Transportation Energy Impact Analysis

- From Connected and Automated Vehicles (CAVs)
- Utilizing "Big Data"

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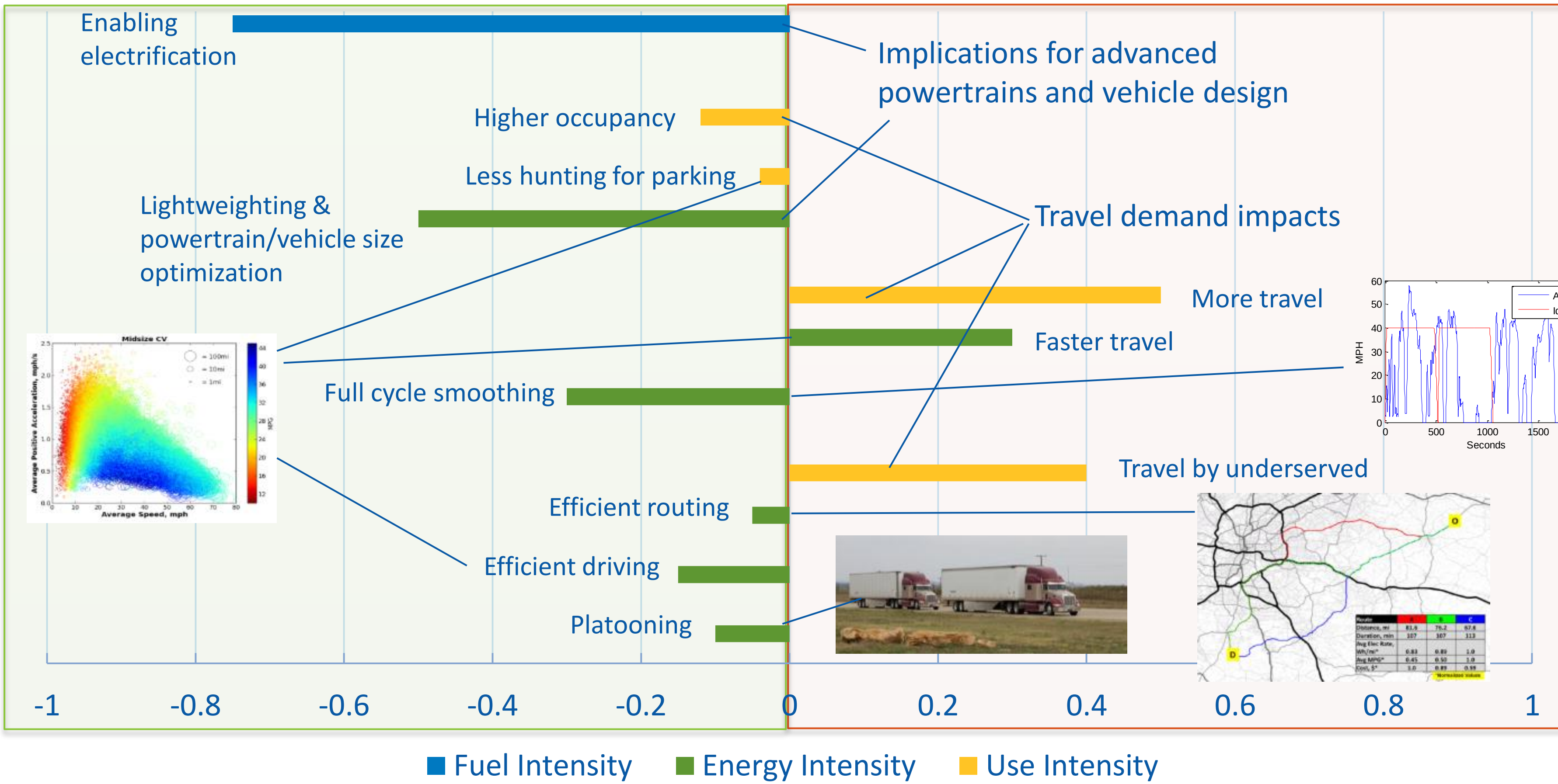
5.13.2015

NREL/PR-5400-64333

Comprehensive CAV Energy Impact Assessment, and Feature/Scenario-Level Evaluations

- **Identified dramatic potential energy impacts** (across automation levels)
  - Informed by related NREL work and literature review
  - Significant uncertainties remain; further research warranted/on-going.

