No Brakes or Steering Wheel?

Avoiding a future automotive energy dystopia

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The future of automotive energy use

- Future cars and light trucks will be increasingly **more efficient**
  ~95% ICEs →HEVs, PHEVs and ultimately more BEVs.
- Total vehicle miles traveled (VMT) in the US is closely tied to economic activity and is (even now) **increasing quite rapidly**.
- Full driverless vehicle automation (L5) could lead to a **future energy dystopia** (even if they are all xEVs) due to unbridled increases in VMT.
- A transformation to ultra-safe L3 and L4 vehicles, with significant weight reduction and improved powertrain efficiency, is the **best interim energy efficiency** option.

The future of the automotive industry

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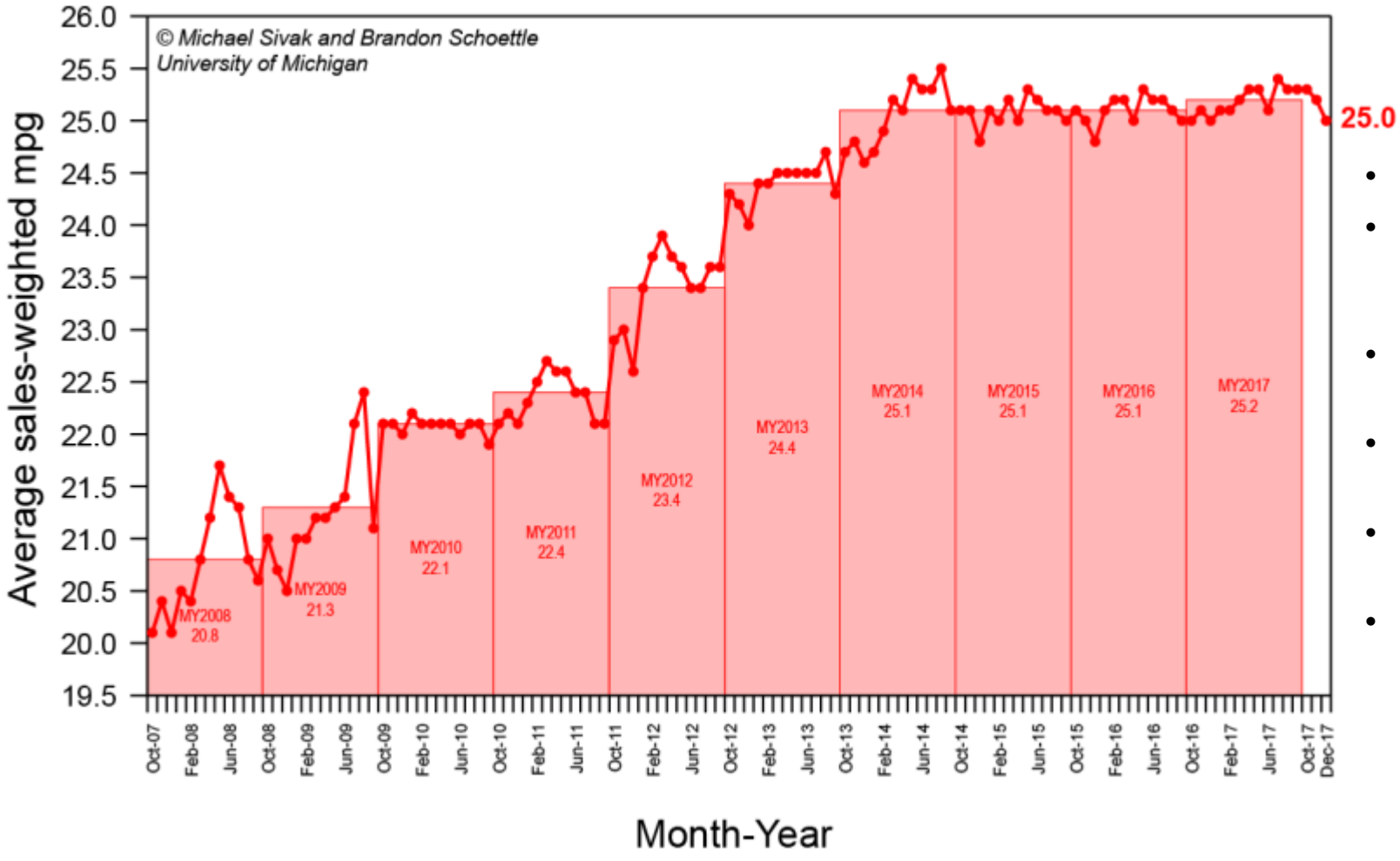
But before we get there, several transformations are required, namely

- An energy revolution
- An automation revolution
- And a complete transformation in the way that vehicles are purchased, owned and operated.

And what about the “energy inefficient interim”?

