIs or Curl Commands

System submits Lat / longs and other meta-data about sites in an opportunity

Specific meta data fields, e.g. site's expected revenue, can be customized to client's specific requirements

Arrow processes route paths to each site submitted by the external system

Fiber paths, plan details, and financial statistics are generated for each request

Summary reports become available for retrieval

Reports are fully customizable, and can be tailored client's needs

Typical reports include:

- Fiber path(s) KML
- Fiber and Equipment CapEx Summary
- Target Location(s) connection length

Reports can be retrieved as a single zip file of all reports or can be called individually

There are 4 API endpoints that can be called by external systems

1 OAuth Authentication	• Log in and receive authentication token • Use this token for all communication with other endpoints (e.g. submit plan)
2 Submit Plan	• Used to submit a plan to Arrow system
3 List of Available Reports	• Returns a list of reports and the way to call them • Set up as a dynamic list of reports, which allows for easy addition and modification of existing reports, as needed
4 Retrieve Individual Report	• Called to fetch individual report • Report format can be specified (e.g. csv, json)

? *Details on the following pages*

❶ "OAuth" endpoint is used to log in and receive authentication token required to interact with all other Arrow endpoints

OAuth Authentication

Name of your Arrow instance

Request Command

POST https://<app name>.aro.altvil.com/oauth/token

CURL curl localhost:8000/oauth/token -X POST -H "Content-Type: application/x-www-form-urlencoded" –d

Required keys / parameters :

- username
- password
- client_id
- client_secret
- grant_type

Credentials provided by Arrow team

Example:

https://demo.aro.altvil.com/oauth/token?username=demo_api&password=;a7Z,/tL%<ta88"n&client_id=demo&client_secret=842G~_YTr8kpW&grant_type=password

curl localhost:8000/oauth/token -X POST -H "Content-Type: application/x-www-form-urlencoded" -d grant_type=password -d client_id=demo -d client_secret=";a7Z,/tL%<ta88"n" -d username=demo_api -d password=password

JSON Response

```
{
   "access_token": "eyJ...ig4",
   "token_type": "bearer",
   "refresh_token": "eyJ...n9M",
   "expires_in": 43199,
   "scope": "openid read",
   "jti": "0dc13440-50ea-40df-82f8-7fe498a39d6d"
}
```

"access_token" value is needed to authenticate with other endpoints

Token is valid for 12 hrs., and can be refreshed using "refresh_token" (grant_type=refresh_token in POST command)

❷ "Process" v1 endpoint is used to define and submit basic RFP plan to Arrow

Submit RFP v1 Plan

Request Command

POST https://<app name>.aro.altvil.com/api-ext/rfp/v1/process

CURL curl http://localhost:8000/api-ext/rfp/v1/process -X POST -H "Content-Type: application/json" -H "Authorization: Bearer {BearerToken}" -d '{requestJSON}'

Authorization:
BearerToken

Value of "access_token" returned by OAuth endpoint

Request Body (JSON):

Unique plan name

Available options:
- ROUTE_FROM_FIBER
- ROUTE_FROM_NODES

```
{
"rfpId" : "Sample Plan",
"fiberRoutingMode":"ROUTE_FROM_FIBER",
"targets":[
        {"id":"target 1","longitude":-100.356068,"latitude":25.761247},
        {"id":"target 2","longitude":-122.2876577586806,"latitude":47.623841305540914}]
}
```

List of target locations (id, latitude, longitude); can be expanded as needed

JSON Response

```
{
  "planId": 3211,
  "planName": "sample rfp a4e82abc-48ca-4fcb-9aed-0654c52bd28a",
  "status": "OK"
}
```

System-generated plan id to reference when calling report endpoints

❷ "Process" v2 endpoint is used to define and submit Direct Routing-type plans to Arrow

Submit RFP v2 Plan

Request Command

POST https://<app name>.aro.altvil.com/api-ext/rfp/v2/process

CURL curl http://localhost:8000/api-ext/rfp/v2/process -X POST -H "Content-Type: application/json" -H "Authorization: Bearer {BearerToken}" -d '{requestJSON}'

Authorization:
BearerToken

Value of "access_token" returned by OAuth endpoint

Request Body (JSON):

```
{
"rfpId" : "Sample Plan",
"routingMode":"DIRECT_ROUTING",
"rfpProjectName": "v2_template",
"targets":[
        {"id":"target 1","longitude":-100.356068,"latitude":25.761247},
        {"id":"target 2","longitude":-122.2876577586806,"latitude":47.623841305540914}]
}
```

