Power in Transition – Challenges, and Opportunities Ahead for our Changing Energy System

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October 25th, 2019

The contemporary electricity system is experiencing a period of unprecedented change that is bringing with it both challenge and much opportunity

Large-scale generation

- Rapid growth in the deployment of renewables
- Changing operational needs as the generation mix evolves
- New dynamics in wholesale market conditions

The grid

- Rapid expansion in DER adoption – Generally without coordination
- New options to support operational and capacity needs
- A growing role for data and IT in service delivery and reliability

The prosumer paradigm

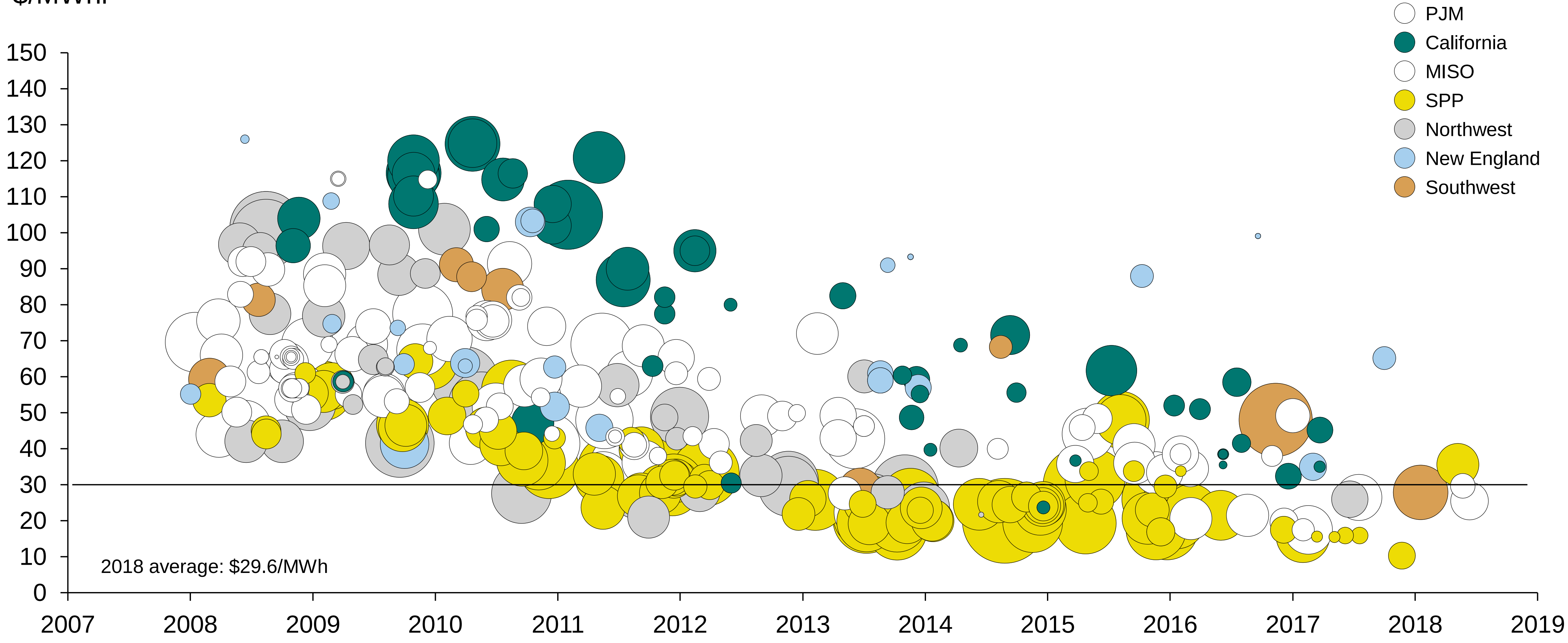
- Growth of consumer interest in shaping own energy service provision
- Advanced analytics creating new value capture opportunities
- Broader electrification driven by convergence of mobility and the built environment

Source: F. O'Sullivan, MIT Analysis

The rise of renewables… Wind and solar at energy’s big table

Secular cost reductions mean wind and solar PV now provide some of the lowest cost MWhs available in many important markets

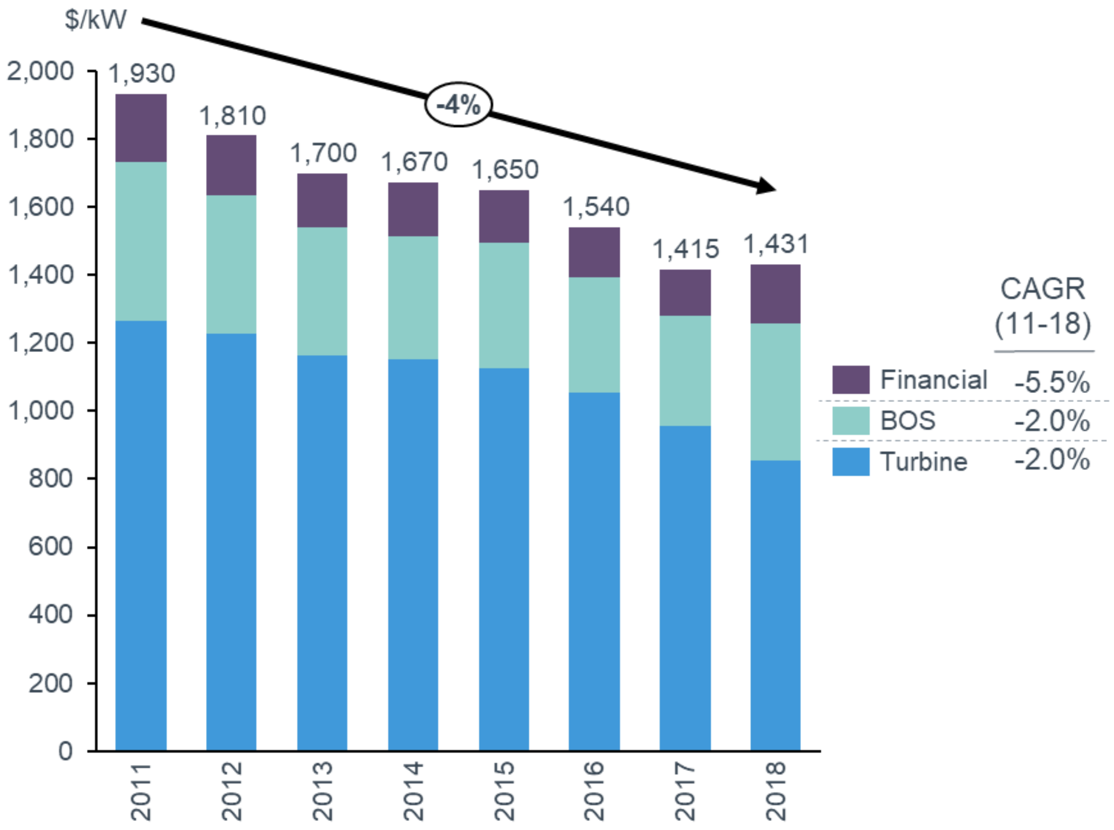
Evolution of US wind PPA prices by region from 2008
$/MWhr



Source: Bloomberg NEF, US DOE SMI Reporting

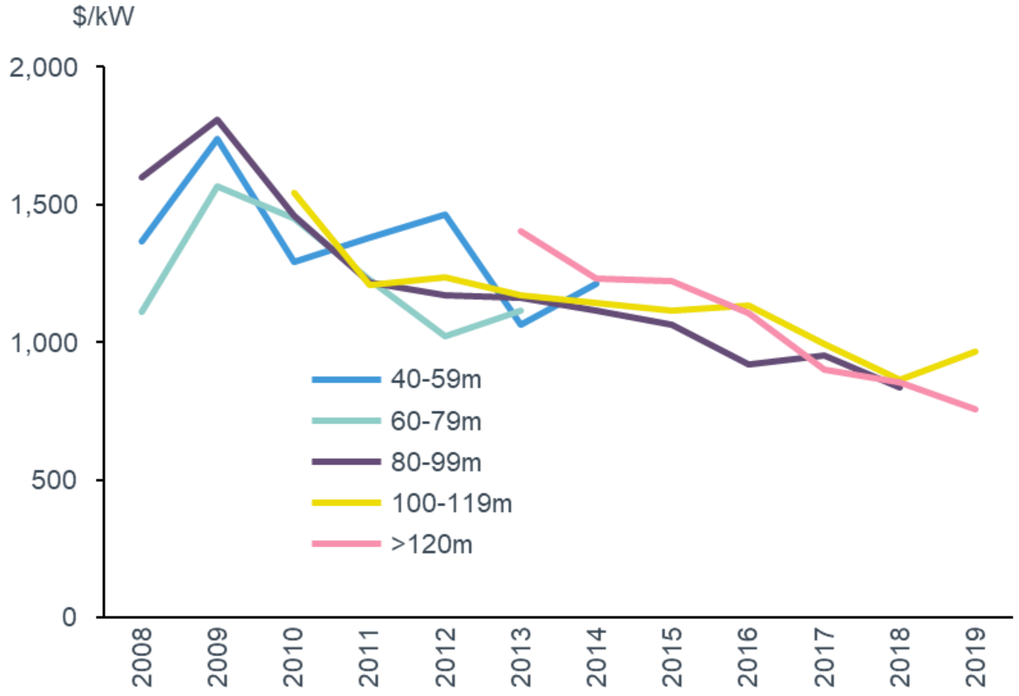
Technological improvements and scale have reduced wind capital costs to less than $1,400/kW, mainly driven by turbine costs

