

R&D Trends and Opportunities in Sustainable ITS



IEA Committee on Energy Research and Technology
Evolving Paradigms for Mobility and Transportation Systems of the Future

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(on detail to U.S. Department of Transportation)
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National Renewable Energy Laboratory



Photo by Dennis Schroeder, NREL 17613

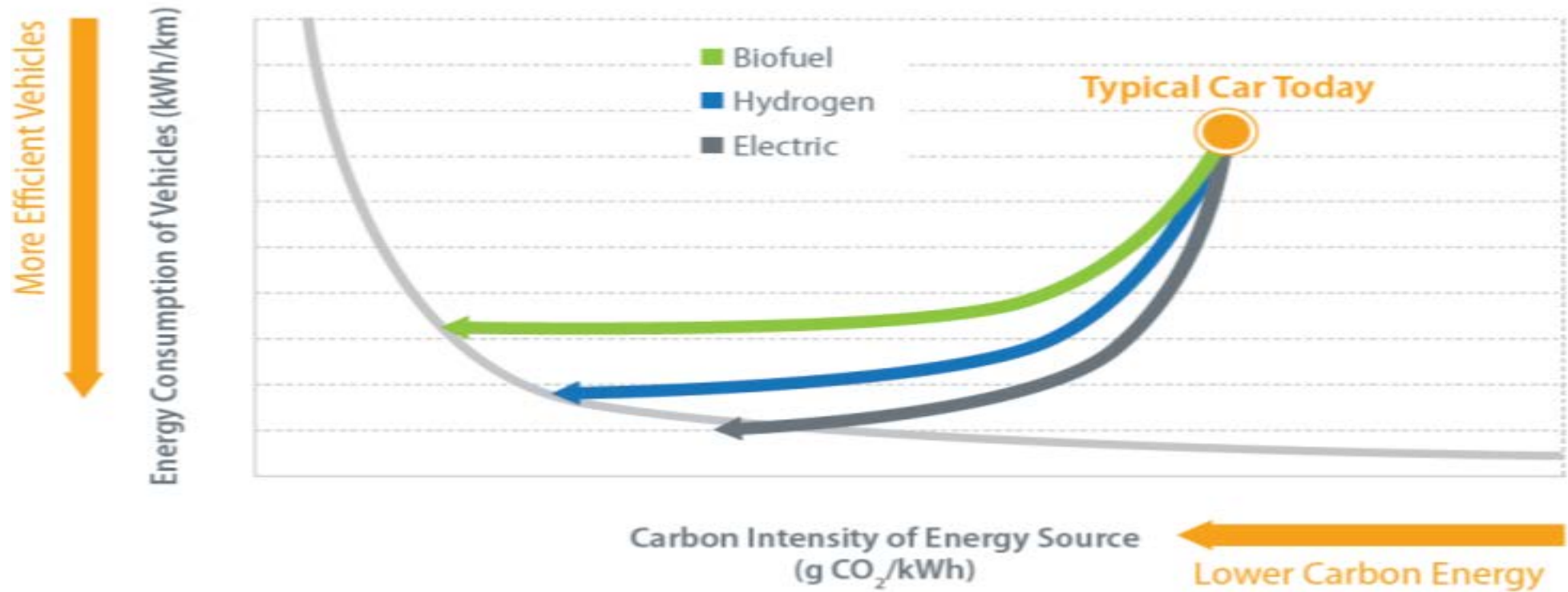
NREL at a Glance

- Only U.S. National Laboratory dedicated to renewable energy and energy efficiency research
- Established in 1979 as Solar Energy Research Institute
- About 2,400 employees with world-class facilities
- Owned by the Department of Energy, operated by the Alliance for Sustainable Energy



