The Integrated Energy Network – The Transition Towards Greater Electrification

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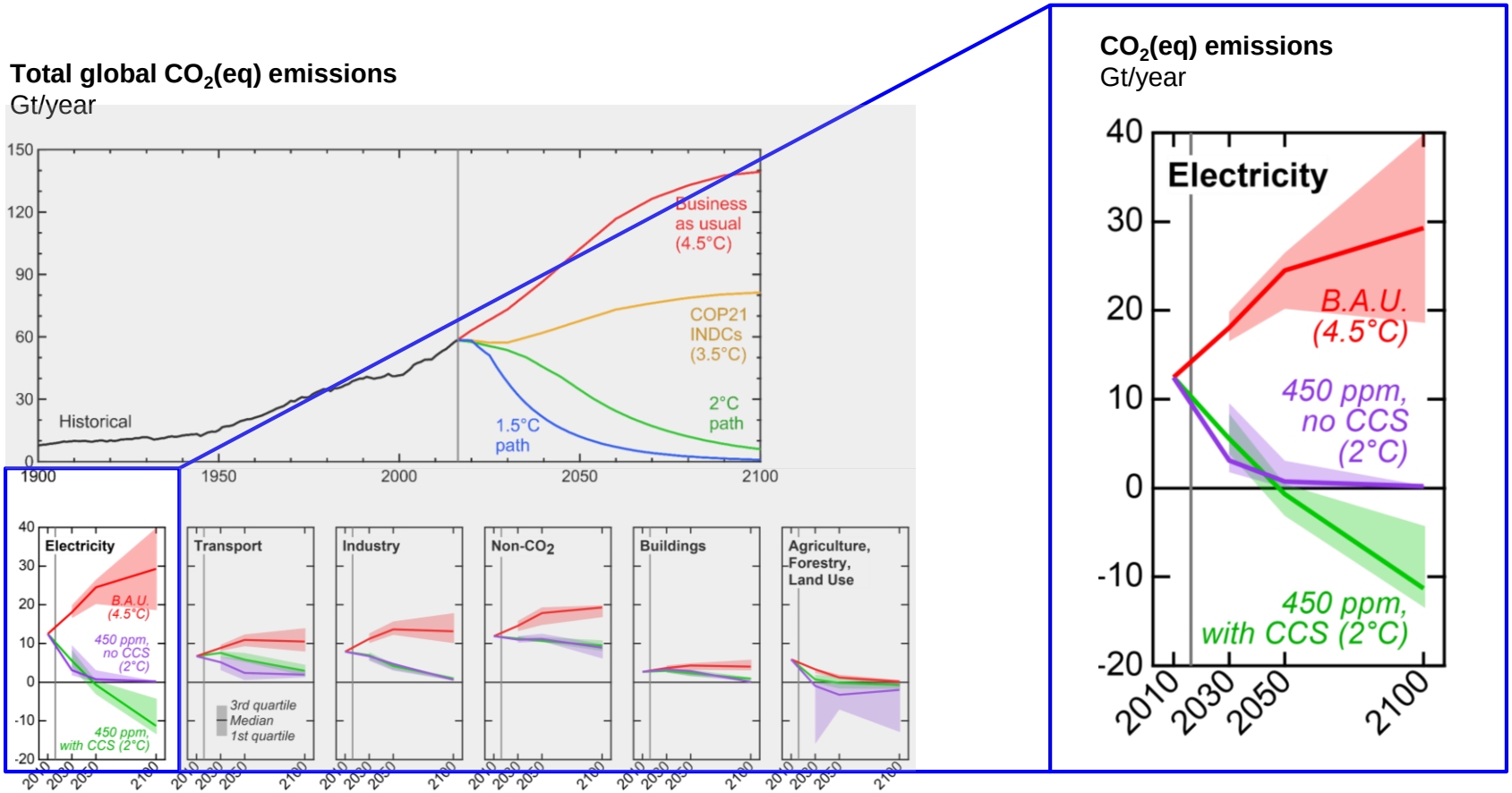
Today's energy system is facing many challenges, and addressing climate change is one of the most significant



Source: Climate Interactive, Patrick Brown, IPCC

Coupled with Decarbonization, two other salient forces are beginning to reshape electricity service delivery: Decentralization, and Digitization

