Electrification and its Implications for the California Electricity System

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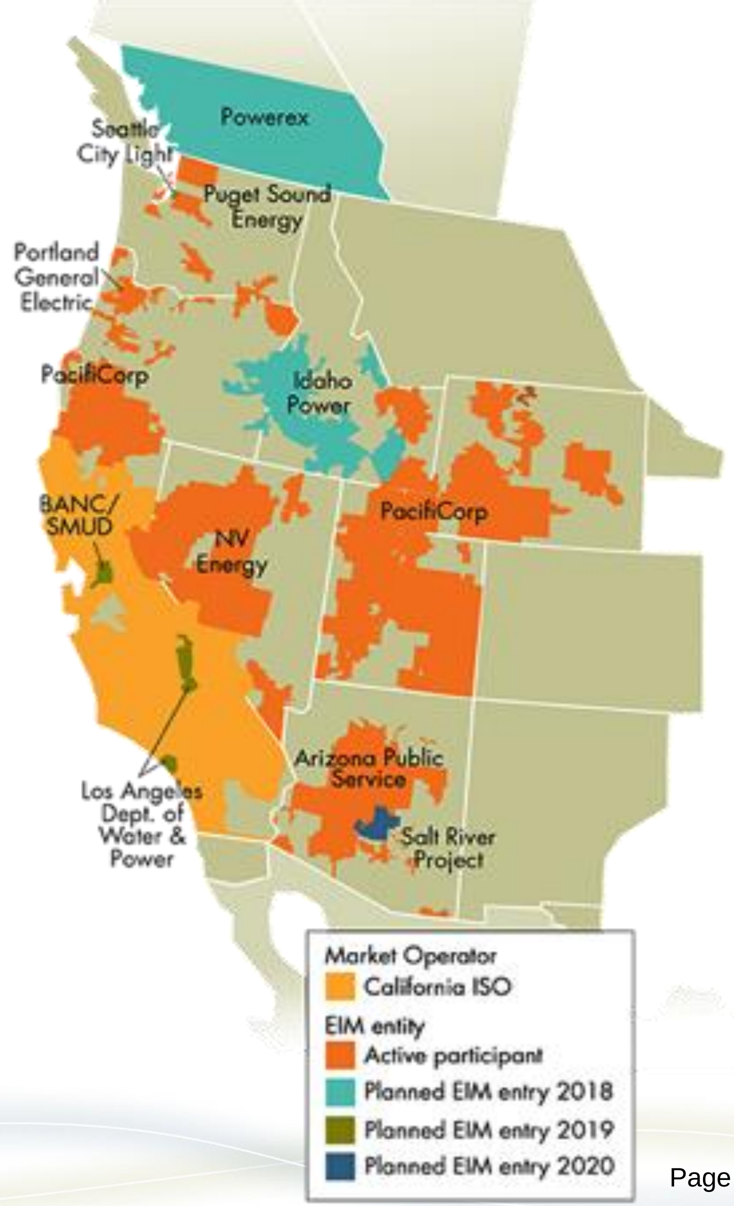
Ideas in this presentation are offered for discussion purposes only, and do not reflect the views or policies of the California ISO.

