



Energy+Environmental Economics

Transportation Electrification: *Recent Developments and Implications for the Grid*

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About Energy and Environmental Economics, Inc. (E3)

- + **Founded in 1989, E3 is an industry leading consultancy in North America with a growing international presence**
- + **E3's 50+ consultants operate at the nexus of energy and environmental economics, regulation and public policy**
- + **Our team employs a unique combination of economic analysis, modeling acumen, and deep institutional insight to solve complex problems and provide thought leadership for a diverse client base**





Outline of presentation

- + Update on state of EV technology and key trends**
- + Characteristics of EV charging loads and implications for the grid**
- + Results from selected studies on distribution grid upgrade costs**
- + What's next?**



Automakers are committing to EVs on a global basis

EVERY VOLVO INTRODUCED FROM 2019 WILL HAVE AN ELECTRIC MOTOR

Hybrids, EVs to fill the lineup

VW announces massive \$84 billion investment in electric cars and batteries

General Motors unveils plan to release 20 electric vehicles by 2023

Chinese electric car company Nio seeks to raise \$1.8 billion in IPO

Nissan, Mitsubishi, Renault to launch 12 new electric cars by 2022

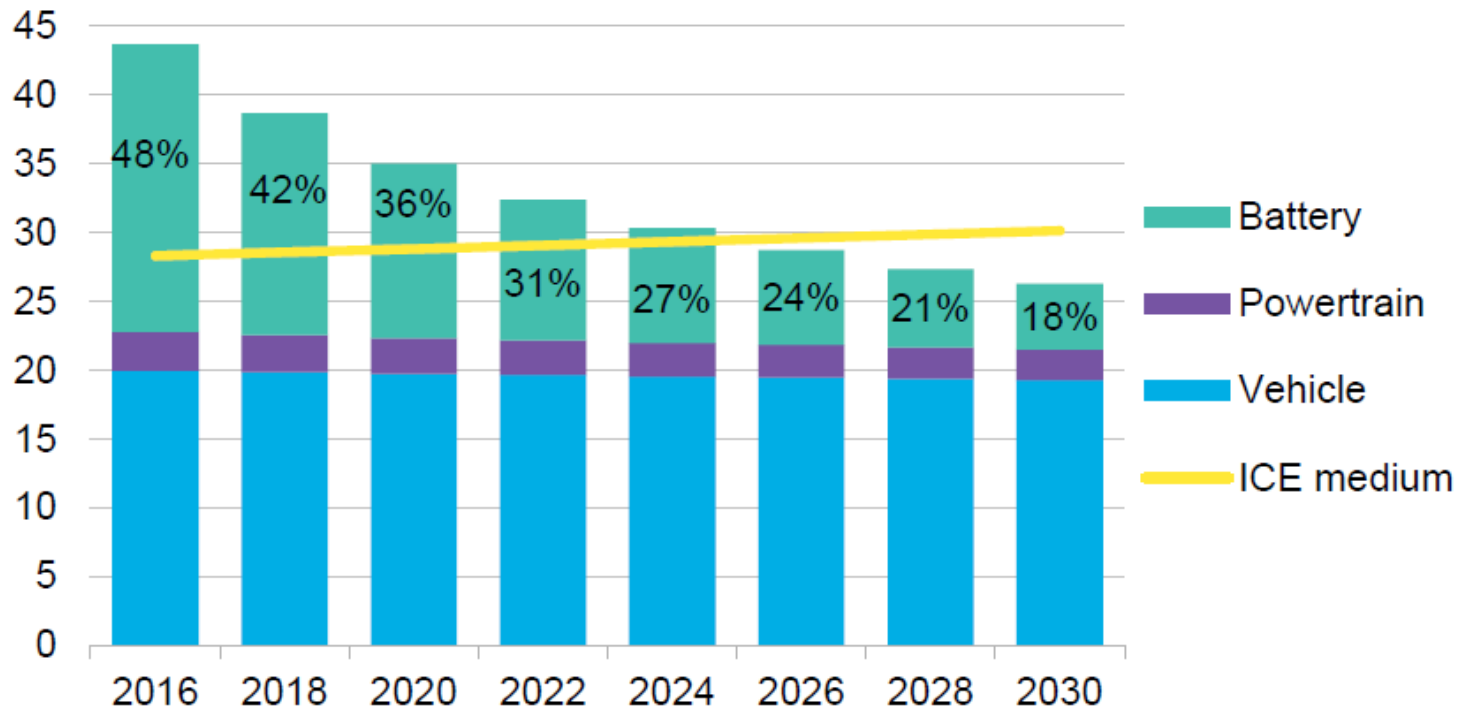
All new Jaguar Land Rover cars to have electric option from 2020



