NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Expected Improvements in Work Truck Efficiency Through Connectivity and Automation

Green Truck Summit
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Connected and Automated Technology: Transformative

Rapidly Advancing: How will this affect commercial vehicle operations?

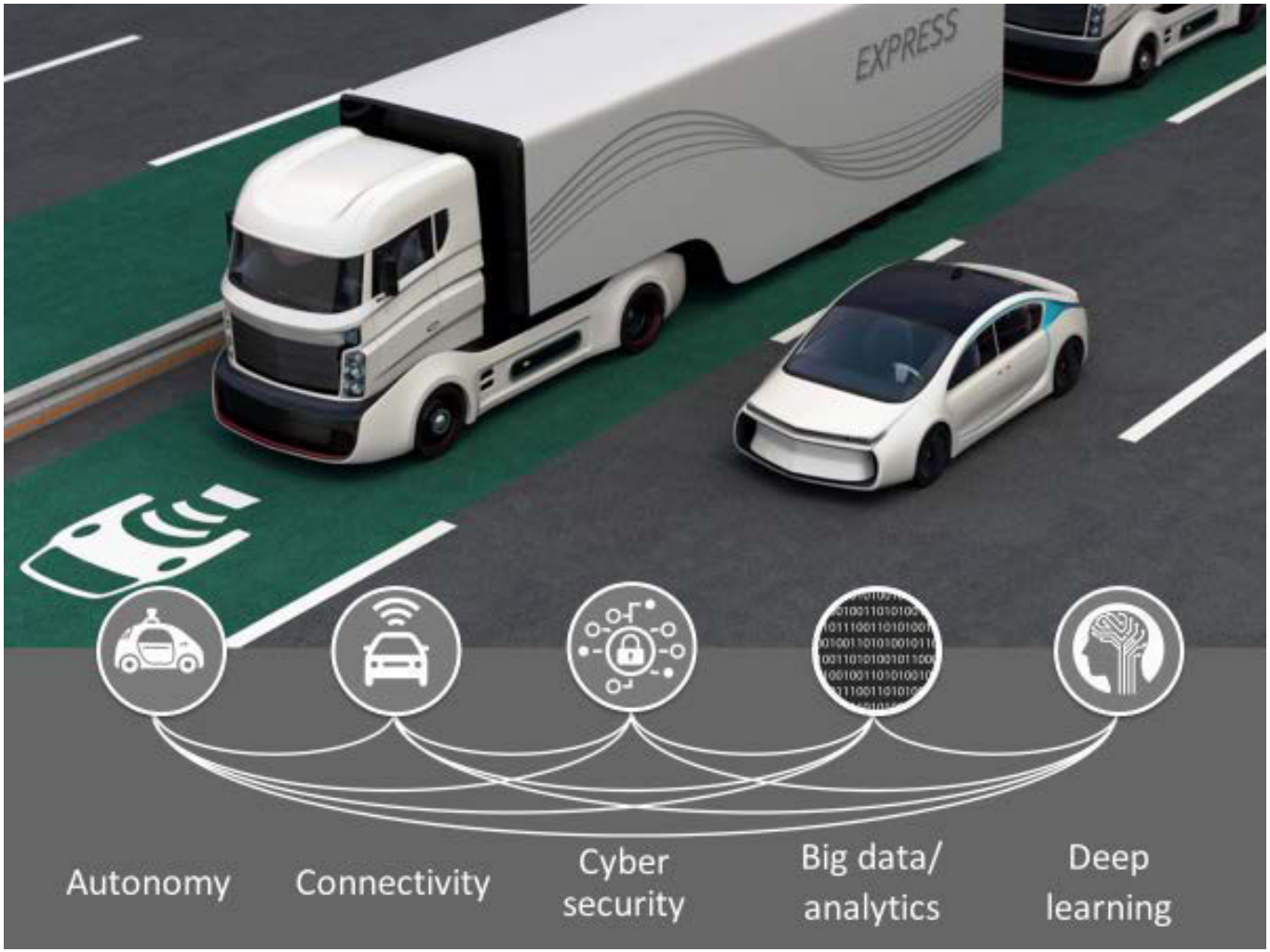


Image (top) courtesy of iStock

Connected and Automated Technologies: What Are They?

