NREL
Transforming ENERGY

Transforming ENERGY Through SUSTAINABLE MOBILITY

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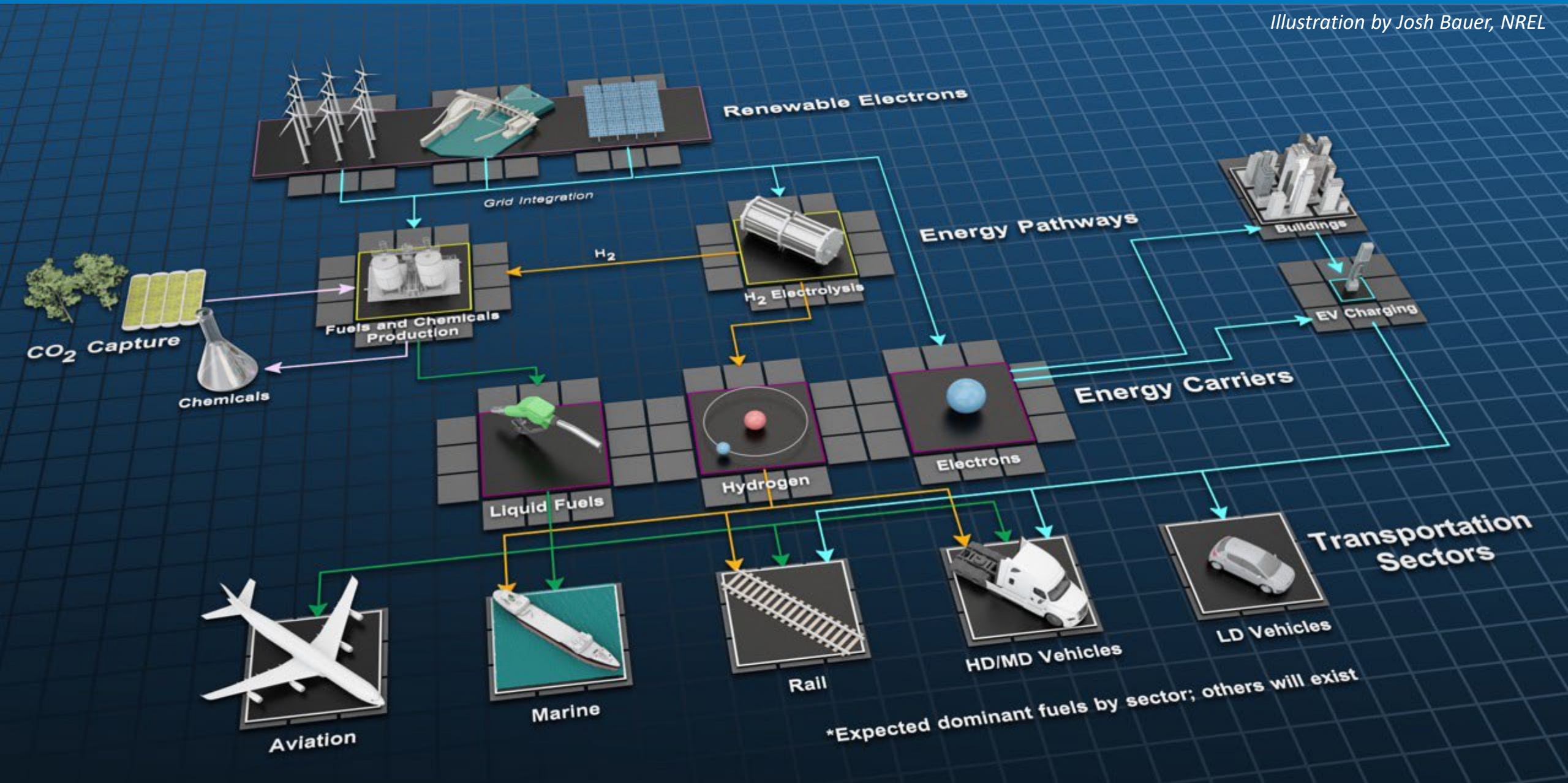
Photo from iStock 1268203592