Decentralization

Decarbonization

The Power System Value Chain

Large-scale generation

- Rapid growth in the deployment of renewables
- Changing operating needs as the generation mix evolves
- New dynamics in wholesale market conditions
- The need to optimize asset utilization in order to remain competitive

The grid

- Manage the integration of renewables and optimized asset utilization
- Optimize performance and reduction of losses
- Improved service reliability and added resiliency
- Optimized integration of DER assets

The prosumer paradigm

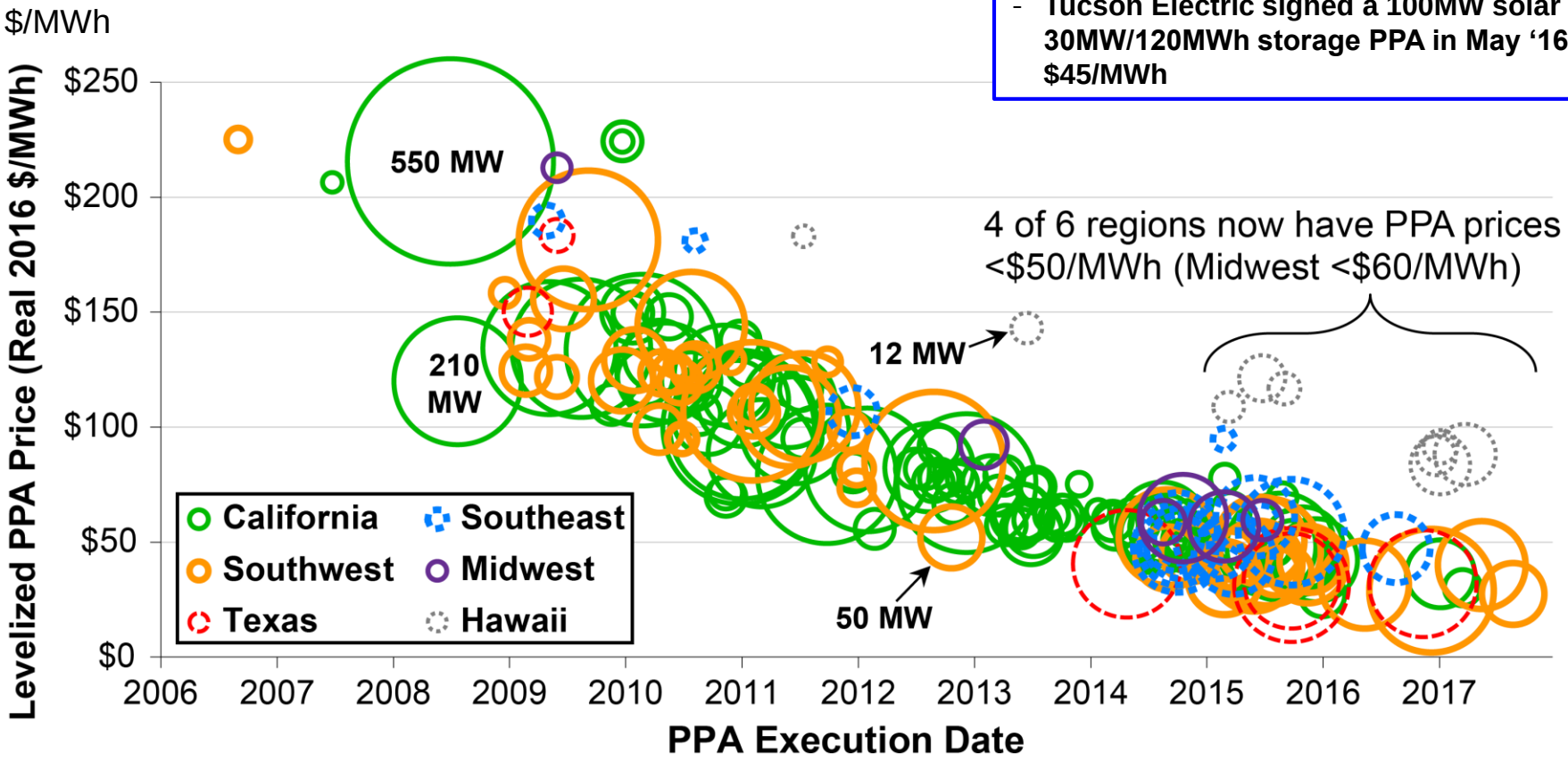
- Expanding consumer interest in DER assets
- Energy usage analytics and value capture from demand management
- Supporting electrification of transport