Topics of this presentation

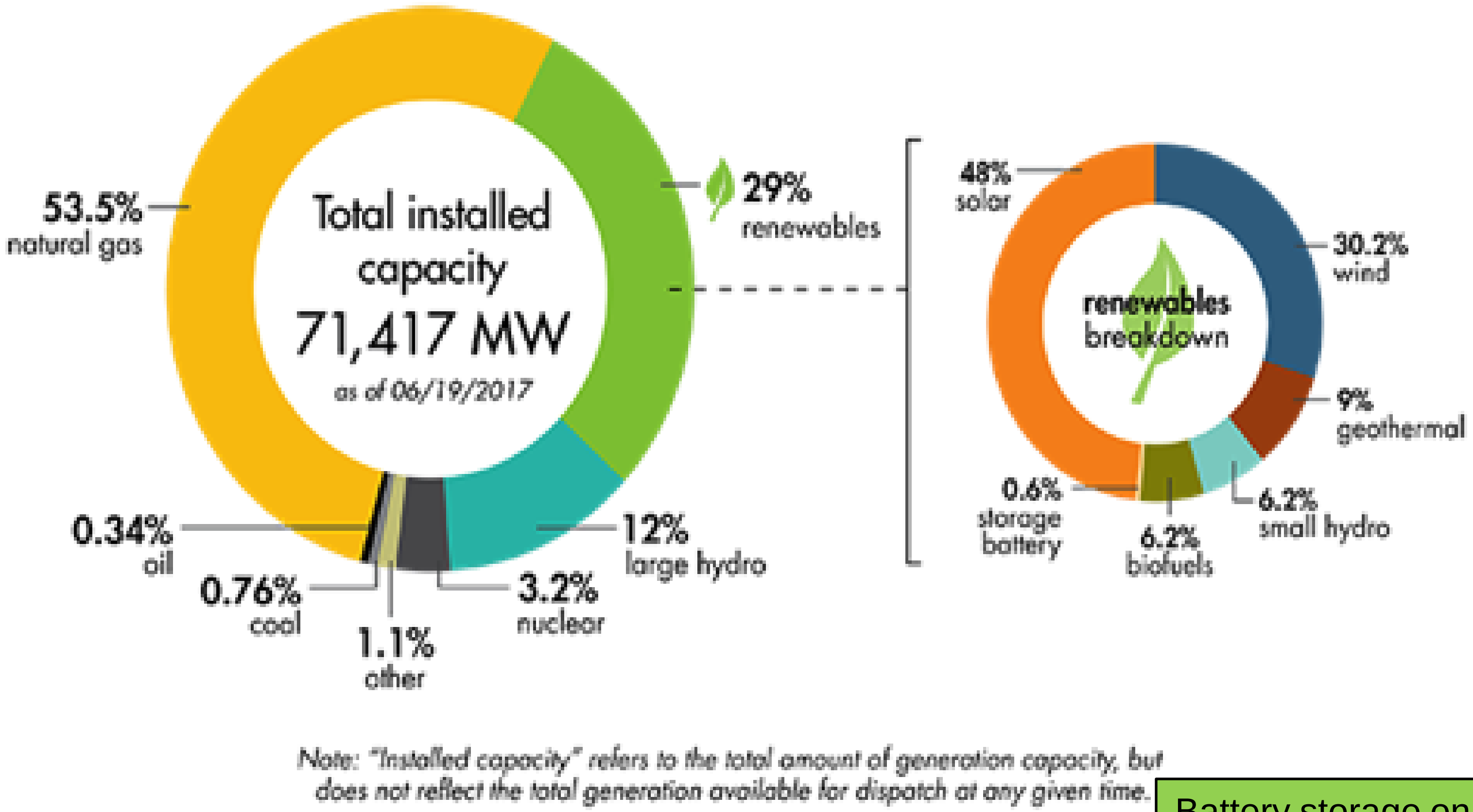
- Some facts about California ISO
- California's energy policies and policy goals
- Challenges to achieving the policy goals
- Electrification: the other 80% of carbon emissions
- Electrification will impact the distribution system
- Multiple strategies for addressing the challenges
- Storage as key to deep electrification
- Open questions and works in progress
- Vision of a future grid architecture

California Independent System Operator

- **71,800** MW of power plant capacity (installed capacity)
- **50,270** MW record peak demand (July 24, 2006)
- **27,488** market transactions per day (2015)
- **25,685** circuit-miles of transmission lines
- **30 million** people served
- **240 million** megawatt-hours of electricity delivered annually (2015)
- Not-for-profit public benefit corporation



California ISO resource mix



Battery storage on the grid

- Over 100 MW participating in CAISO markets today
- 1.325 GW mandated utility procurement, to operate by 2024
- Over 5 GW in the interconnection queue

California ISO is fully committed to achieving the state’s energy and environmental policy objectives.

