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U.S. DEPARTMENT OF
ENERGY

Office of

TECHNOLOGY TRANSITIONS

Easter morning 1900: 5th Ave, New York City. Spot the automobile.



Source: US National Archives.

**Easter morning 1913: 5th Ave, New York City.
Spot the horse.**



Source: George Grantham Bain Collection.

What is Innovation?

“The process of transforming a new or existing idea or invention into a new or improved object, item, process or system that meets a new or existing need in a new or different, and better way.”

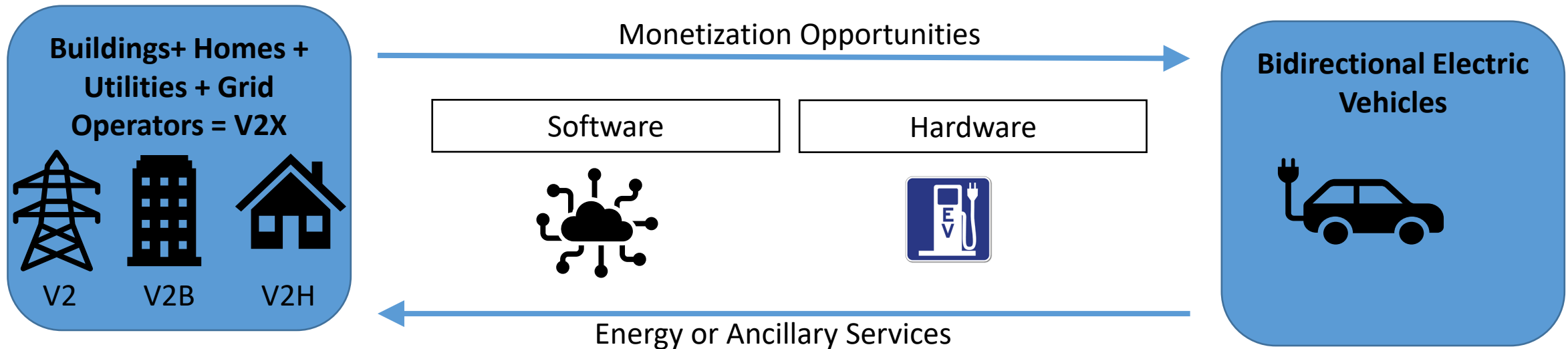


*“If I had asked people what they wanted, they would have said **FASTER HORSES.**”*

Henry Ford

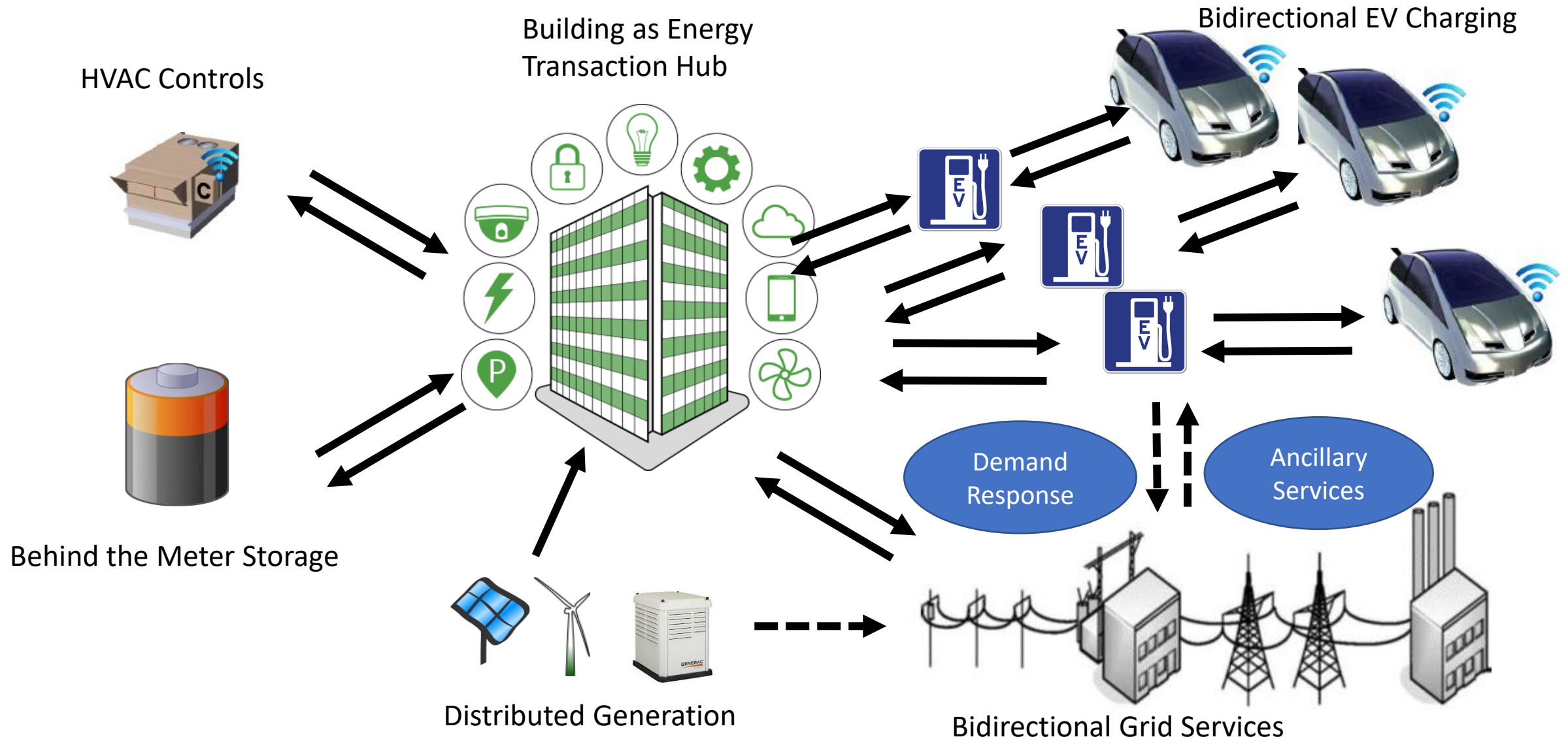
Disruptive Innovation?