Connectivity:
Vehicle to Vehicle (V2V), Vehicle to Infrastructure (V2I), DSRC (5.9 GHz), 4G, 5G, 'cloud connected' passenger and freight mobile devices

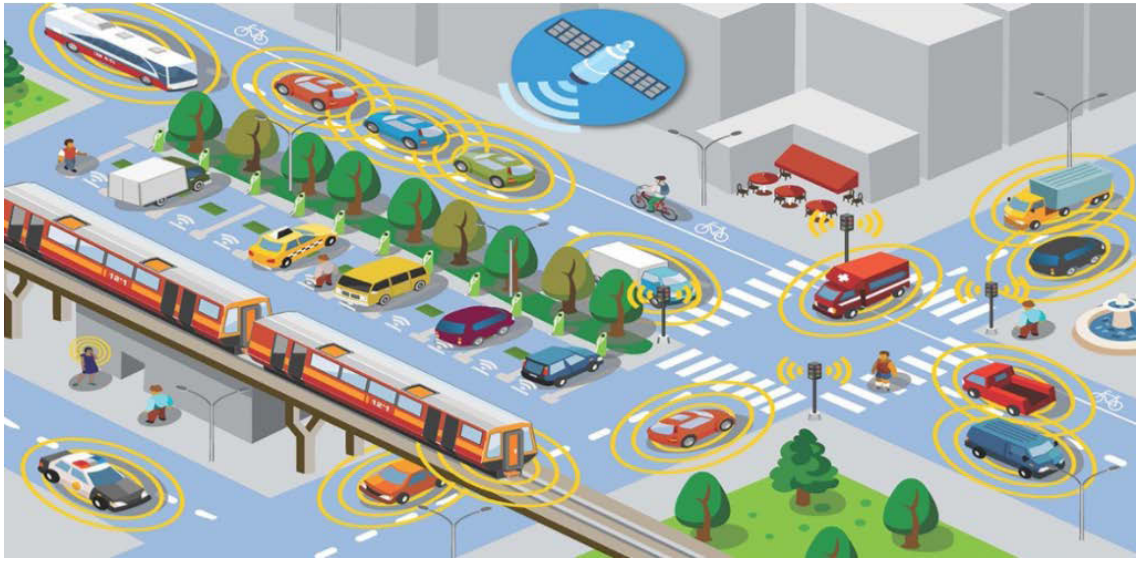


Image courtesy of DOE.eere.gov

Progressing Levels of Automation:
Driver Implications

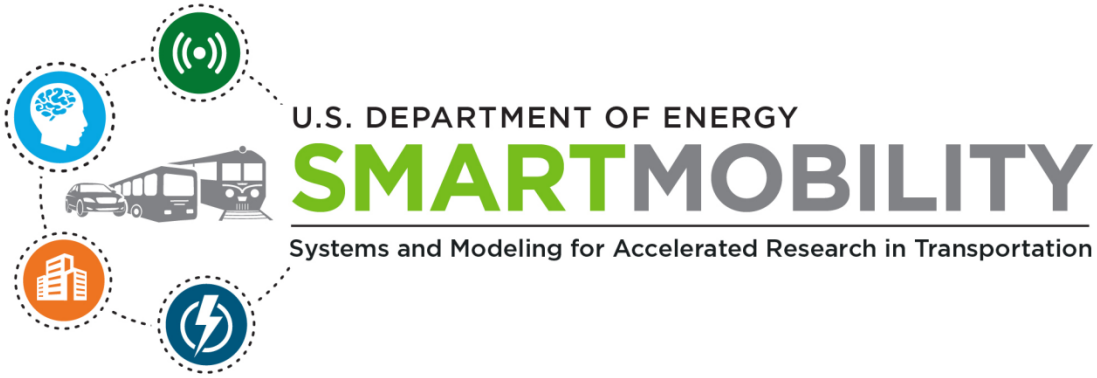
0	1	2	3	4	5
No Automation	**Driver Assistance**	**Partial Automation**	**Conditional Automation**	**High Automation**	**Full Automation**
Zero autonomy; the driver performs all driving tasks.	Vehicle is controlled by the driver, but some driving assist features may be included in the vehicle design.	Vehicle has combined automated functions, like acceleration and steering, but the driver must remain engaged with the driving task and monitor the environment at all times.	Driver is a necessity, but is not required to monitor the environment. The driver must be ready to take control of the vehicle at all times with notice.	The vehicle is capable of performing all driving functions under certain conditions. The driver may have the option to control the vehicle.	The vehicle is capable of performing all driving functions under all conditions. The driver may have the option to control the vehicle.

