Sustainable TRANSPORTATION

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Connected/Automated and Autonomous Vehicles (CAVs)

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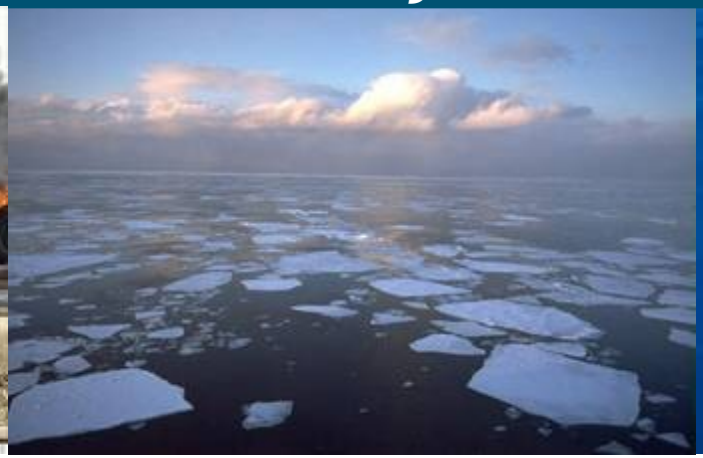
Oil Dependency is Dominated by On-Road Vehicles

- Transportation is responsible for 2/3 of U.S. petroleum usage
- On-Road vehicles responsible for 80% of transportation petroleum usage
- >240M Vehicles on the road

- Economic security, energy security, and environmental stewardship
- Changing energy landscape
  - Natural gas
  - Electrification
  - Fuel Economy Standards