California’s policy objectives:

– Broad decarbonization of the California economy
– Low-carbon, reliable electricity system
– Growth of distributed generation
– Customer choice for adoption of distributed resources and on-site devices of all types
– Environmental justice for disadvantaged communities
– Greater resilience through community resources and micro-grids

Energy and environmental policy targets

2020 Policy Goals

- Greenhouse gas emissions reduced to 1990 levels
- 33% of load served by renewable generation
- Elimination of once-through cooling in coastal power plants

2025 Policy Goal

- 1.5 million electric vehicles

2030 Policy Goals

- 4 million electric vehicles
- 50% of load served by renewable generation
- Double energy efficiency of existing buildings
- Greenhouse gas emissions 40% below 1990 levels

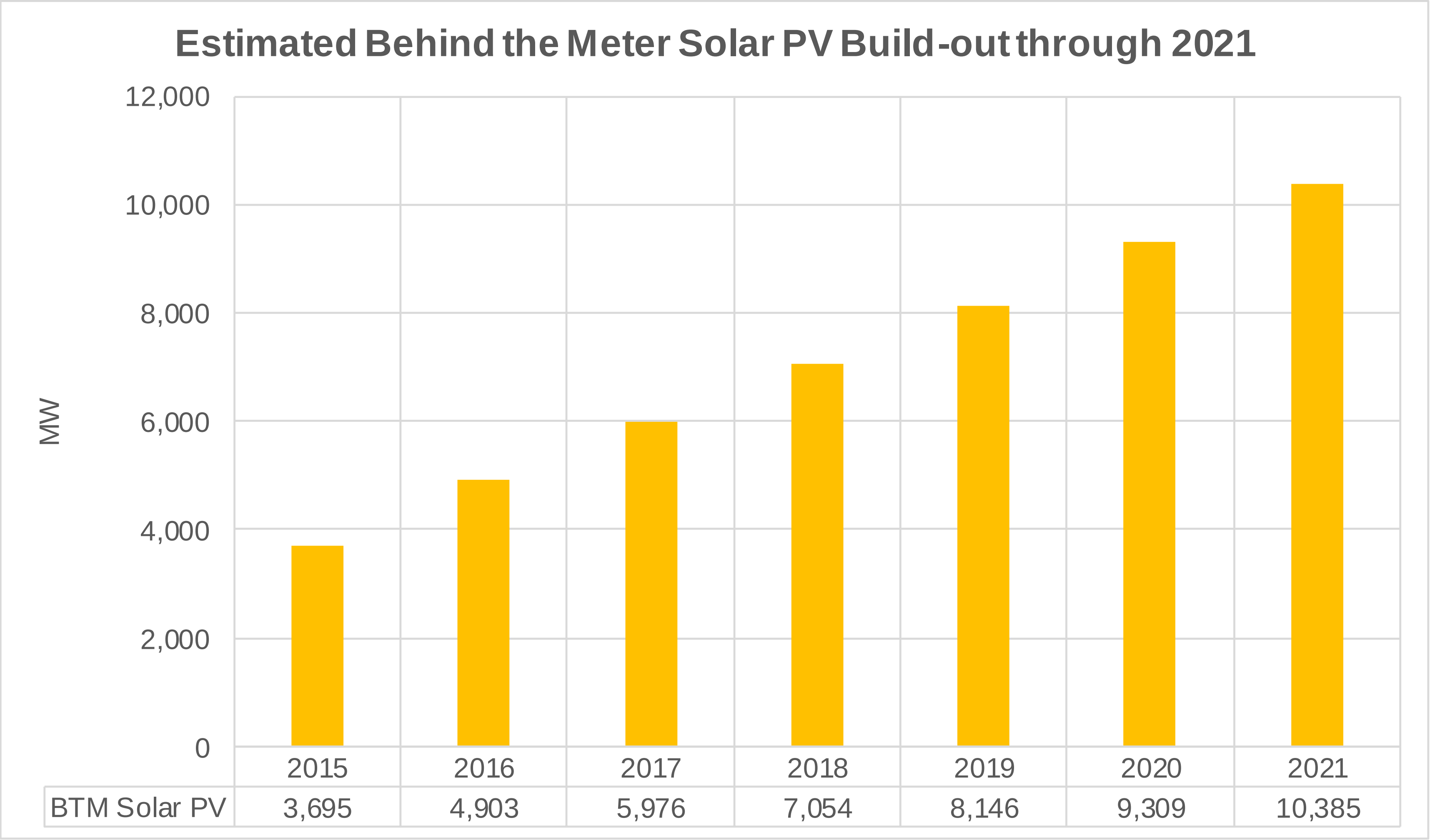
2050 Policy Goal

- Greenhouse gas emissions 80% below 1990 levels
- 100% renewable generation by 2045 (possible 2018 legislation)