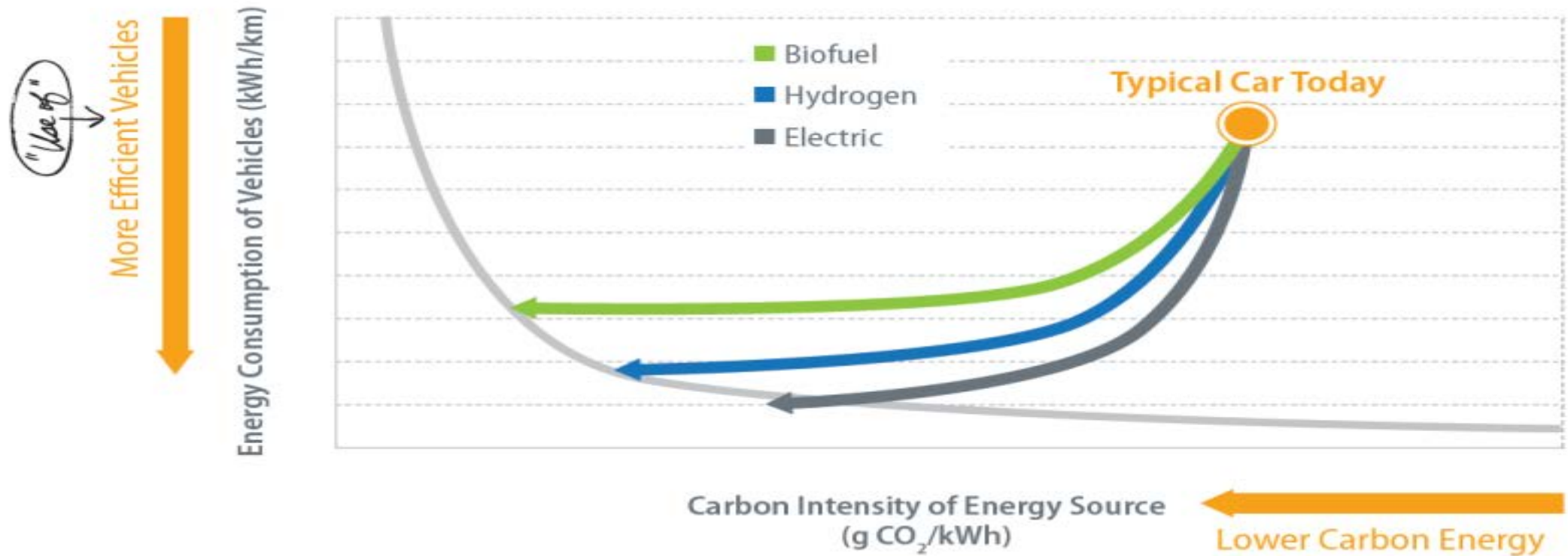
Energy and Environment

– Pathways to 2050 GHG Reductions



For Illustrative Purposes Only

Mobility ↔ Energy/Environment



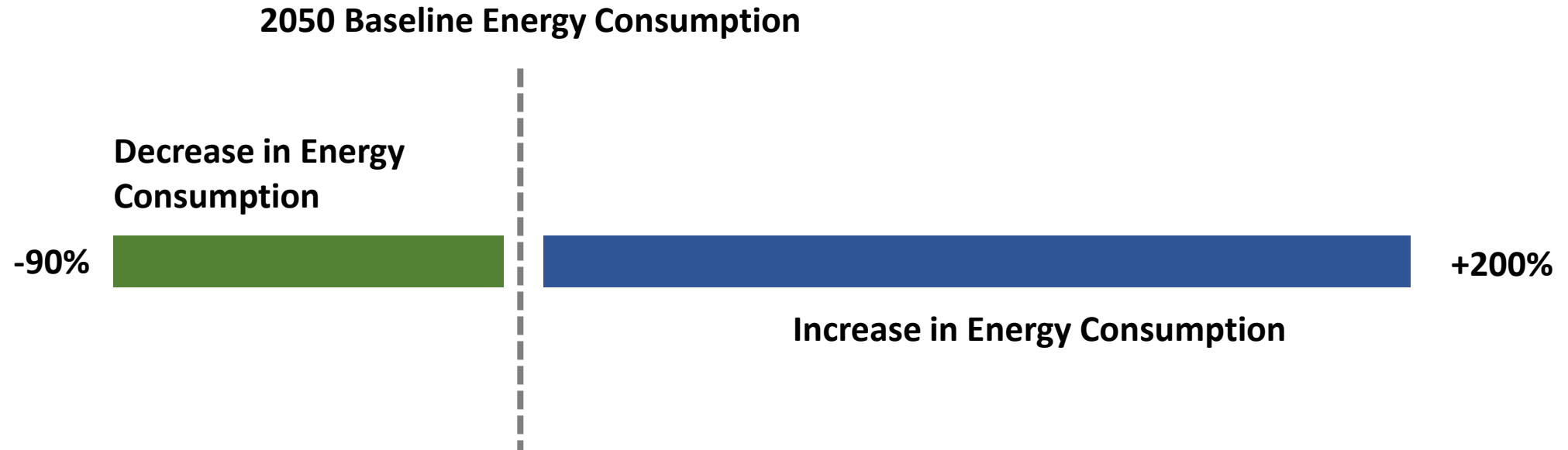
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Mobility

