Impact of Smart Mobility on Electrified Powertrain Benefits

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Problem: Mobility Industry Is Undergoing a Revolution

Better vehicles

Powertrain, electrification, control, light weighting, aero/tires, etc.

Smarter vehicles

Control of speed and/or powertrain using:

- *sensors & connectivity*
- *automation*

Smarter roads

Smarter control of the road networks and traffic flows

Smarter travelers

Mobility as a service, changes in travel needs

Making Technology Decisions Extremely Difficult

Single Vehicle | **Corridor / Small Network** | **Entire Urban Area**

Better vehicles

- How do we build vehicles customers will buy while meeting CO2 regulations?
- How to select the right component and powertrain technology?
- How do we maximize profit?

Smarter vehicles

- How quickly should we deploy connected and automated vehicle (CAVs) technology?
- Do CAVs help or hurt electrification?
- What are the real world benefits and CO2 credits?

Smarter roads

- What are the impact of sensors on mobility, energy…?
- Should we invest in DSRC communication or wait for 5G?
- What policies to implement (pricing…)?

Smarter travelers

- How can we leverage TNC (eg Uber) with other technologies (eg, transit, bike share…)?
- What is the impact of new technologies on congestion, emissions…?

Solution: Improve City Life Through System Simulations

Single Vehicle | **Corridor / Small Network** | **Entire Urban Area**

Better vehicles

Select optimum technology portfolio by comparing impact across millions of combinations

Smarter vehicles

Select technologies with the greatest benefits to customers

Smarter roads

Deploy technologies with greatest impact on road networks and traffic flows

Smarter travelers

Implement optimum policies to maximize mobility while minimizing energy impact

AUTONOMIE ⟷ ROAD RUNNER ⟷ PTV VISSIM / Aimsun ⟷ POLARIS

EVS 32 A world of E MOTION 2019 MAY 19 22
INTERNATIONAL ELECTRIC VEHICLE SYMPOSIUM & EXHIBITION

AUTONOMIE | ROAD RUNNER | POLARIS

Vehicle Energy Consumption, Performance and Cost

- Licensed to >250 companies
- Covers current and future component technologies
- Powertrain control based on actual test data
- 2M+ vehicle models from cars to trucks