Image courtesy of NHTSA.gov

Energy Efficient Mobility Systems (EEMS)

EEMS & The DOE SMART Mobility Initiative:

- System level focus
- Connected & automated vehicles
- Behaviors & decisions
- Across different modes of transportation
- Advanced infrastructure
- Urban design

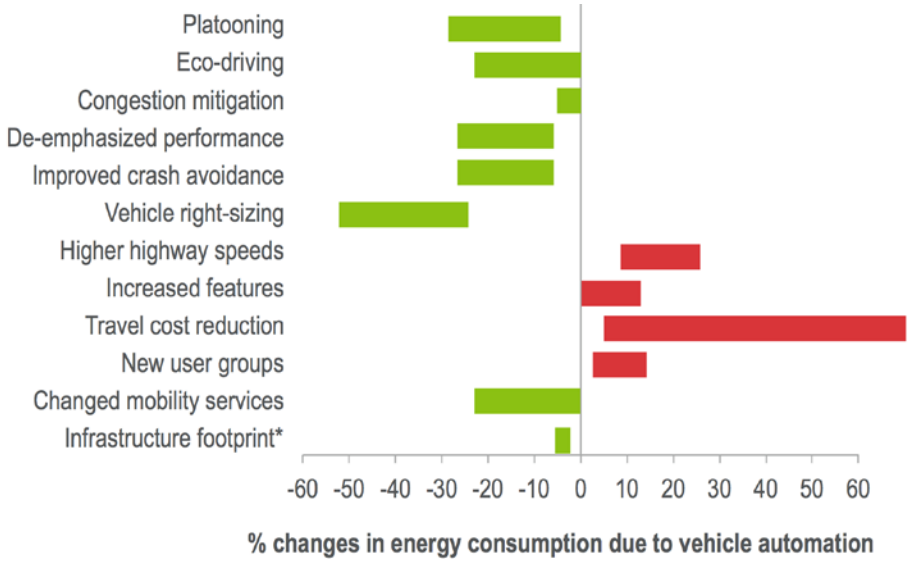


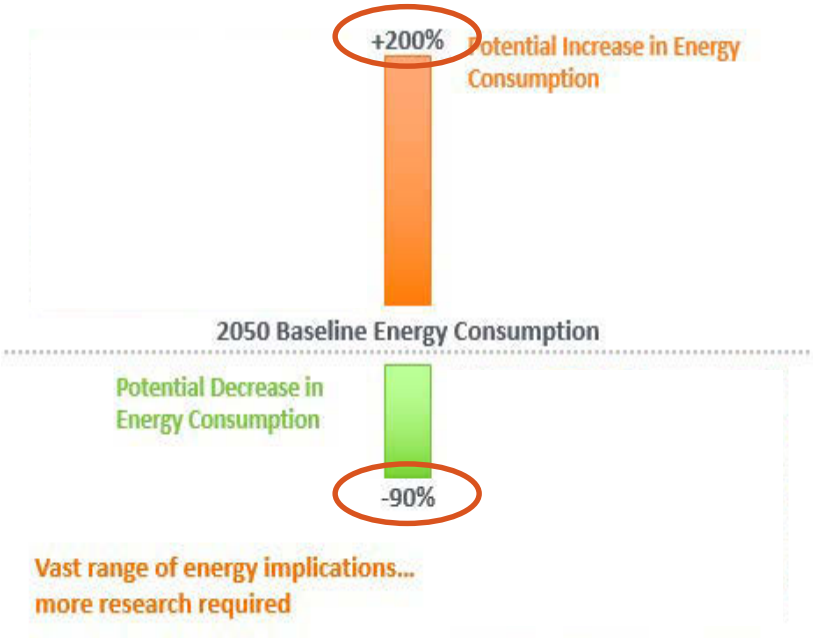
Multi-Year / Multi-Lab Effort
Five Areas

