CALIFORNIA LESSONS: The CSI's Foundational Role in Microgrid Development

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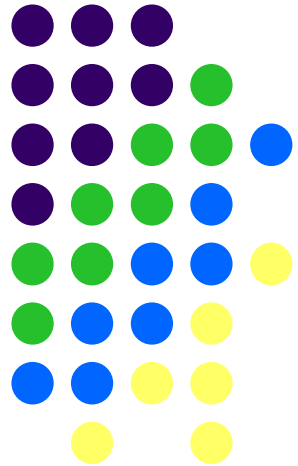

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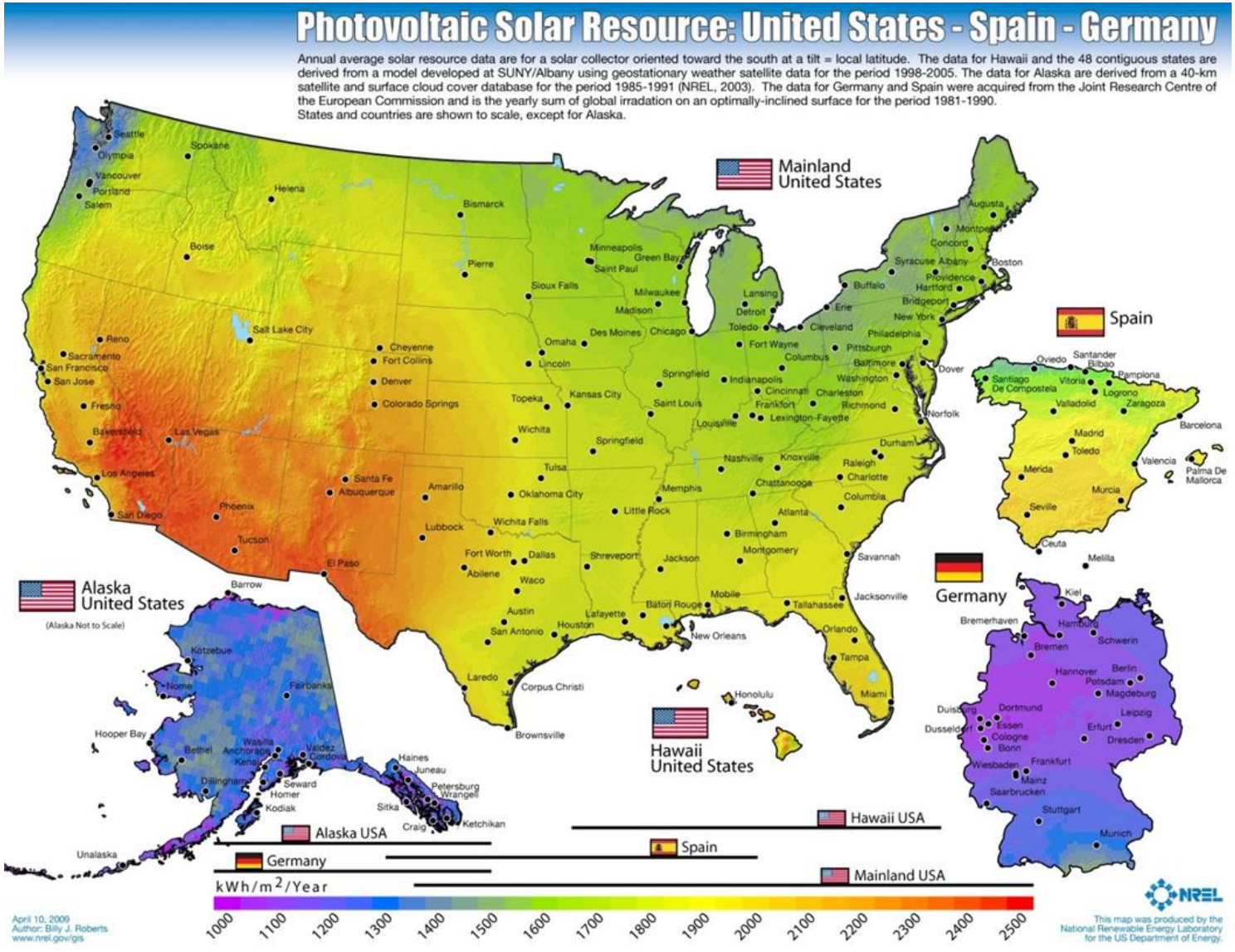
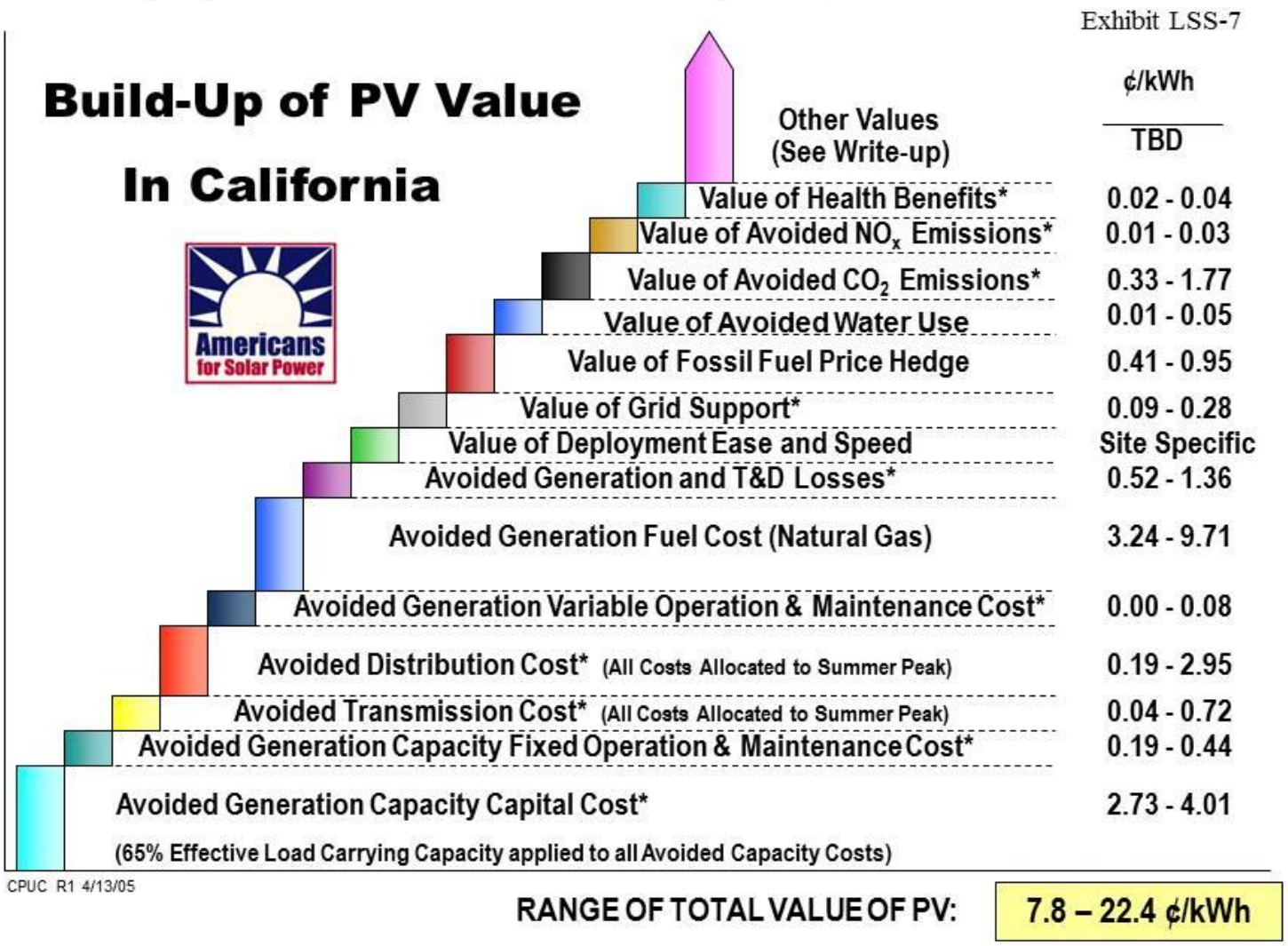
California and Germany: Policy vs. Resource Strength

