



EVs & AVs: Risks & Realities

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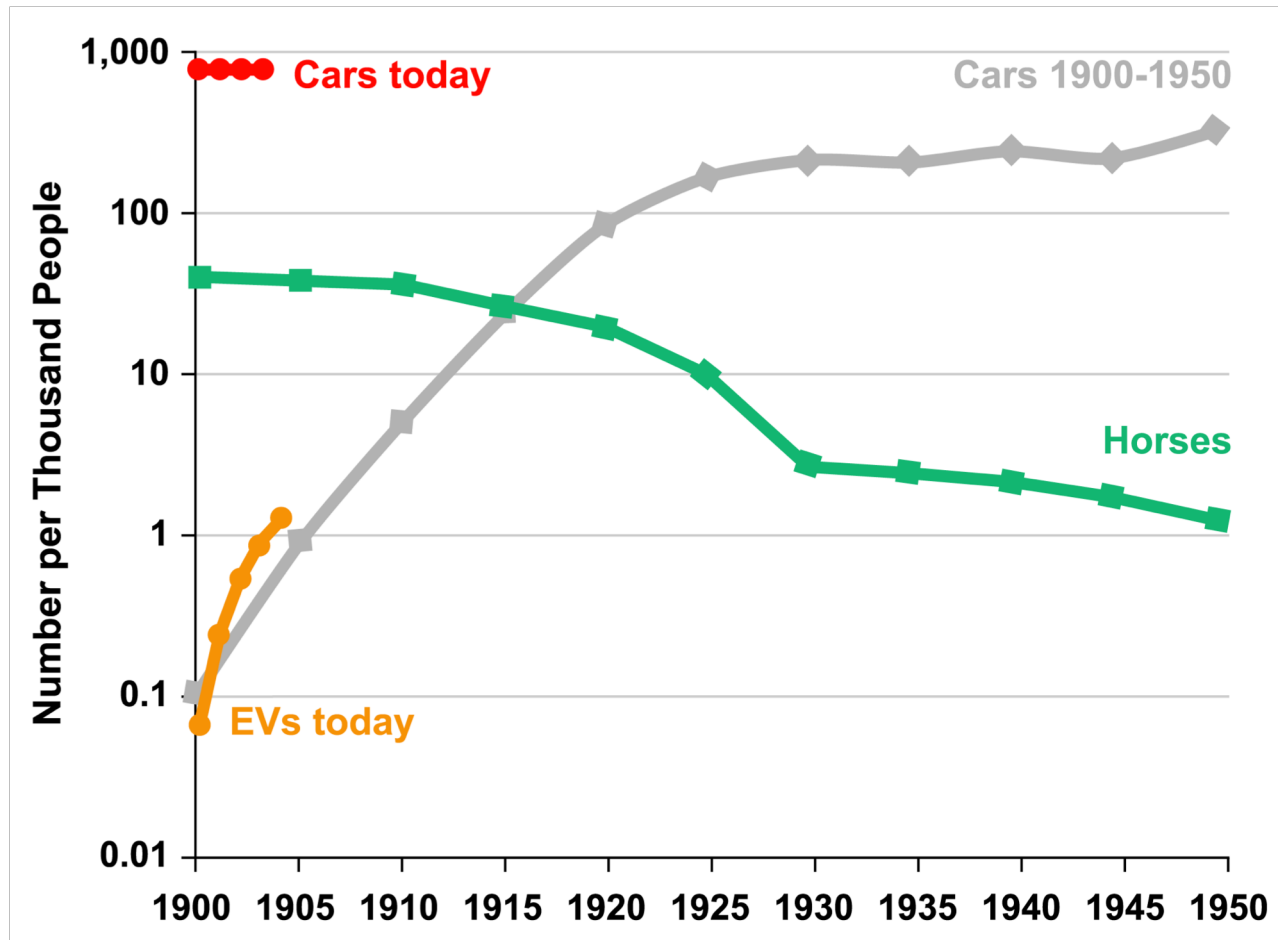
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What If EV Optimists Are Right?