NREL's Vision for Decarbonizing the Transportation Sector



NREL Center for Integrated Mobility Sciences

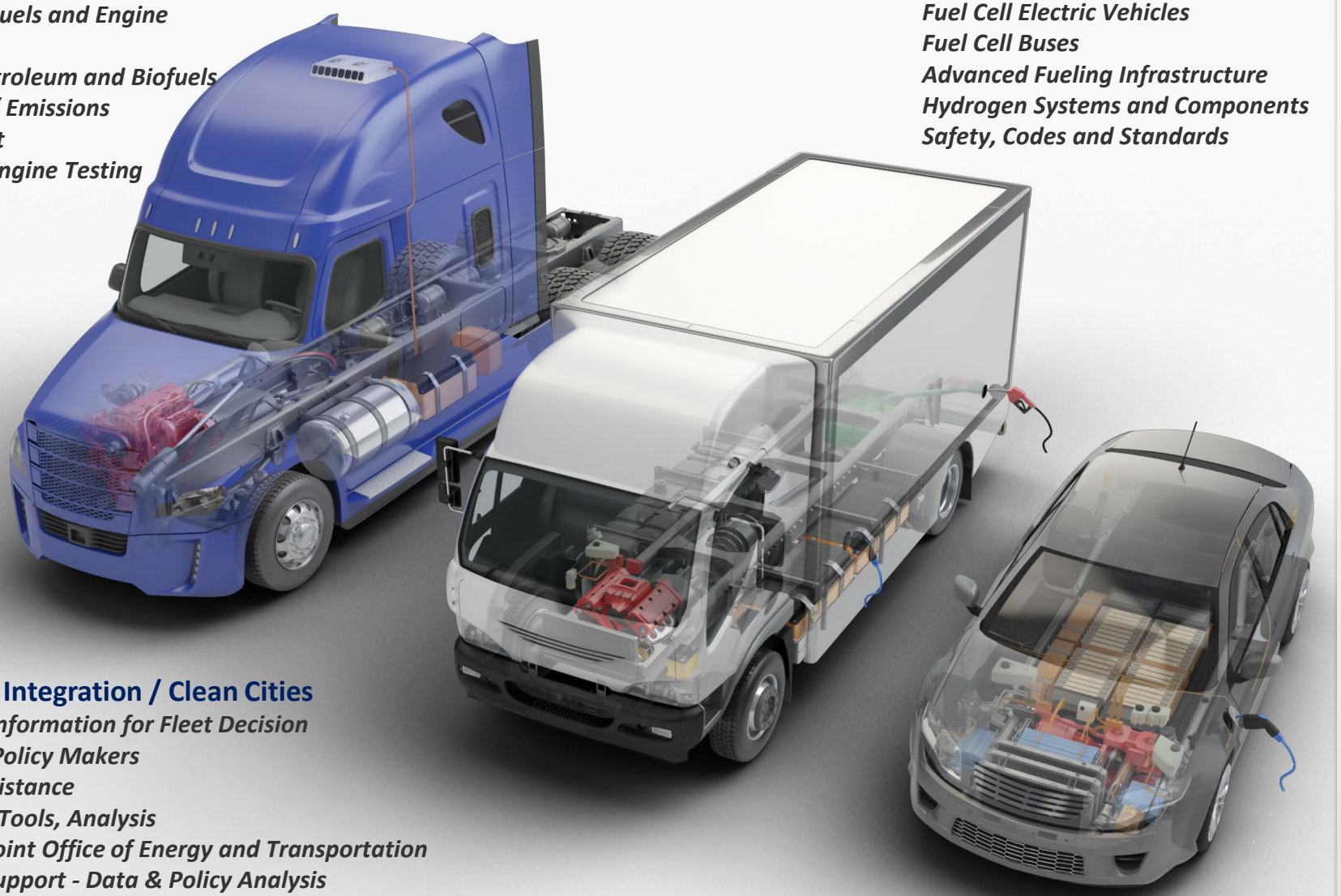
https://www.nrel.gov/transportation/research.html

Advanced Combustion / Fuels

CoOptima – Fuels and Engine Optimization
Advanced Petroleum and Biofuels
Combustion / Emissions Measurement
Vehicle and Engine Testing

Hydrogen and Fuel Cells

Fuel Cell Electric Vehicles
Fuel Cell Buses
Advanced Fueling Infrastructure
Hydrogen Systems and Components
Safety, Codes and Standards



Technology Integration / Clean Cities

Guidance & Information for Fleet Decision Makers and Policy Makers
Technical Assistance
Online Data, Tools, Analysis
Support for Joint Office of Energy and Transportation
Regulatory Support - Data & Policy Analysis

Commercial Vehicle Technologies

Technology Field Testing & Analysis
Big Data Collection, Storage & Analysis
Transit Bus Evaluations
Vehicle Systems Modeling
Super Truck and 21st Century Truck
Vehicle Thermal Management

EV Grid Integration

Extreme Fast Charging – 1+ MW
Vehicle-to-Grid Integration
Integration with Renewables
Charging Equipment & Controls
Fueling Stations & Equipment

Advanced Energy Storage

Thermal Characterization / Management
Life/Abuse Testing and Modeling
Computer Aided Engineering
Electrode Material Development

Advanced Power Electronics and Electric Motors

Thermal Management
Advanced Heat Transfer
Thermal Stress and Reliability

Mobility Systems

Energy Efficient Mobility Systems

Connected and Autonomous Vehicles
Vehicle Systems Modeling
Technology Adoption
Cost of Ownership Modeling
SMART Cities Columbus

Energy Storage

High-performance, **long-lasting**, **cost-effective**, and **safe** batteries are needed to power the next generations of electric vehicles.

