NUFRIEND Insights

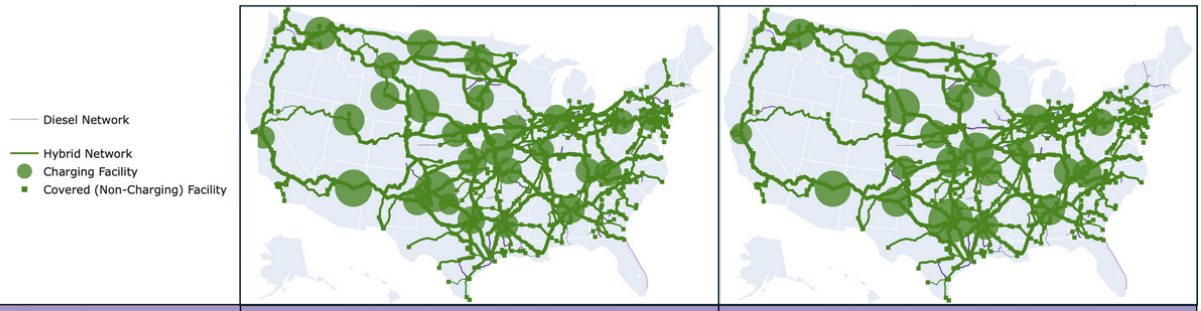
ENERGY TECHNOLOGIES - HYBRID DIESEL-BATTERY

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 BEING DEPLOYED?

- The NUFRIEND framework allows users to select from two hybrid train configurations:
  - 2:1 diesel to battery configuration (i.e., 4 diesel locomotives and 2 battery locomotives per train) or
  - 1:1 diesel to battery configuration (i.e., 3 diesel locomotives and 3 battery locomotives per train).
- The optimization framework determines the optimal charging facility locations and sizes for serving freight demand.
- The simulation framework accounts for region-specific hybrid energy intensity estimates for battery/diesel locomotives.

This NUFRIEND Insights highlights the difference between cost and emissions results for the two hybrid configurations, compared to pure diesel operations.



Configuration	Hybrid 2:1 (Diesel to Battery)	Hybrid 1:1 (Diesel to Battery)
Emissions Reduction	19%	30%
Levelized Cost of Operation	0.66 ¢/ton-mile	0.68 ¢/ton-mile
Cost of Avoided Emissions [1]	320 $/ton CO_2	230 $/ton CO_2

Comparison of simulation results for two hybrid train configurations, assuming a minimum inter-facility distance of 1600 miles. Bubble sizes are proportional to the power (in MW) assigned to each charging facility location.

HOW CAN HYRBID LOCOMOTIVES DECARBONIZE RAIL?

- Hybrid diesel-battery locomotives are an effective transition technology for decarbonizing current operations.
- They enable the rollout of critical infrastructure to support more advanced freight rail decarbonization initiatives.
  - Require the location of initial charging stations on the rail network.
  - Provide immediate emissions reductions through route-level energy optimization.

SUMMARY

- Hybrid diesel-battery locomotives are practical technologies with immediate impacts on emissions reductions.
- These train configurations leverage current (lower) range battery locomotives to optimize train energy consumption.
- The rollout of required charging infrastructure serves as a stepping stone for future full-battery locomotive operations.
- High capital costs can be reduced by innovations in charging technologies and charging station design and utilization.

[1] The cost of avoided emissions measures the average cost required to reduce emissions by one ton of CO2 and serves as a strong evaluation and policy metric.

NUFRIEND Insights for:

RAILROADS

- Immediate gains from strategic deployment of battery locomotives.
- Transition along easy-to-decarbonize routes.

OEMS

- Opportunity to test battery locomotives.
- Innovations in charging stations.
- Need for cost-competitive manufacturing relative to other fuel technologies

ENERGY PROVIDERS

- Coordination to ensure adequate electricity supply.

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