Digitization

The competitiveness of utility-scale PV has improved dramatically over the past five year with PPA prices falling by 70% or more

- NV Power signed a utility-scale solar PPA in August '16 for $34/MWh
- Tucson Electric signed a 100MW solar + 30MW/120MWh storage PPA in May '16 for $45/MWh

U.S. Utility-scale solar PPA prices evolution since 2006

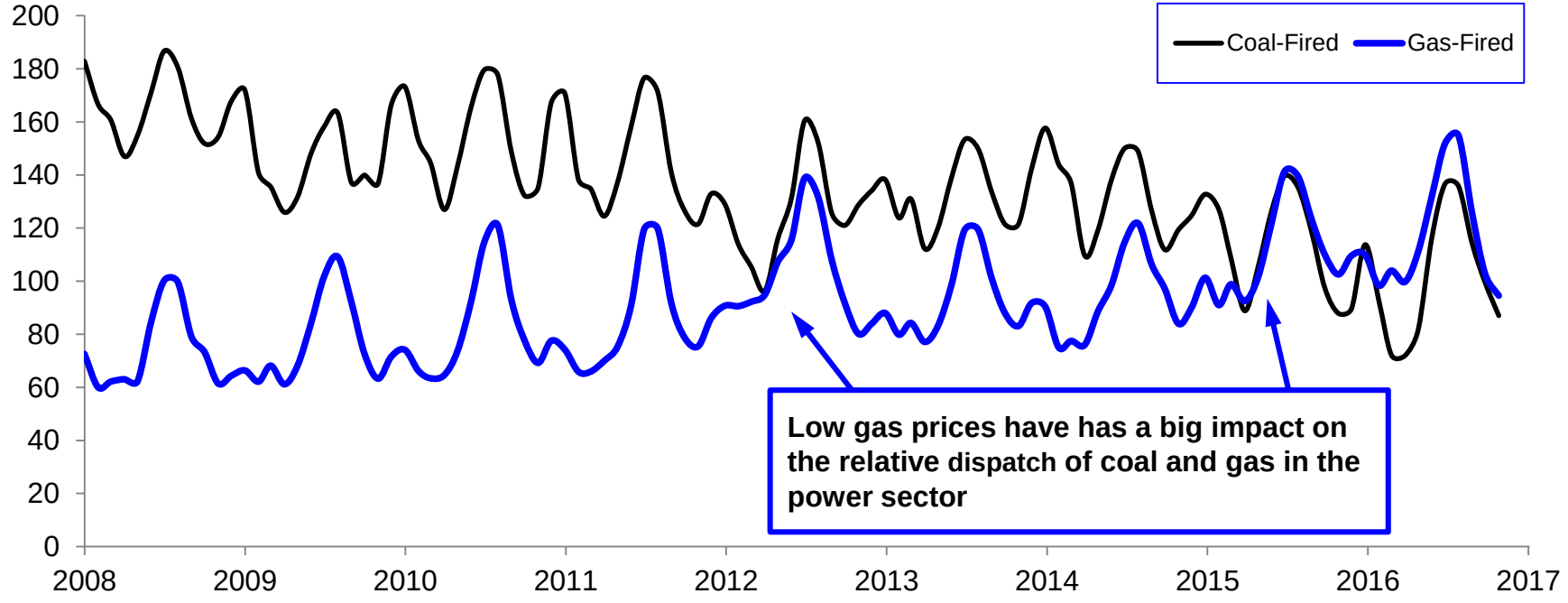


Sources: Bloomberg NEF, "U.S. PPA Market Outlook." 07/08/15. GTM/SEIA, "US DOE SMI Reporting"

Abundant low cost gas is driving large-scale displacement of coal-fired generation in the US… and also aiding gas in other sectors

