CostMAP^{PRO}: Addressing the CO2 Transport and Pipeline Challenge

Carbon Solutions

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Introduction

To meet emissions targets for CO2, the US must capture 100's of millions of tons of CO2 each year. According to the Net Zero America study [1], this would require a massive infrastructure investment to develop more than 100,000 km of pipelines to transport CO2 from nearly 1000 emitting facilities to secure storage sites. **Transporting CO2 on this scale is a massive challenge**, heightened by the **scale** of infrastructure needed (100,000 km of pipeline), the **timing** of decarbonization goals (2035 for electricity generation and 2050 for net-zero emissions targets), and **sensitivity** of community concerns to building large scale pipeline projects.

To meet this challenge, Carbon Solutions LLC has developed ***CostMAP***^{PRO} : the next generation of the Cost Surface Multi-layer Aggregation Program (*CostMAP*) for identifying optimal, low-cost pipeline routes while assessing social, environmental, and community factors. **We present multiple case-studies highlighting the ability to develop pipeline routing networks while incorporating real-world concerns of developers, stakeholders, and community advocates,** showing how user inputs and project specific concerns impact the optimal routes and cost.

Methods

CostMAP^{PRO} is based in Least Cost Path (LCP) analysis and weights for LCP algorithms. Weights are first developed from accumulated data layers such as land cover, topography, and population. Next, a stepwise process computes the cost of moving from cell to cell, calculated as the average cost of the corresponding nodes normalized by the distance needed to travel between nodes. CostMAP generates both a cost network which estimates the cost of construction for a pipeline and a routing network which is meant to incorporate social and environmental concerns in addition to economic costs. A more detailed accounting of the function of *CostMAP*^{PRO} can be found in Hoover et al. 2019 [2]. *CostMAP*^{pro} is used closely in conjuction with *SimCCS*^{PRO} to develop optimized pipeline networks. The process for generating these networks is summarized by the following steps:

1. Generate Routing and Cost Networks from *CostMAP*^{PRO}
2. Generate a Candidate Network of pipeline routes using Delaunay triangulation, *CostMAP's* routing network, and Dijkstra's algorithm to determine pipeline routing [3,4]
3. Trim the candidate network to only the cost-optimized pipeline routes based on the Cost Network and linear optimization performed in *SimCCS*^{PRO}