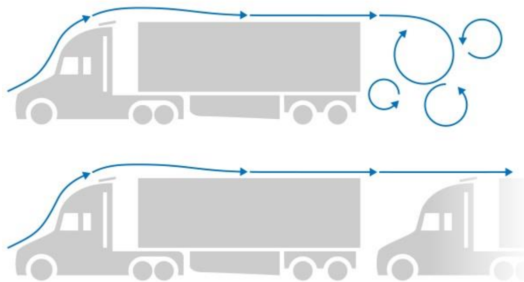
Positive Energy Outcomes | Negative Energy Outcomes

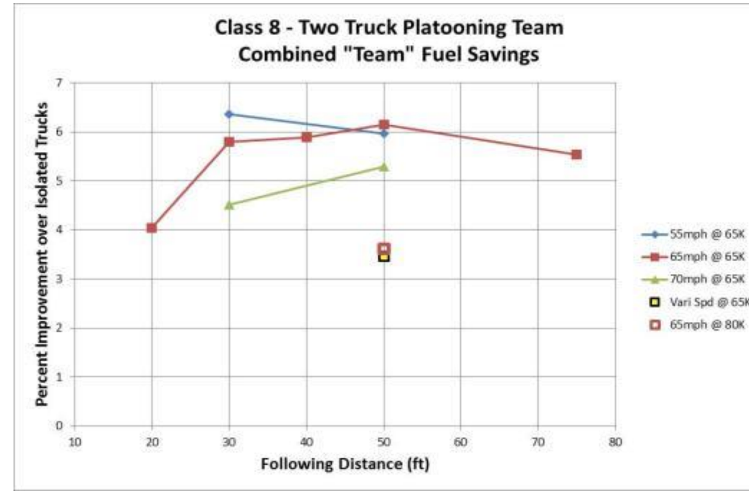


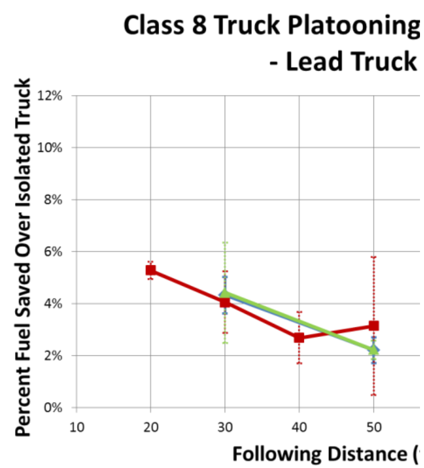
Brown, A.; Gonder, J.: Repac, B. (2014). "An Analysis of Possible Energy Impacts of Automated Vehicles." Chapter 5, Societal and Environmental Impacts. Meyer, G., ed. *Lecture Notes in Mobility: Road Vehicle Automation.* Berlin: Springer.

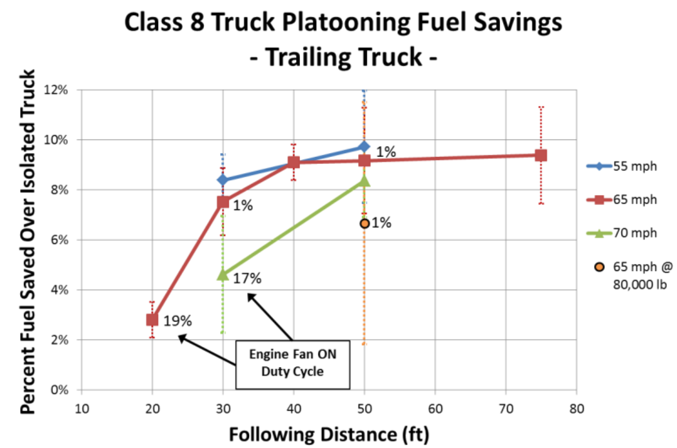
Evaluating Truck Platooning Efficiency Benefits

- **Also potential safety and comfort benefits**
- **Many factors can influence**
  - Vehicle spacing
  - Cruising speed
  - Speed variation
  - Baseline aerodynamics
  - Vehicle loading
  - Engine loading









Results from SAE Type II track testing of Peloton Technology system over a variety of conditions

Lammert and Gonder poster: www.nrel.gov/docs/fy14osti/62494.pdf
Lammert, et al. *SAE Int. J. Commer. Veh.*: www.nrel.gov/docs/fy15osti/62348.pdf