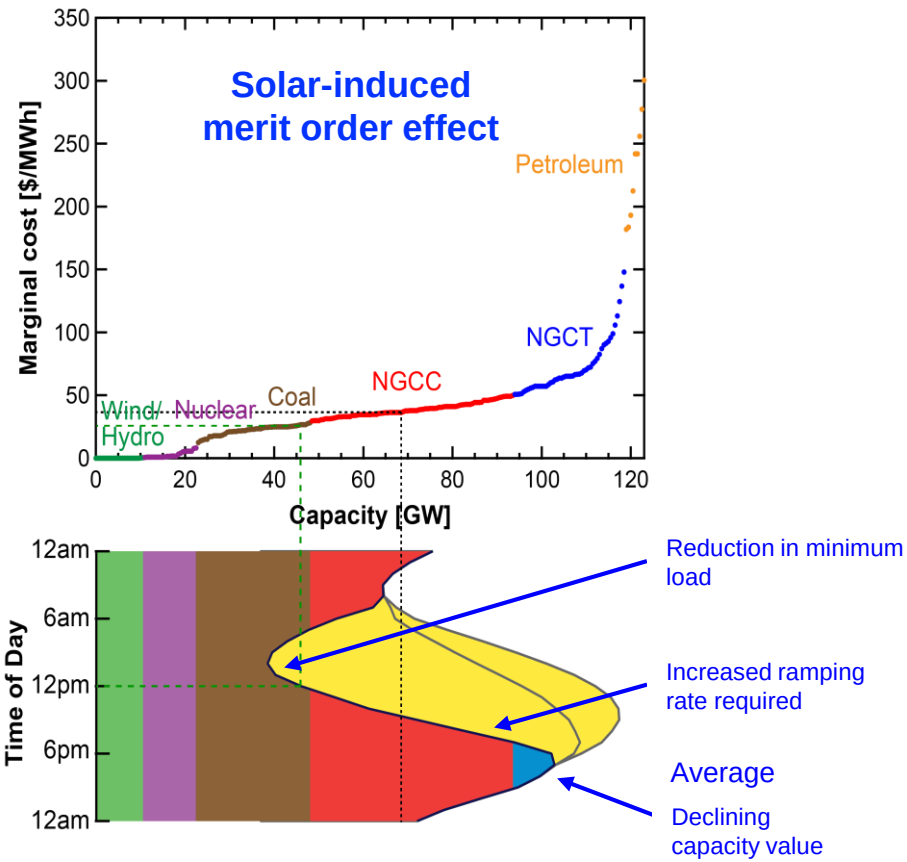
Comparison of coal and gas-fired power generation levels in the U.S. since January 2008

TWhrs

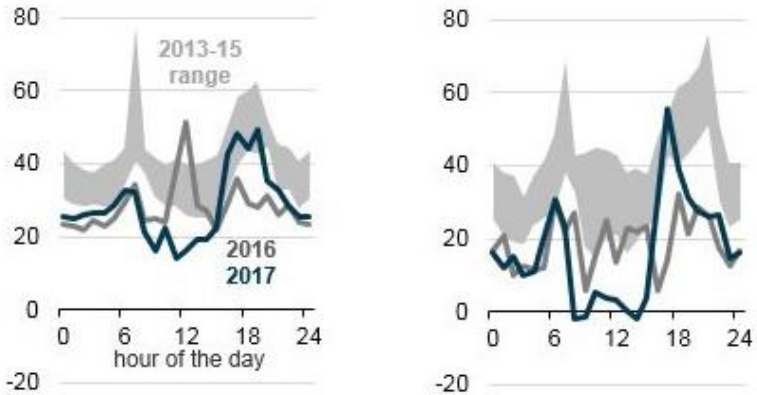


Source: F. O'Sullivan, United States Energy Information Administration

Falling natural gas and renewables prices are helping to reduce the energy costs of electricity provision but other issues are beginning to emerge



CAISO average hourly real-time prices
$/MWh



January **March**

During May 2017, 8% of the hours in CAISO had negative prices

Source: CAISO, U.S. Energy Information Administration, Energy & Environmental Economic

Beyond merit order issues, the operation of a more renewables heavy systems demand that the grid be more flexible