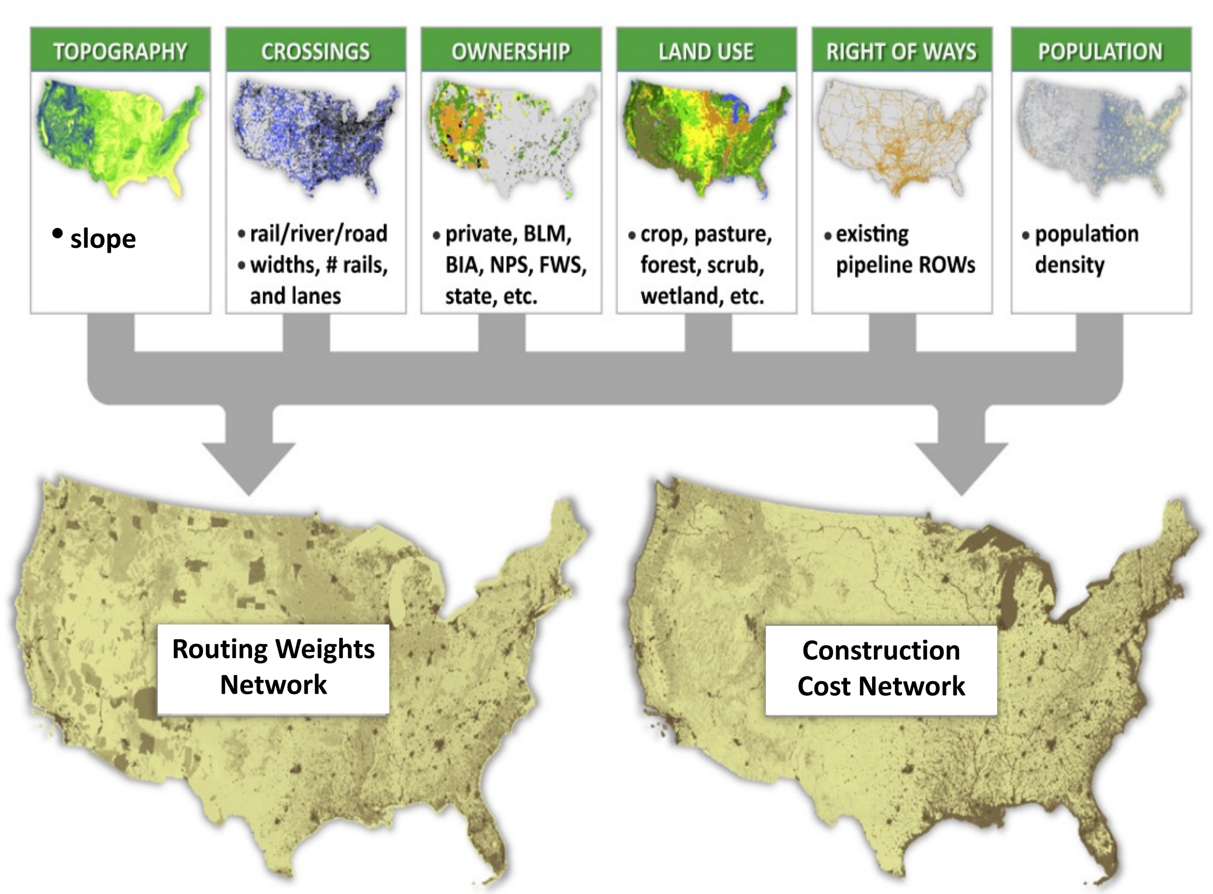


Figure 1: *CostMAP*^{PRO} ingests relevant geographic data and assigns both routing and cost weights to each layer to create separate routing and cost networks. Input data includes fully distributed data like landcover and topography as well as linear features including rivers, roads, and existing pipeline right of ways.

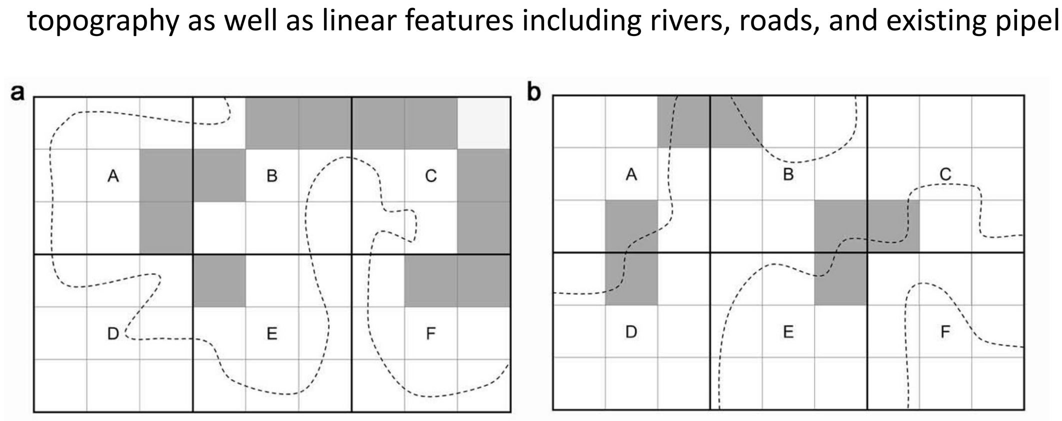


Figure 2: *CostMAP*^{PRO} incorporates both linear features that impede pipeline construction (i.e., rivers) as barriers (a), and linear features that might be desirable for pipeline routing (i.e., existing right of ways) as corridors (b).