NREL Transportation Data Center Projects

Secure Access, Expert Analysis and Validation Support Decision-Making

Alternative Fuels Data Center (AFDC)
Public clearinghouse of information on the full range of advanced vehicles and fuels

National Fuel Cell Technology Evaluation Center (NFCTEC)
Industry data and reports on hydrogen fuel cell technology status, progress, and challenges

Transportation Secure Data Center (TSDC): *Detailed individual travel data, including GPS profiles*

Fleet DNA Data Collection
Medium- and heavy-duty drive-cycle and powertrain data from advanced commercial fleets

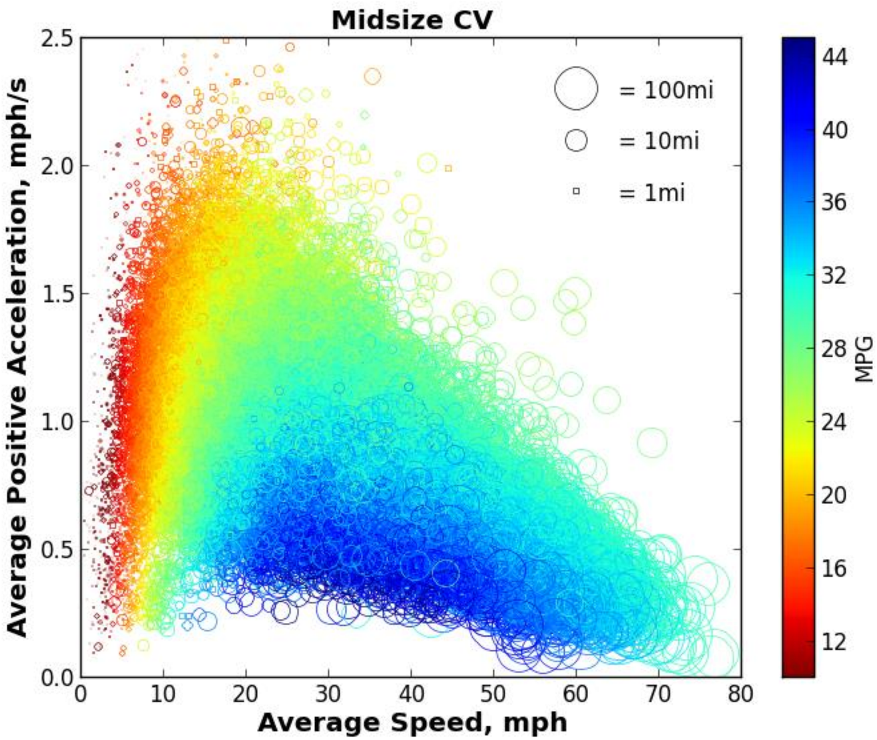
FleetDASH: *Business intelligence to manage Federal fleet petroleum/alternative fuel consumption*

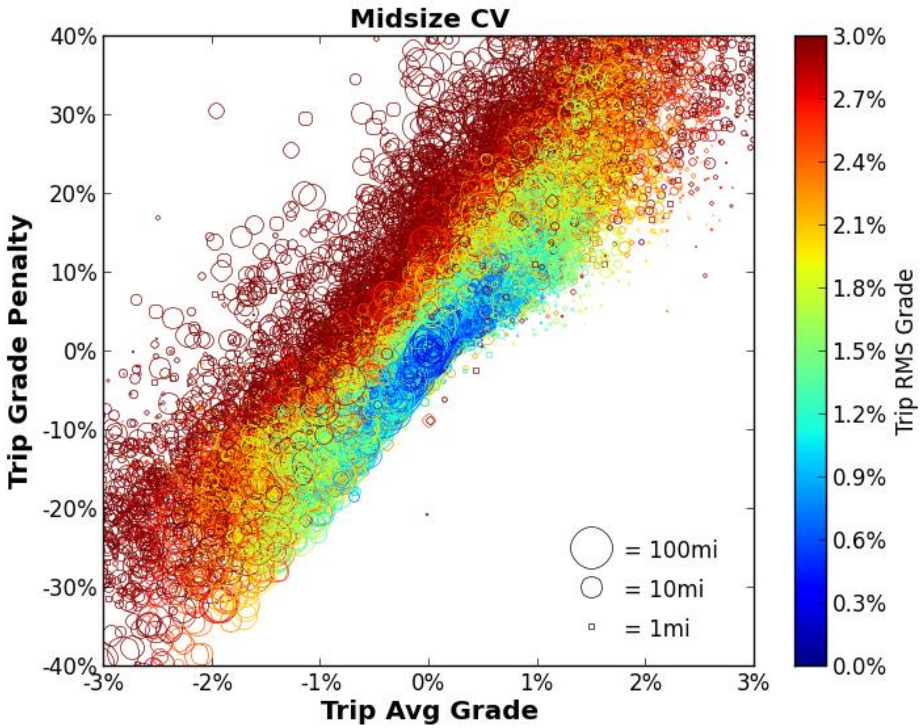
Features	AFDC	NFCTEC	TSDC	Fleet DNA	Fleet DASH
Securely Archived Sensitive Data		Y	Y	Y	Y
Publicly Available Cleansed Composite Data	Y	Y	Y	Y	
Quality Control Processing	Y	Y	Y	Y	Y
Spatial Mapping/GIS Analysis	Y	Y	Y	Y	Y
Custom Reports		Y		Y	Y
Controlled Access via Application Process			Y		
Detailed GPS Drive-Cycle Analysis			Y	Y	