The purchase price premium for EVs is declining with battery costs

U.S. medium BEV pre-tax price breakdown, ICE pre-tax price and share of battery costs

2016 \$ (thousand) and %

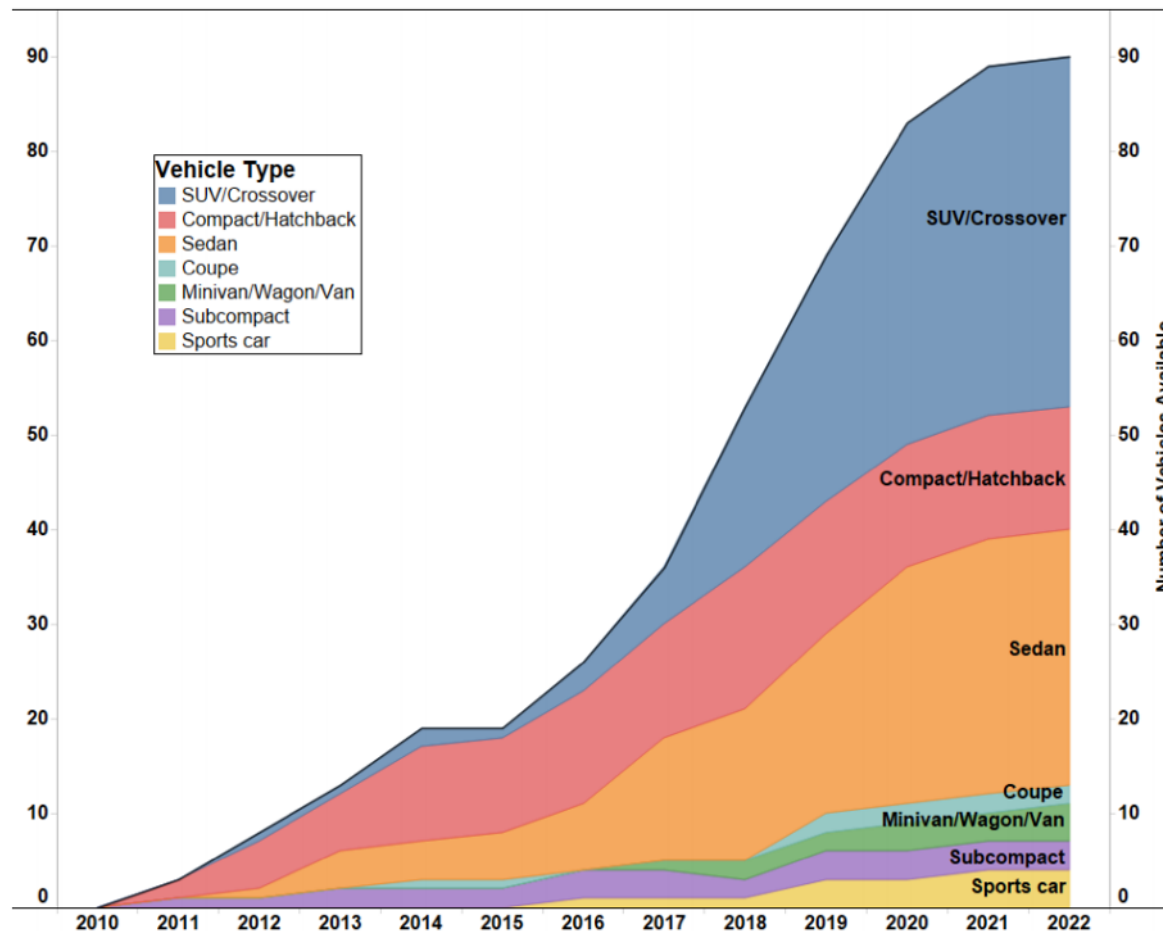


Source: <https://about.bnef.com/electric-vehicle-outlook/>



Vehicle buyers will soon have many ZEV options

EV Vehicle Models Available (2010-22)





