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# Zero Emission Vehicles and Automated Vehicles: Uncertainty and Energy Implications

*For*
*California Energy Commission*
*May 2, 2019 | Sacramento, CA*

*By*
*Nicholas Chase, Lead Economist*

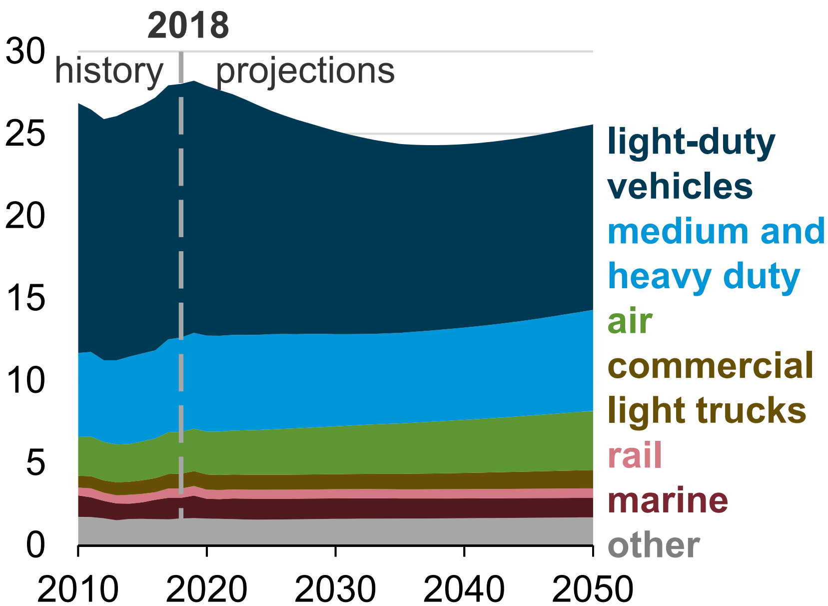
# Overview

- Zero emission vehicles
- Vehicle automation
- Ongoing vehicle automation updates (time permitting)

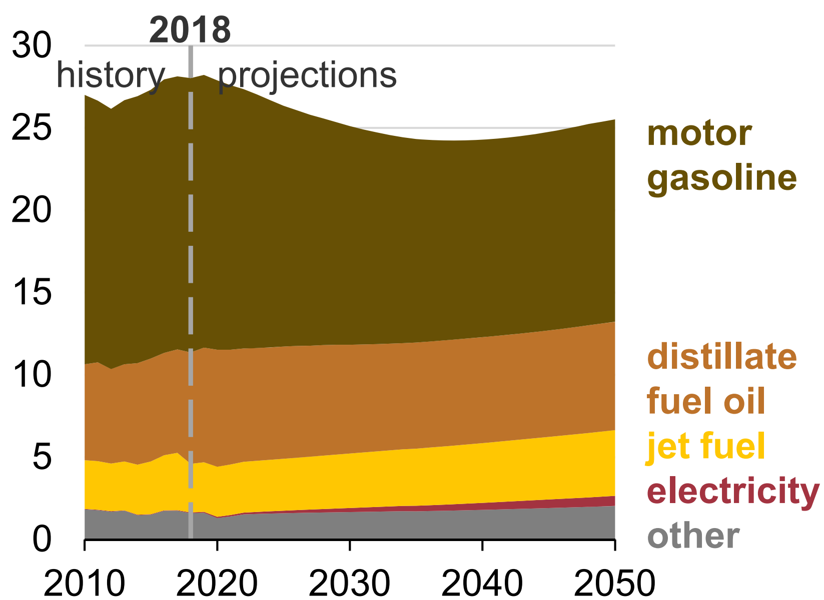
# Zero emission vehicles

# Transportation energy consumption declines between 2019 and 2037 in the Reference case as increases in fuel economy more than offset growth in vehicle miles traveled

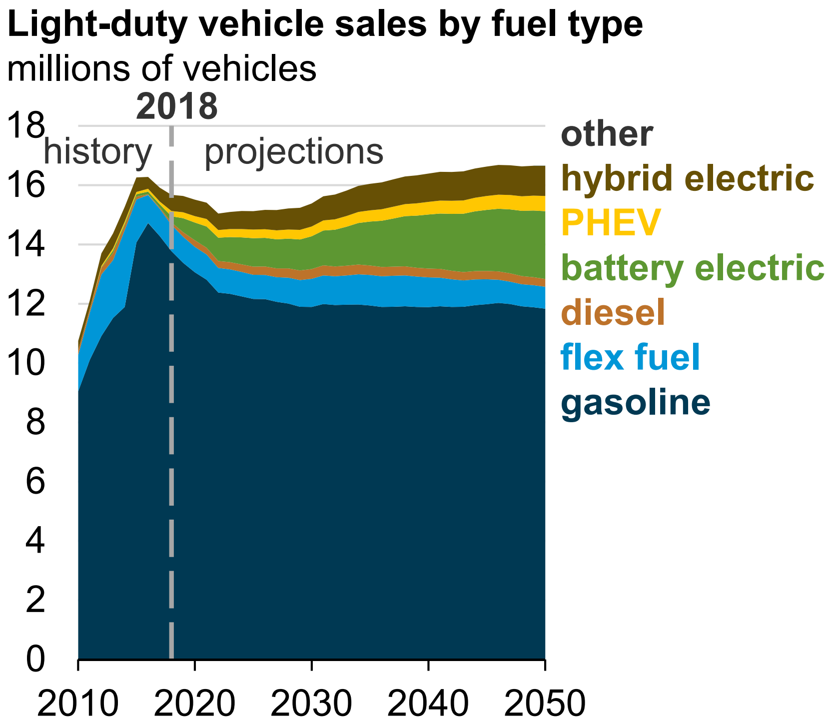
**Transportation sector consumption (by type)**
quadrillion British thermal units

