Modeling the Intermodal Freight System to Ensure a Low-Carbon Resilient Future

Apoorv Agarwal
Technology-to-Market Advisor
ARPA-E

apoorv.agarwal@hq.doe.gov

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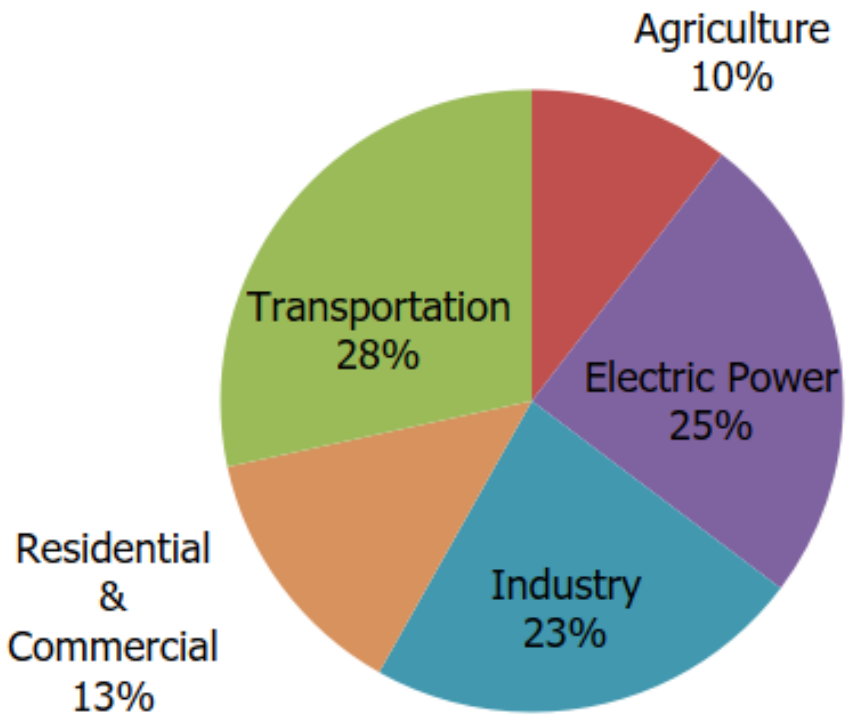
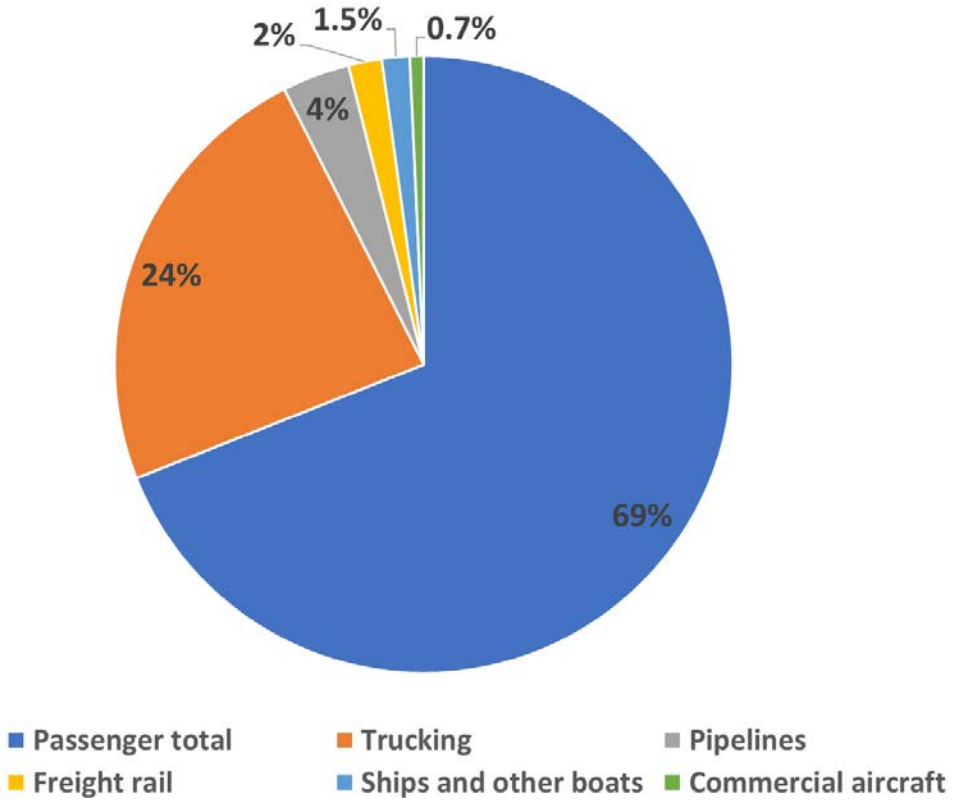
Transportation Accounts for the Highest GHG Emissions of All Economic Sectors in the US – Freight Accounts for a Third of Transportation Related Emissions

