

Northwestern University Freight Rail Infrastructure and Energy Decarbonization (NUFRIEND) Dashboard

User Guide



December, 2022

Version 1.0

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1. Introduction

The NUFRIEND Dashboard is a comprehensive industry-oriented tool to optimize and 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.

1.1. Purpose

The purpose of this user guide is to introduce users to the NUFRIEND Dashboard and highlight its key functionalities and navigational features through examples and screen captures.

1.2. Information

Users can refer to the [NUFRIEND Framework - NUTC](#) webpage for more updated information on the overall project. Any questions regarding the dashboard can be directed to Max Ng and Adrian Hernandez.ⁱ
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1.3. Data Flows

All data used for this dashboard is maintained internally. The dashboard only requires users to specify scenarios through the selection of parameter inputs and does not require any additional data input. Data outputs are both printed and graphically displayed for user inspection.

2. Getting Started

The NUFRIEND Dashboard is publicly available, web-hosted tool accessible by any computer connected to the internet. Access is available on the [NUFRIEND Dashboard](#) webpage.ⁱⁱⁱ Users can end their session by closing the webpage.

2.1. Special Instructions for Error Correction

Upon connection, users will be able to run specific deployment scenarios by selecting any combination of input parameters from the available options. Some scenarios may take up to a minute to load. If the loading screen freezes, or is taking considerably longer, it is advised that users refresh the webpage and rerun the scenario. For any further issues, refer to Section 1.2. Section 3 will provide more detailed instructions on using the dashboard to run specific scenarios.

3. Using the Dashboard

The following section will walk users through specifying a scenario and interpreting its outputs.

3.1. Specifying a Scenario

Users will be greeted with a message reading “Please select the scenario and click “Run”. Initial run may take up to 30 seconds.” Users may specify a scenario by selecting options from each of the parameters in the “General” pane, as well as the more detailed “Parameters” pane, located on the top-left of the window as shown in Figure 1.

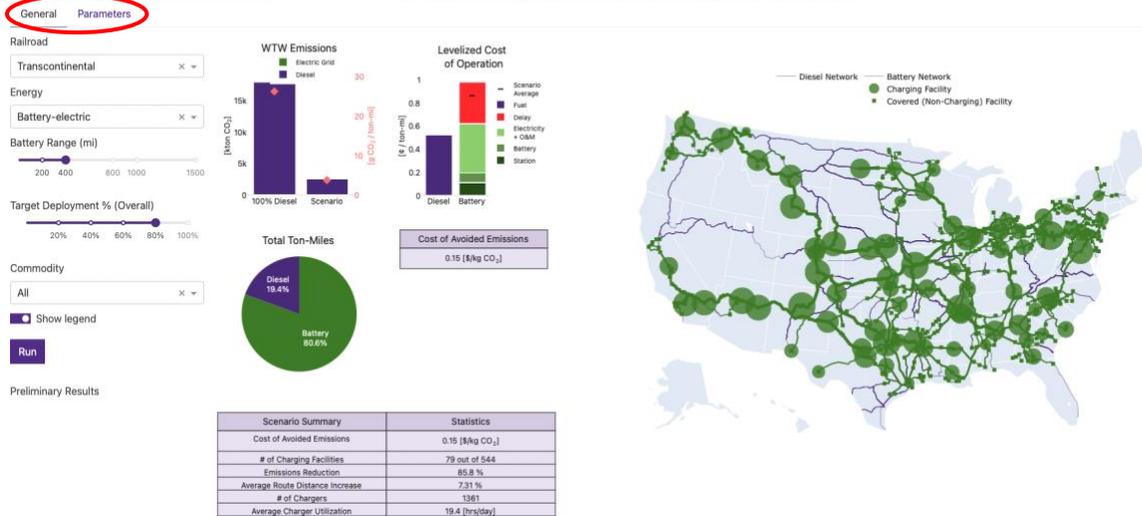


Figure 1 - Location of the "General" and "Parameters" pane buttons (circled in red).

3.1.1. "General" Scenario Pane

Users may specify a scenario by selecting options from each of the parameters in the list on the left-hand pane, shown in Figure 2.

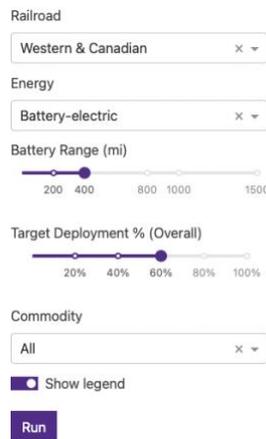


Figure 2 - "General" scenario specification pane.