1. Multi-modal transport of people and goods
2. Market adoption through informed infrastructure investments
3. Understanding consumer mobility decisions
4. City-scale urban mobility models for planning
5. Connectivity & automation to enable safety, energy, and mobility

Research to Consider the Impacts

Will Connectivity and Automation lead to increased or reduced transportation energy use?





What do we need to know to minimize energy consumption of future transportation?

Multi-Modal Choices: Enabled by Connectivity and Automation

Energy Efficient Transport of Goods

Research Questions:

- What new 'modes' might be enabled by Connectivity and Automation?
  - Smarter EVs
  - Drones
  - Light-weight, low-speed vehicles
  - New Delivery Models – 'Uber freight'
  - Reduced 'dead heading' through intelligent logistics
- What are the energy implications of these new modes and technologies?

Photo by Trish Cozart, NREL 19544

Photo courtesy of Smith Electric Vehicles, NREL 22851

Photo by Victor Walker, Idaho National Laboratory, NREL 49989

Connected and Autonomous Vehicles (CAVs)

Energy, Safety & Efficient Mobility

Research Questions:

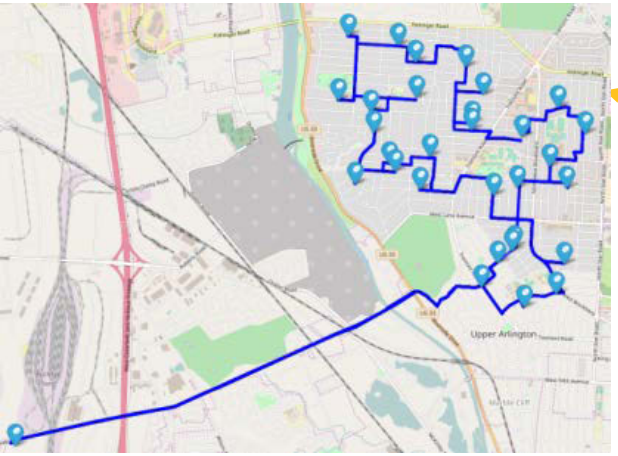
- What are the energy, technology, and usage implications of connected & autonomous technologies?
  - Green routing/route-based controls
  - Intelligent infrastructure for traffic control
  - Platooned vehicles
  - Automated delivery vehicles
  - Intelligent refueling and grid connected energy management systems
- How will these systems operate in the real world?
  - Regulations
  - Safety
  - Operations Implications
  - Driver Management, hours and operations
- 24/7 operations, refueling and staging?

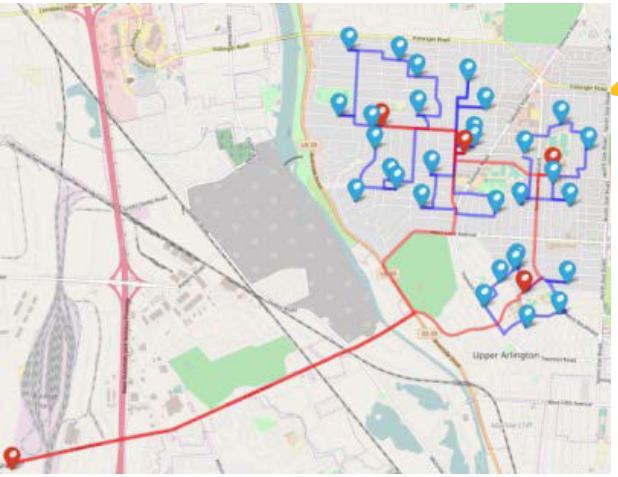
Photo by Ganymed Stanek, Peloton, NREL 31237