2022 Total U.S. Greenhouse Gas Emissions by Economic Sector (Ref: EPA)



2021 Total U.S. Greenhouse Gas Emissions from Domestic Transportation (Ref: BTS)



Overall freight transportation accounts 9% of total GHG emissions in the US

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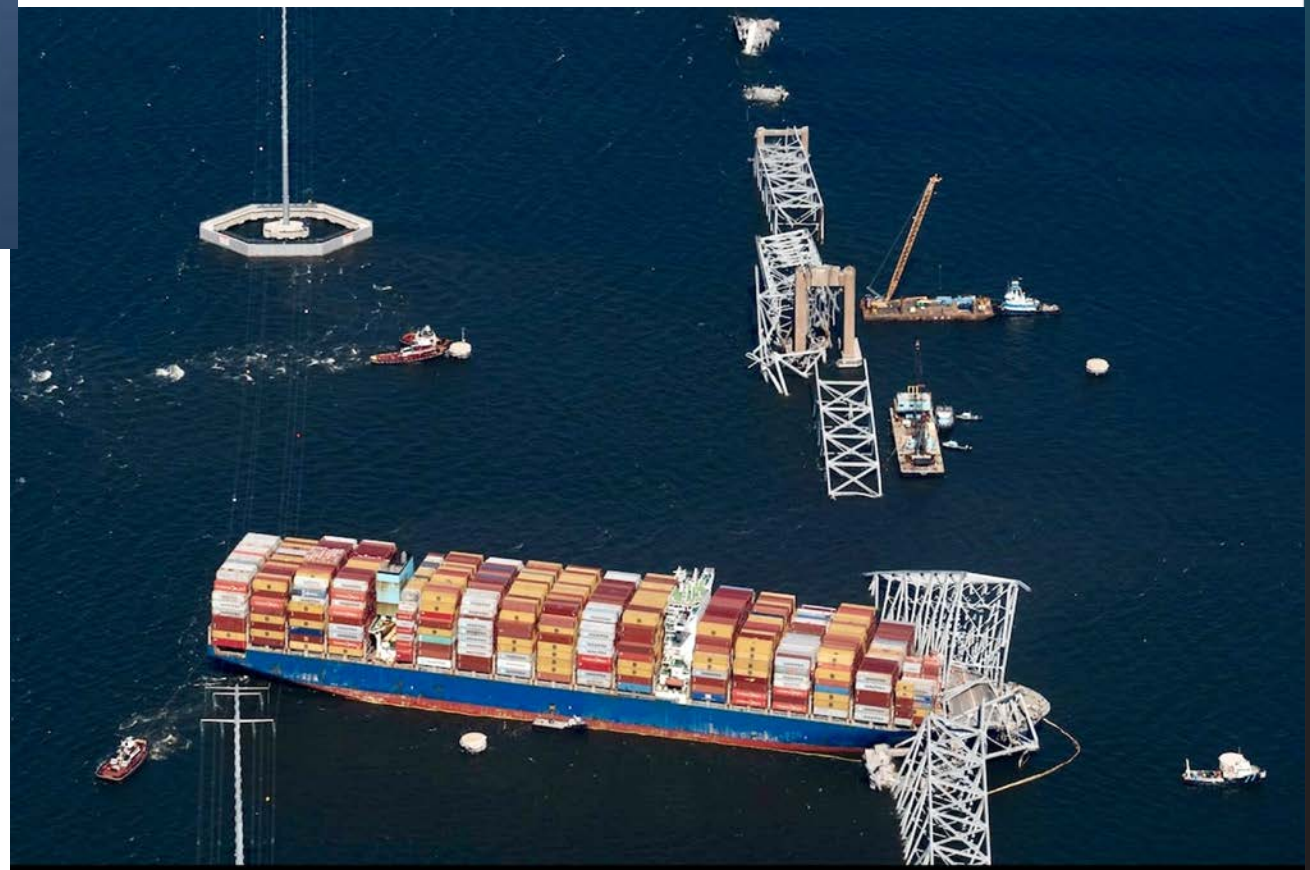
Freight Transportation Resilience is a Major Challenge

Container ships stranded off the Ports Of LA and Long Beach during COVID, November 2021 (Bloomberg News)

Baltimore’s Key Bridge collapses after container ship collision, March 2024 (Washington Post)