Transmission capacity

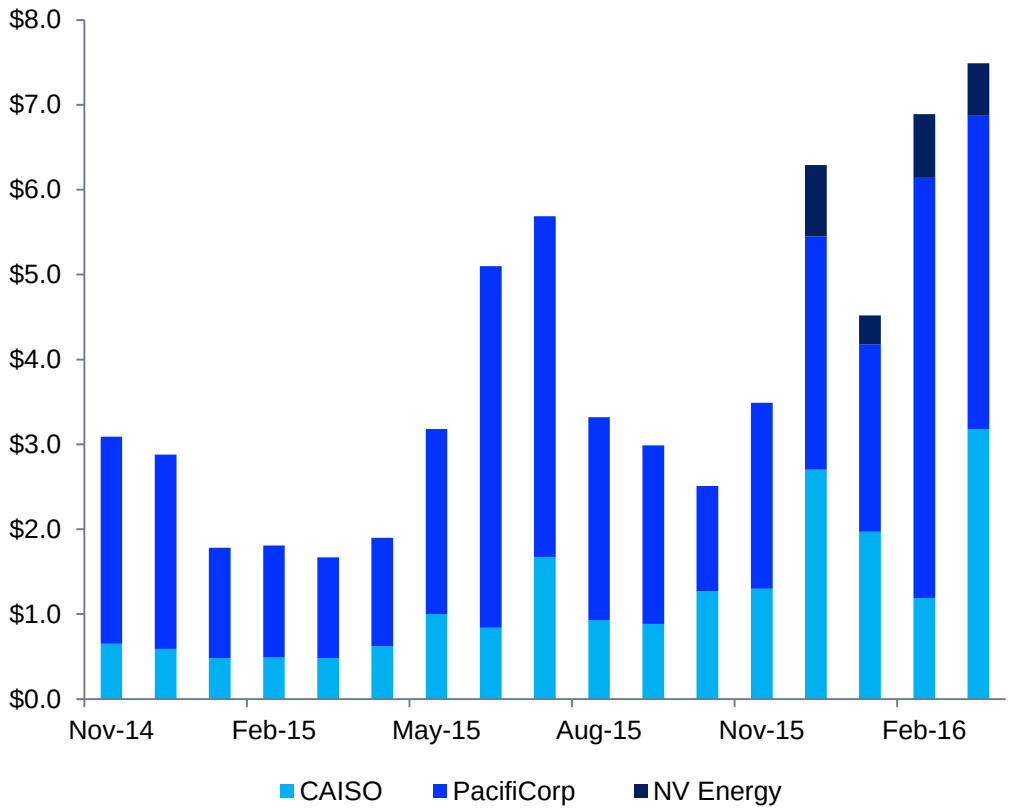
Flexible dispatchable generation

Energy storage

Active demand management

Thoughtful market reform will be important in enabling electricity be competitive in any transition towards greater electrification

Cost savings arising from EIM integration
$ Millions



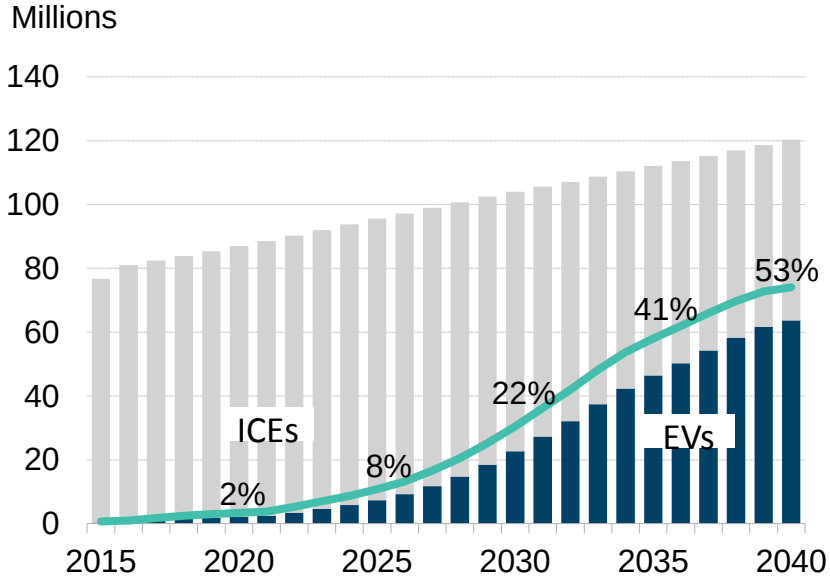
The Energy Imbalance Market – A first step towards greater market integration in the Western U.S.