Medium and Heavy Duty segments are transforming also



Here Today



Coming Tomorrow

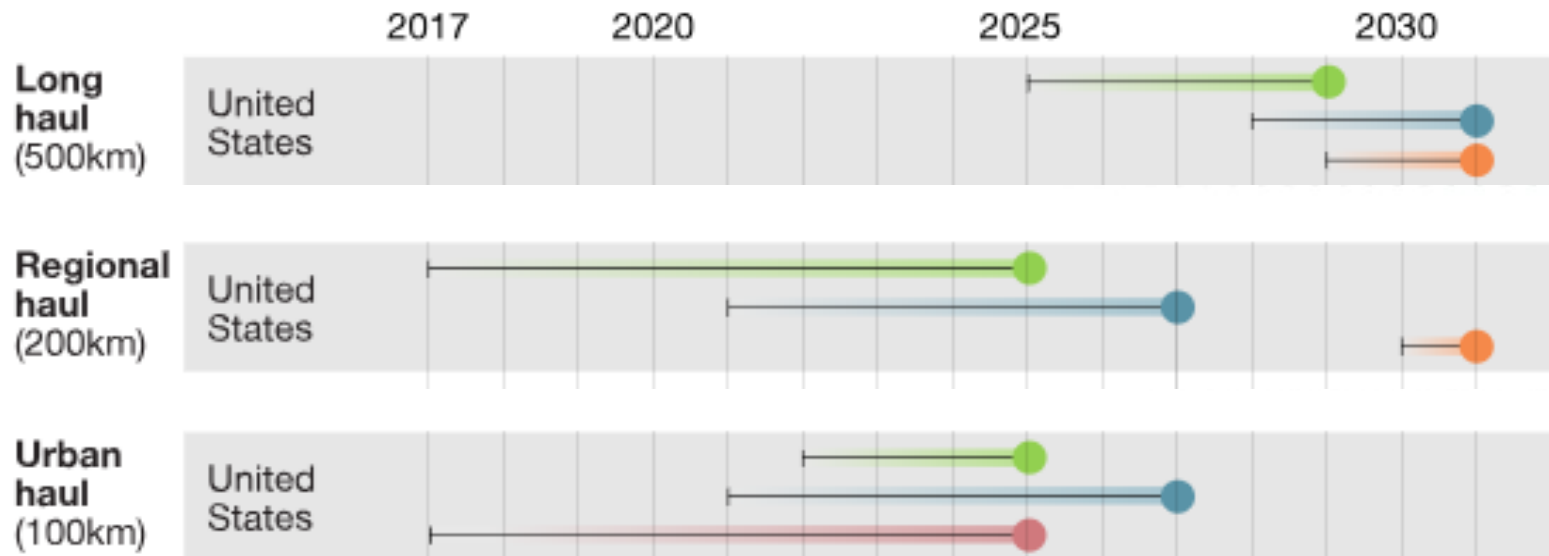




Timing of battery electric vehicle cost parity with diesel counterparts



Timing of battery electric vehicle total cost of ownership parity with diesel vehicle, year achieved range





Technologies and policies are developing to support vehicle-grid integration (VGI)



'Smart' charging (or 'V1G') through targeted utility tariffs or communication from grid operator to aggregator / vehicle



V2H/V2B/V2X capability can enhance PEV value proposition



V2G capability allows PEV to discharge to grid, receive payment for services

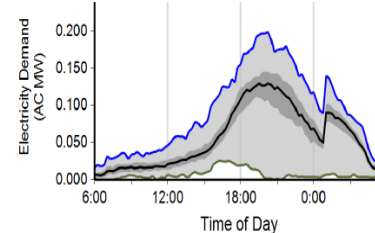


Grid integration measures: Smart Charging (V1G)

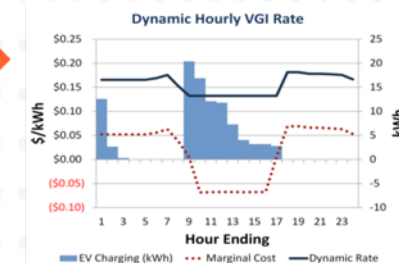
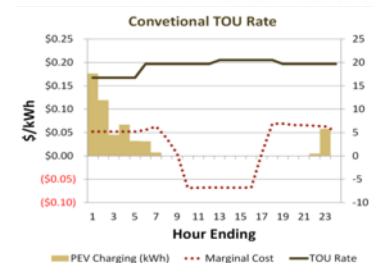
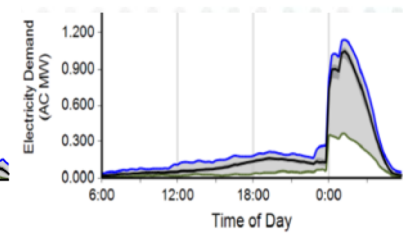
+ Rate design:

- **Time of use** (TOU) rates vary on a fixed schedule and are higher during periods of peak demand on the bulk power system.
- **Dynamic rates** vary from hour to hour with conditions on the bulk system or local grid (SDG&E's Charge Ready Pilot)

Washington DC
(No Time Varying Rates)

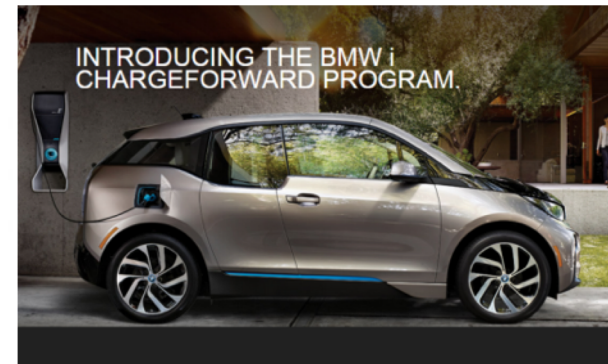


San Diego
(TOU Rates)



+ Demand response:

- The utility or a third party directly controls when and even where a vehicle charges: PG&E/BMW pilot
- Customer is paid for performance and can over-ride if desired.
- Aggregator may employ stationary battery backup to assure performance.

