Transforming **ENERGY** Through Computational Excellence

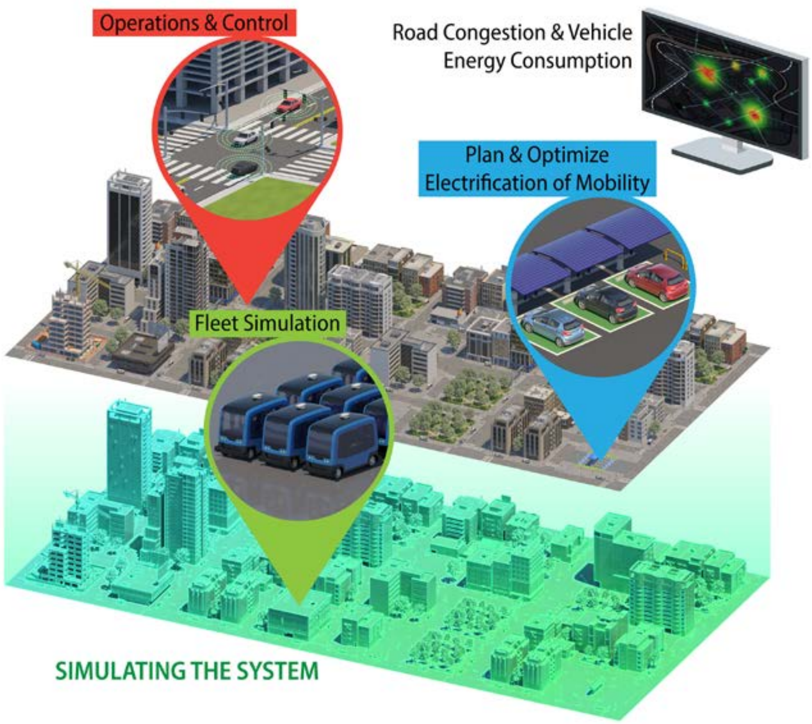
A Virtual Test-Drive of Energy Scenarios

Researchers at the National Renewable Energy Laboratory (NREL) are developing groundbreaking tools to decarbonize transportation systems and reduce emissions.

While planning for growing populations and related demands on aging infrastructure and energy systems, local transportation departments and city planners are facing significant, complex challenges. By capitalizing on rapidly advancing technology, and taking new approaches to planning and operations, NREL addresses mobility and energy-centric challenges including cost and energy efficiency, emissions reduction, decarbonization, and congestion.

Technological advancements bring new options into the public sphere—creating additional opportunities and variables in the already shifting and complex decision-making process.

How do decisions at individual, community, and regional levels affect an entire transportation ecosystem? How can planners develop or enhance systems to keep pace with demands, anticipate future choices influenced by emerging trends, and reach decarbonization goals?



A simulation environment can rapidly provide control and planning that apply to the corresponding system before making capital investments in new infrastructure and software. *Illustration by Besiki Kazaishvili, NREL*

Core Competencies and Capabilities

To empower operation and planning of future mobility systems, NREL offers significant breadth, depth, and integration of tools and capabilities, supported by state-of-the-art equipment, leading-edge techniques, and expert staff.

NREL has harnessed the power of artificial intelligence (AI), machine learning (ML), high-performance computing (HPC), at-scale data management, and visualization to create virtual replicas—digital twins—of existing transportation and mobility systems. These replicas enable visualization and simulated experimentation, enhanced near-real-time operations, and reactive representations of the future.

Measurement of Transportation Systems at Scale: NREL integrates multi-source data with high-fidelity ML models to estimate energy use, determine where and why large systems are losing energy, and model reactions to changes in conditions and controls.

Using probe data gathered from GPS-instrumented vehicles, ML, and visual analytics, NREL researchers uncover hidden performance issues across regions, around the clock. For example, morning and afternoon peaks are usually given special attention by traffic engineers. However, in one study of a mall area, noon showed higher traffic volume than other times.