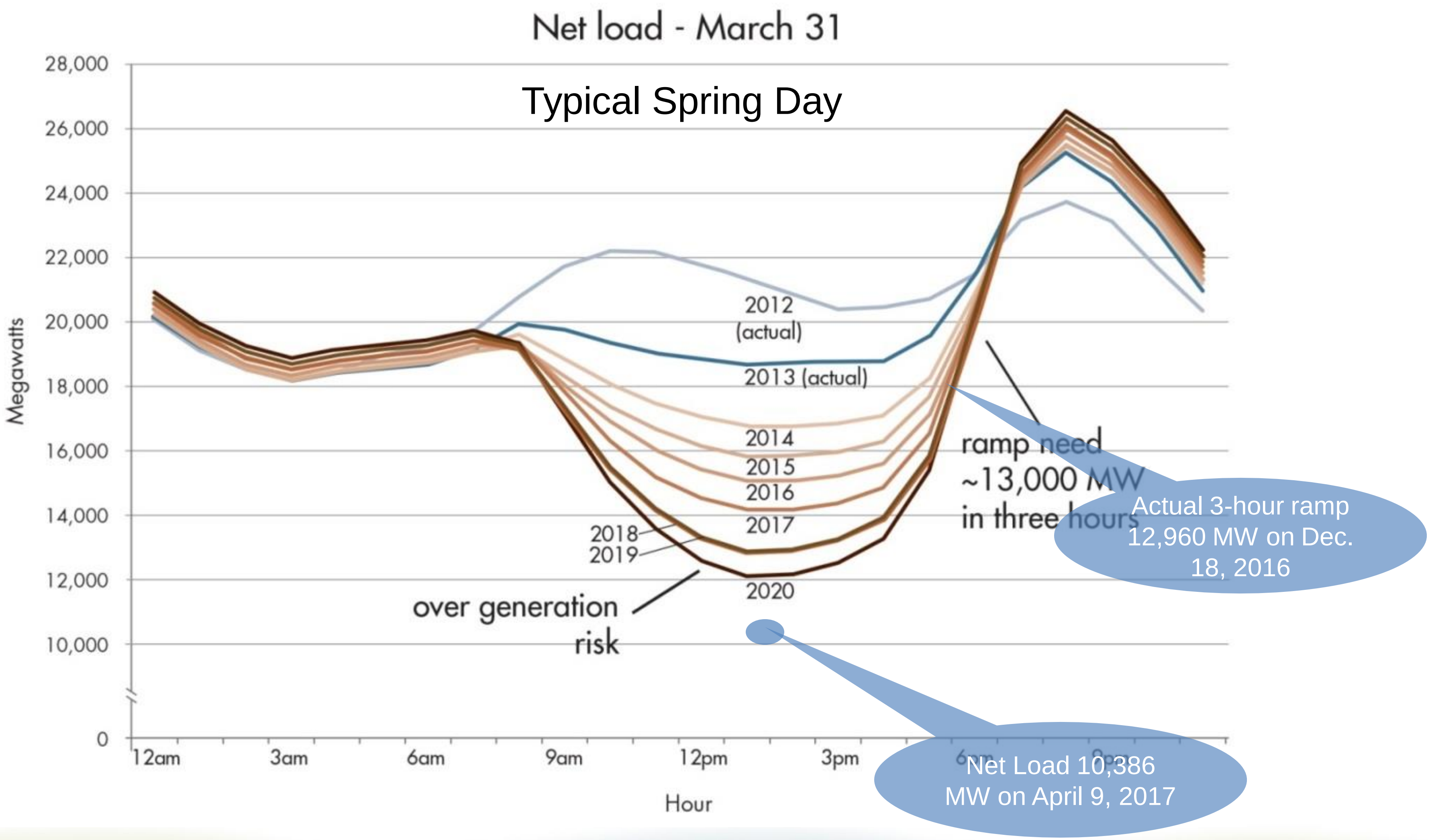
Achieving the goals entails some challenges.

