

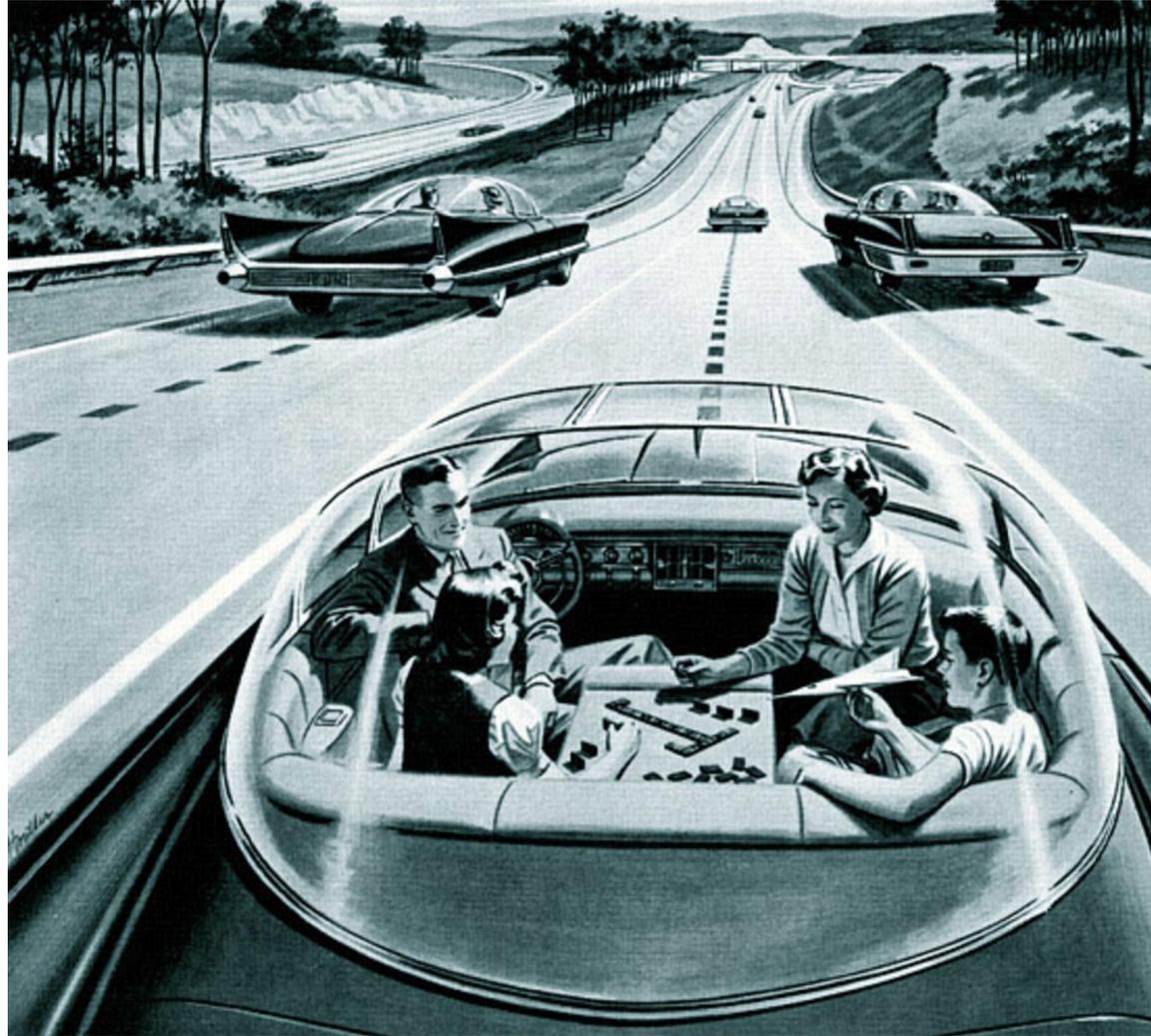
# Energy and the New Mobility – How Disruptive (to Energy) will AVs be?

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U.S. DEPARTMENT OF  
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# The future of automotive transportation is AVs...



...but this is our current reality...