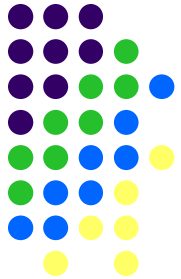


Explicit PV Value Proposition Supported Ratepayer Funding



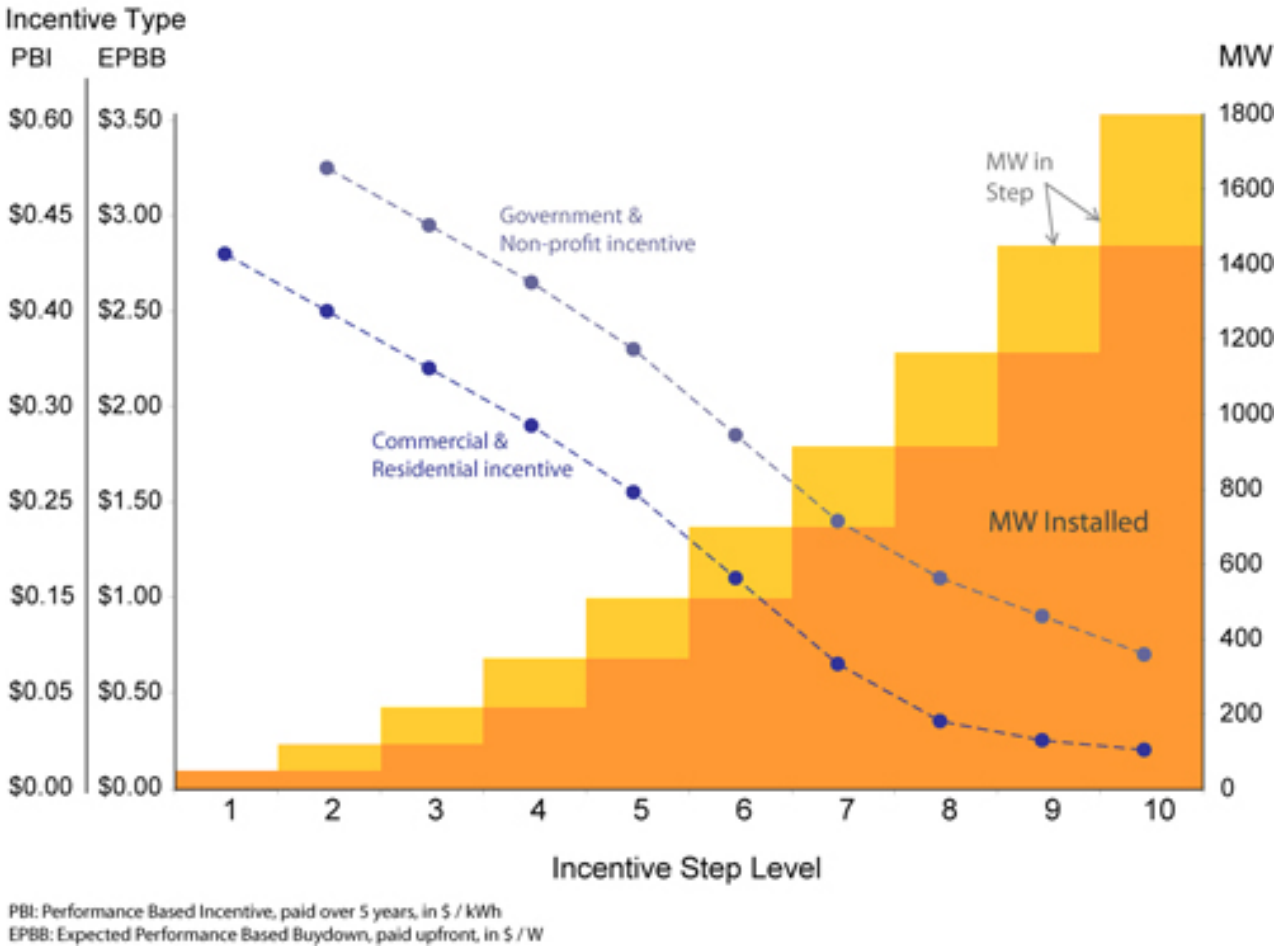
Source: CPUC, Docket No. R.04-03-017, ASPv, *Prepared Testimony on Itron Report on Framework for Assessing the Cost-Effectiveness of the Self-Generation Incentive Program*, April 13, 2005.

California Solar Initiative ("CSI"): Basic Parameters



- $3.3 Billion in Ratepayer-Funded Incentives
  - 10-Year (2007-2016), Solar PV *and* Thermal, Multiple Programs
- Major Goals:
  - 3,000 MW total installed capacity; maximum on-peak performance, preceded by energy efficiency measures
    - Solar energy systems on 50% of new homes in 13 years
  - Self-sufficient solar industry; viable mainstream option
- Incentives for 1 kW-5 MW systems; paid only up to 1 MW.
  - Performance-Based Incentives; paid over 5 years (50^{+} kW)
  - Expected Performance-Based Incentives; paid up-front (<50 kW; capacity-based)
  - Incentives decline at least 7% per year; ratcheted down at specific installed capacity level thresholds
- Most CSI programs closed at the end of 2016
- Net metering for solar PV production remains.