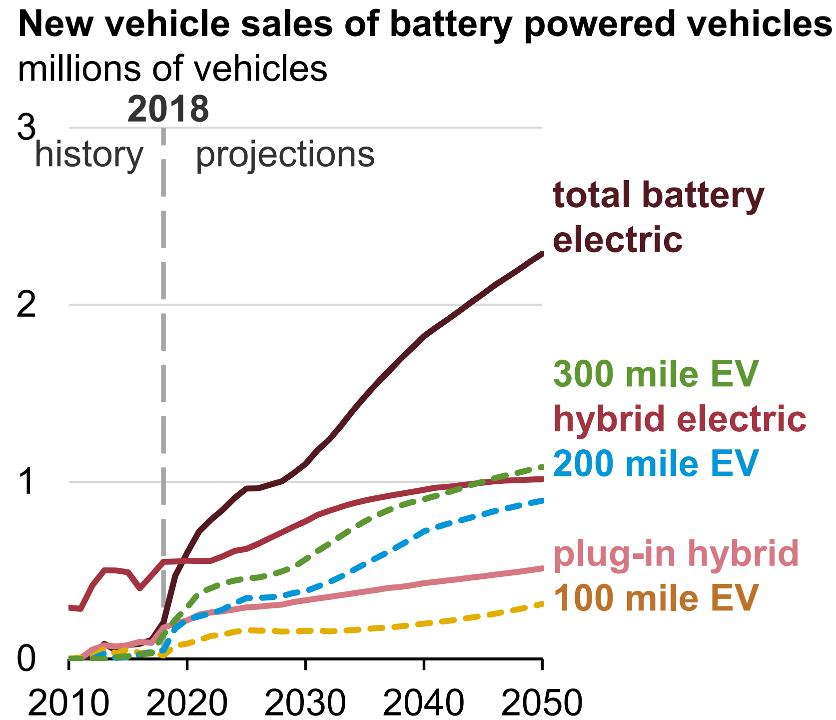



**Transportation sector consumption (by fuel)**
quadrillion British thermal units



# Alternative and electric vehicles gain market share in the Reference case but gasoline vehicles remain the dominant vehicle type through 2050



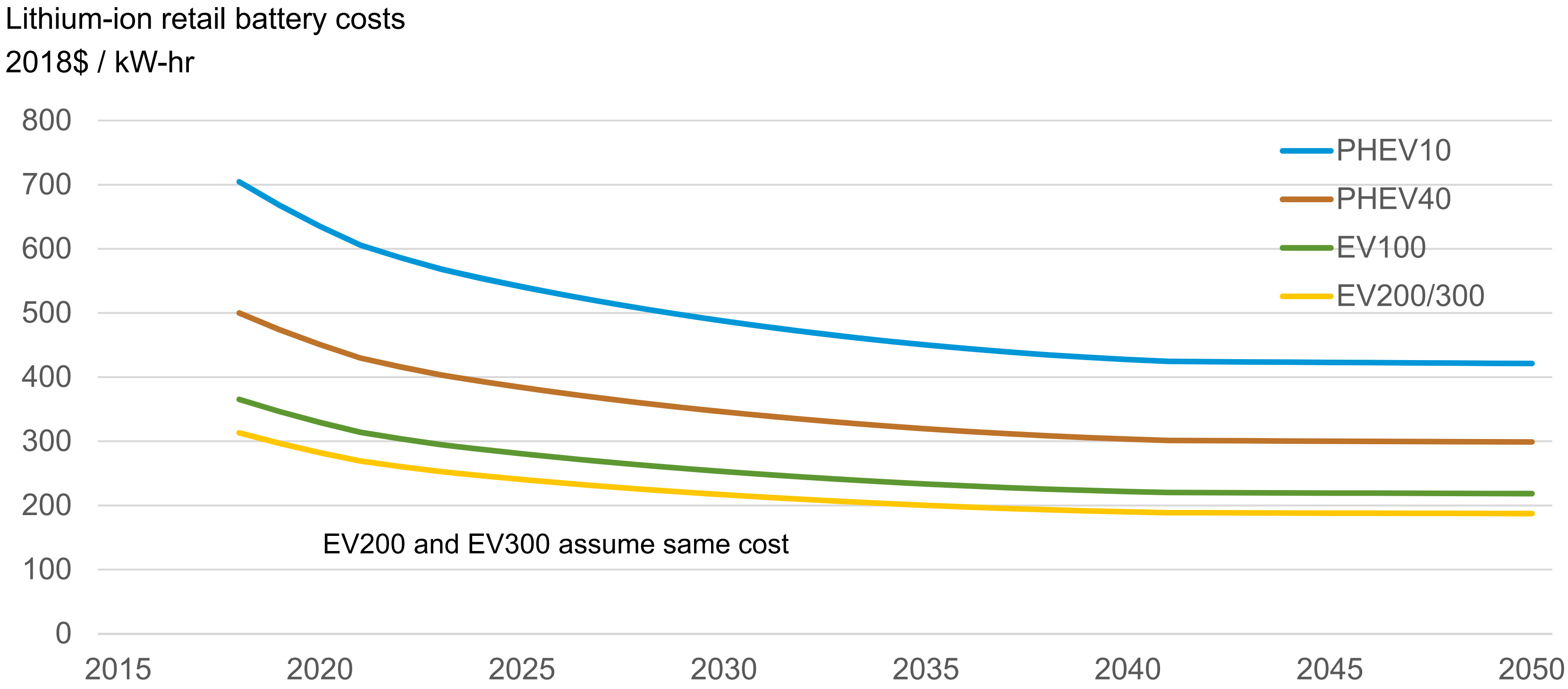
# Modeling vehicle choice in the NEMS—involves manufacturers (building) and consumers (buying)

- Manufacturers Technology Choice Component (MTCC)
  - Adopt vehicle subsystem technologies (86) based on value of fuel economy and/or performance improvement
  - Alternative fuel vehicles (15)
- Consumer Vehicle Choice Component (CVCC)
  - Determines consumer acceptance by vehicle fuel type (conventional gasoline, hybrid, diesel, etc.) by size class utilizing 9 attributes
- Meeting CAFE through the MTCC and CVCC
  - CAFE credits and banking

# Policies promoting battery electric vehicle sales

- California Zero-Emission Vehicle Mandate, adopted by nine other states
- California SB-32 for GHG Reduction
  - Further increases electric vehicle share
  - Decreases VMT
- State and federal tax credits
  - Federal credit up to a maximum of $7,500
    - Full amount limited to 200,000 vehicles per manufacturer then begins to phase out
  - State tax credits and incentives not modeled in NEMS

# AEO2019 battery cost, projections from 2018




*Source: EIA, AEO2019 Reference case*

# Modeling the Zero Emission Vehicle Mandate in NEMS

- Regions which contain ZEV states must sell a minimum amount of ZEVs (BEVs and hydrogen fuel cells) and optional PHEVs
  - Required “credit” percentage based on a manufacturers conventional vehicle sales
  - Credits earned per vehicle vary by ZEV capability - longer range BEVs and PHEVs produce more credits
  - Credits may be banked, spent, and can travel
- Assumed to follow an optional compliance pathway
  - Lower initial requirements in exchange for higher midterm credits
  - Allowed Mfrs to bank a high number of credits before 2018 (more favorable credit terms)
- Vehicles are sold according to least cost optimization by Mfr