Electric Vehicles (EVs) can be both a mobility asset and an energy asset

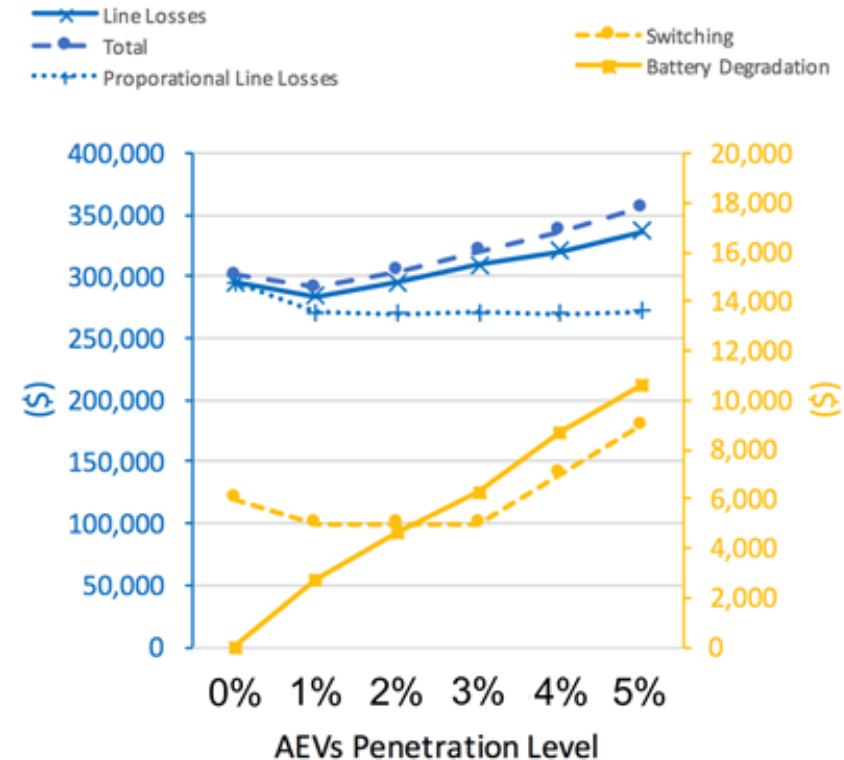
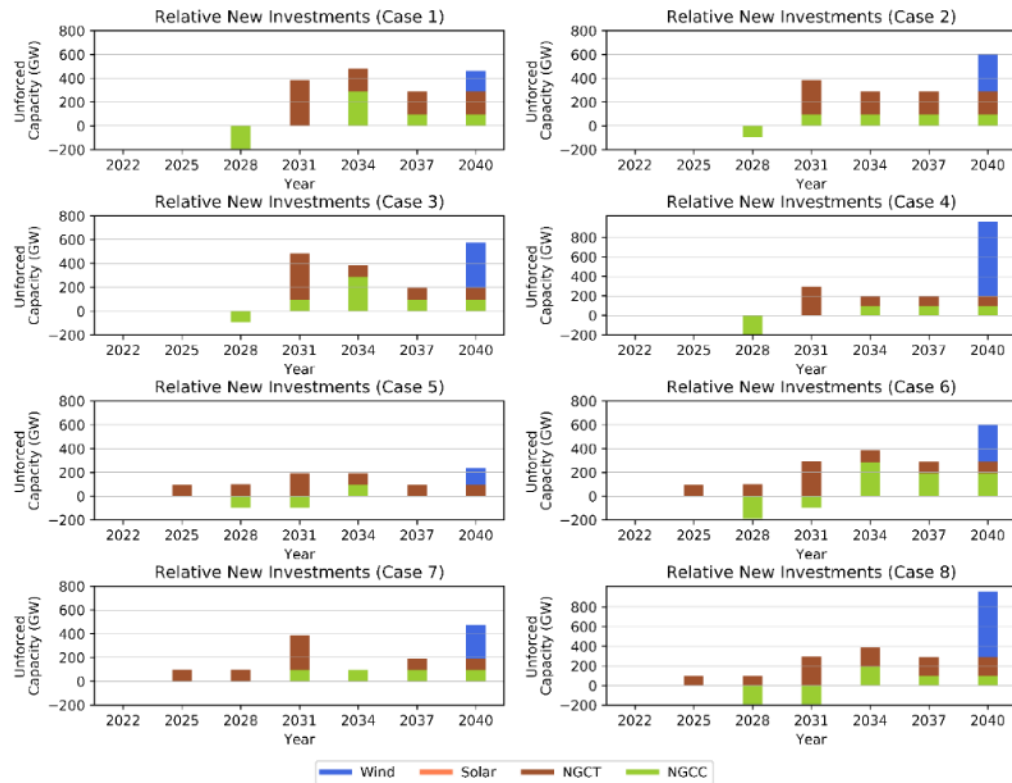


