Potential Energy Impacts of Connected and Automated Vehicles: Opportunities and Approaches

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Automated Vehicle Symposium Breakout Session Presentation

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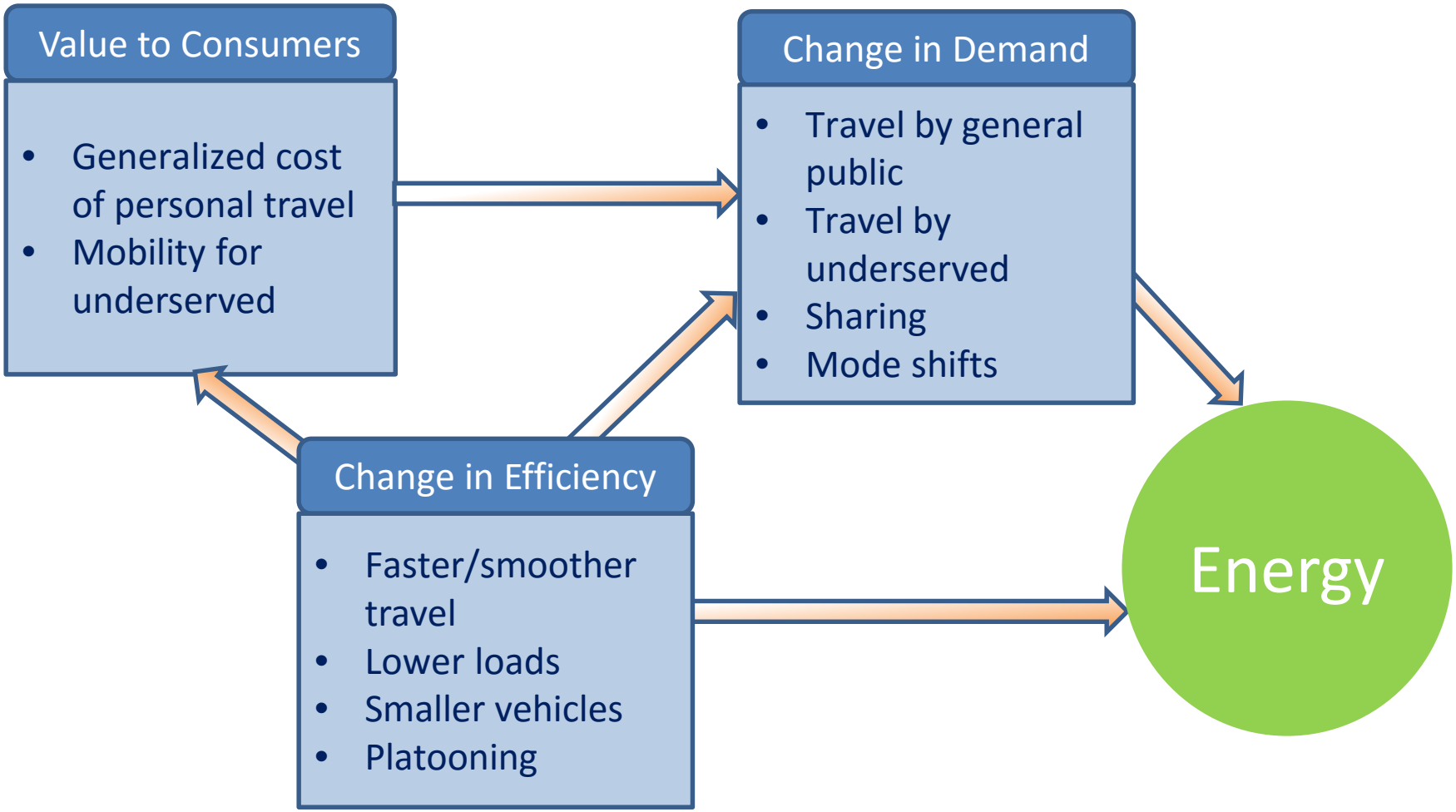
UIC = University of Illinois at Chicago

On-Going Collaborative Research Project

This short presentation:

- High-level scenario assessment based on literature inputs and rough assumptions
- Methodology summary for more detailed and comprehensive analysis (on-going work)

