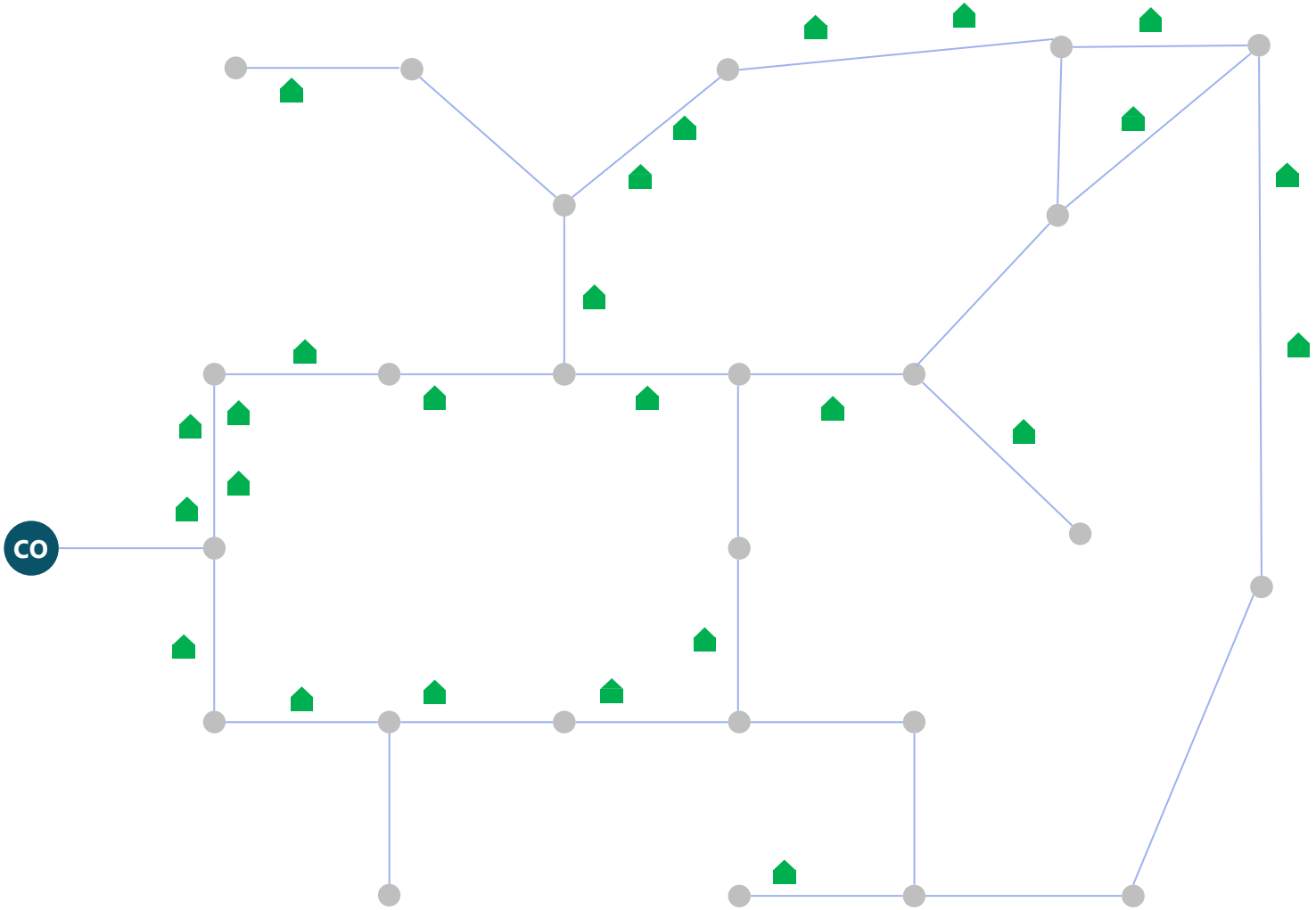
# Arrow Platform

## Routing and Pruning Algorithms

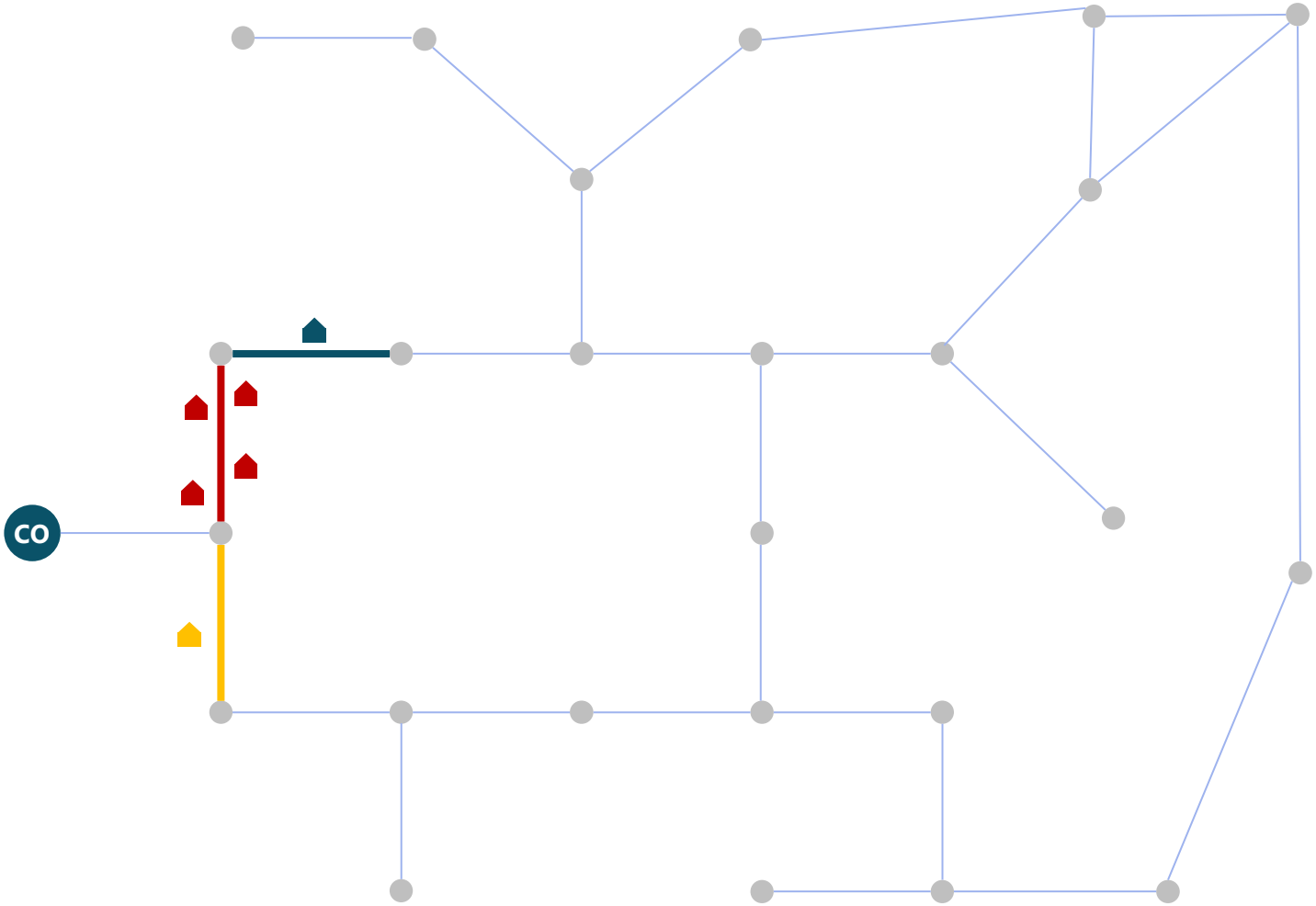
# All network optimizations undertake the same major steps, with inputs at each step varying depending on what the user is solving for