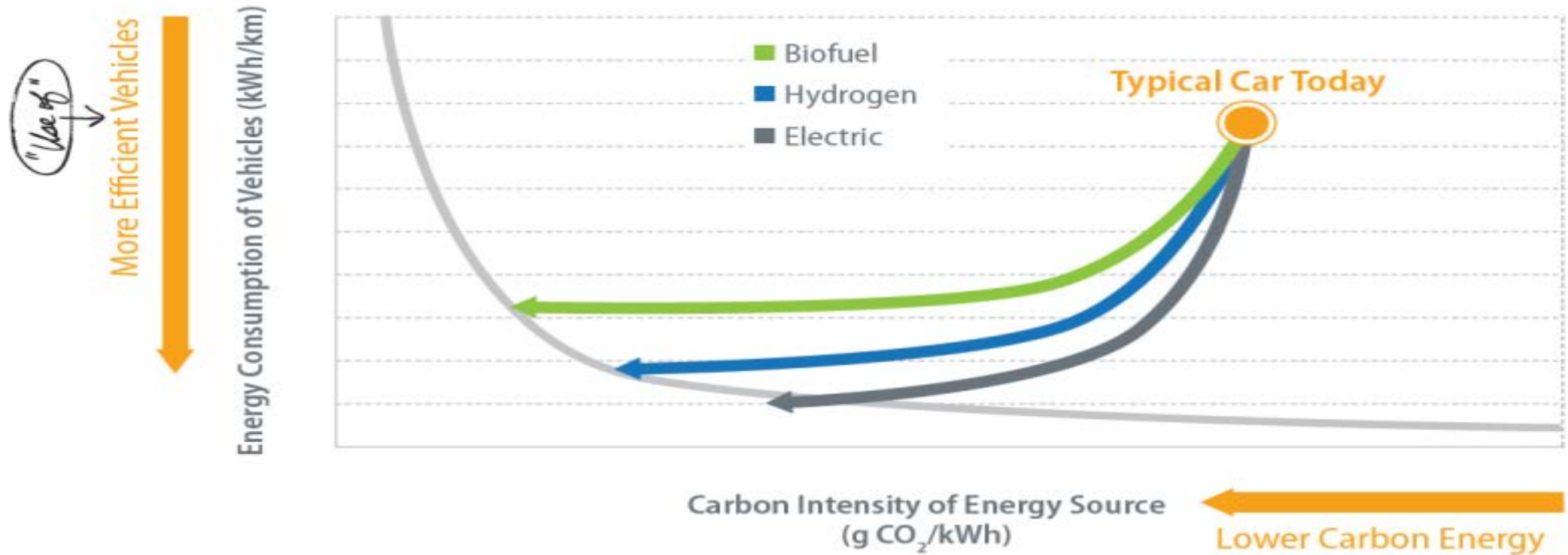
– New mobility paradigm impact on GHGs

Potential Energy Implications of Connected and Automated Vehicles



Source: Brown, A.; Gonder, J.; Repac, B. (2014). "An Analysis of Possible Energy Impacts of Automated Vehicles." Springer Book Chapter