The Cost of Oil is Not Just Monetary

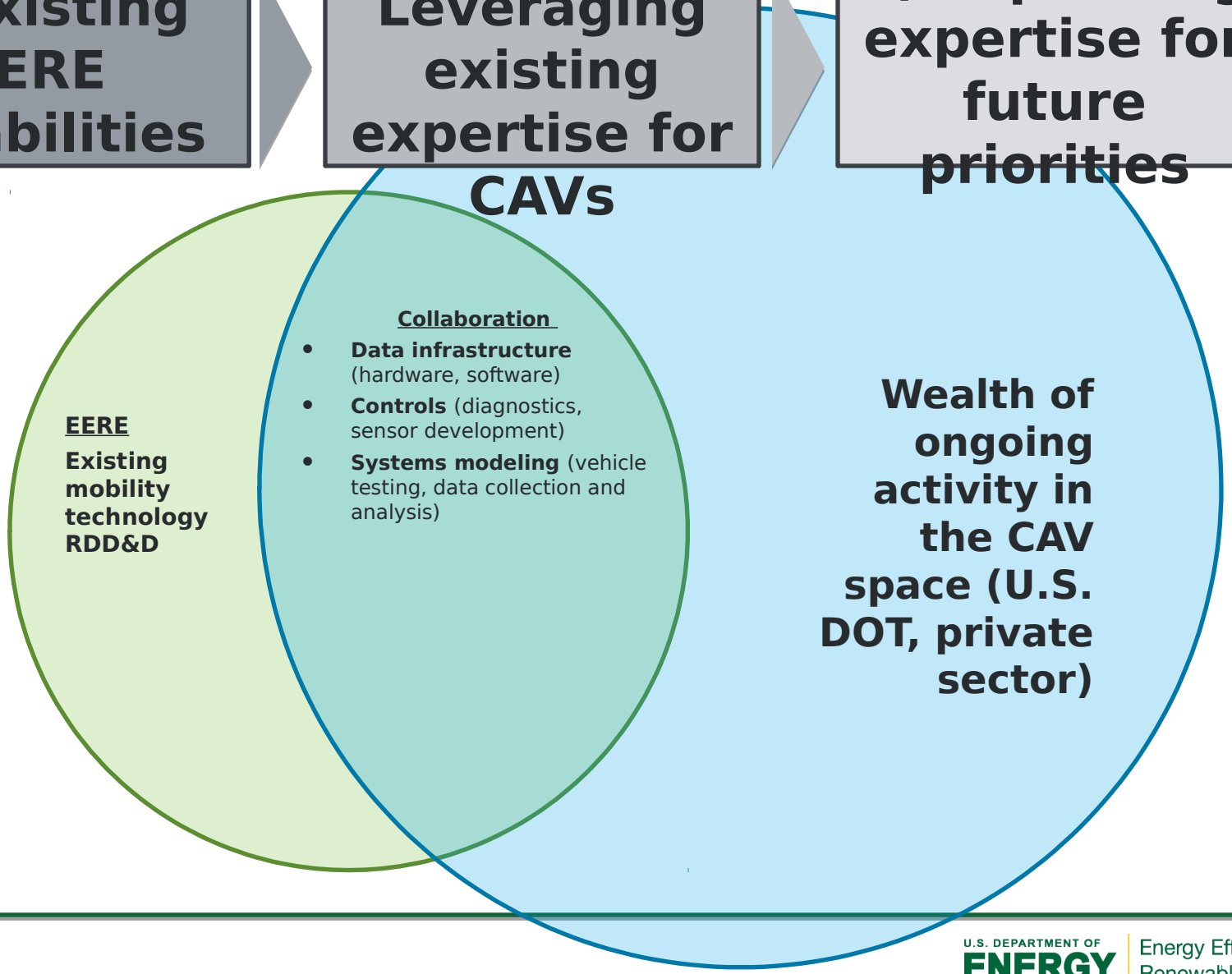


Overview and Outline: EERE in a CAV Context

1) Existing EERE Capabilities

2) Leveraging existing expertise for CAVs

3) Expanding expertise for future priorities



EERE Existing Capabilities

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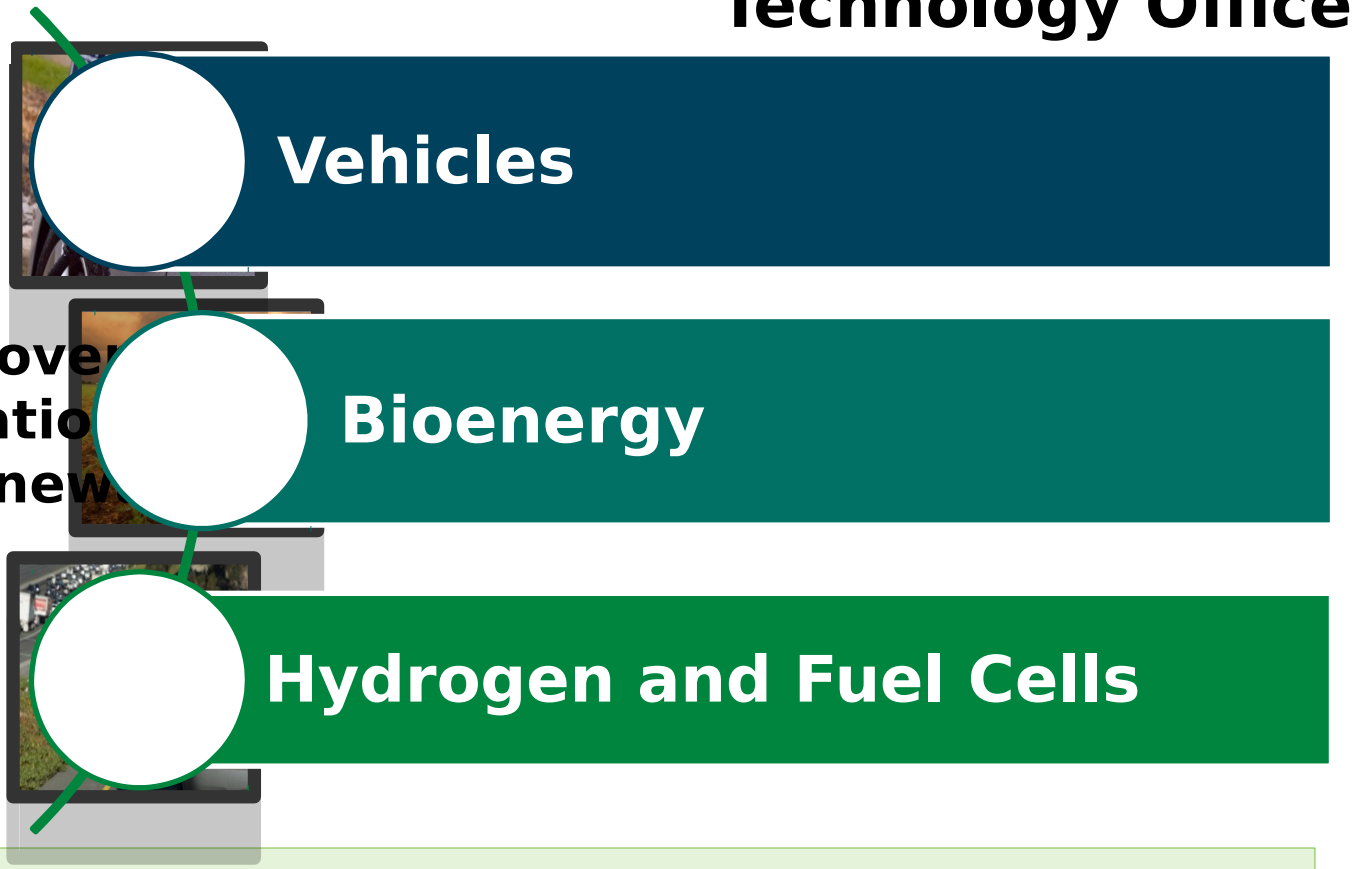
Technology Offices



