NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Efficient Mobility Summit

Transportation and the Future of Dynamic Mobility Systems

In a world that is increasingly connected, a new school of thought has emerged that views transportation as a more dynamic mobility system—a meaningful change from today's transportation infrastructure that was designed to accommodate linear trips and single-occupant vehicles.

On October 27, 2015, the U.S. Department of Energy's National Renewable Energy Laboratory (NREL) brought together local and national thought leaders to discuss the convergence of connectivity, vehicle automation, and transportation infrastructure investments at the *Future Energy Efficient Mobility Workshop*. NREL provided a collaborative setting for exploration of opportunities and challenges that will accompany a more connected vehicle and mobility infrastructure. Meeting participants represented a variety of organizations, including federal, state, and local agencies, automakers, national laboratories and leading research institutions, transportation data providers, and civil engineering firms.

The half-day workshop was held in conjunction with the Colorado Department of Transportation's (CDOT) Transportation Matters Summit and featured four panel sessions that showcased perspectives on efficient mobility from federal and state agencies, automakers and their suppliers, transportation data providers, and freight companies. The following summary provides highlights from the meeting's exchanges of ideas and existing applications.

Vehicle Connectivity and Automation

Automakers and their suppliers are rapidly investing in systems that provide drivers with more freedom and enhanced safety through increased vehicle automation and connectivity. Increased vehicle automation addresses the primary cause of most automobile accidents—human error—and has the potential to provide drivers with extra time, an increasingly scarce resource.

In addition to these safety and quality-of-life enhancements, vehicle innovations have the potential to tap significant energy savings opportunities. As an example, more efficient routing alternatives can be derived using real-time traffic flow and road conditions.

Participants at the *Future Energy Efficient Mobility Workshop* gather around a Hyundai Tucson Fuel Cell in front of NREL's Energy Systems Integration Facility, following a tour of the facility. *Photo by Ellen Jaskol, NREL 35095*

Such intelligent vehicle systems can reduce overall transportation system congestion, producing notable societal benefits.

Connected and automated vehicle parking presents a visual example of these benefits, considering the extraordinary amount of time and fuel that is wasted while looking for parking. If vehicles are able to park autonomously, not only would the traveler gain time and save fuel, but parking structures themselves could be designed more efficiently—with lower clearances and tighter vehicle spacing, freeing up valuable real estate. Taking this one step further, if car-sharing services adopted autonomous vehicles, travelers would no longer need to retrieve or return the original vehicle that they arranged for. The car would simply drive to its next programmed destination.

Connected and automated vehicles also complement the electrification ecosystem, increasing efficiency and use of the vehicle-charging infrastructure. Connectivity can further enhance smart vehicle charging capabilities and better optimize hybrid vehicle battery discharging.

**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.**

Many of these scenarios are being put to the test through real-world technology demonstrations. The Drive Me Project in Gothenburg, Sweden, a collaboration between Volvo and Swedish government agencies, will put 100 vehicles equipped with sophisticated on-board sensors, controls, and intelligent network systems on public roads and in the hands of consumers. The vehicles will have the ability to handle complicated driving scenarios and allow for seamless transitions from automated to human control. The project is expected to commence in 2017.

Several companies are experimenting with retrofitting existing vehicles and testing the integration of new vehicle components. For example, Arrow Electronics created a prototype semi-autonomous Corvette for the annual Indianapolis 500 automobile race, upgraded with a military-grade GPS system, infrared cameras, and automated controls. The vehicle was retrofitted so that its driver—a former racecar driver and quadriplegic—could effectively steer and control braking while traveling at speeds as high as 100 miles per hour.

The integration of new technologies with existing vehicles provides much greater market potential and a platform for increased deployment of next-generation vehicle automation and connectivity technology. This interaction presents a significant opportunity in the overall transportation system efficiency that may warrant deeper exploration.

Data and Intelligent Systems

As vehicles and transportation systems become more automated and connected, they will inevitably produce and rely on more data. The extent to which travelers, transportation planners, automakers, and information technology companies harness and utilize all of this data will be critical in making roadways more efficient, safer, and less energy intense. As part of its vision for efficient mobility, NREL has proposed reimagining transportation as a system of travelers and decision points, rather than a static system of drivers and roads. This shift in approaching transportation as a system hinges on interoperability, which will depend highly on effective use of disparate data sources.

Applications that marry traffic and energy efficiency calculations with individualized incentives can provide travelers with both information and motivation to make more energy-efficient travel choices. The challenge in appropriately incentivizing efficient travel behavior requires a solution that is appealing to the user and the transportation system at large, by also benefiting other system users.

