Sustainable TRANSPORTATION

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

Connected/Automated Vehicles (CAVs) and DOE

Jacob Ward
Program Manager, Analysis
Vehicle Technologies Office
Energy Efficiency and Renewable Energy
U.S. Department of Energy (DOE)

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Perspective: CAVs in a DOE Context

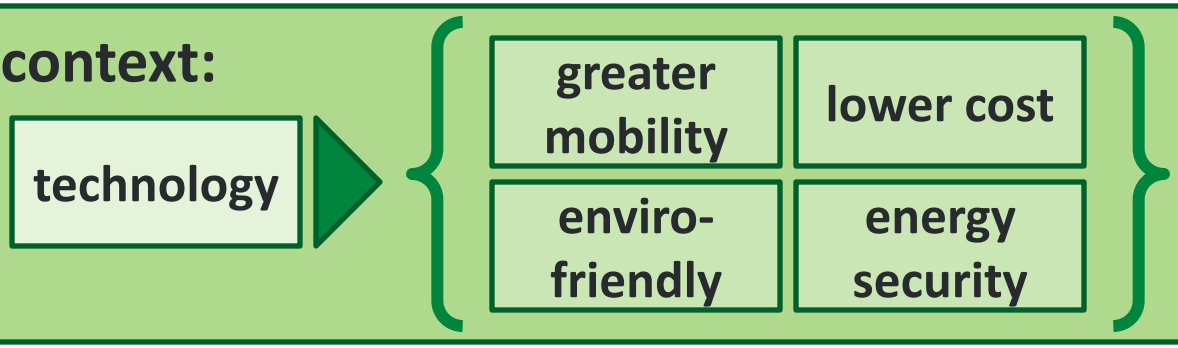
DOE mission

The mission of the Energy Department is to ensure America's ***security and prosperity by addressing its energy, environmental and nuclear challenges*** *through* ***transformative science and technology solutions.***

VTO mission

The U.S. Department of Energy's Vehicle Technologies Office develops and deploys ***efficient and environmentally friendly highway transportation technologies*** *that will enable America to use* ***less petroleum.*** *These technologies will provide Americans with greater* ***freedom of mobility and energy security, while lowering costs and reducing impacts on the environment.***

CAVs in context:



EERE Existing Capabilities

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- Efficiency Improvement
- Fuel Diversification
- Domestic & Renewable
- Reduced GHG

Technology Offices

Vehicles

Bioenergy

Hydrogen and Fuel Cells

National goals & Standards

- Reduce GHG emissions in the range of 17% by 2020 *
- 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 Cities)
  - Grid Systems Integration