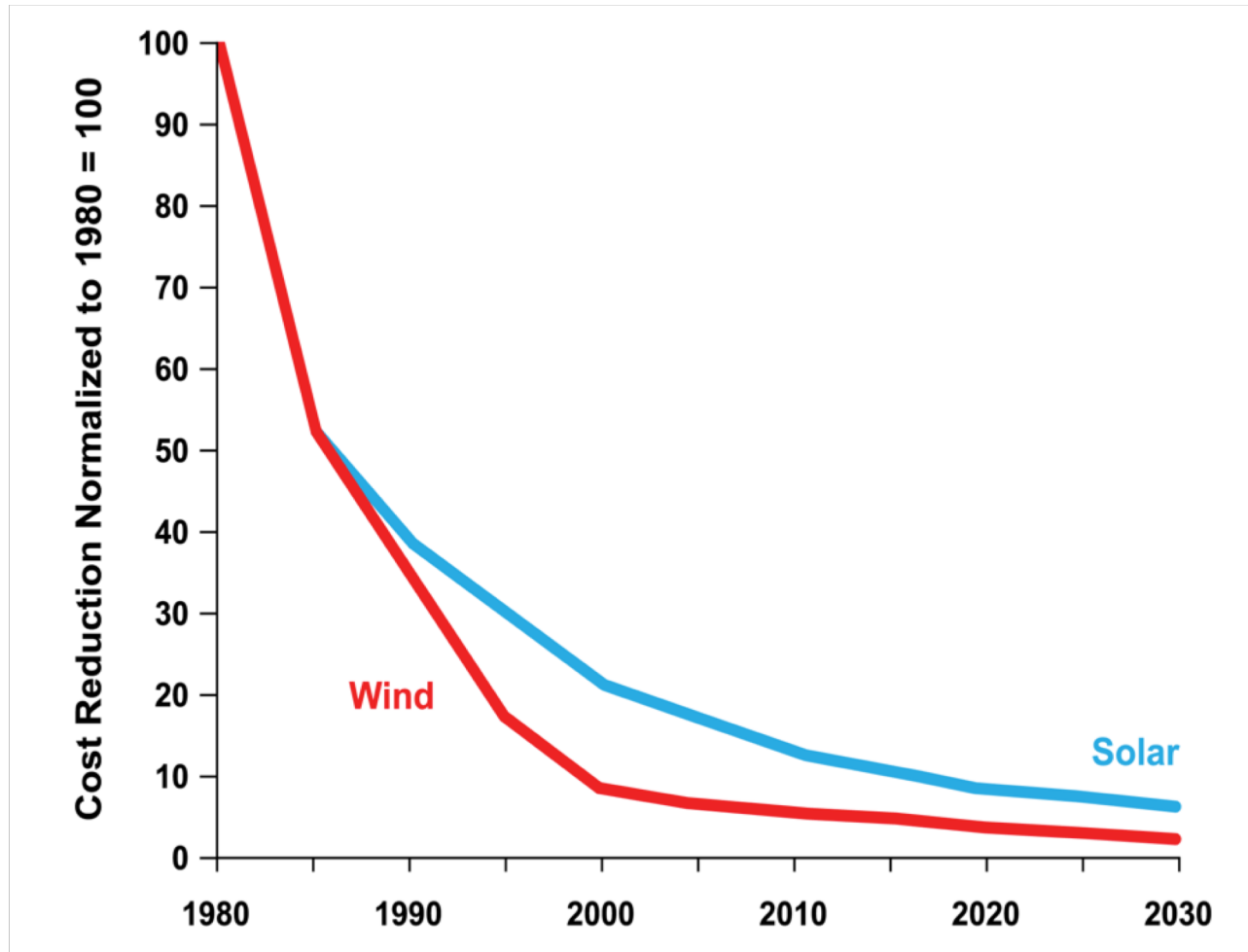
100x EV growth → displaces ~ 10 % world oil

Horse → car because 10x safer & 100x more useful



EV vs ICE → Fuel Swap, Oil to Nat. Gas & Coal

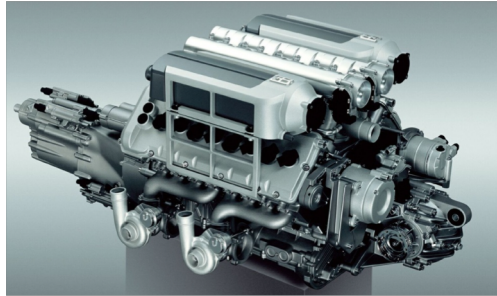
Myth of “disruptive” clean-tech progress: **Big wind & solar gains are history**