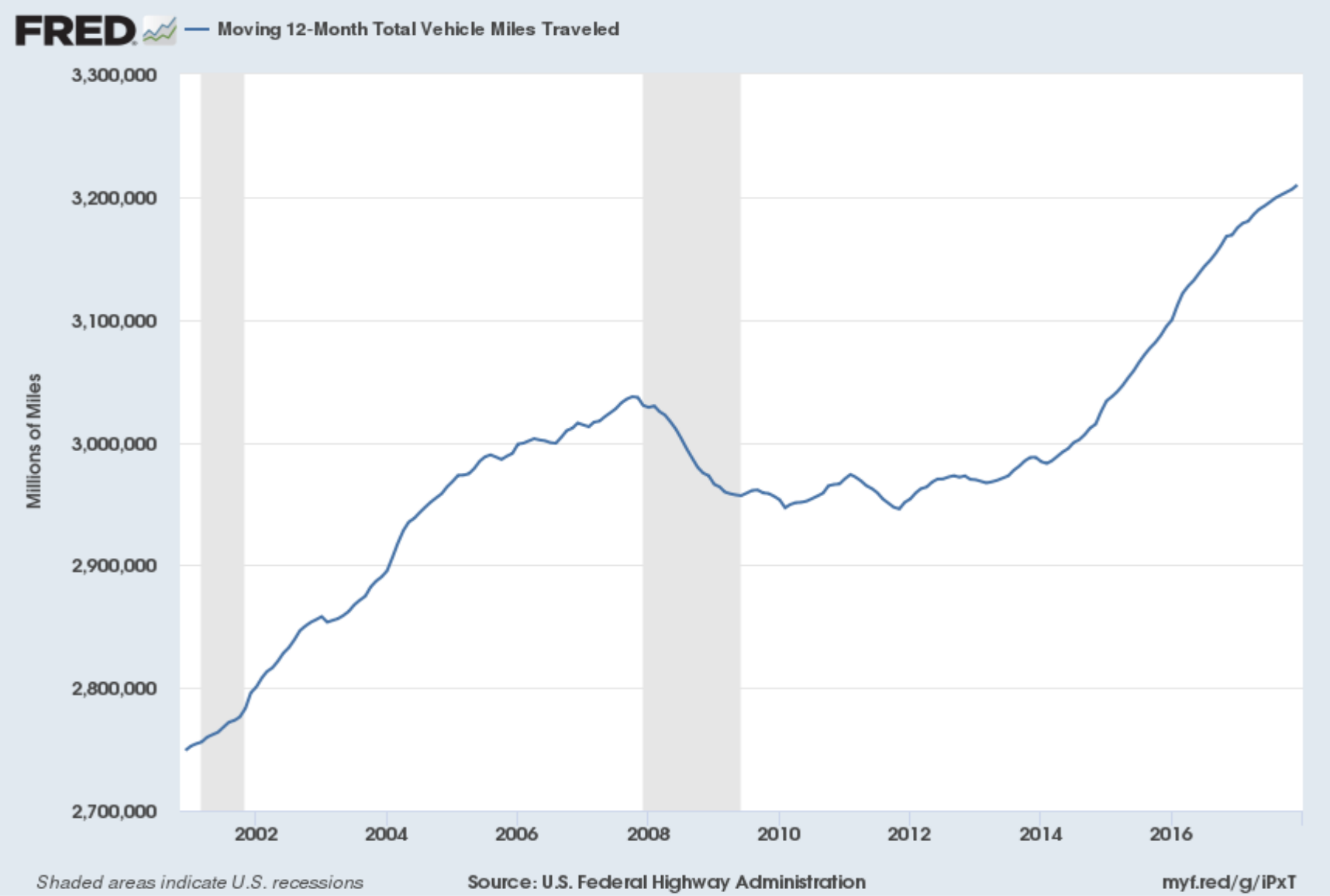
The automotive industry today



- **2017 sales:** ~17.2 million (at $34k average)
- **Total vehicle fleet:** 190 million cars, 50 million pickup trucks, 12 million heavy-duty (HD) vehicles (trucks, buses).
- **65% of sales:** pickup trucks, SUVs, crossovers and minivans.
- LD vehicle fleet takes **10-15+ years** to turn over.
- **xEV sales** (US, 2017): 1.2% BEVs (including PHEVs), 2.7% HEVs
- Average personal vehicle cost: **~$0.60/mile**.