US onshore wind capital costs



US turbine price by rotor diameter

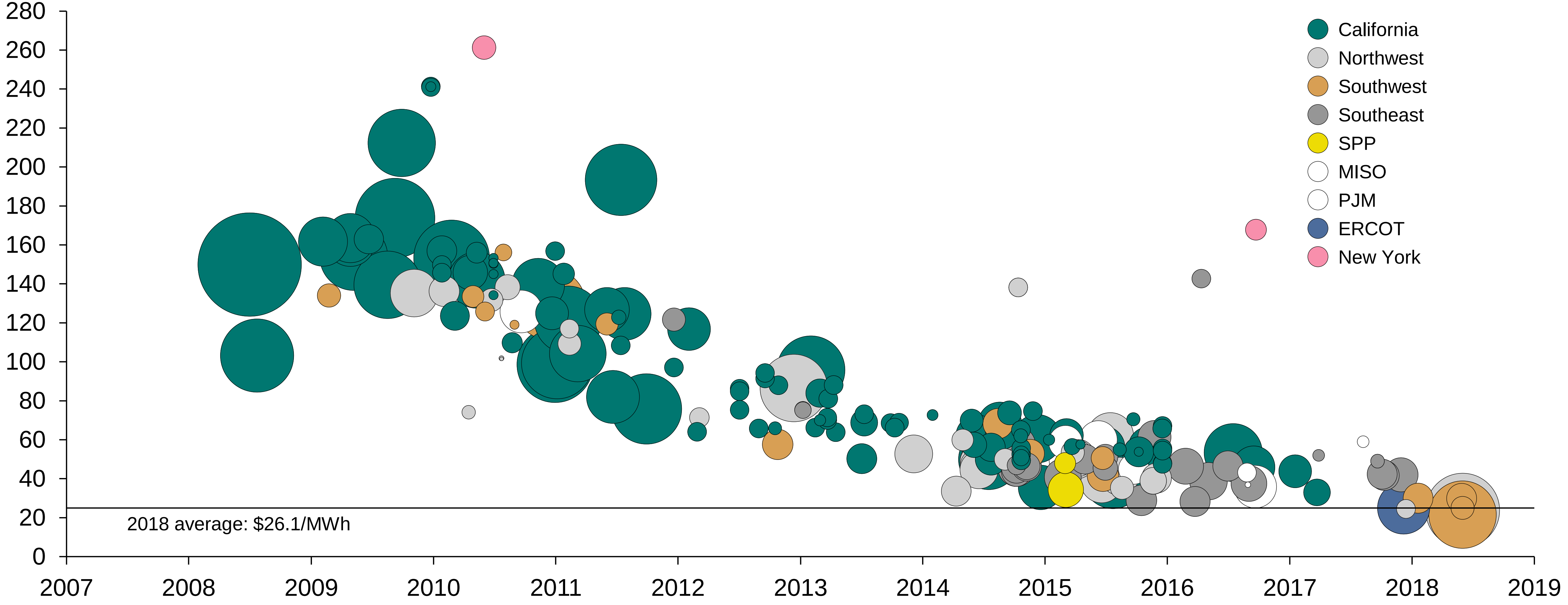
- Turbines with rotor diameter greater than 100m have dominated in recent years – rotors smaller than 100m make up just 5% of 2018/19 submissions
- 120m rotors cheaper than 100-119m rotors on a per MW basis as they are commonly installed on higher rated turbines



Source: IHS, BNEF

Solar has made even more remarkable progress than wind in terms of overall competitiveness – Utility-scale solar is now the lowest cost source of capacity

Evolution of US wind PPA prices by region from 2008
$/MWhr

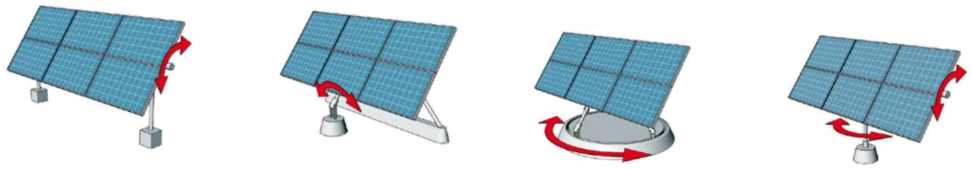


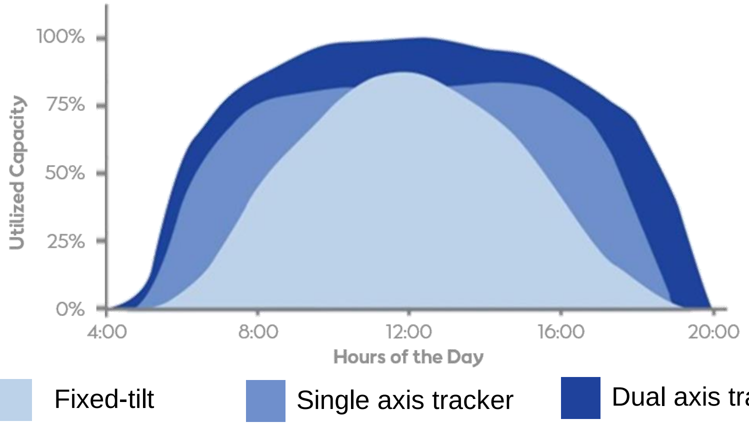
Source: Bloomberg NEF

The embracing of tracking technology over the past decade has significantly increased the efficiency of utility scale solar

Tracker technology overview

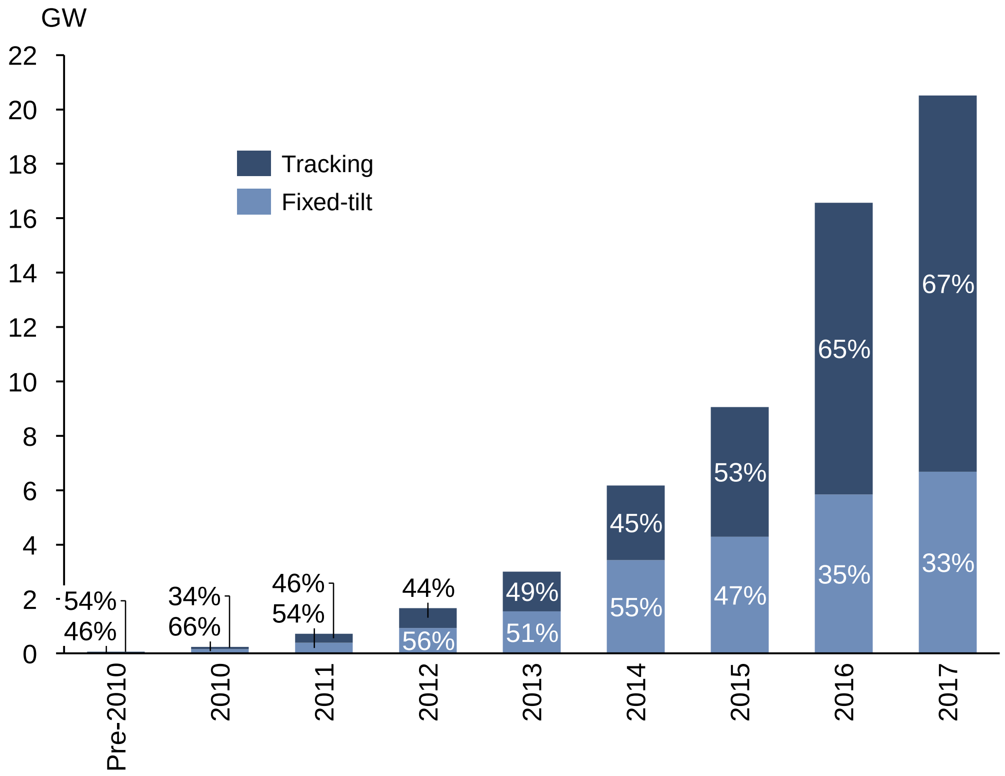
- Fixed-tilt panels achieve maximum power output only a few hours per day
- Single axis tracker panels rotate around a central axis, following the sun from E to W
- Dual axis and azimuth tracker systems allow maximum efficiency throughout the day





US utility-scale solar capacity by tracker

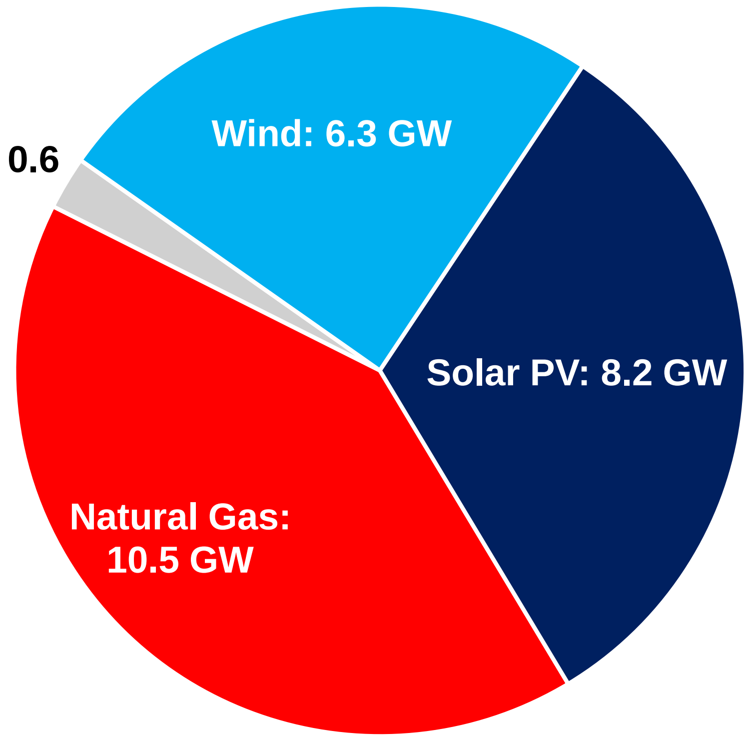
- Continued dominance of tracking projects (79% of newly installed capacity) relative to fixed-tilt projects