- CAISO's development of the EIM is aiding the optimization of the real-time dispatch and reducing costs appreciably
    - Estimated $120M in real-time dispatch savings since November '14
- Aiding California in meeting its renewable energy targets by reducing renewables curtailment
    - Reduced Q4 '16 CA renewables curtailment by 24GWhs
- Acting as a stepping stone to much greater western integration in a manner designed to best integrate high levels of variable resources

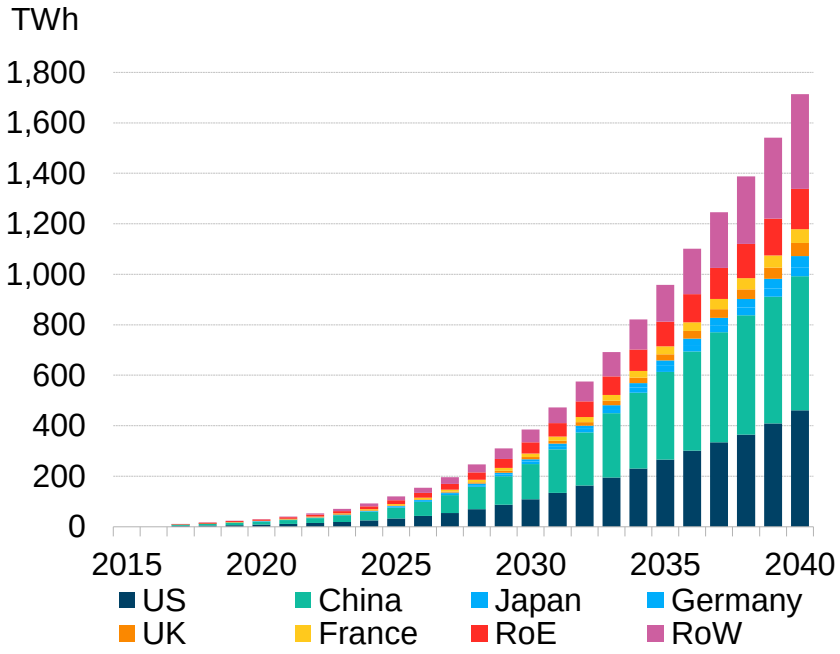
Source: MIT Analysis, CAISO, F. O'Sullivan

We are now witnessing the nascent steps towards the large-scale electrification of mobility