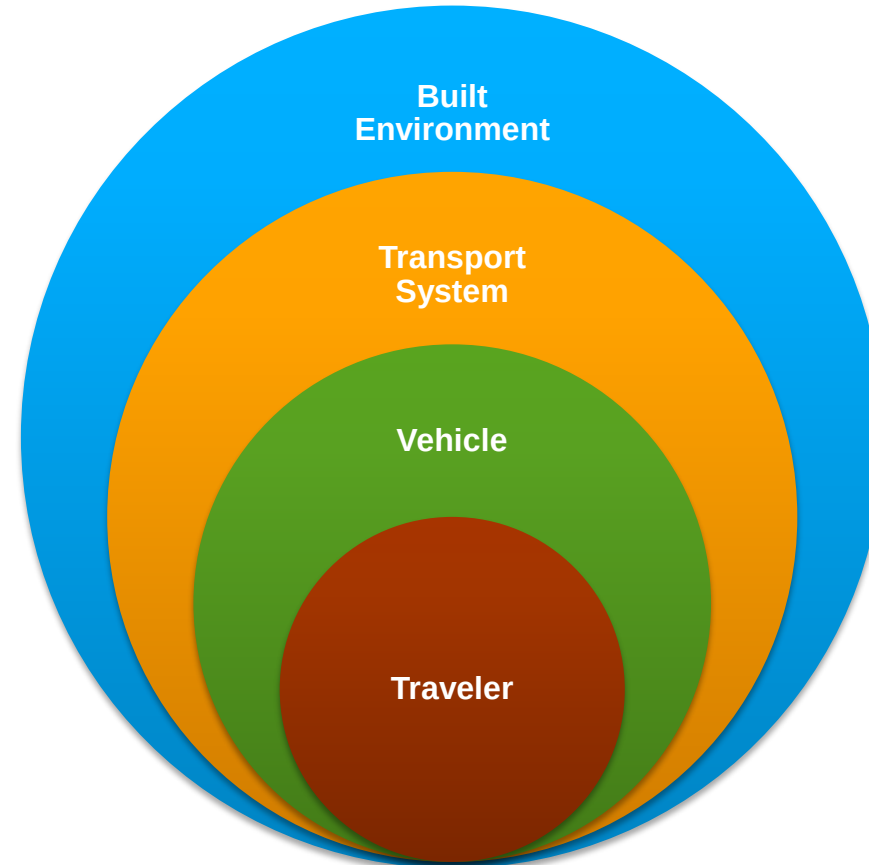
Mobility ↔ Energy/Environment



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NREL's Research Vision for Sustainable Mobility

NREL is working to approach sustainable transportation as a network of travelers, services, and decision points connected by communication technology and decision-making tools—rather than just by vehicles and roads—to significantly reduce related energy consumption.



Partners



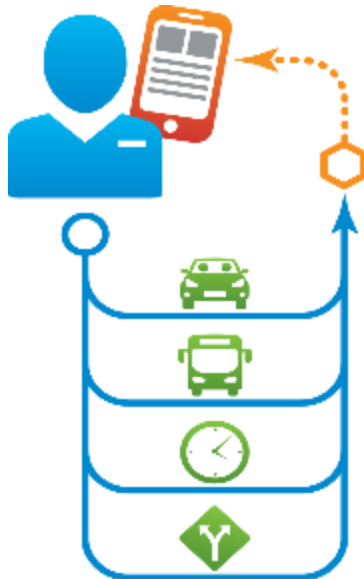
I-95 CORRIDOR
COALITION



Understanding Traveler Behavior and Decision-making

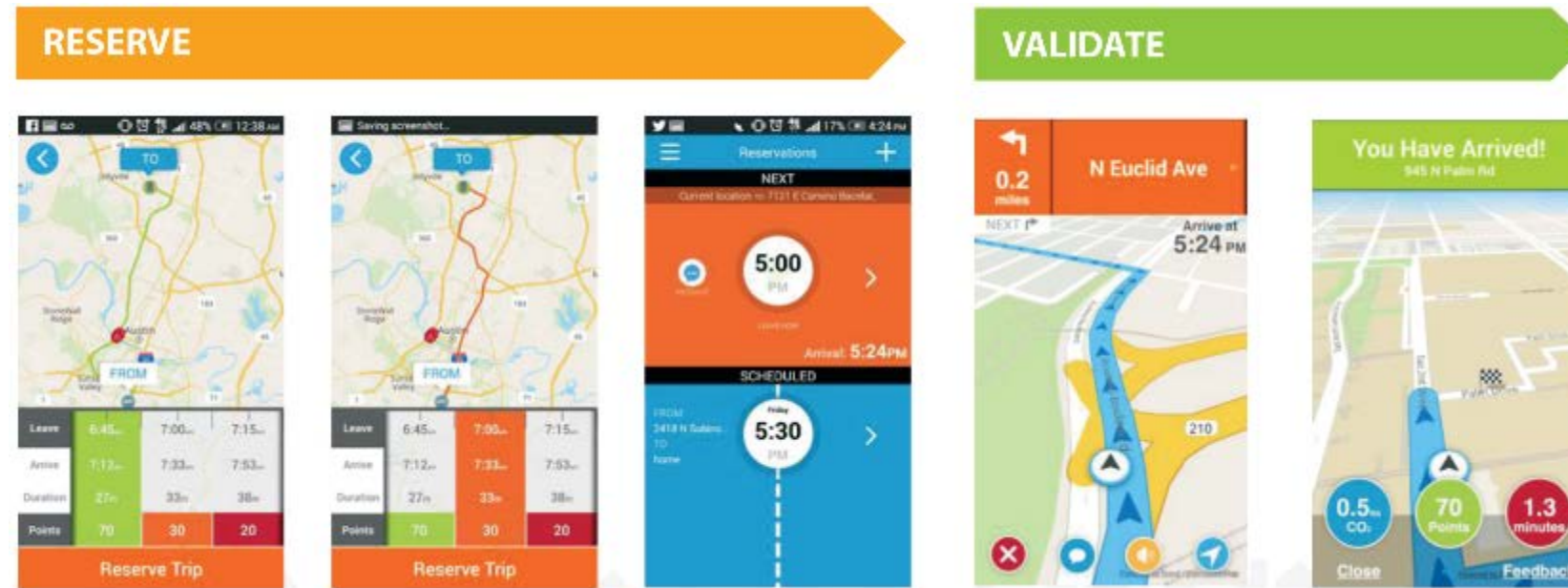
NREL's Connected Traveler project seeks to incentivize more energy efficient traveler decisions