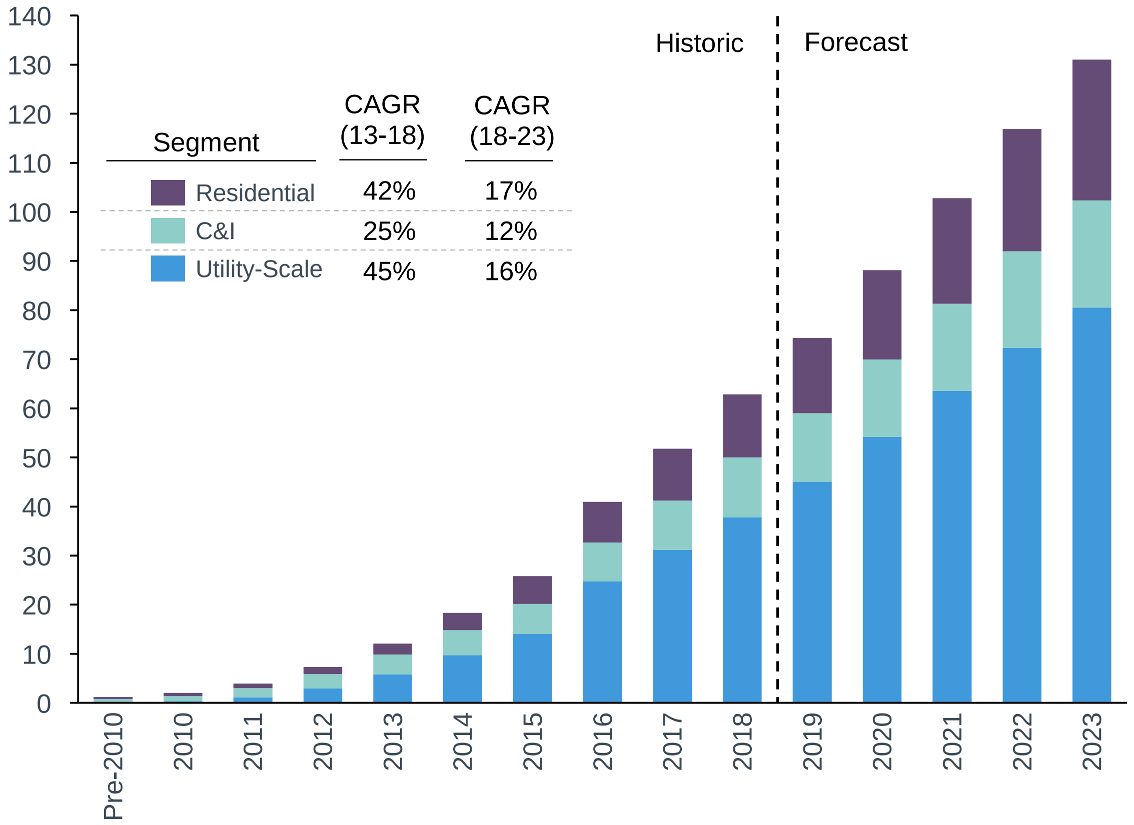
Source: MIT Analysis, Lawrence Berkeley National Laboratory

Technologies like solar PV are particularly important because of the deployment flexibility that they enable

2017 U.S. Generation Capacity Additions by Type
GW_{AC}



US PV capacity by system type
GW_{dc}

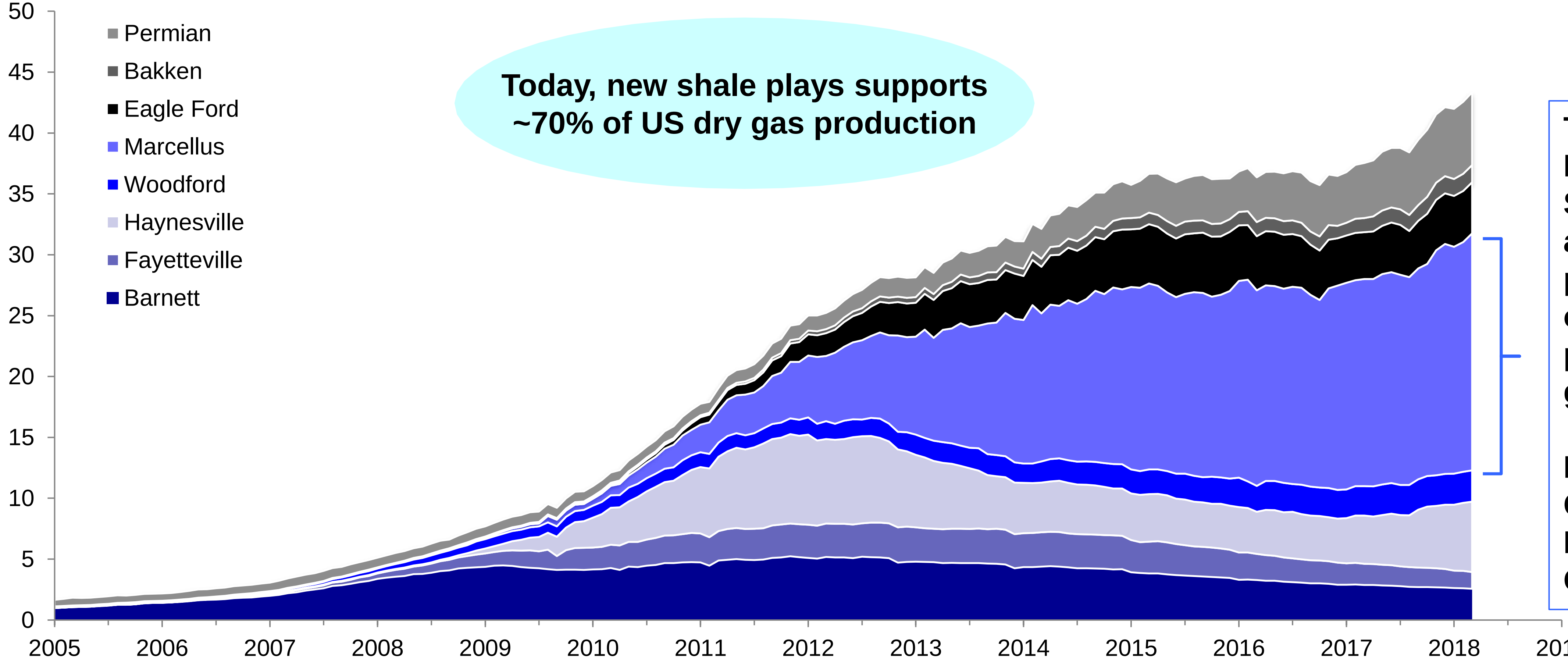


In the US, more than 60% of all PV capacity is in the form of utility-scale units

Source: MIT Analysis, Woodmac, National Renewable Energy Laboratory, Lawrence Berkeley National Laboratory, Solar Energy Industry Association, European Photovoltaic Industry Association

Dramatic technology-driven impacts on the energy system are not just confined to renewables resources… Just consider on the shale boom

Illustration of gas production growth from the main U.S. shale plays since 2005
Bcf of gas per day



The Marcellus Shale alone now produces over 7 Tcf per year of gas.

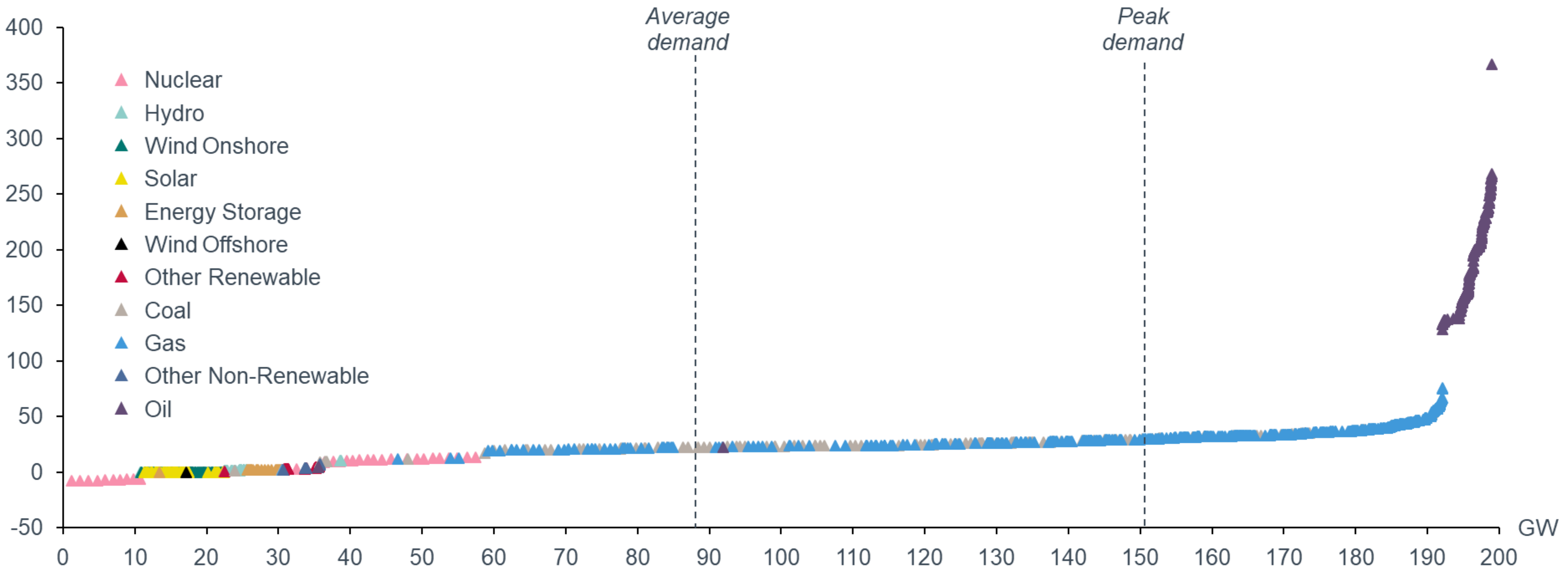
More than Canada, Iran or Qatar

Source: United States Energy Information Administration, HPDI Production Database

The evolving concept of competitiveness… The challenges in moving from marginal to meaningful renewables penetration

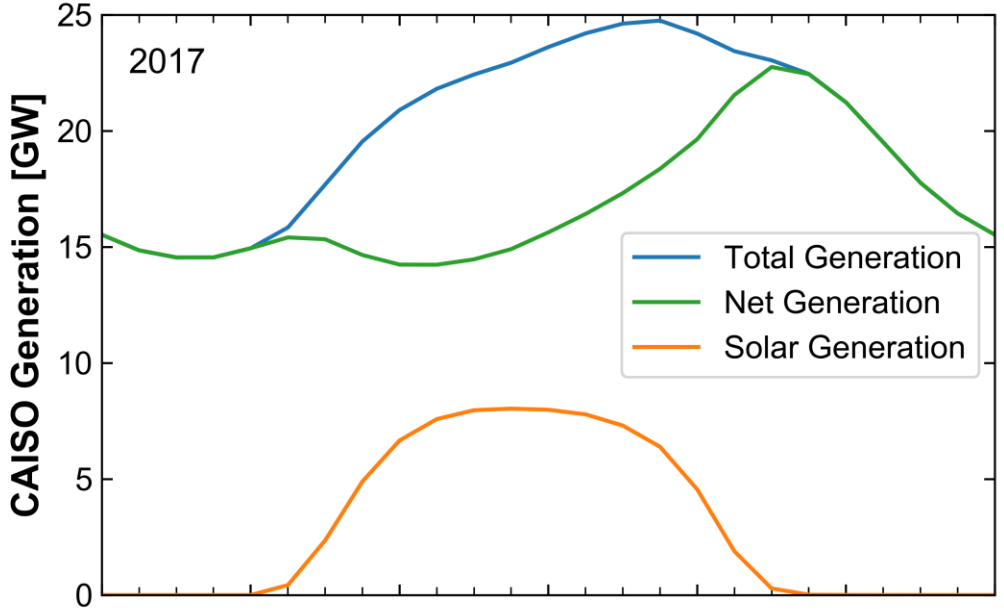
Given the way power markets function, wind and solar always represent some of the lowest cost supply – Consider the PJM system