NREL's battery research spans:

- Battery lifespan, performance, and degradation studies
- Extreme fast charge batteries
- Battery materials synthesis
- Machine learning for advanced battery design
- X-ray diagnostics of battery materials
- Multi-scale modeling of battery physics.

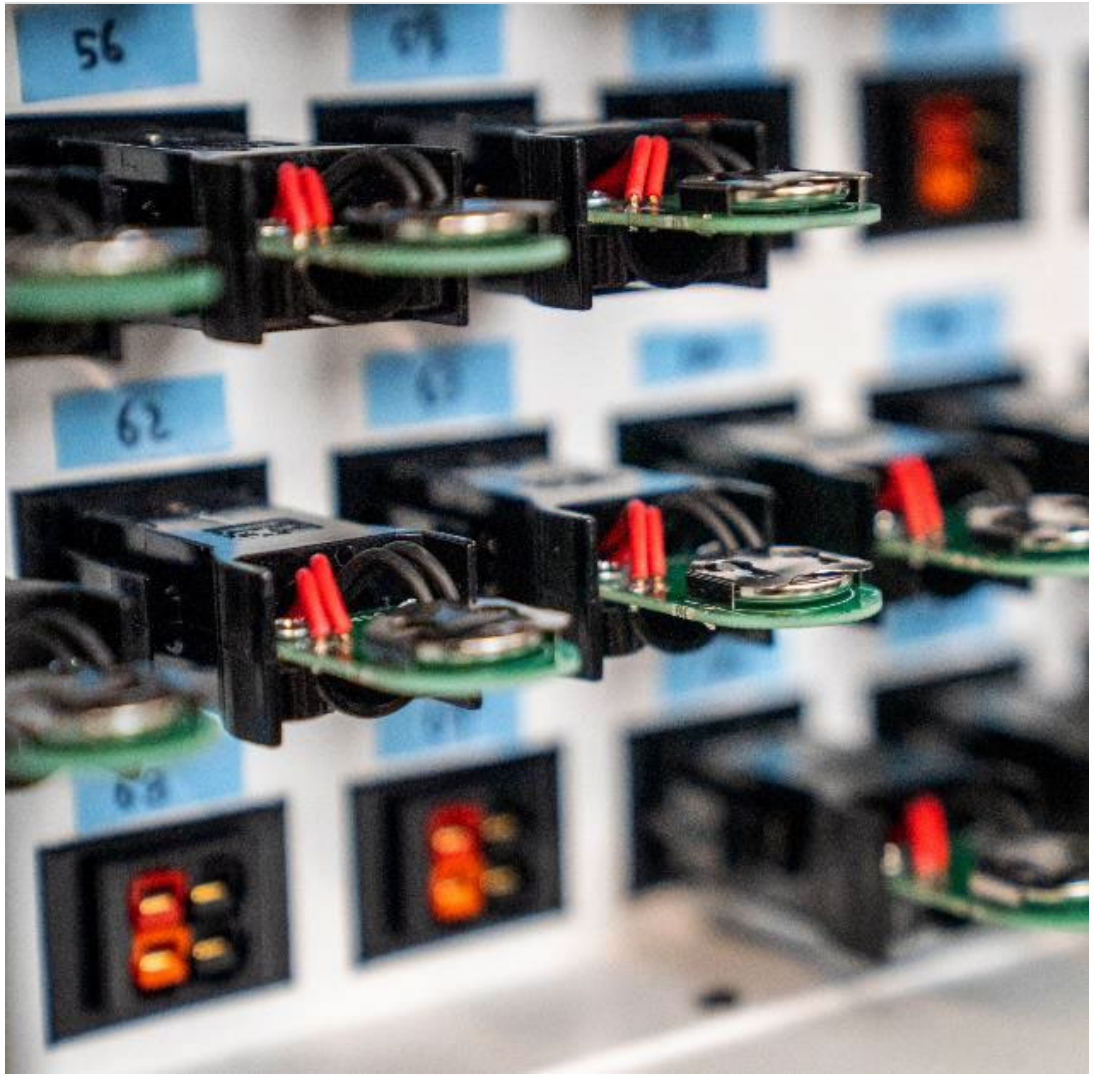
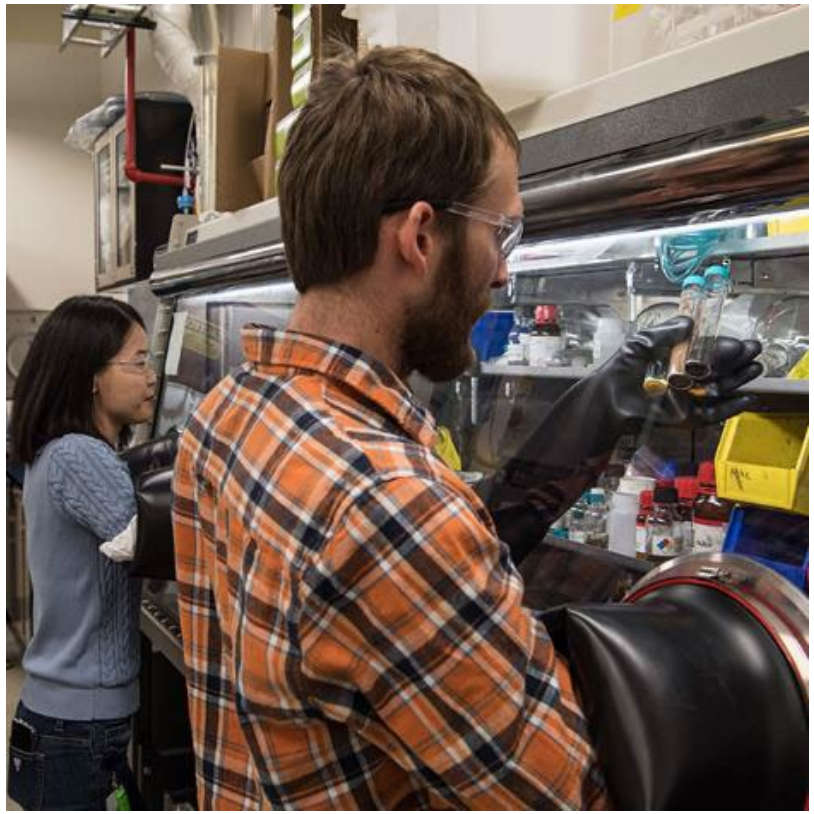
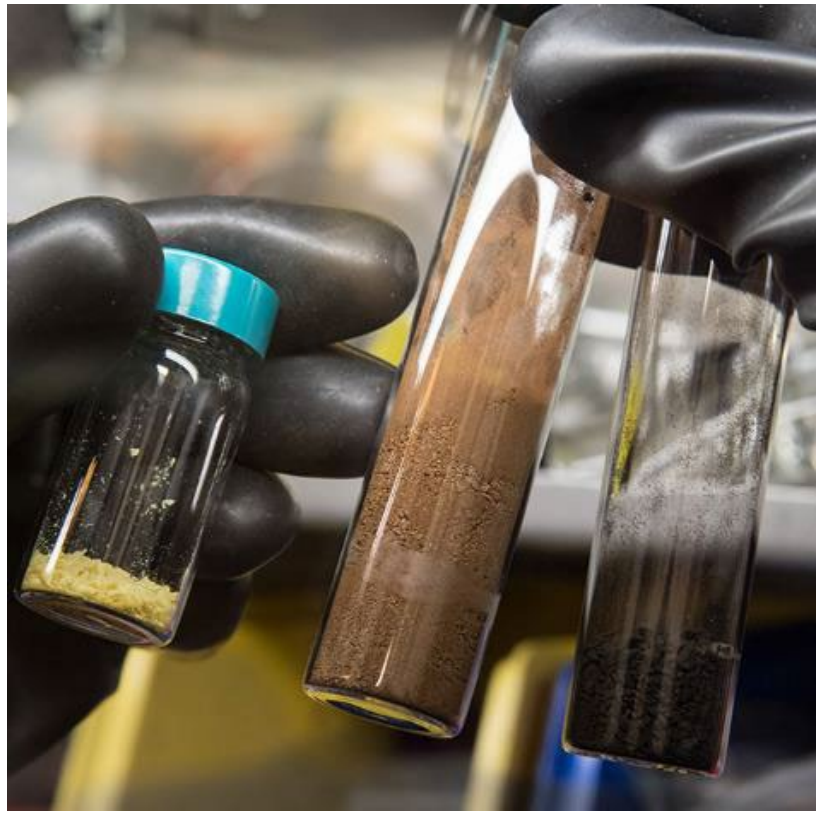