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***Everything that you have heard about AVs  
and their energy implications is wrong...***

# Common myths about AVs and energy

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- ▶ All AVs will be EVs

# Common myths about AVs and energy

- ▶ All AVs will be EVs
  - *Initially they will be HEVs and PHEVs (or conventional IC vehicles) due to the significant power consumption required for machine vision, perception, data fusion, computation, decision making, and automation.*



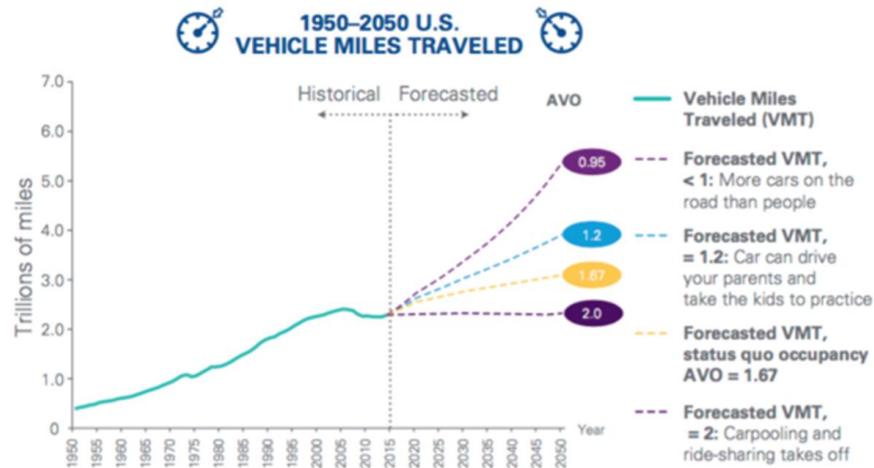
# Common myths about AVs and energy

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- ▶ AVs will reduce our total VMT

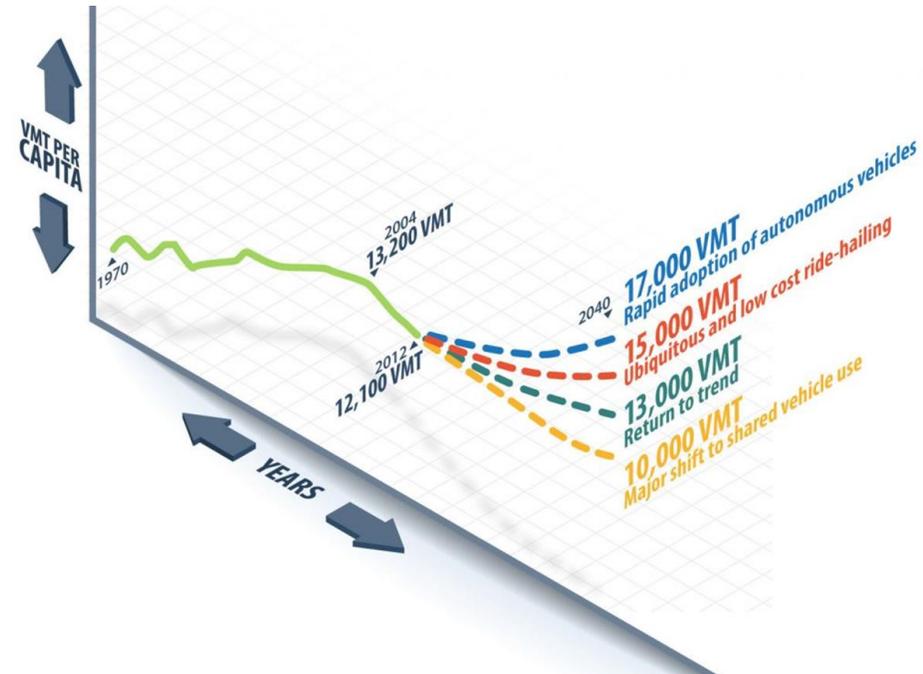
# Common myths about AVs and energy

- ▶ AVs will reduce our total VMT
  - *To the contrary...VMT could double or treble.*



Note: (a) Discounted 25% from U.S. BTS total VMT for 1995, 2001, 2009, 2014 (assumed to be commercial miles), (b) Multiplied by NHTS occupancy rates applied 2009 rate to 2014 numbers).