Assessment Structure: Main factors



Scenarios Description

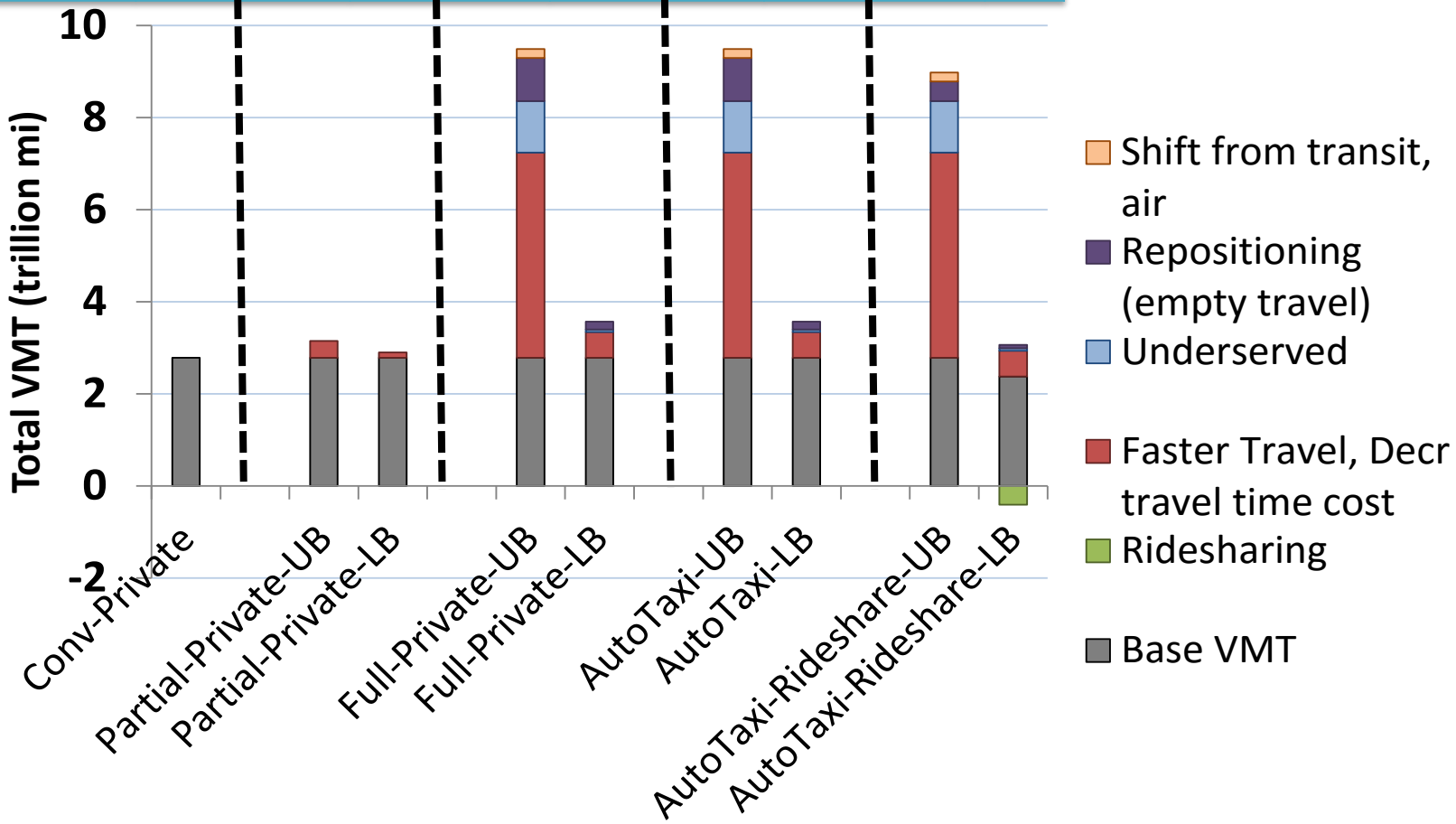
Scenario:	Conv-Private	Partial-Private-UB	Partial-Private-LB	Full-Private-UB	Full-Private-LB	AutoTaxi-UB	AutoTaxi-LB	AutoTaxi-Rideshare-UB	AutoTaxi-Rideshare-LB
Automation Level	N/A	Partial		Full		Full		Full	
Vehicle Ownership	Private	Private		Private		Shared		Shared	
Ridesharing	No	No		No		No		Yes	
Efficiency Improvement	N/A	Low	High	Low	High	Low	High	Low	High
VMT Demand Impact*	N/A	High	Low	High	Low	High	Low	High	Low
CAV Incremental Cost**	N/A	Low	High	Low	High	Low	High	Low	High

*Includes travel time costs (Low time cost leads to high VMT and thus higher energy use)
**Includes vehicle purchase cost

UB: Upper bound of energy impact (higher energy use)
LB: Lower bound of energy impact (lower energy use)
"Partial" = NHTSA Level 1-2; "Full" = NHTSA Level 3-4
Auto taxi = Fully automated vehicle providing transportation as a service

Travel Demand May Increase Significantly with Full Automation

	Conv-Private	Partial-Private-UB	Partial-Private-LB	Full-Private-UB	Full-Private-LB	AutoTaxi-UB	AutoTaxi-LB	AutoTaxi-Rideshare-UB	AutoTaxi-Rideshare-LB
Total VMT (Trillion)	2.8	3.1	2.9	9.5	3.6	9.5	3.6	9.0	3.1
Total PMT (Trillion)	4.65	5.26	4.84	14.27	5.67	14.27	5.67	14.27	5.67
Average Occupancy	1.67	1.67	1.67	1.50	1.59	1.50	1.59	1.59	1.85



Visualizing Average Consumption Rate/100 mi (and Reduction Source)