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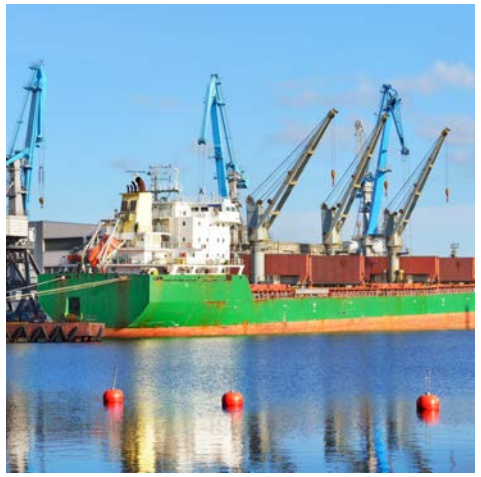
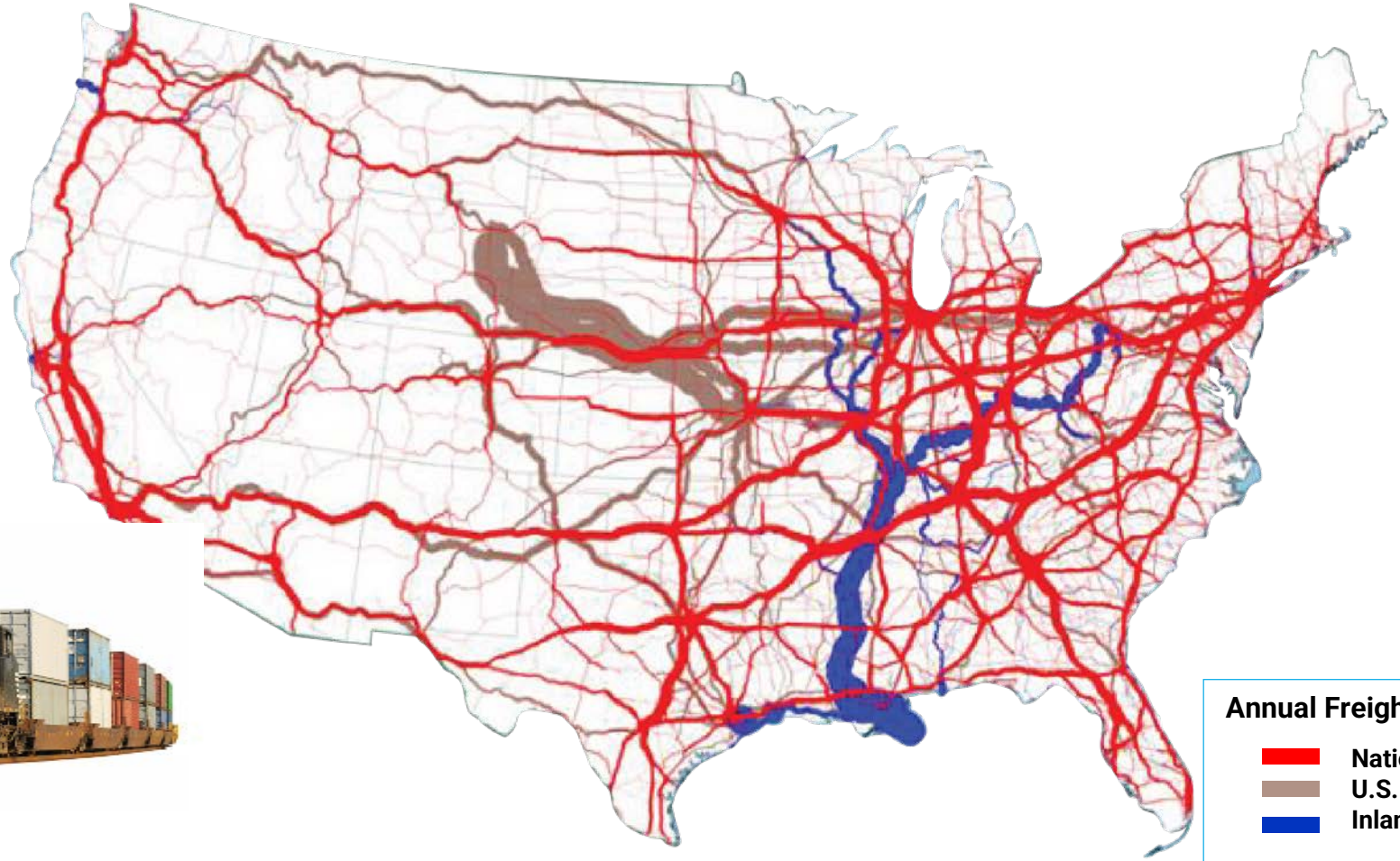
Ultimate Goal:
How to speed decarbonization of the freight sector while increasing energy and supply chain resiliency?