Photo by Werner Slocum

Leading the Charge to Better-Performing Lithium-Ion Batteries

NREL leads the Silicon Consortium Project, which brings together researchers from six national laboratories to eliminate barriers to developing smaller, cheaper, better-performing lithium-ion batteries by aiming to replace graphite anodes with silicon.





Photos by Dennis Schroeder, NREL 61175 and 61173 (left to right)

DOE's Leading Commercial Vehicle Technologies Lab for Over 20 Years

NREL's Robust Commercial Vehicle Research and Industry Partnership Experience

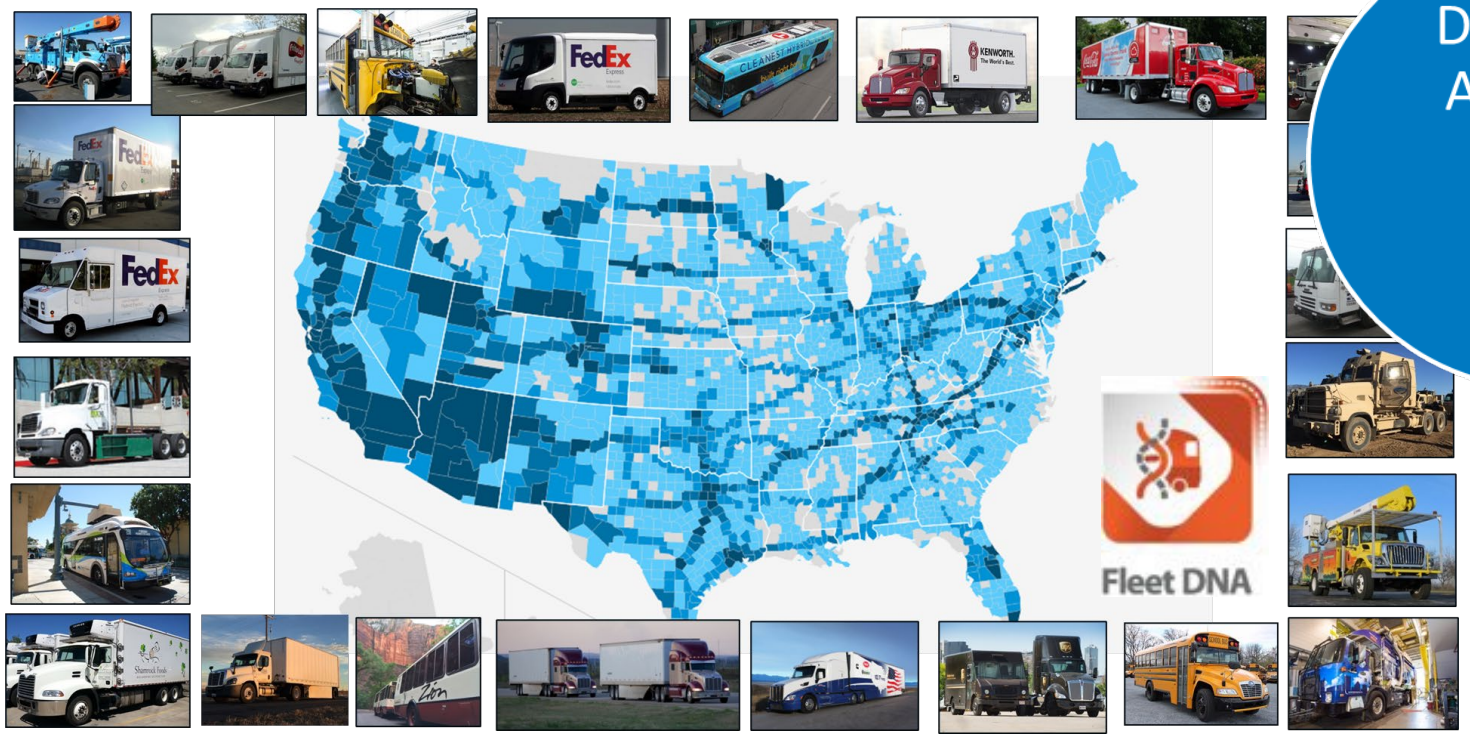
DOE Commercial Fleet Evaluation projects	Real World Fleet Data and Advanced Analytics
SuperTruck I, II, & III	DOE Infrastructure Corridor projects
MD/HD CAV experience	Freight Mobility research
MD/HD Technology Development projects	Airport and Port Electrification and Mobility projects