- International Energy Agency (IEA) conservatively estimates 130 million electric vehicles globally by 2030
 - These EVs would contain 10 times the amount of energy storage needed by the grid

Bidirectional Transactions (e.g. V2G, V2B, V2H, V2X)



Impact on Transmission and Distribution Grid



Guo, Zhaomiao, Zhi Zhou, and Yan Zhou. "Impacts of Integrating Topology Reconfiguration and Vehicle-to-Grid Technologies on Distribution System Operation." IEEE Transactions on Sustainable Energy 11, no. 2 (2019): 1023-1032.

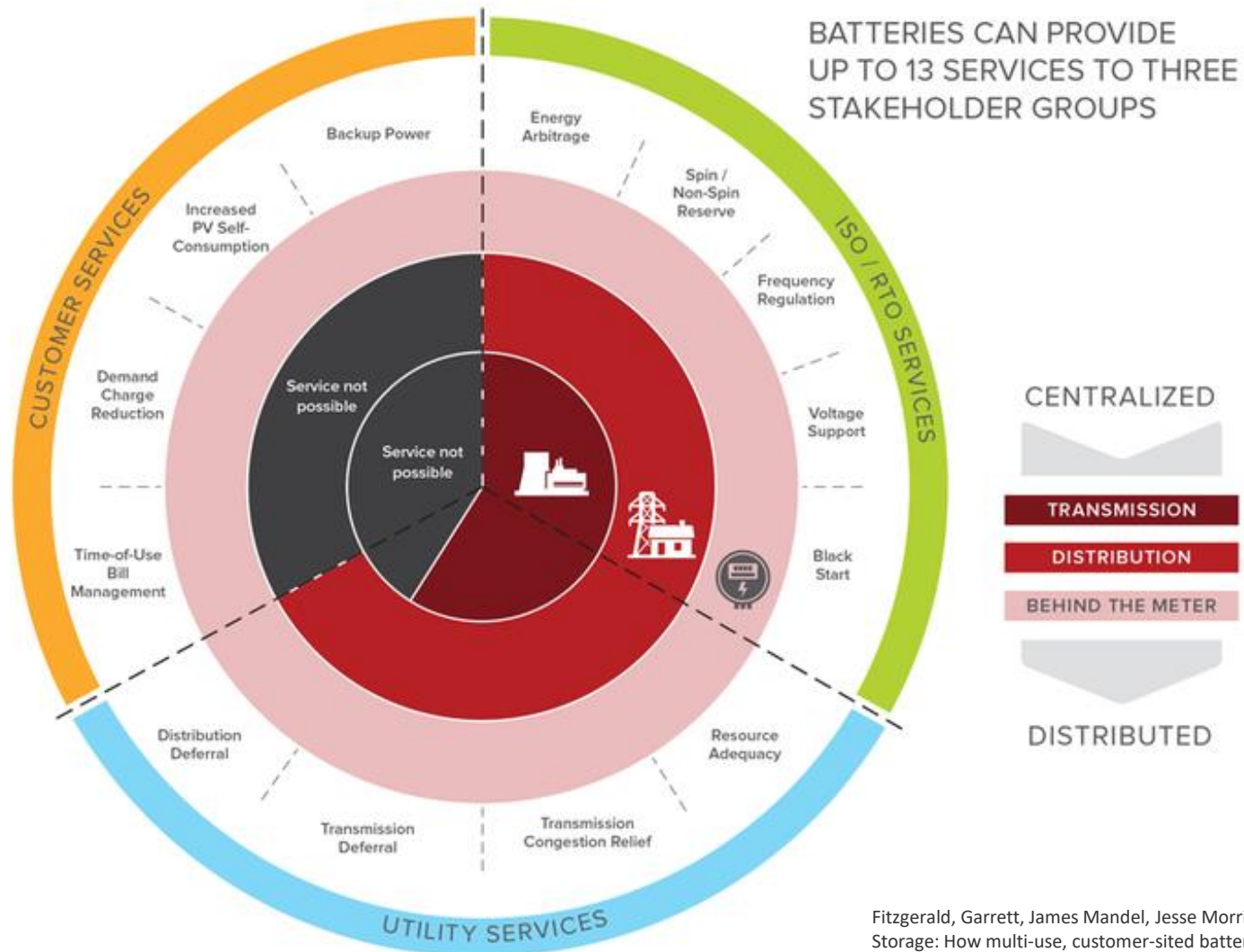
Transmission System:

- Increases in PEV charging demand may lead additional investments in conventional units
- High penetration of PEV requires the system to have additional ramping capability

Distribution System:

- Grid impact (e.g. Line losses and switching frequency) may be nonlinear with EVs penetration level
- A low level of EVs is the most beneficial, which indicate an upgrade need to improve grid efficiency

V2X Services and Benefits

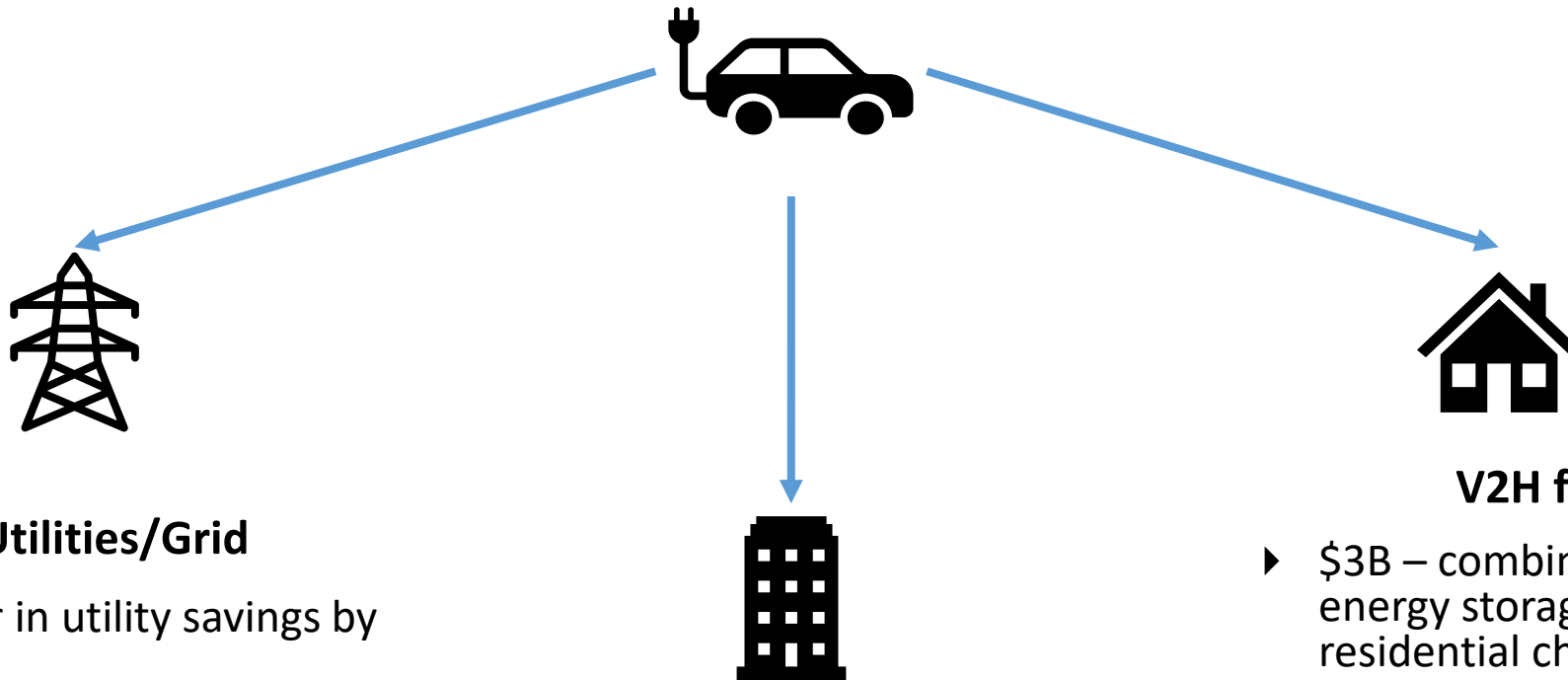


V2X Benefits

- ▶ Reduces the cost of electrification of transport
- ▶ More sophisticated integration for fleets
- ▶ Defers investment in traditional grid infrastructure
- ▶ Provides resilience
- ▶ Contributes to reducing CO2 and pollution from vehicles and power plants
- ▶ Supports additional renewable energy integration
- ▶ Catalyst to modernize the grid