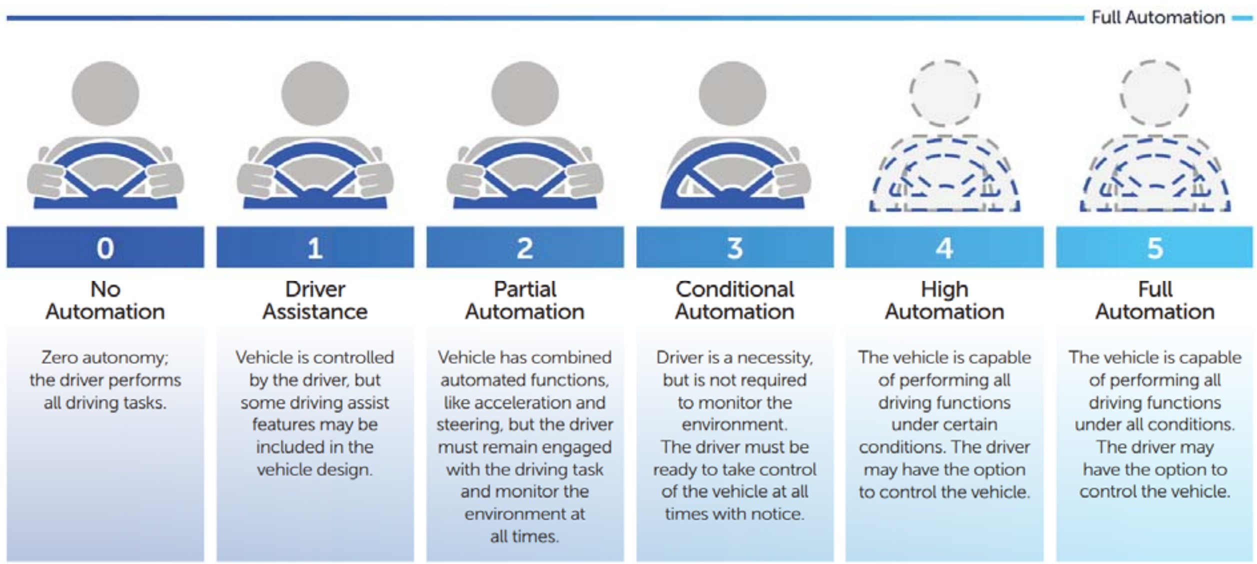
# Uncertainties

- Policies
  - Future light-duty vehicle CAFE/GHG standards
  - Change in State Policies, including authority to issue own standards or mandates
- Battery technology breakthrough
  - Solid state batteries
  - Ultra-fast charging capability and infrastructure
- Autonomous vehicles and change in mobility
  - Change in sales patterns, travel, powertrain choice, and regulatory compliance pathways

# Vehicle automation

# Definition of vehicle automation

- Operational and safety-critical control functions occur without driver input
- Connected and automated vehicles




*Source: U.S. Department of Transportation, Automated Driving Systems 2.0, A Vision for Safety*

# Potential benefits underlie interest but there are also key uncertainties and obstacles

## Benefits

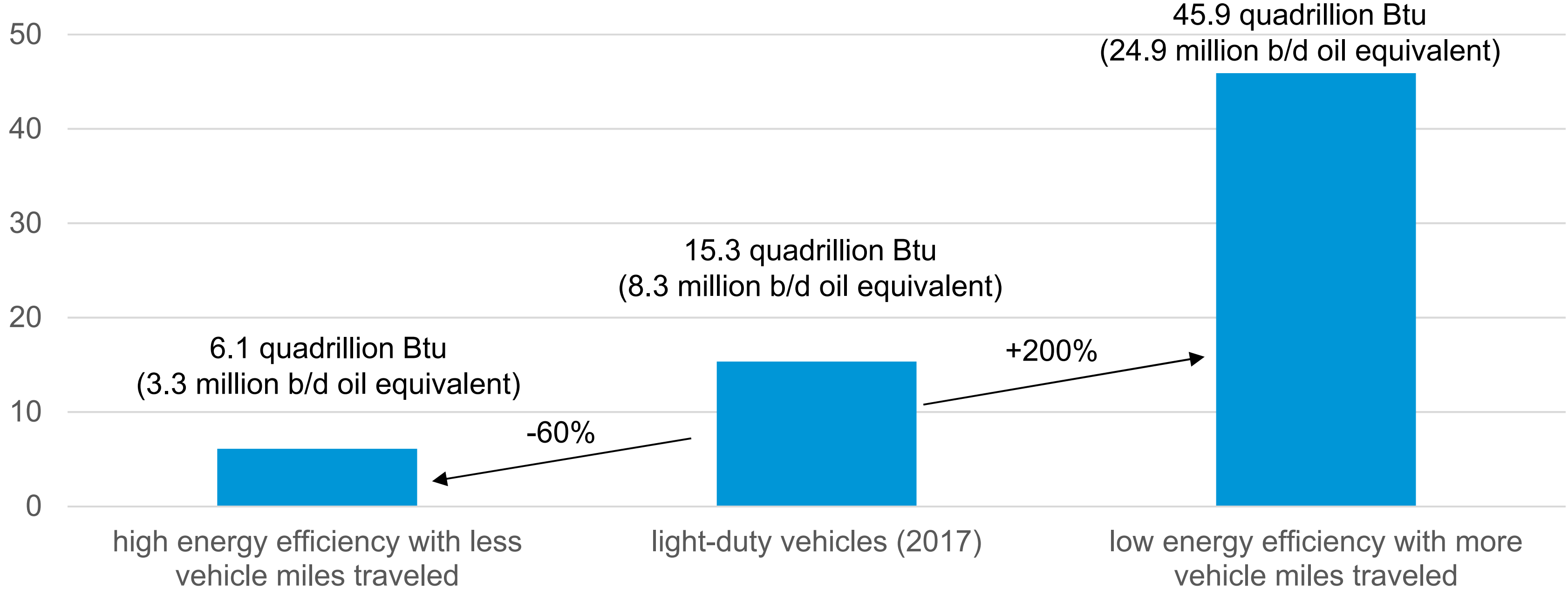
- Road safety
- Increased system efficiency
  - Route harmonization
  - Reduced congestion
- Increased mobility for underserved population
- Less time driving

## Obstacles

- Consumer acceptance
- Technology cost and function
- Cybersecurity
- Legal framework
- Infrastructure
- Policy