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| **Graph Reduction** | **Equipment Placement** | **Initial Network Generation** | **Pruning** | **Final Network Generation** |
| **Map locations** to road edges<br><br>**Remove unnecessary road segments** (reduce the graph) | **Build initial path towards CO** (create directed graph)<br><br>**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<br><br>Determine which pruning step **satisfies optimization criteria**<br><br>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



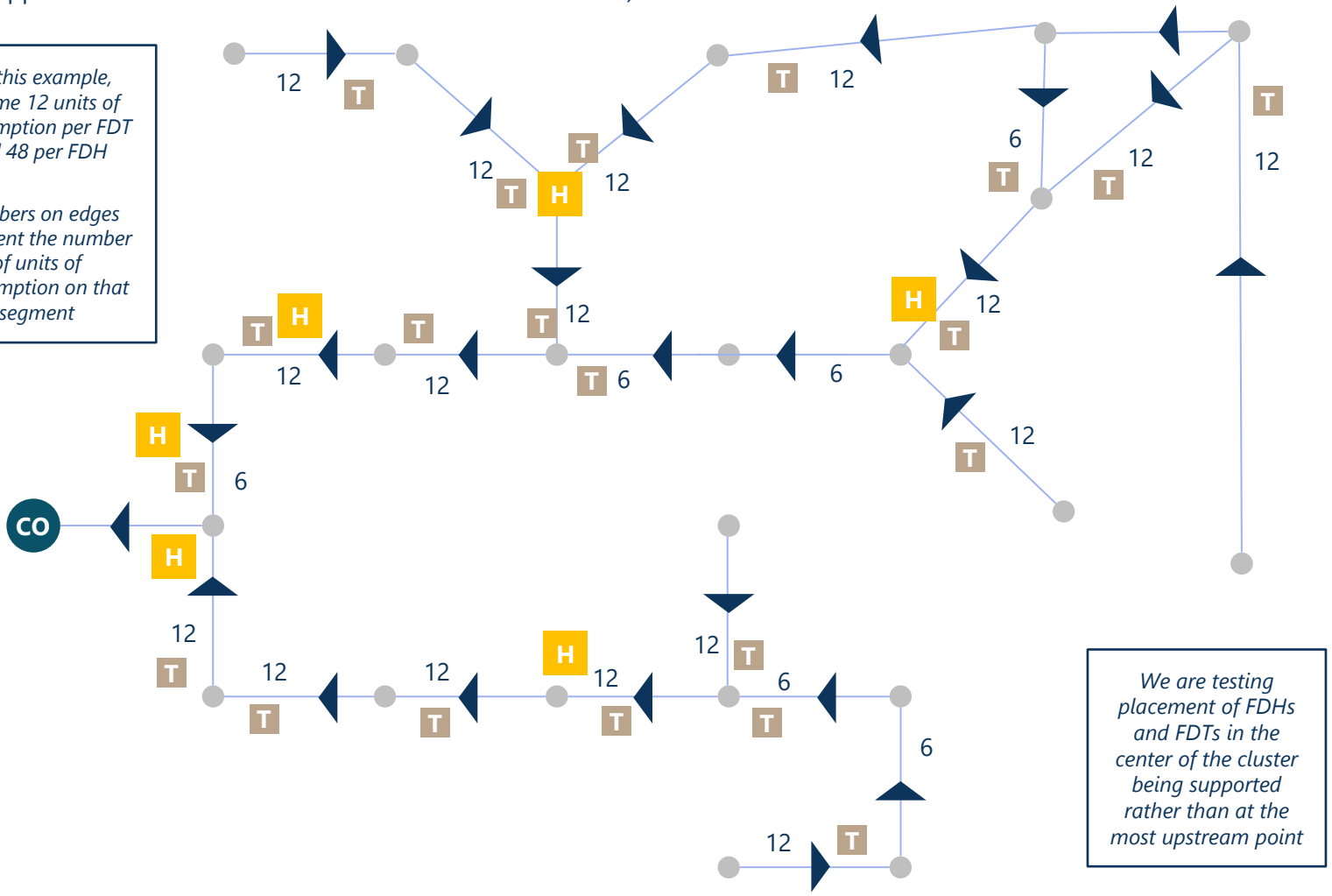
1. Map all locations to the nearest road segment
2. Record the point where the location maps to the road, and the corresponding distance between road edge and the location



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)

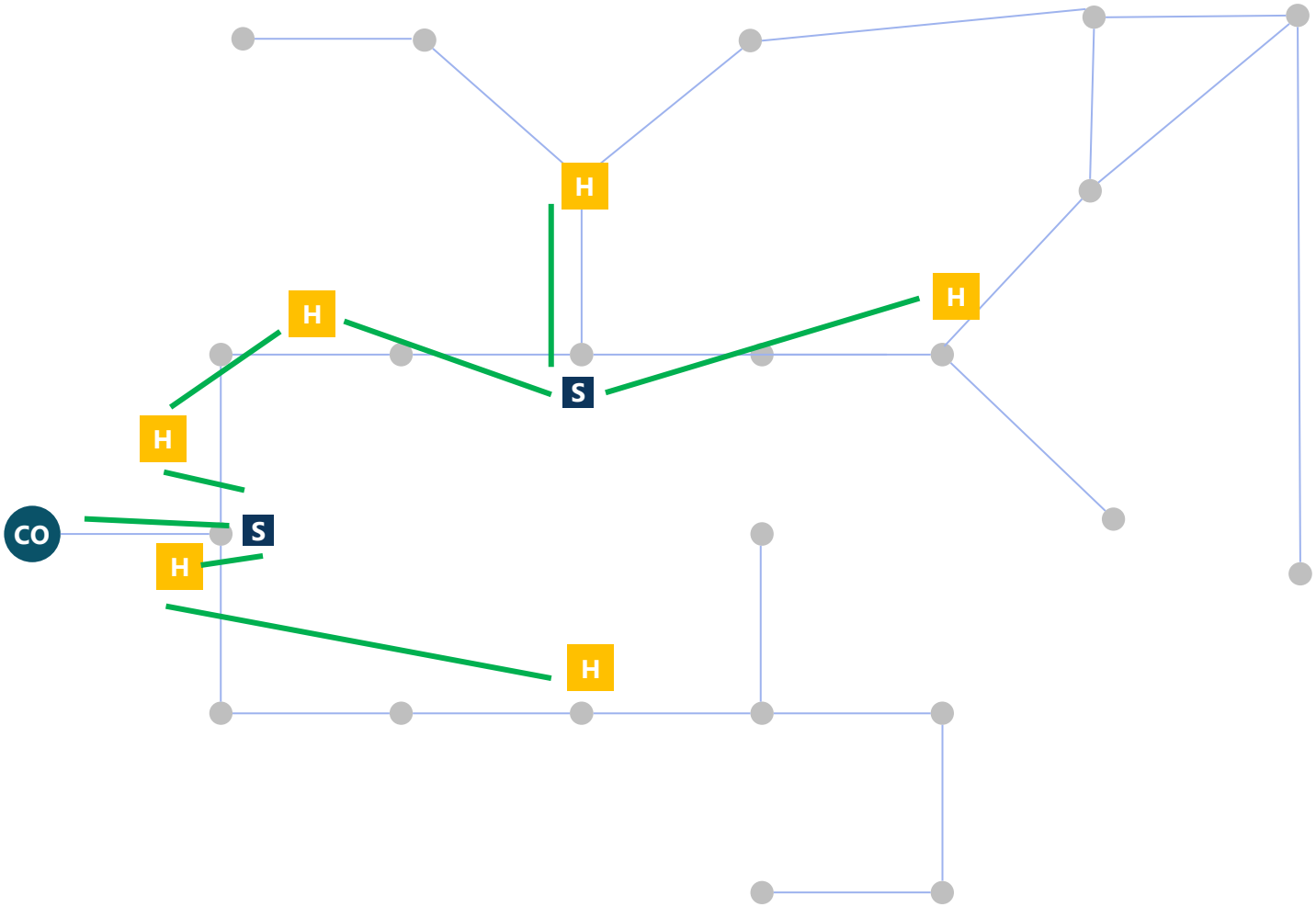
*For this example, assume 12 units of consumption per FDT and 48 per FDH*