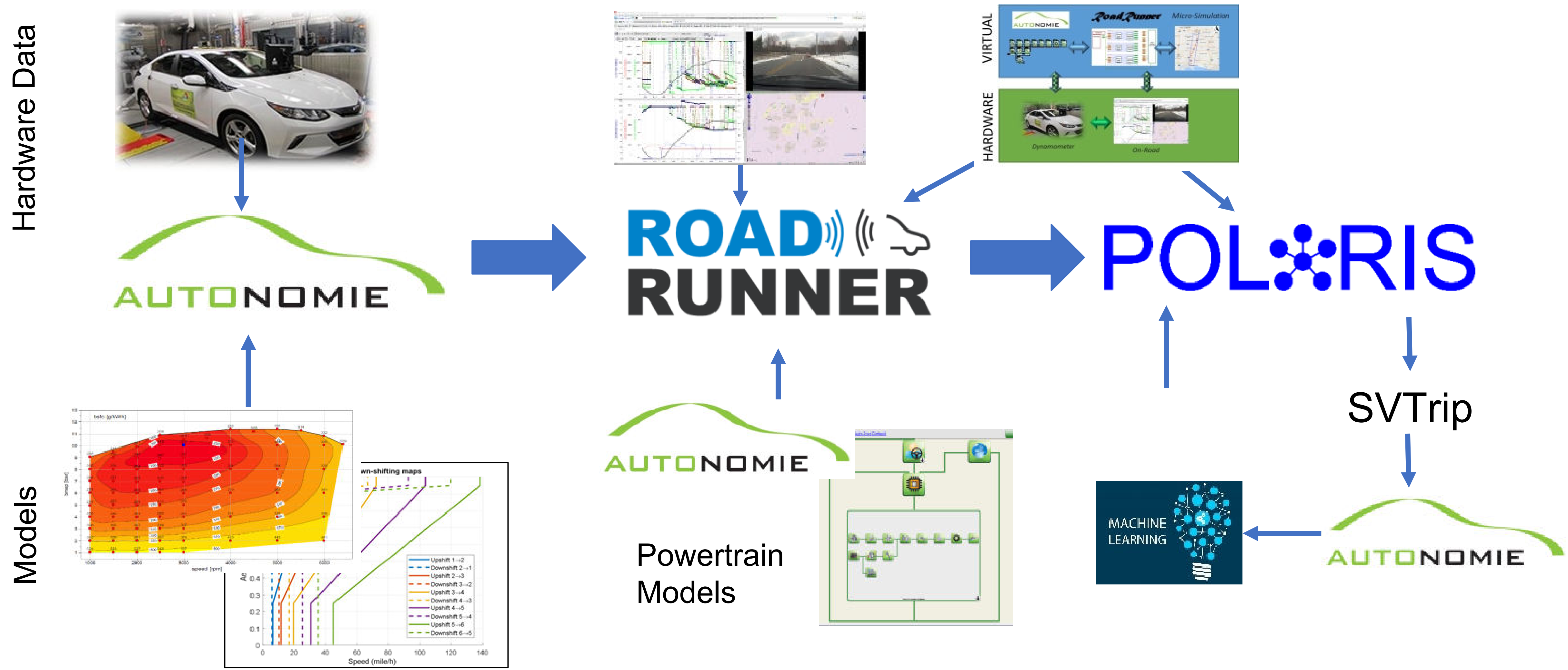
Vehicle Energy Consumption of CAVs

- Eco-driving control for CAVs
- CAV energy impacts
- Powertrain Component operating conditions
- Predictive Powertrain Control

Model Metropolitan Area Transportation System

- Models traveler decisions with continuous feedback from traffic system
- Different modes (drive, walk, bike, transit…)
- Realistic traffic flow (traffic light, stop signs)

New System Approach Leverages Multiple Integrated Tools

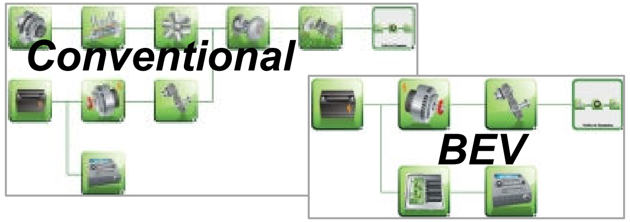


RoadRunner Simulation Process

1. Define Scenario and Select Powertrain

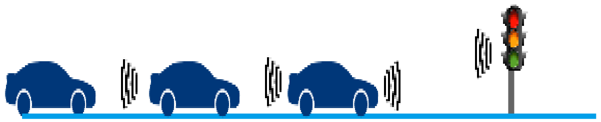
Routes:
Real-world routes from HERE maps

Vehicles: Powertrain models from Autonomie



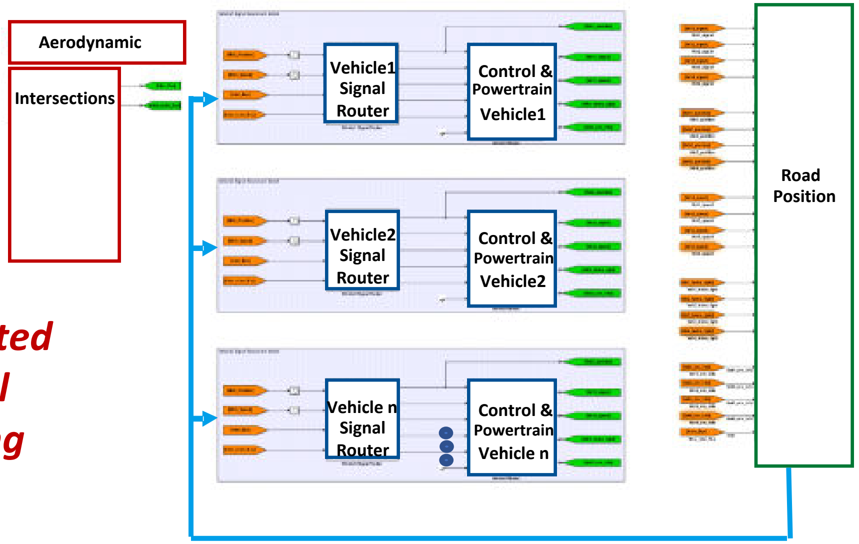
Control: Human, CAV w/ eco-driving, etc.