Source: U.S. BTS data, NHTS data, U.S. Census data, KPMG Analysis



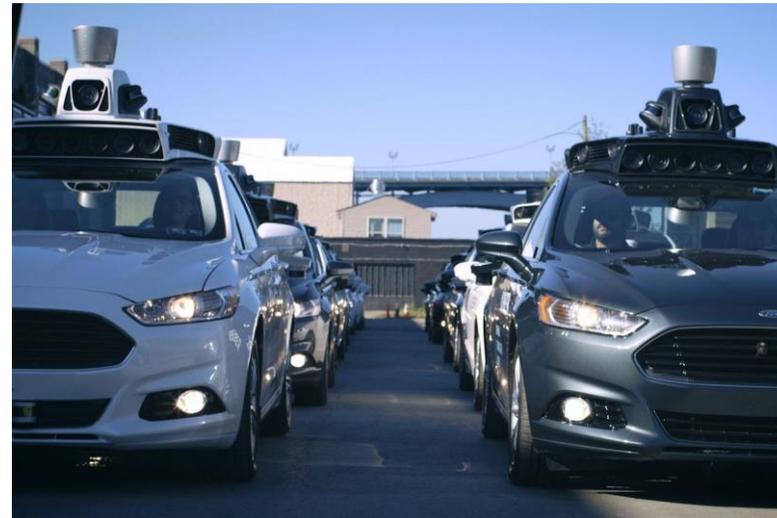
# Common myths about AVs and energy

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- ▶ AVs will ease congestion

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- ▶ AVs will ease congestion
  - *No, reducing the cost of travel will simply induce more travel (the rebound effect). And we will drive by proxy.*



# Common myths about AVs and energy

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- ▶ AVs will encourage ride-sharing

# Common myths about AVs and energy

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- ▶ AVs will encourage ride-sharing
  - *If cost per mile is reduced, there will be even less incentive to share rides than there is today. Why share a ride at \$1.00/mile when there is minimal sharing today at \$2.00-3.00/mile?*