Total VMT (Trillion)	2.8	3.1	2.9	9.5	3.6	9.5	3.6	9.0	3.1
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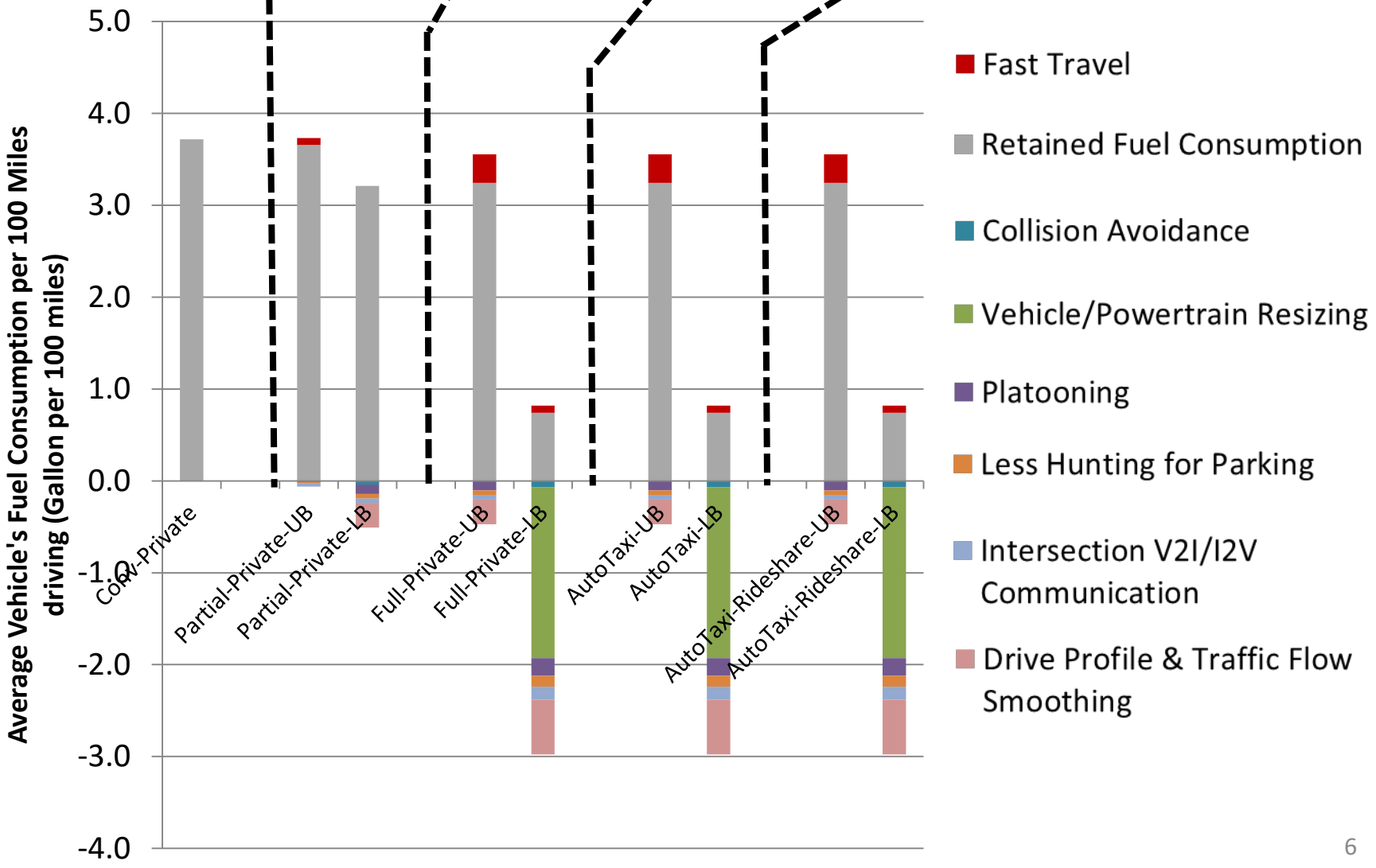

Total US LDV Fuel Consumption per Year

Total VMT (Trillion)	2.8	3.1	2.9	9.5	3.6	9.5	3.6	9.0	3.1
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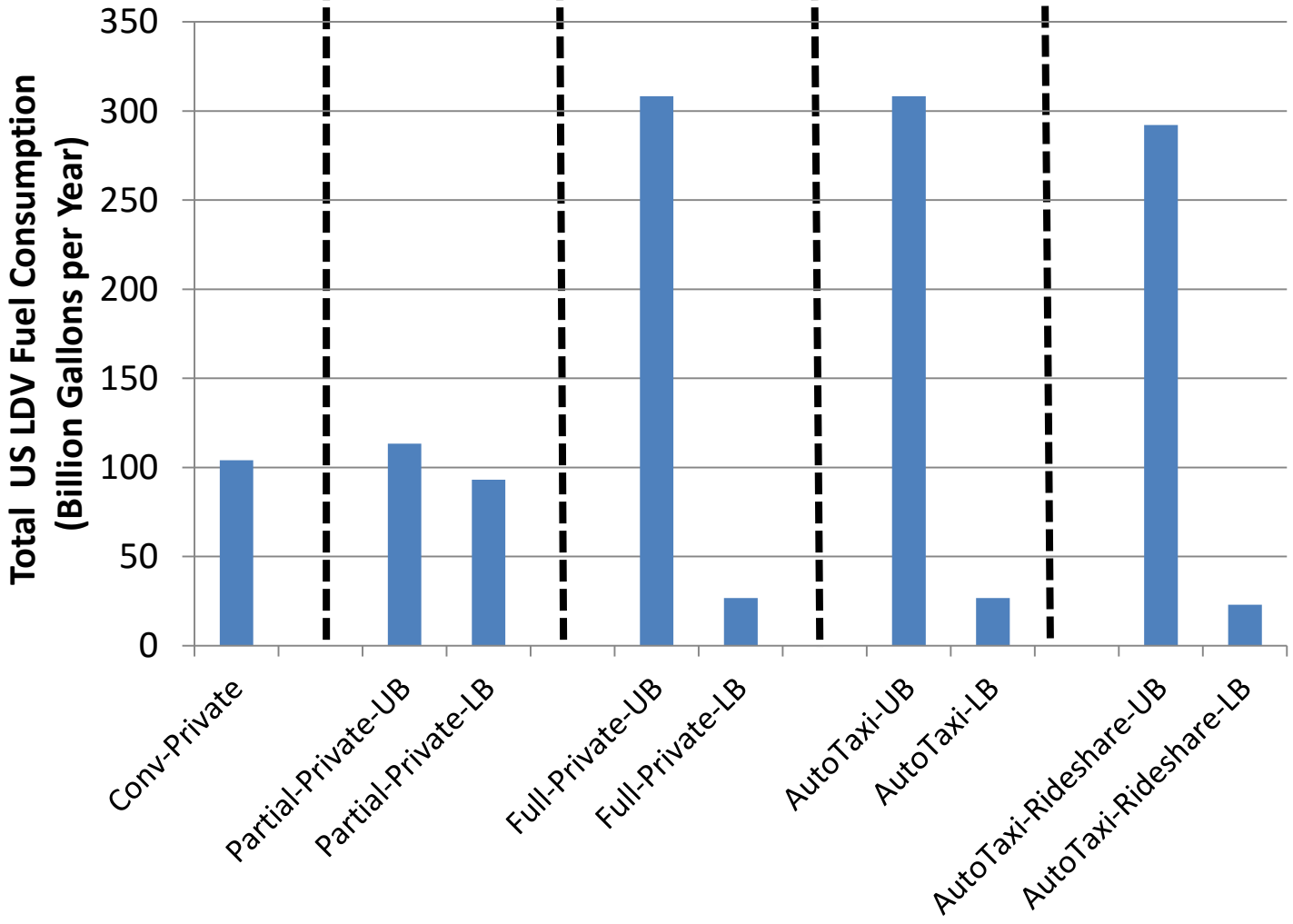