Fitzgerald, Garrett, James Mandel, Jesse Morris, and Hervé Touati. The Economics of Battery Energy Storage: How multi-use, customer-sited batteries deliver the most services and value to customers and the grid. Rocky Mountain Institute, September 2015. <<http://www.rmi.org/electricity_battery_value>>

Savings & Market Opportunity for Bidirectional EV Chargers



V2G for Utilities/Grid

- ▶ \$15B per year in utility savings by 2030¹
- ▶ \$1K - \$5K annual revenue per EV

V2B for Buildings

- ▶ \$3B per year in electric bill savings for 5M US commercial buildings²
- ▶ \$2K - \$65K annual revenue per EV

V2H for Homes

- ▶ \$3B – combined market for home energy storage backup power and residential chargers by 2025²
- ▶ TBD annual revenue per EV

Market Size by 2025³

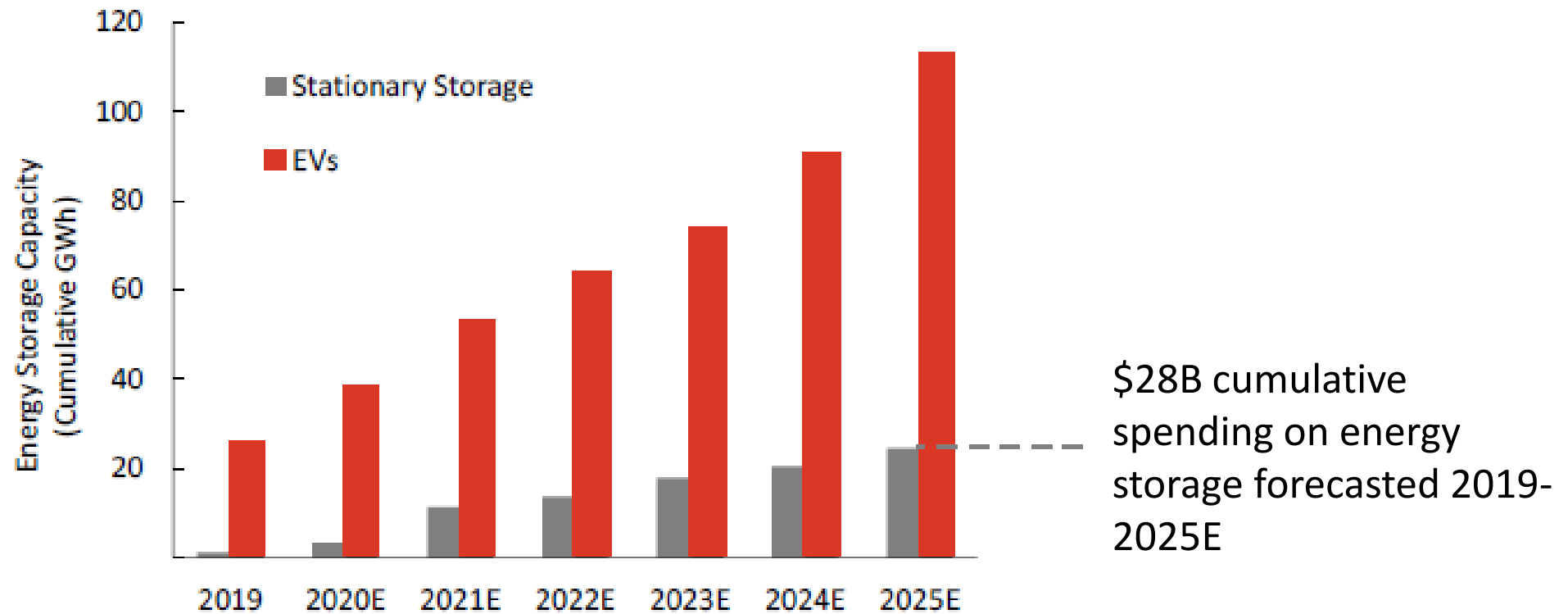
- ▶ \$3.5B residential chargers
- ▶ \$5B workplace chargers
- ▶ \$14B public chargers