US Road, Rail and Water Transportation Network is Interconnected





Credit: Wikipedia

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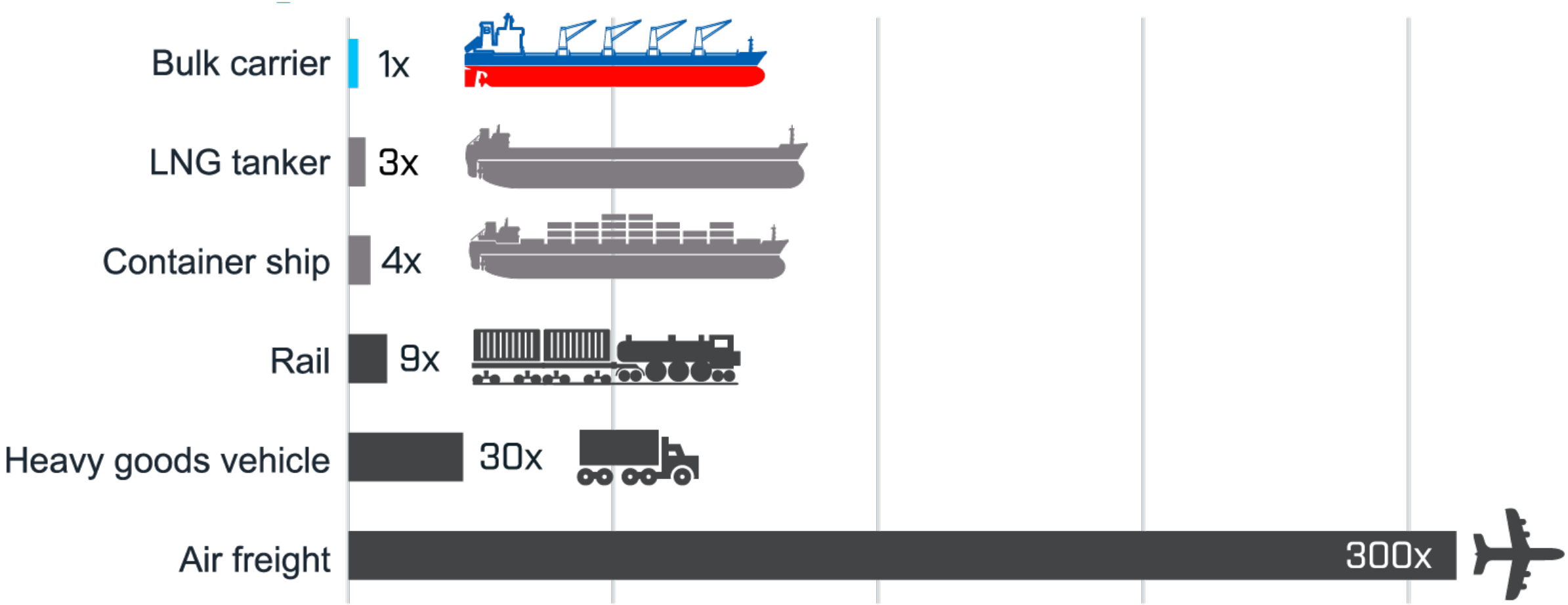
Ships & Rail are significantly more efficient than Road & Air

Grams of CO_2 emitted per ton-mile



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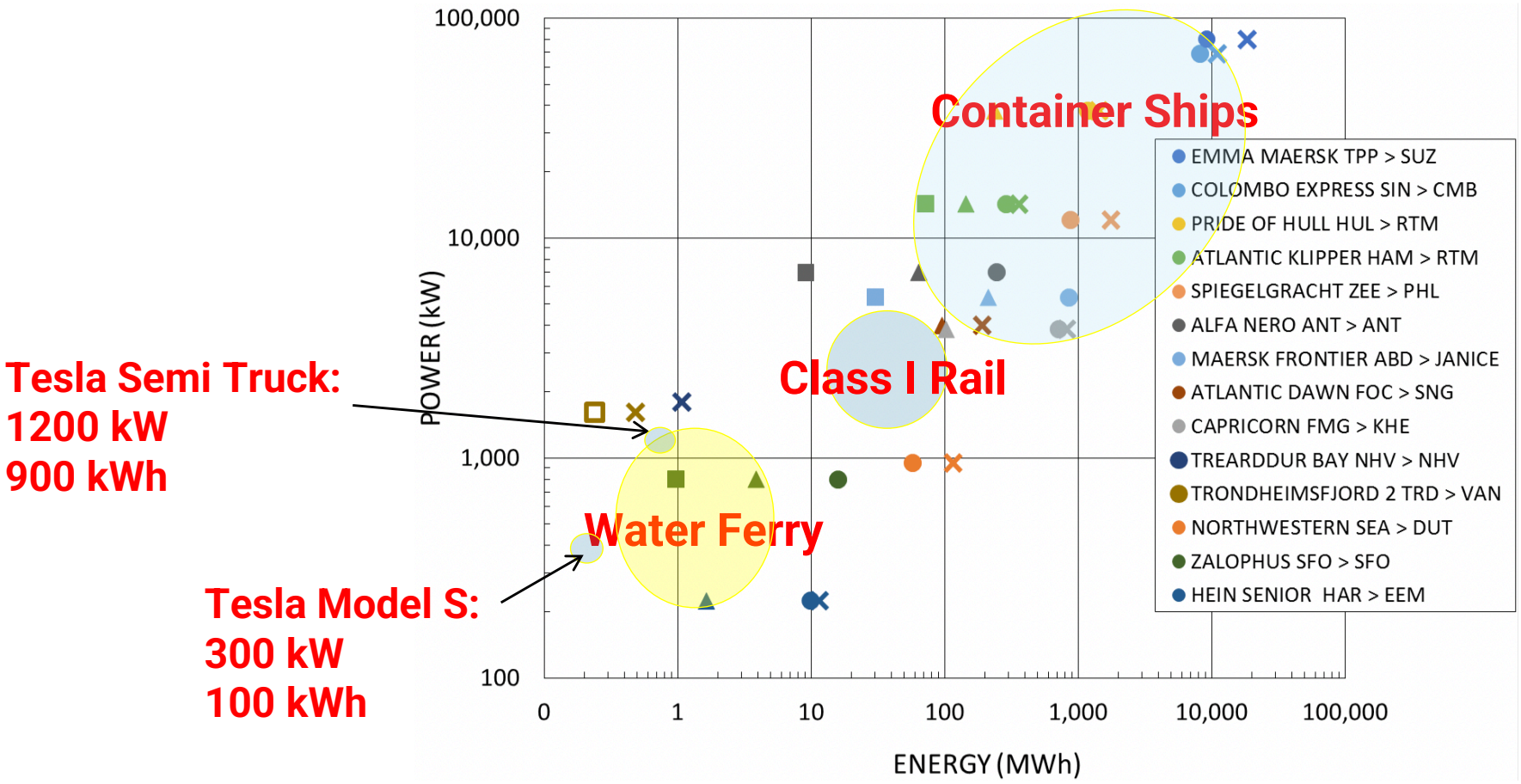
Rail, Road and Maritime Energy System Requirements