Photo by Dennis Schroeder, NREL 46592

Photo by Dennis Schroeder, NREL 47291

Examples & Early Research: Exploring Local Multi-Modal Freight Movement





Consider a 'traditional' delivery route vs one that uses new 'last mile' modes (automated & connected)

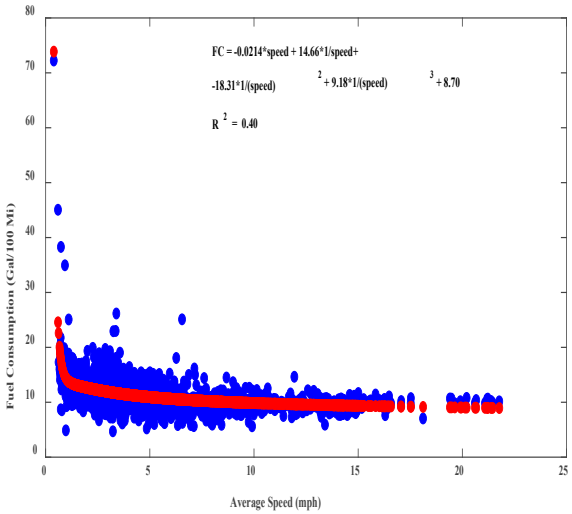
Technologies to Explore:
Automated Delivery
Drones
Personal Vehicle
(EV / Advanced vehicle tech)
Baseline

How to understand the energy, time and cost of various modes and technologies?

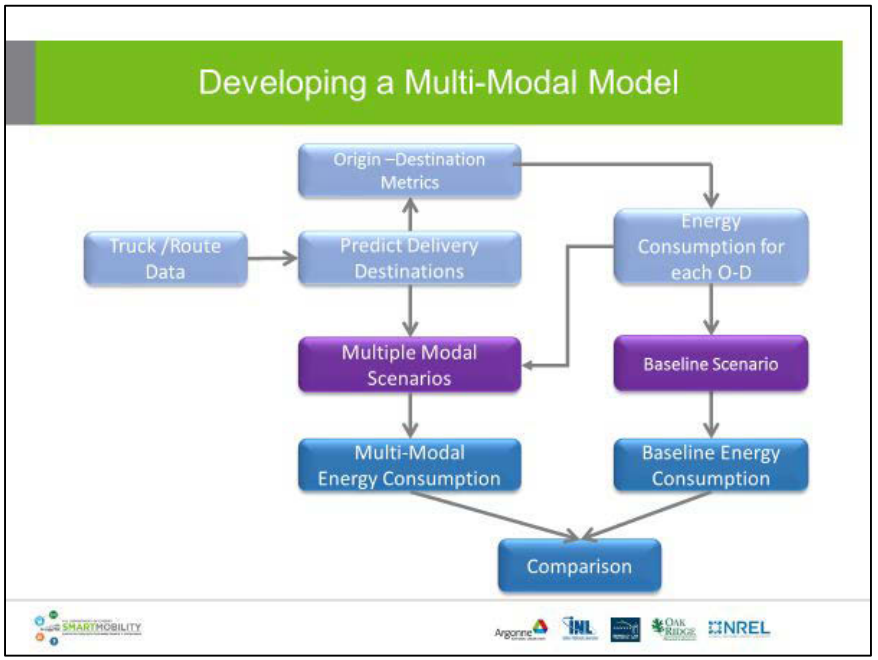
Examples & Early Research: Exploring Local Multi-Modal Freight Movement