Scenario Parameters:

- Railroad: the railroad network over which the technology's deployment will be considered.
- Energy: the energy technology that will be deployed for decarbonization of freight rail.
- Battery range: the approximate range (in miles) of battery-electric locomotives.^{iv}
- Target deployment: the targeted percentage of ton-miles (approximate) that will be served by the selected energy technology.^v
- Commodity: the commodity group for analysis of the deployment scenario.^{vi}

Buttons:

- Show legend: allows users to show or remove legends from outputted plots.

- Run: runs the scenario based on the user-provided inputs.

3.1.2. “Parameters” Scenario Pane

More detailed parameters are located in the “Parameters” pane, as shown in Figure 3. Here, users can access key assumed values and update some more detailed scenario parameters. The most reasonable values have been set as parameter defaults; it is not necessary to tweak any of these parameters to run a scenario.

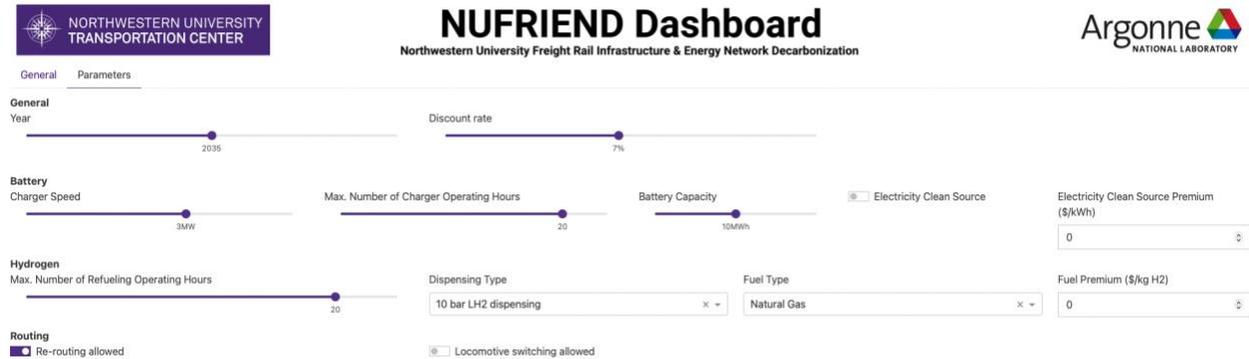


Figure 3 - "Parameters" pane for detailed scenario specification.

Assumed Values:

- Year: the year of analysis for cost and emissions estimates; assumed to be 2035.
- Discount Rate: the discount rate for capital investments; assumed to be 7%.
- Charger Speed: the power of each charger; assumed to be 3 MW.^{vii}
- Battery Capacity: the capacity of each battery pack on each battery-electric locomotive; assumed to be 10 MWh.^{viii}

Scenario Parameters:

Battery:

- Max Number of Charger Operating Hours: the maximum daily charger utilization (in hours).
- Electricity Clean Source: whether or not zero-carbon electricity is sourced for the charging of battery-electric locomotives.
- Electricity Clean Source Premium: the added cost of sourcing clean electricity (in \$/kWh).

Hydrogen:

- Max Number of Refueling Operating Hours: the maximum daily refueling pump utilization (in hours).
- Dispensing Type: the technology used for the hydrogen refueling station dispenser.
- Fuel Type: the type of hydrogen fuel pathway (i.e., production) considered.
- Fuel Premium: the added cost of the type of hydrogen used relative to hydrogen produced via Natural Gas (in \$/kg H₂).

Routing:

- Re-routing Allowed:
 - Yes (purple): flows can be re-routed from their baseline routes to new routes served by the selected energy technology.^{ix}
 - No (white): flows are only served by the selected energy technology when their baseline route is served by the selected energy technology, otherwise they are served by diesel.
- Locomotive Switching Allowed:
 - Yes (purple): flows are switched between diesel and the selected energy technology along a path as the selected energy technology’s service becomes available.

- No (white): flows are only transported by a single energy technology (e.g., diesel, or the selected energy technology) for the entire duration of their trip.