Installed Power of a vessel (MCR) versus the Energy required for a specific route and multiples of that route (square: limit of battery, triangle: limit of gaseous H, circle: limit of liquid H, open symbol, no solution, adapted from IEEE 2017)

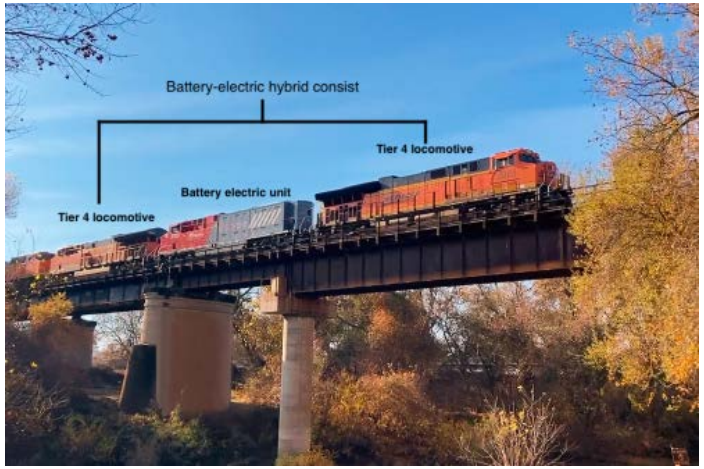
ARPA-E LOCOMOTIVES PROGRAM

2021-2024

LOCOMOTIVES Program – Modeling of Class I RR

- First completely **Open-Source ARPA-E** program
- Complete Class I railroad system modeled at high resolution with elevation and curvature
- Detailed GHG emissions estimates for any train configuration
  - Any fuel type or locomotive electrification option (diesel, pure electric, hybrid, hydrogen, biofuels, etc.)
  - Any composition and size of cargos/cars
- Mapped out required charging/fueling infrastructure as a function of new energy storage requirements and target deployment scenarios
  - Life-cycle impacts analyzed using GREET
- **Expanded the dialogue for freight decarbonization!**

Locomotive Energy Sources Modeled



Diesel-Electric Hybrid Consists

Fuel Cell Locomotives

Battery Electric Locomotives

Progress Rail EMD® Joule BEL

Wabtec FLXdrive BEL

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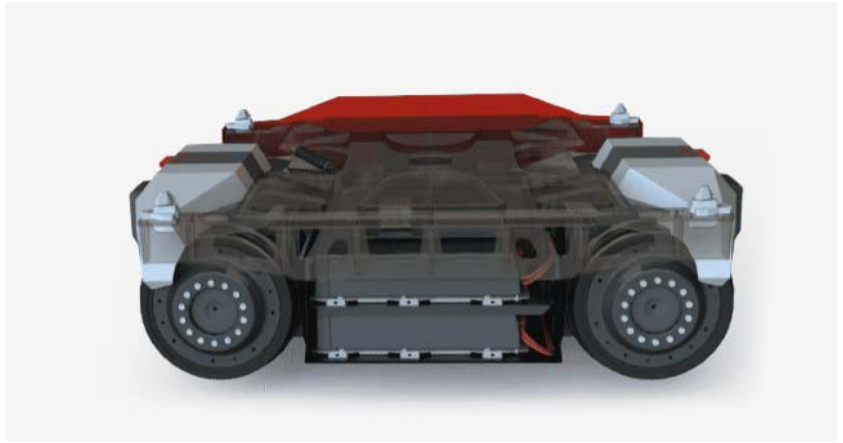
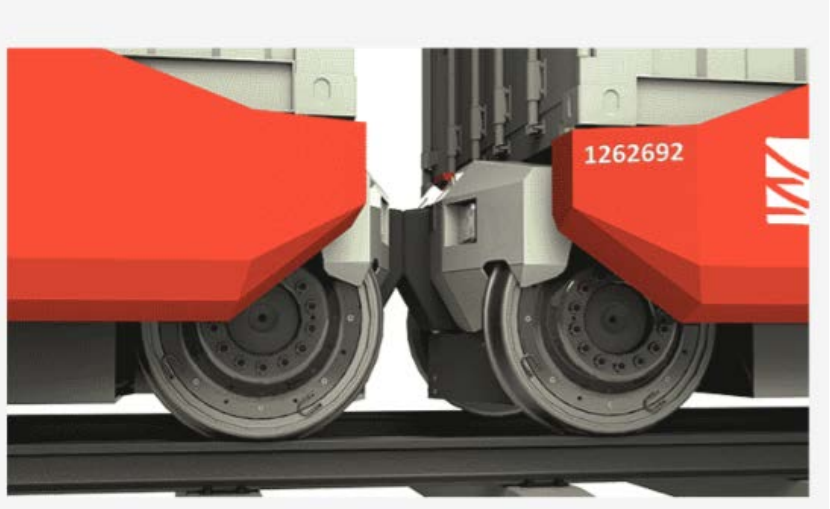
Rail Decarbonization and Disaggregation