LD vehicle fuel economy has stagnated since 2014

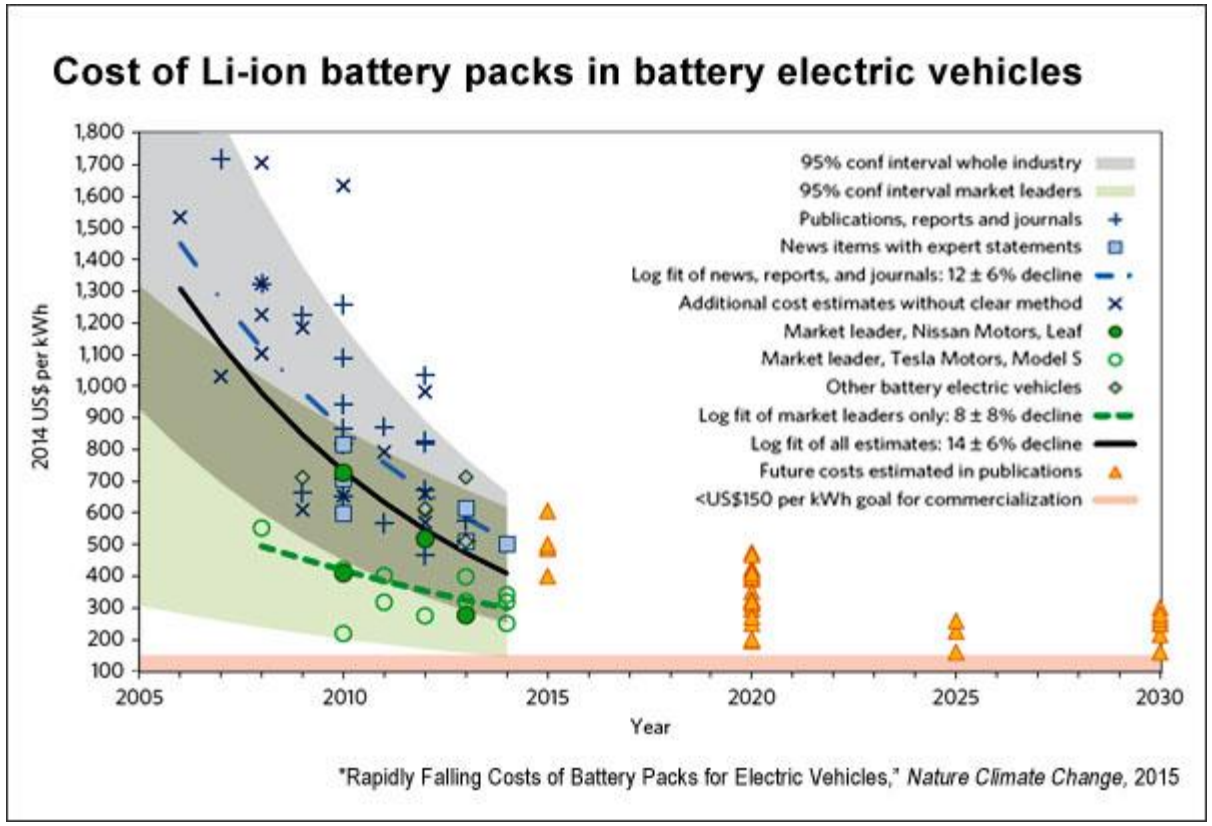
…while VMT has soared – 3.2T miles per year in the US