3.2. Scenario Visualization

Upon selection of a scenario and clicking “Run”, users will see a loading wheel as the dashboard works display the scenario visualization. The scenario visualization includes aggregate scenario plots, summary tables, and a network map, each of which provide more information through interactive hovering.

3.2.1. Scenario Plots and Summary Tables

The scenario plots and summary tables include interactive bar and pie plots and important metrics.

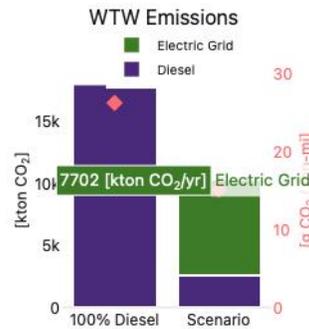


Figure 4 - Well-to-Wheel emissions comparison.

Well-to-Wheel (WTW) emissions of the selected scenario are compared against those of diesel operations, as in Figure 4. As some scenarios will require diesel service on the regions where the selected energy technology is not in service, the “Scenario” bar contains a mix of emissions sources. Users can hover for information on the emissions associated with each energy source.

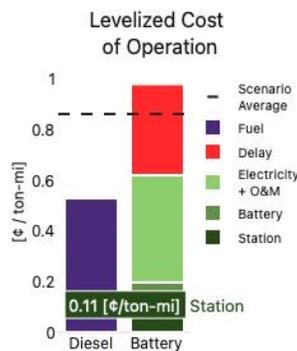


Figure 5 - Levelized cost of operation comparison.

The scenario’s levelized cost of operations (in ¢/ton-mile) is compared against diesel’s, as shown in Figure 5. The overall cost is broken down into individual components representing refueling/charging station capital costs (where applicable), battery-pack capital costs (only for the battery-electric case), fuel/electricity costs, and any delay costs (associated with additional refueling/charging time). Hovering shows each cost component’s value. The “Scenario Average” dash shows the average cost per ton-mile for the scenario, given that some freight may still be moved by diesel locomotives.

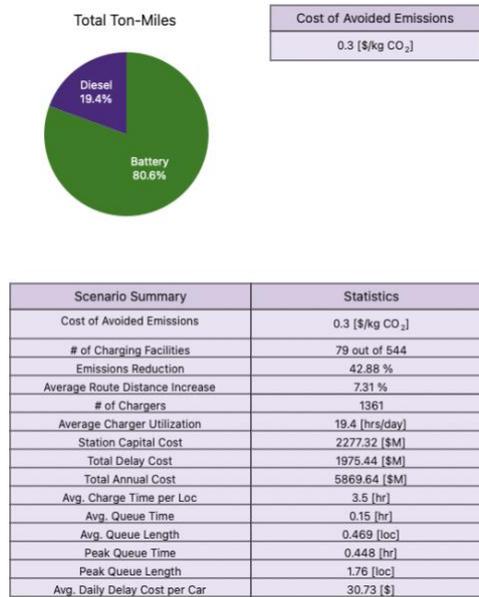


Figure 6 - Deployment pie chart and summary tables.

The actual deployment percent is shown in a pie chart. Here, users can visualize the percentage of ton-miles served by the selected energy technology and the percentage served by diesel. Hovering provides absolute values of ton-miles per year. The cost of avoided emissions represents an important policy metric for the evaluation of a deployment scenario’s economic and environmental potential and is output in a small table to the right of the pie chart. Other important scenario metrics are summarized in the bottom-most table.

3.2.2. Network Map

Network-level information can be accessed by interactively hovering over the network map.

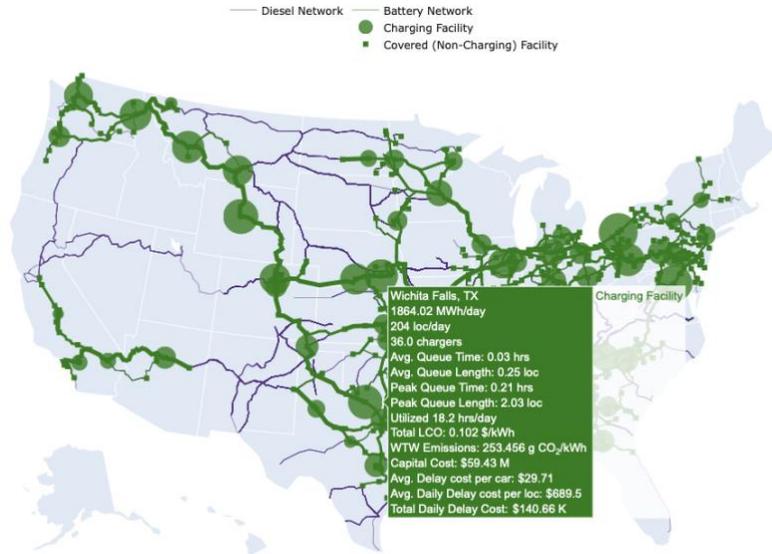


Figure 7 - Network map showing location-specific information from hovering.