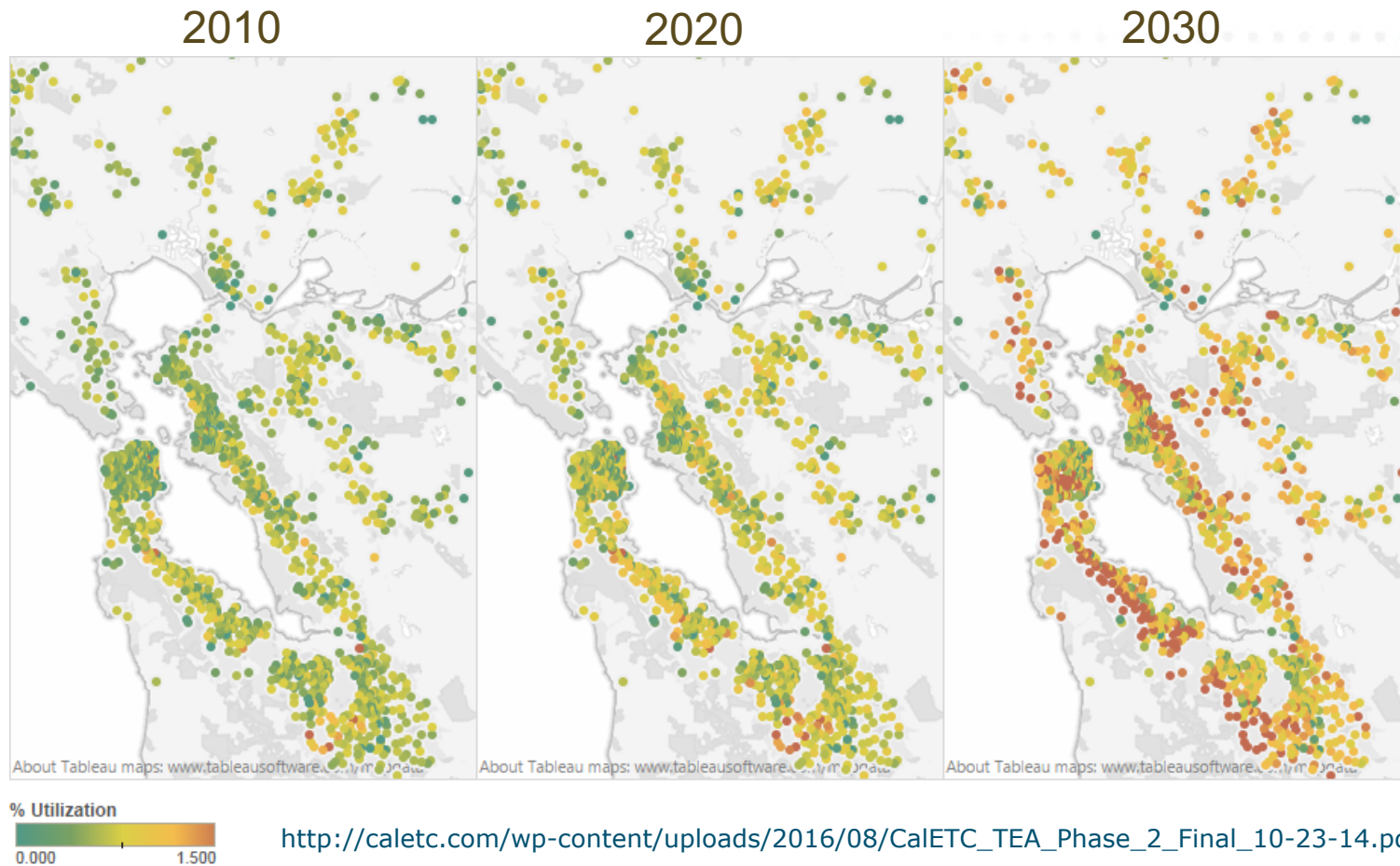


GET UP TO \$1,540* FOR CHARGING YOUR BMW i3.