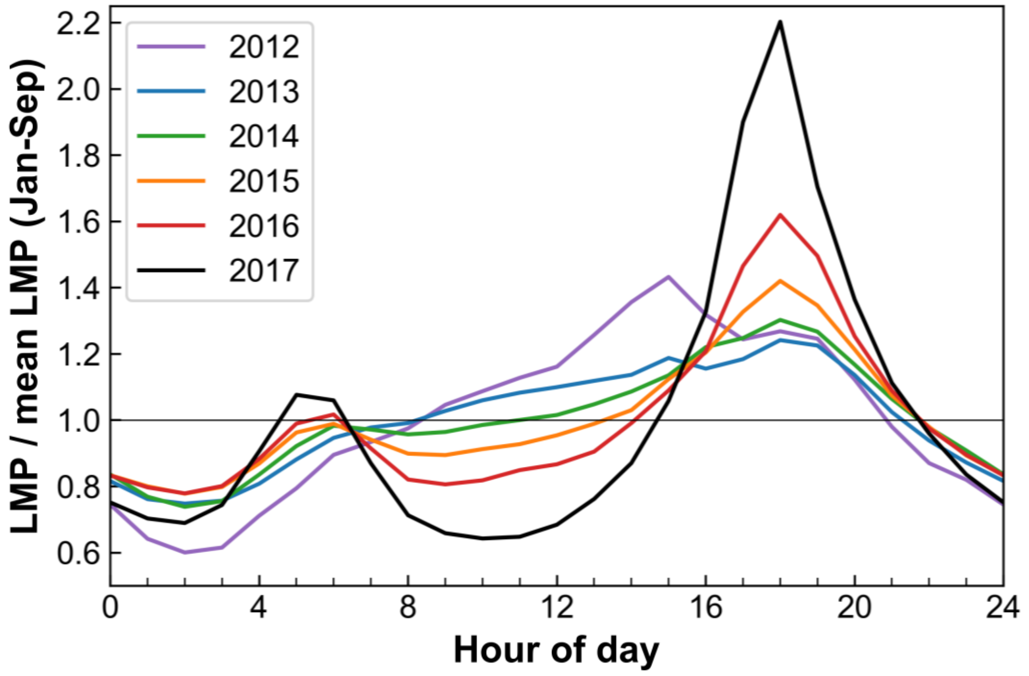
Illustration of the 2019 PJM merit order curve
$/MWh



Source: WoodMac Power and Renewables

More than 16% of CA's power now comes from solar and this is having a profound impact on the economic and the technical operation of its power system

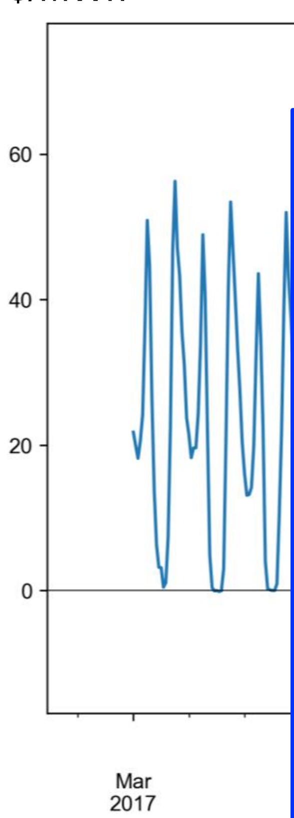




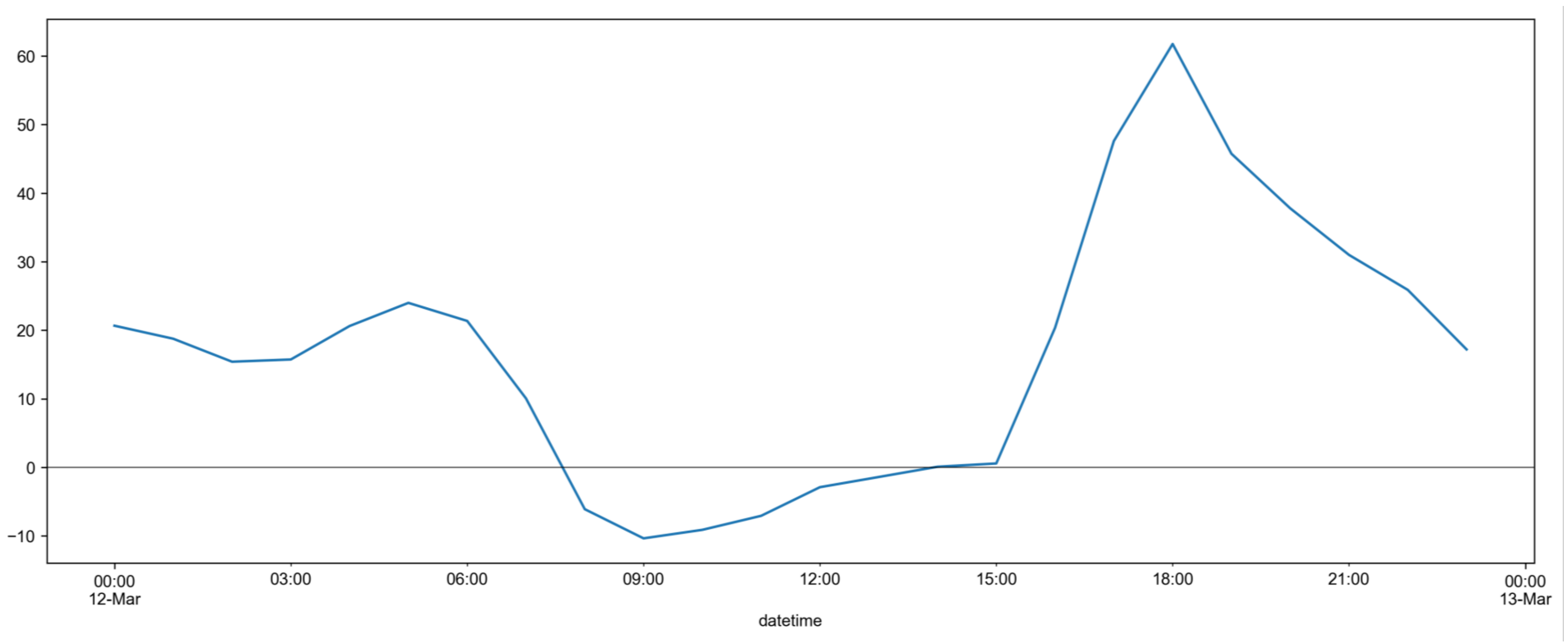
Source: P. Brown, F. O'Sullivan, CAISO

Growing instances of negative power prices raise issues regarding how fit-for-purpose today’s market constructs are

Average hourly CAISO DAM LMP in March 2017
$/MWh



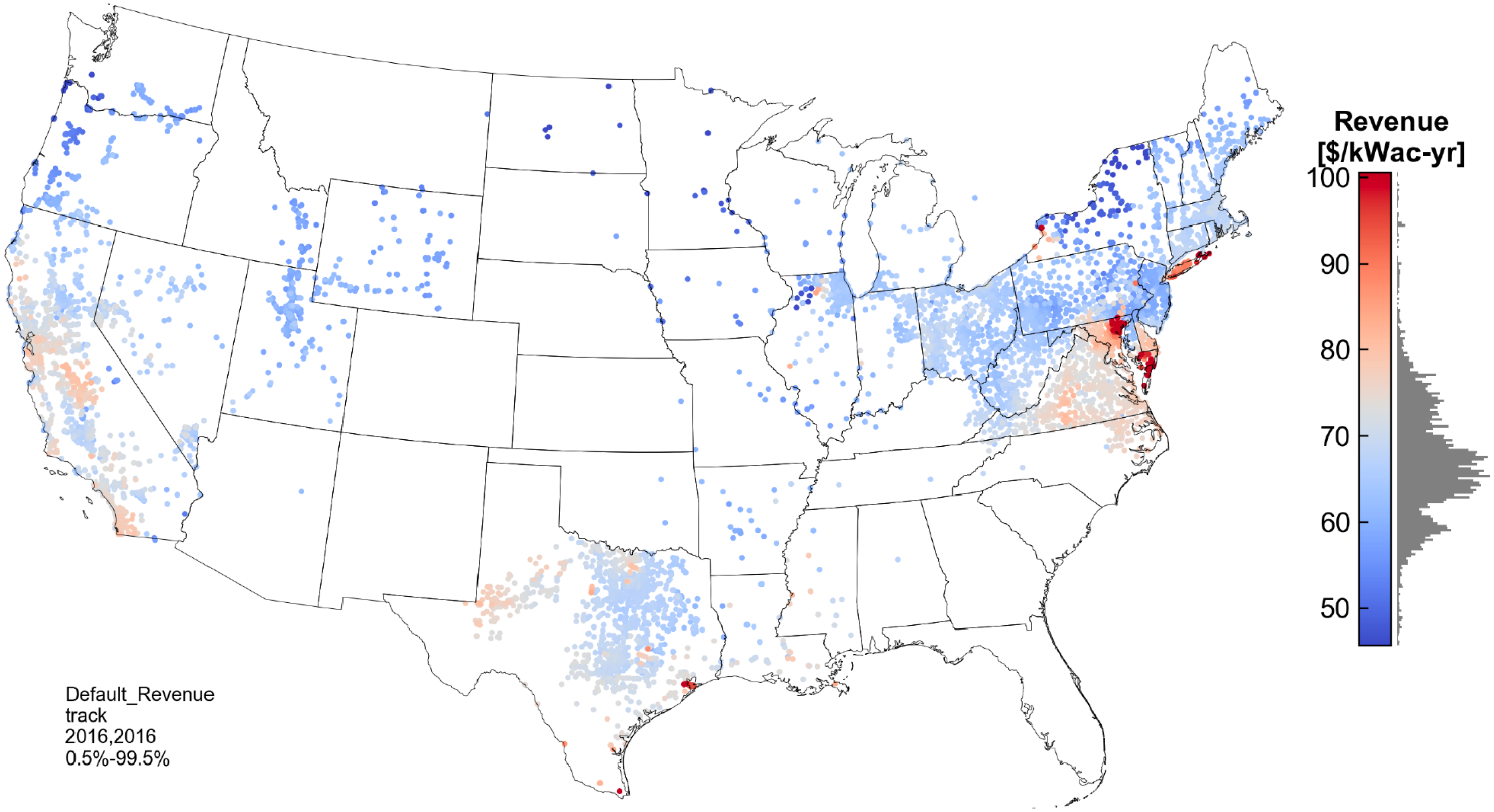
Average hourly CAISO DAM LMP on March 12th 2017
$/MWh



