Roadmap for CO_2 Transport Fundamental Research Workshop
Dublin, Ohio February 2023

Multi-modal modeling for decarbonization scenarios and industrial decarbonization, CDR, and CO_2 conversion

Lawrence Livermore National Laboratory
Wenqin Li (li76@llnl.gov)
Corey Myers (myers79@llnl.gov)

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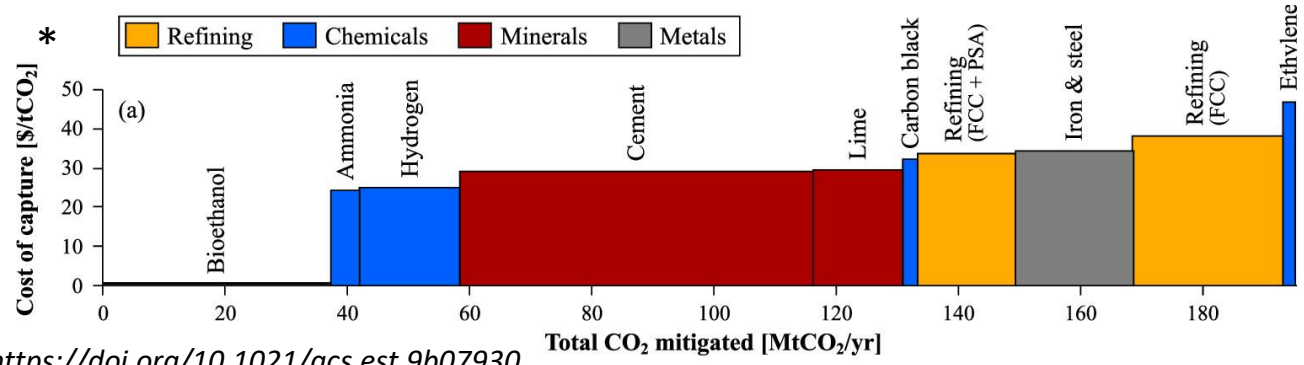
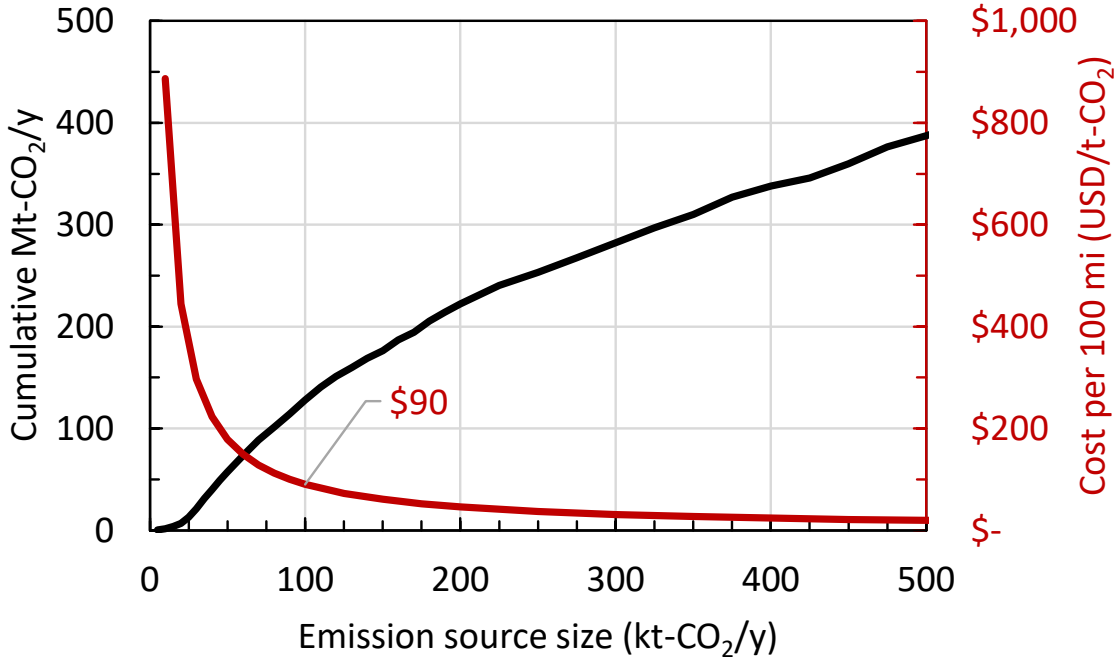
What is the use case and why should you care?

Schedule matching capture, transport, and storage is a significant project risk

- ~128 Mt-CO_2/y comes from <100 kt-CO_2/y sources (45Q is now available to these emitters)
- Many are low-cost capture opportunities



*https://doi.org/10.1021/acs.est.9b07930



- When pipeline transport is too costly →
  - smaller companies at financial disadvantage
  - more DAC deployment at a higher cost to society
  - additional valley of death for the nascent DAC industry

What modalities did we consider?

Transport via liquified CO_2 (LCO2) is established via truck, rail, and intermodal

Holubnyak and Quillinan (2022). Overview of Probable Market Regions: State Perspective. DOE FECM-CO2Freight Transport Workshop.