Analyses Leveraging TSDC Travel Data

Distribution of driving from hundreds of thousands of operating profiles

- **Explored powertrain fuel economy sensitivity to real-world speed/acceleration and road grade**

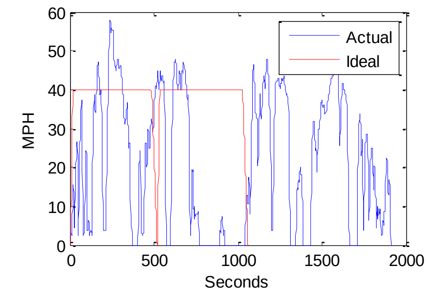


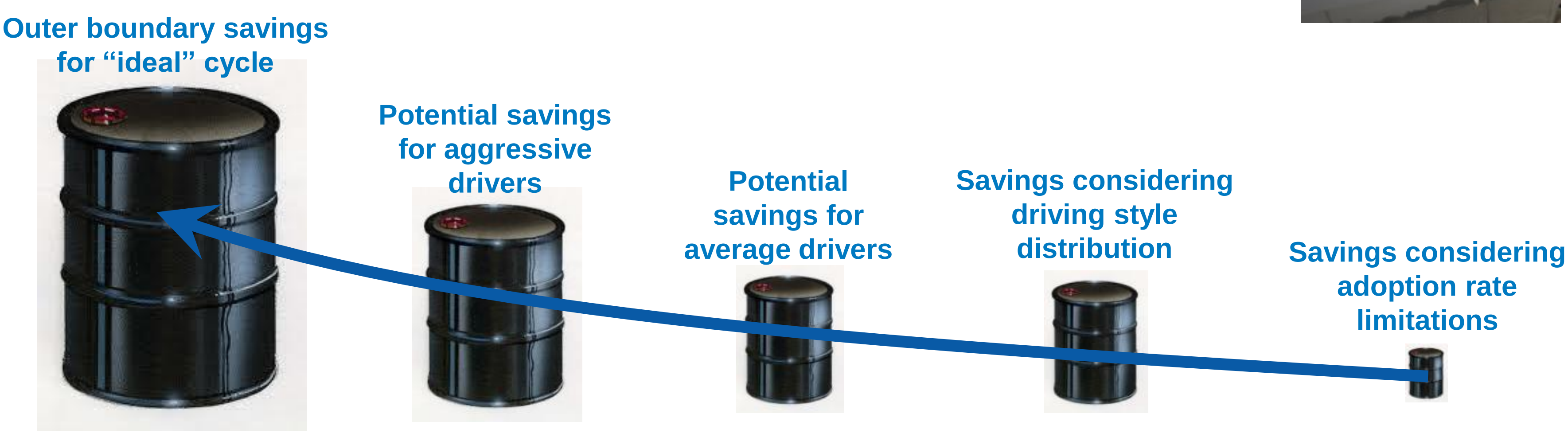


- Neubauer, J., Wood, E. “Accounting for the Variation of Driver Aggression in the Simulation of Conventional and Advanced Vehicles” 2013 SAE World Congress, http://www.nrel.gov/docs/fy13osti/57503.pdf
- Wood, E., Burton, E., Duran, A., Gonder, J. “Contribution of Road Grade to the Energy Use of Modern Automobiles Across Large Datasets of Real-World Drive Cycles” 2014 SAE World Congress, http://www.nrel.gov/docs/fy14osti/61108.pdf