Global light duty vehicle sales



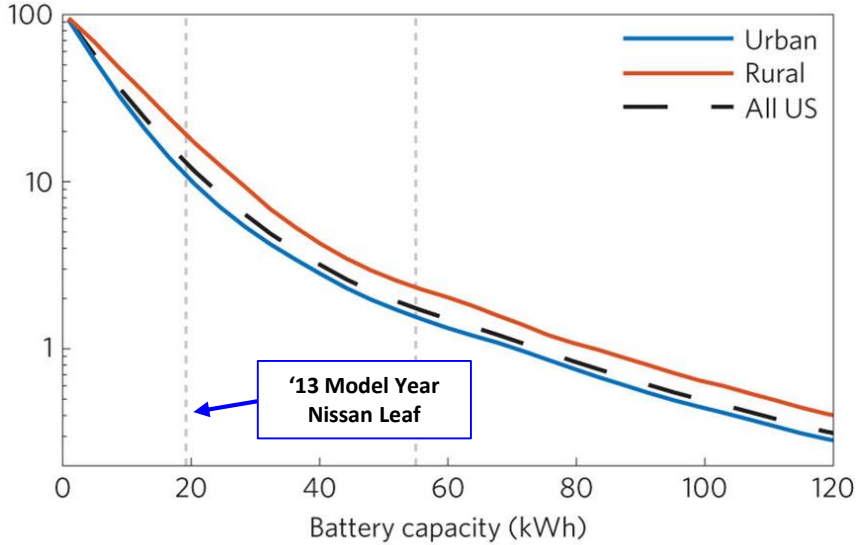
EV electricity demand



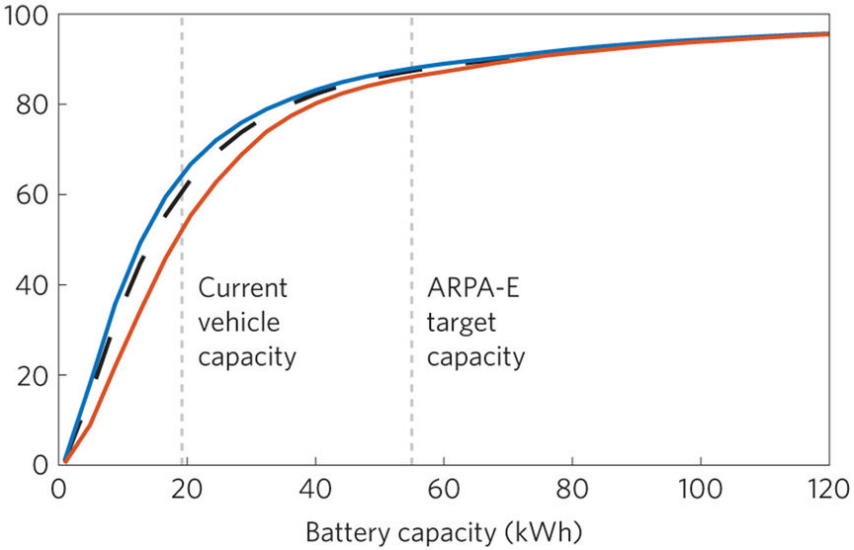
Source: Bloomberg NEF

Today's EV technology is approaching the performance level needed to deliver mobility services for the majority in major markets

Daily vehicle adoption potential vs. battery capacity
Percentage of all personal LDV trips in U.S.

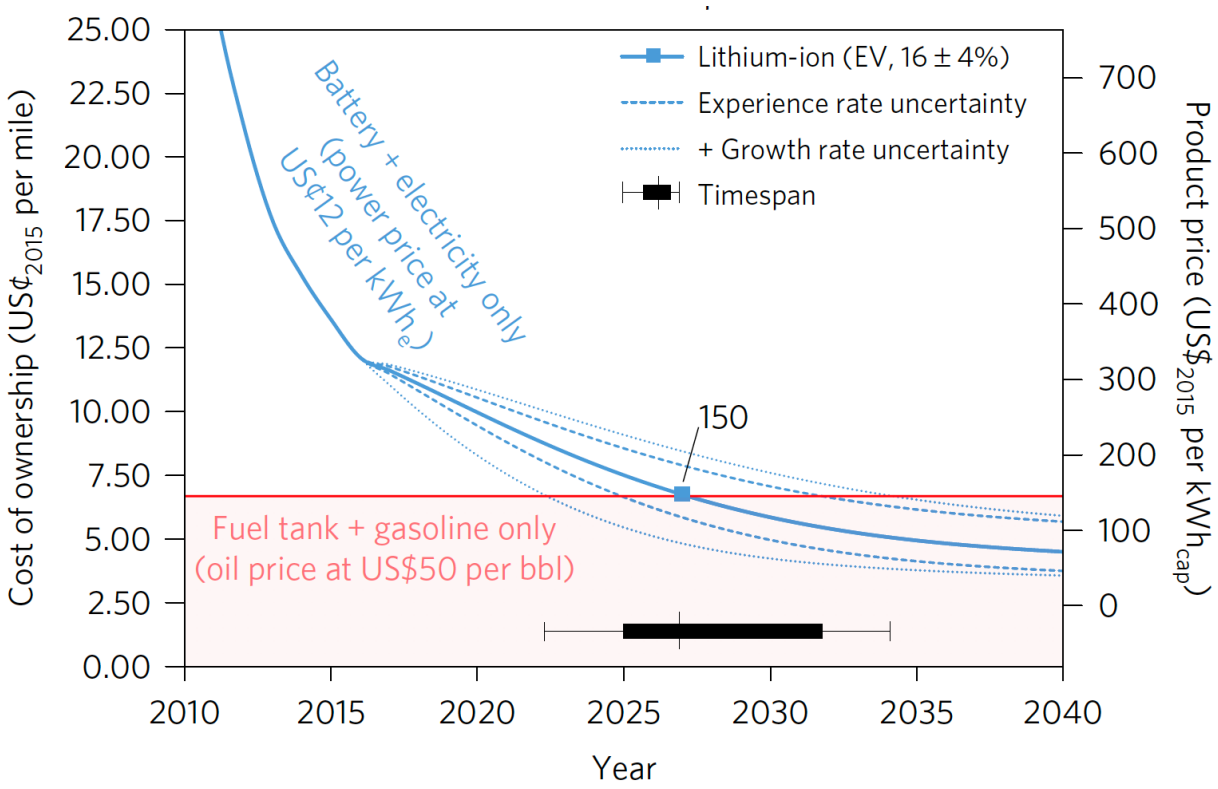


Gasoline displacement potential vs. battery capacity
Percentage of personal LDV gasoline usage in U.S.