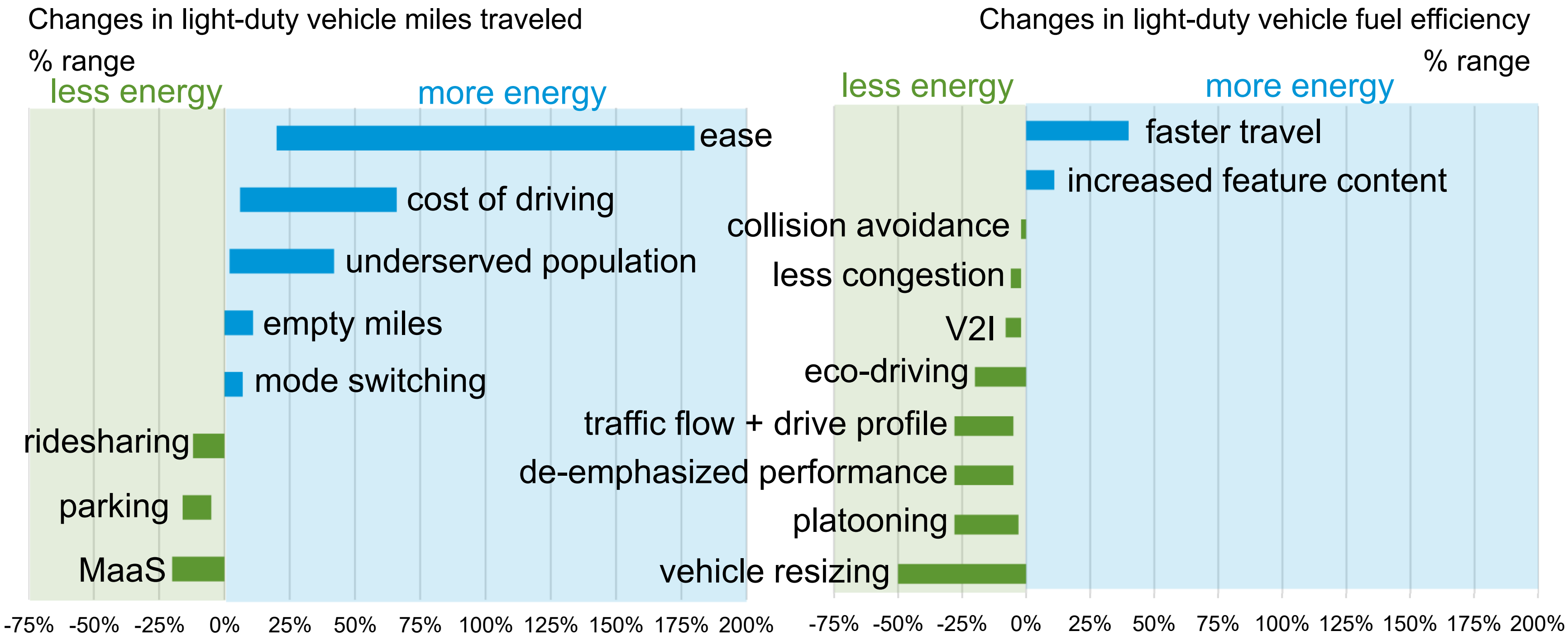
# Range of potential effects of autonomous vehicles on light-duty vehicle energy consumption

2017 U.S. delivered energy consumption
quadrillion Btu




*Source: 2017: EIA, AEO2018 Reference case, extrapolation based on upper and lower limits from Estimated Bounds and Important Factors for Fuel Use and Consumer Costs of Connected and Automated Vehicles (Stephens et al)*

# There is uncertainty about how highly automated vehicles could affect future transportation energy demand




*Sources: Help or Hindrance? The Travel, Energy, and Carbon Impacts of Highly Automated Vehicles (Wadud et al); Estimated Bounds and Important Factors for Fuel Use and Consumer Costs of Connected and Automated Vehicles (Stephens et al)*

# Additional ways vehicle automation technology could affect transportation energy consumption

- Alternative fuels and energy efficient powertrains
- Commercial trucks
- Mass transit

# Description of scenarios

- Reference case
  - Autonomous vehicles enter fleet light-duty vehicles
    - 1% of new sales by 2050
  - Autonomous vehicles used more intensively
    - 65,000 miles/year and scrapped more quickly
  - Autonomous vehicle fuel type
    - 100% conventional gasoline internal combustion engine
  - Autonomous vehicles affect mass transit
    - Increases use of commuter rail
    - Decreases use of transit bus and transit rail

# Description of scenarios–two scenarios examine energy implications from more widespread use of autonomous vehicles

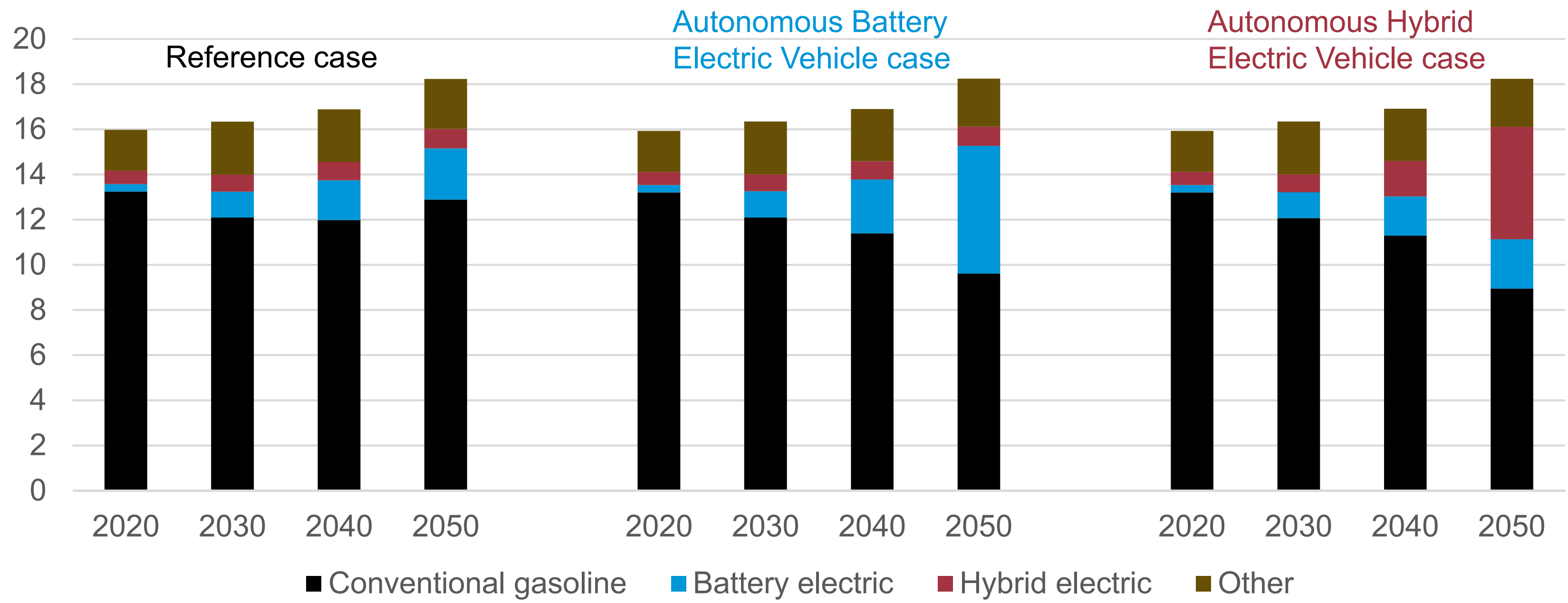
- Identical assumptions
  - Autonomous vehicles enter household and fleet light-duty vehicles
    - 31% of new sales by 2050
  - Autonomous vehicles used more intensively
    - 65,000 miles/year (fleet) ; +10% miles/year (household) on average
  - Autonomous vehicles affect mass transit modes
    - Increases use of commuter rail
    - Decreases use of transit rail
    - Decreases use of transit bus until mid-2030s, thereafter, increases transit bus use from automation technology
  - Automation technology included on long-haul fleet commercial trucks enables platooning