Source: P. Brown, F. O’Sullivan, CAISO

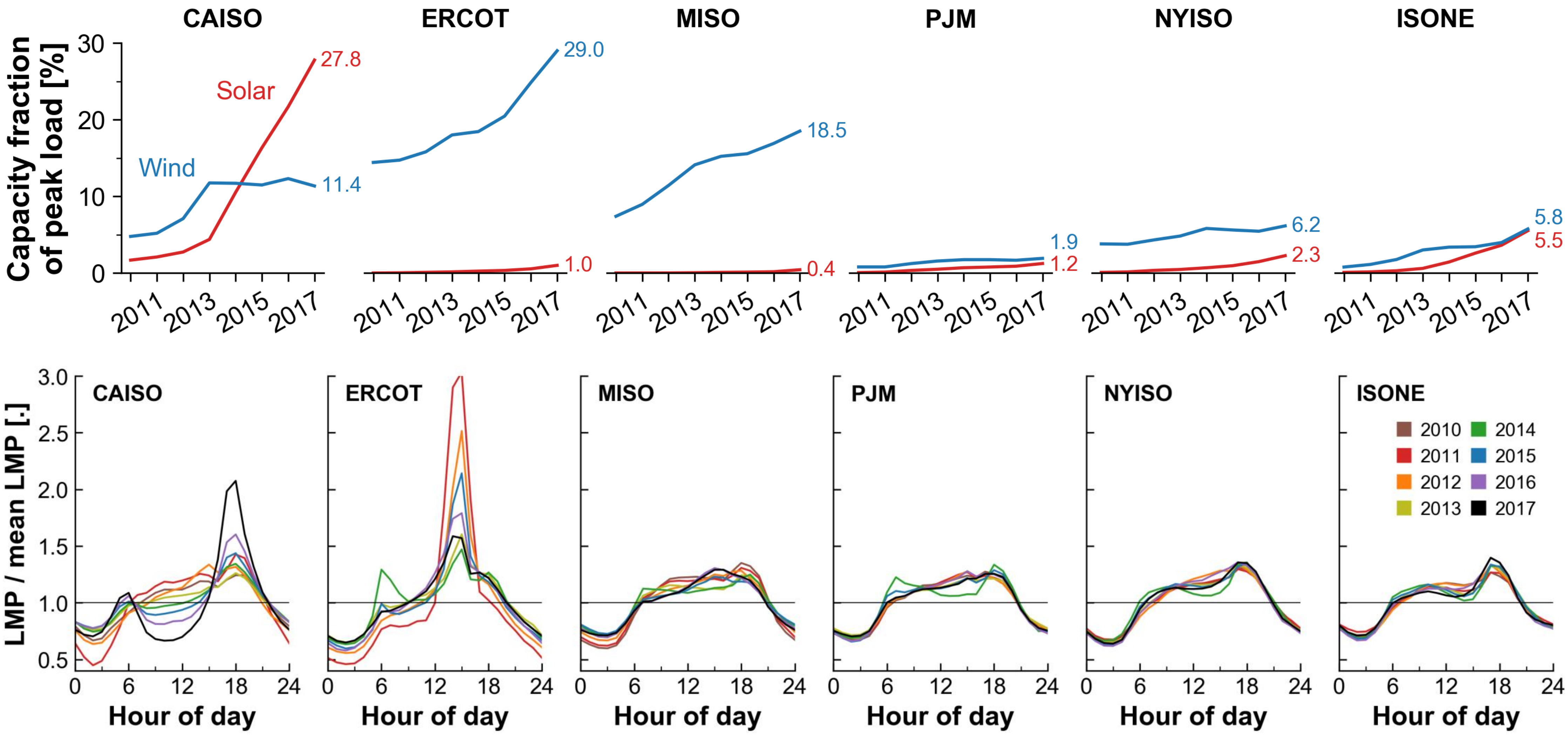
The dynamics surrounding the value of renewable generation as penetration grows means that project economics are becoming more complicated

Modeled yearly revenue for U.S. solar PV generation capacity based on 2016 DAM LMPs
$/kWac-yr



Source: P. Brown, F. O'Sullivan, CAISO

As more wind and solar deployment occurs, the price formation dynamics across our markets are likely to be “interesting” over the coming years

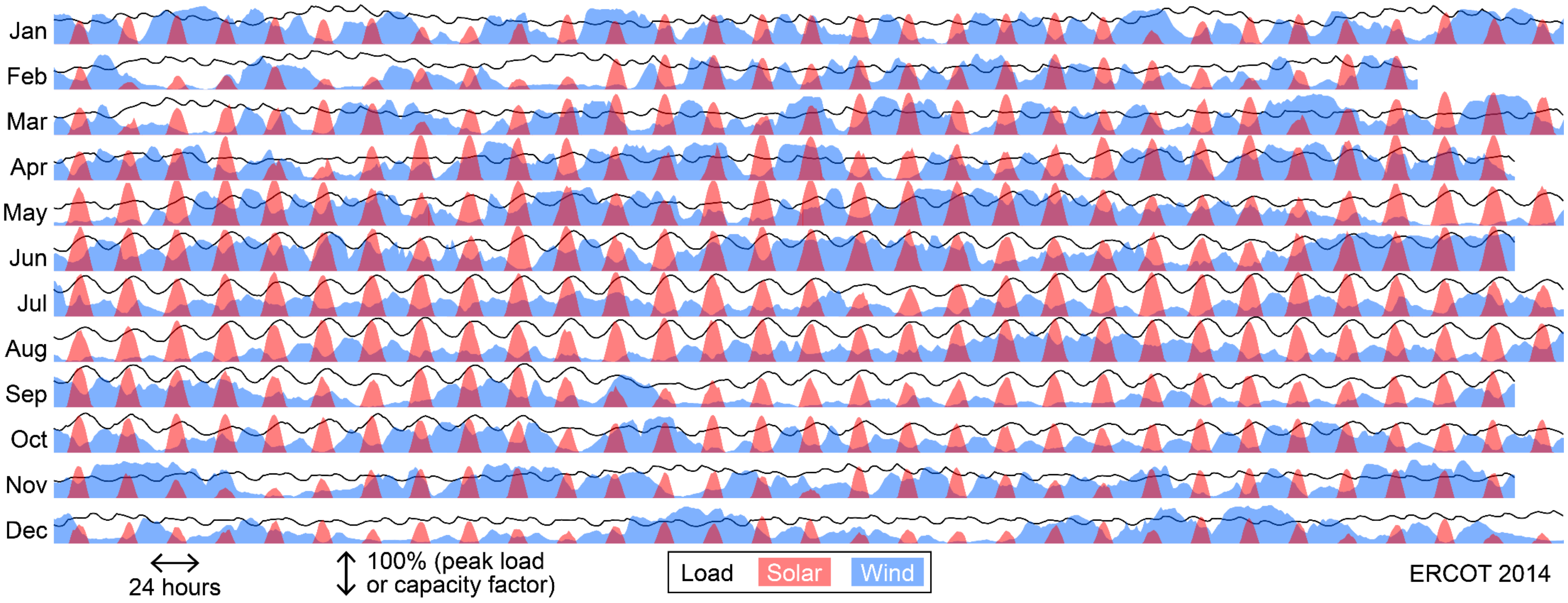


Source: P. Brown, F. O’Sullivan

Retooling the system… Innovations for delivering a future-proofed power sector

Management of intermittency is going to be increasingly important as systems become much more exposed to, and reliant upon renewable resources

Daily variability of wind and solar resource in Texas relative to load in 2014



Source: MIT Analysis, NSRDB, ERCOT, P. Brown

One issue around which there is no debate is the fact that tomorrow’s power system will have to be more flexible to ensure the efficient, reliable and resilient delivery of services

Transmission capacity

Flexible dispatchable generation

Energy storage

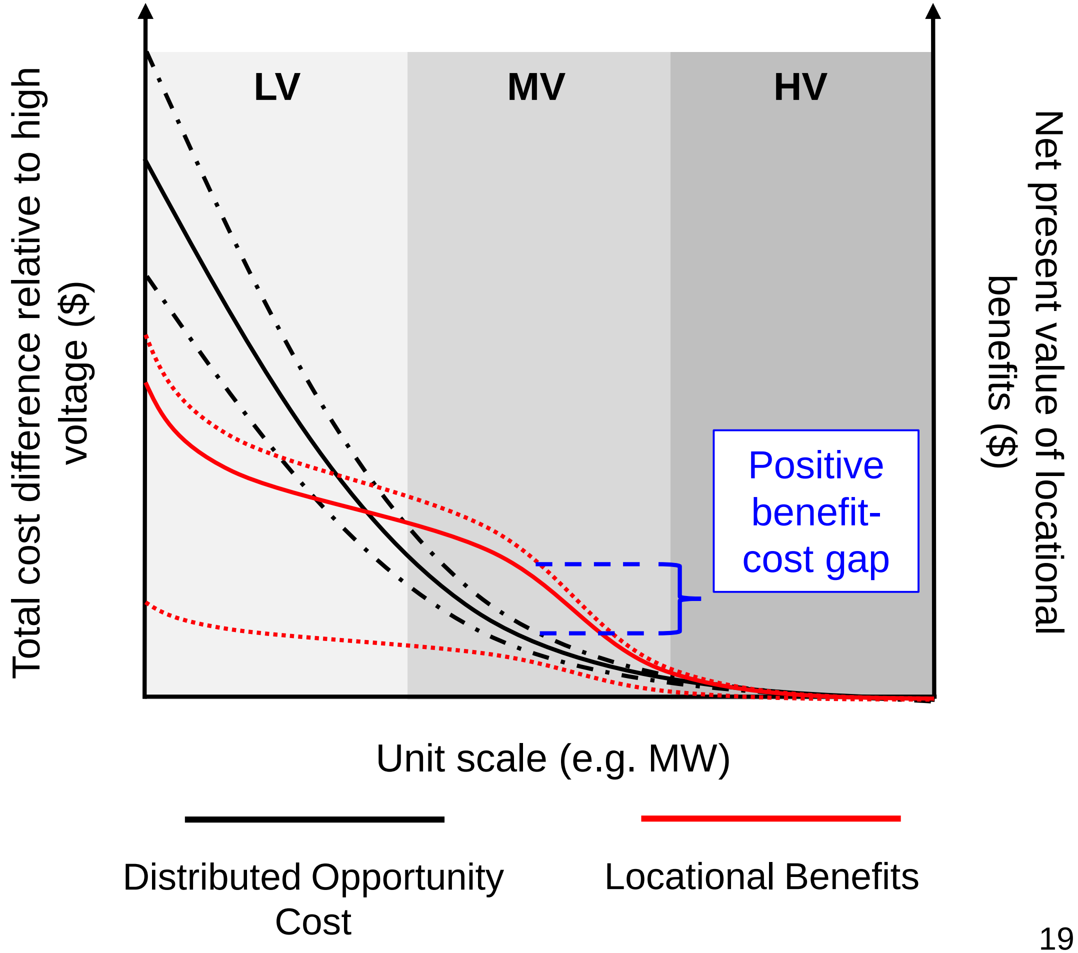
Active demand management

Distributed resources, particularly those that are digitally integrated will certainly play a bigger role in delivering tomorrow’s electricity services