Driver Feedback Analysis Project: Key findings

- **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

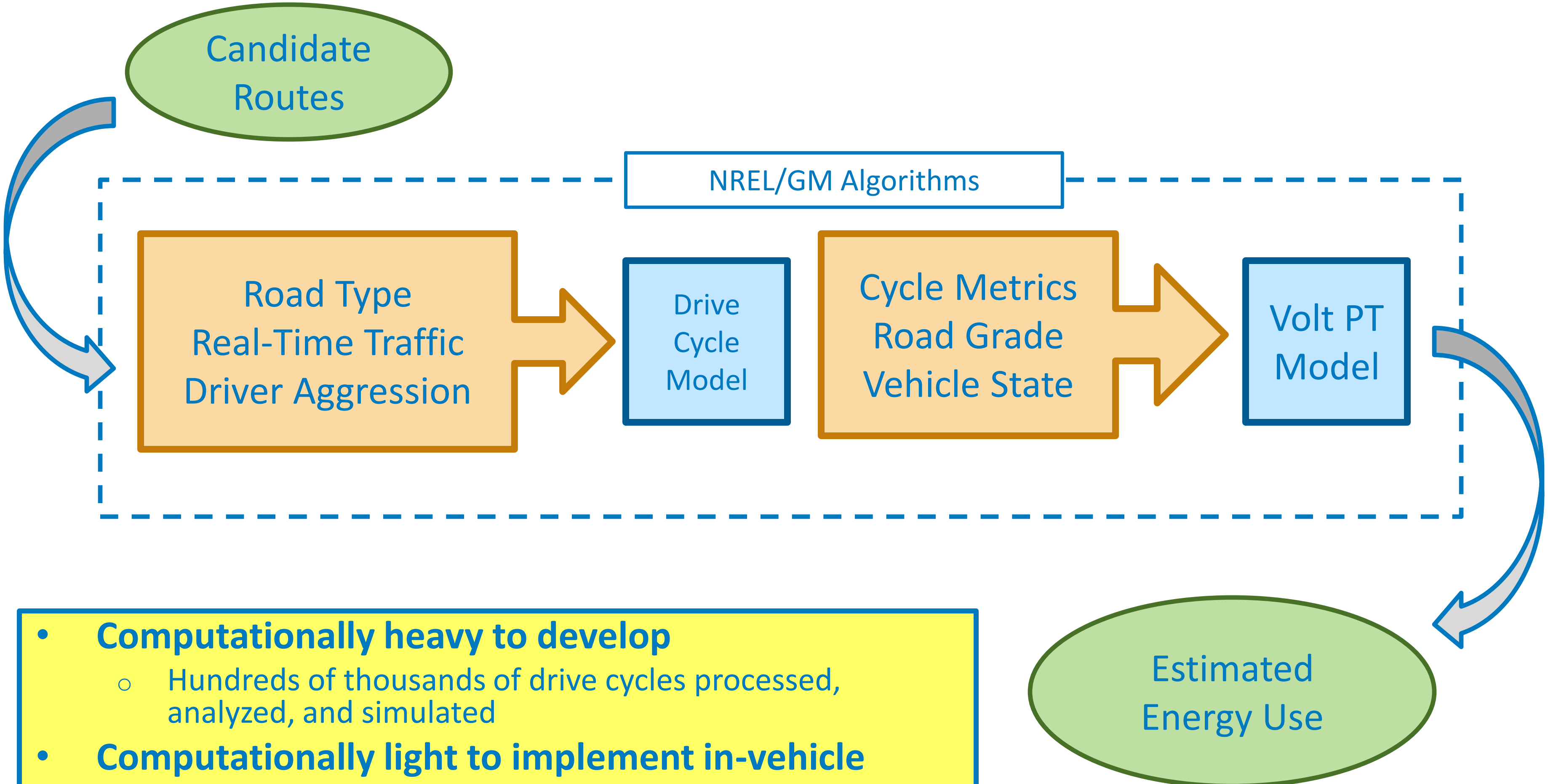




Developed several recommendations to maximize savings…

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.