Unique plan name

Available options:
- DIRECT_ROUTING
- P2P

Project name to use for this request (stores info about data layers and resource managers to use in the plan)

List of target locations (id, latitude, longitude); can be expanded as needed

JSON Response

```
{   "planIds": [ 23199 ],
    "rfpId": "test v3",
    "status": "COMPLETED",
    "request": {"rfpProjectName": "v2_template",  "analysisStrategy": "AUTO_ANALYSIS_AREA",  "fiberRoutingMode":
            "ROUTE_FROM_FIBER", "routingMode": "DIRECT_ROUTING", "rfpId": "test v3", "targets": [ { "latitude": "47.450329", "id":
            "14296258", "longitude": "-122.445911" } ]  }
}
```

System-generated plan id to reference when calling report endpoints

Confirmation of settings used for this plan

❸ "Report-definition" endpoint returns a dynamic list of available reports and the way to call them

List of Available Reports

Request Command

GET https://<app name>.aro.altvil.com/api-ext/rfp/v1/report-definition

CURL curl http://localhost:8000/api-ext/rfp/v1/report-definition -X GET -H "Authorization: Bearer {BearerToken}"

Authorization:
BearerToken

Value of "access_token" returned by OAuth endpoint

JSON Response

```
[   {
      "reportData": {
         "id": 31,
         "reportType": "RFP",
         "name": "rfp_output",
         "displayName": "RFP Output",
         "media_types": [
            "csv",
            "json",
            "xls"
         ]
      },
      "href": "/api-ext/rfp/v1/{planId}/report/31.{mediaType}"
   },
   {
      "reportData": {
         "id": 34,
         "reportType": "RFP",
         "name": "RFP_KML",
         "displayName": "RFP KML",
         "media_types": [
            "kml"
         ]
      },
      "href": "/api-ext/rfp/v1/{planId}/report/34.{mediaType}"
   } ]
```

Report id to reference when retrieving individual reports

Report name

List of available download file formats / media types

URL to retrieve report:
{planId} = unique plan id from "Submit Plan" endpoint's response body
{mediaType} = eligible report file format, specific to the report

❹ "Report" endpoint is used to fetch individual reports, once the plan is processed

Retrieve Individual Reports

Request Command

GET https://<app name>.aro.altvil.com/api-ext/rfp/v1/{planId}/report/{id}.{mediaType}

CURL curl http://localhost:8000/api-ext/rfp/v1/{planId}/report/{id}.{mediaType} -X GET -H "Authorization: Bearer {BearerToken}"

Authorization:

BearerToken

Value of "access_token" returned by OAuth endpoint

Variables:

- {planId} – *Unique report id provided in plan submission response*
- {id} – *id identifying specific report, from report-definition endpoint response*
- {mediaType} – *file extension code from list of available media types associated with given report*