Locational & non-locational services offered by DER

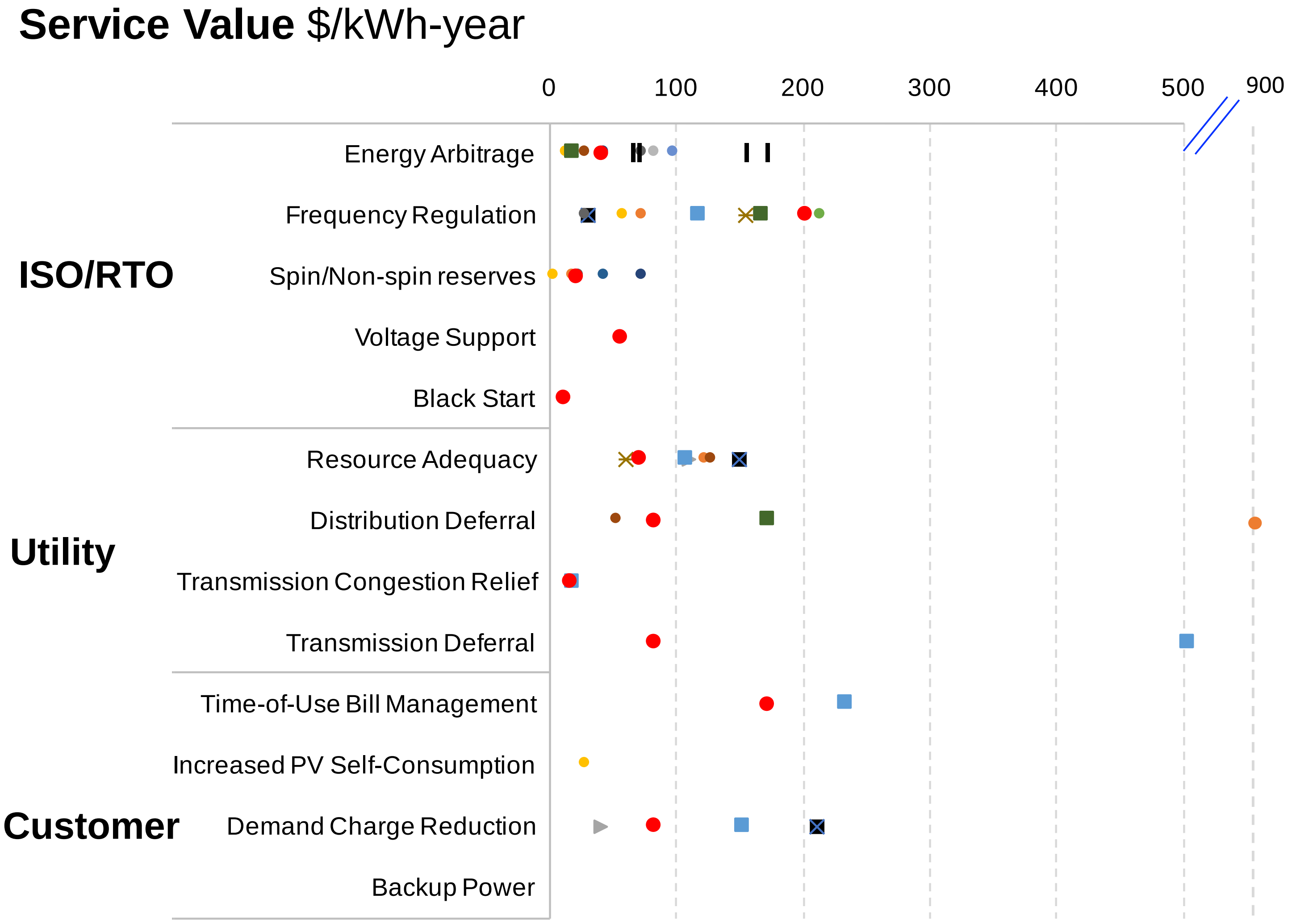
Locational	Non-locational
- Network capacity	- Energy
- Constraint mitigation	- Firm capacity
- Loss reduction	- Operating reserves
- Voltage control	- Price suppression
- Power quality	- Price hedging
- Reliability and resiliency	
- Land use	- Emissions mitigation
- Employment	- Energy security

Locational benefits > distributed opportunity cost in certain deployment



Source: MIT Analysis, MIT Utility of the Future Study Group

Advanced storage systems do have the potential to provide a wide range of valuable services across the entire power system value chain



Stacking storage services enhances the return on investment

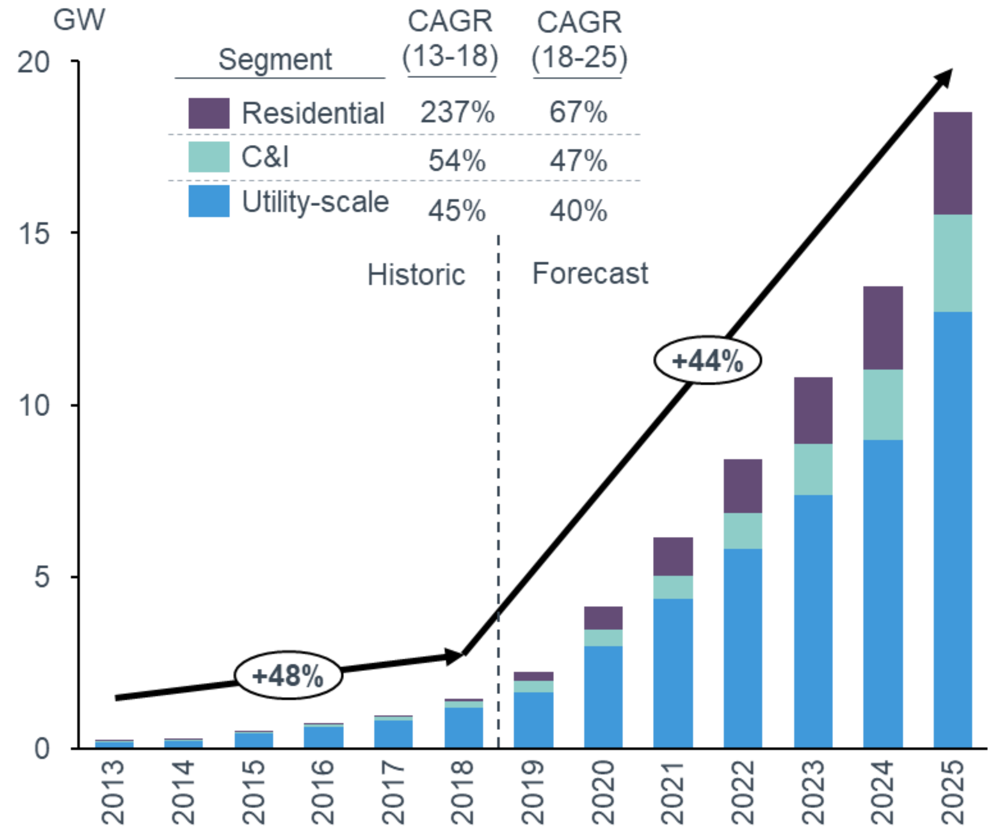
Possibility of 2-3X increase in asset value

Market and regulatory barriers are extensive

Source: Estimates include those from RMI, NYSERDA, NREL, Brattle Group, Kirby, EPRI, Sandia, and Sakti et al.

The next decade will witness a profound expansion in storage deployments - Utility-scale storage will lead, but residential and C&I will grow at a faster rate

US storage capacity by customer segment



Key trends

- Residential:
  - Economics currently challenged as most residential customers do not have demand charges or time-of-use rates (TOU), CA is moving all residential customers to TOU rates in 2019 and some utilities are starting to experiment with residential demand charges
  - The allure of backup power was cited by developers and installers as a major influence on customers purchasing storage
  - 2018 and early 2019 saw several moves toward using residential storage for grid services
- C&I:
  - Majority of capacity installed to date driven by high demand charges in CA, HI, and the Northeastern states
  - Rate structure and state/local incentives like SGIP in CA and the upcoming SMART program in MA will continue to drive adoption
- Utility-Scale:
  - Declining battery costs will make BESS increasingly competitive as a source of new peaking capacity, particularly in dense urban areas where it will be difficult to site transmission or large generation resources
  - Upgrade deferral use cases are expected to grow as utilities seek “non-wires” alternatives to traditional network investments