- **Efficiency Improver**
- **Fuel Diversificatio**
- **Domestic & Renew**
- **Reduced GHG**

National goals & Standards

- Reduce GHG emissions in the range of 17% by 2
- Reduce net oil imports by 50% by 2020 *
- Achieve CAFE Standards 54.5 mpg by 2025

*Major Administration Goals

EERE Existing Capabilities: Current RDD&D Focus

- **EERE is DOE's primary applied research office**
- **Research, Development, Demonstration, and Deployment**
  - Vehicle Electrification
  - Materials Lightweighting
  - Advanced Combustion
  - Drop-in Biofuels
  - Fuel Cell Technology
  - Hydrogen Infrastructure
  - Deployment (e.g., Clean C
  - Grid Systems Integration

EV Everywhere grand challenge blueprint

Clean Cities
U.S. Department of Energy

H_2 USA

Early EERE CAV R&D efforts tie existing expertise to CAV energy needs

Existing EERE Core Expertise

- **Transportation energy system analysis**
- **Vehicle communications and data collection**
- **Alternative fuel technologies and systems**

Recognizing Key Energy-Related Needs for Connected Mobility

- **Co-optimization of safety and efficiency**
  - Vehicle re-design (potential significant lightweighting)
- **Interoperability** across connected mobility communication systems
- **Alternative fuels enabling potential:** enhanced ROI and adoption?
- **Predicting vehicle use systems response**
  - Rebound effect(s)
  - Increased mobility access