# The potential AV energy implications are staggering!

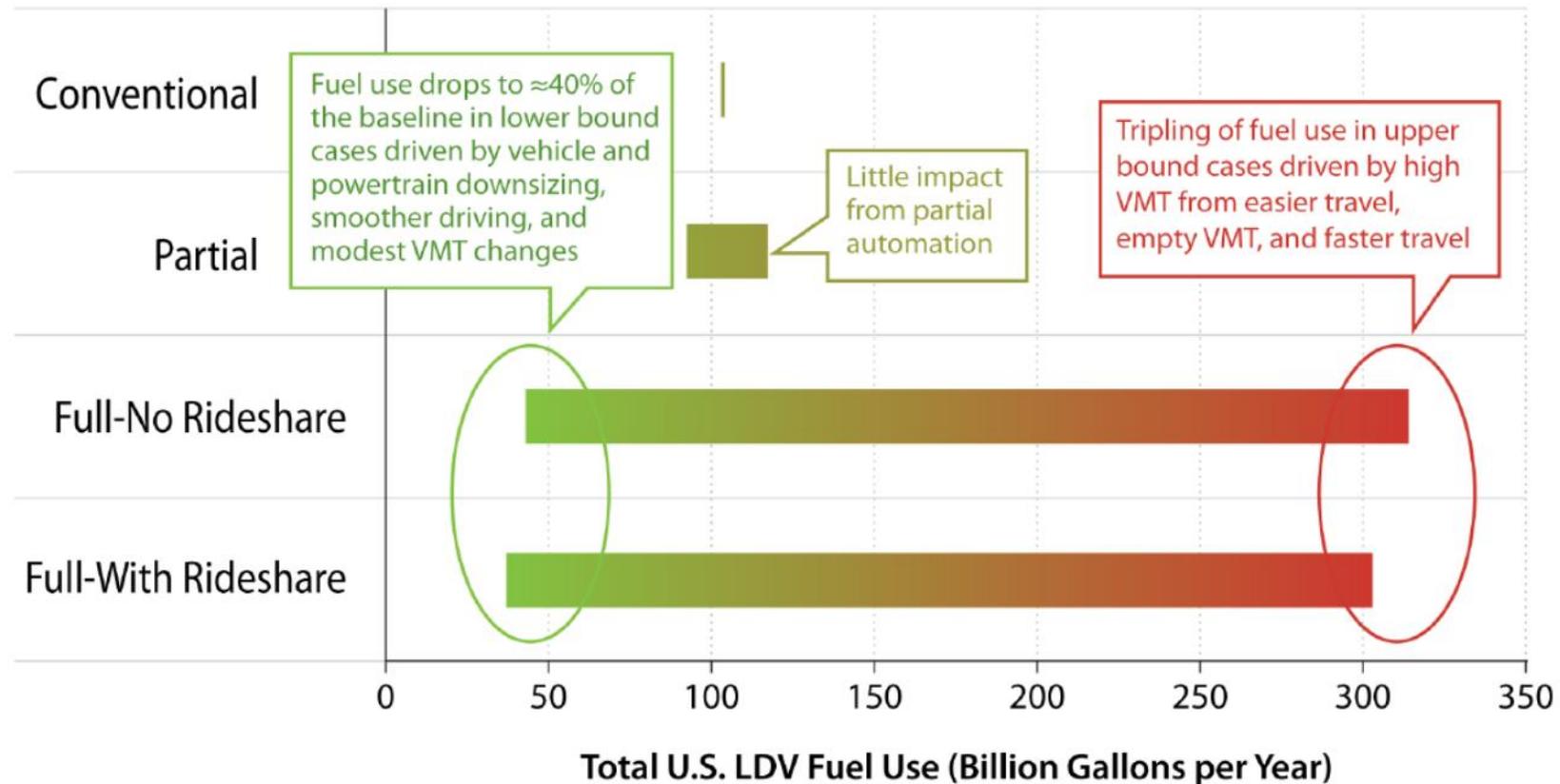
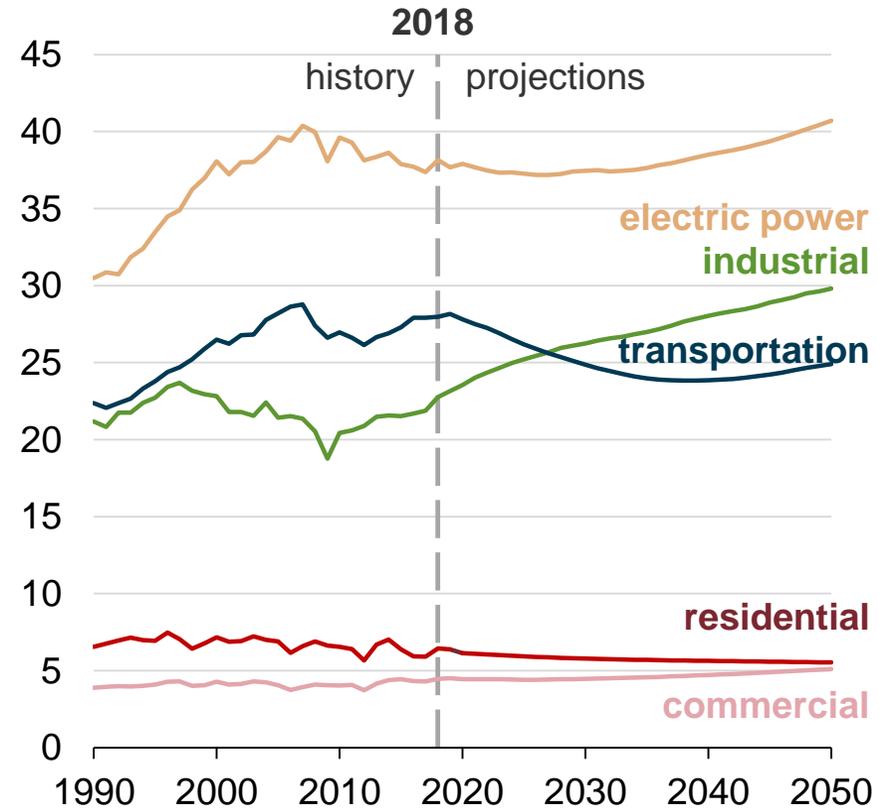
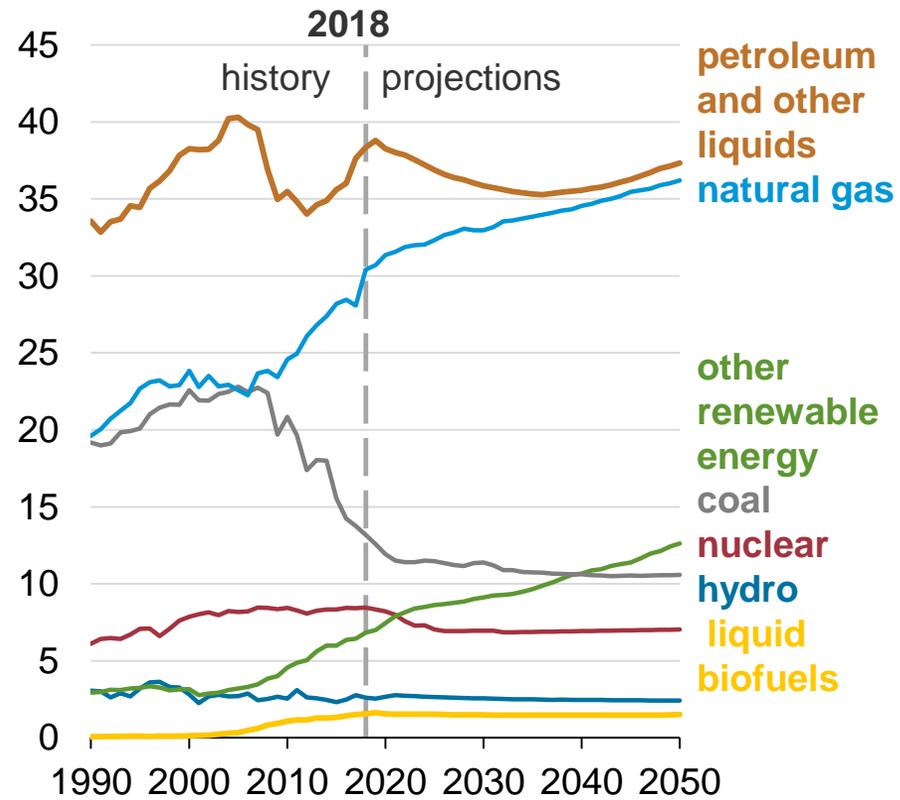