Distribution grid impacts of EV Adoption in the SF Bay Area

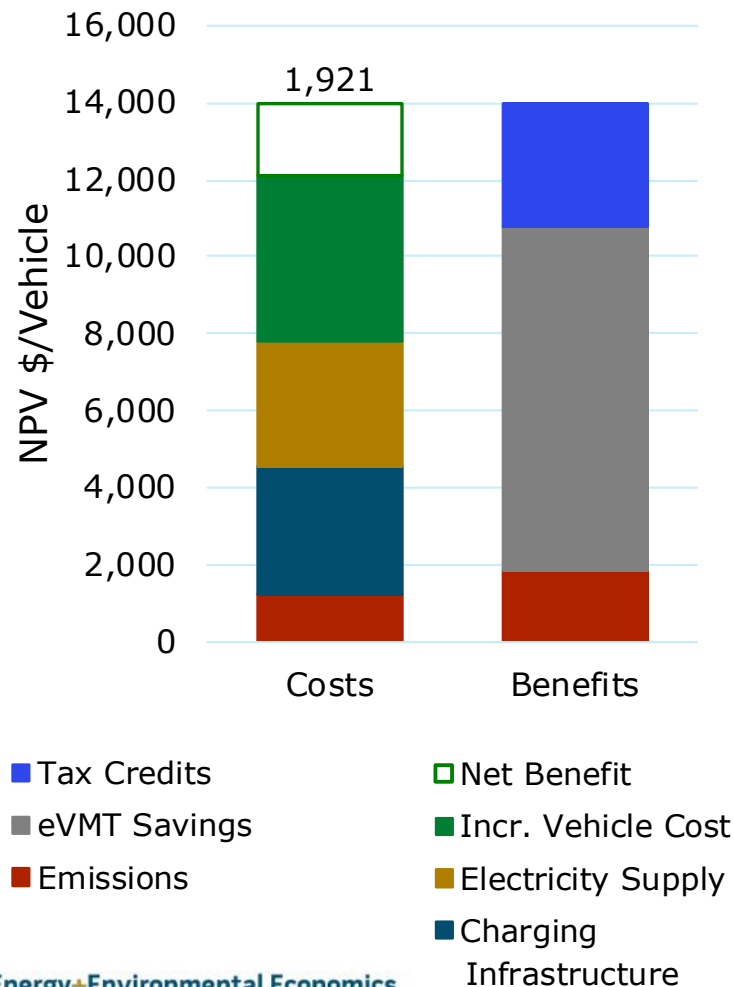
Feeder and substation utilization
with “ZEV most likely” vehicle adoption and TOU rates



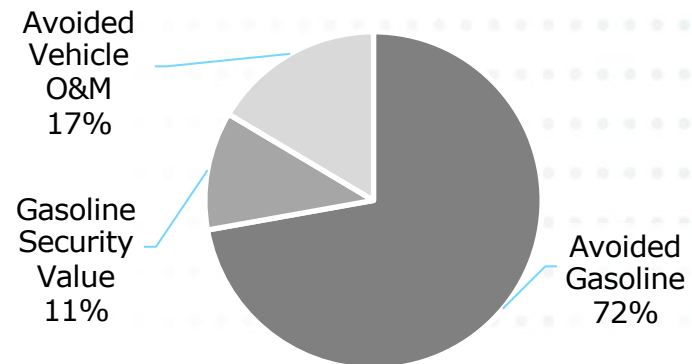


NYSERDA Cost Benefit Analysis of LDV Electrification in New York

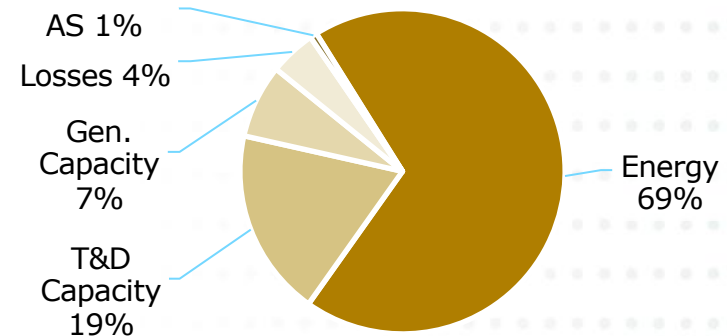
Societal Benefits on Long Island, Base Case