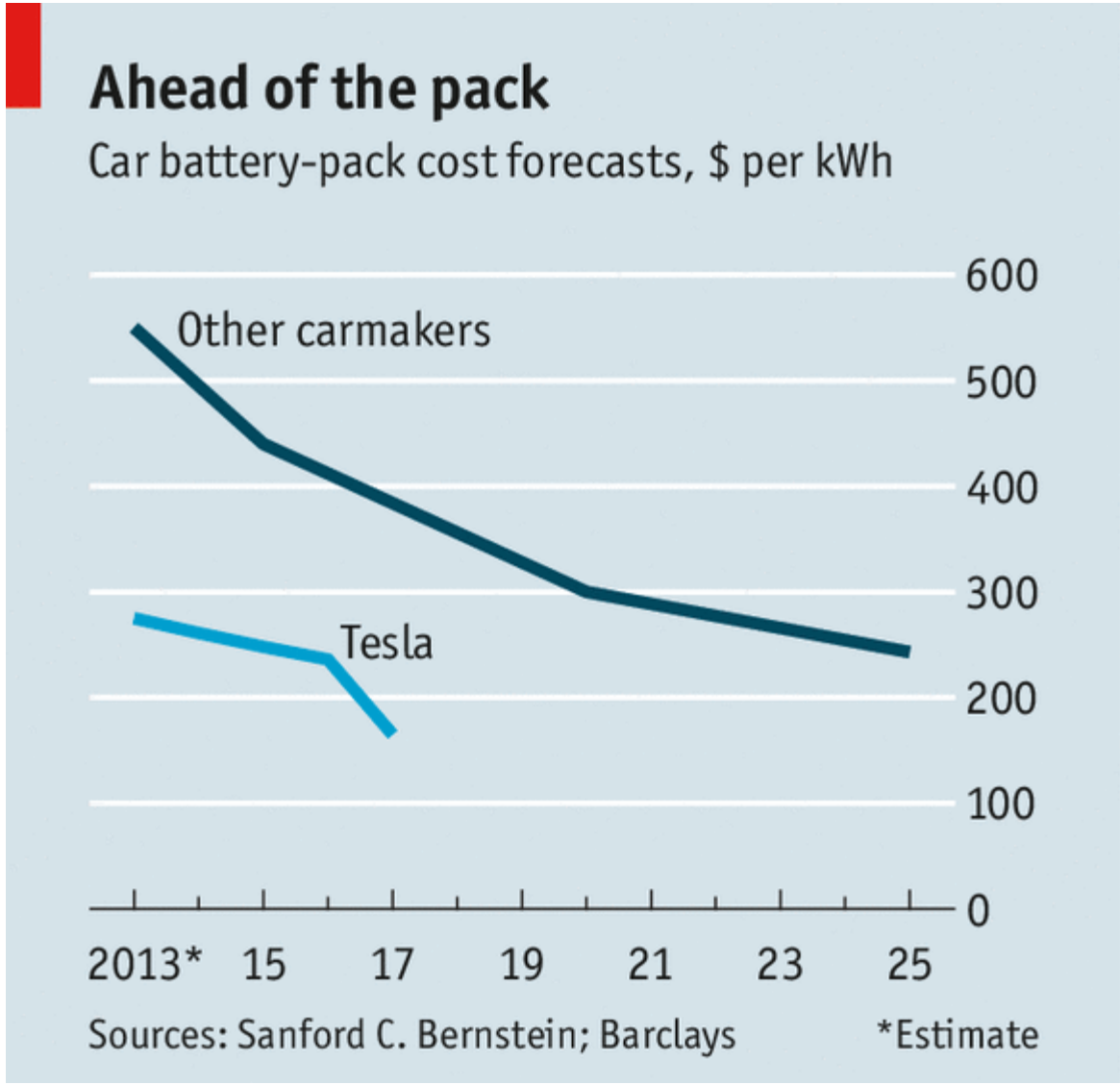


The future of powertrains

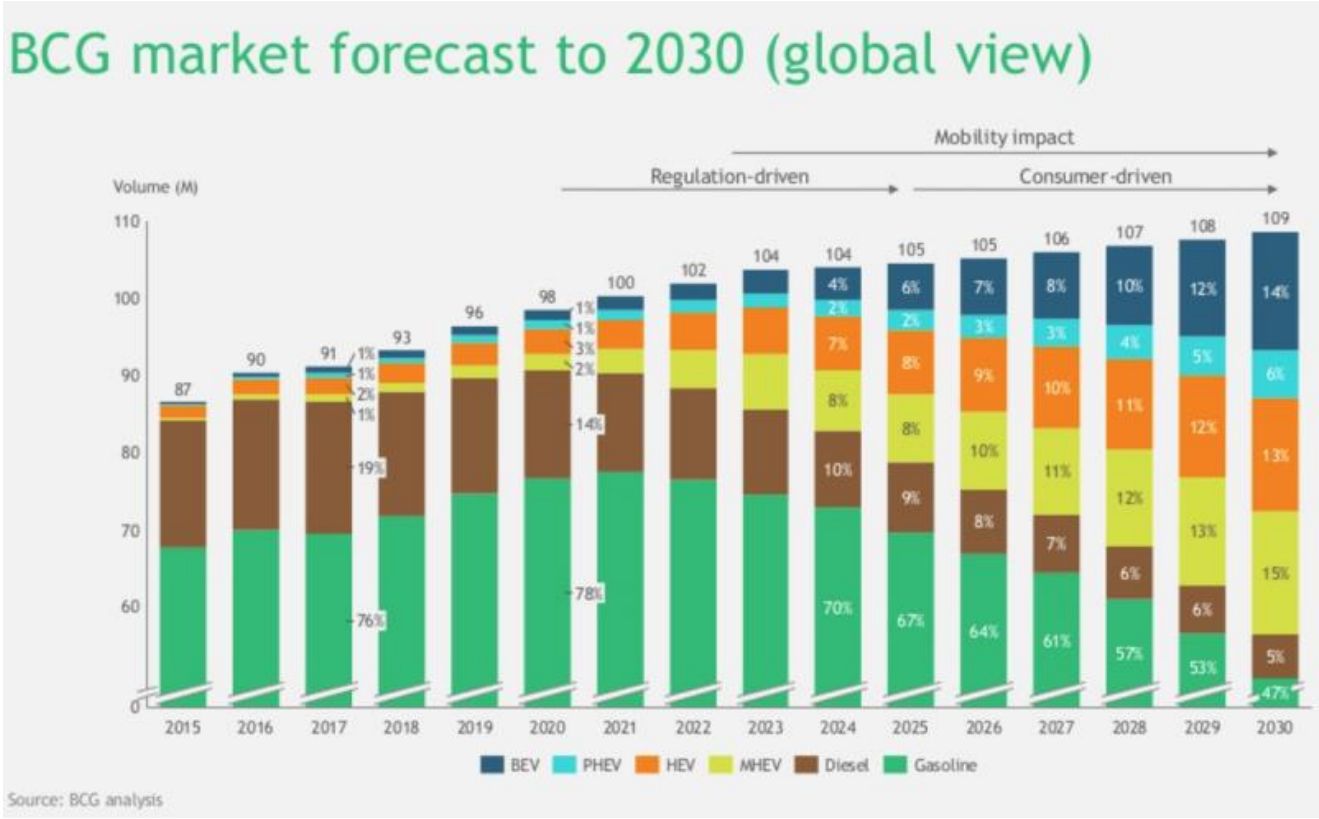
Powertrain Costs:

- 80 kWh battery pack ~$12k; 200 kW motor and inverter ~$2k for a combined $14k
- 200 kW conventional engine + transmission ~$6k