Case Study: Midwest CCS Projects

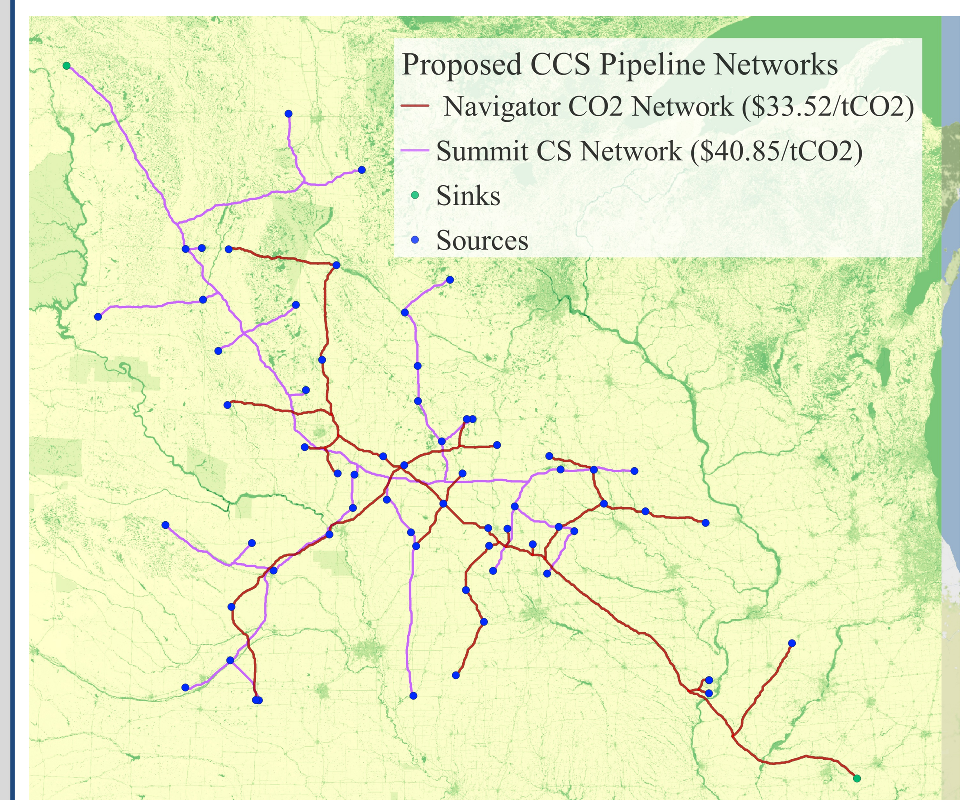


Figure 3 (above): Two Proposed pipeline networks in the U.S. Midwest recreated using *CostMAP*^{PRO} and *SimCCS*.

Current CCS pipeline proposals in the U.S. Midwest have received public criticism that threatens future development in the area. These projects are designed t o transport CO2 produced by ethanol plants in Iowa and surrounding states to geologic reservoirs located in Illinois and North Dakota. However, the planned pipeline routing and construction process has been met with public concern over safety, the use of eminent domain, loss of productive farmland, environmental concerns, and concerns over preserving cultural sights in the region.

We recreated two such proposed CCS pipeline networks using both *CostMAP*^{PRO} and *SimCCS* softwares. We then explore different routing scenarios by adjusting the routing weights used by *CostMAP*^{PRO}.

Figure 4 (below): The proposed Summit CCS Network with alternative routing scenarios created using *CostMAP*^{PRO}. Transportation costs are included in $/ton CO2.