eVMT Savings

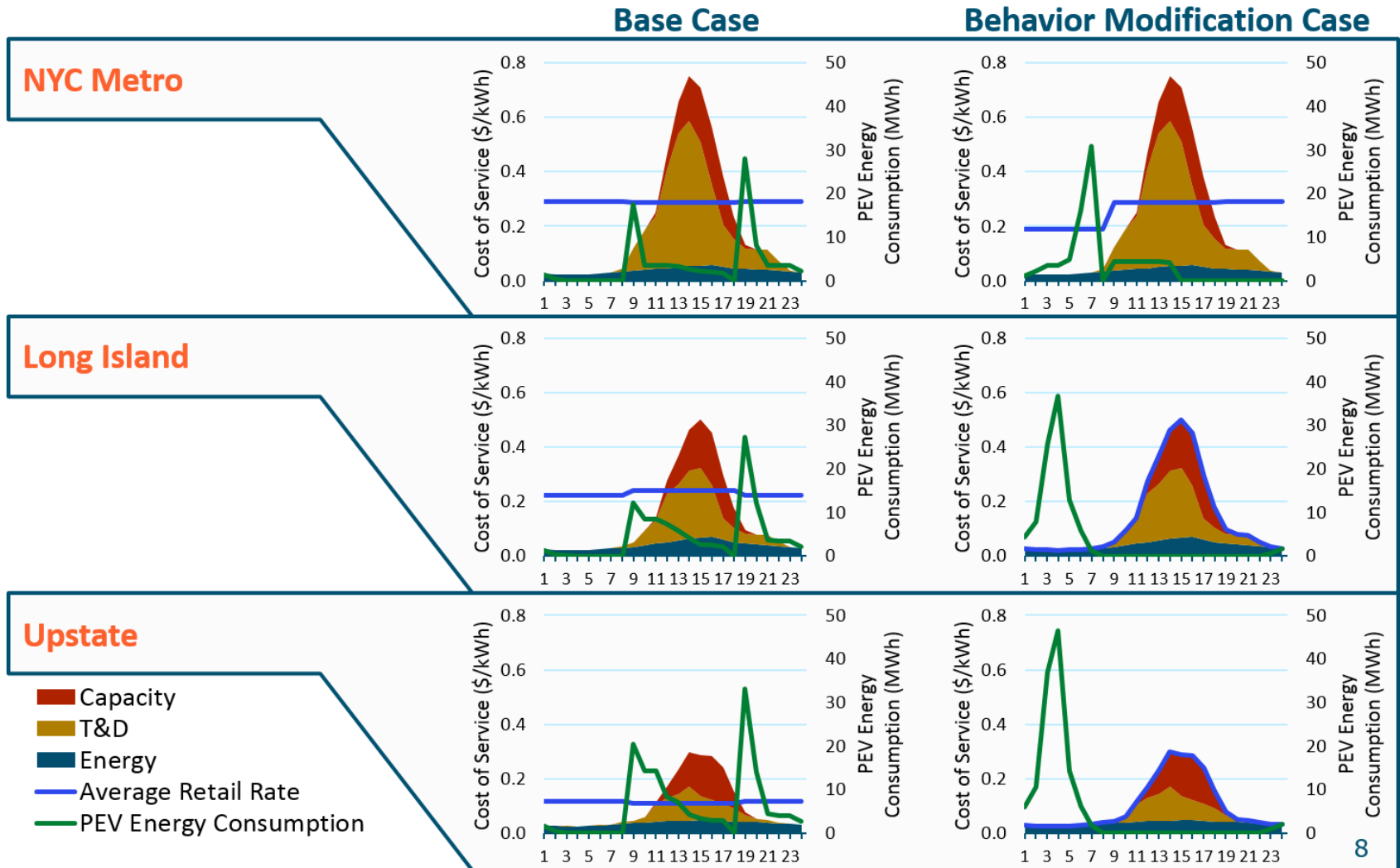


Electricity Supply Costs



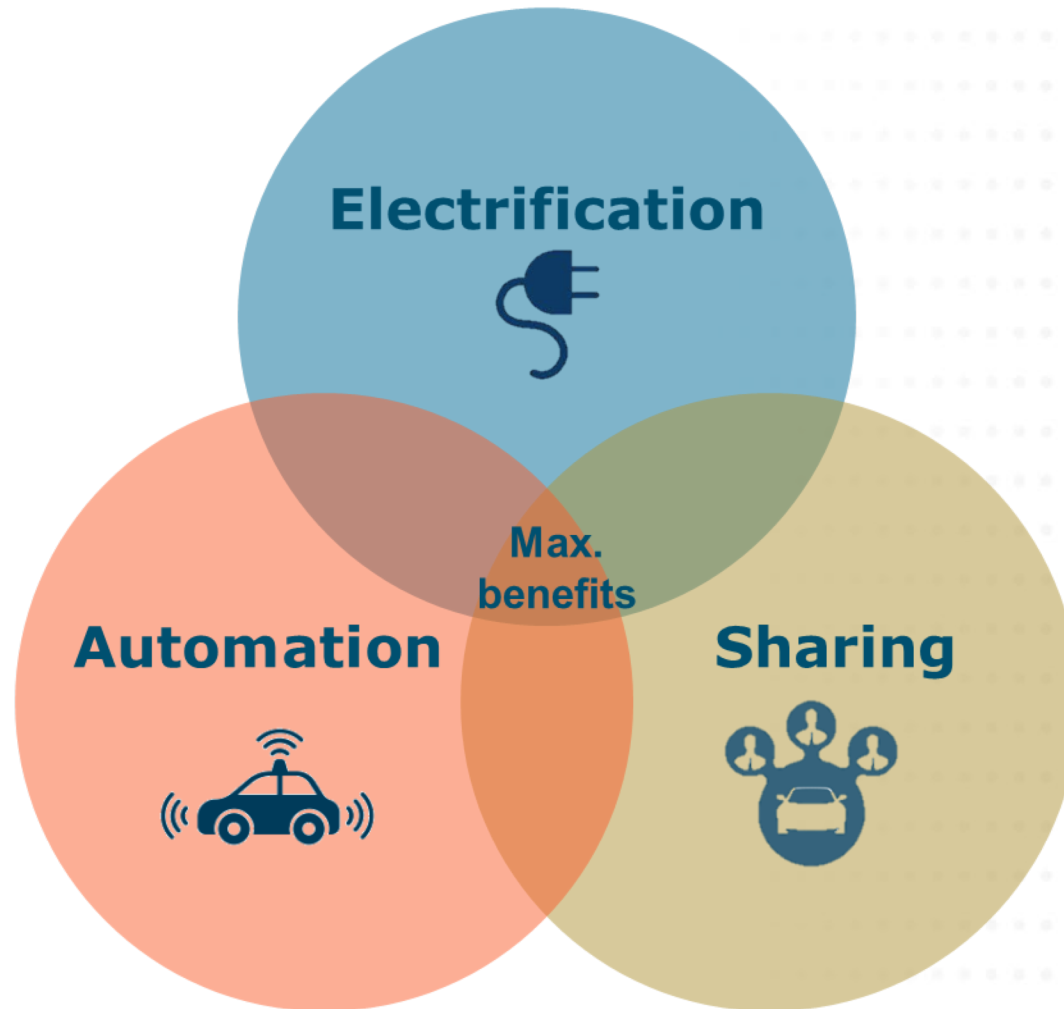


Avoided T&D costs drive savings from smart