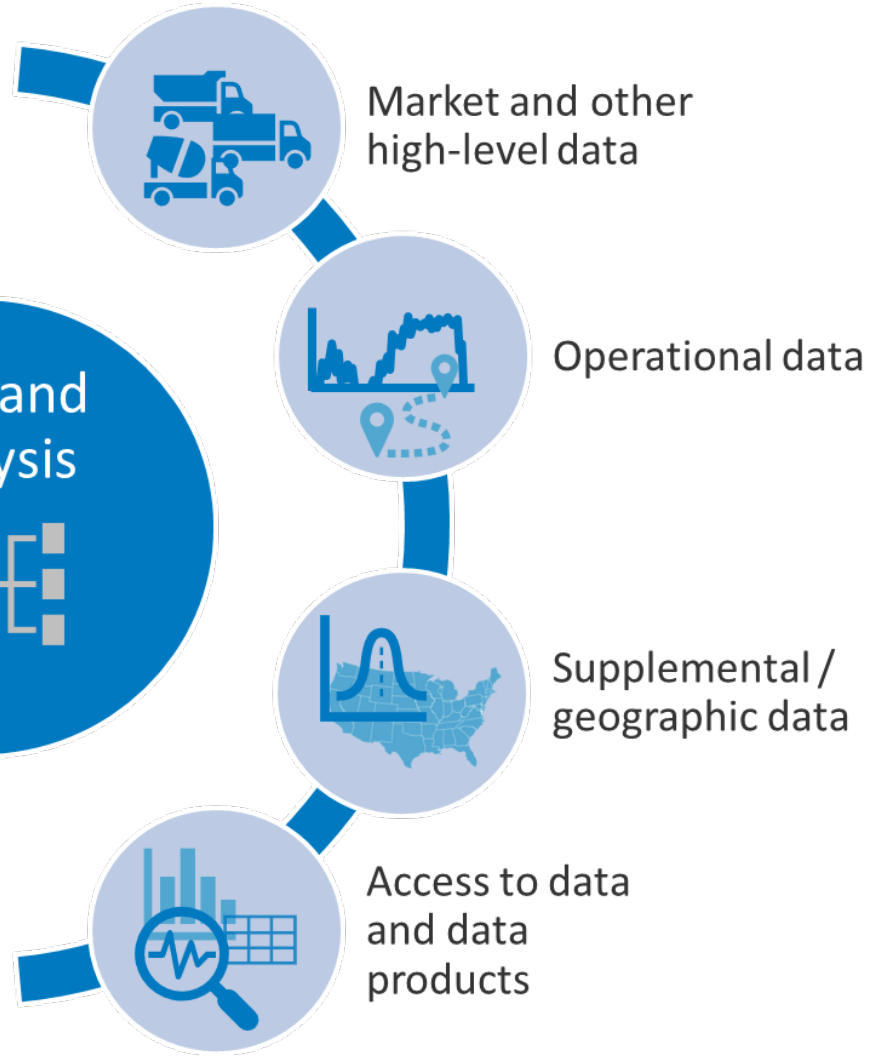
… Over 50 Partners in Total

FleetREDI - *Fleet Research, Energy Data, and Insights*

GOAL

Provide research community with ***updated, integrated, and comprehensive commercial vehicle data and intelligence*** for strategic planning, R&D portfolio development, and current and future R&D projects.





Transportation Research Analysis Tools (sample)

FleetDNA: Secure data repository of commercial fleet transportation data used to help vehicle manufacturers and developers optimize vehicle designs and inform vehicle technology deployment decisions

DRIVE & DriveCAT: **D**rive-Cycle **R**apid **I**nvestigation, **V**isualization, and **E**valuation Tool – uses GPS and CAN data to characterize vehicle operation and produce custom vehicle drive cycles based on real-world activity

FASTSim: **F**uture **A**utomotive **S**ystems **T**echnology **Sim**ulator - conduct fast parametric sweeps to evaluate the impact of technology improvements on efficiency, performance, cost, and component life in conventional and advanced vehicles.

EVI-Pro Suite: **E**lectric **V**ehicle **I**nfrastructure **Pro**jection Tool - Identifies electric vehicle charging infrastructure and projects future consumer demand for charging infrastructure by region area based anticipated number of PEVs.

Route E - predicts the energy consumption of a given vehicle over a proposed route accounting for driving conditions such as anticipated traffic congestion, traffic speed, road type (including number of lanes), road grade, and turns

T3CO: Transportation Technology Total Cost of Ownership tool enables levelized assessments of the full life cycle costs of advanced technology commercial vehicles.

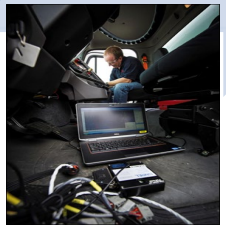
H2FAST: Hydrogen Financial Analysis Scenario Tool

BLAST: **B**attery **L**ifetime **A**nalysis and **S**imulation **T**ool – Pares battery degradation model with electrical and thermal performance models, used to assess battery lifespan for behind-the-meter, vehicle, and stationary applications.

https://www.nrel.gov/transportation/data-tools.html

“Adaptable” Fleet Evaluation Process

Step 1 Vehicle Inventory and Fleet Coordination



Step 2 In-use Vehicle Data Collection

Step 3 Duty Cycle Analysis

Fleet DNA

DRIVE

DriveCAT

Step 4 Assessment of ZEV Technology and Efficient Operations

FASTSim

RouteE

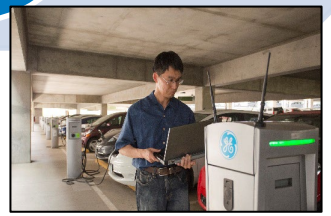
Step 5 Infrastructure Requirements and Charging Strategies