Figure ES-2. Estimated bounds on total U.S. LDV fuel use per year under the base (Conventional) and three CAV scenarios, based on the study's synthesis approach from CAV feature impact ranges reported in existing literature

### Energy consumption by sector (Reference case) quadrillion British thermal units



### Energy consumption by fuel (Reference case) quadrillion British thermal units



# Making future AVs more energy efficient

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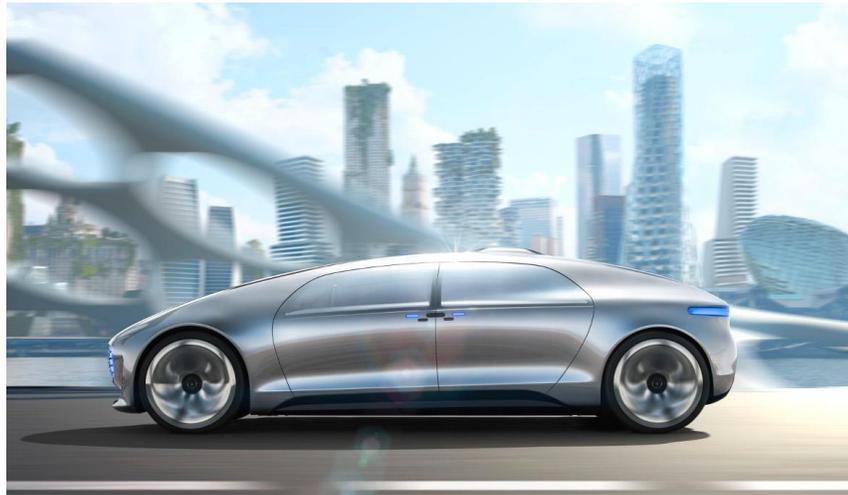
- ▶ Downsize
  - Downweight
    - Improve the efficiency of IC engines
      - Increase hybridization
        - » Increase electrification
          - Ultimately full electrification

(considering only vehicle-related technologies, and not infrastructure, regulation, policy, incentives, etc.)