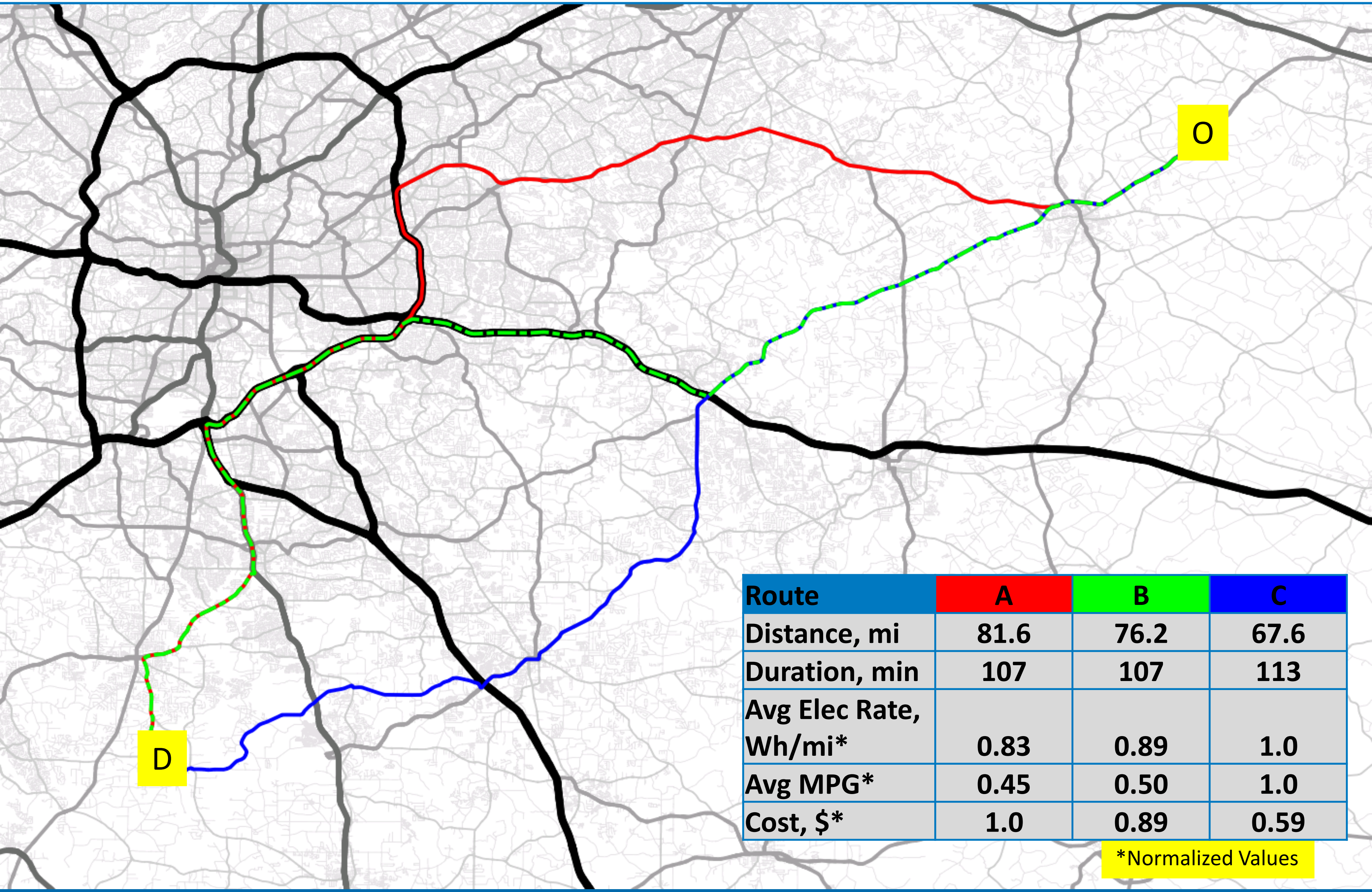
Collaborative Project with GM on Green Routing and Adaptive Control for the Chevy Volt



- **Computationally heavy to develop**
  - Hundreds of thousands of drive cycles processed, analyzed, and simulated
- **Computationally light to implement in-vehicle**
  - Does not require determination of time/speed trace or real-time simulation of high-fidelity vehicle model

Gonder, J.; Wood, E.; Rajagopalan, S. "Connectivity-Enhanced Route Selection and Adaptive Control for the Chevrolet Volt." *Proceedings of the 21st World Congress on Intelligent Transport Systems*, Sept 2014. www.nrel.gov/docs/fy14osti/60960.pdf