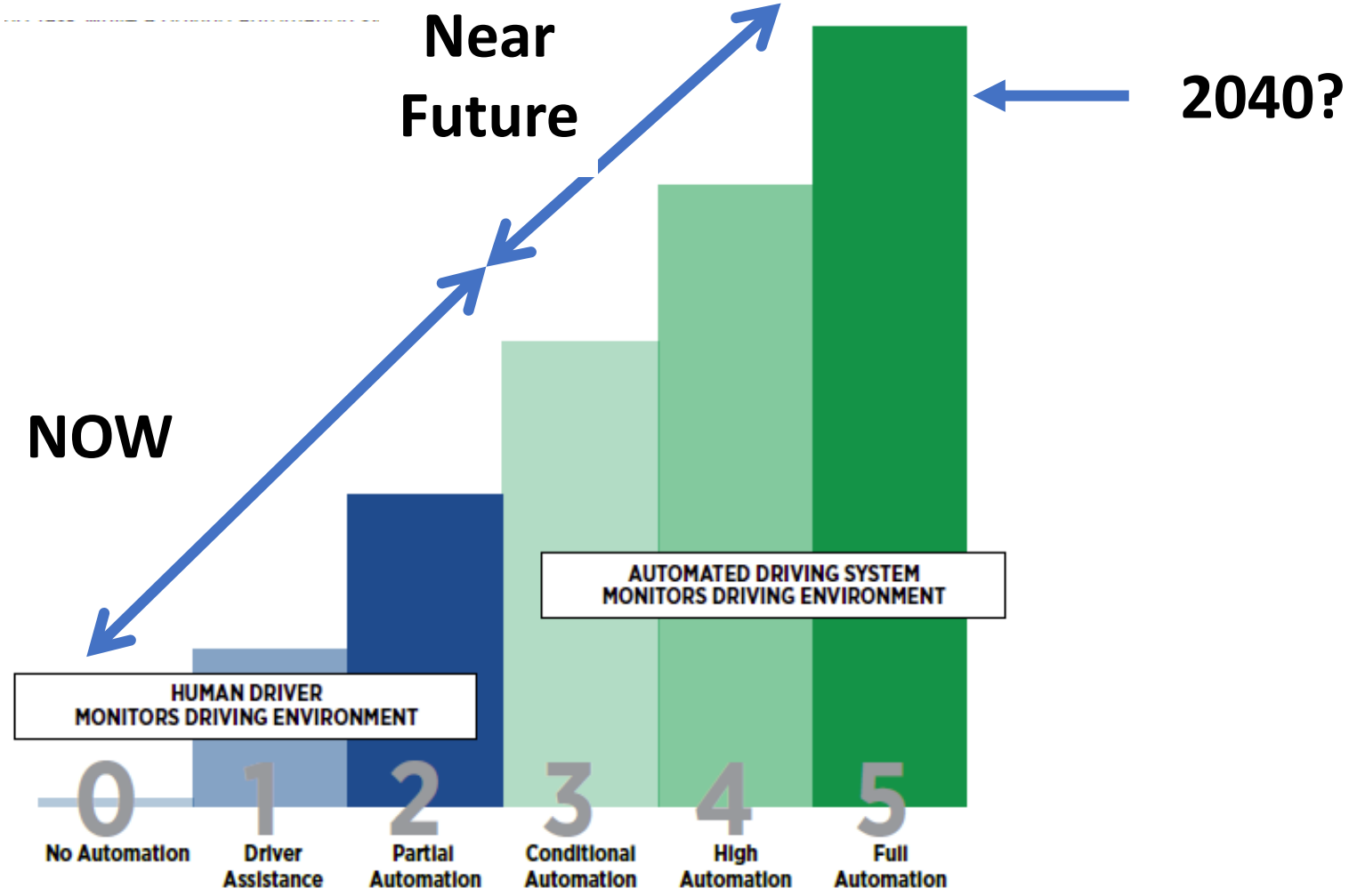


The notion of an EV “tipping point” is overblown…



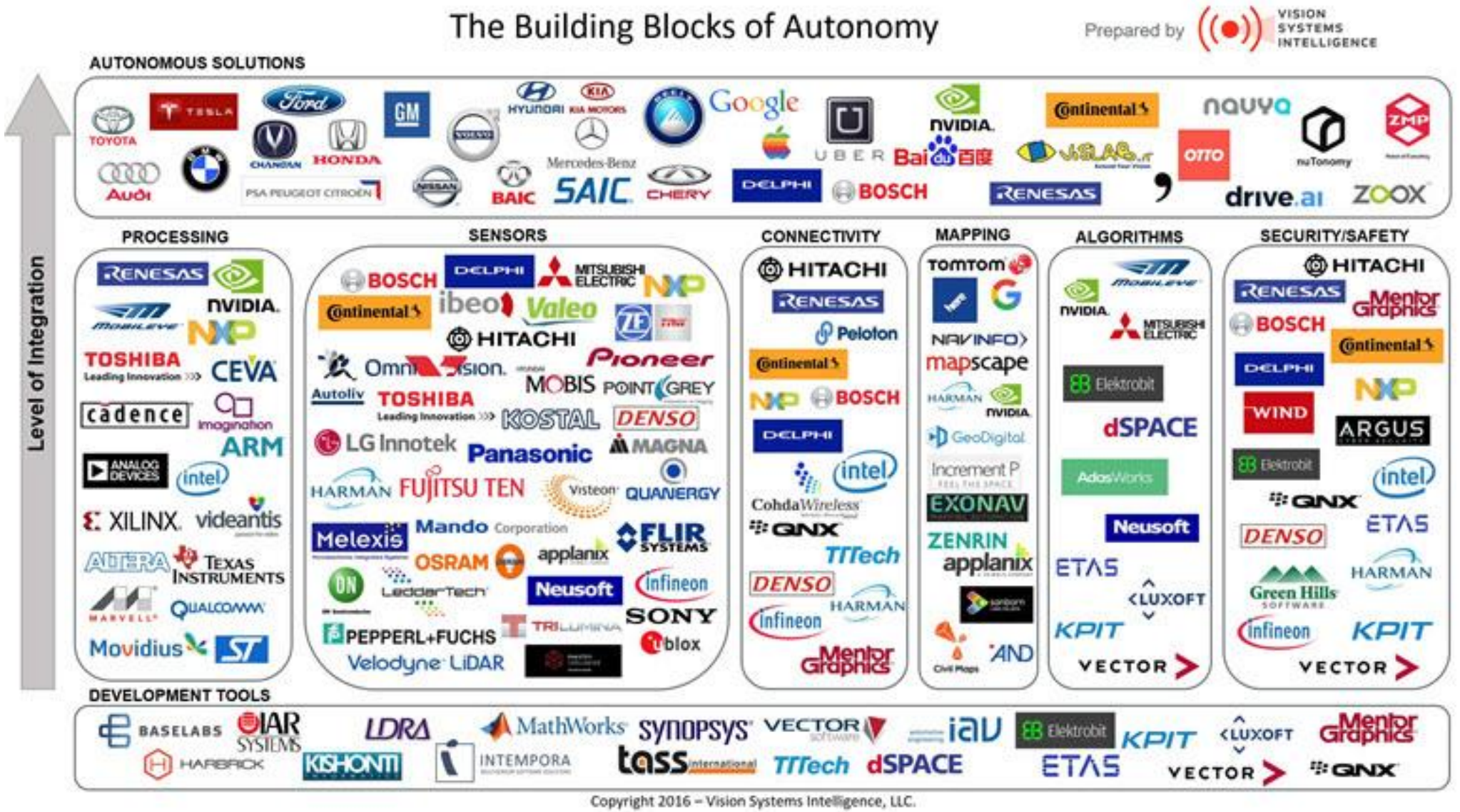
Just as there are $15k and $100k vehicles sold today, there will be a wide array of vehicle (and propulsion) choices in the future – and people will choose the option that best meets their economic and practical needs.

The future of vehicle automation



The development of vehicle automation is occurring rapidly on a number of fronts.