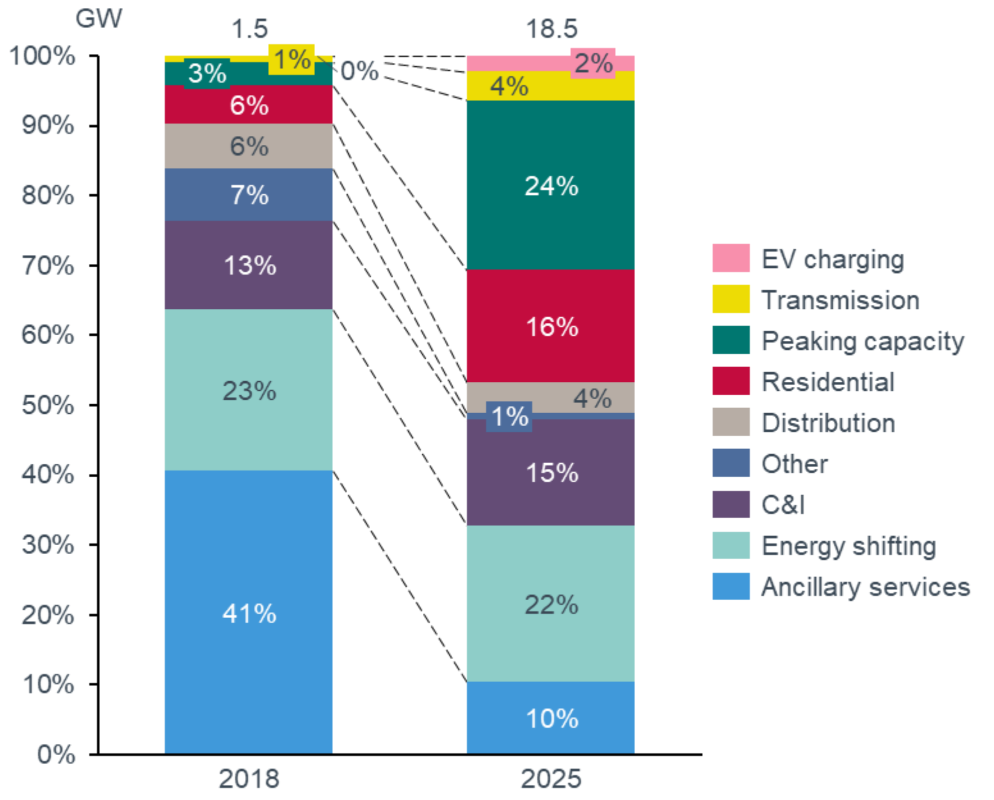
Source: BNEF Long-term storage outlook 2018

The evolving concept of competitiveness… The challenges in moving from marginal to meaningful renewables penetration

Energy storage use cases

Use Case	Description
Ancillary service	Provide or absorb short bursts of power to maintain the balance of supply and demand and hence the frequency of the grid
Peaking capacity	Provide capacity to meet the system's peak
Energy shifting	Energy storage is charged at times of low prices and surplus supply and discharges to meet demand at a late time
Transmission deferral	Energy storage is used as an alternative to a traditional transmission network reinforcement
Distribution deferral	Energy storage is used as an alternative to a traditional distribution network reinforcement
Residential PV plus storage	The primary application is to increase the rate of self-consumption from the PV system
C&I storage	Reduce the customer's peak load thus reducing demand charges. Also increase the rate of self-consumption from the PV system when paired
EV charging	Reduce demand charges and costs from time-of-use rates for operators of EV fast chargers

Historic and forecasted energy storage by use cases

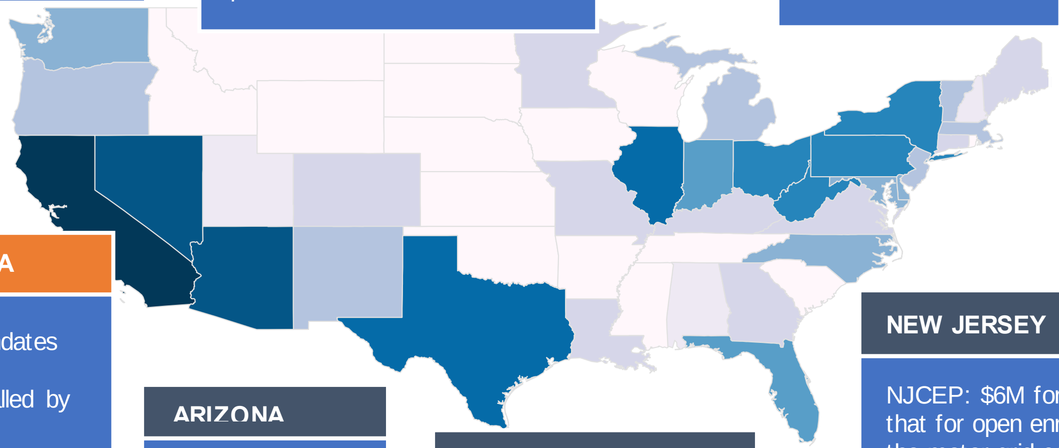


Source: Long-Term Energy Storage Outlook 2018

The plethora of service storage can provide is only matched by the number of state-level initiatives and mandates designed to support deployment

Energy Storage
MW
- ≤ 0.2
- ≤ 1
- ≤ 2
- ≤ 6
- ≤ 11
- ≤ 29
- ≤ 87
- ≤ 180
- ≤ 314
- ≤ 674

*does not include pumped-hydro or CAES



OREGON

House Bill (H.B. 2193) mandates 5MWh of energy storage by 2020.

WASHINGTON

Two laws enacted:
- 2.5x credit under RPS for energy storage output from renewables
- Utilities must include storage in all integrated resource plans

MASSACHUSETTS

House and Senate Bill (H.4568) set in motion the process for an energy storage mandate. Target set at 200 MWh by 2020.

NEW YORK

Fourth state in the US with an energy storage mandate. Initial target goal of 1.5GW by 2025.

CALIFORNIA

AB2514 mandates 1.325GW of storage installed by 2024

HAWAII

RFP for 30 to 100 MWh of storage operational by 2017 (now delayed)

ARIZONA

$4M residential energy storage program

TEXAS

Senate Bill 943 allows energy storage projects to participate in wholesale market.

NEW JERSEY

NJCEP: $6M for FY 2016. Half of that for open enrolment for behind-the-meter grid-connected projects. Open enrolment continues in 2017 with $3M for similar projects.

Source: Multiple sources

FERC Order 841 has outlined a series of requirements for the RTOs designed to address wholesale market barriers for storage

Order 841 requirements for RTOs:

- Must ensure participating resources are eligible to provide all capacity, energy and AS the resource is technically capably of delivering
- Execute all storage wholesale transactions at the relevant LMP
- Ensure resource can be dispatched and set the wholesale price
- Recognize the operational characteristics of storage
- Establish a minimum size requirement that is no greater than 100 kW
- Allow storage to de-rate capacity to meet minimum run-time needs

Order 841 allows RTOs the flexibility to:

- Establish new AS products
- Set minimum run-time requirements for storage
- Establish bidding parameters to accommodate storage’s physical and operational characteristics
- Enable storage to self manage its SOC
- Determine if storage can provide AS without participating in the energy market
- Address technical details such as make-whole payments and conflicting dispatch instructions

Source: 162 FERC ¶ 61,127. Electric Storage Participation in markets operated by regional transmission organizations and independent system operators.

The flexibility of deployment that storage offers means that along with Order 841, extensive regulatory reform is needed at the state-level to efficiently accommodate storage

Some open issues relating to storage integration at the utility and customer level

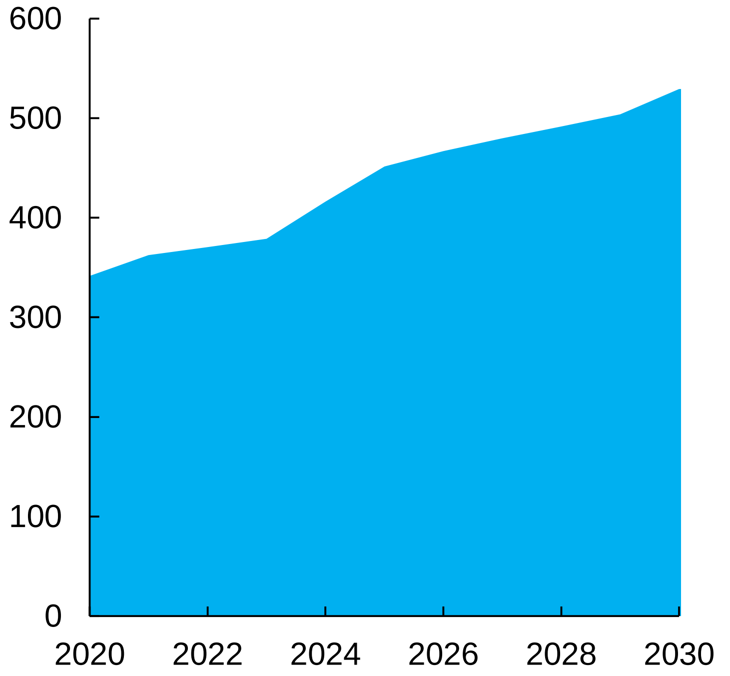
- Extensive opacity remains regarding utility ownership and operation of storage assets
- Storage is not yet integrated fully into resource adequacy and T&D planning processes
- The quantification of the value of storage-provided benefits to the grid and to customer is not well defined
- Little clarity regarding what services distribution and BTM storage assets can/should be allowed to provide
- No established protocols for managing the potential for simultaneous dispatch
- Need to review the impact of storage availability on the suitability of existing and future rate designs
- Etc etc etc

The growth of the ”more engaged customer”

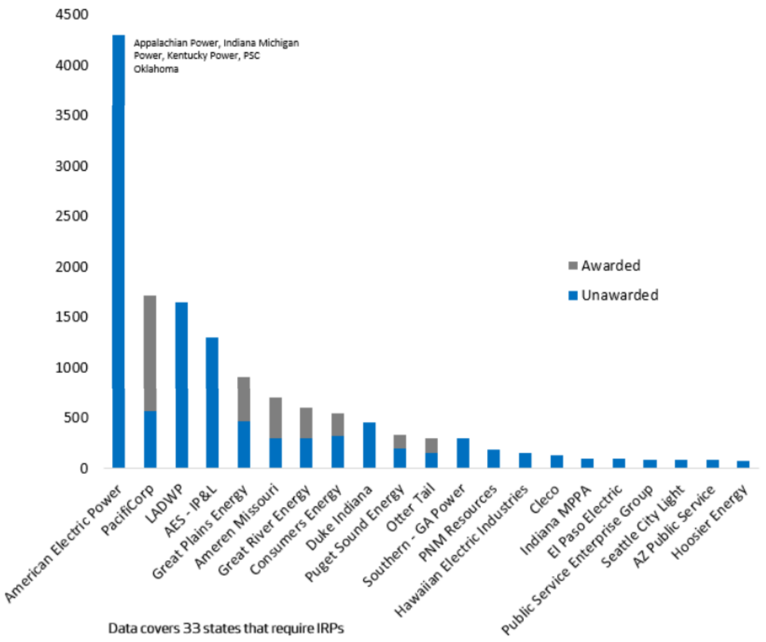
RPS targets, and new state-level clean energy mandates continue to support renewables growth, but IRP processes and the ever expanding appetite for corporate PPAs are become increasingly important factors