EV Everywhere grand challenge blueprint

Clean Cities
U.S. Department of Energy

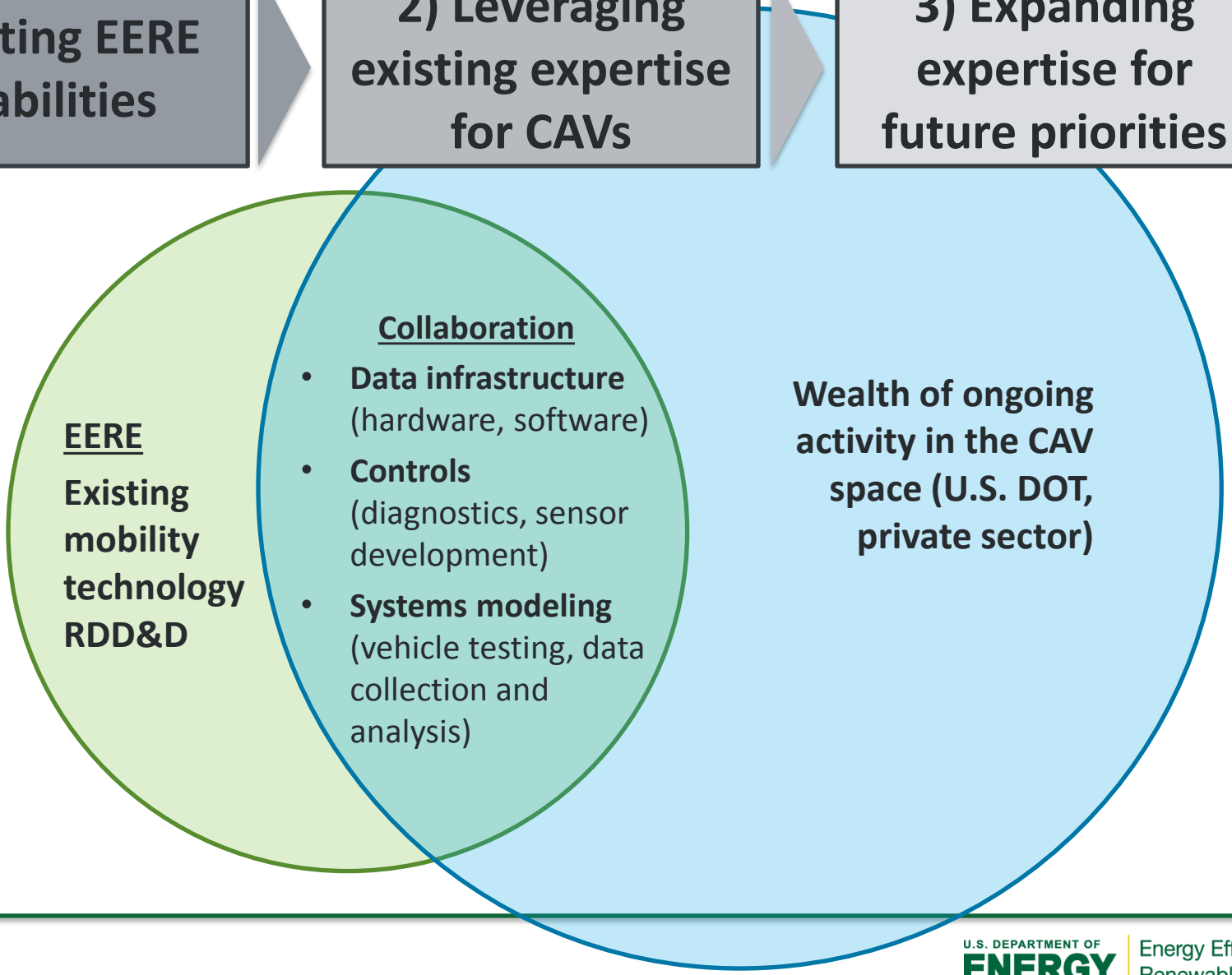
H_2 USA

Another Perspective: EERE in a CAV Context

1) Existing EERE Capabilities

2) Leveraging existing expertise for CAVs

3) Expanding expertise for future priorities



Synergies and [DOE] Opportunities in Connected Mobility & Energy

Existing Activities

can DOE contribute [efficiently/effectively]?

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

can outcomes affect DOE mission(s)?