Truck

25t double jacketed, vacuum insulated tankers

Rail

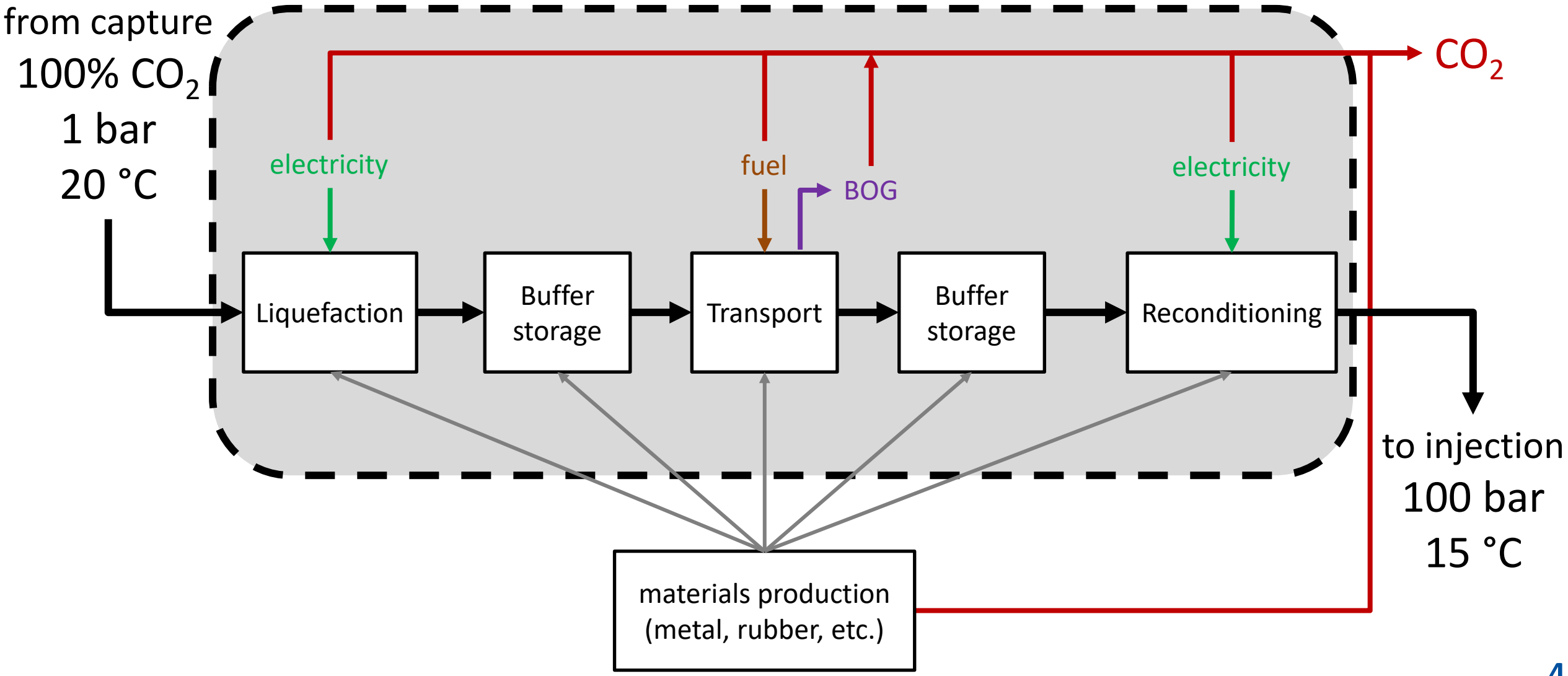
80t double jacketed, vacuum insulated tankers