Metropia, a leading company in providing efficient travel incentives, seeks to do just that through the deployment of a mobile application. Metropia predicts and suggests more efficient travel routes from real-time and historical traffic data, and to encourage travelers to follow the more efficient alternative, the company rewards travelers with points they may redeem for prizes, such as gift cards. The concept was in part inspired by efforts in Colorado to accommodate the increasing traffic demand that accompanies the state's annual ski season. Previous research had shown that getting one out of every 10 drivers to change their departure time reduced the overall average travel time from two hours to 80 minutes. Connecting system and individual benefits to realize these efficiencies requires real-world data on traffic conditions, as well as understanding individual preferences and travel options.

Workshop participants included officials from the U.S. Department of Energy, state transportation departments, automotive manufacturers, technology suppliers, telecommunications and information technology companies, and mobility service providers. *Photo by Ellen Jaskol, NREL 35105*

A sizable industry has emerged to support the data needs of decision-makers by providing insight and access to data from disparate sources. One company that supports these needs, Inrix, began modestly by collecting basic GPS data to provide real-time traffic information. It has since evolved to include 85% of the 10-million already connected vehicles on the road in addition to roughly five million miles of roadway. Access to this vast collection of data allows government agencies to better plan and manage roadways, while providing en route information to travelers.

Many transportation data companies are expanding their offerings into the cloud and offering value-added services, such as tools to manage parking more efficiently—an approach that can be married with vehicle automation. According to Inrix, vehicle parking is responsible for nearly one-third of all of the miles driven in downtown Los Angeles. To make the case for greater implementation of value-added services in the cloud, it will be critical to quantify the benefits that result from a reduction in vehicle miles travelled due to parking.

There are a number of other sizable opportunities that can utilize data to realize energy savings by enhancing the connectivity of travelers and infrastructure. In particular, the timing of signals provides immediate opportunities to enhance energy security and emergency preparedness.

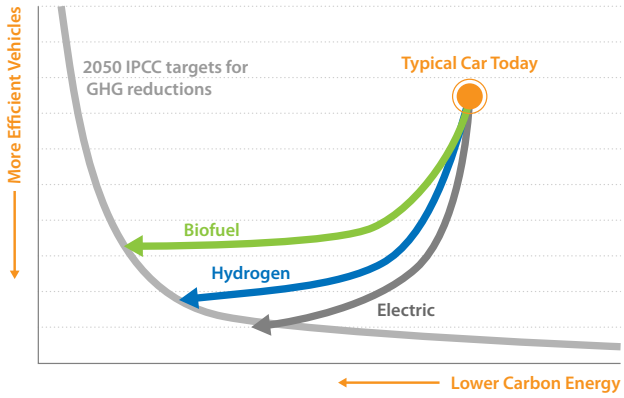
Freight and Mobility

Creating efficiencies to move consumer products across the United States' highways provides similar opportunities to reduce energy consumption. Currently, the fuel used in the movement of freight accounts for 26% of our nation's petroleum use and a significant expense for private industry, one that can exceed driver wages.

According to the North American Council for Freight Efficiency (NACFE), the average truck is driven about 500 miles a day and consumes roughly $45,000 in diesel fuel each year. The freight industry has already developed technologies that significantly impact petroleum usage through lightweight trailers, enhanced aerodynamics, and greater use of alternative fuels. These technologies have made it possible to operate freight vehicles using half the amount of power that was required in the past. Working with government agencies can further enhance the energy efficiency of freight vehicles by establishing solutions such as designated trucking lanes and continuing to regulate vehicle emissions and design.

In addition to these options, NACFE is investigating a number of technologies that can reduce fuel consumption—including telematics, vehicle automation, platooning, and increased electrification. Semi-automated truck platooning, which utilizes wireless controls to dynamically manage and decrease vehicle spacing, reduces aerodynamic drag to increase fuel efficiency. Increased automation and connectivity could allow drivers to select more efficient routes and platoon with other drivers. Automation could alleviate the monotony that drivers experience from driving several hundreds of miles a day.

If these technologies are deployed using electric-drive or biodiesel-powered vehicles, energy savings for freight could increase even more. Further, there is opportunity for freight vehicles and cars to work together through cloud-based systems that synchronize traffic patterns, manage road usage, and leverage partnerships with ride-share services that could move both goods and people.



NREL seeks to dramatically reduce energy use and greenhouse gas emissions through the integration of multiple sustainable mobility strategies, including energy efficient vehicle technologies and less carbon-intensive fuels.