On-Going Collaborative Research Project

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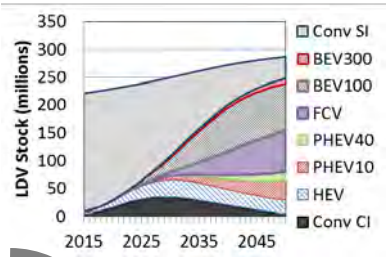
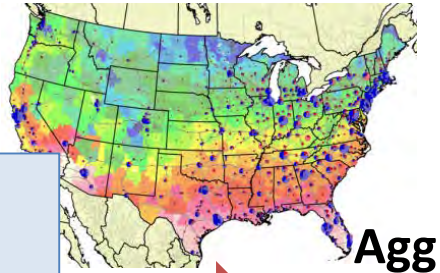
Analysis framework: Conceptual calculation flows

Establish scenarios of different powertrain and CAV feature **adoption rates** over time





Quantify potential efficiency and travel behavior impacts of CAV features in different driving situations

2015

Calculate national-level **energy use and GHGs** from aggregating driving situation impacts by the proportion of national VMT each represents

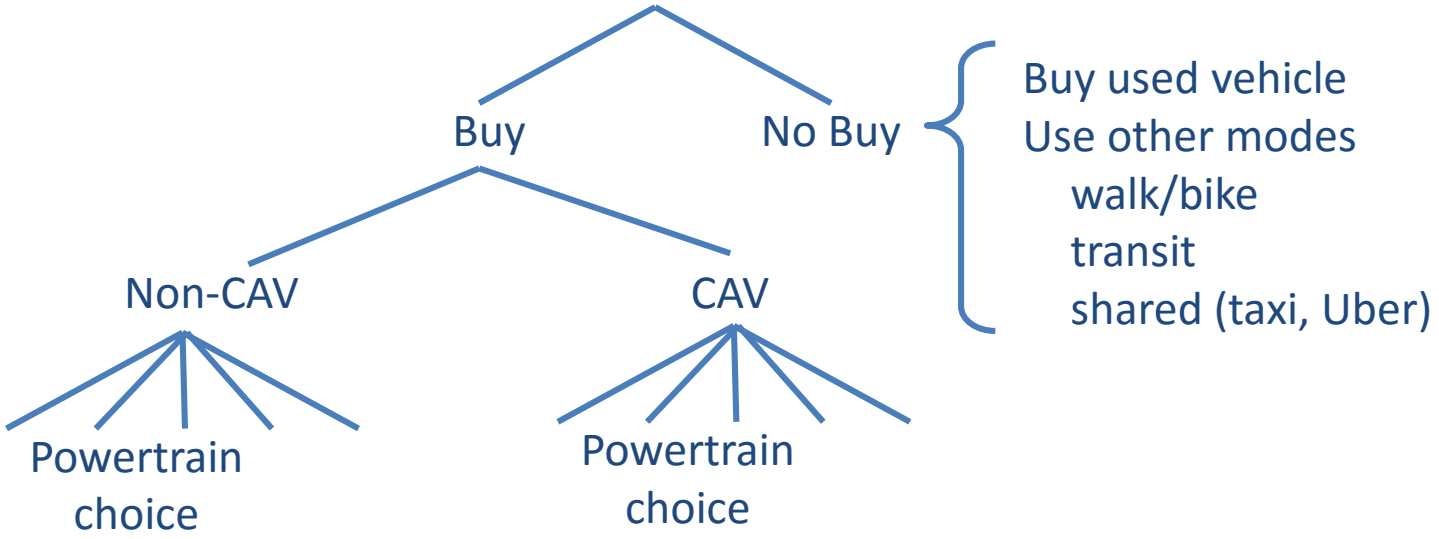
2040

Aggregate petroleum and GHG impacts of scenarios

Transfer regional analyses to estimate national evolution of **VMT distributions** over time

Estimating CAVs Adoption: Adapt consumer choice model to include CAVs purchase decision