- Funded by ARPA-E's TRANSNET program
- NREL is partnering with premiere transportation research organizations



Real-Time Learning and Technology Transfer

- Adaptive learning will be applied to refine control strategies based on energy savings potential and likelihood of adoption by traveler
- Project will leverage Metropia platform to validate incentive effectiveness and hone control strategies



Eco-Driving Can Enhance Fuel Economy

Traveler

Vehicle

- **Driving changes can save fuel**
 - 30%-40% outer bound for “ideal” cycles
 - 20% realistic for aggressive drivers
 - 5%–10% for majority of drivers
- **Existing methods may not change many people’s habits**
 - Other behavior influences dominate
 - Current approaches unlikely to have broad impact

Outer boundary savings
for “ideal” cycle



Potential savings
for aggressive
drivers



Potential
savings for
average drivers



Savings considering
driving style
distribution



Savings considering
adoption rate
limitations



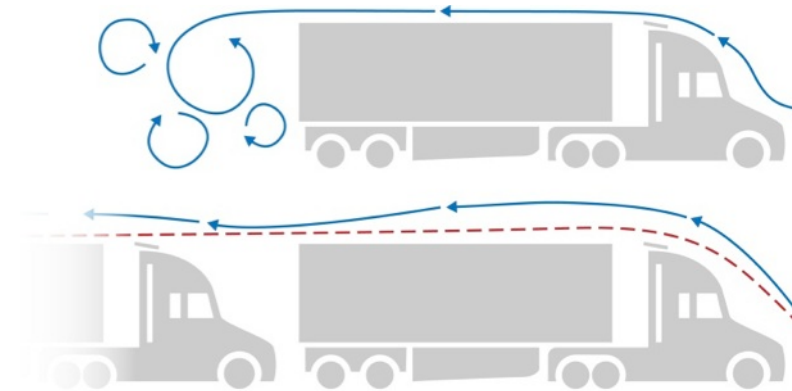
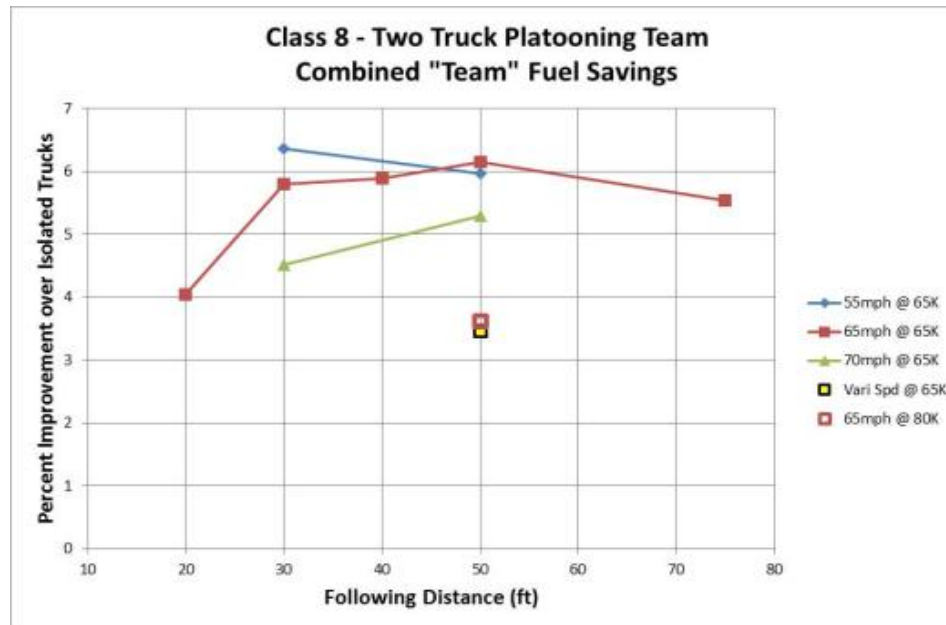
Gonder, J.; Earleywine, M.; Sparks, W. “Analyzing Vehicle Fuel Saving Opportunities through Intelligent Driver Feedback.”
SAE International Journal of Passenger Cars – Electronic and Electrical Systems, September 2012; 5:450-461.

