# NUFRIEND Insights

VARYING TECHNOLOGY DEPLOYMENTS

Northwestern University Freight Rail Infrastructure & Energy Network Decarbonization (NUFRIEND) is a comprehensive industry-oriented tool to simulate the deployment of new energy technologies across U.S. freight rail networks. Scenario-specific simulation and optimization modules provide estimates for carbon reductions, capital investments, costs of carbon reductions, and operational impacts for any given deployment profile.
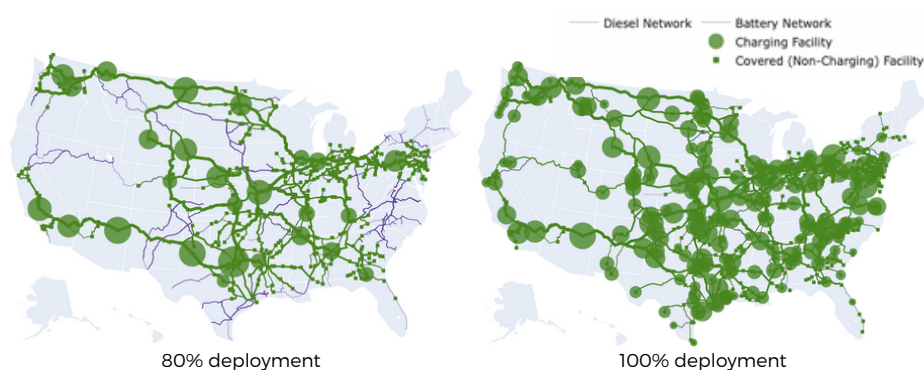
WHAT IS TECHNOLOGY DEPLOYMENT?

- Alternative technology deployment is measured as the percent of total ton-miles it serves, with diesel serving the rest.
- Drop-in fuels (e.g., biodiesel, renewable diesel, and e-fuels) can be blended with diesel and deployed in fueling facilities.
- Battery-electric and hydrogen locomotives are limited to moving freight on routes with charging/refueling stations.

This NUFRIEND Insights models variations in future battery-electric locomotive (BEL) deployment in an aggregated U.S. Class I railroad network, to analyze their costs and emissions.
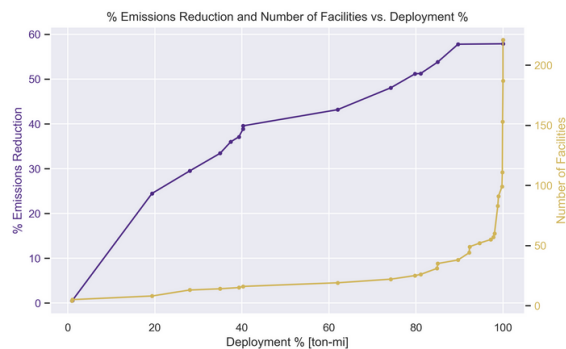
Optimization results for an aggregated transcontinental U.S. rail network with varying shipment percentage served by 600-mile range BELs.

80% deployment   100% deployment

Networks required to capture different deployment percentages.

WHAT CAN WE LEARN FROM VARYING TECHNOLOGY DEPLOYMENT?

Varying technology deployment affects leveled costs, emissions reductions, and helps identify **deployment sweet-spots.**

Emissions Reduction:

- Emissions reductions potential is highly dependent on the specific routes that are decarbonized.
- Different routes carry different commodity spreads with specific energy intensities and emissions.

Number of Charging Facilities:

- Near linear growth in number of charging facilities for a reasonable range of deployment (0%-80%).
- Number of facilities skyrockets as serving last-mile routes requires facilities nearly everywhere.

SUMMARY

- Decarbonizing every last-mile shipment may require an unrealistic number of facilities but may not have a significant impact on total emissions.
- Battery-electric emissions reduction extents are capped by the electric grid's generation mix and emissions.
- As the densest corridors may be decarbonized first, there are diminishing marginal returns to deployment.
- The NUFRIEND tool can help individual railroads analyze different problem components over varying deployment levels to detect alternative technology deployment sweet-spots.

NUFRIEND Insights for:

RAILROADS

- Assessment of benefits from advanced roll-out planning
- Potential gains from traffic-dense corridors or easy-to-decarbonize routes
- Value of hybrid diesel and battery-electric locomotives in planning roll-outs

ENERGY PROVIDERS

- Emissions reductions potentials rely on cleaning up the national electricity generation mix
- Coordination to ensure adequate electricity supply for connected charging infrastructure

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