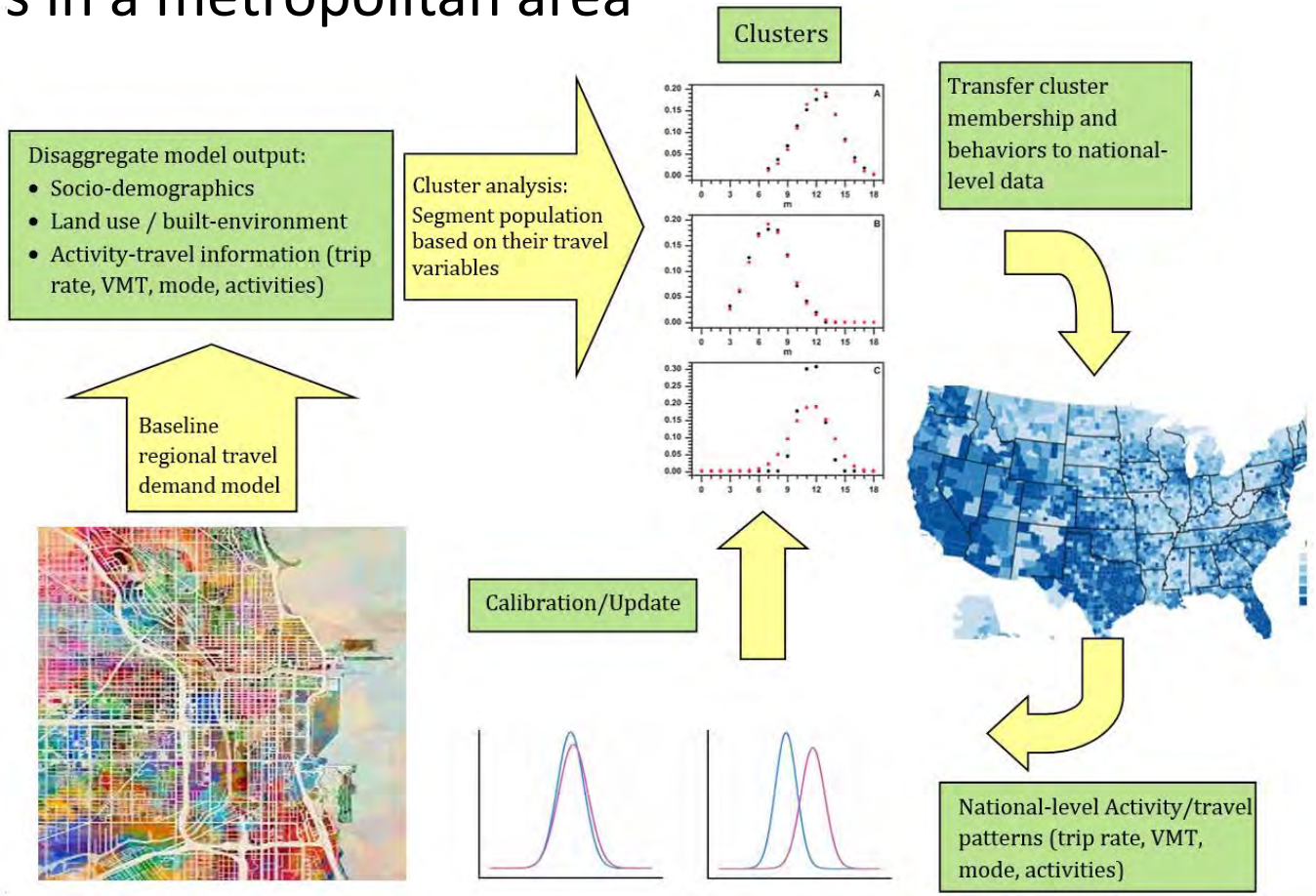
- Quantify utility to consumers within different market segments and resulting impacts on ownership and operation decisions
- Utility components: stress, energy, time, mobility, productivity
- Revise ORNL's MA^{3}T choice structure to include CAVs
  - In addition to buy/no-buy a new vehicle, add the options of buying a CAV and using AutoTaxis



Estimating Impacts on Travel Demand:

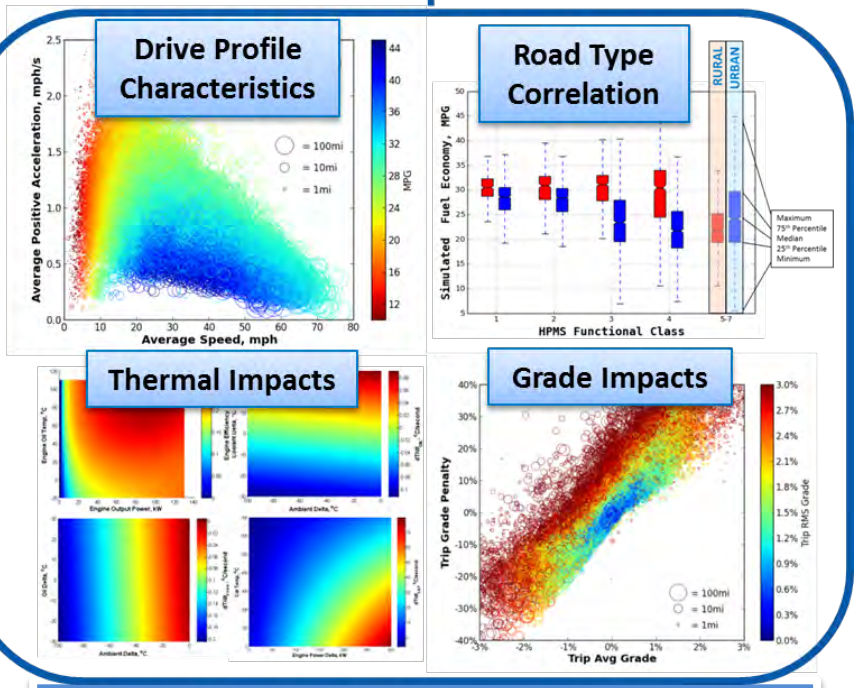
Use transferability modeling to expand detailed travel simulation results to the national level

- Transfer results from transportation system simulations of CAVs in a metropolitan area



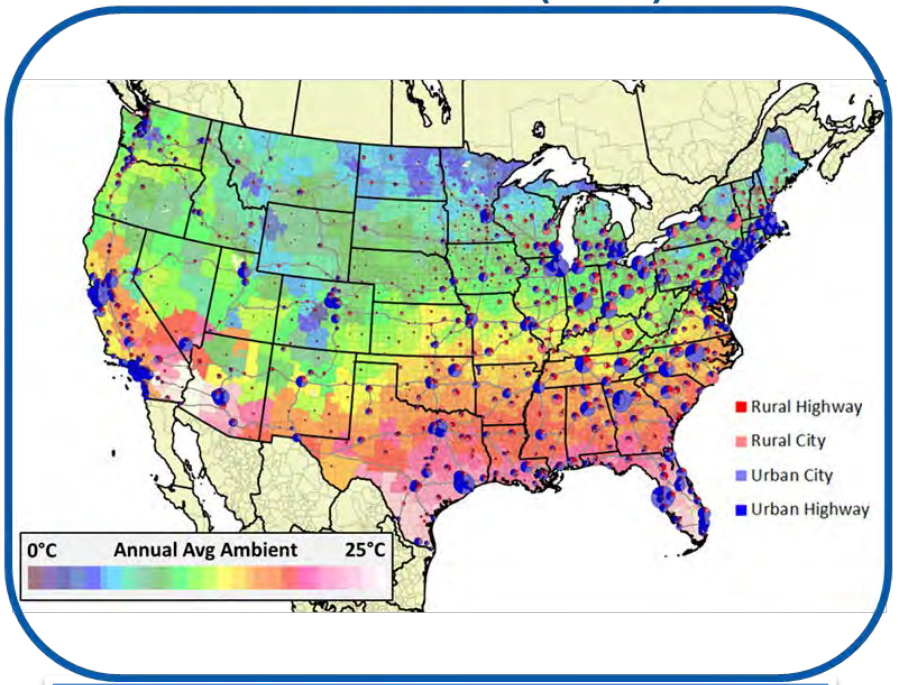
Aggregate energy/GHG impacts of CAV features nationally:

Fuel Consumption *Rates*

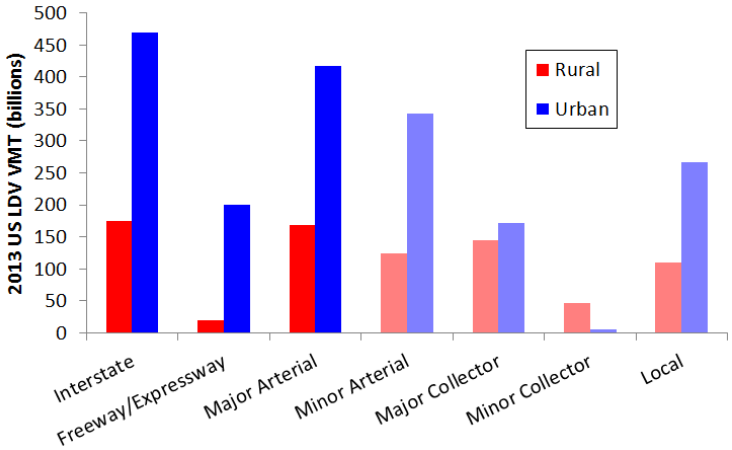


Quantify different CAV feature fuel economy impacts in different driving situations

Vehicle Miles Traveled (VMT) *Volumes*



Consider the relative proportion of national VMT represented by each driving situation



Calculate national total energy use and GHG emissions by summing VMT for the entire U.S. road network

Preliminary Conclusions

- Potential energy and GHG emission impacts from CAVs are uncertain
- Previous work is difficult to synthesize into consistent scenarios
- On-going DOE-supported simulation and data collection efforts will supply detailed inputs into the presented national-level assessment methodology

Planned Future Work

- Further develop and validate expansion aggregation methods and apply these to detailed simulation/data collection results
- Estimate potential adoption of CAVs technologies by different population segments
- Consider multiple scenarios for analysis
  - Driverless taxis, with/without ridesharing
  - Connected vehicles in an urban environment (traffic smoothing)
  - Connected vehicles on highways (CACC, platooning)

Back up slides

Details of Initial High-Level Scenario Energy Calculations

- Disaggregate the fuel consumption into road type (highway/urban), level of service (congestion/non-congestion).
- Search literature to quantify each CAV feature's energy impact on specific road type/level of service condition under different scenarios.
- Re-calculate CAVs' specific energy impact on applicable road type (urban or highway) and condition (congested or non-congested) into aggregated national average energy impact on overall driving
- Estimate the total fuel consumption for average LDV per year with breakdown of CAV features' impacts.

Assumptions (based on GPRA BaSce)

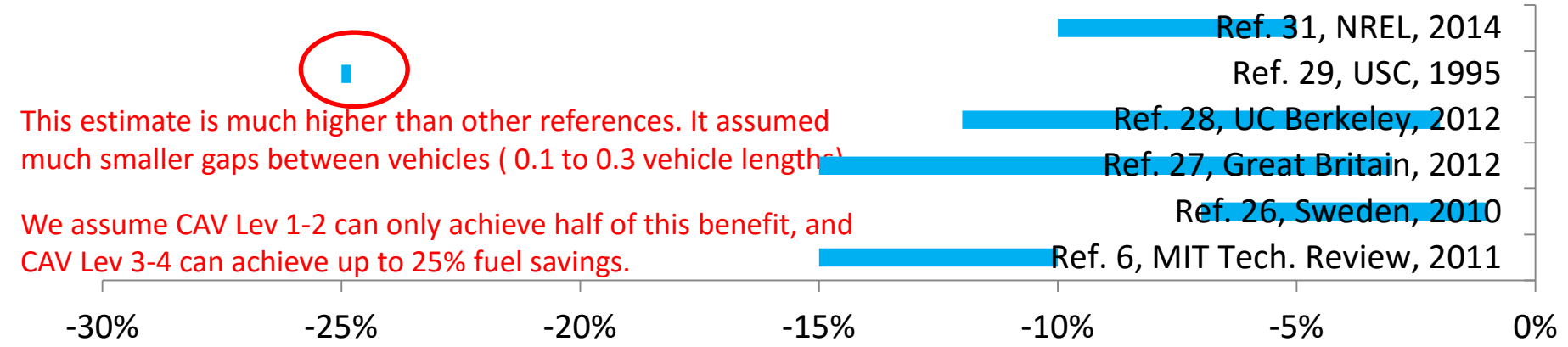
- Average LDV annual mileage, 13350 mile/year
- Average LDV fuel economy, 26.9 mi/gal
- Gasoline price: $2.93 2010$ / gal

VMT % and fuel economy by road type and level of service

	VMT %	MPG
Highway Congested	18%	29.7
Highway Non-congested	27%	35.0
Urban Congested	22%	21.4
Urban Non-congested	33%	25.2

Based on assumptions from EPA MOVES model national default inputs and EPA fuel economy tag inputs.