Number of vehicles, Connectivity level

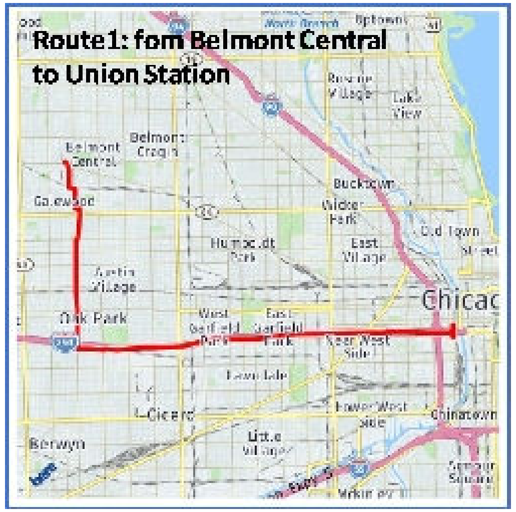


Automated Model Building

2. Simulate Scenario

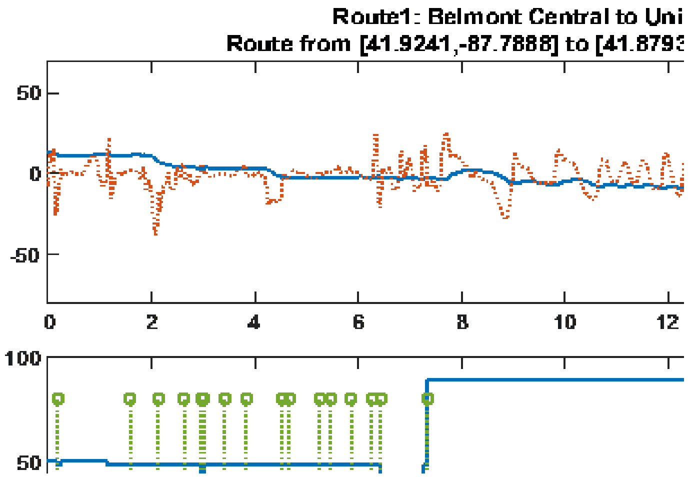


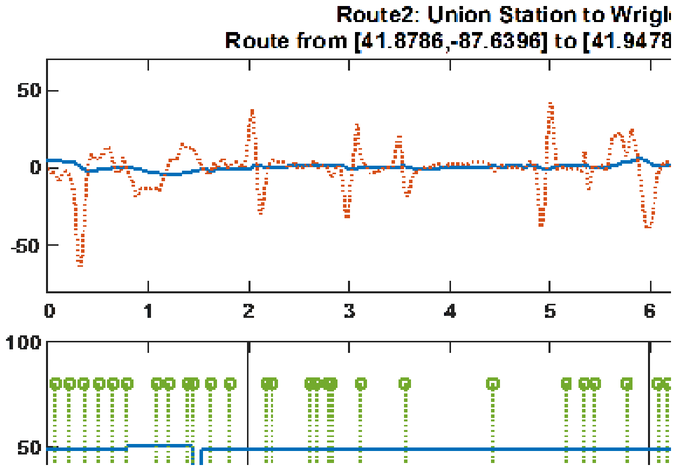
Eco-Approach Scenario Selected Routes

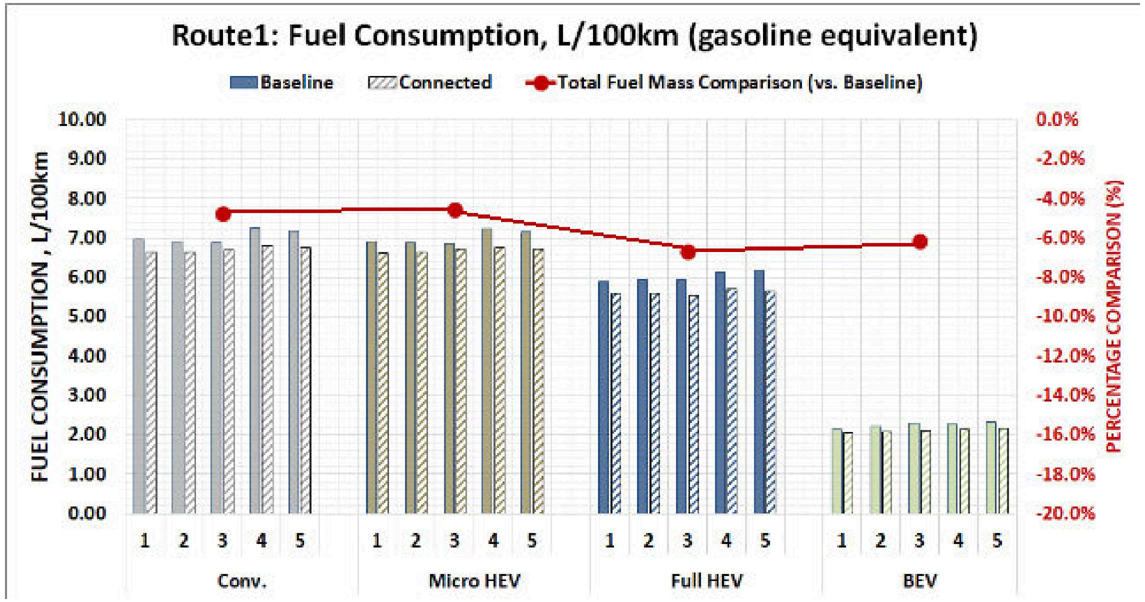


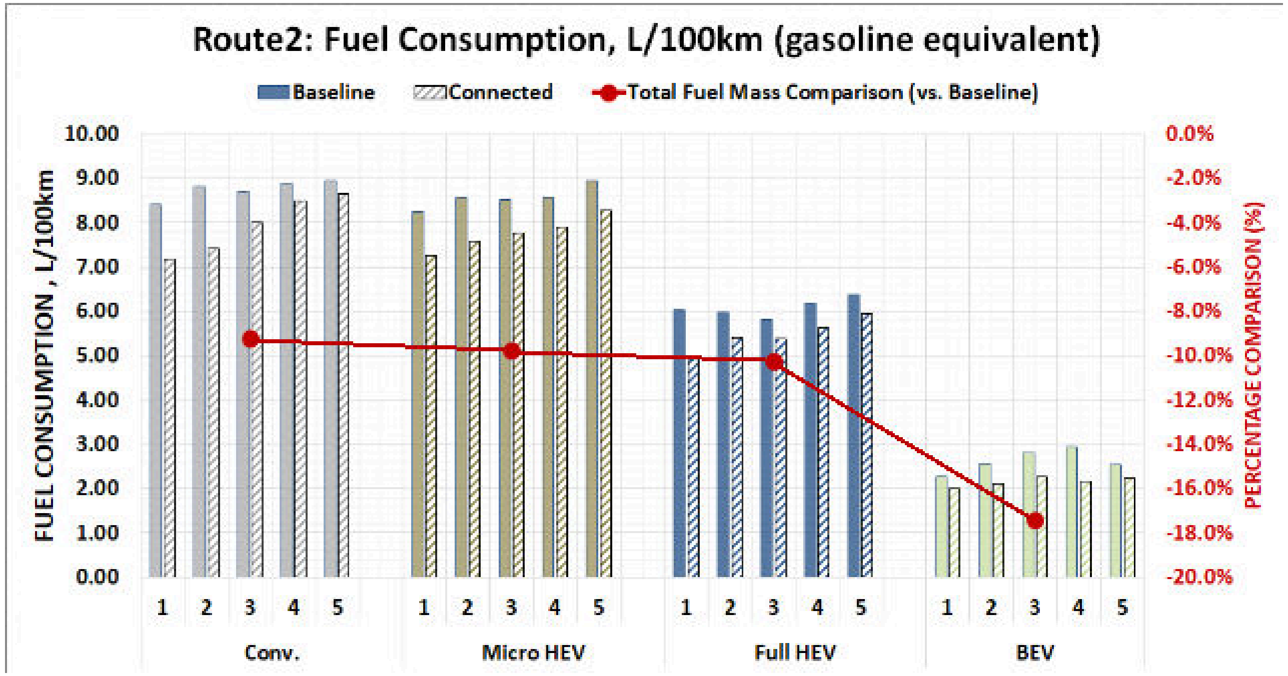
#1 – Mix of urban and highway

– Urban