EV vs ICE → A Complexity Swap

PROPULSION

Complex physical-chemistry
1000s of parts



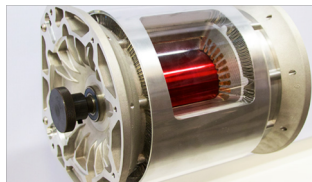
ICE →

FUEL

Simple



Simple



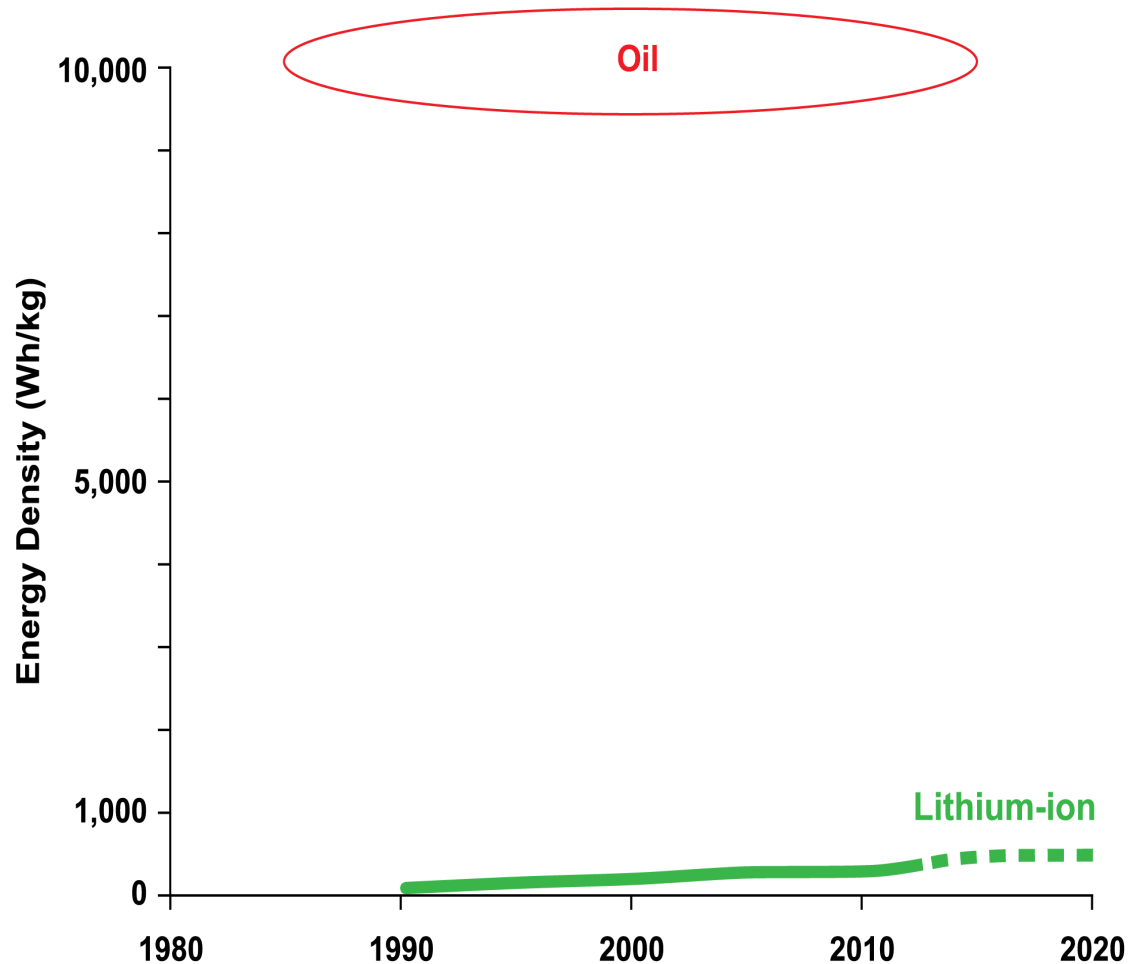
EV →

Complex electro-chemistry
1000s of parts



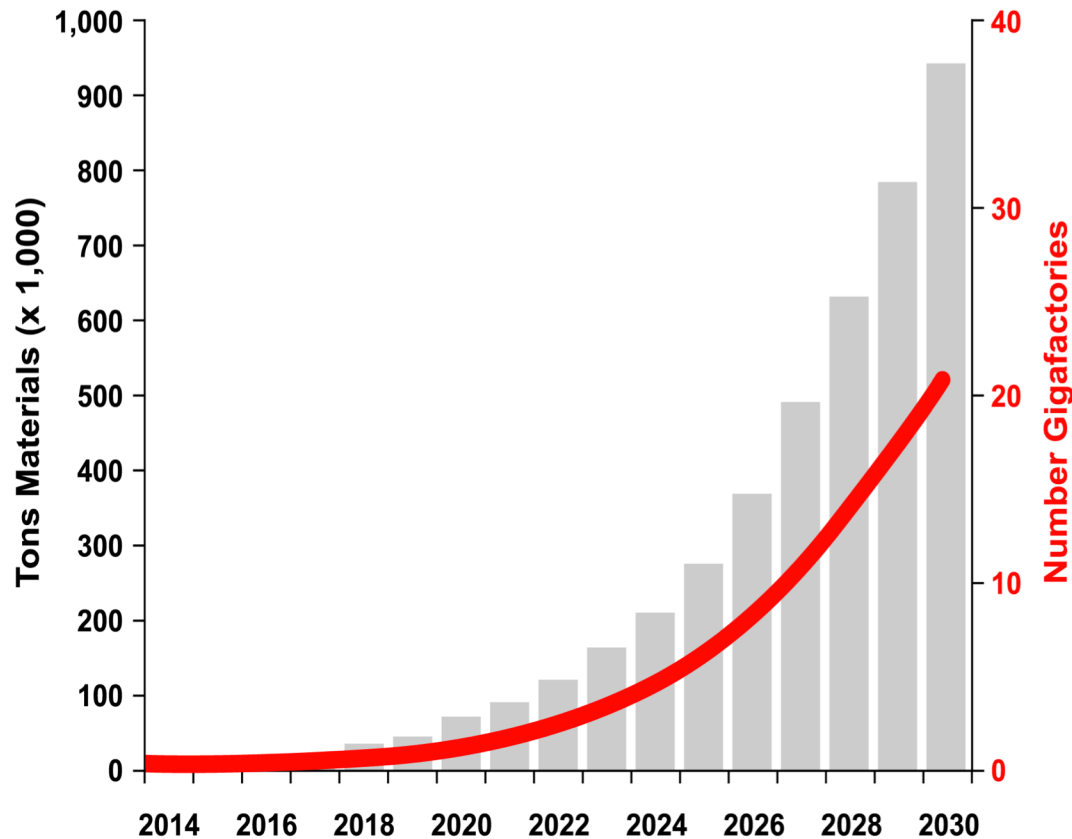
Batteries Will Never Beat Hydrocarbons

2% improvement in ICE > **20%** improvement in batteries... AND
100 BOE to fabricate **1 BOE** batteries



Magic Batteries → Mining Bonanza

Store energy in **1 lb** hydrocarbons → **1000 lb** materials mined



Silicon Silliness: Apps vs Automobiles

“Smartphone substitution seemed no more imminent in the early 2000s than large-scale energy substitution seems today.”