# Description of scenarios–two scenarios examine energy implications from more widespread use of autonomous vehicles

- Autonomous Battery Electric Vehicle case
  - Increasing share of autonomous vehicles are battery electric through 2050
    - 96% of fleet and 82% of household autonomous vehicles by 2050
- Autonomous Hybrid Electric Vehicle case
  - Increasing share of autonomous vehicles are hybrid electric through 2050
    - 96% of fleet and 71% of household autonomous vehicles by 2050

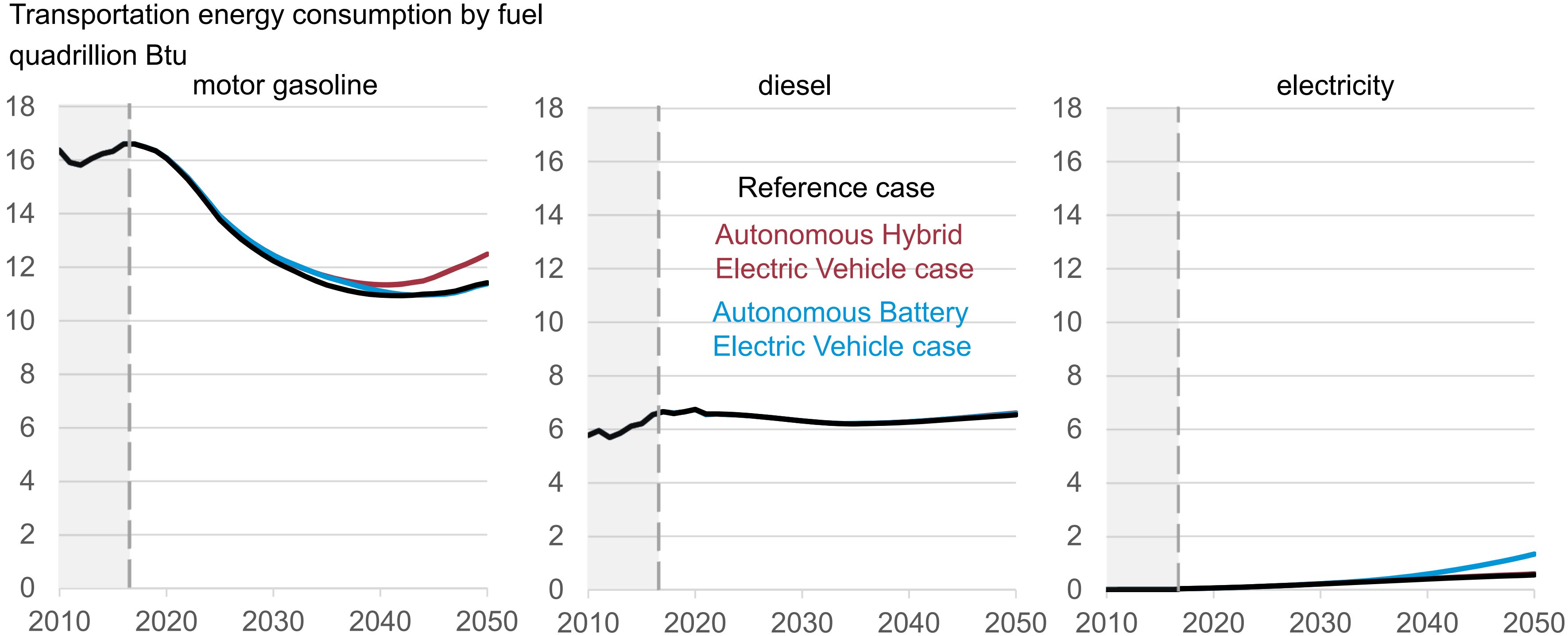
# Light-duty vehicle sales by fuel type across scenarios

U.S. light-duty vehicle sales
million




*Source: EIA, AEO2018 Reference case, Autonomous Battery Electric Vehicle case, Autonomous Hybrid Electric Vehicle case*

# Transportation fuel consumption differs between cases because of changes in light-duty vehicle fuel type




*Source: EIA, AEO2018 Reference case, Autonomous Battery Electric Vehicle case, Autonomous Hybrid Electric Vehicle case*