ASCO product catalog, US Version 3.3

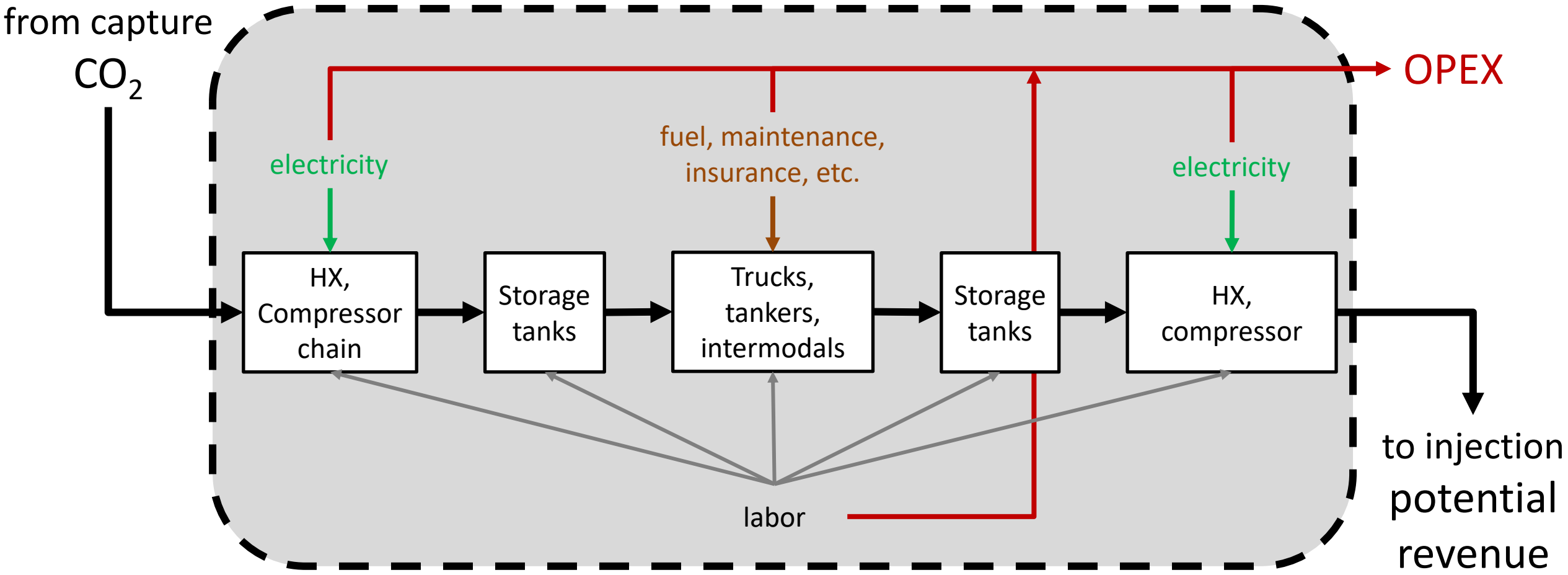
Intermodal

20t double jacketed, perlite insulated 20’ intermodals

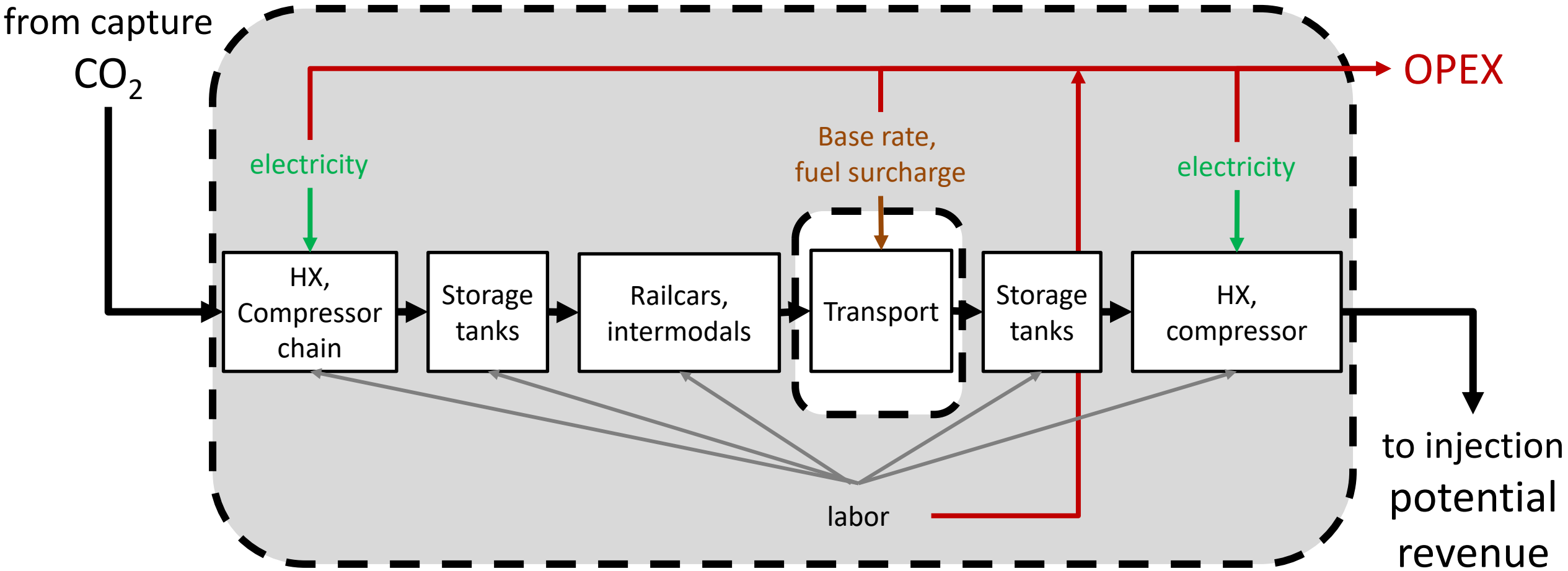
(Important) Minutiae