Each of the bubbles on the network represents a refueling/charging facility required to serve locomotives on the rail network, as in Figure 7.^x The network’s nodes contain location-specific information on their size (refueling/charging capacity), traffic (in number of locomotives), delay time, daily utilization, levelized cost, emissions, and capital costs. This information is accessible at every facility location.

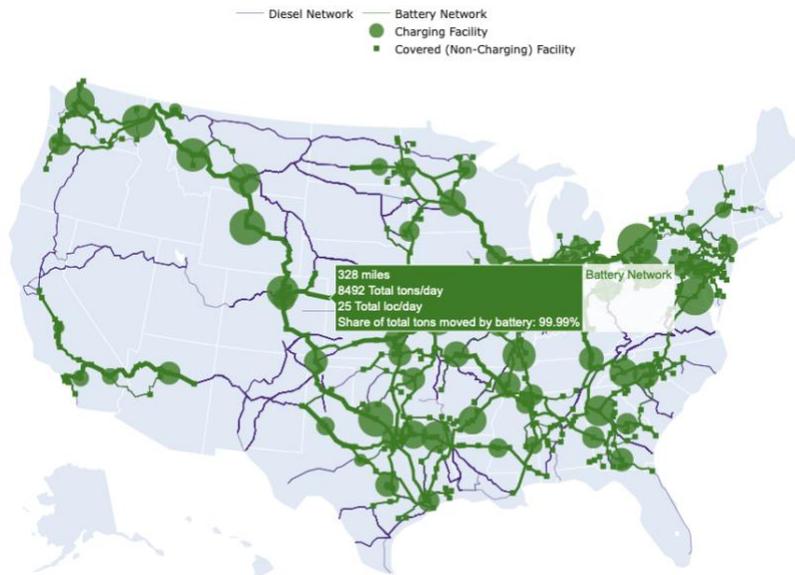


Figure 8 - Network map showing track-specific information from hovering.

Track-specific information is also output for tracks served by the selected energy technology, as in Figure 8. By hovering over them, users can see the track segment’s length, the daily flow, and the share of goods moved by the selected energy technology.

Template Revision History

Date	Version	Description	Author
December 2022	1.0	Initial Version	Northwestern University Transportation Center and Argonne National Laboratory

This dashboard has been developed by Northwestern University Transportation Center (NUTC: Hani S. Mahmassani, Pablo Durango-Cohen, Adrian Hernandez, Max Ng) and Argonne National Laboratory (ANL: Amgad Elgowainy, Michael Wang, Joann Zhou, Nazib Siddique) as part of the Lowering CO₂: Models to Optimize Train Infrastructure, Vehicles, and Energy Storage (LOCOMOTIVES) project funded by the Advanced Research Projects Agency - Energy (ARPA-E) under the United States Department of Energy (USDOE).

ⁱ URL: <https://www.transportation.northwestern.edu/research/featured-reports/locomotives.html>

ⁱⁱ max.ng@u.northwestern.edu (Max Ng), AdrianHernandez2025@u.northwestern.edu (Adrian Hernandez)

ⁱⁱⁱ URL: <https://nufriend.transportation.northwestern.edu>

^{iv} Only applicable when “Battery-electric” is selected for the “Energy” parameter.

^v These flows are estimated from the Carload Waybill Sample, compiled by the Surface Transportation Board: <https://www.stb.gov/reports-data/waybill/>.

^{vi} Note that all commodity groups are decarbonized and this parameter only affects the visualization of results.

^{vii} *ibid* (iv).

^{viii} *ibid* (iv).

^{ix} So long as the new route’s travel distance does not exceed 1.5 times that of the baseline route’s travel distance.

^x Note that refueling/charging facilities are only assumed to be necessary for hydrogen or battery-electric locomotives, as biofuels and e-fuels are considered to be drop-in fuels and can utilize existing diesel refueling facilities.