Green Routing Example



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

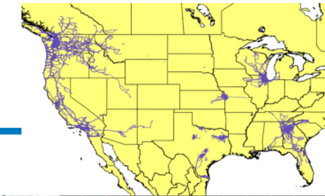
*Normalized Values

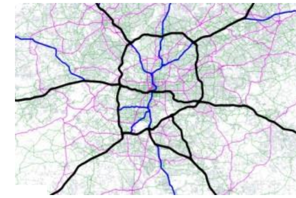
Volt Collaboration Summary

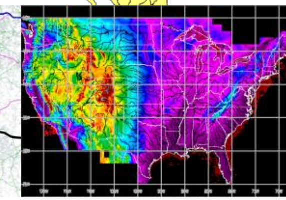
- **Demonstrated ability to model vehicle speed/accel profiles relative to road type**
- **Constructed high-level powertrain model employing cycle metrics and vehicle state as inputs**
- **Applied model using real-world distribution of O/D pairs, demonstrating:**
  - Aggregate energy savings of up to 4.6% for green routing (relative to passenger value of time)
  - Average energy savings of 3.3% for mode scheduling

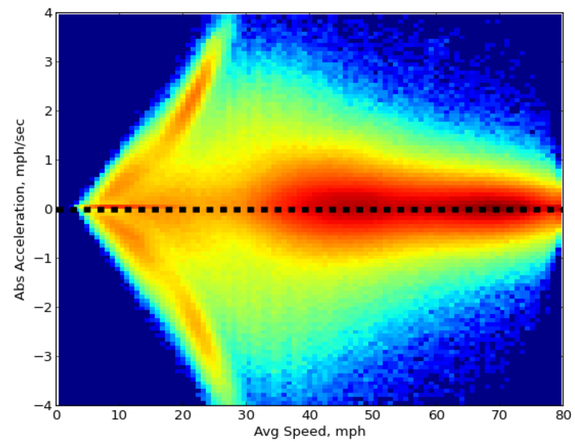
Modest aggregate savings, but may be cost-effective