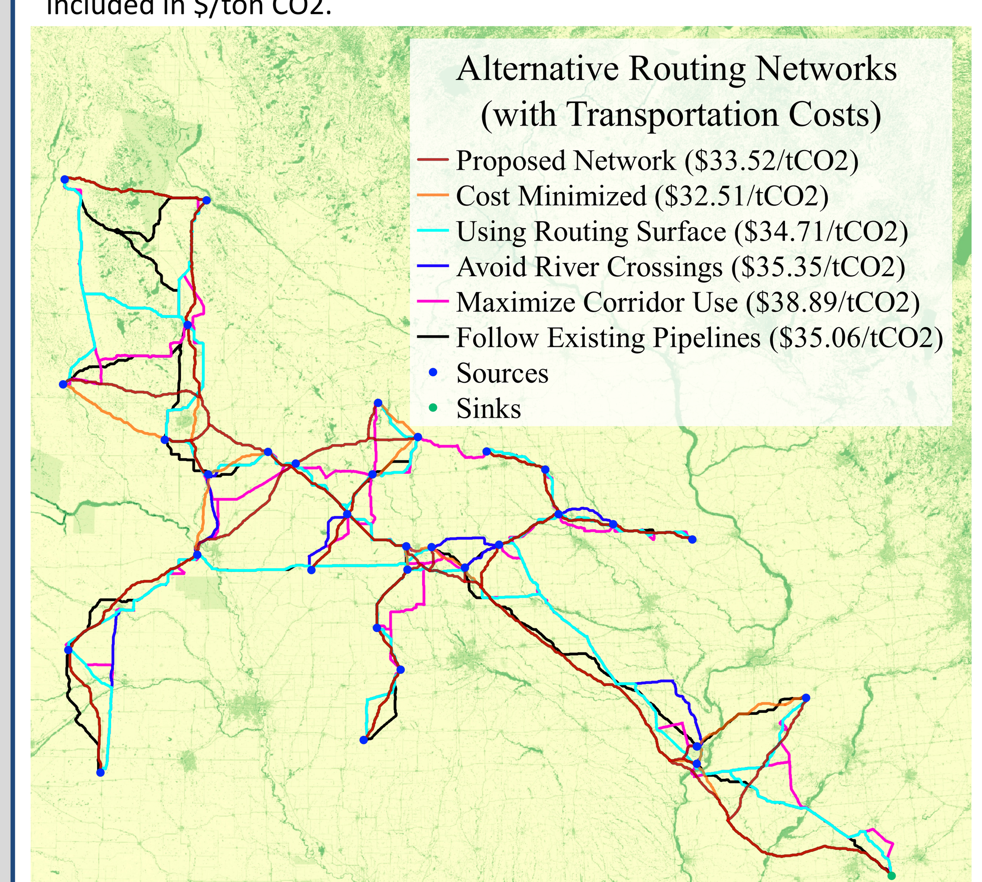
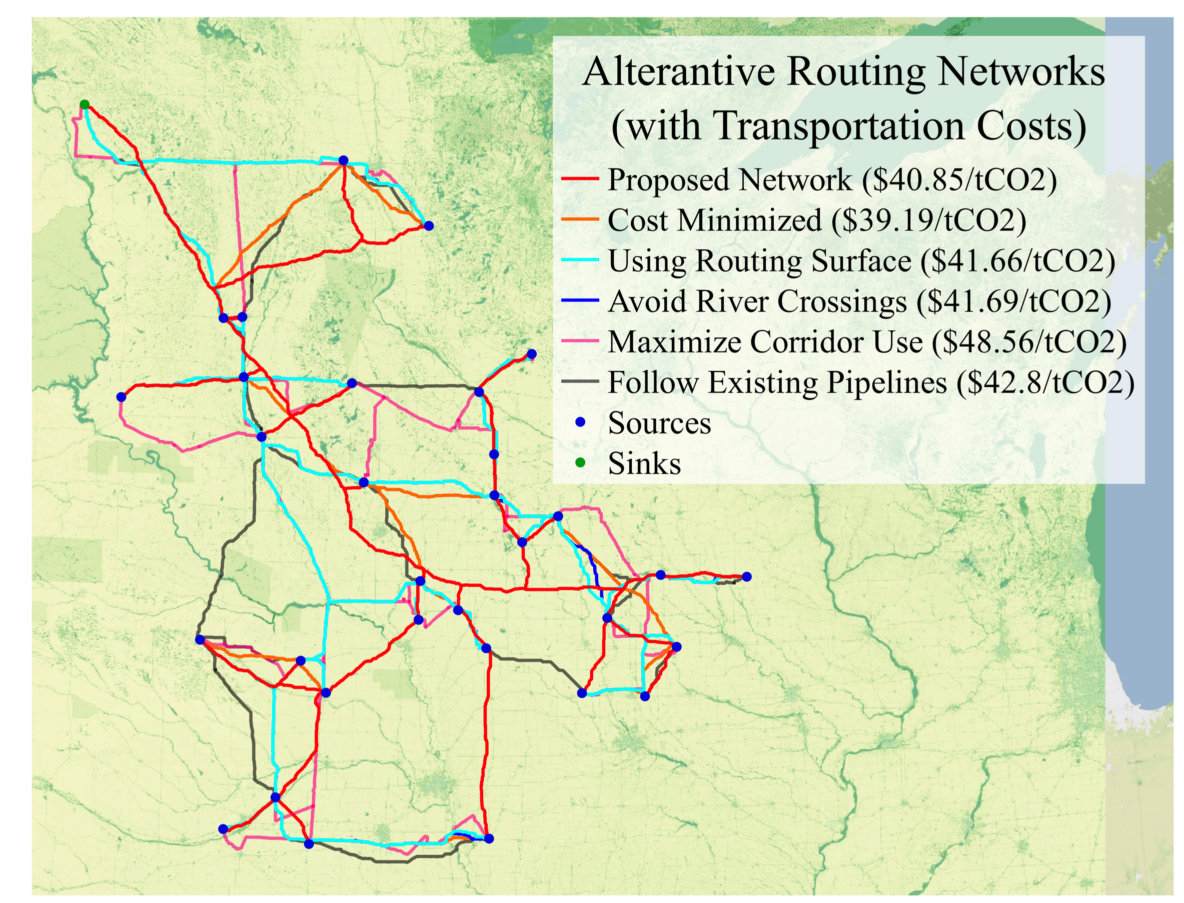