IMF 2018

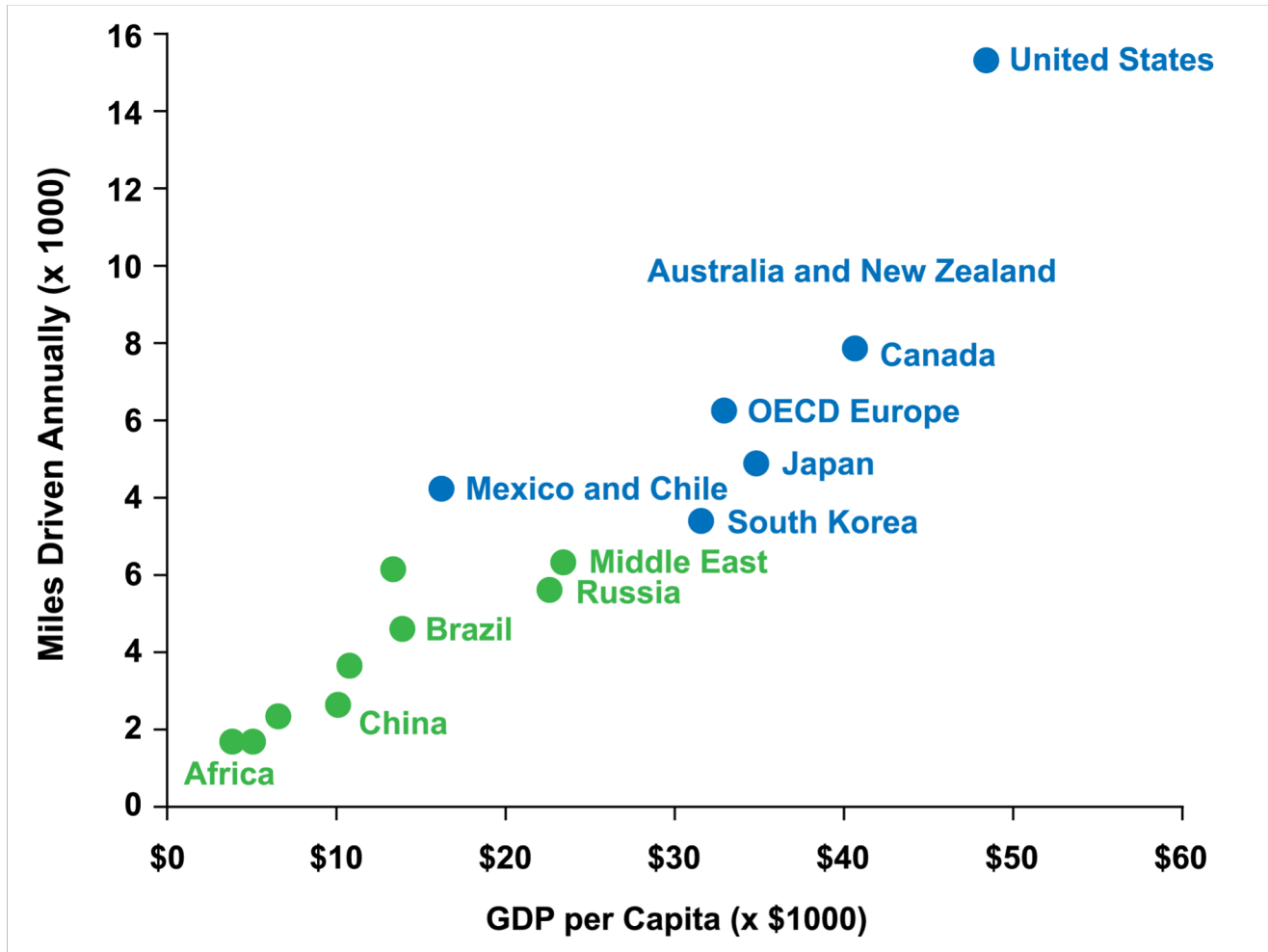
Only in comic books do **energy**-machines scale like **logic**-machines...

- **Ant-sized** solar array would power an office building
- A **3 cent** book-sized battery would fly an **A380** to Australia