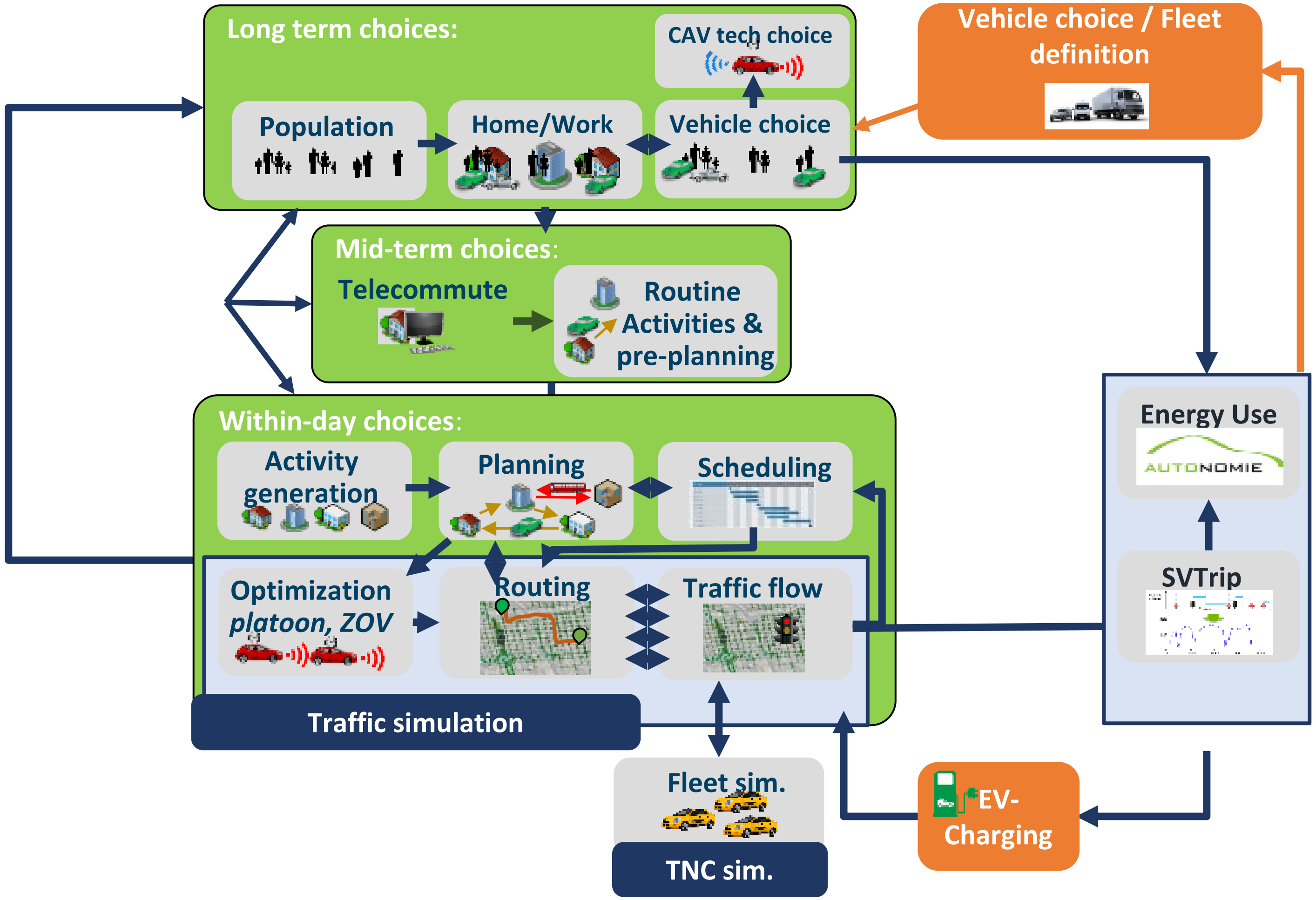





Route1: Fuel Consumption, L/100km (gasoline equivalent)
Baseline
Connected
Total Fuel Mass Comparison (vs. Baseline)
FUEL CONSUMPTION, L/100km
PERCENTAGE COMPARISON (%)
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0.0%
-2.0%
-4.0%
-6.0%
-8.0%
-10.0%
-12.0%
-14.0%
-16.0%
-18.0%
-20.0%
1 2 3 4 5
Conv.
Micro HEV
Full HEV
BEV


Route2: Fuel Consumption, L/100km (gasoline equivalent)