# Thank you

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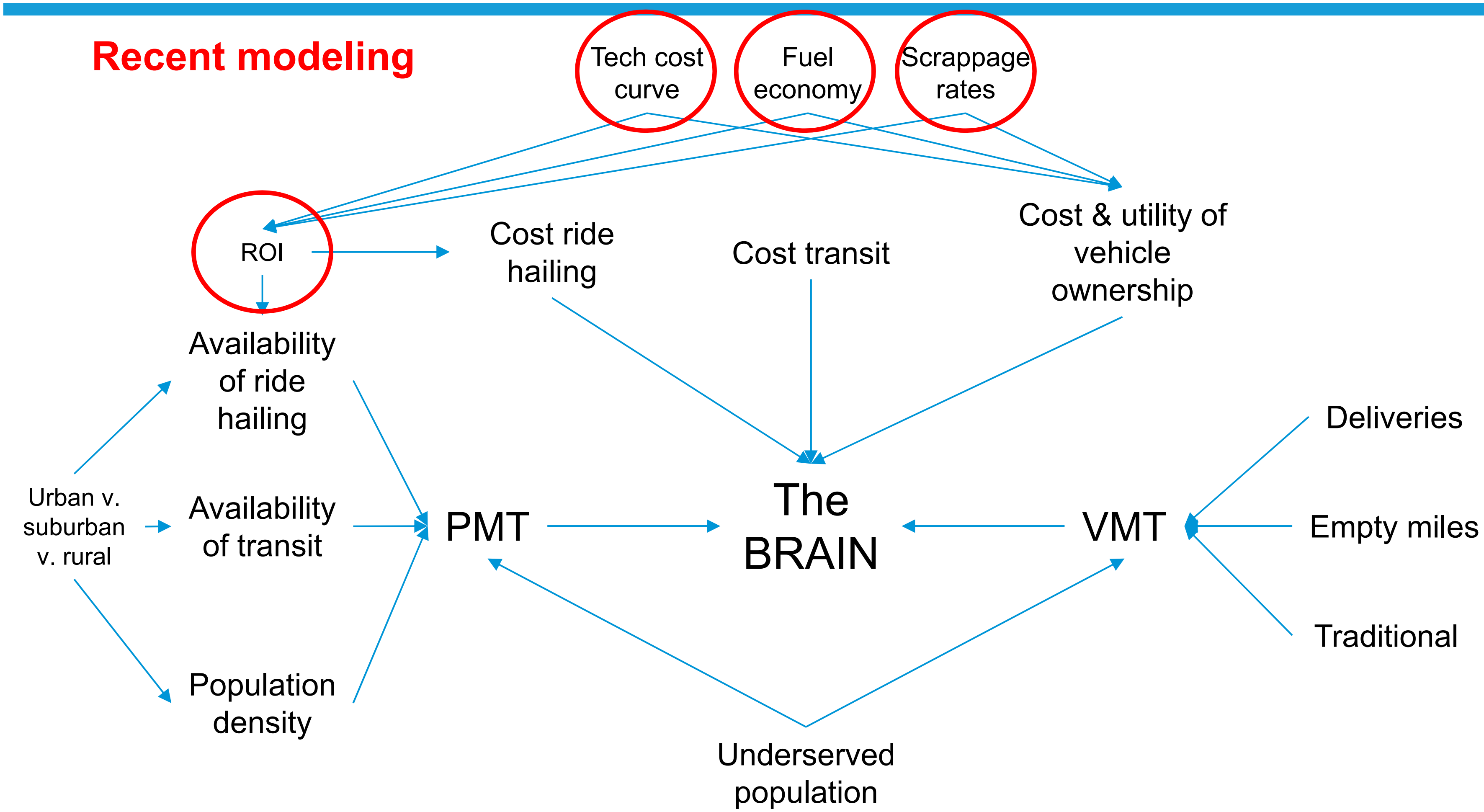
Autonomous Vehicles: Uncertainties and Energy Implications | https://www.eia.gov/outlooks/aeo/section_issues.php#av

U.S. Energy Information Administration home page | www.eia.gov

Annual Energy Outlook | www.eia.gov/outlooks/aeo

# Ongoing vehicle automation updates (time permitting)

# Recent modeling



# Recent modeling focus: adding levels of highly automated vehicles—

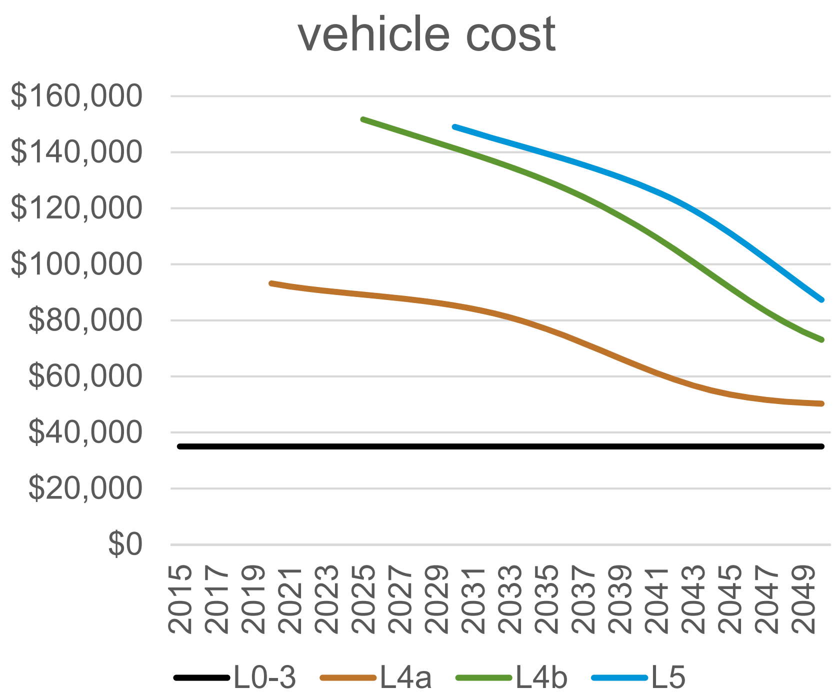
- Levels of vehicle automation (introduction year, cost, weight, fuel economy, etc.):