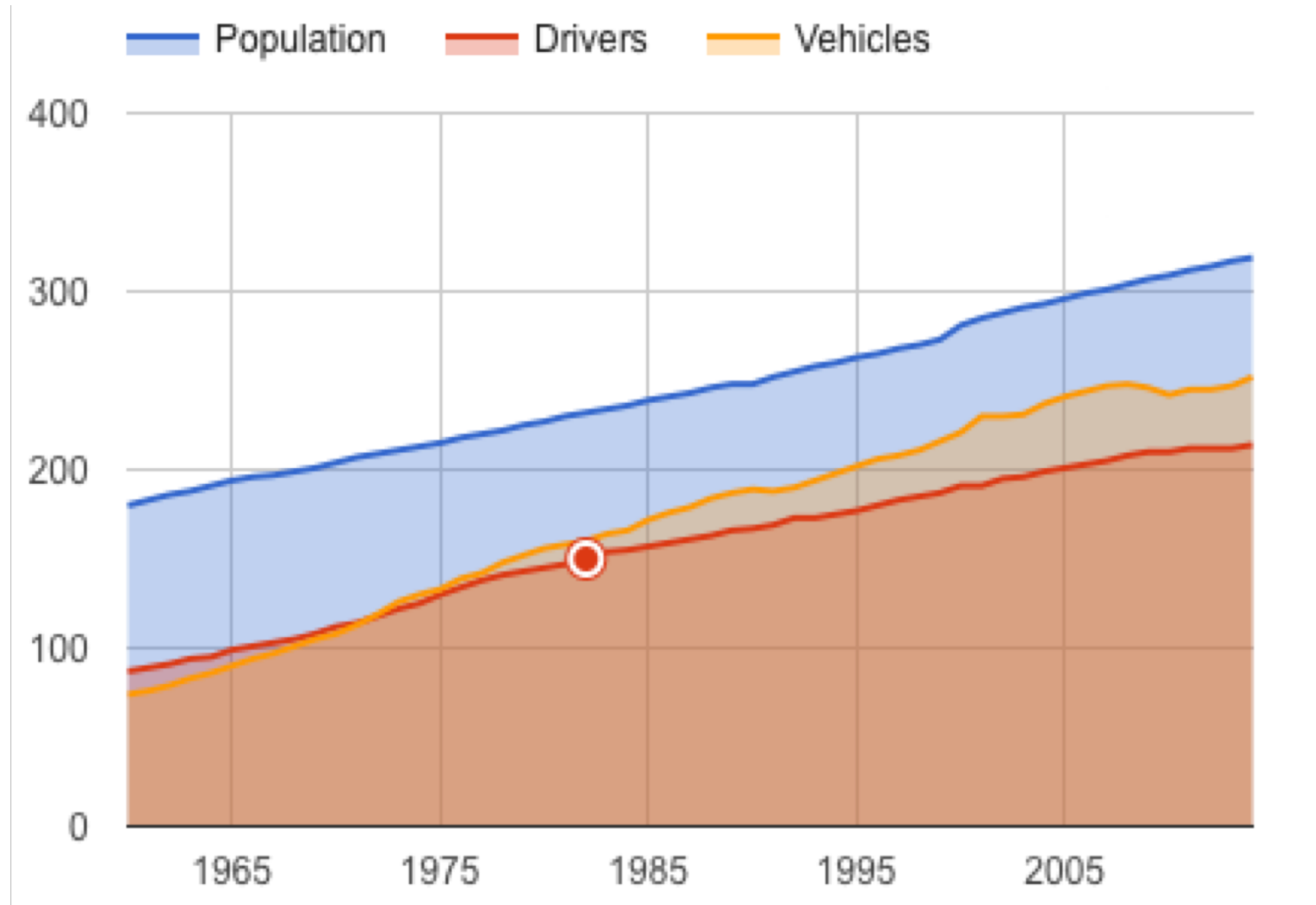


Uber Effect → More Driving

Wealth Increases Driving



Another Uber Effect: More (Fun) Cars



Robo Car: Eternal Dream Of Self-Driving

January 5, 1918, Scientific American

The car of the future will have no such thing as a “driver’s seat.” Driving will be done from a small control board.”



October 10, 1957, Engineering News

“You ... push the button marked ‘Electronic Drive.’...Fantastic? Not at all. The first long step ... was successfully illustrated by RCA.”