Potential Outcomes

Current State of Research – CAV Energy Benefits

Researchers have performed *preliminary* estimations of *some* benefits

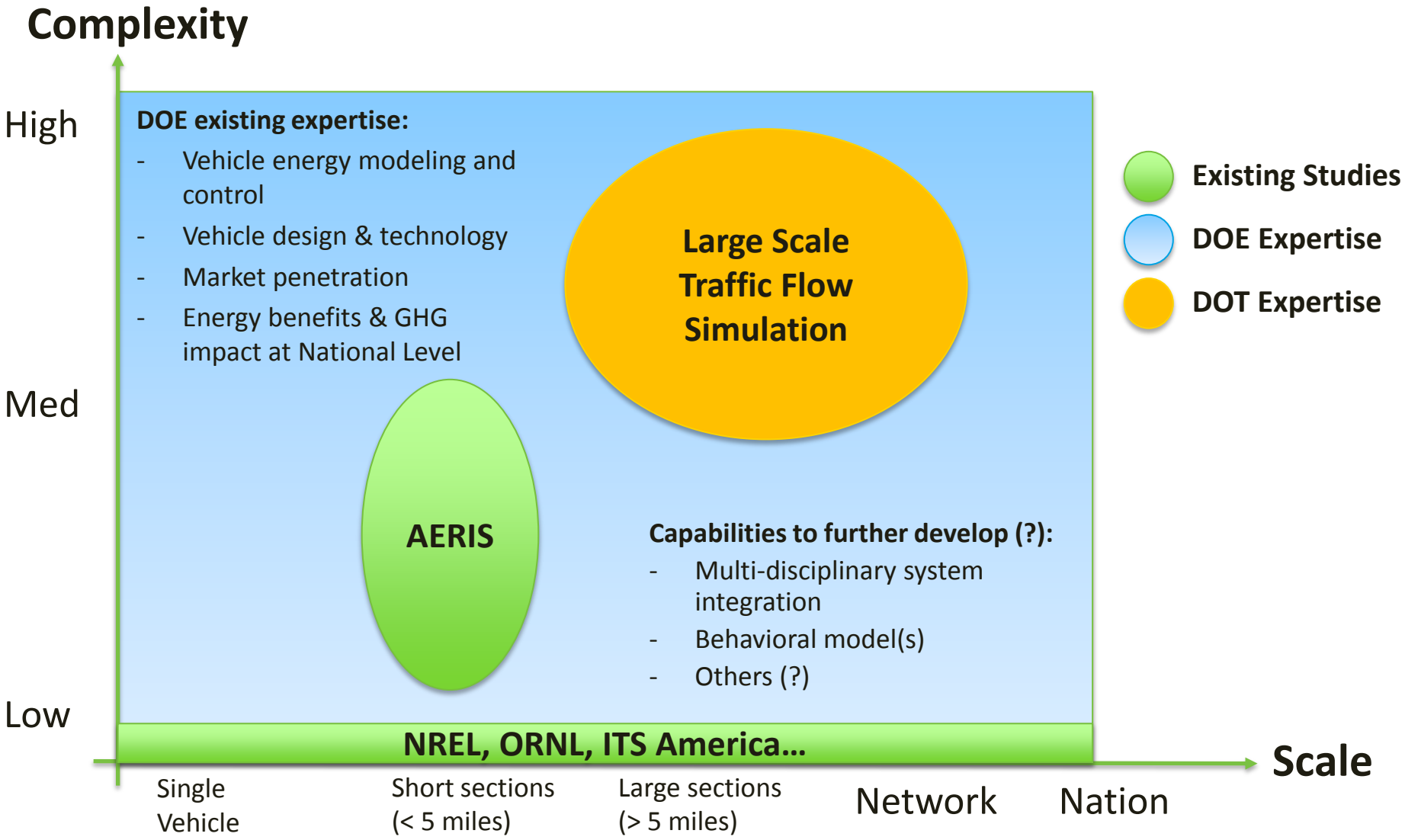
Examples of DOT/AERIS - *Estimations per Vehicle*

Technology	Benefit
Eco Approach & Departure	• 5-10% fuel reduction for an uncoordinated corridor • Up to 13% fuel reduction for a coordinated corridor
Eco-Traffic Signal Timing	• 5% fuel reduction when optimizing for the environment (e.g., CO2) • 2% fuel reduction when optimizing for mobility (e.g., delay)
Eco-Traffic Signal Priority	• Eco-Transit Signal Priority provides up to 2% fuel reduction benefits for transit vehicles • Eco-Freight Signal Priority provides up to 4% fuel reduction benefits for freight vehicles

The accelerated introduction of advanced vehicle technologies will allow for mobility optimization → **advanced technologies allow us to decouple energy from mobility**

While safety benefits can be extrapolated, **energy benefits cannot be generalized as they completely depend on the network and scenario**

Current State of Research & Expanding CAV Intersection(s)