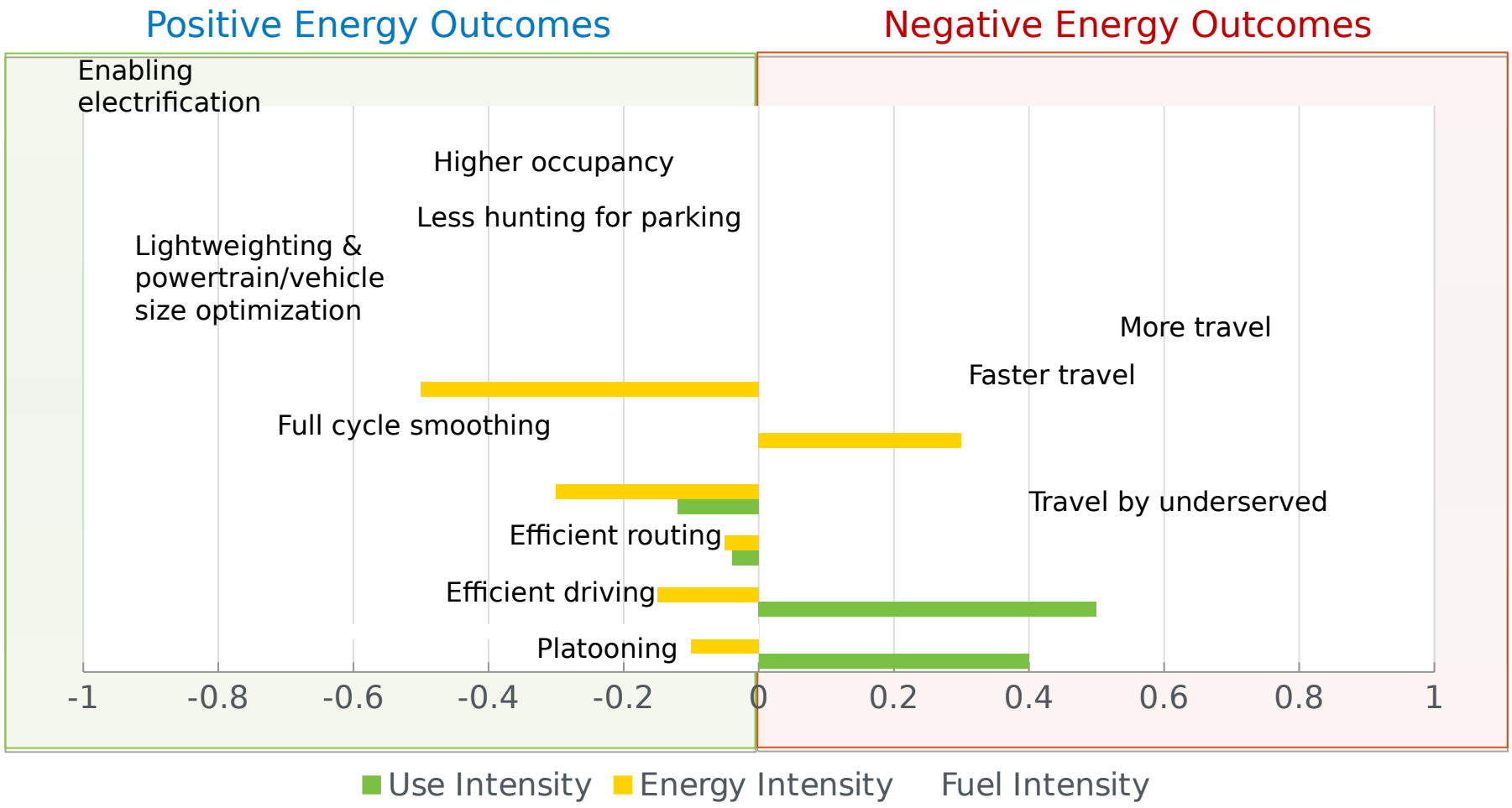
Current EERE R&D Efforts at the Nexus of Energy and Mobility

- **Foundational studies** on potential energy effects
  - Synergistic gains from safety initiatives
  - Fuel efficiency algorithms
  - Vehicle redesign (lightweighting and aerodynamics)
- **Deeper research** in opportunity areas
  - Advanced vehicle design
  - Novel diagnostics, controls, and sensor development

Synergies Between Connected Mobility & Energy

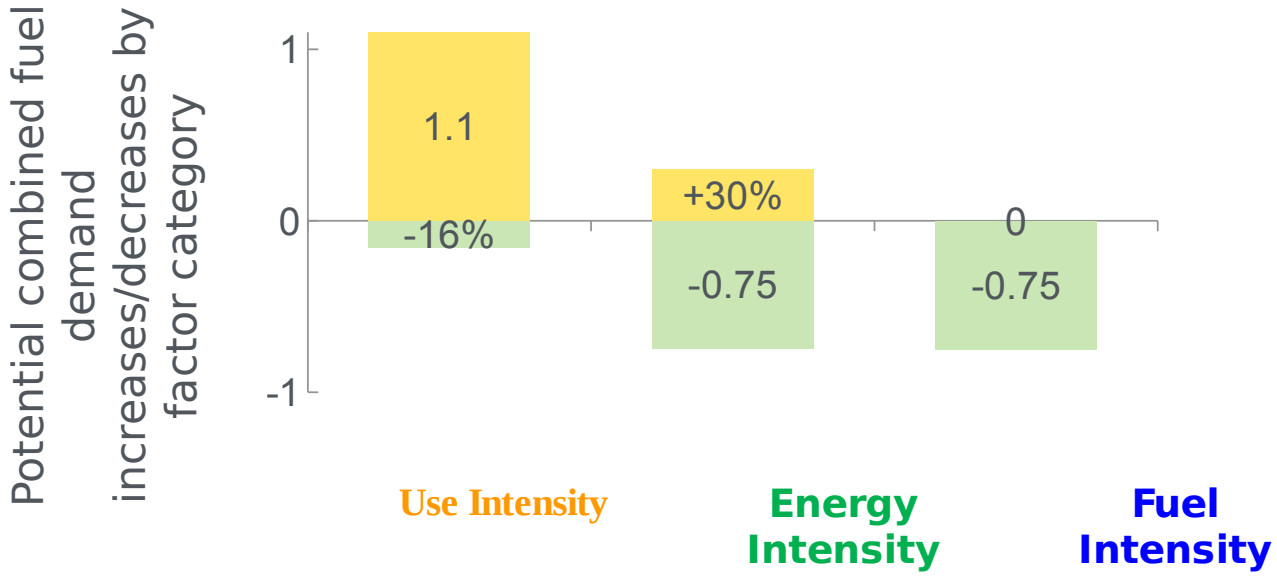
Autonomy	• Efficient driving • Platooning • Assisted parking
Safety & Collision Avoidance	• Reduced idling • Significant light weighting • Enhanced aerodynamics
Multimodal Transportation	• Lowest carbon trip planning • Automated carpooling
V2X	• Vehicle-to-Vehicle (V2V) • Traffic signal management (V2I) • Grid system integration (V2G)
Data as a Service	• Big data analytics • Efficient routing • Optimizing corridor efficiency