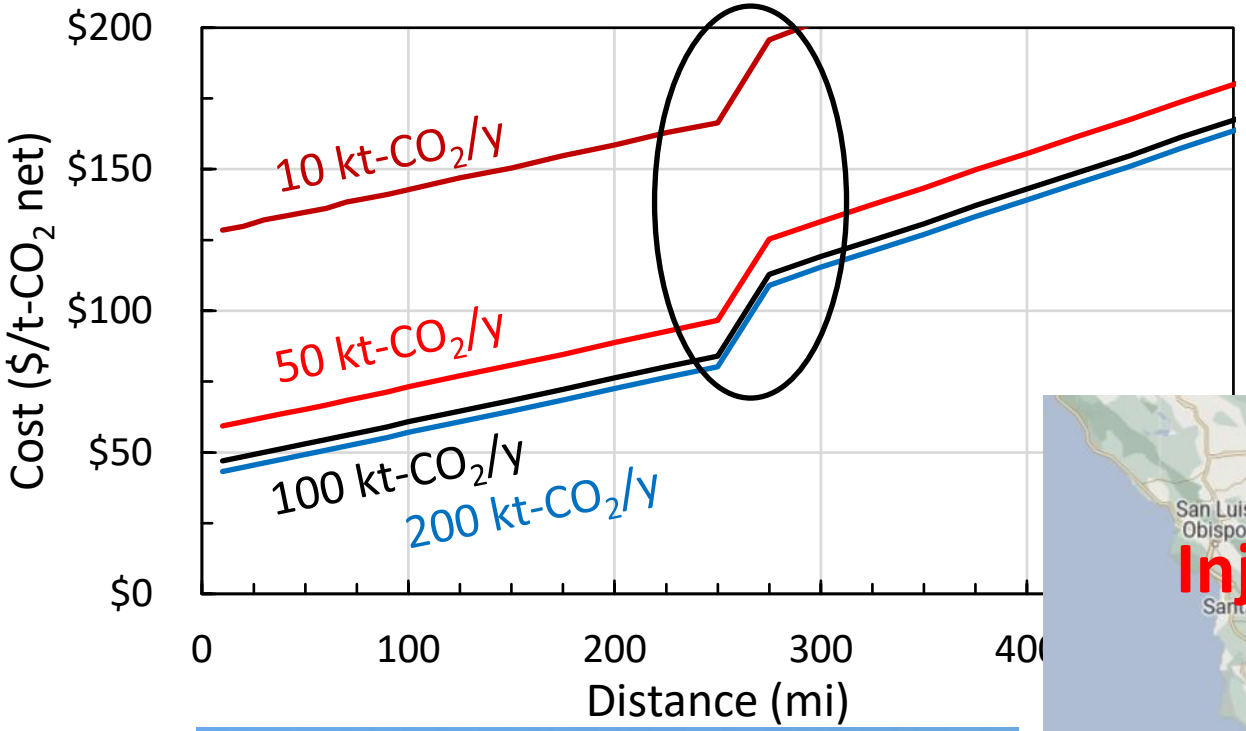
(Important) Minutiae Trucking



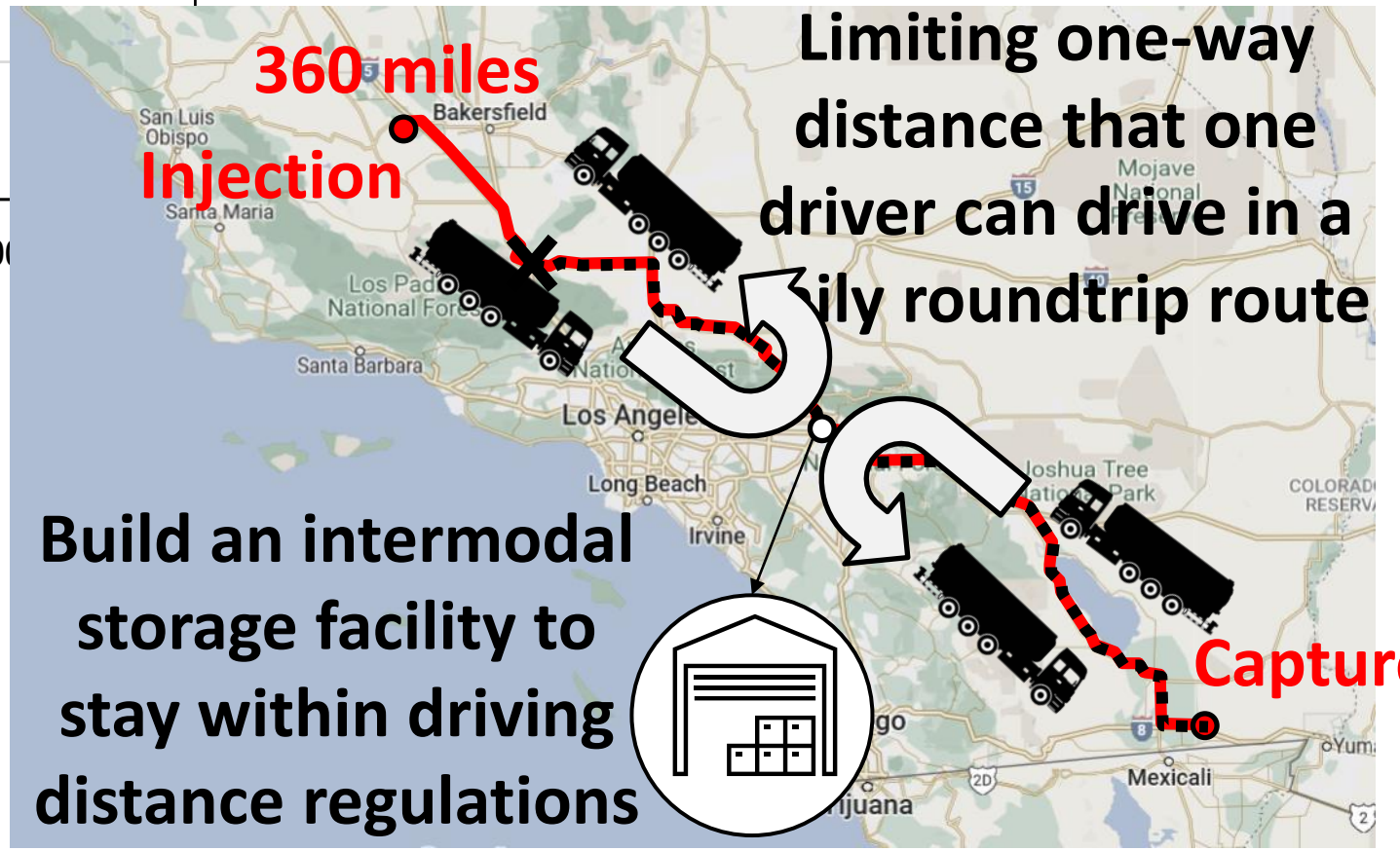
(Important) Minutiae Rail



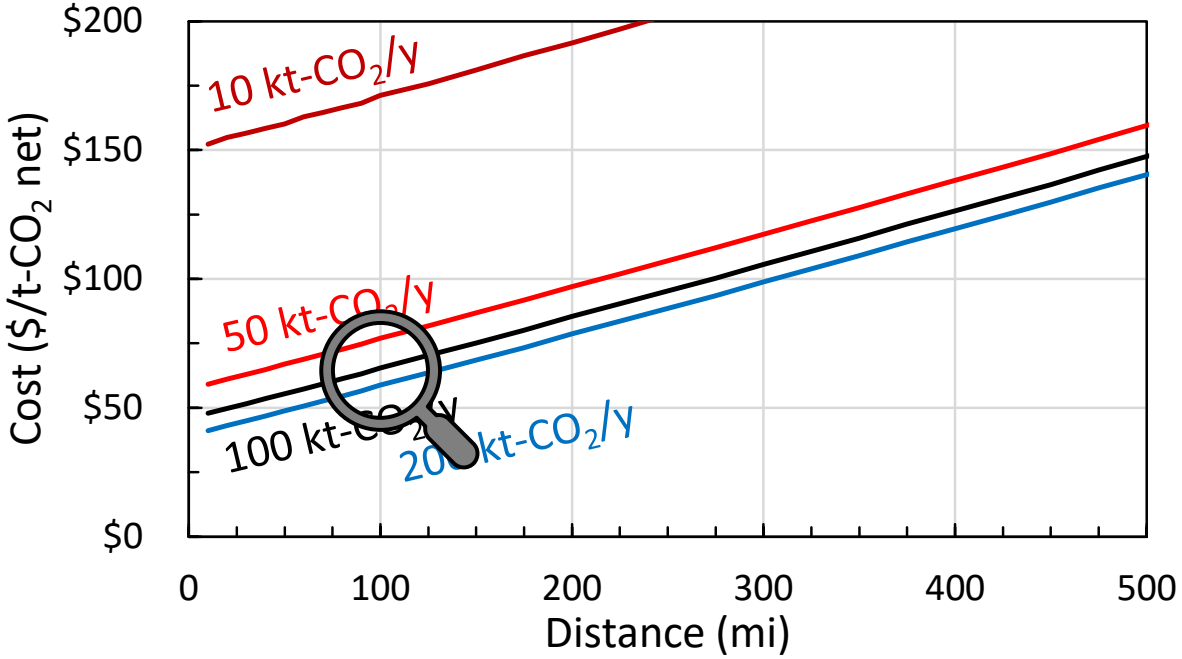
Truck-based transport (baseline)