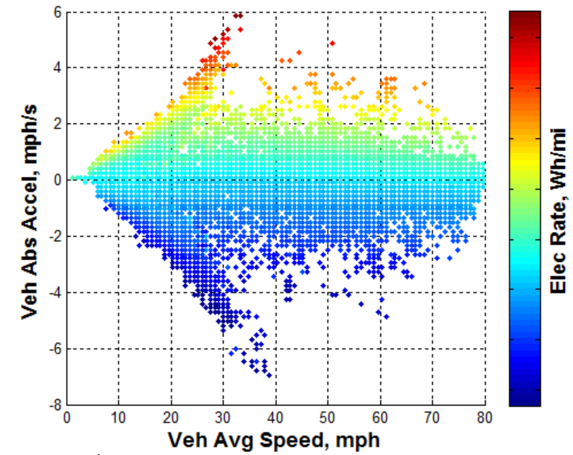
NREL IG 18563

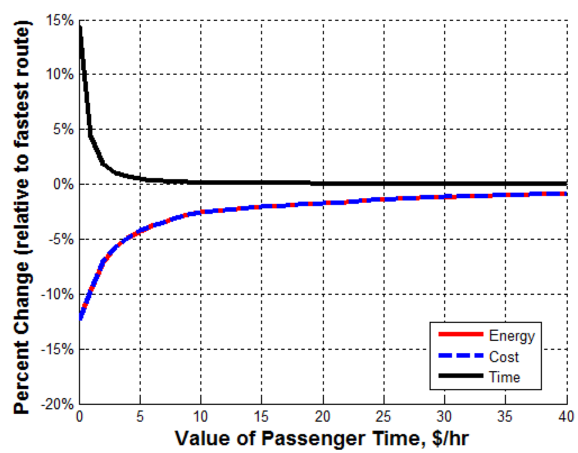


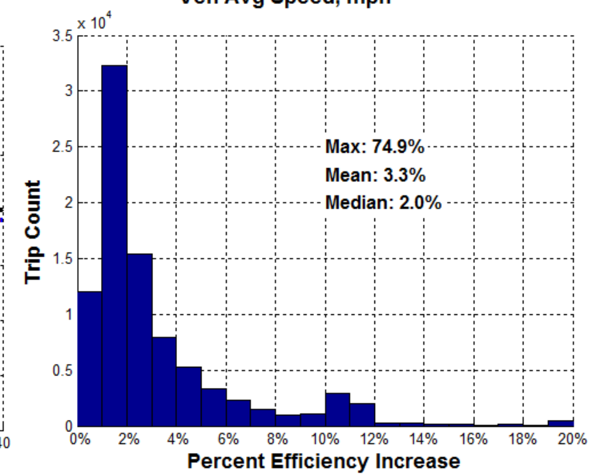












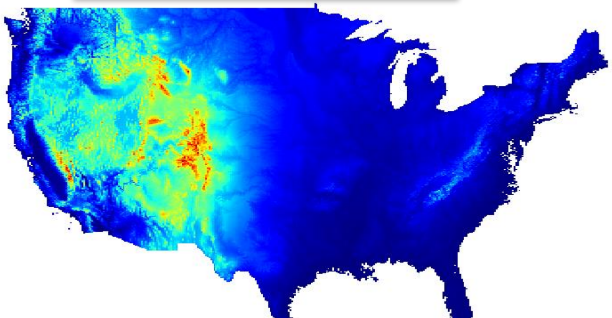
Aggregating Real-World/Off-Cycle Analyses

Merging impacts evaluation and multiple data layers

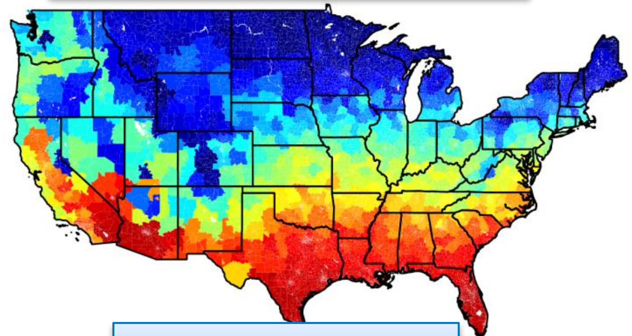
Objectively evaluating benefits of diverse technologies difficult to assess with standard certification cycles

- DOE and regulators want to maximize real-world fuel savings
- Manufacturers want credit for actual savings achieved

Elevation / Grade

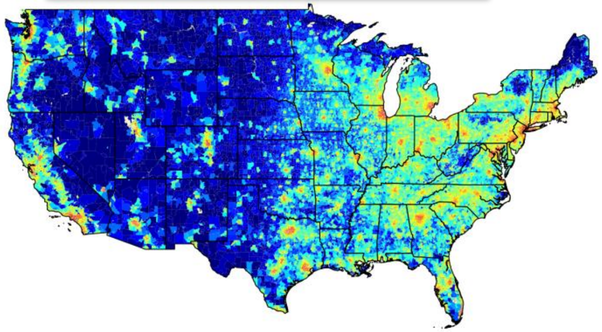


Ambient Temperature

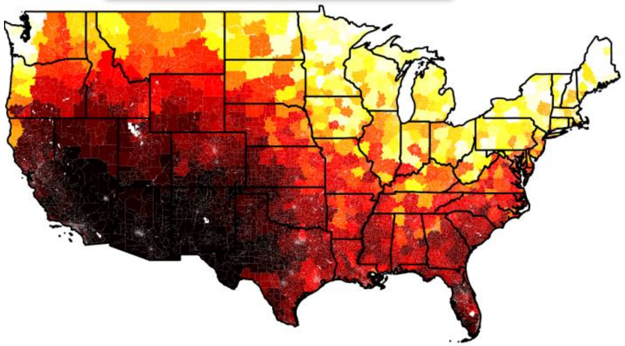


GPS Drive Cycles

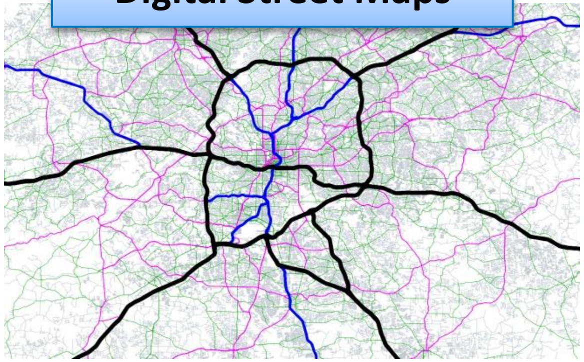
Vehicle Registrations



Solar Intensity



Digital Street Maps



Thanks! Questions?