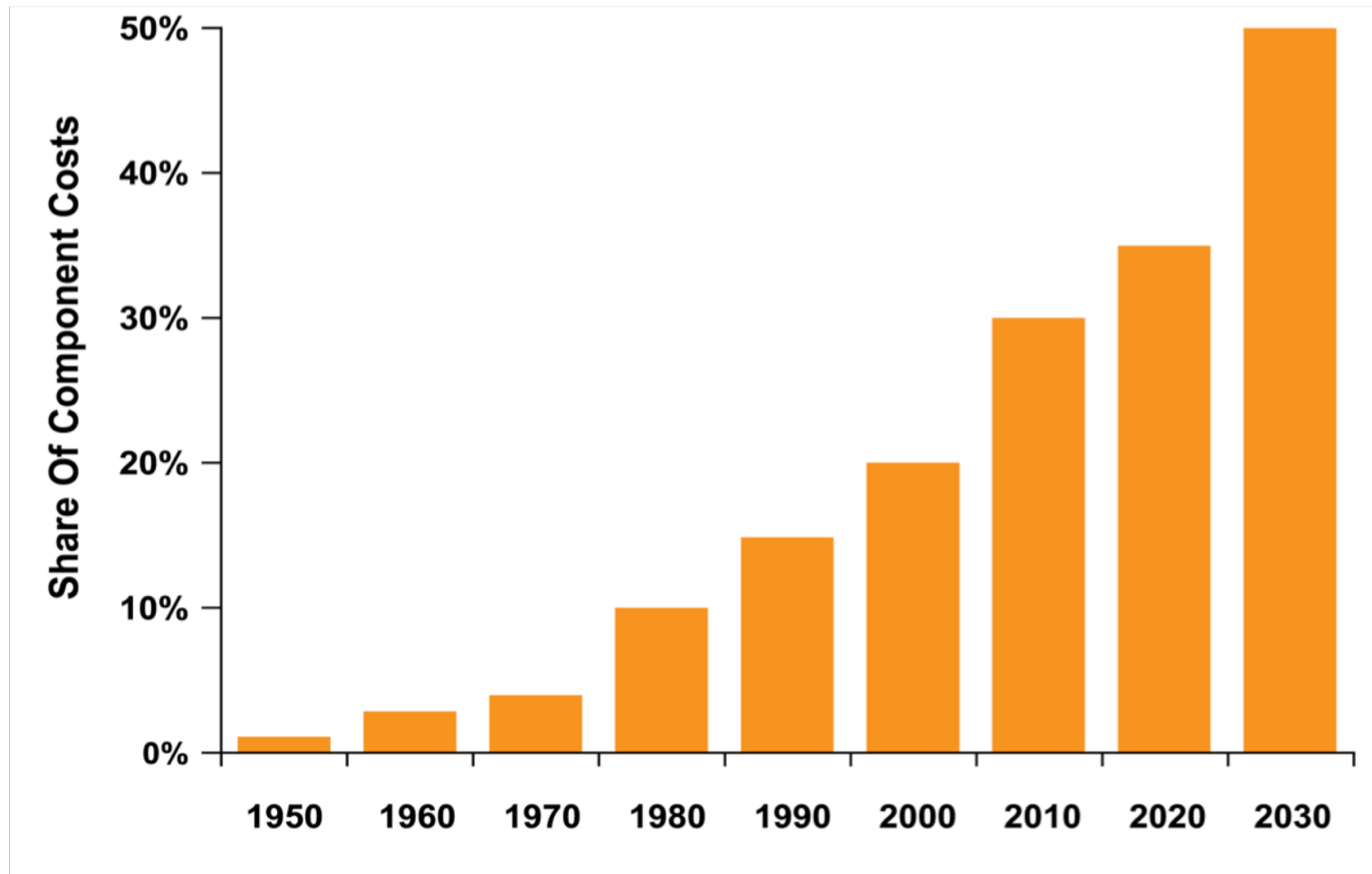


2019

Robots so far ~ 20 million miles & 1 death
Humans ~1 fatality per 100 million road-miles