- Severe system net load shapes – the “duck” curve
- Real-time variability of renewable energy production
- Zero marginal cost energy depresses prices and revenues in the wholesale spot market
- Distributed energy resources (DER) seek wholesale market participation and revenues
  - “Value stacking” for multiple revenue streams
  - “Smart” distribution-level electrification creates more DER
- Hard-to-forecast autonomous DER adoption and behavior – crucially needed for infrastructure planning
- Regulatory frameworks, business models, industry culture are all based on the traditional centralized, one-way paradigm
- Crucial role of local governments in transportation and building electrification is not yet well recognized and supported

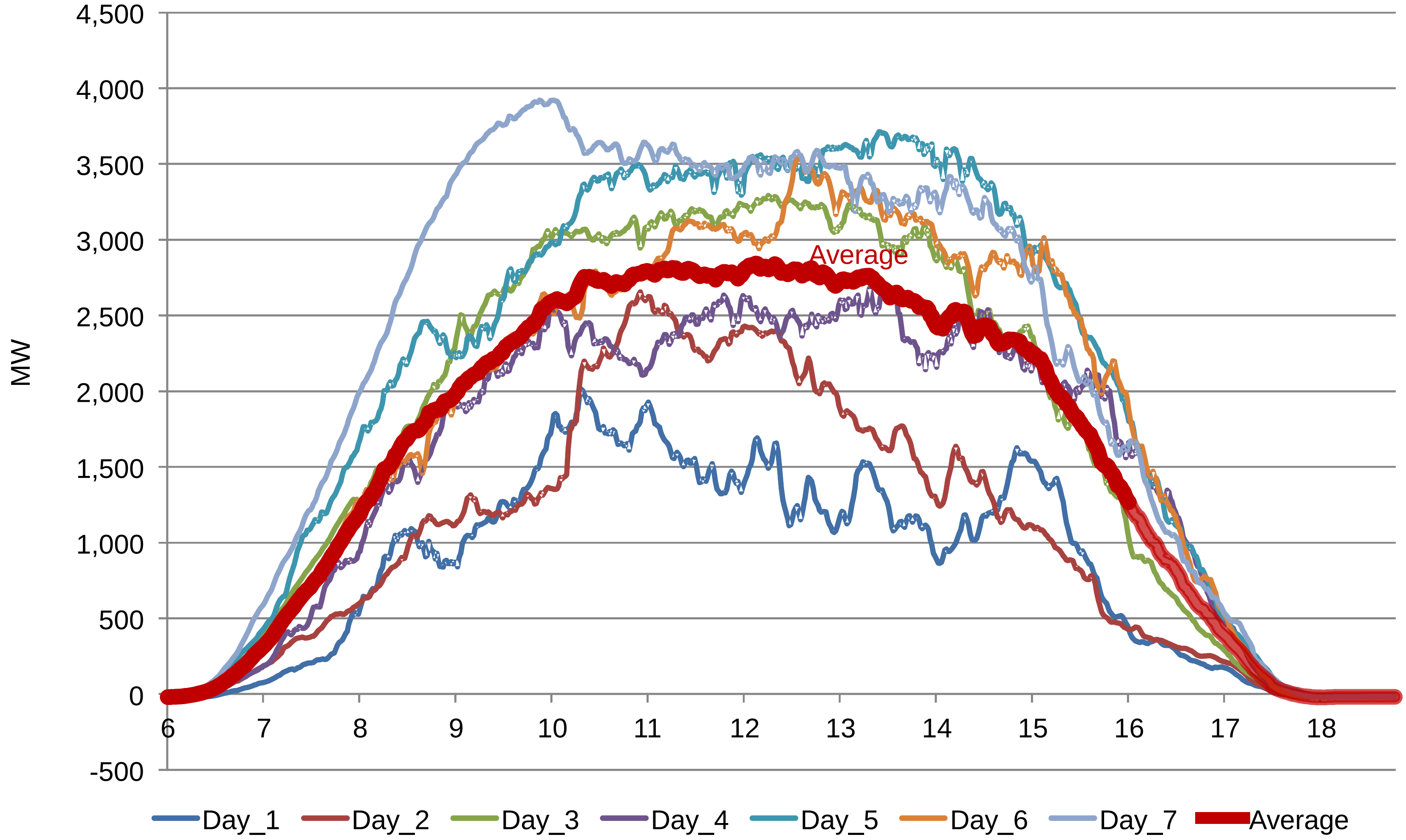
Distributed Solar PV in California



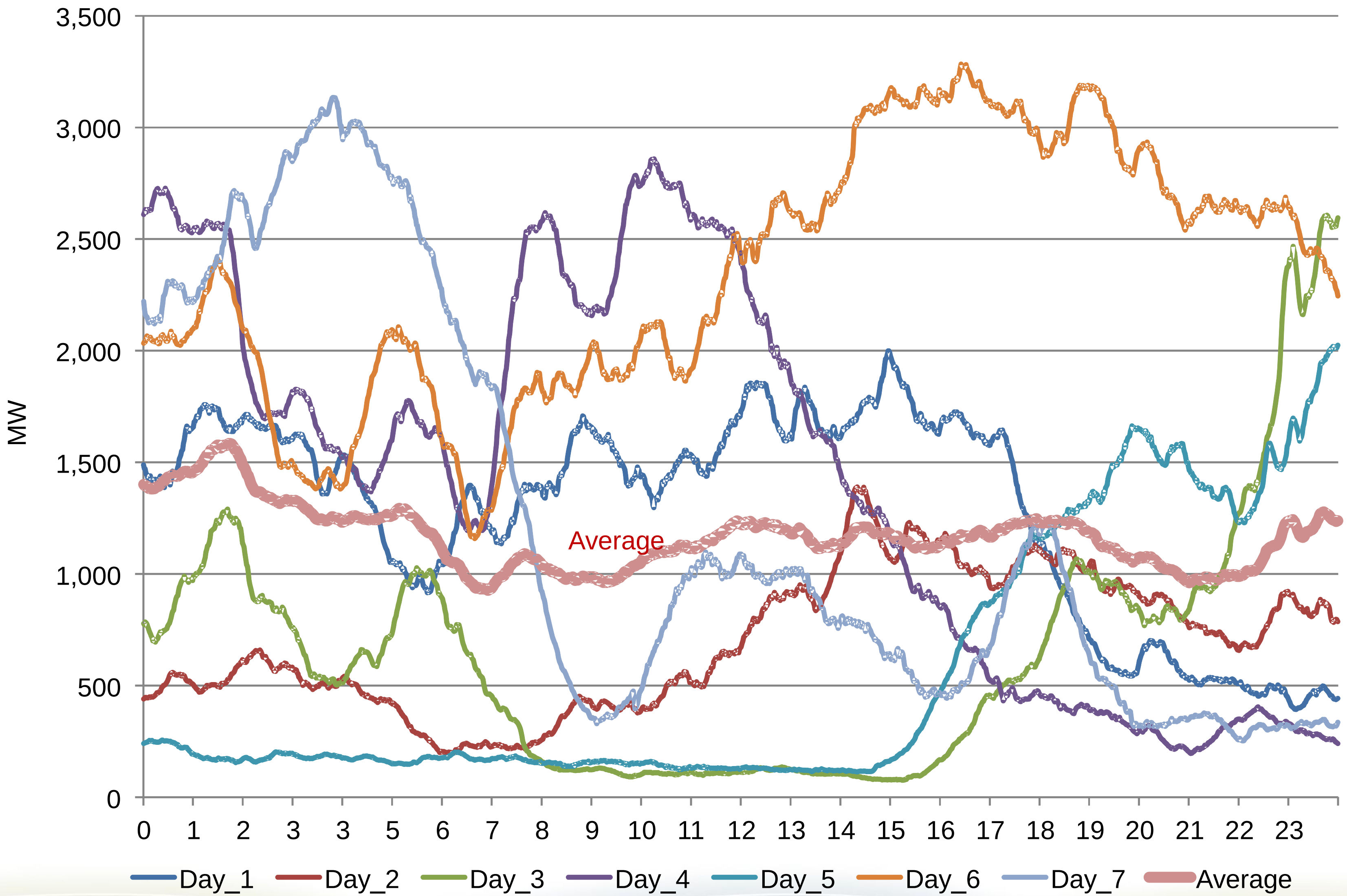
Recent events surpass previous forecasts of net load and afternoon ramp with high solar PV on the system.