Figure 5 (below): The proposed Navigator CO2 CCS Network with alternative routing scenarios created using *CostMAP*^{PRO}. Transportation costs are included in $/ton CO2.



Cost of Pipeline Project $/ton CO2			
	Navigator	Summit	Combined
Proposed	$33.52	$40.85	36.67
Cost Minimized	$32.51	$39.19	$28.03
Using Routing Surface	$34.71	$41.66	$29.76
Existing Pipelines	$35.06	$42.80	NA
Maximum Corridors	$38.89	$48.56	NA
Avoid River Crossings	$35.35	$41.69	NA

Table 1 (above): Transport costs for each routing scenario and network

Miles of Pipeline			
	Navigator	Summit	Combined
Proposed	2821	3203	6024
Cost Minimized	2677	3076	4208
Using Routing Surface	3039	3466	4717
Existing Pipelines	2906	3484	NA
Maximum Corridors	3302	3794	NA
Avoid River Crossings	2986	3467	NA

Table 2 (above): Pipeline lengths for each routing scenario and network

- Alternative routing surface resulted in large changes to the network path with moderate changes to cost.
- Costs increased with greater deviations between cost and routing networks
- Both costs and pipeline length were drastically reduced by combining networks

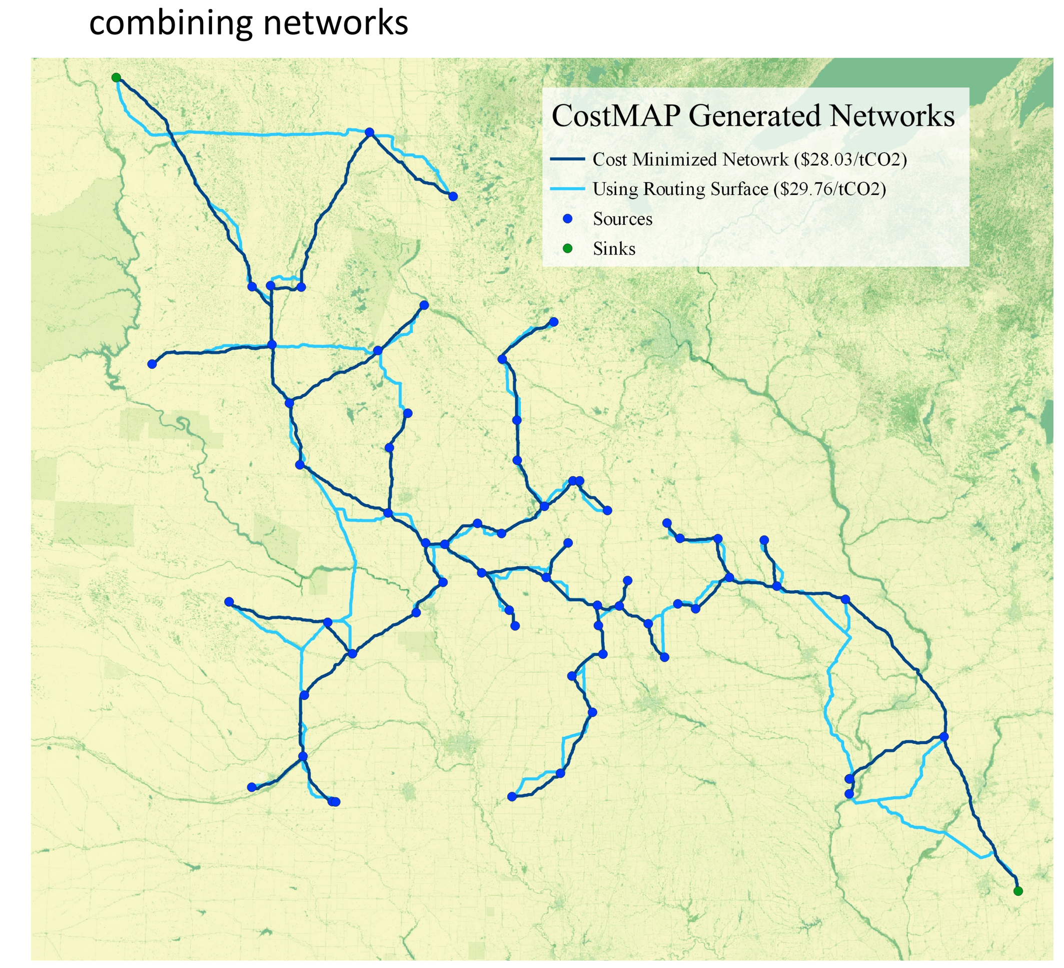


Figure 6 (above): Combined simulation using all proposed sources and sinks

Other Use Cases

Offshore Routing: Offshore storage is becoming an attractive option for CCS projects along the US Eastern Seaboard and the Gulf of Mexico. To account for additional routing concerns related to pipeline routing offshore, we include seafloor slope, marine protected areas, shipping lanes, anchorages, and security zones.

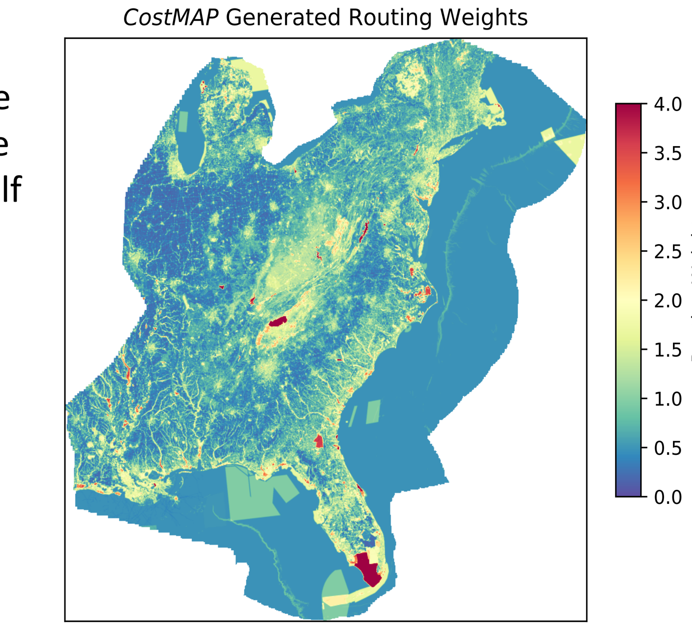


Figure 7 (above): CostMAP generated routing surface using offshore protected areas and slope data.

Social Impacts: Incorporating social concerns and benefits into pipeline projects is a high priority for minimizes development hurdles and ensuring an equitable energy transition. We utilize data from the Justice 40 initiative and the Climate and Economic Justice Screening Tool (CEJST) to incorporate social and economic concerns into our pipeline routing schemes.