charging in New York study





Three transportation revolutions present new challenges





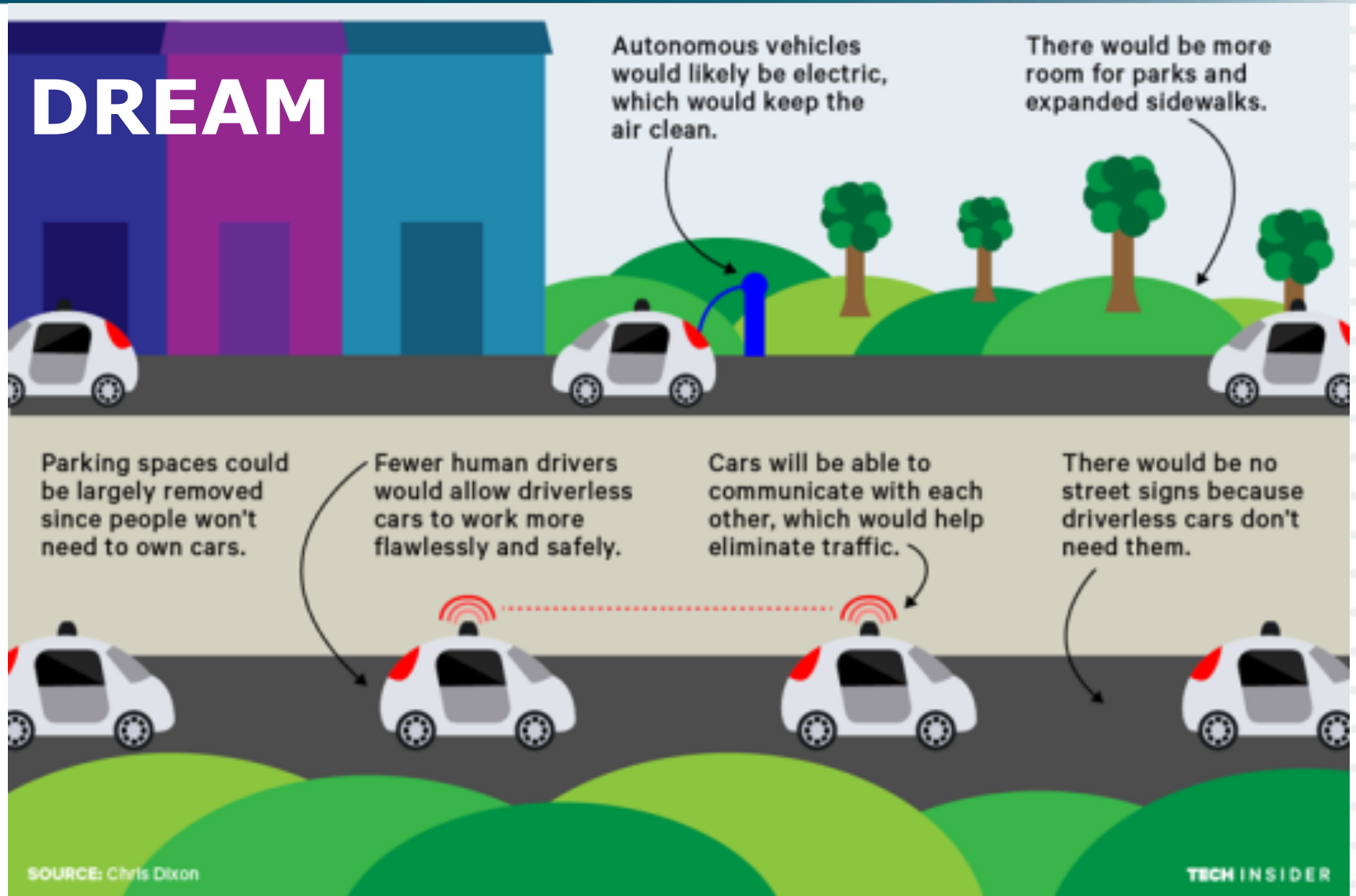
Coming soon: Ultrafast DCFC Charging Plazas