Source 1 : Brattle Group

Source 2: NREL, Industry Interviews

Source 3: Wood Mackenzie Energy Transitions Practice, Inside EVs

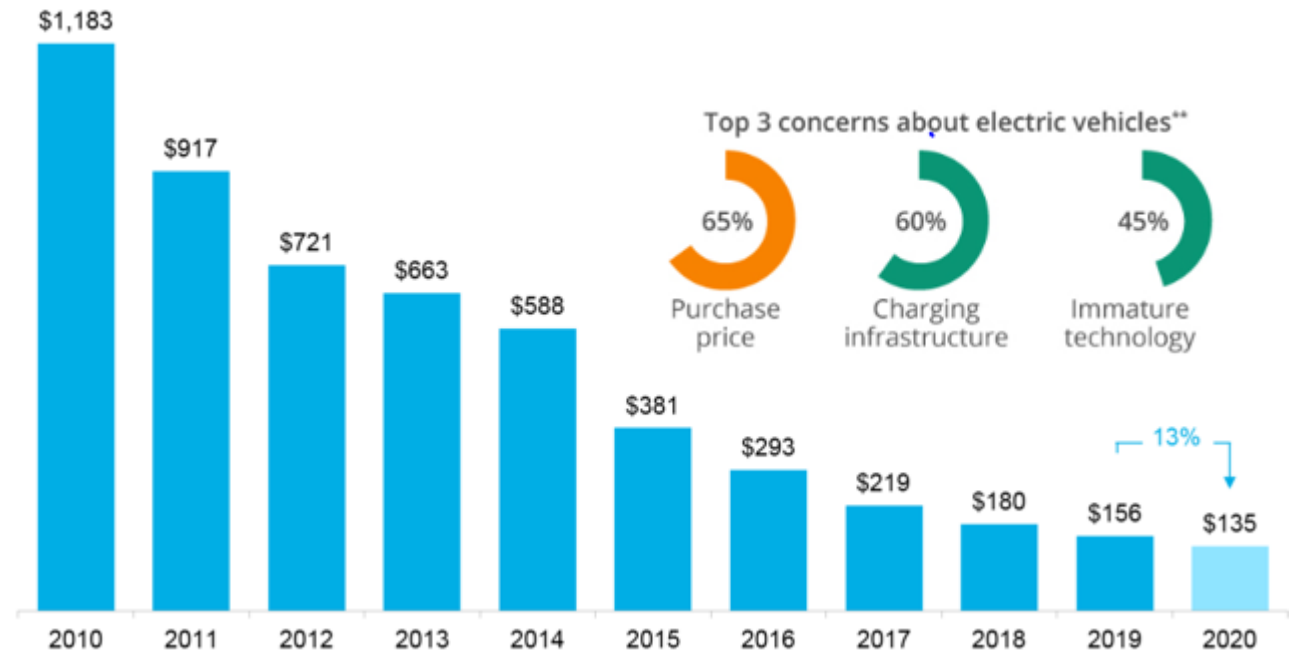
EVs vs Energy Storage Markets



Is there an energy and transportation tipping point coming sooner than we think?

- ▶ Battery prices have gone down almost 91% since 2010
- ▶ In some places roof top solar is cheaper than distribution and transmission
- ▶ 200 mile EV has enough power for a typical single family home for 2 days