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

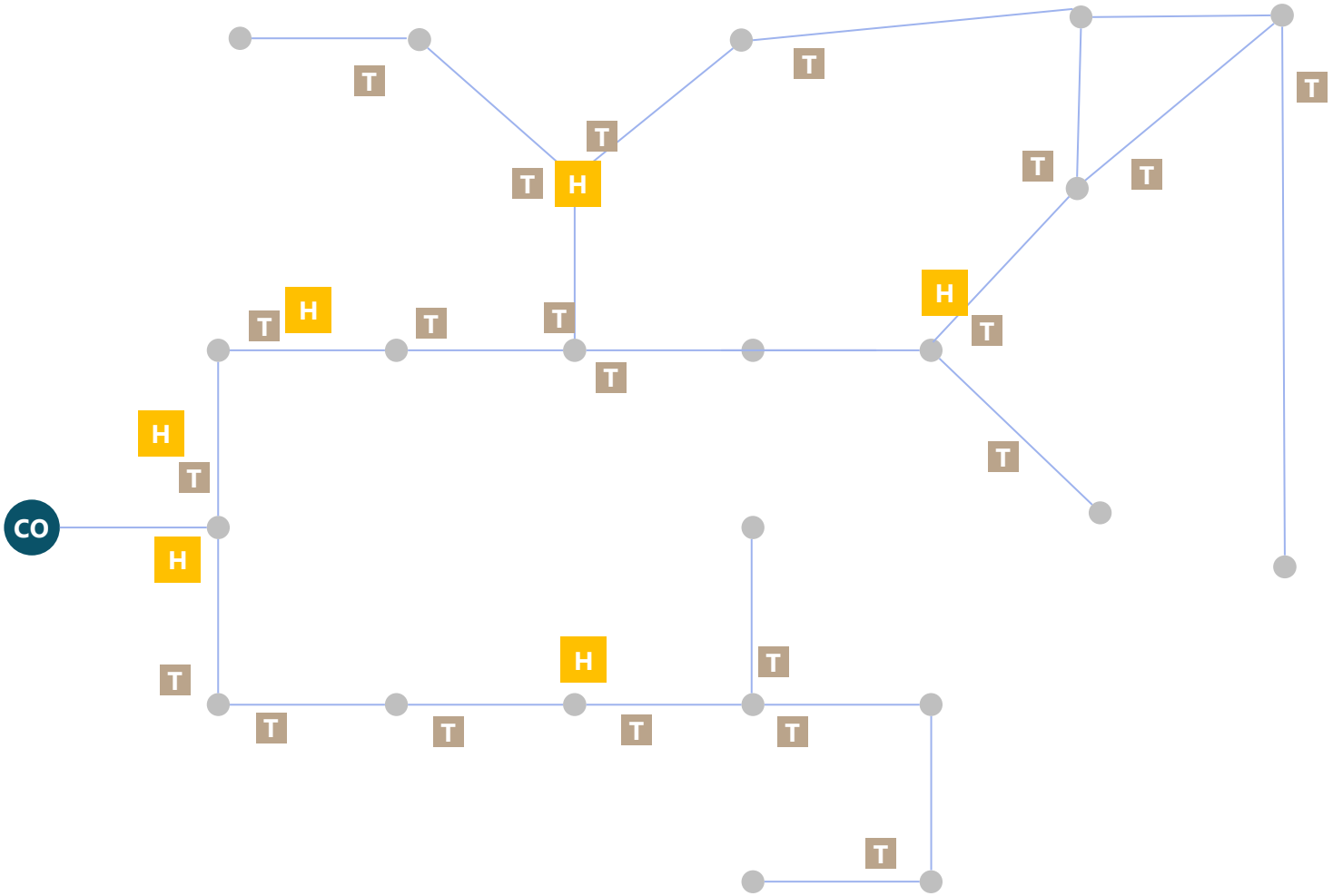


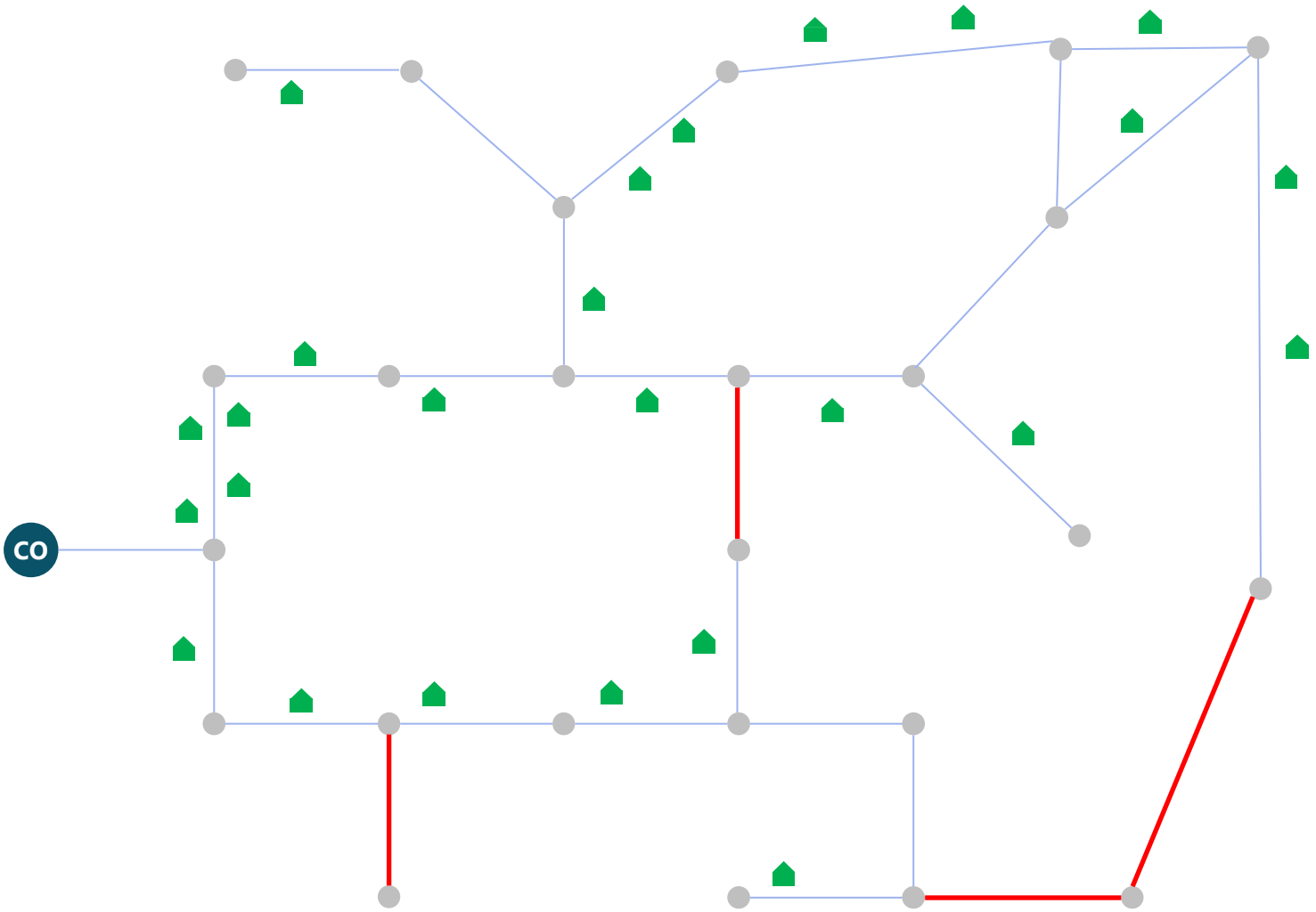

*We are testing placement of FDHs and FDTs in the center of the cluster being supported rather than at the most upstream point*