DOE Scope Under Consideration

Scoping Criteria:

- » Must have a direct or immediately indirect impact on DOE corporate objectives for reduced petroleum consumption and reduced GHG emissions
- » Initial scoping using multi-lab expert opinion to drive foundational studies
- » Foundational studies will drive prioritization of future research portfolios

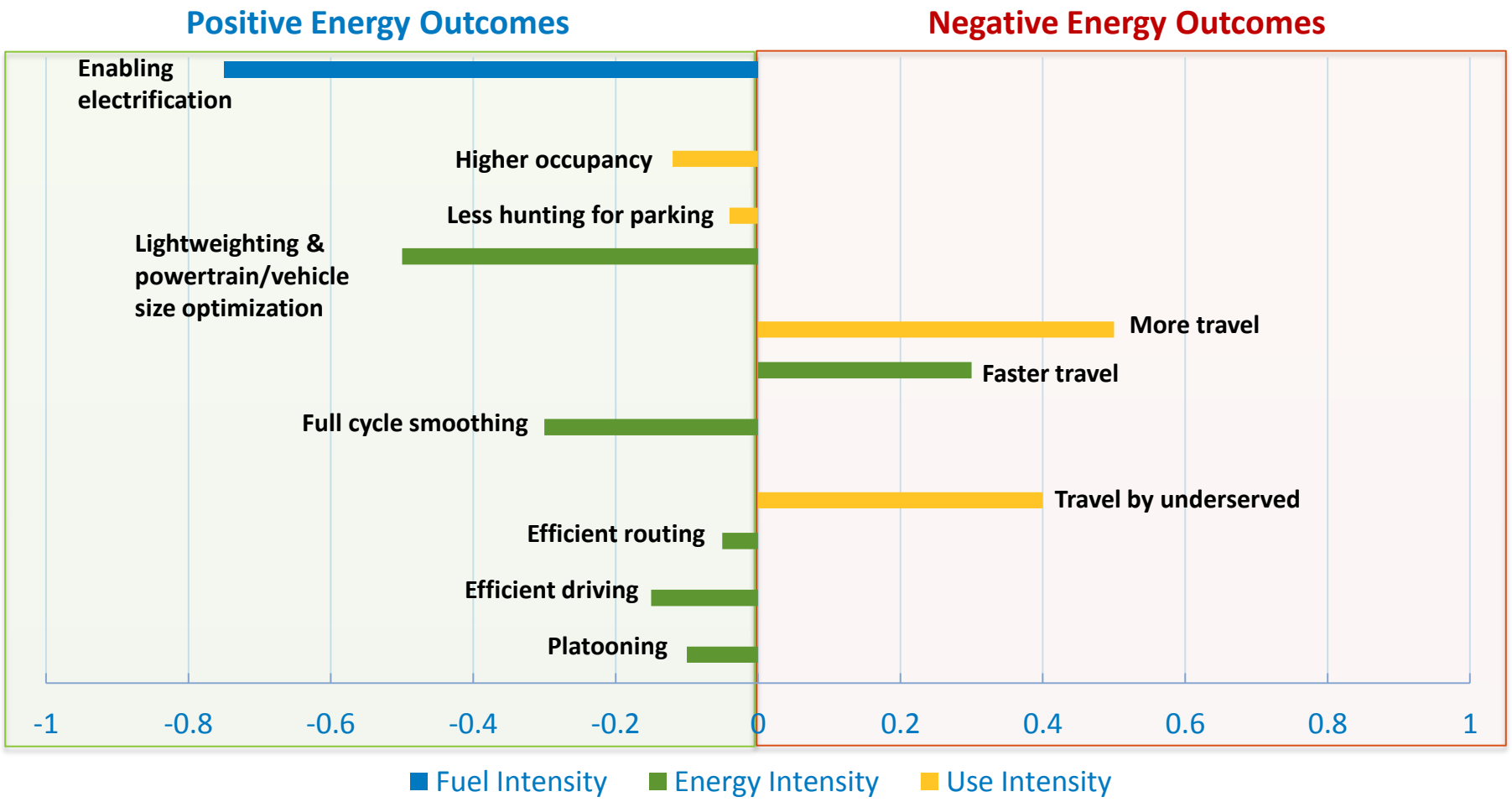
In-scope Activities

- Efficient driving (i.e., smoother braking…) and routing (i.e. Eco-routing)
- Powertrain and vehicle optimization (i.e., aero, light weighting, downsizing, control…)