Baseline
Connected
Total Fuel Mass Comparison (vs. Baseline)
FUEL CONSUMPTION, L/100km
PERCENTAGE COMPARISON (%)
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0.0%
-2.0%
-4.0%
-6.0%
-8.0%
-10.0%
-12.0%
-14.0%
-16.0%
-18.0%
-20.0%
1 2 3 4 5
Conv.
Micro HEV
Full HEV
BEV

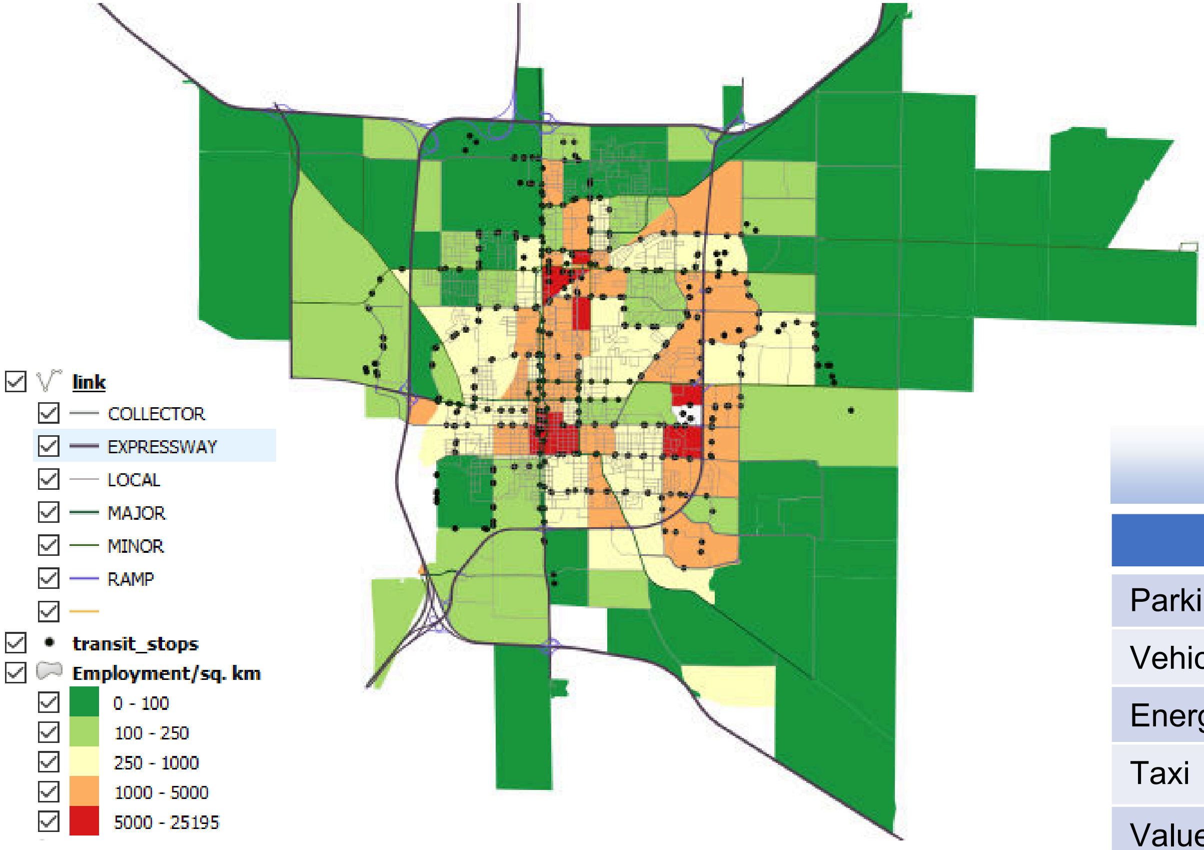
POLARIS : Agent-Based Activity-Travel Simulation Model