Solar production varies from one day to the next – first week of March 2014



Wind production varies from one day to the next – first week of March 2014



California ISO

The larger challenge: broad electrification of all fossil-fuel uses: transportation, buildings, industry, agriculture

– The electric system accounts for only 20% of GHG emissions
– Transportation about 42%, buildings about 35%

Grid objectives for accommodating new electrification demand

– Transportation and building electrification impacts will occur largely in the distribution system
    - "Smart" electrification can lead to growth of dispatchable DER
    - Shape local load and supply profiles locally
    - Manage short-term volatility locally
    - Extreme load profiles and volatility exported to transmission tend to increase use of gas generation
– Shape added demand from electrification to minimize need for new transmission infrastructure and to increase capacity factors
    - Peak demands occurring a few hours per year tend to drive costly transmission investment

These challenges are manageable with multiple complementary strategies.

- Incentives for renewables to be controllable and dispatchable
- Wholesale market models to enable DER and storage participation
- New coordination framework between ISO and distribution utilities for T-D interface operations and integrated T&D planning
- Incentives to flatten load profiles and mitigate variability locally
  - Structure T&D charges to reflect impact on the system
- Price signals to incentivize work-place EV charging and to expand other uses of plentiful daytime solar energy
- Engage and support cities & counties to electrify local transportation and building energy needs
  - Building retrofit programs using thermal storage & heat pumps
- Micro-grids for local resilience may also provide T&D services
- Expand regional coordination to optimize diversity benefits

Storage may be key to broad electrification.

- Energy storage of various types and scales could meet the challenges of high-volume solar PV
  - At grid-scale: charge at low/negative prices to make good use of mid-day excess supply
  - Co-locate with utility-scale PV and wind to smooth output to grid
  - Discharge to mitigate steep ramp and late afternoon peak
  - Provide demand response, frequency response and regulation
  - With rooftop PV: minimize back-flow on distribution, to increase circuit “hosting capacity” and defer distribution upgrades
  - Manage local variability locally and flatten load profiles
  - Building climate systems using heat pumps, thermal and battery storage, PV and control systems can maintain desired internal temperature with smooth interconnect to the grid

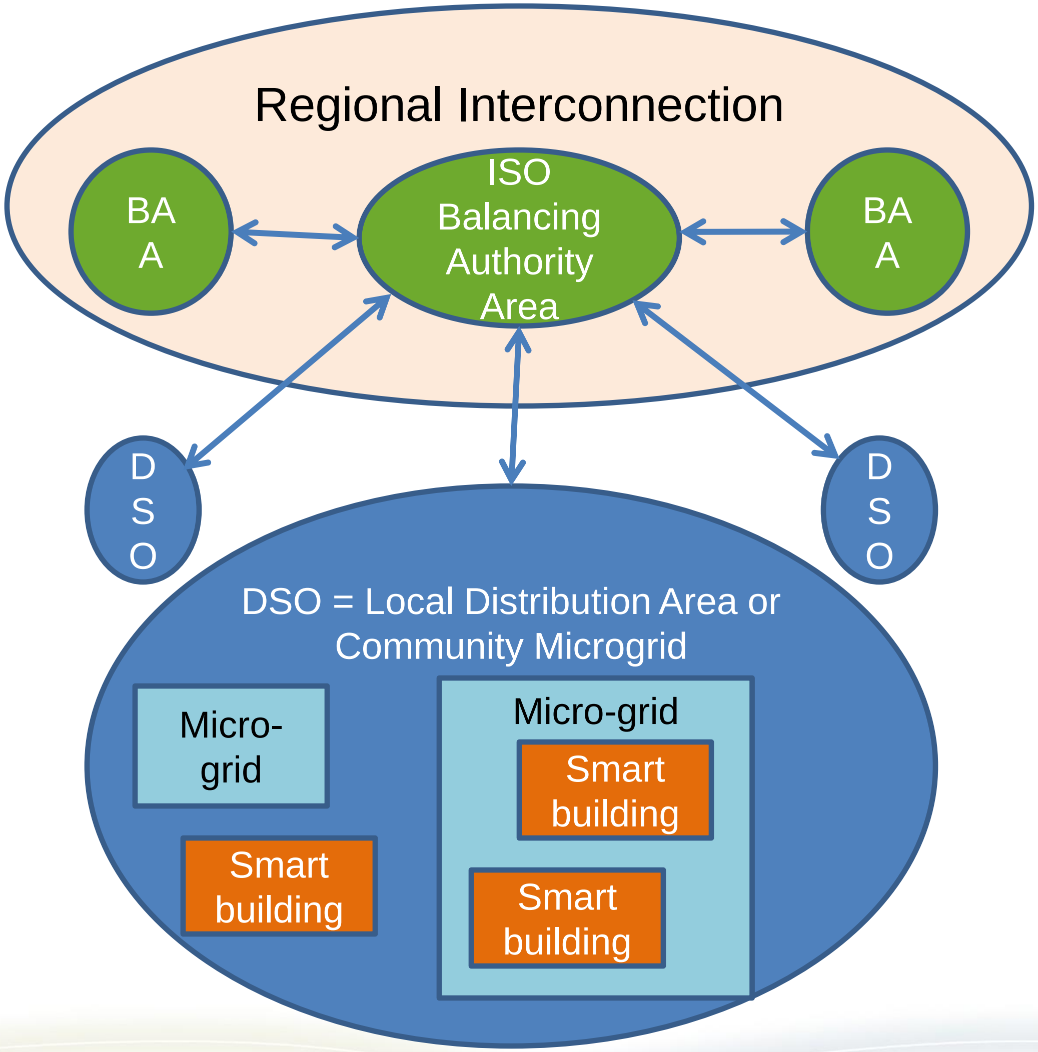
Policy makers need to expand thinking outside the box of centralized control and energy as commodity.