Evaluating Truck Platooning Efficiency Benefits

Vehicle

Combined Fuel Savings Potential of Many Factors can Influence Savings

- o Vehicle spacing
- o Cruising speed
- o Speed variation
- o Baseline aerodynamics
- o Vehicle loading
- o Engine loading



Preliminary Results from NREL SAE Type II track testing of Peloton Platooning System over a Variety of Conditions



Photo from Mike Lammert, NREL

Eco-Routing Can Enhance PHEV Performance

Transport
System

Vehicle

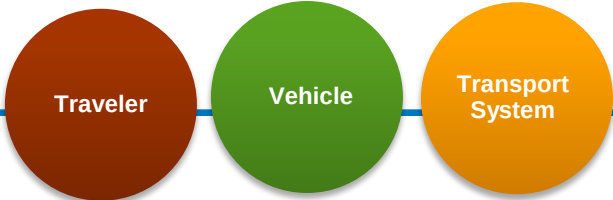
Aggregate Energy Savings Potential of 4.6%

- Demonstrated ability to model vehicle speed/acceleration profiles relative to road type
- Constructed high-level powertrain model employing cycle metrics and vehicle state as inputs
- Applied model using real-world distribution of origin/destination pairs



Route	A	B	C
Distance, mi	81.6	76.2	67.6
Duration, min	107	107	113
Avg Elec Rate, Wh/mi*	0.83	0.89	1.0
Avg MPG*	0.45	0.50	1.0
Cost, \$*	1.0	0.89	0.59

US DOT AERIS Glide Path Project (Not affiliated with NREL)



Application Overview

- Collects signal phase and timing (SPaT) and Geographic Information Description (GID) messages using vehicle-to-infrastructure (V2I) communications
- Provides speed recommendations to the driver using a human-machine interface or sent directly to the vehicle's longitudinal control system to support partial automation