Vocation	Class	FC (gal/100 mi)		
		Mean	Median	Standard Deviation
Parcel Delivery	4	11.54	11.14	2.87
	5	12.73	11.76	4.20
	6	12.72	11.42	5.01
	7	14.44	14.05	2.69
	8	24.37	15.99	57.90
Beverage Delivery	8	16.18	15.15	5.33
Food Delivery	3	14.15	13.67	2.54
	7	15.00	14.15	4.67
	8	24.35	18.71	31.09
Linen Delivery	5	11.54	10.17	5.16
	6	11.00	10.11	3.46
	7	14.44	14.82	2.02
Refuse Pickup	8	34.18	30.51	17.95
Freight	8	19.03	16.67	17.69
Refrigerated Truck	8	16.55	13.77	13.19

Understand the energy profiles of technology



Understand the effects of route



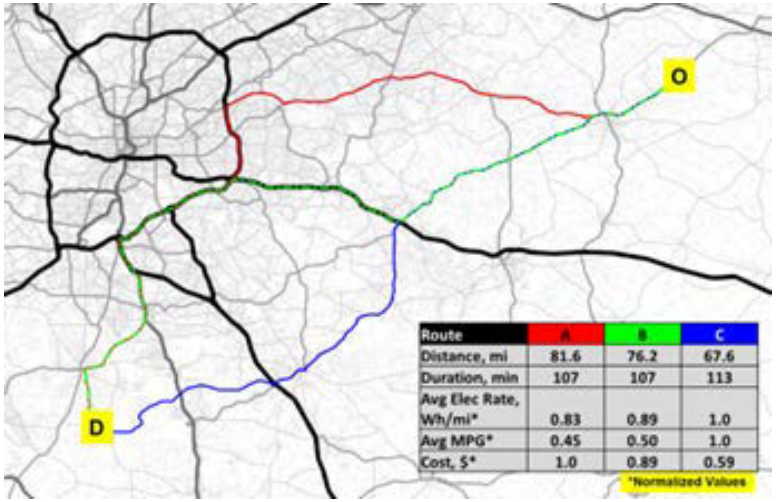
Optimize scenarios for cost (time and energy)

Goal:
Repeatable tools for multiple locations/regions and other modes (such as platooning, EV, etc.)

Examples / Early Research: Exploring Green Routing and Signal Connectivity

Route Based Controls:

- Connectivity enables real-time control of hybrid or powertrain system to optimize for route and/or conditions



Signal / Intersection Control:

- Using connected vehicle data to enable control of traffic and or intersections and minimize time and energy

- Truck Control?

Summary: How Can We Use These Technologies to Improve Operations?

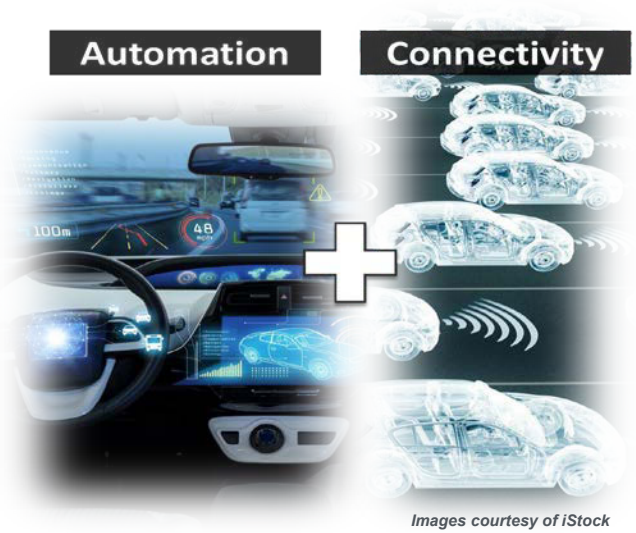


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Photo by Tracy Ochsner, City of Fort Collins, NREL 27237

- **Connectivity and electrification are here; automation is coming – they will transform commercial transportation**
- **Without integration and optimization, these transformations could magnify negative health, climate and economic problems.**
- **With integration we have the chance to take advantage of the benefits AND mitigate the negative consequences**
- **But this will require careful connection of all of the pieces from components to controls to systems to produce an efficient transportation system**

Thank You!

Questions?

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