Polaris Highlights:

- Simulate **regional** mobility
- Provides detailed travel information by each **agent**
- Fully **integrated** demand, dynamic traffic assignment, and simulation
- Integrated with **energy** model for regional energy analysis
- **Open-source** C++ for Windows/Linux
- Supports **HPC**
- 4-8 hr for 10M agents

Case Study for Privately Owned Partial and Full Automation for Bloomington, IL



Model characteristics:

- Agents:
  - 65,000 households, 156,000 people
  - 680,000 auto trips
  - 923 transit vehicle trips
- Physical systems:
  - 222 TAZs
  - 2,833 activity locations
  - 3,947 links
  - 470 transit stops

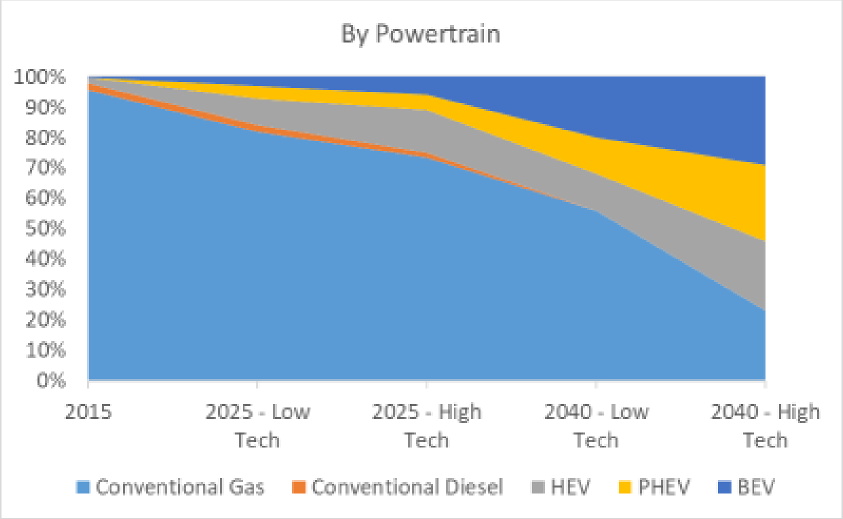
Cost Assumptions

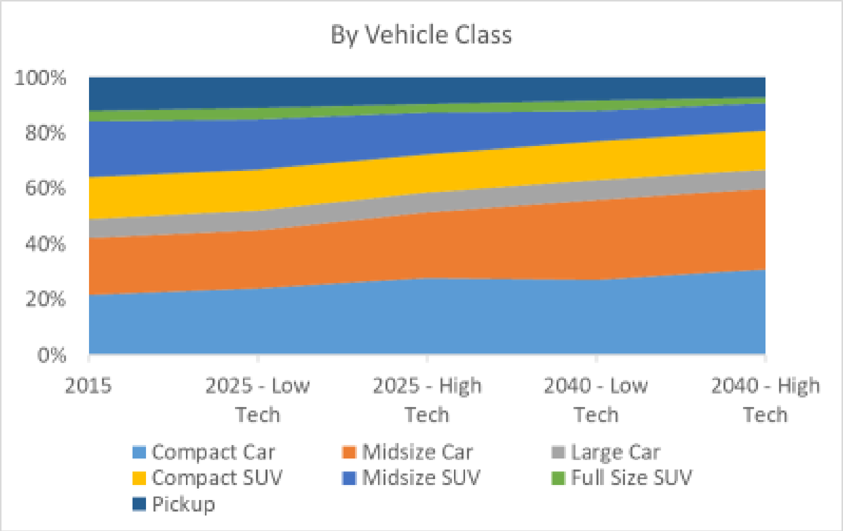
Description	Cost
Parking	$0/hr
Vehicle Ownership	$20/veh
Energy	$0.13/mile
Taxi	$3 + $0.8/mile
Value of Time	$10/hr
Unloaded Vehicle Pricing	0 , $0.33/mile