Parallel Systems





https://moveparallel.com/

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4 LOCOMOTIVES Teams

ARPA-E LOCOMOTIVES:
Funding Opportunity Announcement: https://arpa-e-foa.energy.gov/Default.aspx?foaId=e8647d89-1cac-4b58-8622-1b04de8958c4 (TOPIC R)
Selections: https://arpa-e.energy.gov/technologies/exploratory-topics/rail-ghg-reduction

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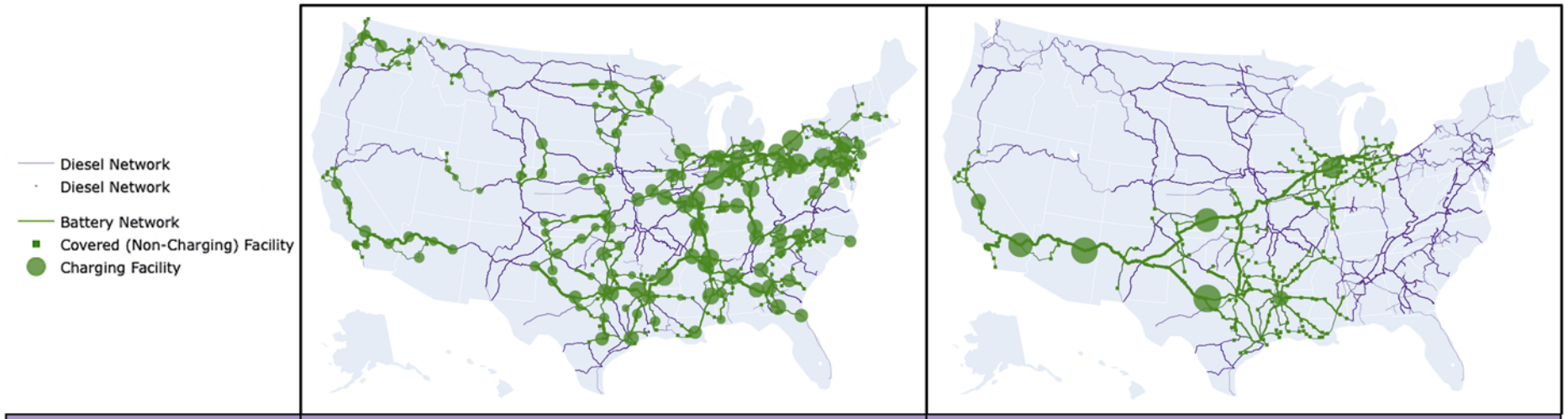
Why do BEL ranges matter?

NUFRIEND Insights



BEL Range	200-mile	800-mile
Cost of Avoided Emissions	900 [$/ton CO_2]	100 [$/ton CO_2]
# of Charging Facilities	143 out of 544	7 out of 544
Emissions Reduction	7%	29%

Optimization results of an aggregated transcontinental US rail network where 20% shipments are served by BELs.

- Longer-range BELs require a smaller capital investment while attaining a higher carbon reduction.
- Longer ranges mean more flexibility for railroads to deploy BELs and leverage economies of scale in heavily trafficked corridors.

https://transportation.northwestern.edu/docs/2022/2022-nufriend-insights-ranges.pdf

ARPA-E INTERMODAL PROGRAM

2024 -

Goal: Roadmap to Resilient Net-Zero Intermodal System

- Support the deployment of **energy infrastructure** and **logistics** for moving goods across maritime, rail, and road transportation in the United States. Two goals:
  1. Develop models that enable prioritization of low-carbon energy infrastructure deployment
  2. Develop logistics models that enable predictive and responsive optimization of modal choice, inter- or intra- modal transfer, and routing consistent with future energy systems.

Stakeholders

Federal Government
- R&D needs
- Input to policy decisions
- National coordination