Required growth in renewables generation to meet existing RPS targets to 2030

TWhrs

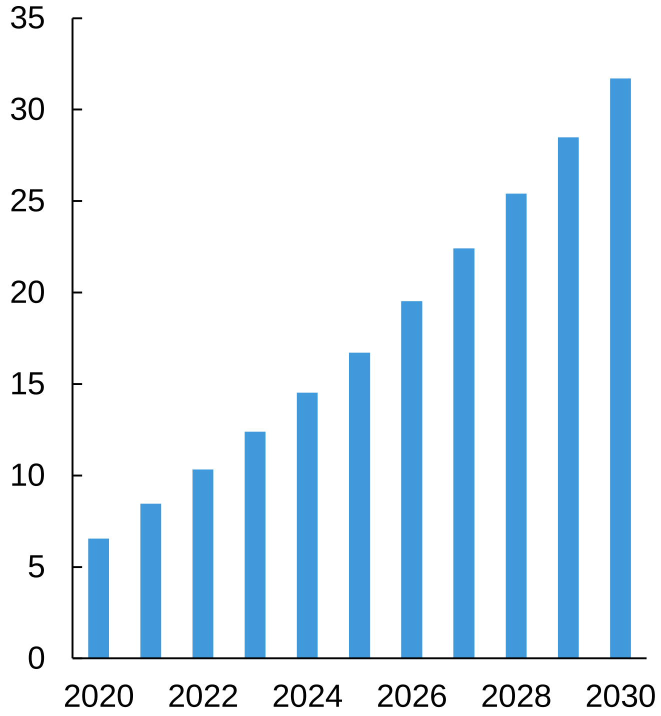


11 GW of currently outstanding IRP demand across the US



Shortfall in US corporate PPA commitments to 2030 based on existing contracted capacity

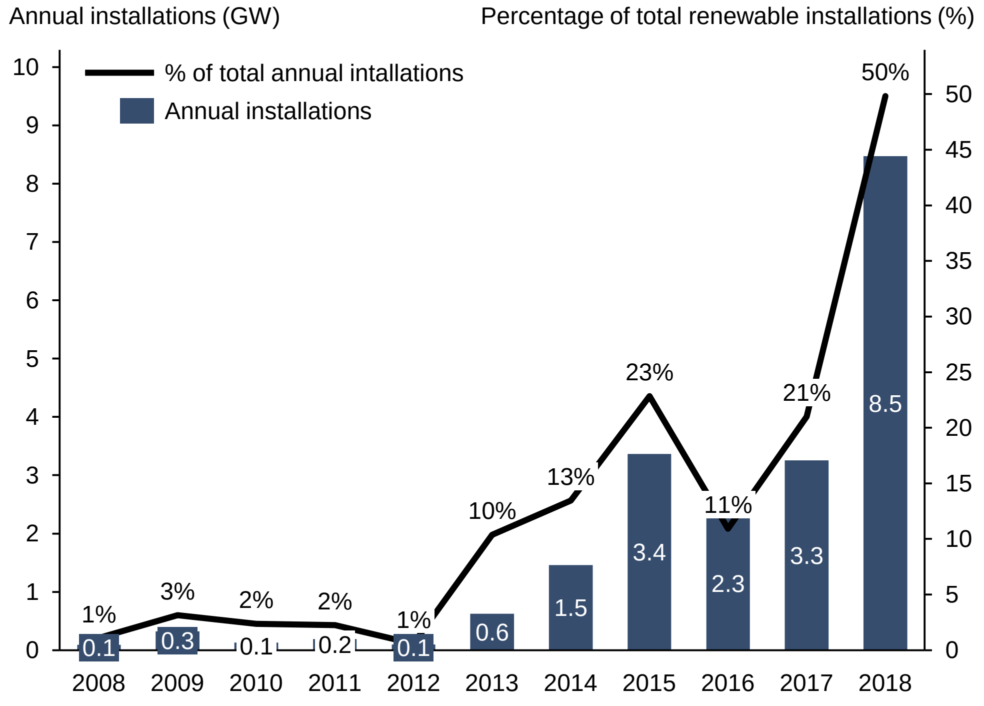
GWs



Source: EIA, Vestas, BNEF, LCE

Corporate PPAs are already a key part of the wind market and there is runway for appreciable growth – Initial momentum came from large players like Amazon, Google & Facebook, but innovations in deal structuring are unlocking new opportunities with smaller entities that want to procure renewables

US corporate PPAs have grown to a substantial and increasing portion of renewable installation volume



Corporate PPA market growing across geographies and deal structures, accessing wider pool of corporations

Corporate clean energy PPAs are gaining popularity across all regions, including in those where slower demand was expected due to cheap power prices, such as ERCOT

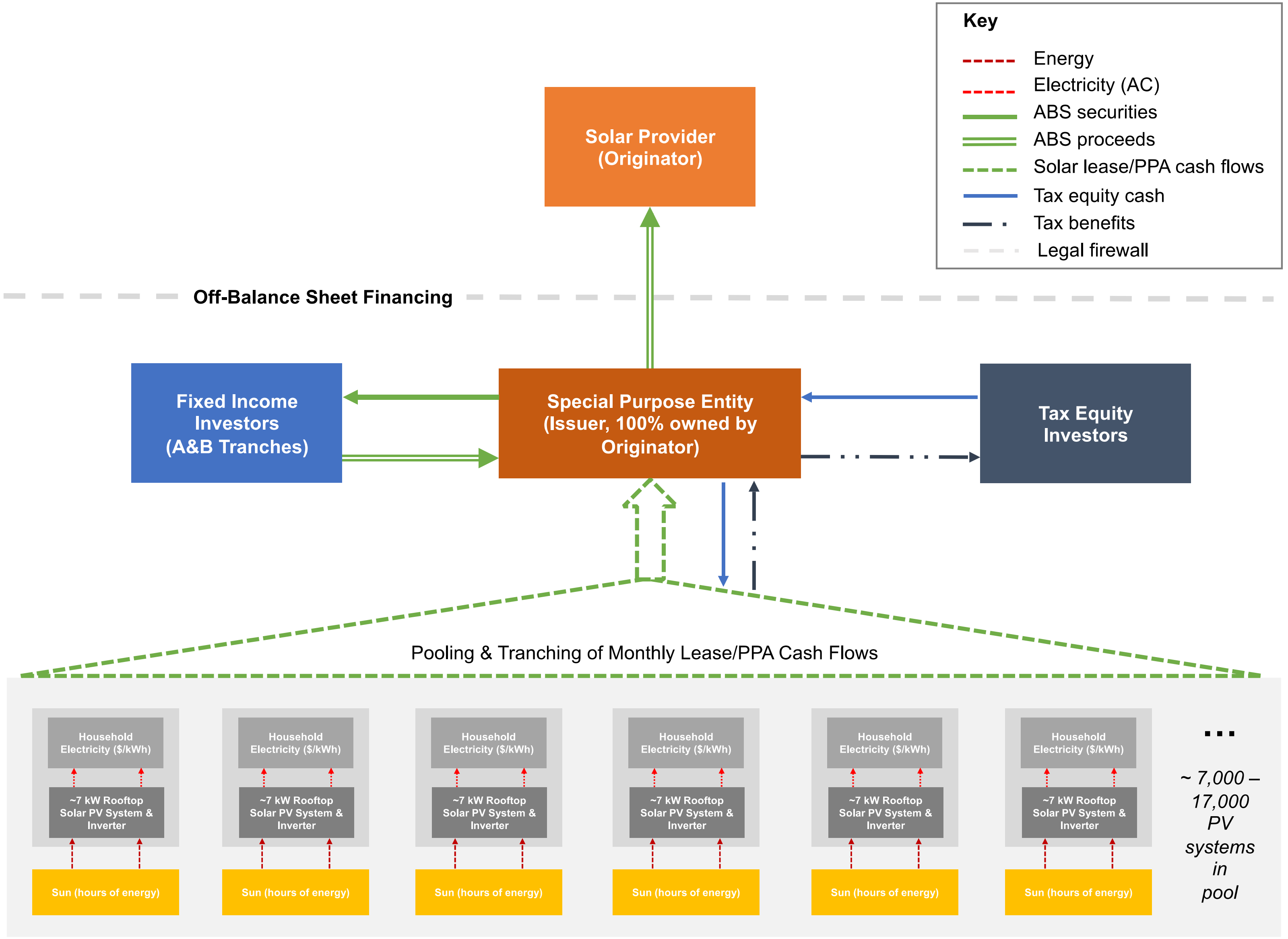
While major corporations still procure most volume, corporate PPA growth is driven by smaller corporations bundling procurement to capture scale economics of large generators

- Facebook was the largest clean energy purchaser in 2018, procuring 2.3 GW in the US
- 34 corporations signed their first renewable energy PPA in 2018, making up 31% (2.7 GW) of total volume

Most early corporate PPAs were physical PPAs, however virtual PPAs are now 66% of all corporate PPA volume, with green tariffs from regulated utilities making up most of the rest

Source: BNEF

An interesting adjunct to the growth in the residential solar business has been the emergence of new financial products to support the market



Sources: Kroll, U.S. Department of Energy NREL, SEIA, SolarCity, Marathon Capital, MIT

The next wave of commercial innovation will likely leverage data and IT to much greater extent to shape new services

Google + 

= **$3.2B**

ORACLE + OPOWER = **$500M**

The key to enabling these new services and achieving an efficient balance of centralized and distributed systems lies in how we structure our rates

- **The more widespread adoption of smarter devices means customer can no longer be lumped into broad classes**

- **The definition of rates specific to individual technologies is an untenable approach that must be avoided**

- **Rate design efforts should simply focus on charging or remunerating specific *services,* regardless of what technology is used**

- **The potential for regulatory arbitrage should be avoided through ensuring symmetrical rates for injection and withdrawal**

Source: MIT Utility of the Future Study, F. O'Sullivan

**“The future, you do not need to foresee it,
but enable it”**

Antoine de Saint Exupéry