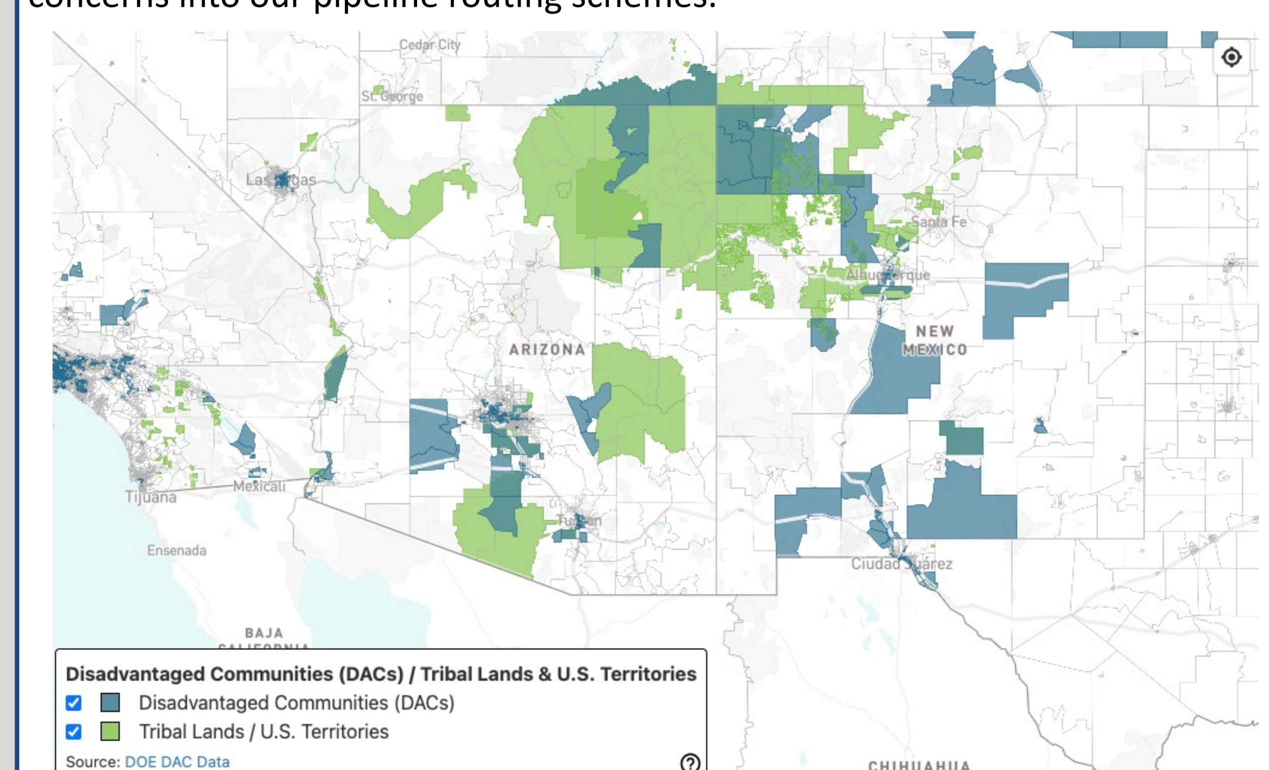


Figure 8 (above): Disadvantaged and tribal communities as defined by the Justice40 initiative dataset [5].

Parcel Boundaries: Land acquisition and negotiation is a major hurdle for pipeline corridor development. We've incorporated individual parcel boundary and cost data into our routing and cost network to ensure that costs are minimized, and developers can negotiate with the fewest possible number of landowners.

Existing Pipeline ROW's: *CostMAP* can use existing pipeline right of ways or can incorporate existing CCS pipelines with available capacity to explore routing options that maximize the use of existing infrastructure.

References & Additional Information

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[3]Middleton, R.S., Kuby, M.J., Bielicki, J.M., 2012. Generate candidate networks for optimization: The CO2 capture and storage optimization problem. Computers, Enivornment and Urban Systems, 36, 18-29. doi:10.1016/j.compenvurbsys.2011.08.002

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[5]S. Young, B. Mallory, and G. McCarthy. "The Path to Achieving Justice40." <https://whitehouse. gov/omb/briefing-room/2021/07/20/the-path-to-achievingjustice40>.