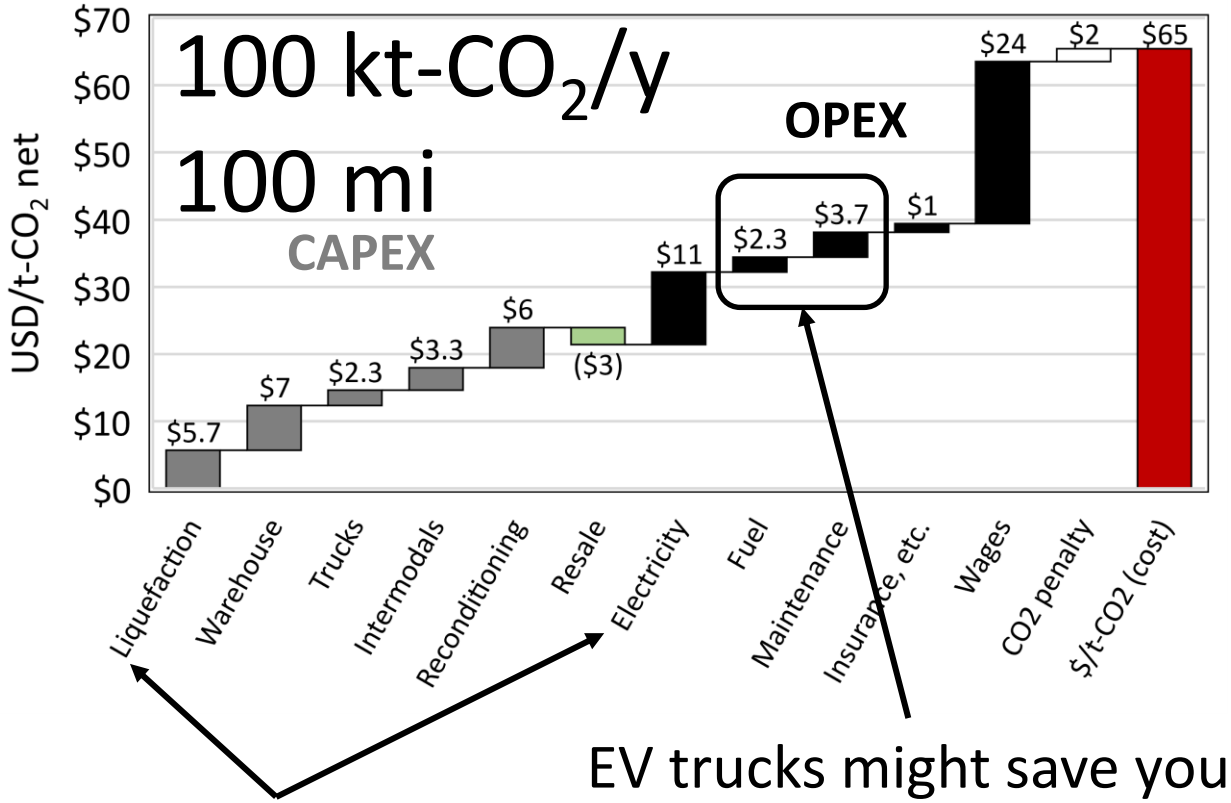


"11/14 rule" (49 CFR 395.3)
Imposes limits on the hours of service for drivers.



Truck-based transport (intermodals)





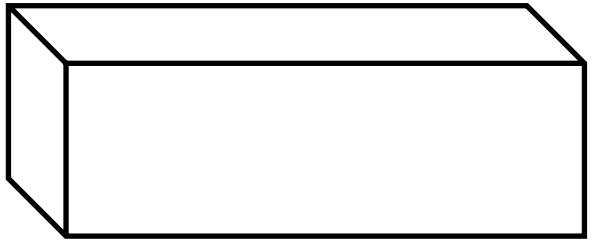
SCO2 could reduce these costs

EV trucks might save you a few dollars on fuel and maintenance

~37% of your 'cost' is providing permanent, good wage jobs that don't require a college degree

Rail-based transport *(why it's more expensive than you think)*

Coal, aggregate, etc.



~100 t per car

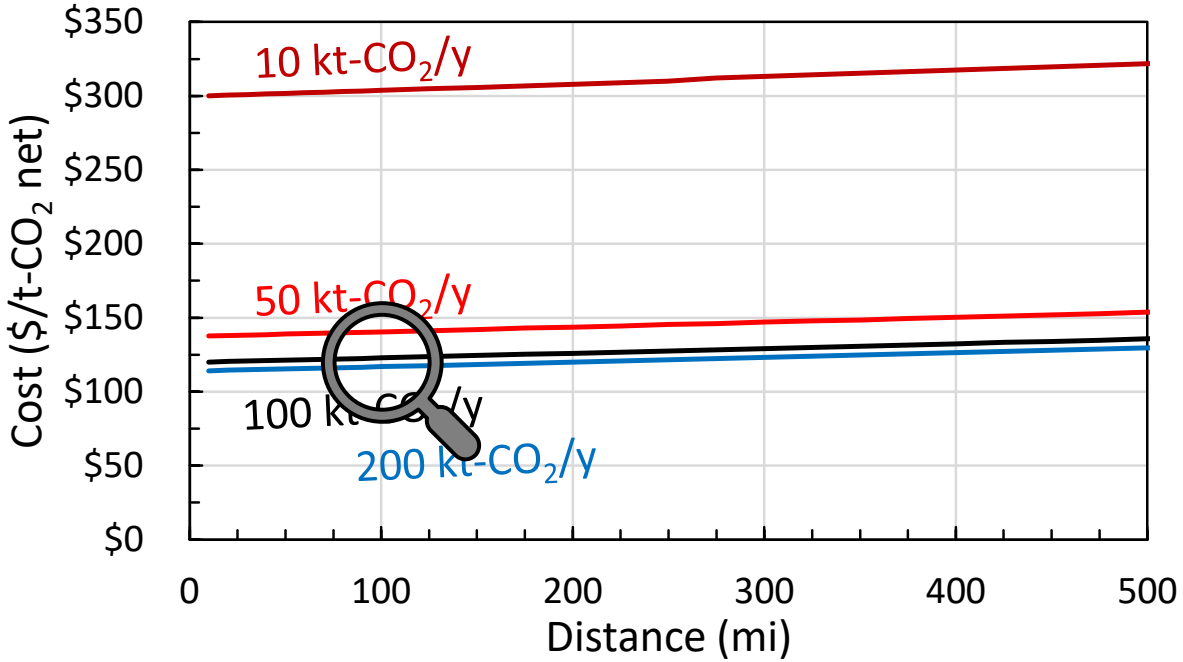
Grease, corn syrup, etc.