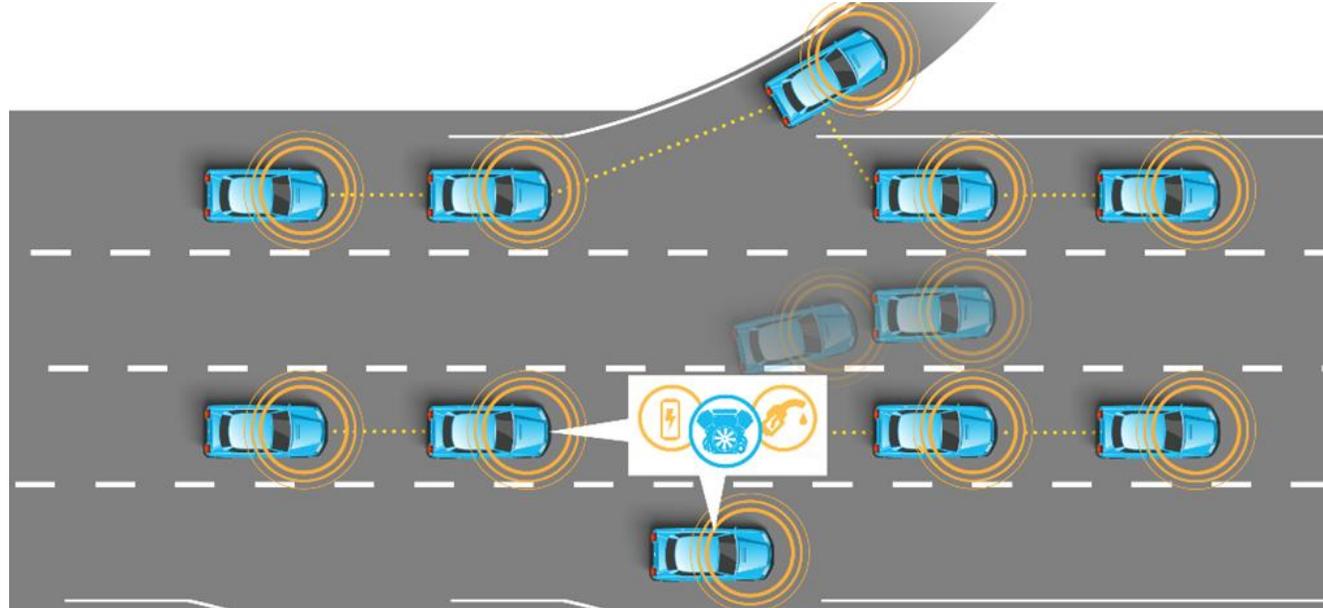
# From this...



# to this....



# ARPA-E NEXTCAR Program Motivation



**Facilitating energy-efficient L1-L3 AV operation through vehicle connectivity and automation.**

**Using eco-routing, eco-driving, hybrid energy flow optimization, platooning and other connected and L1-L3 automation techniques, to improve individual vehicle energy efficiency by 20%.**

# Essential Capabilities Required to Replace an Incumbent Vehicle Technology

Any new technology must be comparable to or better than the incumbent in:

Criterion	Measure
<b>Power</b>	Power density (or energy density including the fuel/energy storage capacity) ⇒ <b>Customer Acceptance</b>
<b>Efficiency</b>	Fuel economy or energy efficiency (over real-world dynamic driving) ⇒ <b>Regulation</b>
<b>Emissions</b>	Regulated criteria pollutants (and CO <sub>2</sub> ) ⇒ <b>Regulation</b>
<b>Cost</b>	Total cost of ownership (including capex and energy cost) ⇒ <b>Customer Acceptance</b>
<b>Reliability</b>	Mean time between failures, maintainability ⇒ <b>Customer Acceptance</b>
<b>Utility</b>	Acceleration, driveability, NVH, cold or off-cycle operation, ease of use, transparency to the user, and acceptable range ⇒ <b>Customer Acceptance</b>
<b>Fuel Acceptability</b>	Use a readily available fuel or energy source with acceptable range and ease of refueling ⇒ <b>Customer Acceptance</b>
<b>Safety</b>	Non-negotiable ⇒ <b>Regulation</b> (and <b>Customer Acceptance</b> )