EVI-Pro

Step 6 Cost of Ownership

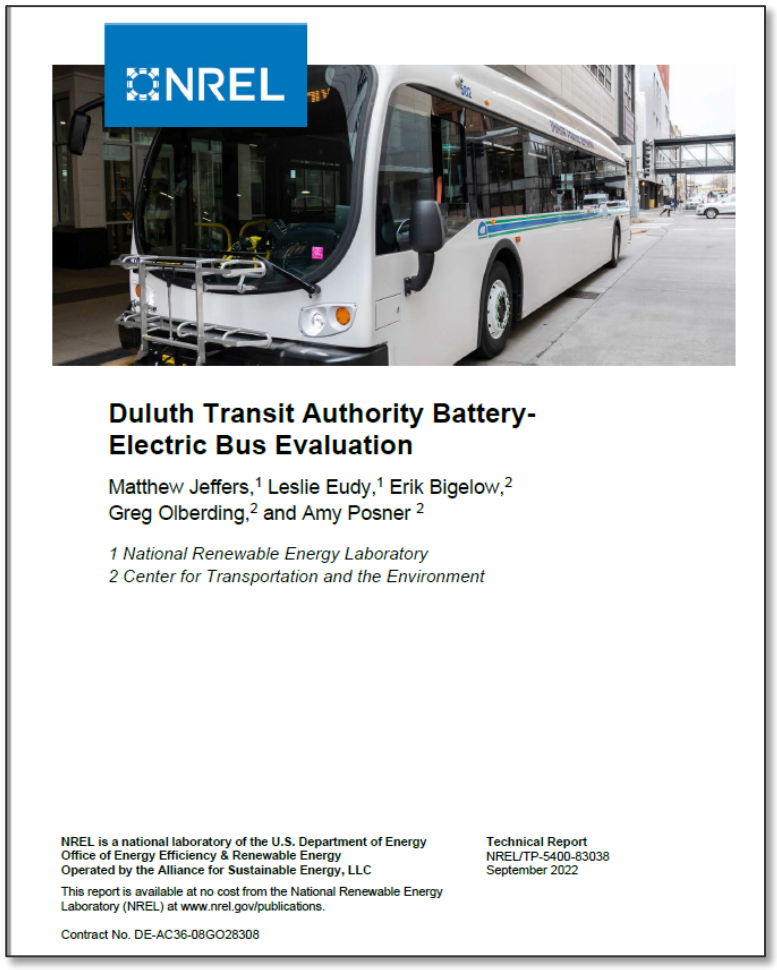
T3CO

Step 7 Detailed Charging Infrastructure Requirements



Step 8 Results / Reporting

Duluth, MN Battery Electric Bus - Cold Weather Evaluation



https://www.nrel.gov/docs/fy22osti/83038.pdf

Summary:

- NREL, CTE conducted study
  - Seven 40-foot Proterra Catalyst EV buses with 440 kWh
  - Ten GILLIG diesel buses as baseline
- Eight 50kW Tritium/Proterra depot chargers
- Data collection “late” 2018 though spring 2021
- All buses equipped with diesel fuel-fired heaters
- Buses parked / charged in doors

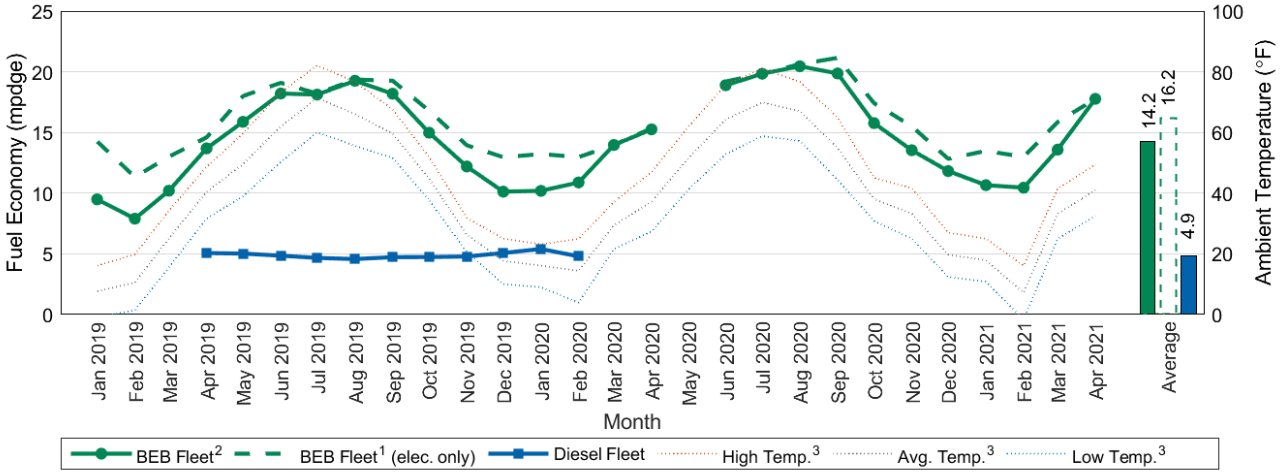
Duluth, MN Battery Electric Bus - Cold Weather Evaluation