Hundreds of BILLIONS have been invested…



Future transportation energy usage – *the potential dystopia*

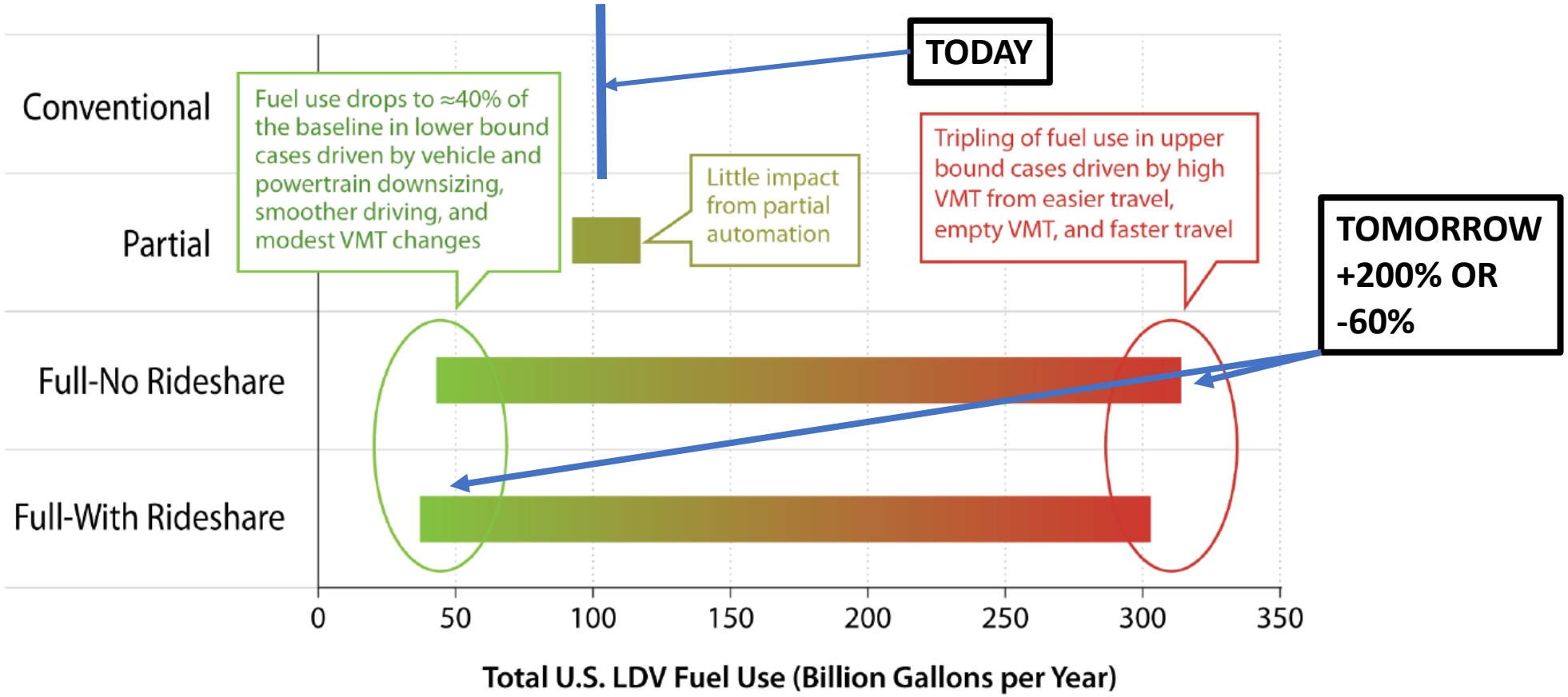
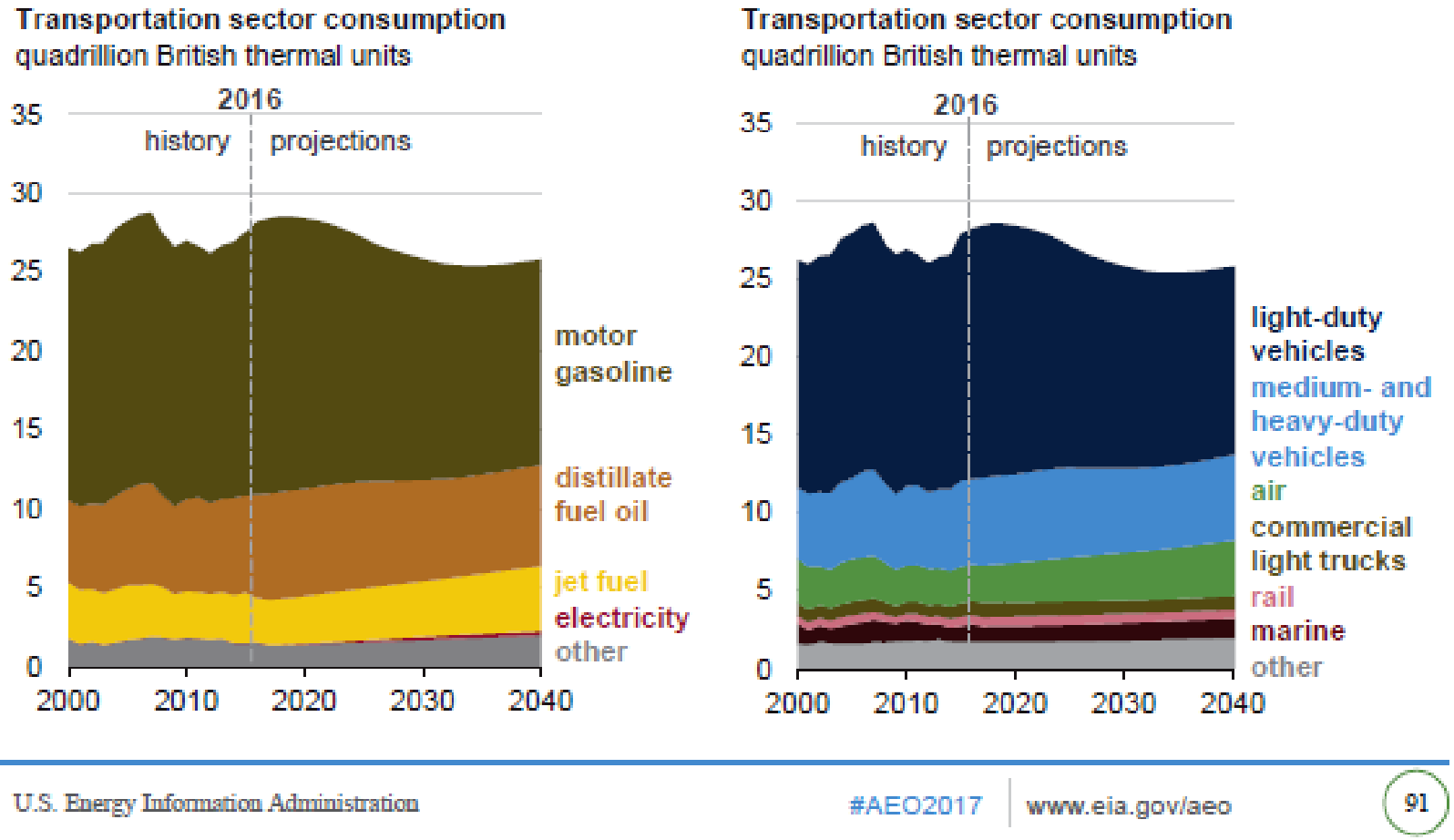


Figure ES-2. Estimated bounds on total U.S. LDV fuel use per year under the base (Conventional) and three CAV scenarios, based on the study's synthesis approach from CAV feature impact ranges reported in existing literature

Gonder et al., NREL 2016

Future automotive energy usage in the US – *petroleum*



~140 billion gallons per year gasoline usage (2016) – mainly light-duty

~40 billion gallons per year diesel fuel usage (2016) – mainly heavy-duty

3x VMT and 3x petroleum consumption would be catastrophic!!