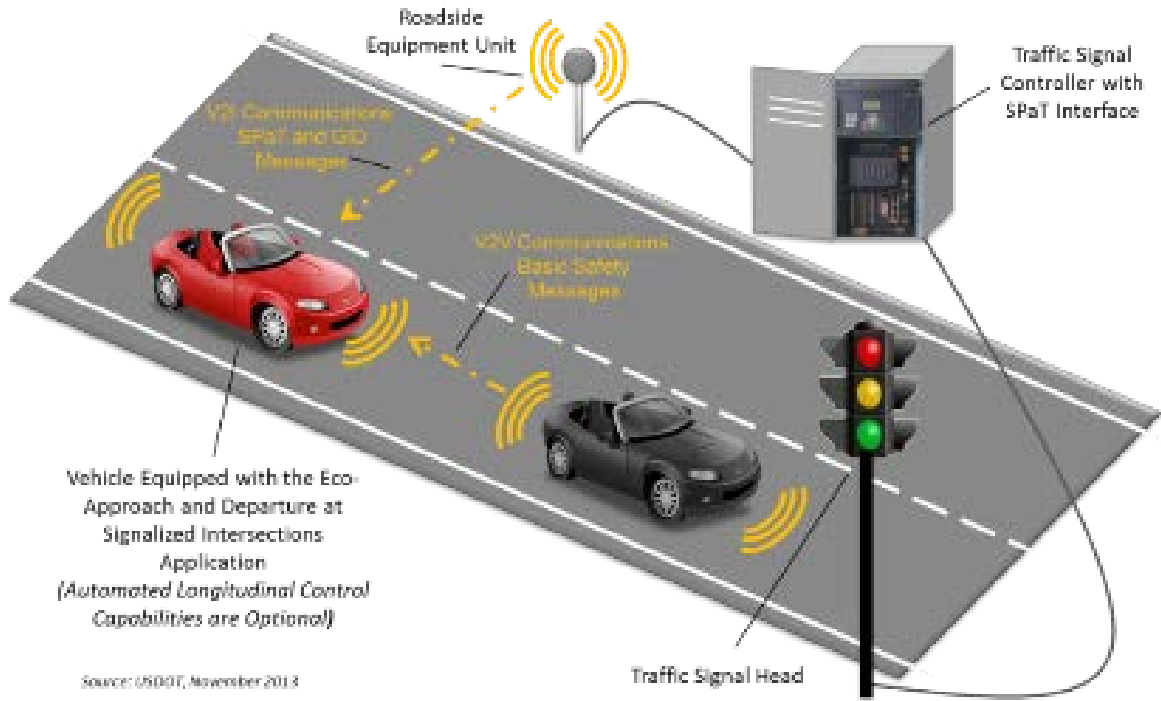


Table 2. Relative savings in fuel consumption (%) between different driving modes

Phase	Green						Red						On
Time in Phase (s)	2	7	12	17	22	27	2	7	12	17	22	27	Average
D vs. U	11.80	11.75	7.59	5.20	7.56	12.05	25.08	37.80	18.34	21.71	-0.55	13.53	7.34
A vs. U	4.67	7.55	35.25	20.94	20.28	31.71	32.65	47.91	-3.95	26.48	20.05	22.8	22.20
A vs. D	14.73	17.27	29.93	16.60	13.76	22.36	10.11	16.25	12.16	6.10	20.48	10.83	15.88

Summary of Preliminary Results

- DVI-based driving provided a 7% fuel economy benefit
- Partially automated driving provided a 22% benefit

U = No Signal (Manual)

D = Signal to Driver

A = Automated Signal and Response

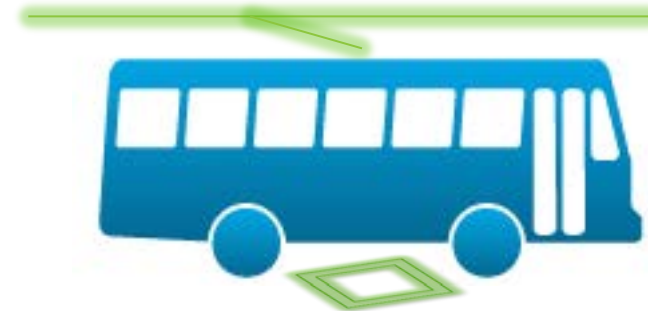
Light-Duty Vehicles

- Target urban areas and highly utilized roads show 1% of roadway cuts consumption by 25%



Transit Buses

- Minneapolis route data used to select charge points and battery sizes
- For same net present value as HEV solution, WPT bus achieves 50% cut in consumption from conventional



Heavy-Duty Trucks

- Target moderate- to high-grade roadway segments
- 100-kW WPT on 1.5% or greater grade allows engine downsizing and 9% fuel savings



Exploit Integration of Energy Systems

Vehicle

Built
Environment

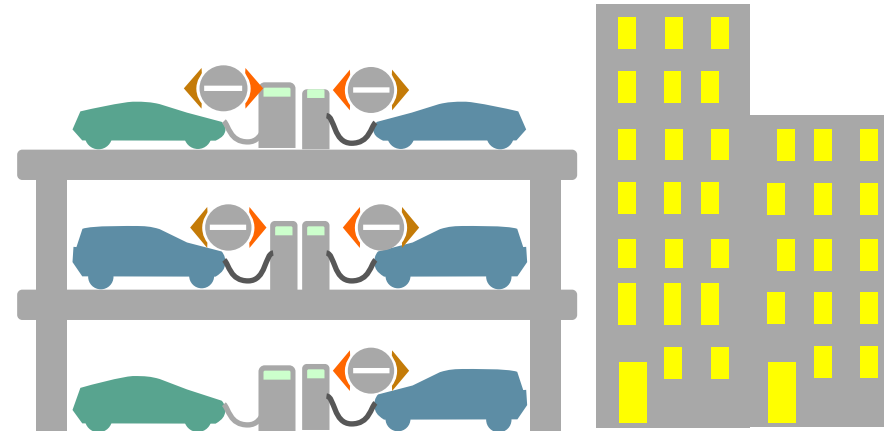
Emergence of asset management replacing asset ownership in electric and transportation markets

Convergence of land use planning and energy consumption

Vehicle electrification creates opportunities and also complicates transportation infrastructure funding

Car companies are becoming major players in energy storage

Some electric and gas utilities are providing increased “transportation services”