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

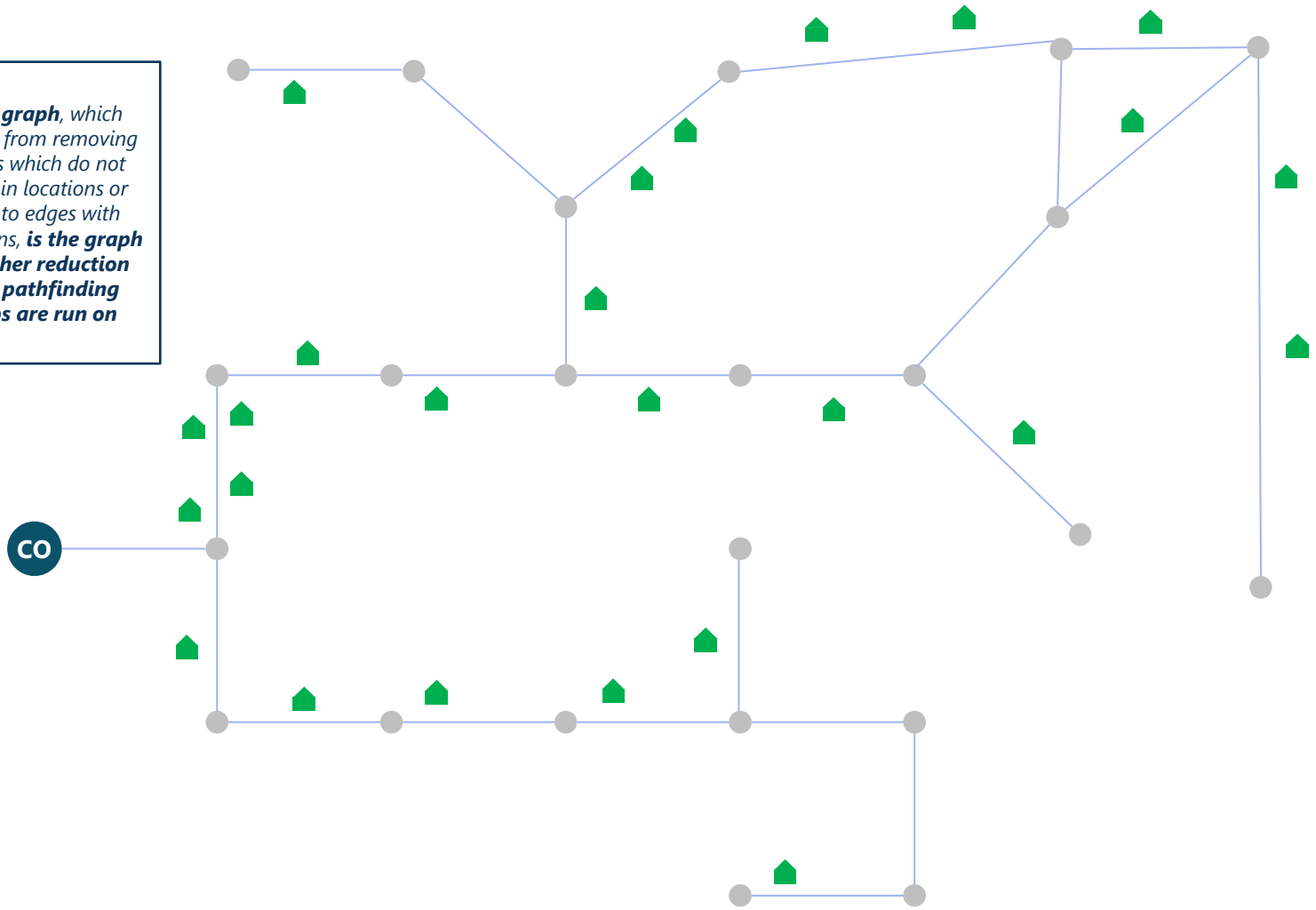


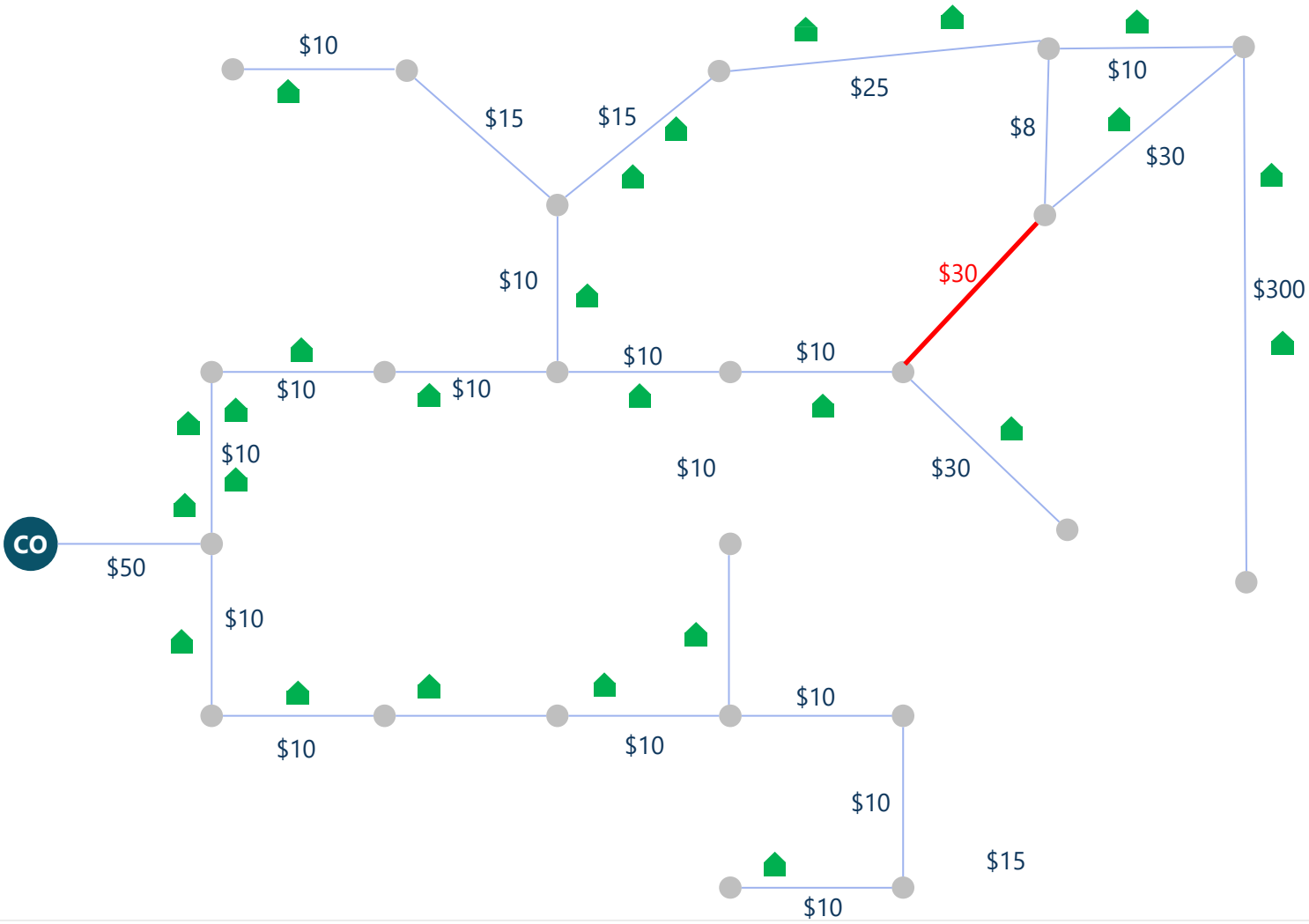
1. Similar to feeder fiber, distribution fiber is placed to link FDTs within the same FDH to minimize distance
2. Splice points are placed where needed