Future automotive energy usage in the US – *electricity*

	Miles Traveled per year	Energy Efficiency	Electrical Energy Usage
TOTAL VMT (total vehicle miles travelled 2016)	3.13×10^{12}		1.98×10^{12} kWh/yr
Light-duty vehicles	2.15×10^{12}	0.30 Wh/mile	6.45×10^{11} kWh/yr
Medium-duty vehicles	0.63×10^{12}	1.00 kWh/mile	6.30×10^{11} kWh/yr
Heavy-duty vehicles	0.35×10^{12}	2.00 kWh/mile	7.00×10^{11} kWh/yr

- **Total Electrical Energy Consumption in the US (2016): 4.077×10^{12} kWh**
- **Fully electrified transportation today would be an additional ~50% of current installed generation capacity.**

3x VMT would require +150% installed generation capacity!!

But new transportation paradigms will save us, right?

- Ride-hailing and car sharing (TNCs) do not reduce VMT. Only *ride-sharing* by 2 or more passengers does.
- No measurable reduction in VMT from TNCs – already movements away from public transportation.
- And as mobility becomes cheaper and more convenient to use, we know that people will simply use more of it – *Jevon's paradox*.
- What about individual vehicle ownership?

  Personal cost is ~$0.60 per VMT, TNC is ~$2.00 per VMT.

  Again the answer depends on individuals' VMT.

  Low VMT = shared vehicle, average or high VMT = purchased.

Averting this near-term potential energy dystopia?

- Reducing **VMT**, for example through ride-sharing (tough to do).

- Reducing **vehicle specific energy consumption** (easier to do).
  - Much more efficient vehicle powertrains – conventional vehicles, hybrids and BEVs.
  - Reductions in aerodynamic drag, rolling resistance, vehicle mass, auxiliary and parasitic losses – essentially through *significant weight reduction*.

How can vehicle weight be reduced significantly?

- The usual routes – optimized mechanical design, material substitution, lightweight materials – improved *passive* safety.

- Through ensuring intrinsic *active vehicle safety* – sufficient to allow L3 or L4 automation *while still requiring a driver*.

The upshot…

The conventional wisdom

Future vehicles will be efficient, EVs, L5, and shared. But this reality is many decades off.

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The conventional wisdom

Future vehicles will be efficient, EVs, L5, and shared, is many decades off.

And requires the convergence of a number of distinct issues.

The reality

By focusing on safe implementation of *L3 and L4 automation*, vehicles will be able to be light-weight and more efficient.

But this still requires a driver which will keep an *upper bound on VMT*.

And this will lead to the improved energy efficiency of our future vehicle fleet, preventing dystopia.

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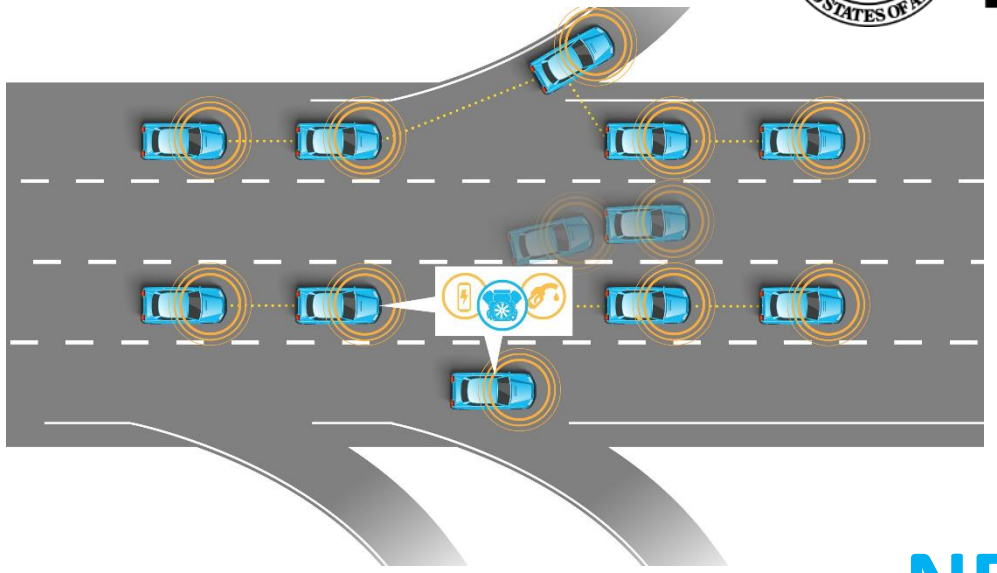
U.S. DEPARTMENT OF ENERGY



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