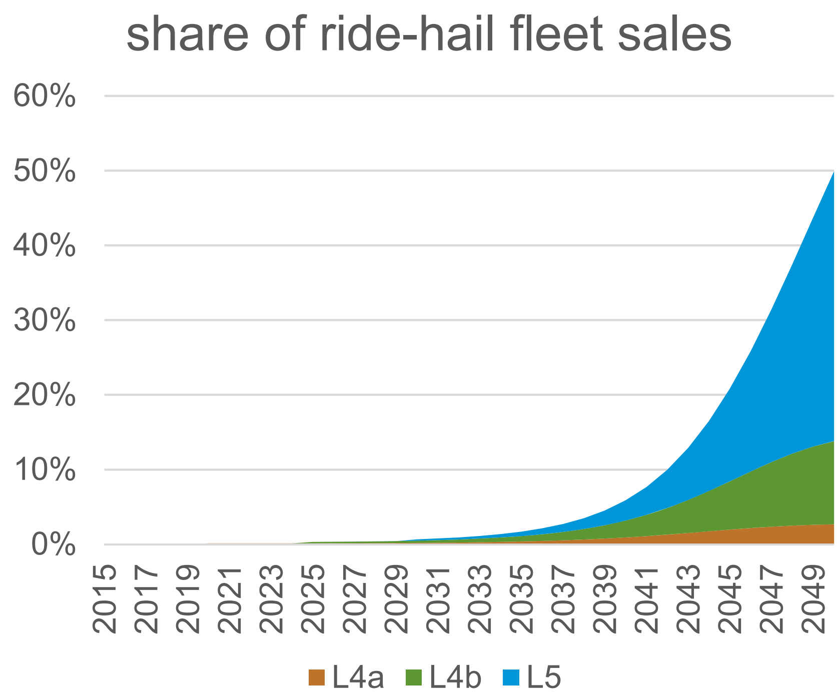
| automation level | description |
| --- | --- |
| Level 1 | driver assistance technology |
| Level 2 | partial automation technology |
| Level 3 | conditional automation technology |
| Level 4a | low speed (<35 mpg) operation in limited geofenced areas such as urban centers |
| Level 4b | full speed operation in limited geofenced areas such as limited access highways |
| Level 5 | fully autonomous vehicle that can operate on all roads and all speeds |

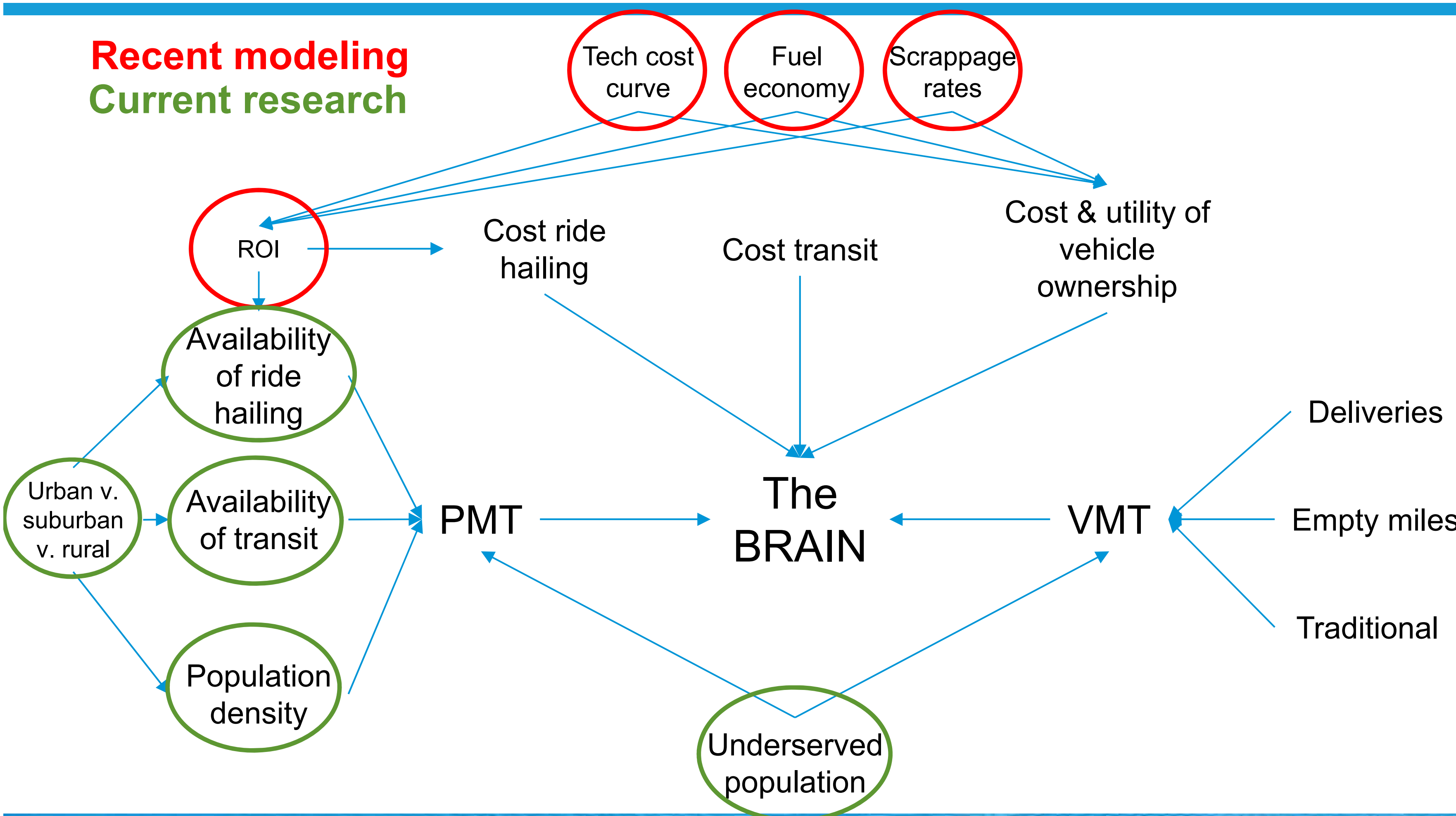
# Recent modeling focus–and the economics of ride-hailing fleet adoption

- Separates taxi fleet (taxi and future Transport Network Companies) with unique VMT and scrappage curves
- Economics of adoption:
  - **Return on Investment (ROI)** as net present value (NPV) of fare revenue minus operating cost (driver, revenue miles, data costs, etc.)
  - **Logit function** adoption with (dis)utilities related to new technology and operational domain parameters
  - **Technology cost**:
    - LiDAR system (low-resolution and high-resolution) as experience function with time-based R&D
    - HAV system as time-based R&D function