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***

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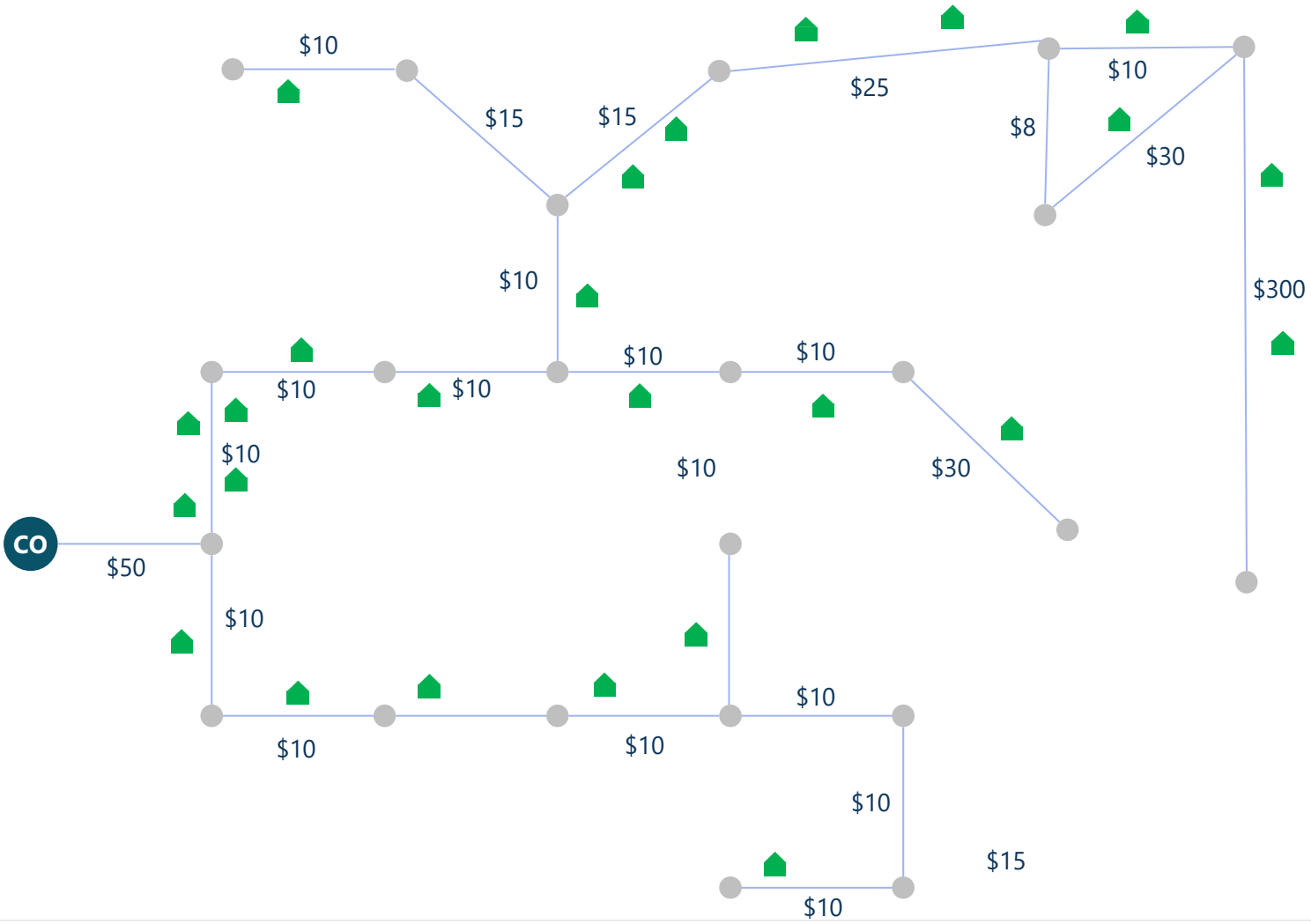