Federal and State Initiatives

To support many of the opportunities in connectivity and automation, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) is working to bring its SMART Mobility framework, or "Systems and Modeling for Accelerated Research in Transportation," to the forefront on a national level. The agency plans to do so through collaborative research efforts of multiple national laboratories that will increasingly approach transportation as a collection of mobility systems. To identify key areas for the adoption of new transportation priorities, EERE and its labs established five pillars that will help to define and establish transportation as a system:

1. **Connected and Automated Vehicles** – Quantify the energy impacts, inform policy and research, and identify additional technology opportunities enabled by connected and automated vehicles
2. **A Systematic Approach to Vehicles and Fueling Infrastructure** – Establish electrification, shared ride services, and a dynamic charging/fueling infrastructure that is based upon technology capabilities and demographic information to maximize utility
3. **Multi-modal Transportation** – Allow for the seamless movement of goods and people across transportation modes with greater integration that allows for more dynamic system operation
4. **Urban Sciences** – Understand the simulation environment and energy implications of mobility system, through analysis to the city scale to inform policy and city decisions and interactions among urban systems
5. **Decision and Behavioral Science** – Understanding how people, companies, and those along the value chain make decisions with respect to the overall transportation system.

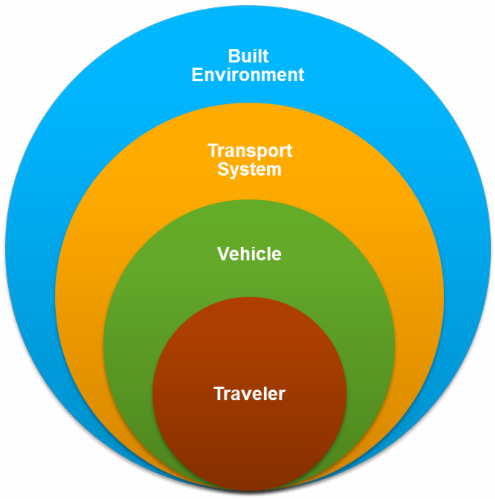
The U.S. Department of Energy is actively pursuing partnerships with other federal agencies, state and local governments, universities, nonprofit organizations, and industry to build new concepts, models, and visions for a new transportation system.

At the state level, CDOT announced its Road X initiative, a $20-million research plan that integrates technology and transportation through public–private partnerships with the stated goal of creating a crash-free, injury-free, delay-free, and technologically transformed travel infrastructure. CDOT hopes to make Colorado one of the most technologically advanced transportation systems in the nation and a leader in safety and reliability. CDOT and NREL have signed a memorandum of understanding that outlines opportunities for collaboration, establishing objectives that will lead to a more efficient mobility system in Colorado.

Transforming the System: Future Research

The workshop made clear that the energy savings potential of next-generation mobility systems is both vast and transformative, but it will require innovative solutions that are both dynamic and multi-disciplinary. A number of questions and comments were raised throughout the workshop that are important to consider as transportation systems continue to advance and evolve. Outstanding questions and areas for future research include:

- The role of the federal government and policy in moving new mobility initiatives forward.
- With increased electrification, gas taxes collected will go down. How will states and local governments fund new infrastructure projects?
- The reliability and interoperability of smart car systems—should drivers worry about technical problems while driving long distances?
- Vehicles connected to a cloud-based system and cyber security.
- The intersection of the ride- and car-sharing economy with driverless vehicles.
- The impacts of self-driving vehicles on public transit—how will public transit be affected?
- How to best use all of the data that are available from drivers and vehicles to continually enhance efficient mobility.
- What are the benefits of a more connected society? What are the benefits of greater mobility?



NREL views transportation as a network of travelers, services, and decision points that are connected by communication technology and decision-making tools—a meaningful change from today's linear trips and single-occupant vehicles.

Collaborating with NREL

For more information about NREL's sustainable transportation research programs, contact:

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NREL's Sustainable Transportation RD&D

As the only national laboratory solely dedicated to renewable energy and energy efficiency, NREL spearheads the research, development, and deployment (RD&D) needed to put sustainable transportation solutions on the road. The laboratory's innovative and integrated approach helps government, industry, and other partners develop and deploy the components and systems needed for market-ready, high-performance, low-emission, fuel-efficient passenger and freight vehicles, as well as alternative fuels and related infrastructure.

For more information on NREL's transportation RD&D capabilities and successes, go to *www.nrel.gov/transportation*.

Workshop Participants

- AECOM
- Antero
- Argonne National Laboratory
- Arrow Electronics
- ATKINS
- Azuga
- City of Lakewood – City Council
- Colorado Department of Transportation
- Colorado Energy Office
- COO Plenary Group
- Denver RTD
- eTuk
- FCA North America
- I-70 Coalition
- Idaho National Laboratory
- Inrix
- Metropia
- National Conference of State Legislatures
- NextEnergy
- North American Council for Freight Efficiency
- Oak Ridge National Laboratory
- Regional Air Quality Council
- Rocky Mountain Institute
- Southwest Energy Efficiency Project
- U.S. Department of Energy
- University of Washington
- Verizon
- Volvo Car Corporation

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