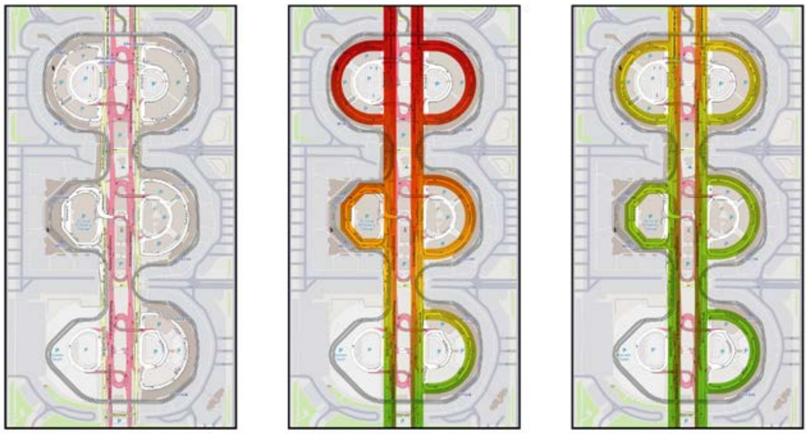
Such measurements inform strategies for improving traffic flow and reducing energy loss; strategies are assessed through simulations and validated through field studies.

Large-Scale System Simulation: High-fidelity simulations determine the greatest energy efficiency options and ensure that new traffic control strategies—like real-time smart connected traffic signals, alternative routing, speed harmonization, ramp metering, and dynamic speed limits—can be validated and calibrated. Urban planners, technology developers, automakers, and fleet operators use these insights to develop systems and equipment that streamline commutes and deliveries and optimize travel time, highway speed, and safety.

Fleet Simulation: Simulations also allow for the investigation and optimization of fleet operations, such as transit and freight, under emerging technologies, including electric and autonomous vehicles. Discrete event simulation—which can be executed very quickly—recreates reality with over 90% accuracy and with no calibration. For example, simulating one day of operation of a large airport fleet system takes between one and two seconds of computing time. Models can be driven by simulation-generated data when real-world data are not available.

Operations and Control: Using data science and simulation, researchers can recommend specific improvements for signal controllers and can decrease fuel use for vehicles at intersections. In one study, NREL developed an advanced control algorithm consistent with what could be deployed in the field. The team found that significant time and energy savings could be enabled by the control algorithm.

Planning and Optimization of Infrastructure: NREL researchers developed a planning model for parking and curb modifications and shuttle fleet enhancements. The model—developed for the Dallas Fort Worth International Airport (DFW) over a 20-year horizon—explores the impacts of congestion pricing on mode choice behavior and network congestion. Tens of thousands of operational circumstances



(a) The Open Street Map representation of DFW. (b) A high demand day with no intervention. (c) The same demand day with a simple intervention policy.

NREL developed network heat maps to model approaches that reduce congestion using simple intervention policies. Dallas Fort Worth International Airport. *Image by Christopher Schwing, NREL*

can be considered simultaneously to produce planning decisions robust to variable operating environments. The modeling framework is generalizable to other airports and planning contexts, as well as beyond airports to municipalities, major employment centers, shopping distícts, commercial trucking, etc.

NREL can also analyze the impact of large-scale coordinated electric vehicle charging on the power grid using the Scalable Integrated Infrastructure Planning (SIIP) modeling framework. SIIP simulations can identify needed power system infrastructure to host large-scale electric-vehicle adoption and inform charging infrastructure decisions. The methodology can enable studies of other demand responsive energy agents—such as buildings, battery storage, and microgrids—in order to inform the design of a more integrated, smarter grid.

Partner With Us

Collaborate with NREL to analyze and solve your current and future complex energy, efficiency, and transportation operations challenges.

Learn More About NREL Computational Science
https://www.nrel.gov/computational-science

Contact Us

Technical
Wesley Jones
wesley.jones@nrel.gov
303-275-4070

Partnerships
Steve Gorin
stephen.gorin@nrel.gov
303-384-6216

Cover image from iStock 1054579036

NREL Transforming ENERGY

National Renewable Energy Laboratory
15013 Denver West Parkway, Golden, CO 80401
303-275-3000 • www.nrel.gov

NREL prints on paper that contains recycled content.

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC

NREL/FS-2C00-81392 • February 2022