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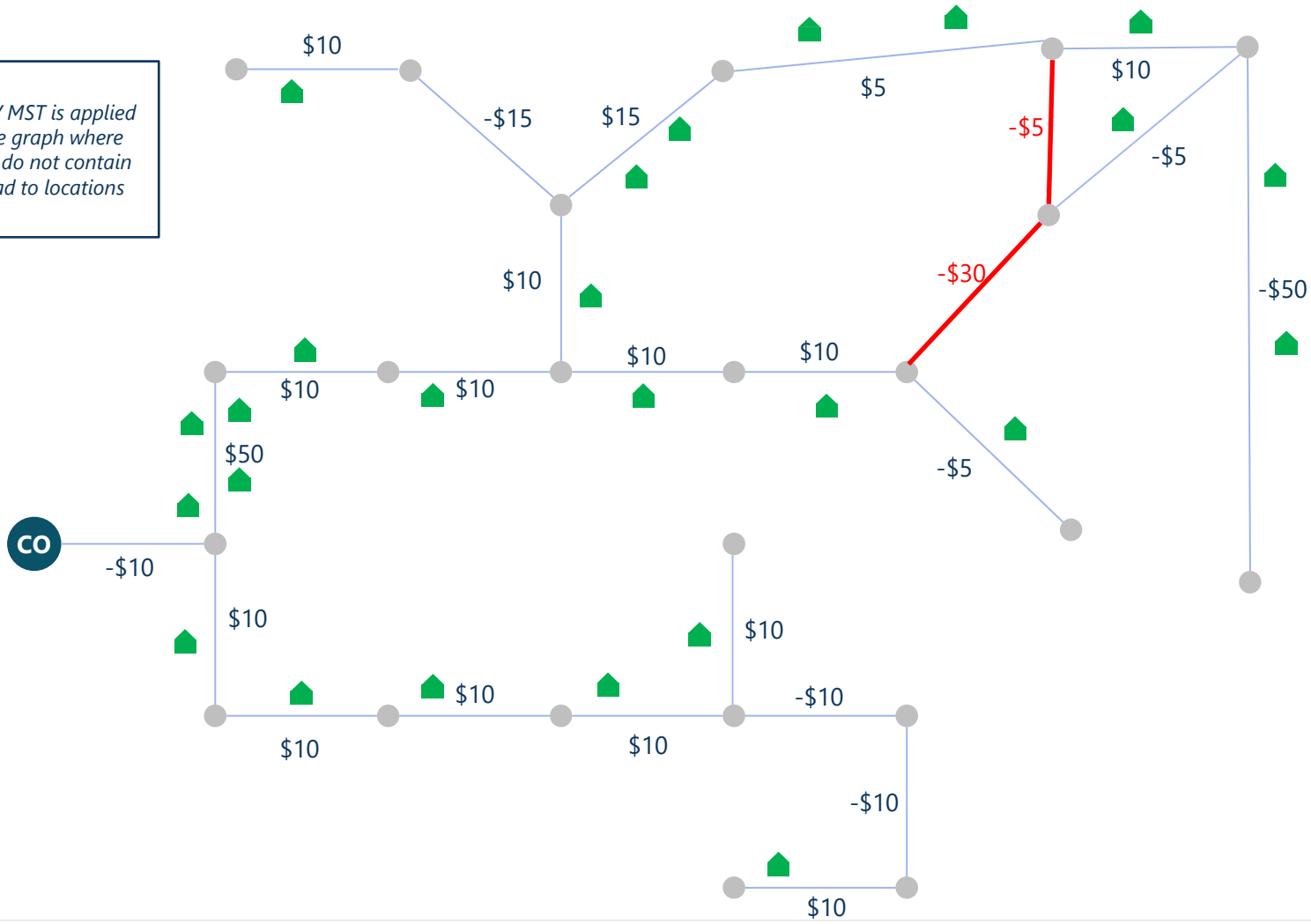
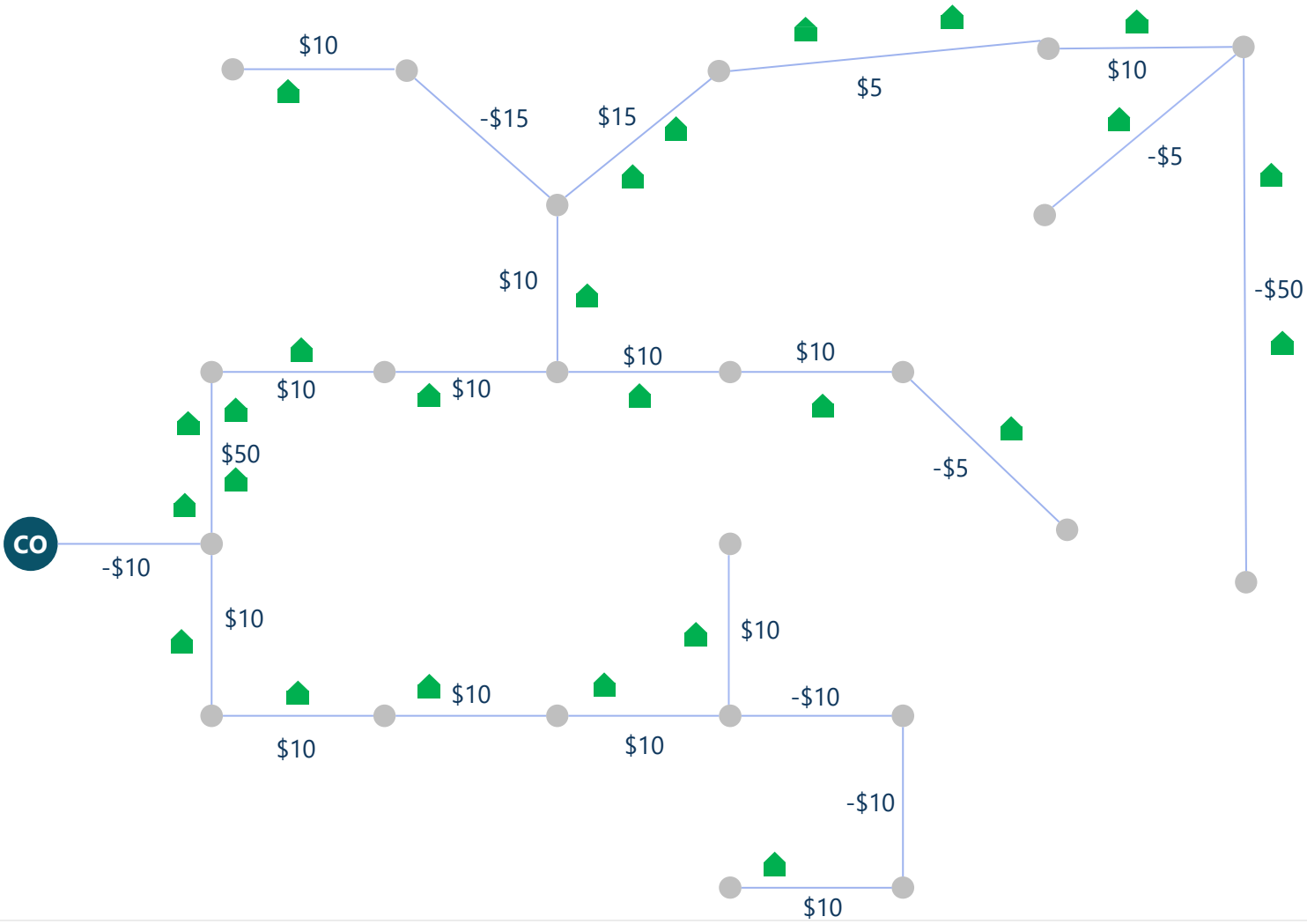
[50, 15…15, 10…10, -10..-10, -15…-15, -30, -50, -200]