Foundational studies estimate ranges of energy effects



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.

Foundational studies convey energy effect uncertainty



- Energy impacts can be dramatic
  - Potential for large improvements in energy and fuel intensity
  - Increased use intensity may counteract
- Significant uncertainty exists
  - Total combined impacts from >90% savings to >150% increase in energy use—further research warranted

Current efforts inform expanding EERE expertise for future priorities

Current EERE R&D Efforts (Foundational studies, deeper research)

- *DOE prioritizing CAV "layers" in which to participate*
- *Coordinating across agencies to leverage funding*

Possible Future Research

- Refine foundation studies on energy impacts
  - Understanding and reducing uncertainties
  - Better system interaction modeling
  - Further energy-focused data collection and analysis
- Increased collaboration with USDOT
  - Engage with UMTRI, RITA, NHTSA, ITS America, Non-Profits
- Continued leveraging of existing expertise
  - Hardware, software, physical & data infrastructure(s), cyber security
  - Diagnostics, controls, and sensor development
  - Systems modeling and vehicle testing
  - Data collection and analysis

Example:

Modeling and Simulation

1. ***Individual connected vehicle and fleet*** *energy optimization*
2. ***City/corridor*** *connected traffic systems*
3. *Leveraging model observations for* ***Federal policy implications***

Ex 1. Modeling and simulation to optimize connected vehicle/fleet energy use

Energy Impact of "Efficient Driving" for Advanced Powertrains

Benefits of Connected Route-Based Energy Management for Light-Duty Electrified Vehicles

Benefits of Connected Route- and Duty-Based Energy Management for P&D PHEV Truck

Single Vehicle

AUTONOMIE

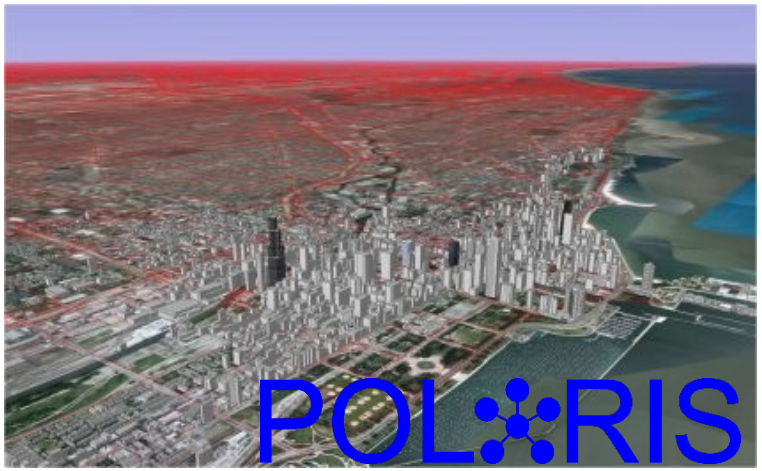
Virtual Proving Grounds for Development and Evaluation of Energy Efficient CAVs

Small Network of CAVs and ITS

Energy Impact of CAVs in the context of an Entire Transportation System

Benefits of Vehicle Electrification/Automation in the Context of a Large Metro Area