- Existing markets, rates and cost recovery based on kWh commodity
  - End users care about energy services and will substitute on-site devices for grid energy => grid may serve as residual supply
  - Cost of reliable grid operation is more a function of variability than volume of energy
- Key societal values are not yet valued financially and compensated
  - Resilience benefits; manage risks of extreme disruptive events
  - Local mitigation of volatility and extreme load profiles
  - System architecture to improve physical and cyber security
- Electrification will be largely local, driven as much by bottom-up adoption as top-down policy
  - Regulators have less control, must become enablers of change
  - Local governments undertake electrification and adopt DER for local economic and resilience benefits, yet they are not viewed as partners for achieving state policy goals.

Open questions and works in progress

- Electrification, DER growth and grid modernization are linked
  - Electrification drives growth of DER that can provide grid services
  - DER growth necessitates distribution grid modernization
- Multiple-use applications can optimize DER value
  - DER can provide services to and earn revenue from multiple entities: customer, distribution operator, transmission/wholesale market
  - Must address open MUA issues: dispatch priority; measurement; double payment; wholesale/retail pricing
- DSOs, local electricity markets and micro-grid systems
  - New distribution system operator (DSO) models can facilitate revenue opportunities for DER
  - Create an “open access” regulatory framework for DSOs analogous to wholesale market framework for ISOs
  - Develop a layered reliability framework to allow hand-off of reserve and adequacy requirements from ISO to DSO at the T-D interface
  - Enable customized reliability/resilience solutions using microgrids
  - Revisit some federal-state regulatory structures (US)

The future grid may be an "integrated decentralized" system, a layered hierarchy of optimizing sub-systems.



- Storage, DG and controls on premises form a building-level microgrid
- Each layer only needs to see its interchange with next layer above & below, not details inside other layers
- ISO optimizes regional bulk system only up to the T-D interfaces
- Layered control structure reduces complexity, allows scalability, and increases resilience & security
- Fractal structure mimics nature's design of complex organisms & ecosystems.

Thank you.

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Sources and resources

CAISO report: Electricity 2030: Trends and Tasks for the Coming Years

- http://www.caiso.com/Documents/Electricity2030-TrendsandTasksfortheComingYears.pdf

Using renewables to integrate renewables

- http://www.caiso.com/Documents/UsingRenewablesToOperateLow-CarbonGrid.pdf

Future Distribution Systems, Platforms and DSOs

- http://doe-dspx.org
- https://emp.lbl.gov/sites/all/files/FEUR_2%20distribution%20systems%2020151023.pdf

Grid Architecture

- http://gridarchitecture.pnnl.gov

Decentralization and Layered Optimization

- http://resnick.caltech.edu/docs/Two_Visions.pdf
- https://www.academia.edu/12419512/A_Future_History_of_Tomorrows_Energy_Network