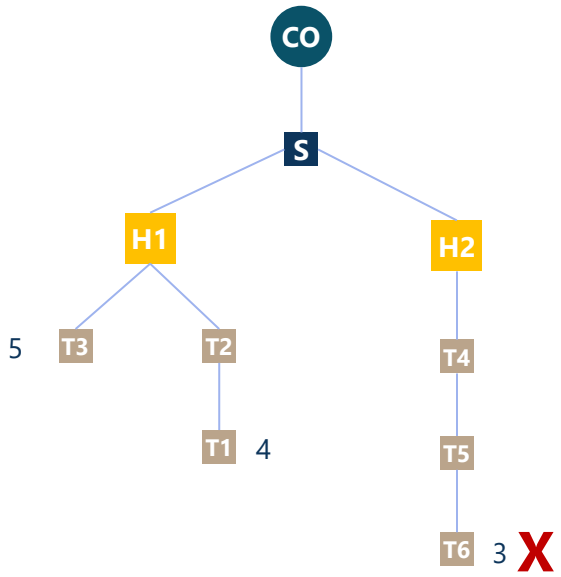
*1/NPV MST is applied to the graph where edges do not contain or lead to locations*



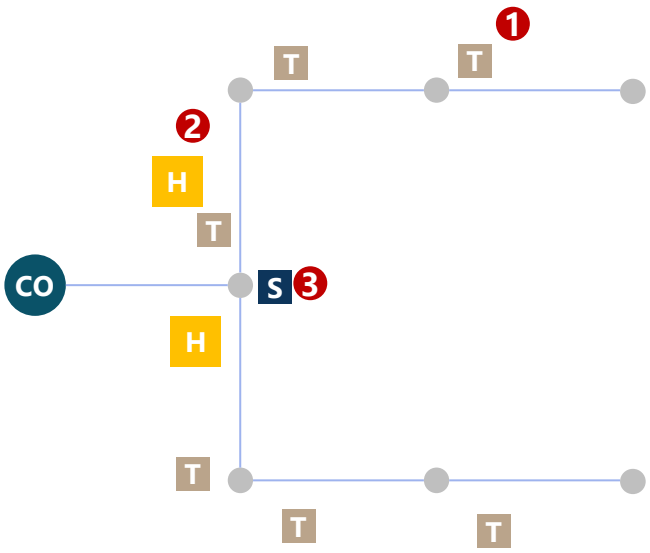
[50, 15…15, 10…10, -10..-10, -15…-15, -30, -50, -200]



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)



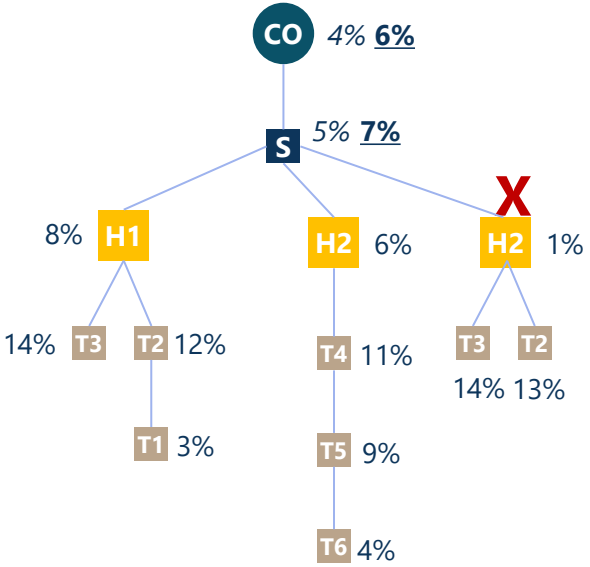
1. Calculate the marginal IRR of each equipment node in the wirecenter
2. Marginal CapEx for the equipment is the marginal cost for connecting and placing that piece of equipment
3. Downstream cash flow for the equipment is the revenue and cost of all the downstream entities



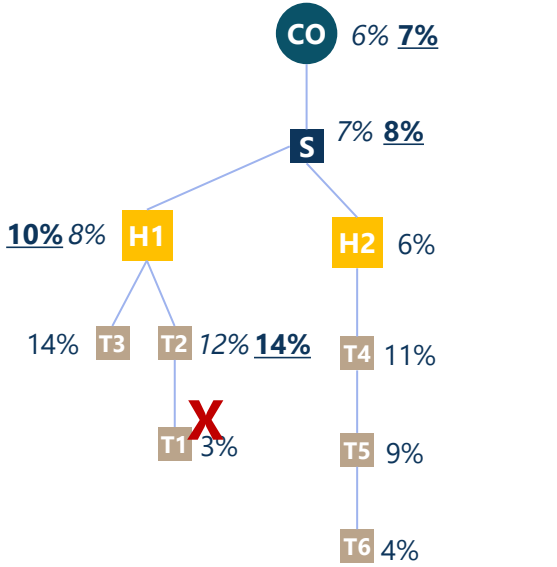

| | Marginal CapEx | Downstream Cash Flow |
|---|---|---|
| 1 T | • *Cost of placing additional fiber to reach this FDT from the FDT upstream*<br>• *Cost of FDT equipment* | • *All downstream entity cash flows (connect CapEx, revenue and costs)* |
| 2 H | • *Cost of placing additional fiber to reach the FDH*<br>• *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*<br>• *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