Behavior Changes and Adoption under various policies / technologies



Entire Urban Area

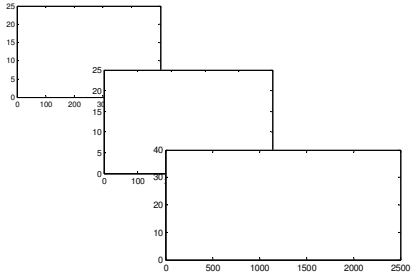
Ex 2. Combining models/simulations for city/corridor energy use

Market Penetration / Fleet Definition

nsportation Simulation

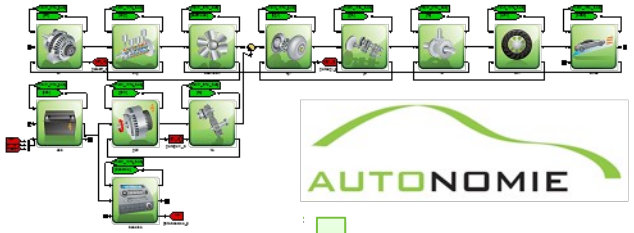
efine network, control & demand

POLARIS



Vehicle speed/grade profiles extraction/generatio n

Vehicle Energy Consumption



Energy consumption of the transportation network from corridor (~100,000 vehicles) to entire cities (>10M vehicles)

Ex 3. Assessing model observations for policy development

Polic
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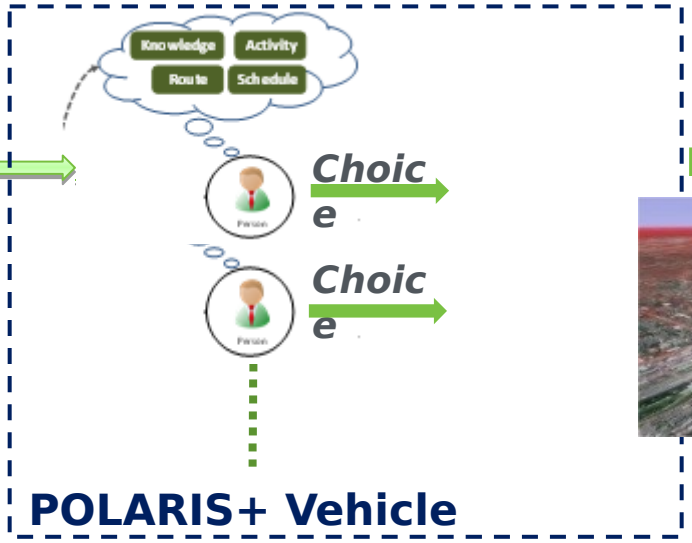

Aggrega
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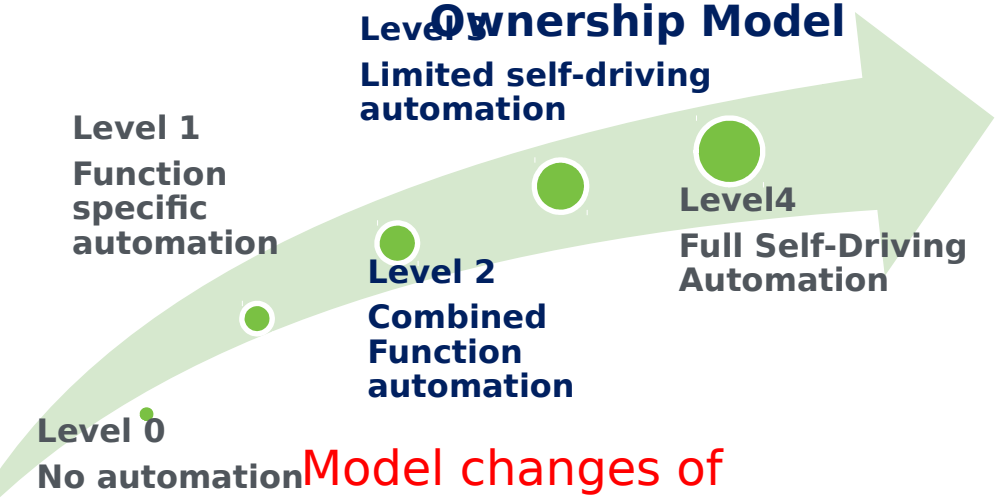
Regional or National

- VMT
- Market Adoption
- Mode Choice/Shift



Vehicle Ownership Model:
Market adoption dynamics based on household characteristics (eg. demographic, existing vehicles ownership, income)

Model changes of traveler's behavior in the context of automation level

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