Source: Needell et al, Nature 16112

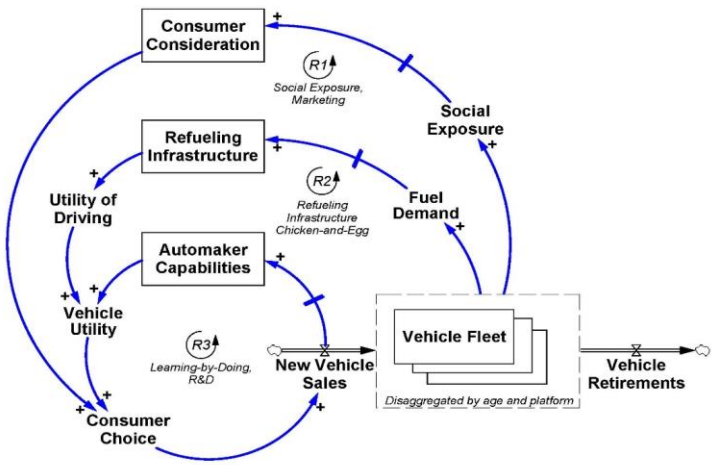
The current trajectory for battery costs points to EV cost of ownership approaching gasoline within the next five years



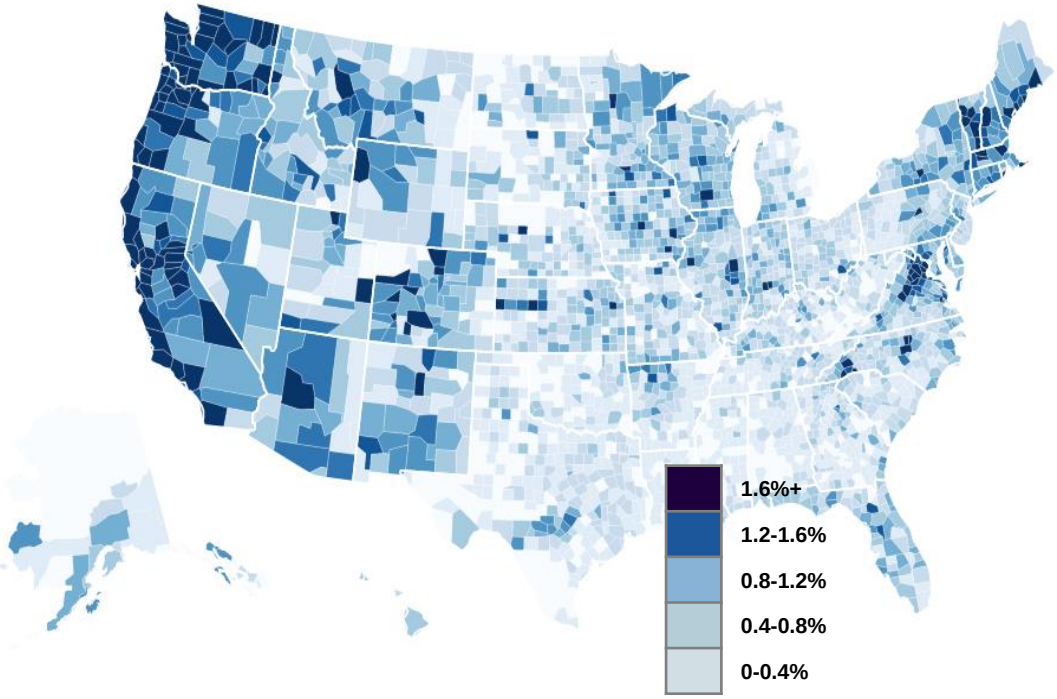
Source: Schmidt et al, Nature 17110

EV cost competitiveness is necessary but not sufficient… Behavioral economics will play a major role in shaping how the technology diffuses into the market

System dynamics model of AVF adoption



Spatial variation in adoption levels of hybrid and EV vehicles
Percent of new vehicle sales



Source: D. Keith, MIT analysis

Some conclusions