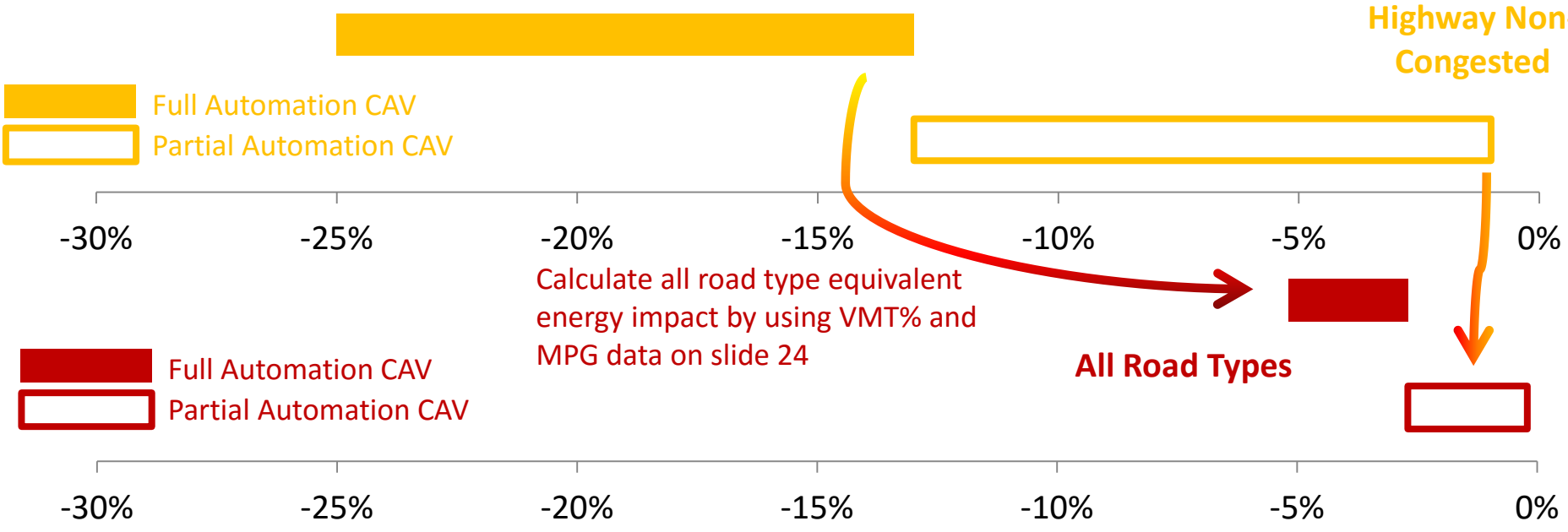
Platooning

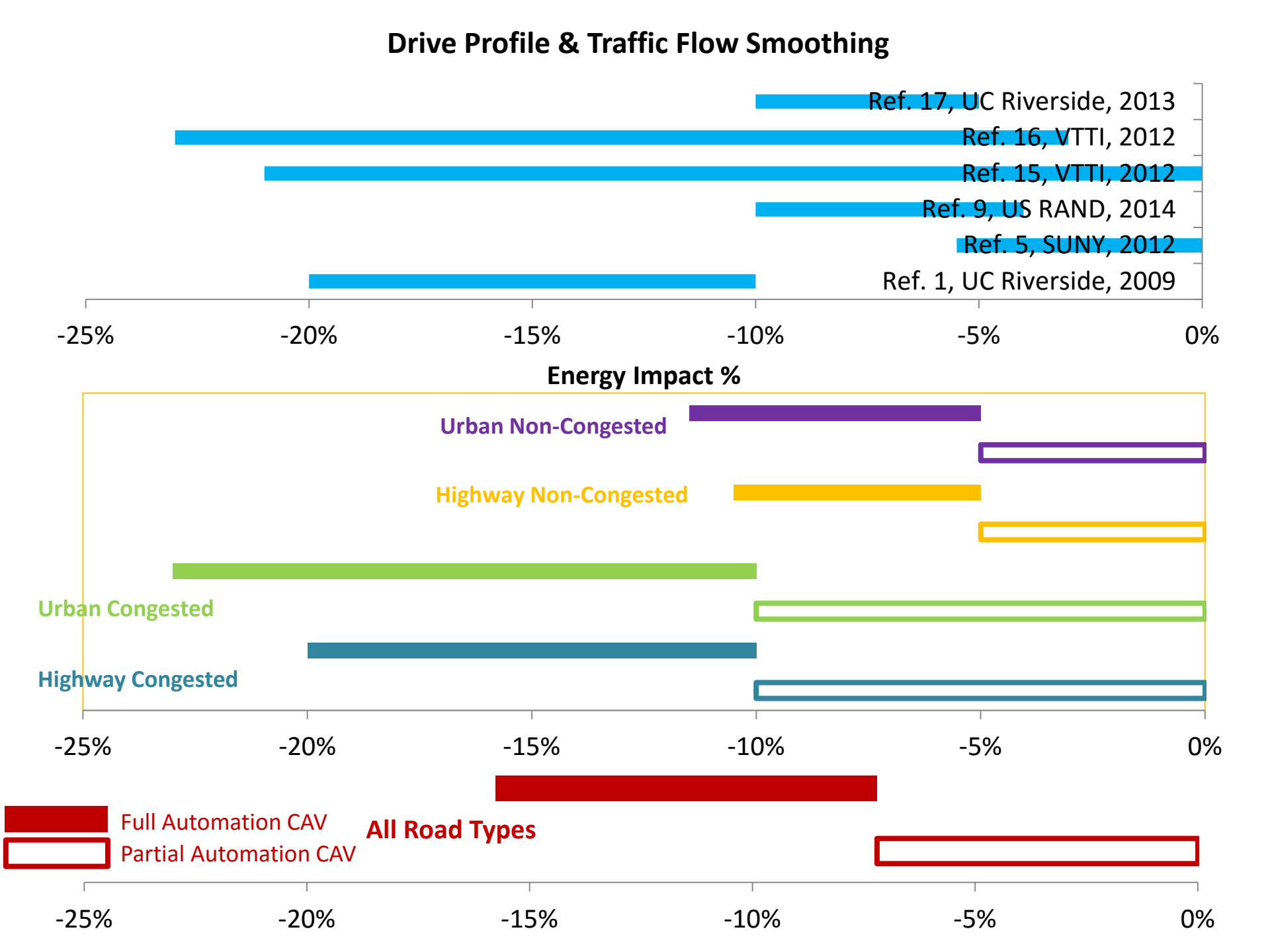


This estimate is much higher than other references. It assumed much smaller gaps between vehicles (0.1 to 0.3 vehicle length)