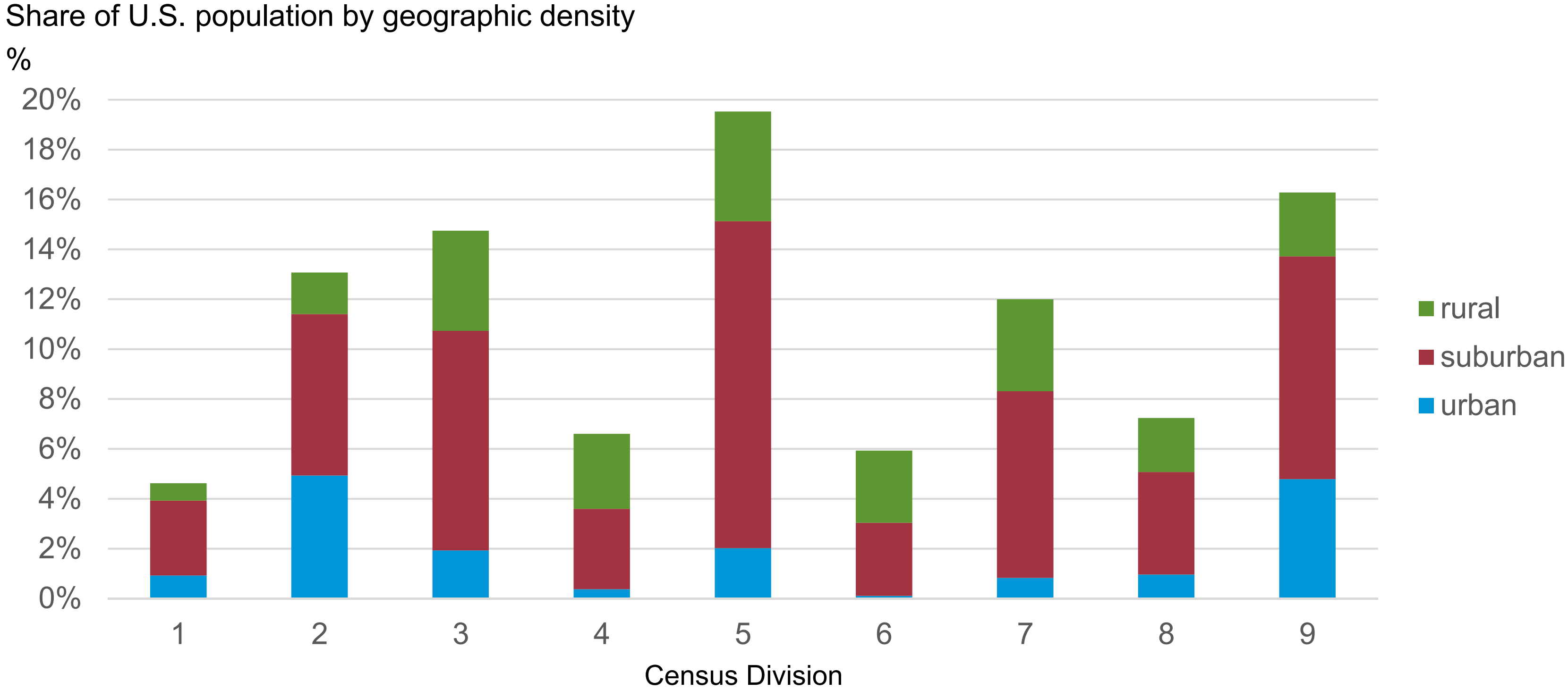
# Example of highly automated vehicle cost and sales into ride-hailing fleet




Recent modeling
Current research
Tech cost curve
Fuel economy
Scrappage rates
ROI
Cost ride hailing
Cost transit
Cost & utility of vehicle ownership
Availability of ride hailing
Urban v. suburban v. rural
Availability of transit
Population density
PMT
The BRAIN
VMT
Deliveries
Empty miles
Traditional
Underserved population

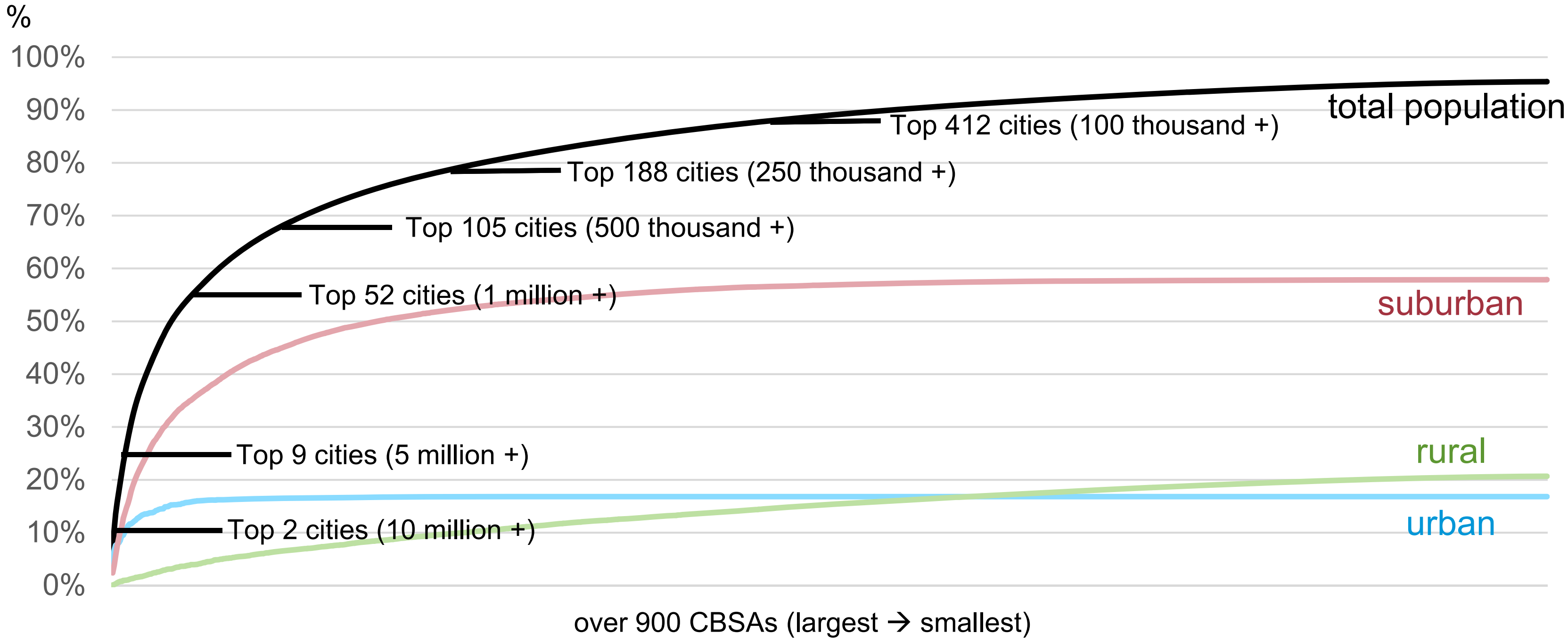
# U.S. population by geographic density and Census Division




*Source: U.S. Census Bureau, American Community Survey (ACS) 2015*

# U.S. population living in Core Based Statistical Areas (CBSAs) by geographic density

Share of U.S. population within CBSAs by geographic density




*Source: U.S. Census Bureau, American Community Survey (ACS) 2015*