- X2X connectivity (i.e., Eco-approach, Eco-routing, Eco-driving, Platooning…)
- Effects on mobility (i.e., traffic patterns, flow) and driver behavior (i.e. VMT, mode shift…)
- CAVs to grid interactions and cybersecurity
- Interaction with built environment and urban form (i.e., car sharing…)
- Business model innovations

Out of Scope Activities

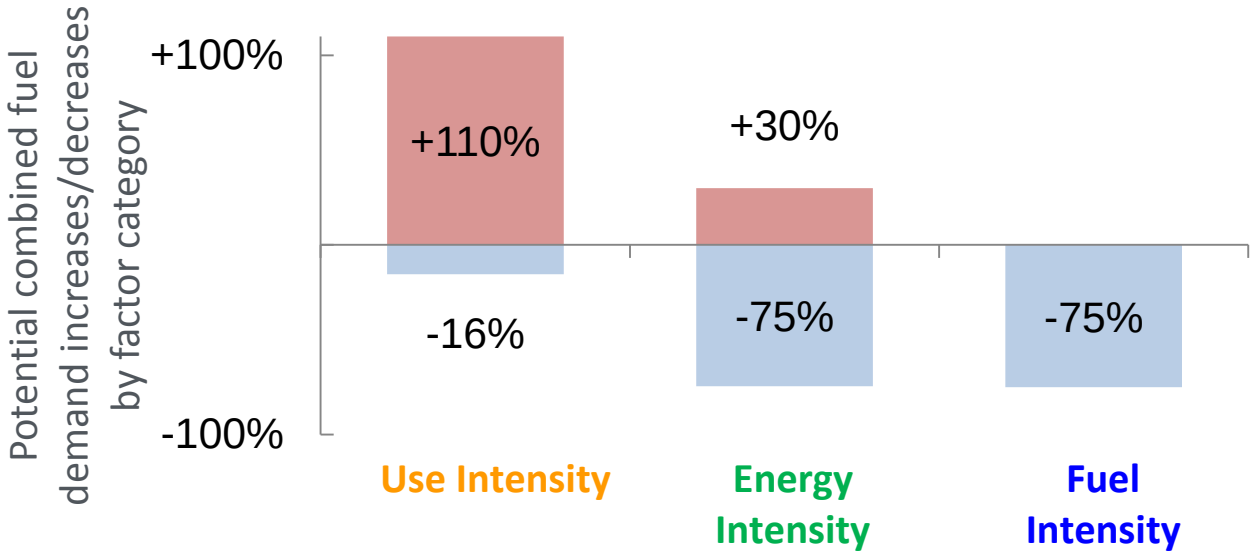
- Safety
- Liability / Legal Issues
- Human Machine Interface (HMI)

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)