A load as big as a Walmart in the footprint of a 7-11





Three Revolutions: Dream Scenario





Three Revolutions: Nightmare Scenario

NIGHTMARE





THANK YOU

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Specs: Electric Delivery Vans (Class 5)

+ Charging: conductive, plug-in

- Level 2 (J1772) *and* DC fast charging capable
 - Level 2: overnight charge
 - DC fast charging: 80% charge in ~1 hour
- Battery packs: 60-100 kWh



+ Manufacturers: Workhorse, Chanje





Specs: Parcel Trucks (Class 6)

+ Charging: conductive, plug-in

- Level 2 (J1772) *and* DC fast charging capable
- Battery packs: 70-120 kWh



+ Manufacturers: Workhorse, Boulder Electric, Thor





Electric Bus Specs

+ Charging options:

- Conductive (plug-in): Level 2, DC fast charging, and pantographs
- Inductive (wireless): limited commercial availability; most expensive option and remains largely in pilot phase
- Battery packs: ~60 – 600 kWh (current best in class is 400 – 600 kWh depending on manufacturer)



+ Many manufacturers:

- **Transit:** BYD, Proterra, Solaris, VDL, Optare, Volvo, Van Hool, and many high-volume manufacturers supplying the Chinese market
 - Transit bus manufacturing volume is dominated by Chinese firms, but competition from US and European manufacturers is growing.
- **School:** Lion, Blue Bird, Green Power, Starcraft, Trans Tech



E-bus Charging Technologies

Traditional plug-in charging



- + **Slow charger: 15-22 kW, full charge in ~10h**
 - 2:1 bus-to-charger ratio
- + **Fast (22-50 kW) and Rapid (50-120 kW) chargers: full charge in 2-6h**
 - 20:1 bus-to-charger ratio
- + **Most common for overnight or layover charging**

Pantograph charging



- + **Direct electrical connection, without plug**
 - 20:1 bus-to-charger ratio
- + **150-300 kW power output**
- + **Offered by many e-bus providers (e.g., Proterra, Solaris, VDL, Volvo, Van Hool)**

Inductive charging (wireless)



- + **Coils under road surface transfer energy to coils beneath bus floor**
- + **Power output up to 200 kW**
- + **Stationary systems (bus positioned over coils) commercially available today**
 - 20:1 bus-to-charger ratio
- + **Dynamic systems (bus charged while in motion) remain in pilot / demo stage**



Challenges and Opportunities

+ Challenges

- Including charges, electric buses have upfront premium of ~\$300,000 over diesel buses (which typically cost \$450,000 – 750,000)
- Existing commercial and industrial rates may not currently be suitable for early state deployment of electric buses, which can significantly impact customer bills
- Bus loads can be 100 kW – 500 kW, depending on charger type

+ Opportunities

- School buses provide a unique opportunity to create a day-time load
- Large batteries of ~200kWh are also potential sources of ancillary services