Bringing it All Together in an Integrated Mobility Future

Electric Vehicles

Connected Vehicles

Vehicle Automation



Connected-Automated-Electric Vehicles



Internet of Things

Machine Learning

Big Data

Mobility on Demand



Smart Cities

Benefits

- Order of magnitude safety improvements
- Reduced congestion
- Reduced emissions and use of fossil fuels
- Improved access to jobs and services
- Reduced transportation costs for government and users
- Improved accessibility and mobility

Source: Adapted from U.S. Department of Transportation



US DOT Smart City Challenge

- A population between approximately 200,000 and 850,000 people within the city limits;
- A dense urban population;
- An environment conducive to demonstrating advanced technologies;
- An existing public transportation system;
- A commitment to integrating transportation services with the sharing economy;
- A commitment to making data open, discoverable, and usable by the public to fuel entrepreneurship and innovation; and
- Continuity of committed leadership and capacity to carry out the demonstration throughout the period of performance.

78

Applicants

\$50 Million

In funding from US DOT and Vulcan, Inc.

1

Winning City



local officials, companies, academics and non-profits joined our webinars

people participated
in our Smart City Forum

companies have expressed interest in partnering

applications
received for the Smart City
Challenge

Smart City
Challenge Finalists announced in
March at SXSW

Smart City
Challenge Winner announced in June



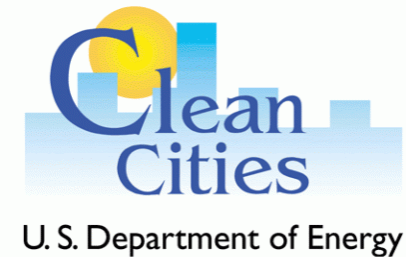


City Implementation ★

		COLUMBUS VISION AND OUTCOMES				
INITIATIVES		Access to Jobs	Connected Citizens	Smart Logistics	Sustainable Transportation	Connected Visitors
★	1. Smart Corridor CMAX, Street Lights, Hubs, DRSC, Mobillieye, Service Info	✓	✓	✓		
★	2. Linden Neighborhood Kiosks, Street Lights, Service Info, Personal Transit	✓	✓		✓	
	3. AV Deployment Service Info, Service Order, AV, Infrastructure, Smart Corridor-Morse	✓			✓	
★	4. EV Development EV, Refueling, Smart Grid	✓			✓	
	5. Smart Logistics & Parking Event, Truck Parking, Truck Routing, Truck Delivery	✓		✓		✓
	6. Common Payment Deployment Enhanced Human Services, Payment Integration, ADA	✓	✓	✓	✓	✓

DOE and DOT MOU on Transportation Systems

1. Collaborate on SMART Mobility and Smart City Challenge
2. Leadership and best practices on data
3. Leverage DOE expertise on transportation electrification
4. Leverage DOT Expertise on automated and connected Vehicles
5. Utilizing existing stakeholder networks, such as DOE's Clean Cities Coalitions, for institutional knowledge on pre-existing local resources and effective outreach pathways in the near-term and as a template for how city stakeholders can engage and support Smart City Challenge and SMART Mobility efforts that continue, or grow, in the longer-term.
6. Explore opportunities to support a technologist in cities



The Opportunity to Reimagine the Urban Landscape



“If we can reconceive of our government so that the interactions and the interplay between private sector, nonprofits, and government are opened up, and we use technology, data, social media in order to join forces around problems, then there’s no problem that we face in this country that is not soluble.”

– President Barack Obama

Session Questions

- **Alongside the opportunity for a more integrated and efficient transportation system comes an unparalleled level of technical and institutional complexity**
 - Traditional sectors are being asked to collaborate in ways that aren't immediately familiar, apparent, or perhaps beneficial
 - Government institutions will need to determine how to balance potential policy trade-offs
 - The uncertainty posted by the speed of transformation will require new approaches to policy and regulation
 - We don't know the outcome, yet people are testing it in the real world.

Session Questions

- **Specific R&D Opportunities**
 - **Need to better understand traveler behavior**
 - Transportation system models need to be updated to reflect more dynamic traveler choices
 - Fill existing gap between system design and behavioral psychology
 - **Machine learning will be critical**
 - We have more data than we know what to do with
 - Predictive modeling will be enabled with better transportation system modeling and machine learning
 - **We need better data transparency**
 - With more data comes increased concerns for PII and cybersecurity
 - **Cybersecurity concerns will increase with connectivity and there is no apparent end game**
- **A more aggressive, adaptive approach is needed for R&D**



Thank You

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