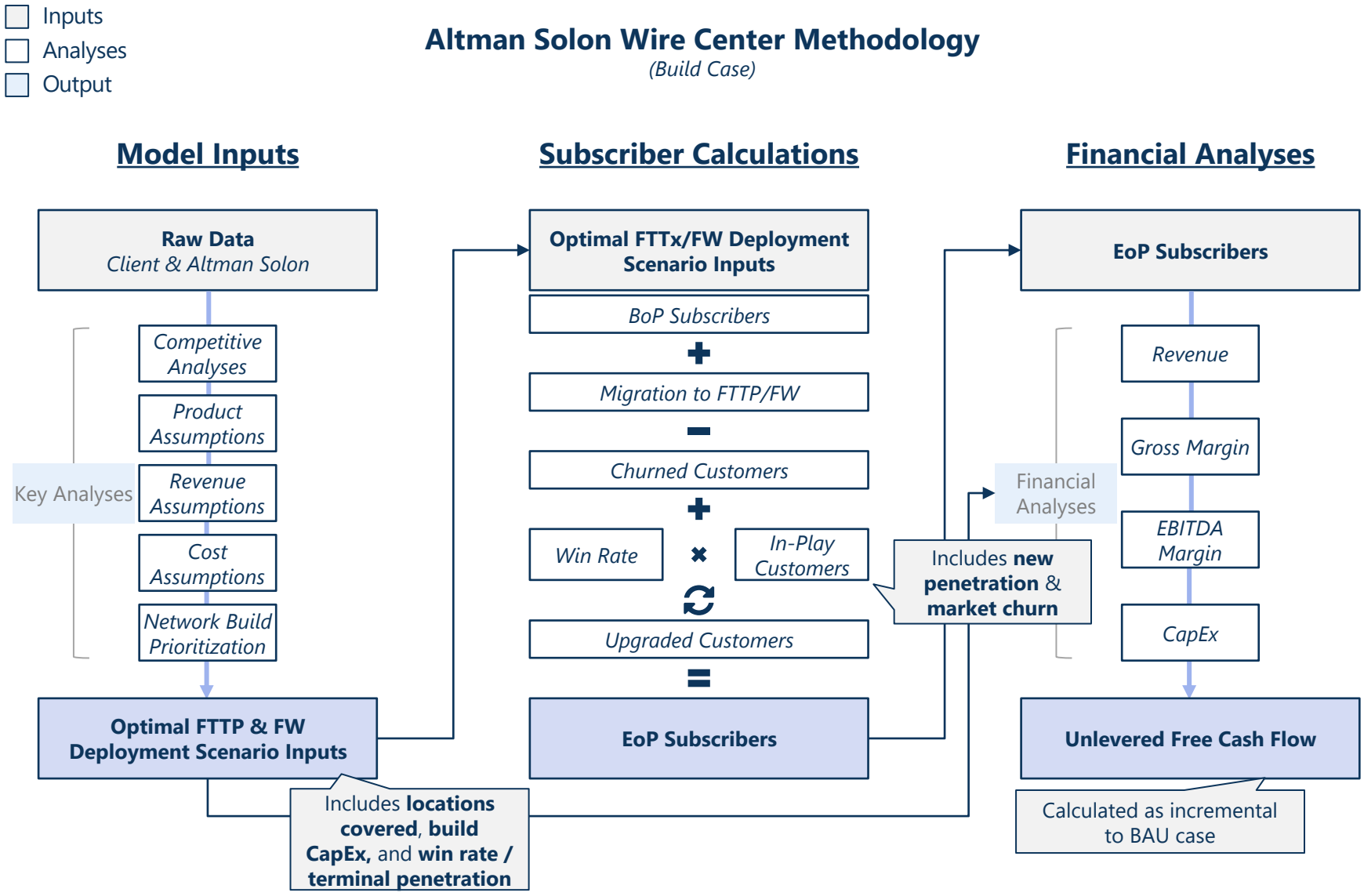
Example: https://demo.aro.altvil.com/api-ext/rfp/v1/3211/report/31.csv

Response

"location_id","link_status","length_meters","segment_guid","segment_name","fiber_source"
"target 2","not connected","0.0","NA","NA",""
"target 1","connected","4675.427178876296","NA","NA","Red Alestra"

Response data structure / layout depends on the media type selected for the report, e.g. csv

Each wire center is run through a detailed annual forecast, with key inputs & data provided by both Altman Solon & clients



Wireless node placement software uses the following methodology

1

Determine Set of Potential Site Locations

Potential site types consist of:

- *Existing structures*
- *Existing client sites*
- *New sites*

Each site type has different costs associated with it

2

Estimate Rate Reach Curves for Potential Sites

NASA has 30m x 30m data on:

- *Foliage density*
- *Clutter density*

Based on this data, Arrow can estimate impedance near site and **calculate a rate reach boundary***

3

Optimally Place Nodes for 100% Coverage

Begin by placing nodes in lowest capex/prem-passed locations, based on:

- *Coverage (# of households)*
- *Costs (site type)*

Continue placing nodes until 100% coverage for geography is reached

4

Forecast Detailed Cash Flow for All Nodes

Calculate detailed cash flow for each of the sites placed in step 3 based on:

- *Site CapEx (site type, morphology)*
- *Penetration (competition)*
- *Incremental CPGA*
- *ARPU*
- *CCPU*
- *Sub lifetime*

5

Route Fiber and Prune Low IRR Nodes

Route fiber to all nodes in the 100% coverage placement

Leverage pruning engine to **sequentially remove nodes until IRR or budget constraint is met**

- *Decision to prune is based on capex of fiber as well as detailed cash flow projections from previous step*

6

Calculate Overall Scenario Financials

Calculate scenario financials for pruned scenario incorporating:

- *Site CapEx*
- *Fiber CapEx (or OpEx)*
- *Subscriber Revenue, OpEx*
- *Cash Flow*

*Not intended to replace detailed RF designs but highly effective to accelerate planning purposes

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