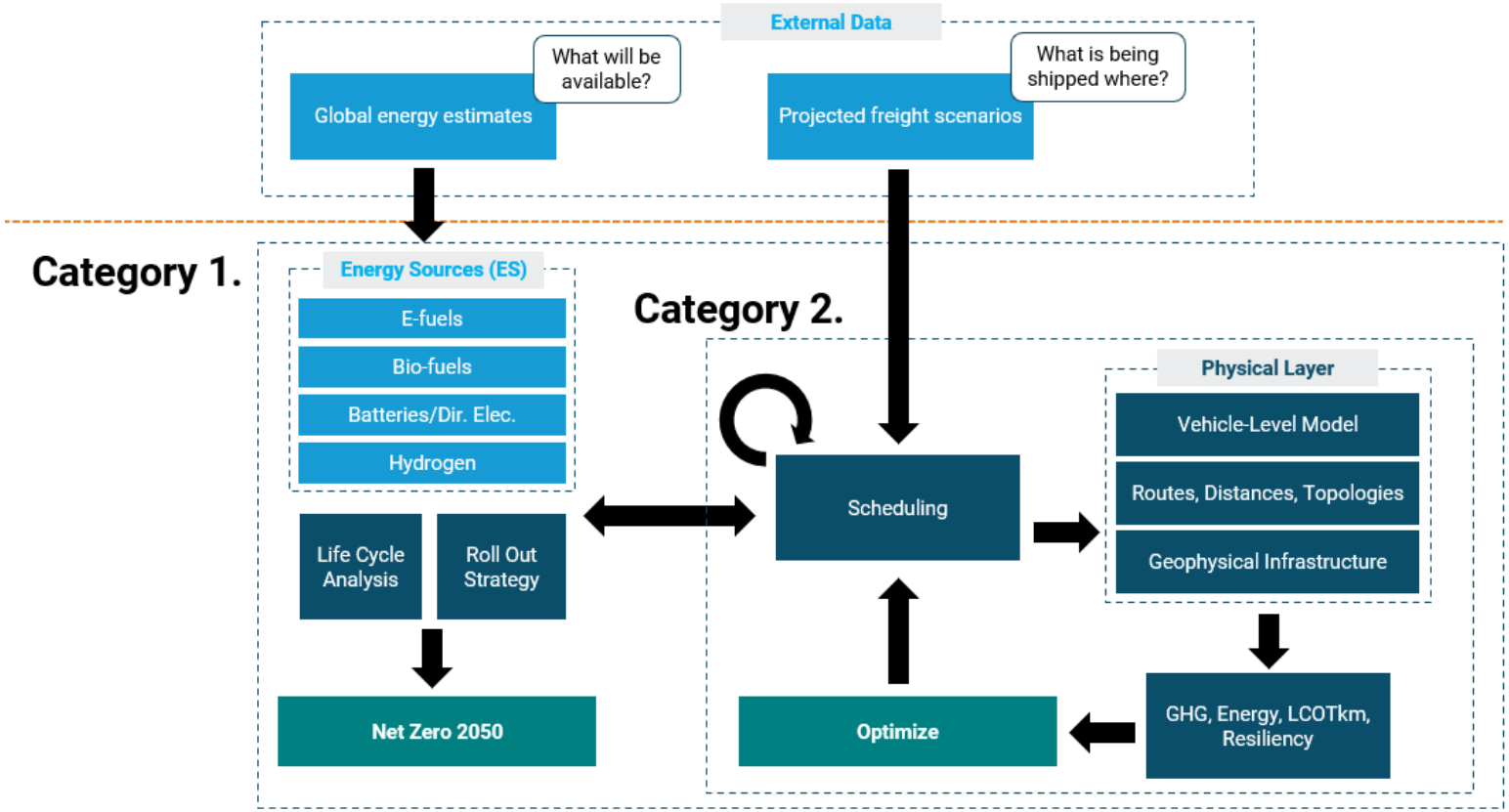
Local Gov. + Private Organizations
- Infrastructure to be built
  - Ex. Port of LA, State of CA
- Green Corridor establishment
- Consortiums, collectives of shippers

Logistics Industry
- Shippers, freight forwarders
- Asset decisions
- Scheduling, routing decisions

INTERMODAL – Categories of Outcomes

Category 1: Intermodal Infrastructure Model - A complete validated model of the national intermodal freight transportation network

Category 2: Intermodal Logistics Model - A complete and validated set of logistics models of the national intermodal freight transportation system