Annual lithium-ion battery demand by application

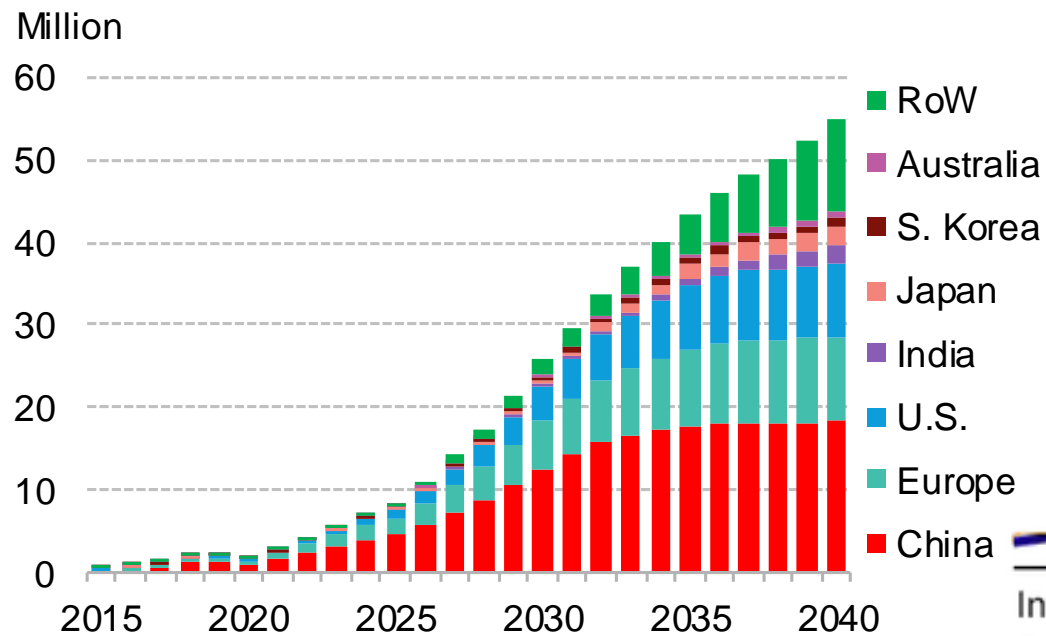


*Source: BNEF

** CarGurus, BNEF, based on November 2018 survey of 1279 vehicle owners in the U.S.

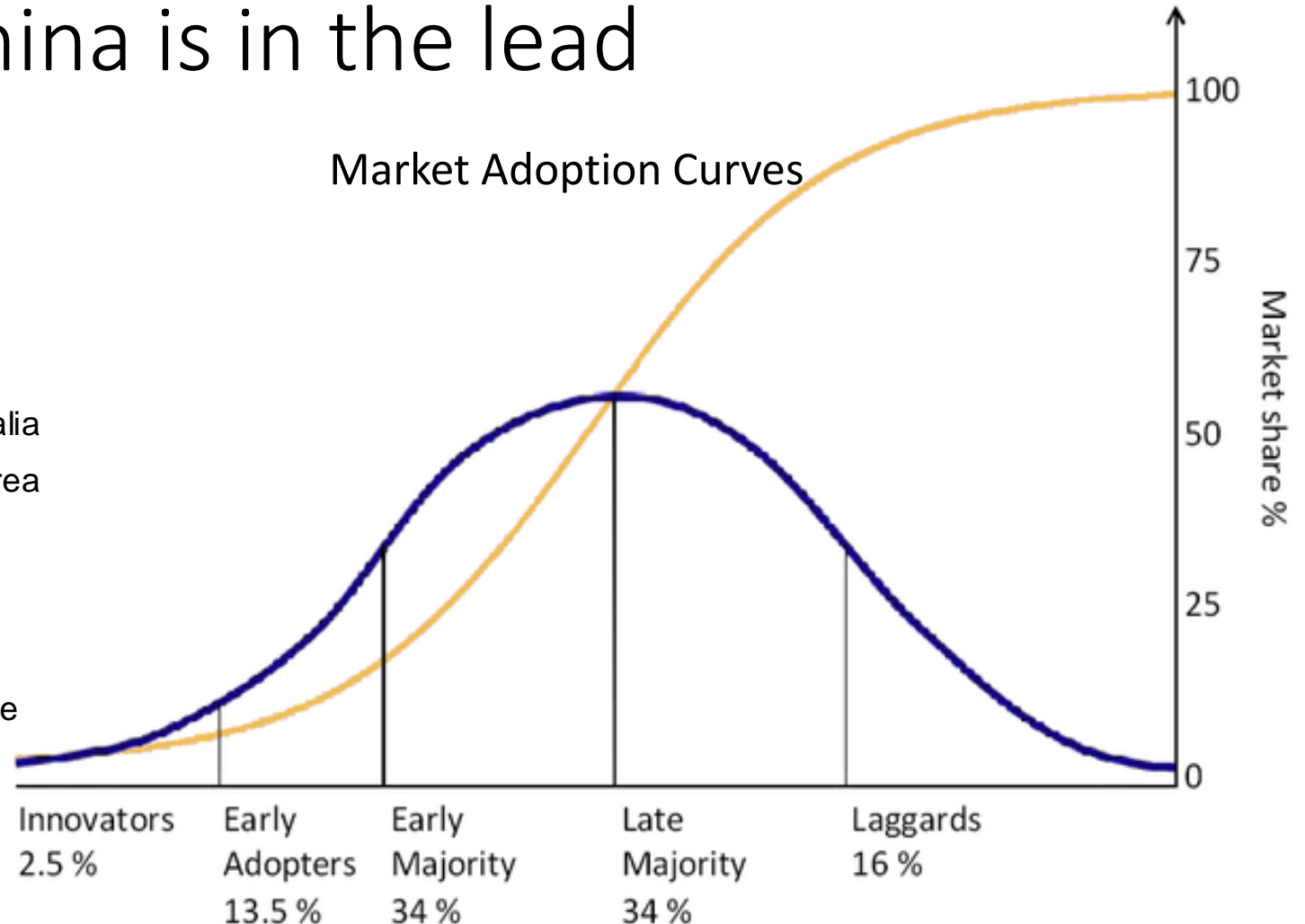
But who will dominate may depend on the race to market adoption and China is in the lead