Flexibility	Start (min)	Duration (min)
Low	5	5
Intermediate	15	15
High	60	60

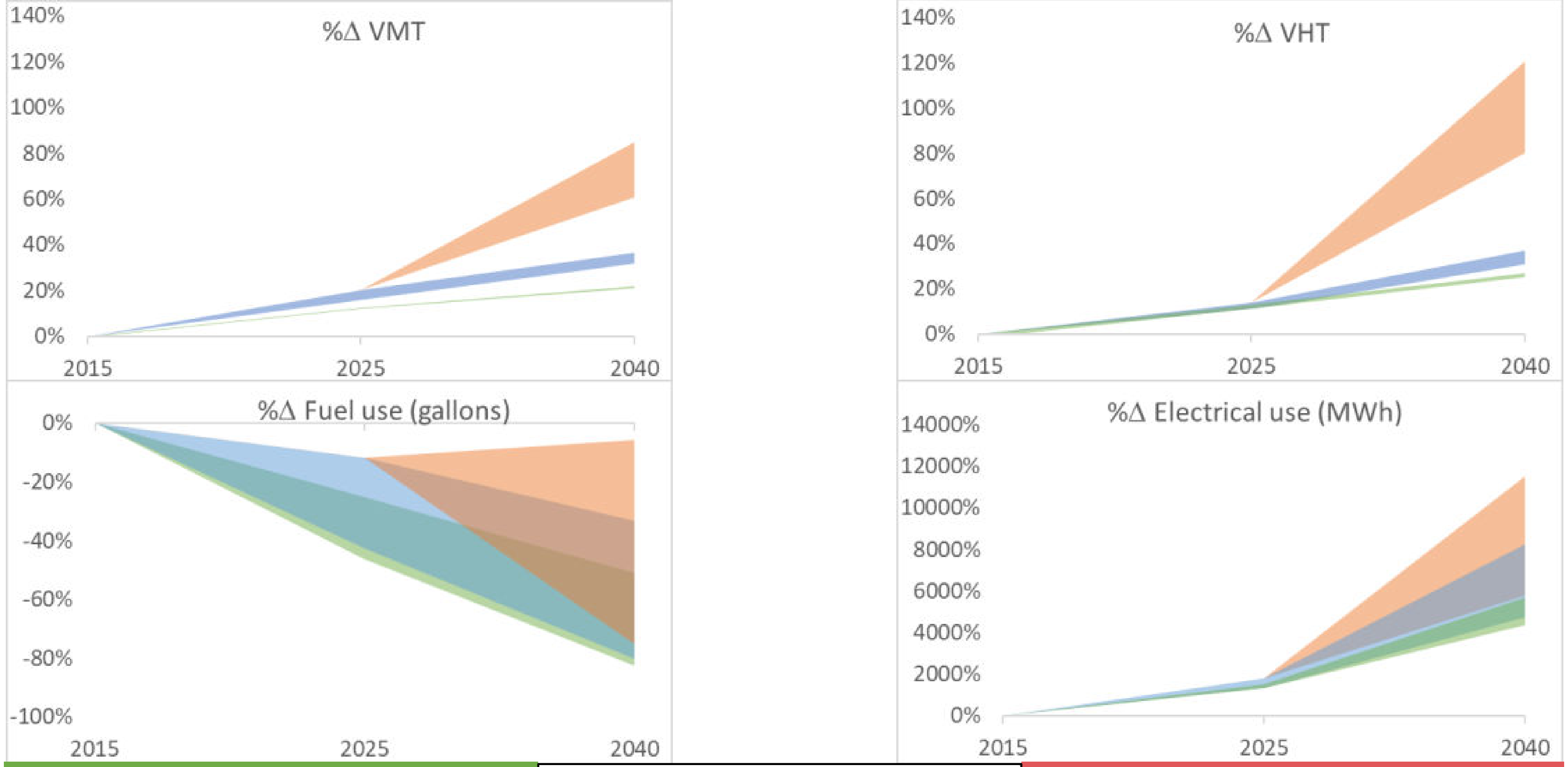
Scenarios Defined by CAV, Vehicle Technologies and Cost Assumptions

- **Timeframe**: 2015, 2025, 2040
- **CAV technologies**:
  - Level 3/4 (2025 & 2040)
  - Level 5 (2040 only)
- **CAV costs**:
  - $2500 & $7500 (2025)
  - $0 & $2500 (2040)
  - $0 or $0.33/mile unloaded vehicle charge (2040)
- **Value of travel time savings**: 50% of baseline
- **Vehicle assumptions**:
  - 2015 dist. from Polk/IHS registration data
  - Low and high technology penetration cases
  - CAV accessory loads: 600W, 1000W, 2500W





Range in performance metrics over all scenarios by year (best and worst case for base, CAV4 and CAV5)