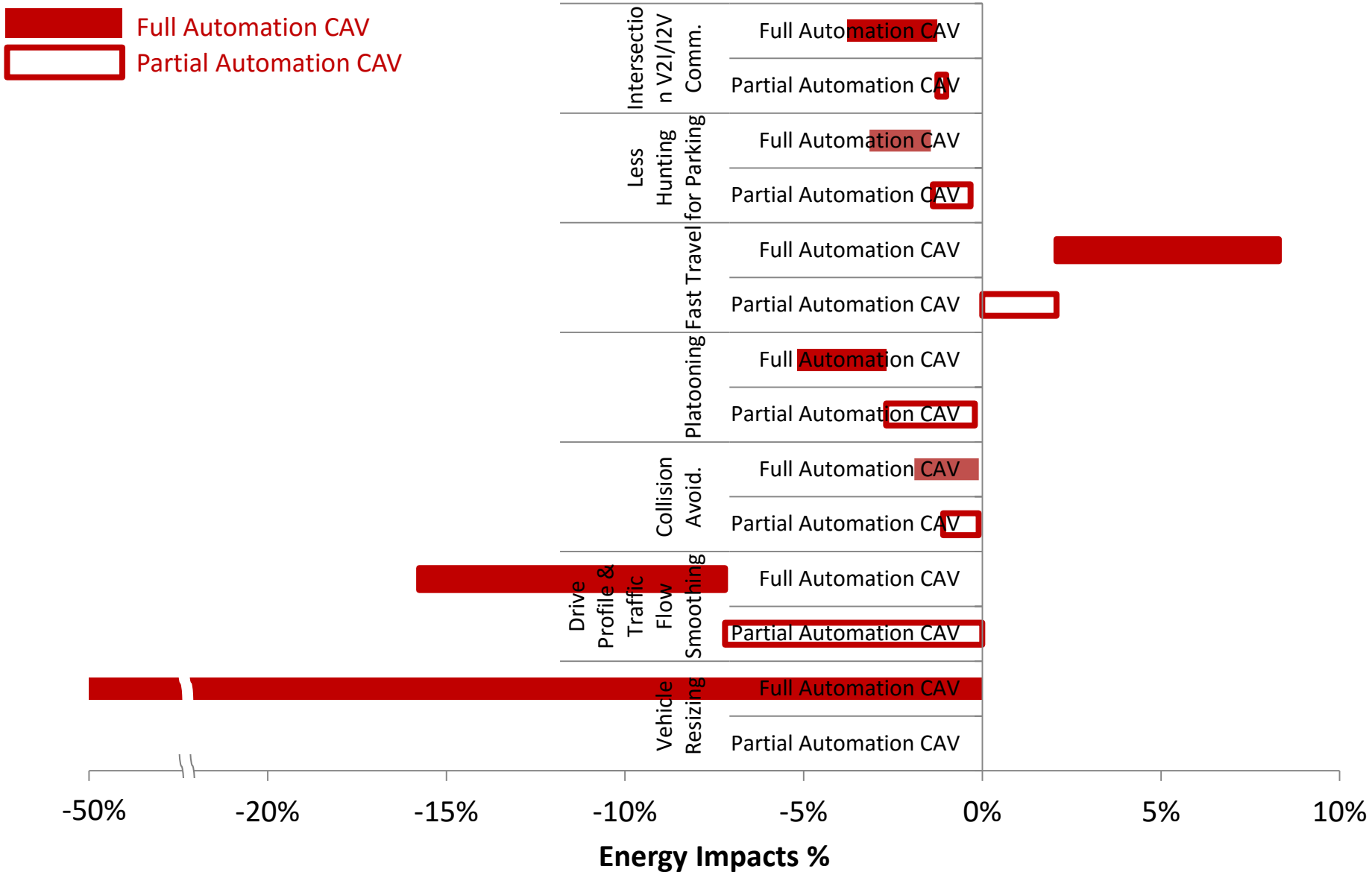
We assume CAV Lev 1-2 can only achieve half of this benefit, and CAV Lev 3-4 can achieve up to 25% fuel savings.

Assuming platooning benefits occur only on non-congested highway driving, i.e. 27% of total VMT.




Drive Profile & Traffic Flow Smoothing
Ref. 17, UC Riverside, 2013
Ref. 16, VTTI, 2012
Ref. 15, VTTI, 2012
Ref. 9, US RAND, 2014
Ref. 5, SUNY, 2012
Ref. 1, UC Riverside, 2009
-25%
-20%
-15%
-10%
-5%
0%
Energy Impact %
Urban Non-Congested
Highway Non-Congested
Urban Congested
Highway Congested
-25%
-20%
-15%
-10%
-5%
0%
Full Automation CAV
Partial Automation CAV
All Road Types
-25%
-20%
-15%
-10%
-5%
0%

Vehicle-Level Energy per Mile Impact Ranges of CAV Features



Explanation of Bar Chart Format for Presenting CAV Features' Energy and Demand Impacts:

- Reductions: for visualization, the reduction from the original attributed to each feature moves from above to below the x-axis.
- Increments: add on top of top of the original bar.
- The final height of the bar (in the positive region only) shows the net fuel consumption including all impacts