Annual passenger EV sales by region



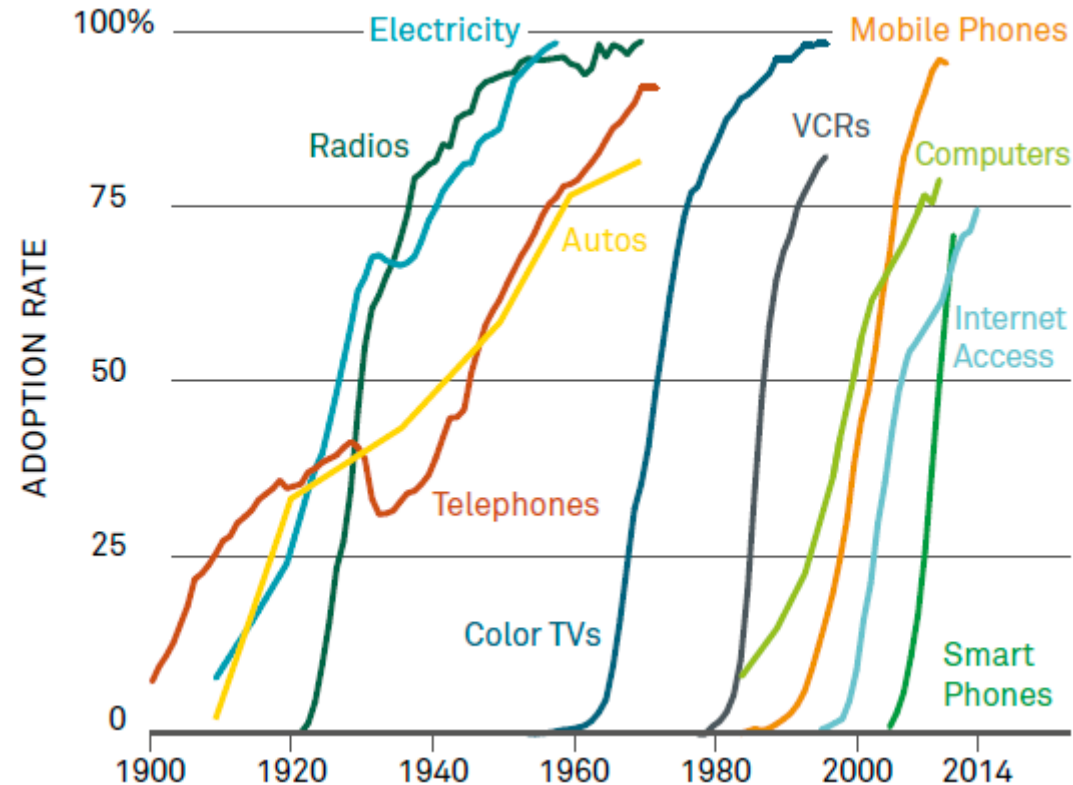
Source: BNEF

Market Adoption Curves




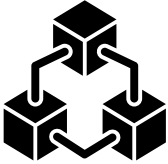

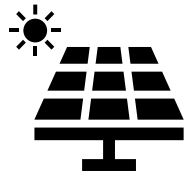
Source: OnDigitalMarketing

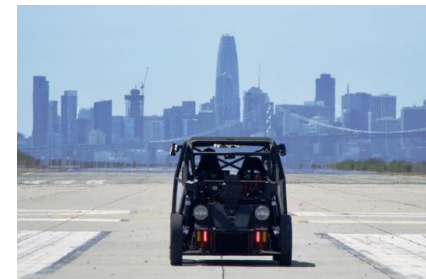
U.S. technology adoption rates are accelerating



Source: BlackRock Investment Institute, Federal Communications Commission, U.S. Census Bureau, World Bank and Statista, July 2014. Note: Adoption rates are based on household ownership except for cell phone and smart phones, which are based on ownership per capita.

Convergence of these technologies/innovations may be a game changer

- ▶ Bi-directional vehicles
- ▶ Bi-directional electric vehicle charging infrastructure
- ▶ Artificial Intelligence (for dynamic decision making) 
- ▶ Transactive Services (e.g. Blockchain) 
- ▶ Digitization (of the grid) 
- ▶ Autonomous Vehicles
- ▶ Business Model Innovation (e.g. transportation as a service)
- ▶ More Renewables/Distributed Energy Resources (DER) 



Metaphorically ...



Ford Model T?



Most cars today?

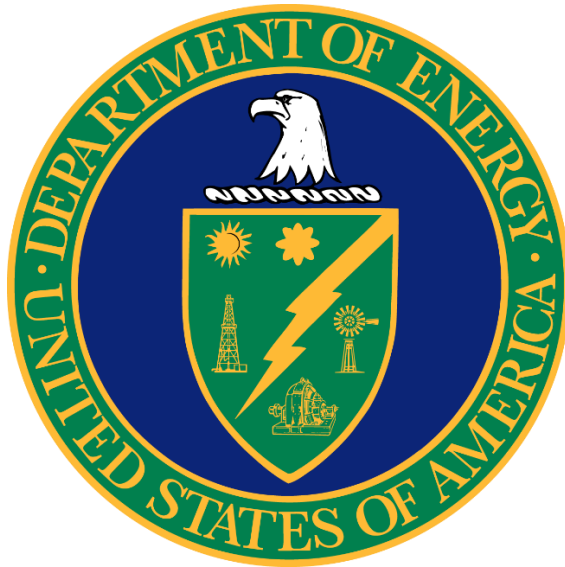


Most EVs/hybrids today?



Bidirectional EVs?

Thank you



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