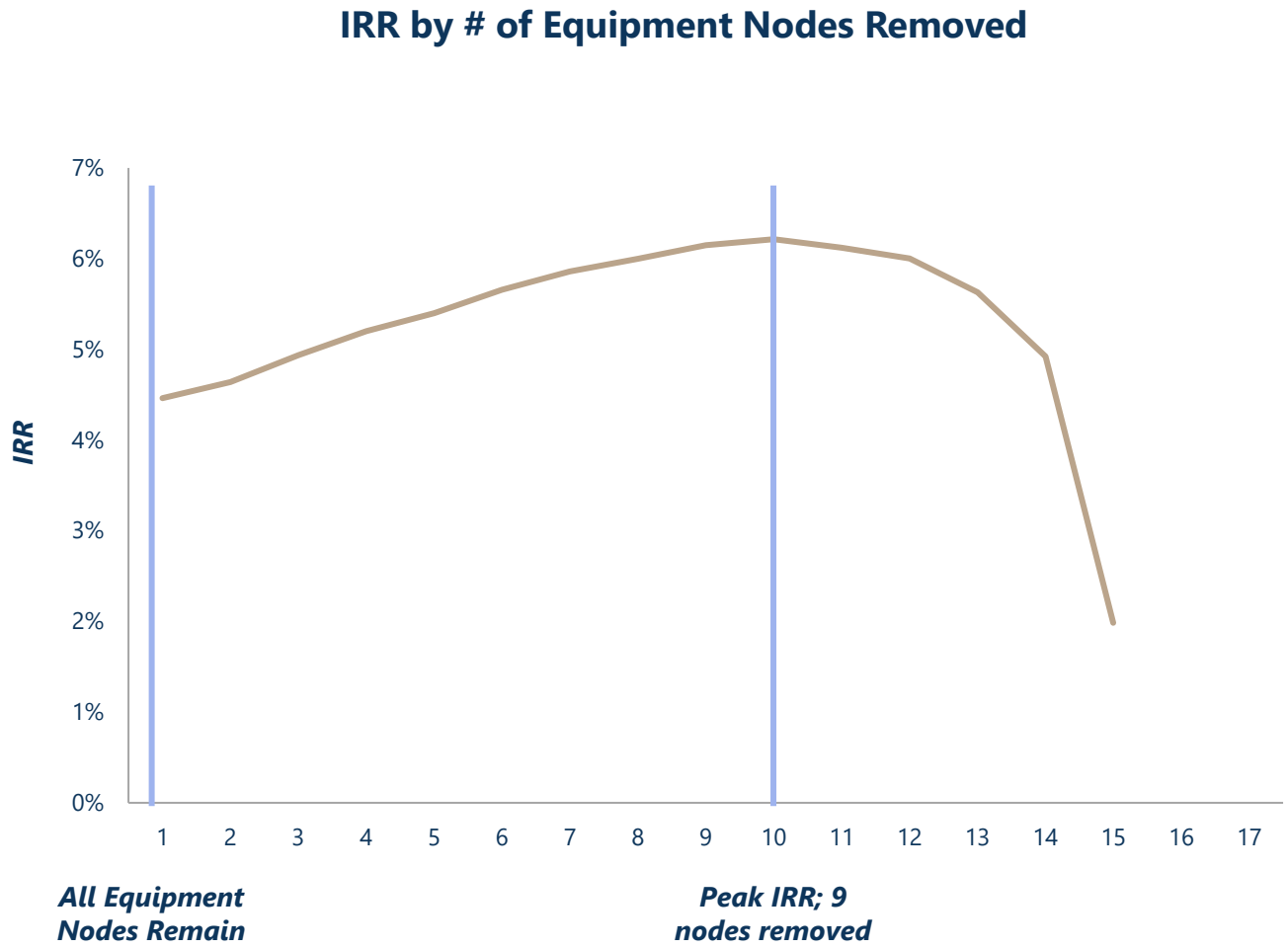
**Remove lowest-IRR equipment node and re-calculate affected nodes' IRRs**



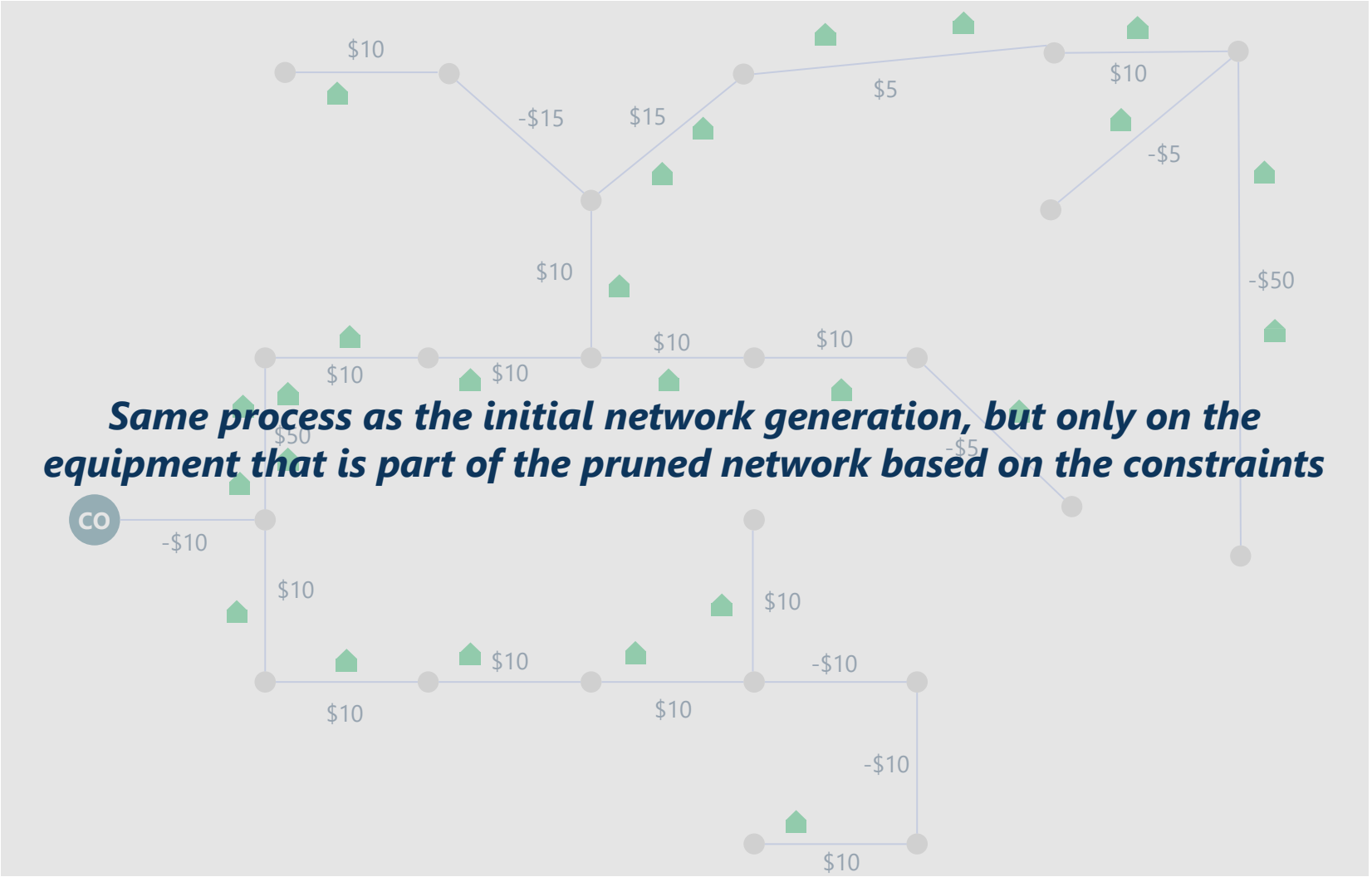

**Repeat until system-wide IRR has peaked (next removal decreases IRR)**



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***