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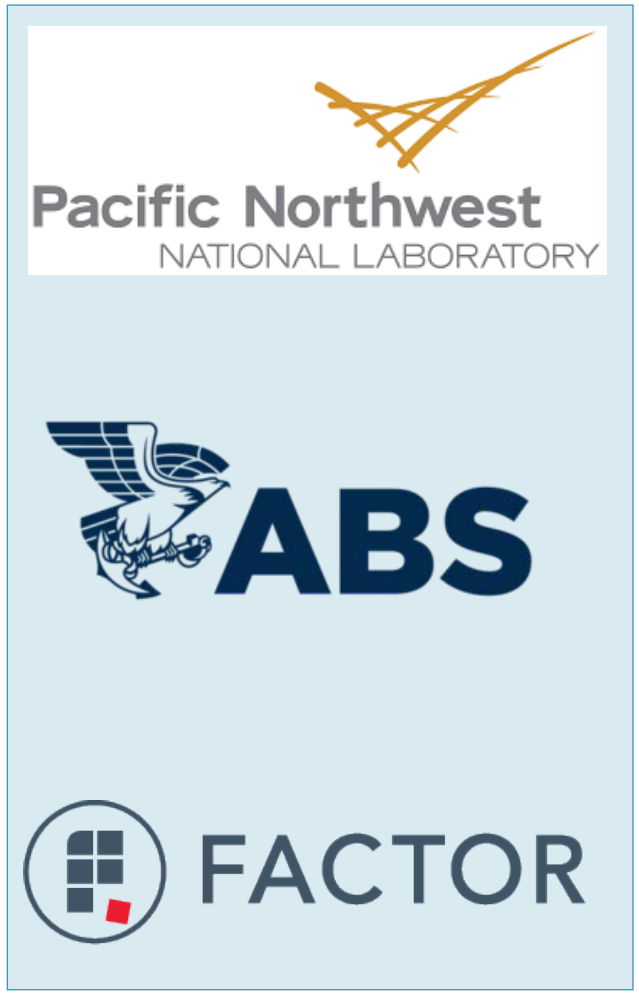
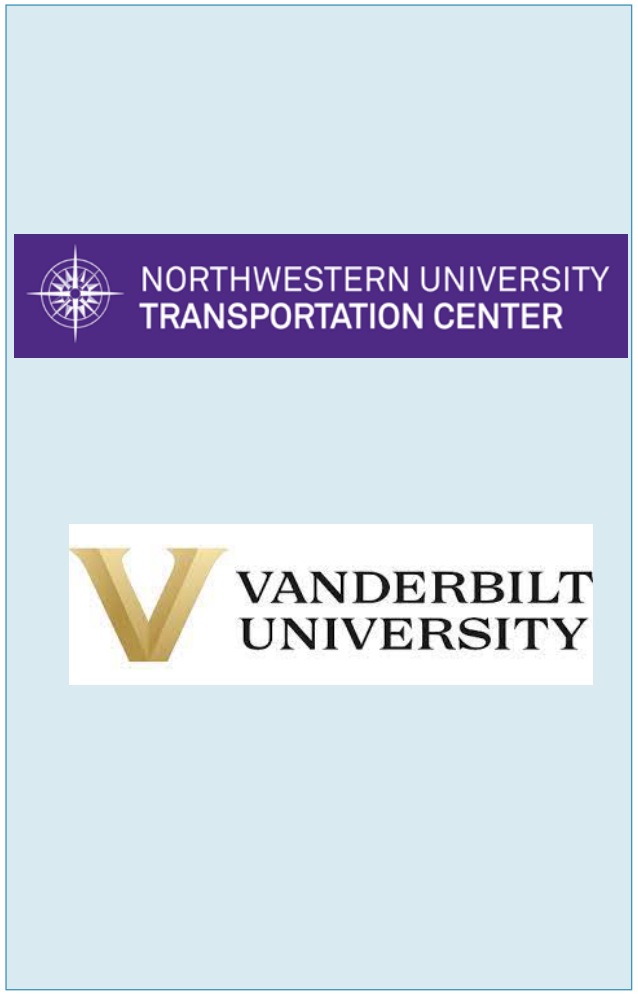
7 INTERMODAL Teams





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Funding Opportunity Announcement: https://arpa-e-foa.energy.gov/Default.aspx#FoaId521a7aa4-b255-4c3b-a211-b128d2a4a0e4 (TOPIC B)
Selections: https://arpa-e.energy.gov/technologies/exploratory-topics/intermodal-freight

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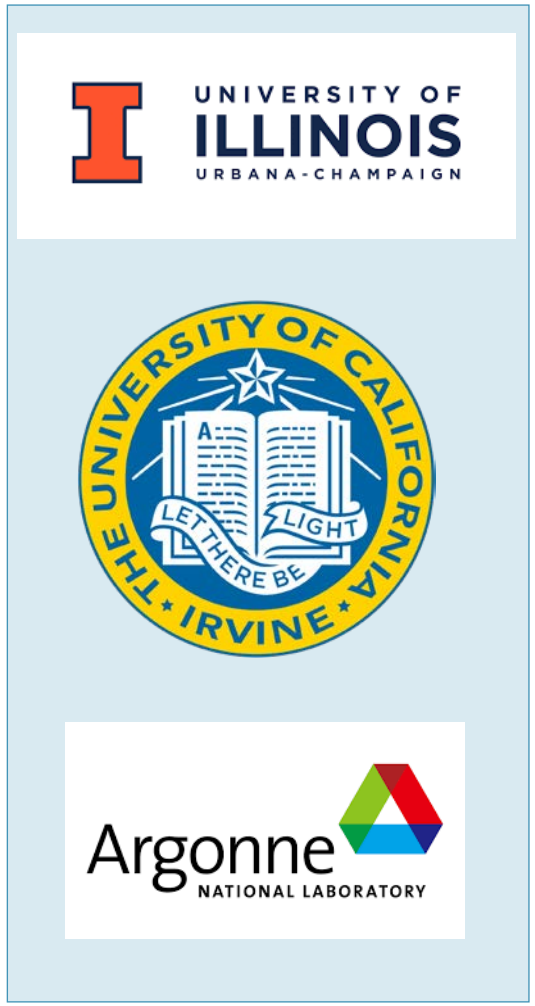

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INTERMODAL Program Challenges

- Data Availability and Heterogeneity
- Model Validation
  - Temporal and spatial resolution
- Energy System Rollout Scenarios and Uncertainty
- Regulatory Regime Uncertainty
- Resiliency Definition and Test Scenarios

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