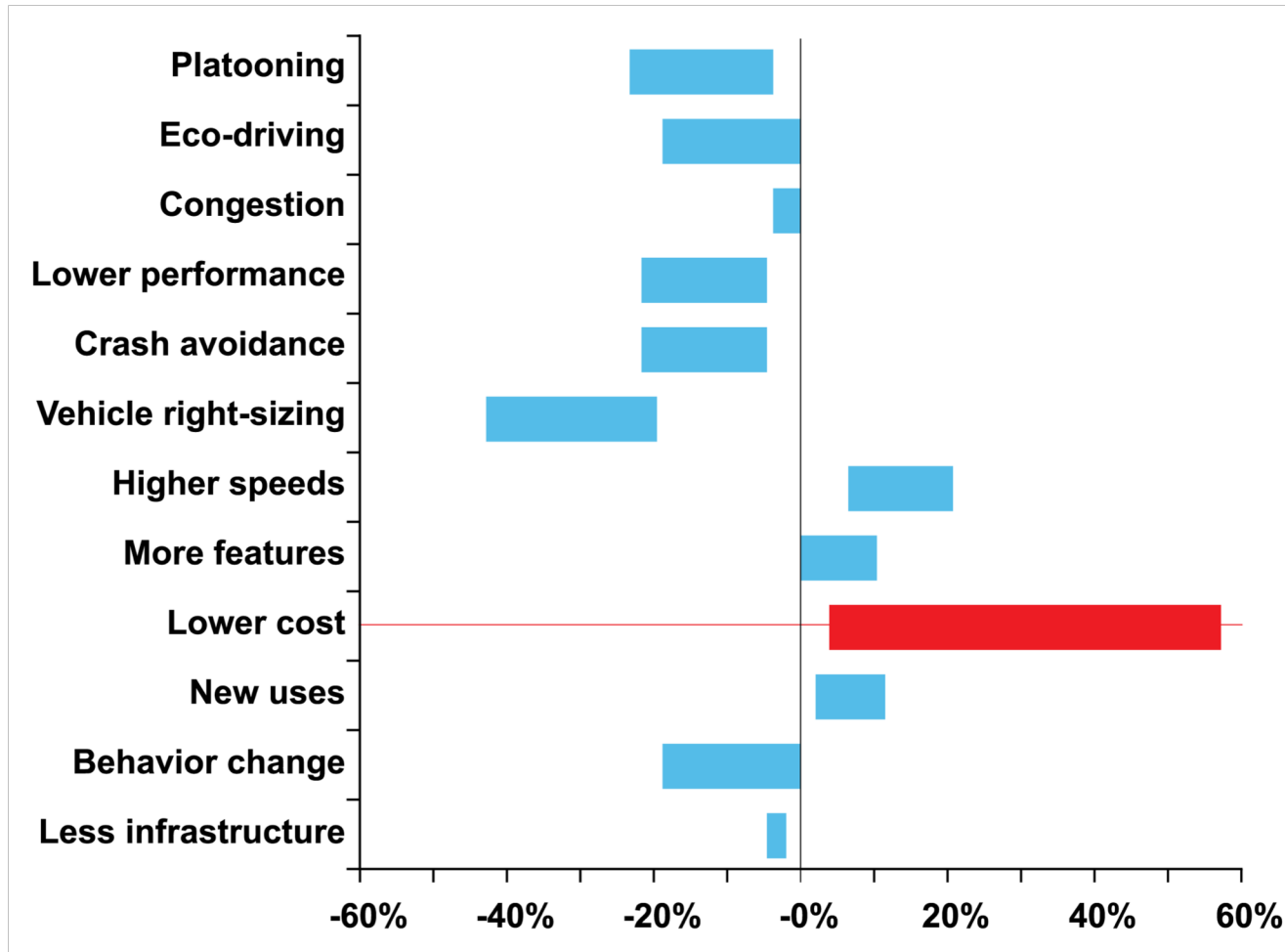
Robocar Effect: Silicon Cars

1.5x increase in energy to fabricate car...*AND*
~10% decrease in *fuel efficiency*



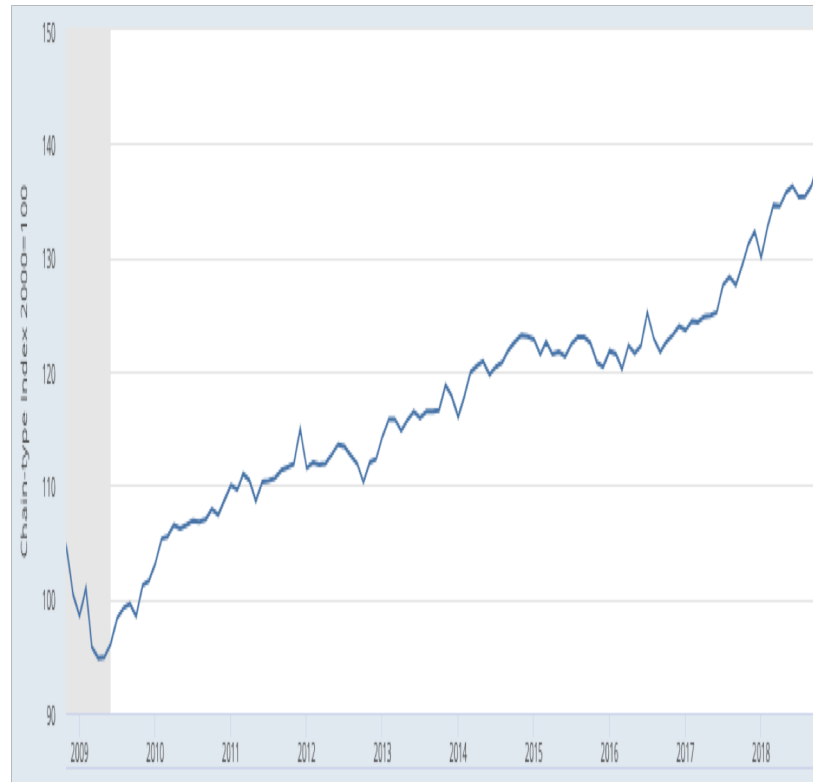
Robo Effect – More Energy Demand

Sensor package today 10x cost of car...but cheaper one day



Digital Effect → E-Commerce & Freight Energy

Since 2009: **1.4x increase** freight transportation index



Wild Card: Air Taxi (finally)

Key enablers:

- Autonomy easier → 'hidden' silicon energy demand
- Materials revolution → 'hidden' 10x fabrication energy carbon fiber
- Air vs. wheels → **~10x energy/lb-mile**

Airbus



Lilium



History & Future Of Mobility