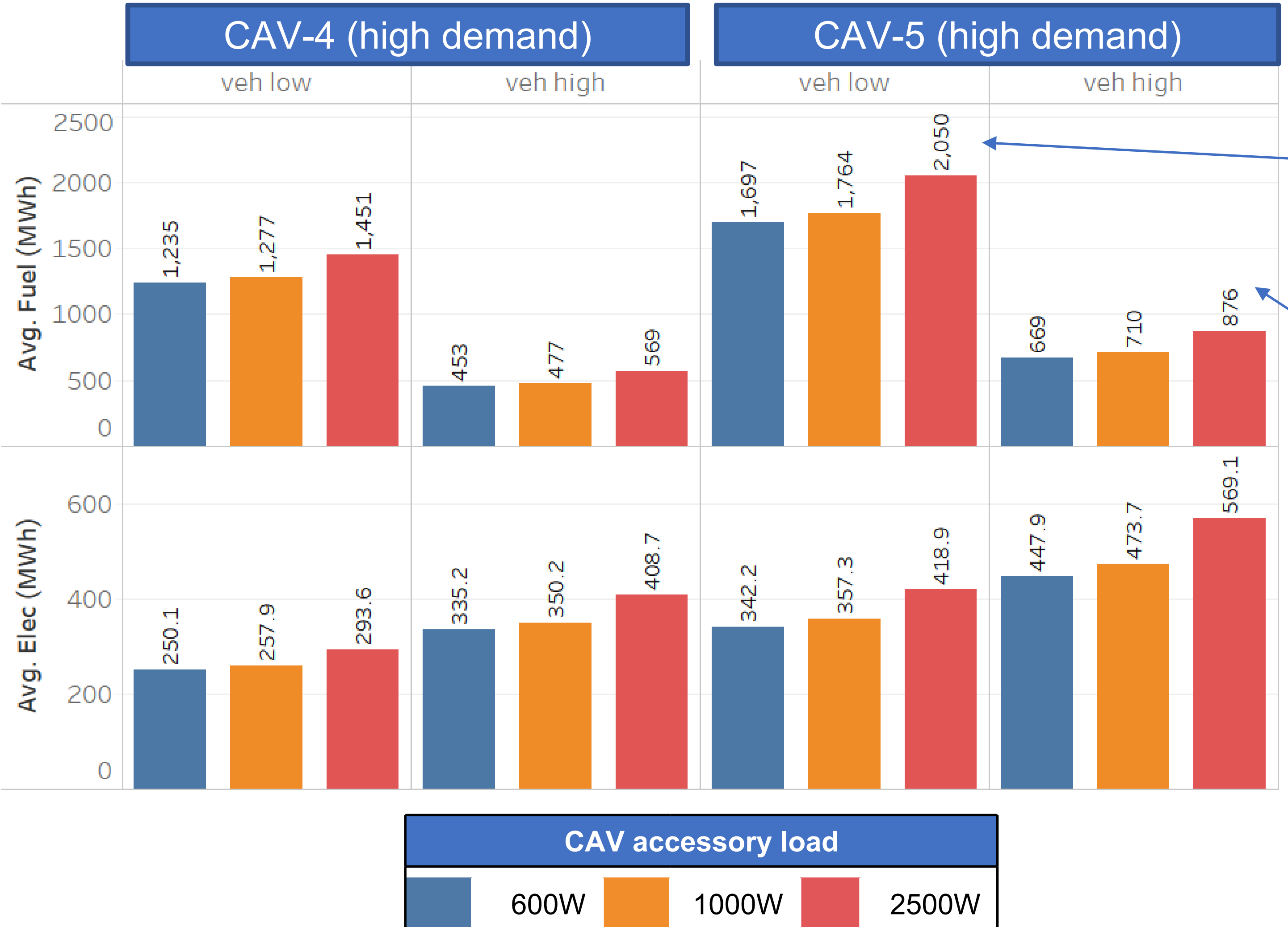


Best case for each scenario is high-tech, 600W, low-cav, w/ZOV charge

Base CAV-4 CAV-5

Worst case for scenario is low-tech, 2500W, high-CAV, no charge

Additional Electrical Loads Due to CAV are Critical to Overall Energy



For low tech scenario: difference of up to 21% fuel and 23% electricity usage based on CAV acc. load

For high tech scenario: difference of up to 31% fuel and 27% electricity usage based on CAV acc. load

Conclusions & Next Steps

- The benefits of vehicle technologies, including electrification, will be greatly impacted by the emergence of connectivity, automation and sharing.
- It is critical to understand the impact of new control possibilities enabled by connectivity and of new mobility and automation on usage to properly design and estimate the impact of electrified powertrains.
- Current analysis highlighted:
  - BEVs are expected to benefit more than other powertrains from Eco-signal in urban driving conditions
  - Connectivity and automation can have a significant impact on PEVs electrical consumption and range