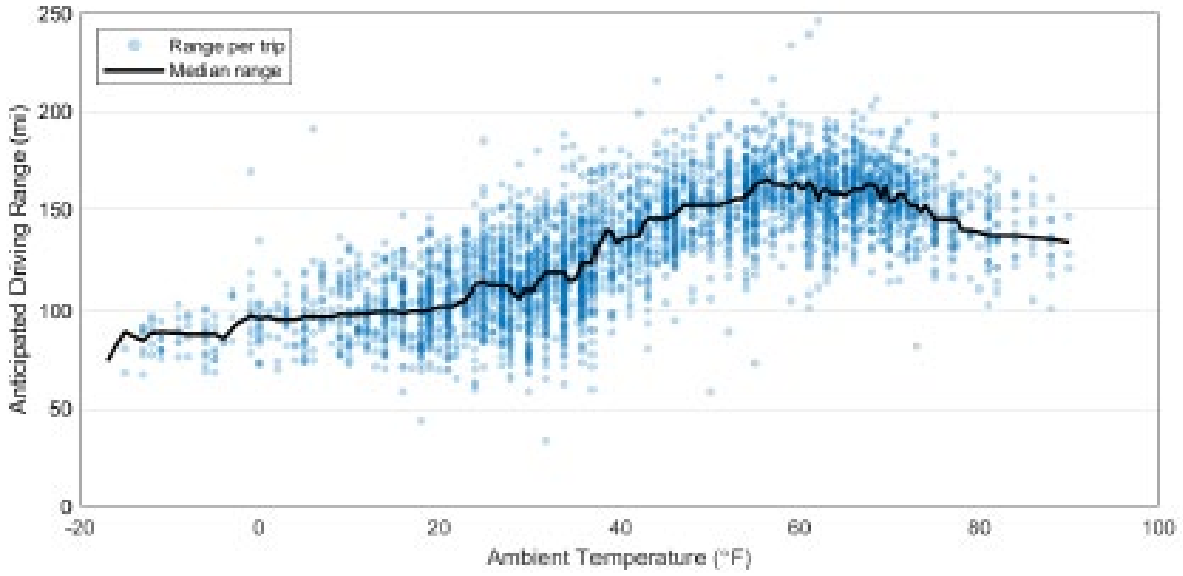
Summary:

- BEBs *averaged* 3x fuel efficiency over the life of the study
  - EV: 14.23 mpdge average
  - Diesel: 4.86 mpdge average
- Cold weather had a greater effect on BEB efficiency compared to diesel
- BEB range correlated with ambient temperature
  - Peak range 165 miles between 55-60 F
  - ~33% decreased range at 25-30 F
  - ~20% decreased range at 85-90F

Key Factors

- HVAC for cold and hot ambient conditions
- Secondary cold weather impacts:
  - Electric defrosters
  - Regen braking controls during snowy conditions





Other Information Resources

- **EPA/DOE Fuel Economy.gov – "Fuel Economy in Cold Weather"**
  www.fueleconomy.gov/feg/coldweather.shtml
  - 20°F vs 77°F - including impacts from heating
    - EV fuel economy can drop roughly 39% in mixed city and highway driving,
    - EV range can drop by 41%"
  - When the cabin heater is not used,
    - EV fuel economy is 8% lower
    - Driving range is about 12% lower.

- **5 Tips from Electrify America website**
  https://media.electrifyamerica.com/en-us/fivetips-charging-electric-vehicles-cold-weather
  1. Charging may take longer
     - INL Study found EV battery accepted 36% less energy at 32 F vs. 77 F
  2. Pay attention to overnight changes in your EV's range
  3. Plan your charges
  4. Park indoors when you can
  5. Understand your EV's cold weather features

Summary of Key Needs Moving to 100% ZEB Fleets

To achieve a successful transition to 100% ZEB transit fleets in the coming years, some of the greatest needs include:

1. Sustained progress from the vehicle, equipment, and infrastructure manufacturing base is needed to continue ***driving down costs, improve reliability and optimize performance***.
2. ***Expansion of charging and fueling infrastructure*** is a fundamental need that will require coordinated efforts and forward-looking planning by transit agencies, utilities, and developers.
3. Comprehensive and standardized training programs to ***develop a highly skilled workforce*** that can improve the efficiency and cost of maintaining ZEB equipment while creating new jobs and ensuring safety.
4. ***Financial support*** for purchasing, installing, and operating ZEBs and the necessary fueling/charging equipment. Federal and State funding for ZEBs and related charging/fueling infrastructure are critical to achieving reasonable payback on the upfront costs, especially in the early years.

These "Key Needs" are supported by the detailed technical discussion throughout the body of the Comprehensive Review


Thank You
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