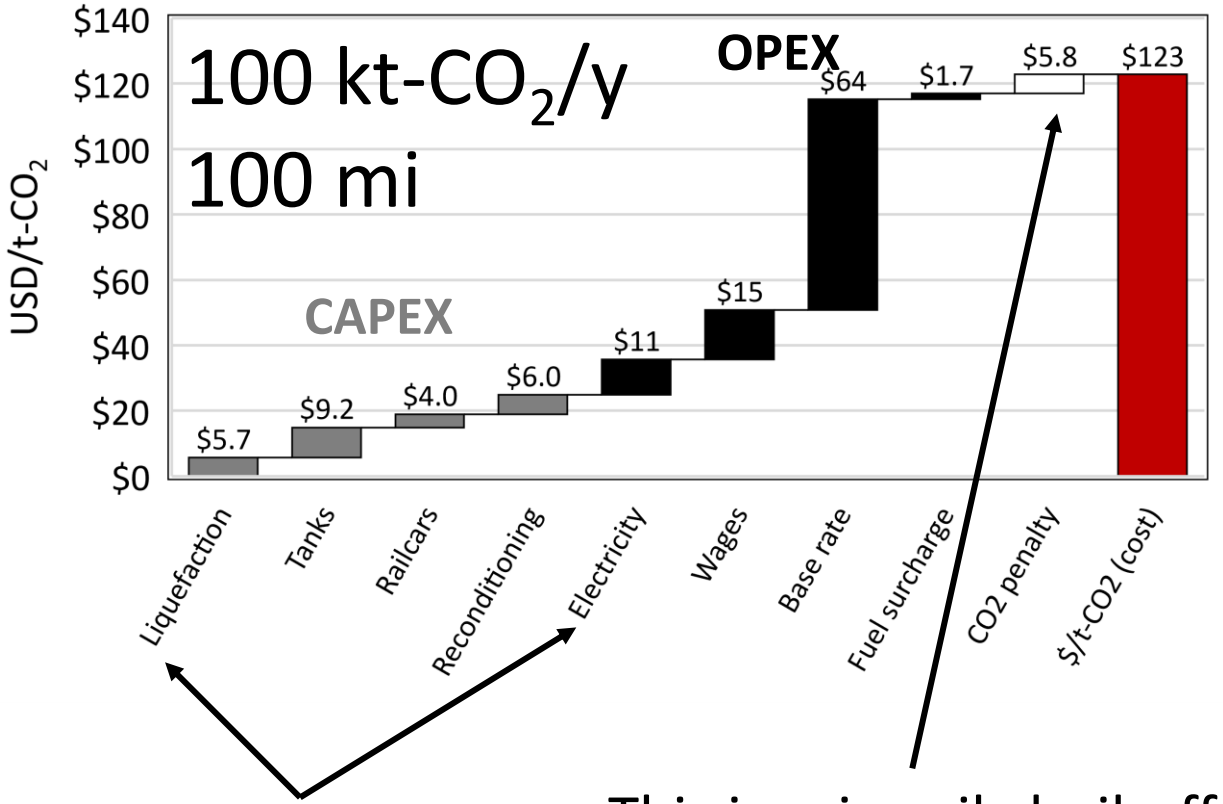
Liquefied CO_2

~80 t per car

Different risk profiles garner different base rates

Rail-based transport (baseline)



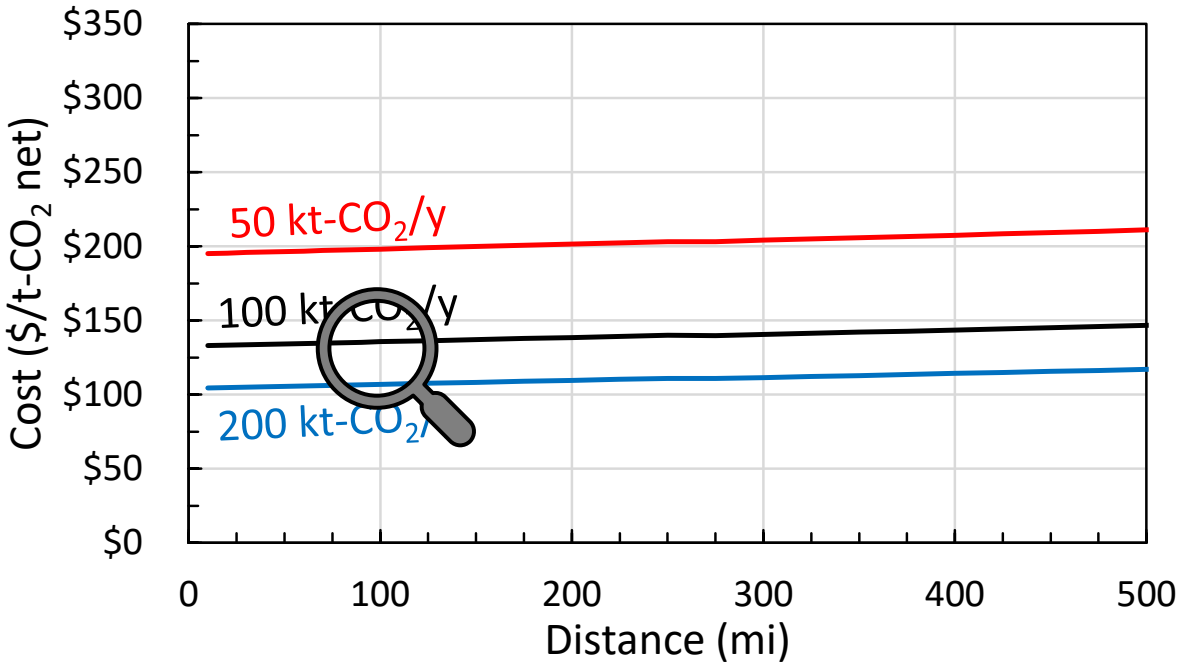


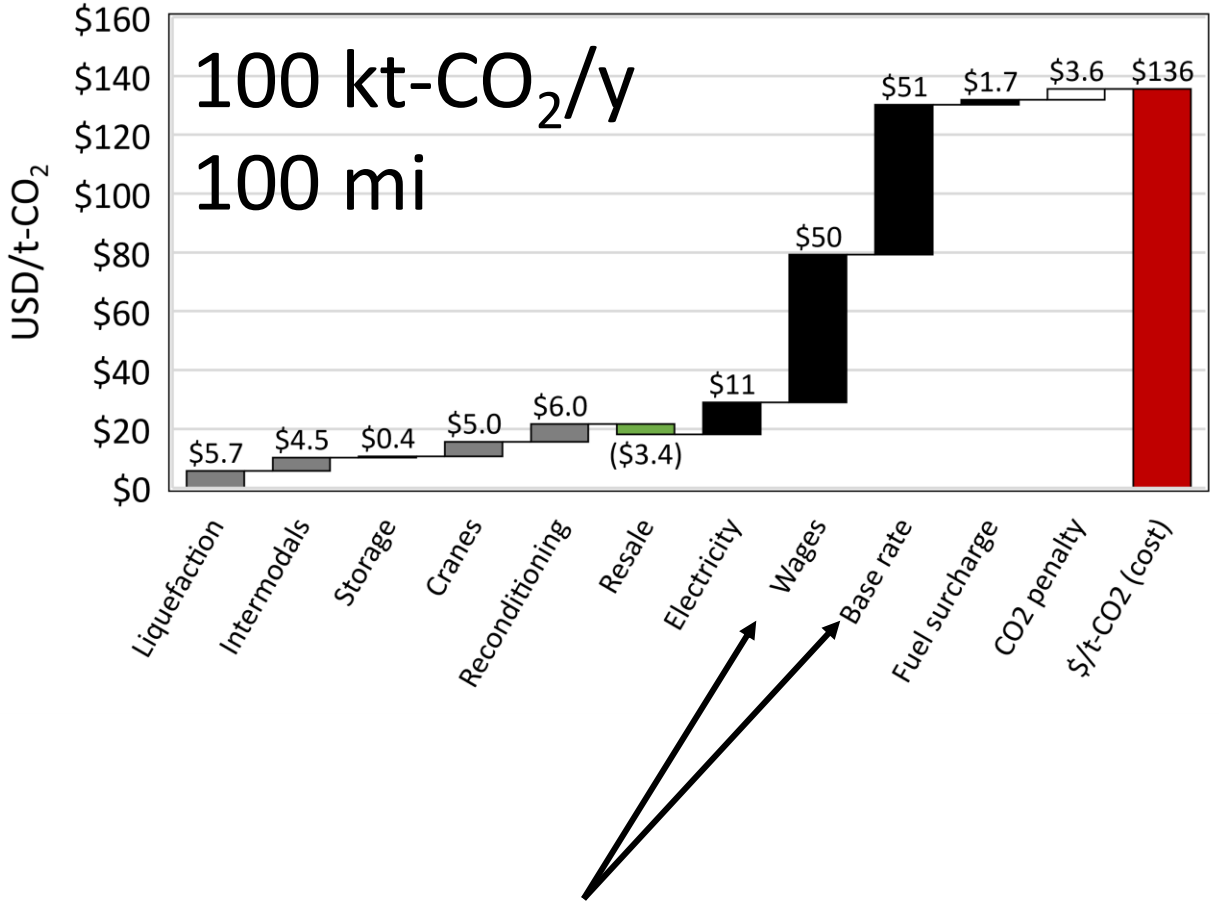
Base rate dominates cost.