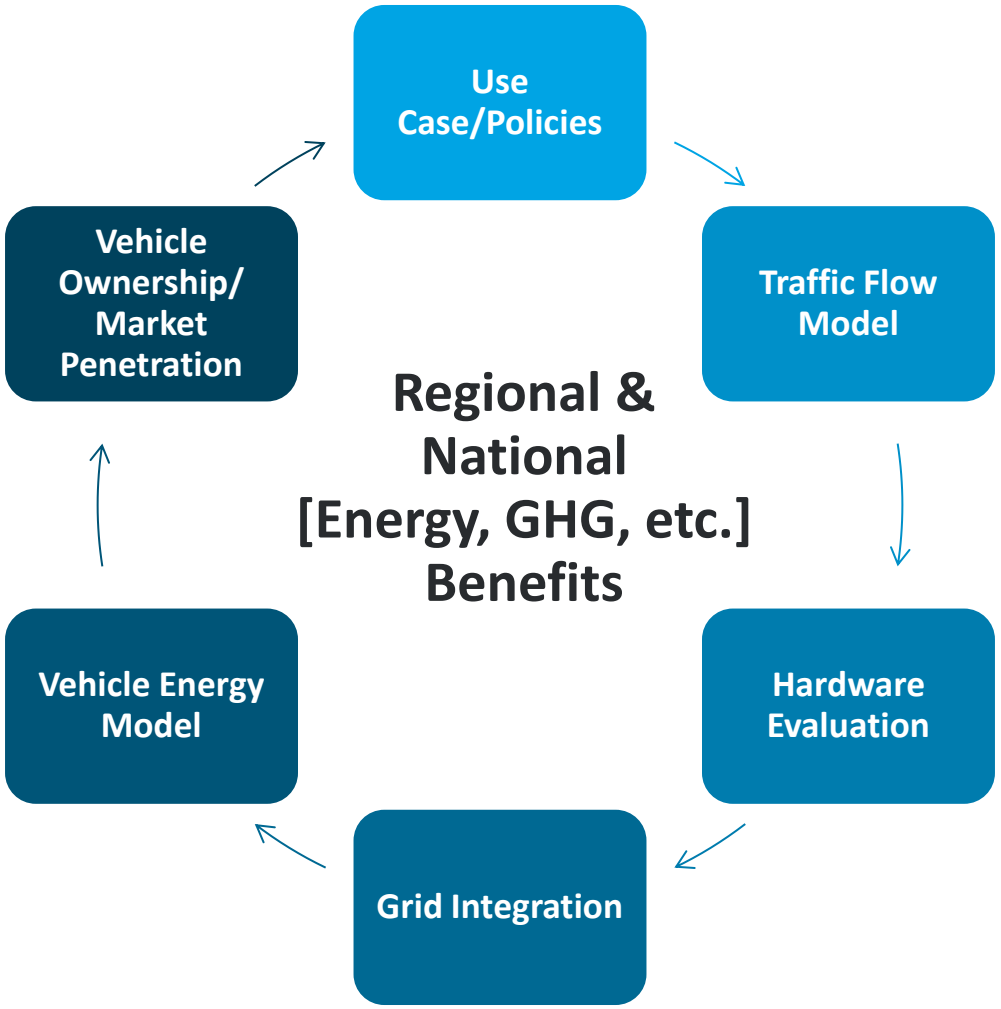
- *DOE prioritizing CAV "layers" in which to participate*
- *Coordinating across agencies to leverage funding*

Possible Future Research

- **Refine foundation studies** on energy impacts
  - Understanding and reducing uncertainties
  - Better system interaction modeling
  - Further energy-focused data collection and analysis
- **Increase collaboration**: engage with USDOT, UMTRI, RITA, NHTSA, ITS America, Non-Profits
- **Continue 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

R&D Efforts at the Nexus of Energy and Mobility

Leverage Existing Expertise



Leverage Existing Expertise

Near Term (FY15-16): Conduct Foundational Studies on Potential Gains

1. **Hardware evaluation** to assess the benefits and provide inputs to the models
2. **Consider vehicle controls** expertise for Connected Vehicles context
3. **Leverage other existing tools, vehicles & High-Performance Computing** for Automated Vehicles

Longer Term (FY17 & beyond)

- **Follow CAV R&D Roadmap** addressing market introduction and technical barriers
- **Perform R&D** to mitigate the technical barriers (emphasize collaborations)
- **Deeper research** based on identified areas of opportunity (vehicle design and technologies)

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Questions? Suggestions?

Jacob Ward

jacob.ward@ee.doe.gov

vehicles.energy.gov