# BEYOND NEXTCAR

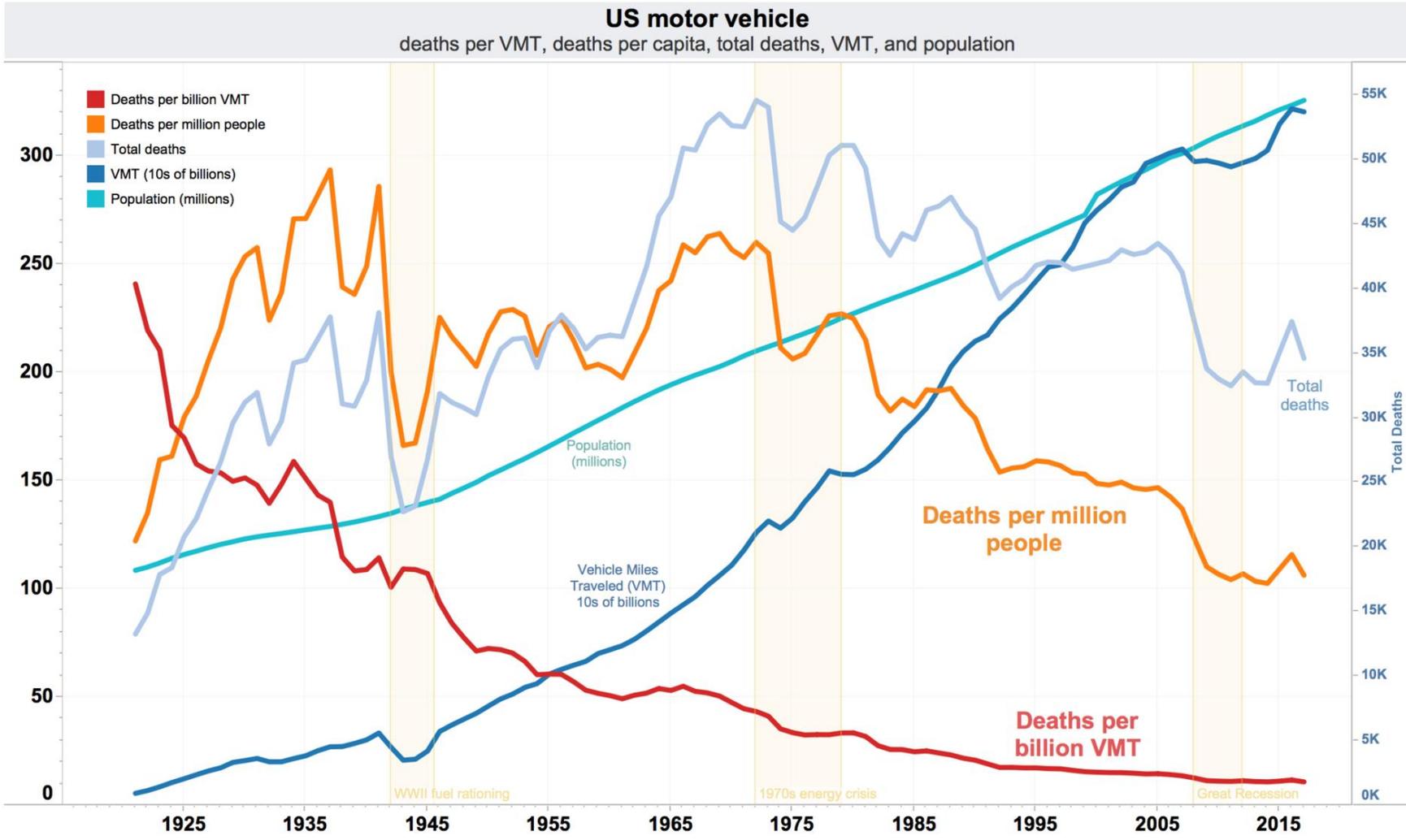
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- ▶ *What **NEXTCAR** energy efficiency techniques can be applied to L4 & L5 vehicles?*

# Safe deployment of energy-efficient L4 & L5 automation is key!







# BEYOND NEXTCAR

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- ▶ ***Vehicle safety is a key enabling technology for energy efficiency.***
- ▶ *Developing a rigorous framework for ensuring AV safety is critical to reducing the energy consumption of the future AV vehicle fleet*
  - *Even if VMT increases significantly.*
- ▶ ***What energy-efficient automotive technologies (beyond those described here) remain to be developed for L4 and L5 AVs?***

# Thank you!

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