SCO2 could reduce these costs

This is primarily boil-off gas. At larger distances, 5-10% of CO_2 can be lost as boil-off gas.
SCO2 could solve this.

Rail-based transport (intermodals)

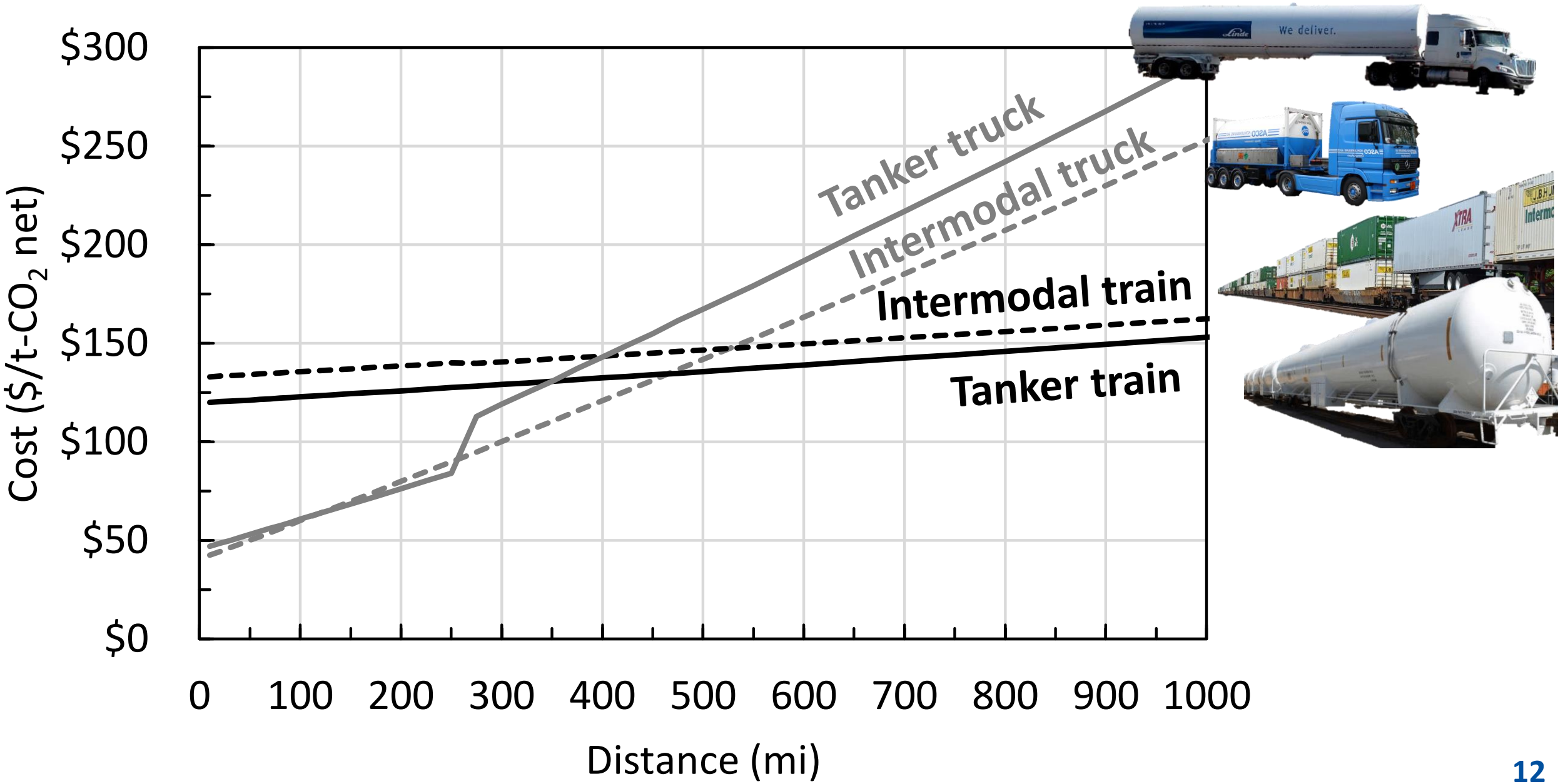




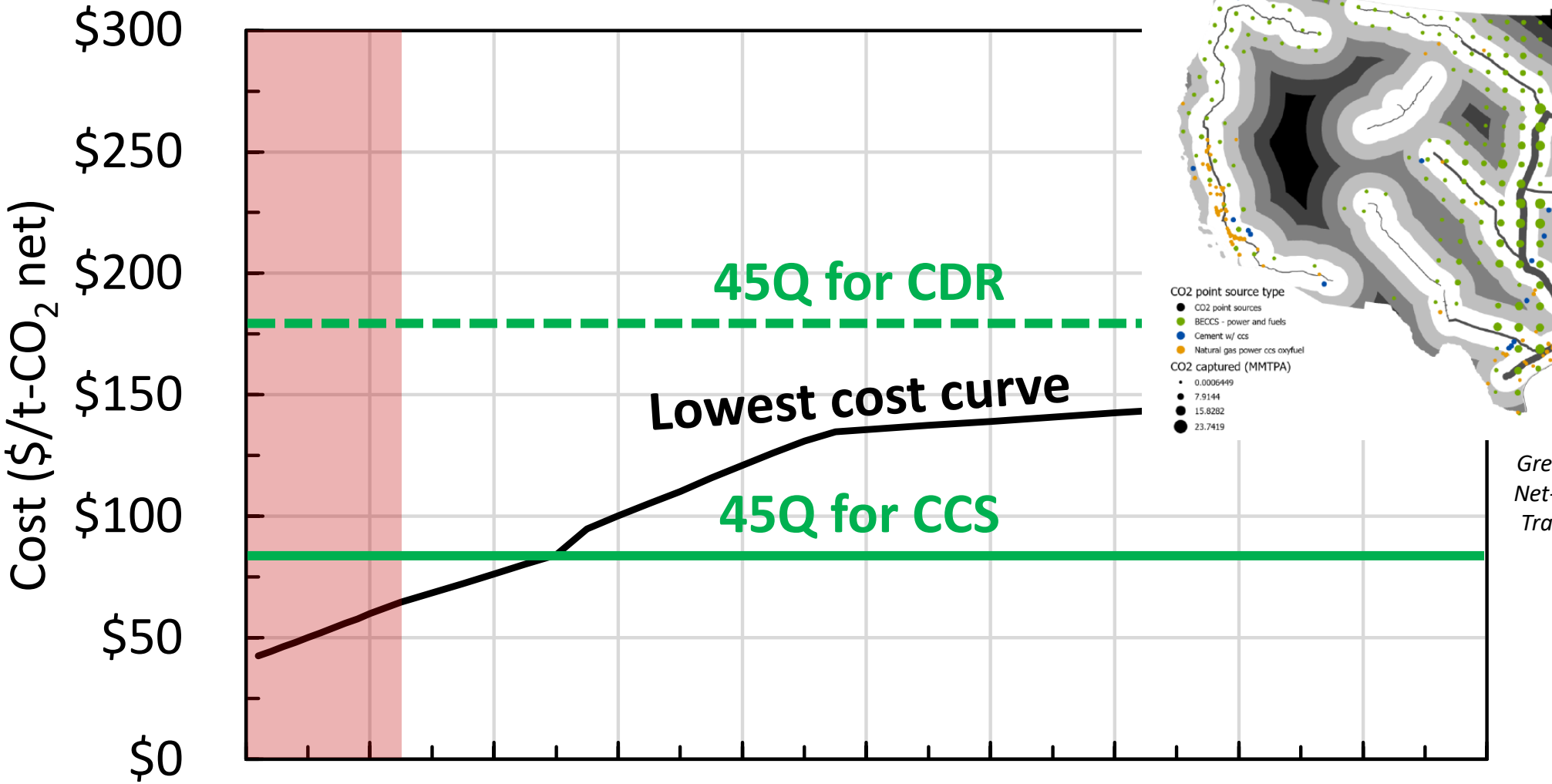
If financing costs are included, rail transport via intermodal and tanker cars are roughly equal cost.

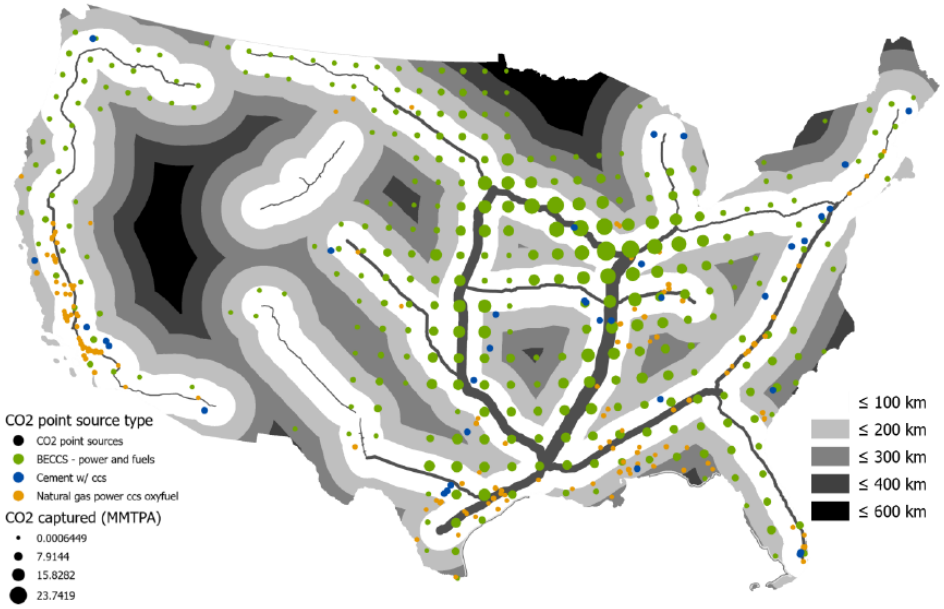
Smaller base rate of intermodals allows for faster logistics but requires more employees.

Cost for 100 kt-CO_2/y



Cost for 100 kt-CO_2/y





Greig and Pascale (2022). Princeton's Net-Zero America study, Annex I: CO2 Transport and Storage Infrastructure transition analysis.

Supercritical CO_2 (may I suggest, "lukewarm CO_2")

Problems with LCO2:

- Boil-off gas (primarily issue for rail)
- Additional energy burden
- Liquefaction and reconditioning equipment become stranded assets if pipeline is built

Problems with SCO2

- Lower density (700-875 kg/m^3) than liquefied (~1040 kg/m^3)
- Shipped in metal tube trailers → weight limitations

Solution for SCO2

- Fiber-reinforced polymer tube intermodals (bring storage volume inline with LCO2)
  → Need to investigate the need for penetration resistance (again, for weight saving)
- High-pressure tube trailers are a niche item (high unit cost)
  → Need domestic manufacturing, possibly via 3D printing
- Initial analysis suggests cost parity with traditional methods is possible, but engineering assumptions need to be verified with RD&D.

Key Takeaways and Next Steps

What do robust, optimized transport networks look like?

Does including the CO_2 from small sources mean our pipelines are undersized?

Do we need government loans to tamp down financing costs?

Can we make intermodal SCO2 transport viable?

For trucks:

- Cheaper than rail for < 500 miles, cheaper than pipelines for <150 kt-CO_2/y & <125 mi
- Higher costs relative to pipelines are due to providing high-paying jobs (*hint: this is good*)
- Intermodals can reduce cost relative to tanker trucks, especially at longer distances
  → US suppliers available, how fast can we crank out intermodals?
- SCO2 might provide a bridge to pipeline transport
  → needs development of fiber-reinforced polymer storage

For rail:

- Rail transport of CO_2 more expensive than typically assumed
- Intermodals increase flexibility and decrease logistic strain
- SCO2 can eliminate schedule crunch of boil-off gas
  → needs development of fiber-reinforced polymer storage