CA CSI: Incentives Declined as Installed Capacity Grew



PBI: Performance Based Incentive, paid over 5 years, in $ / kWh
EPBB: Expected Performance Based Buydown, paid upfront, in $ / W

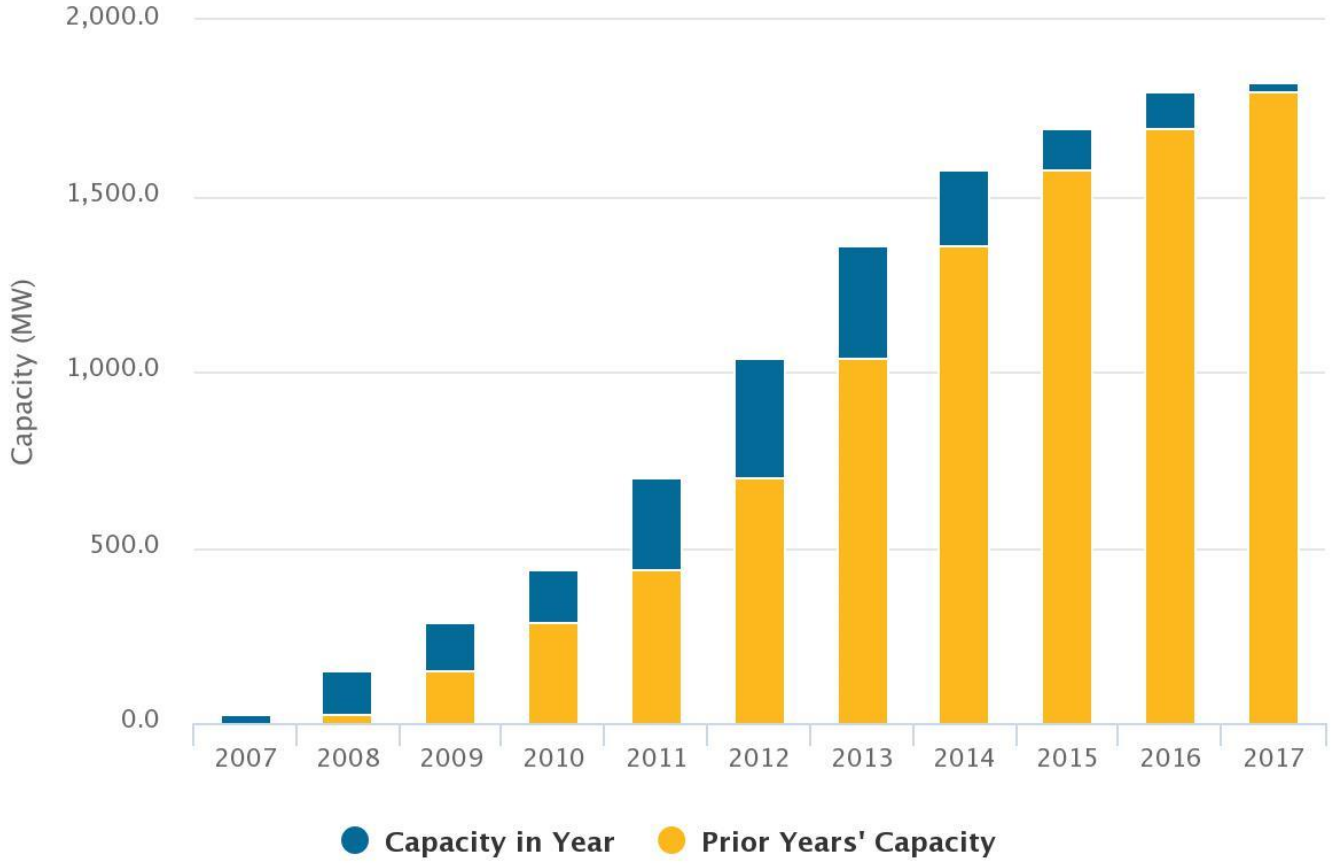
http://www.cpuc.ca.gov/General.aspx?id=6058

The CSI General Market Program pays solar PV incentives all at once for smaller systems or over five years for larger systems; $2.1 billion in total incentives with a 1,750 MW installed PV target.

Expected Performance-Based Buydown (EPBB):
Smaller systems – less than 50 kW,
Intended for residential and small business customers
Upfront, capacity-based incentive that is adjusted based on expected system performance.

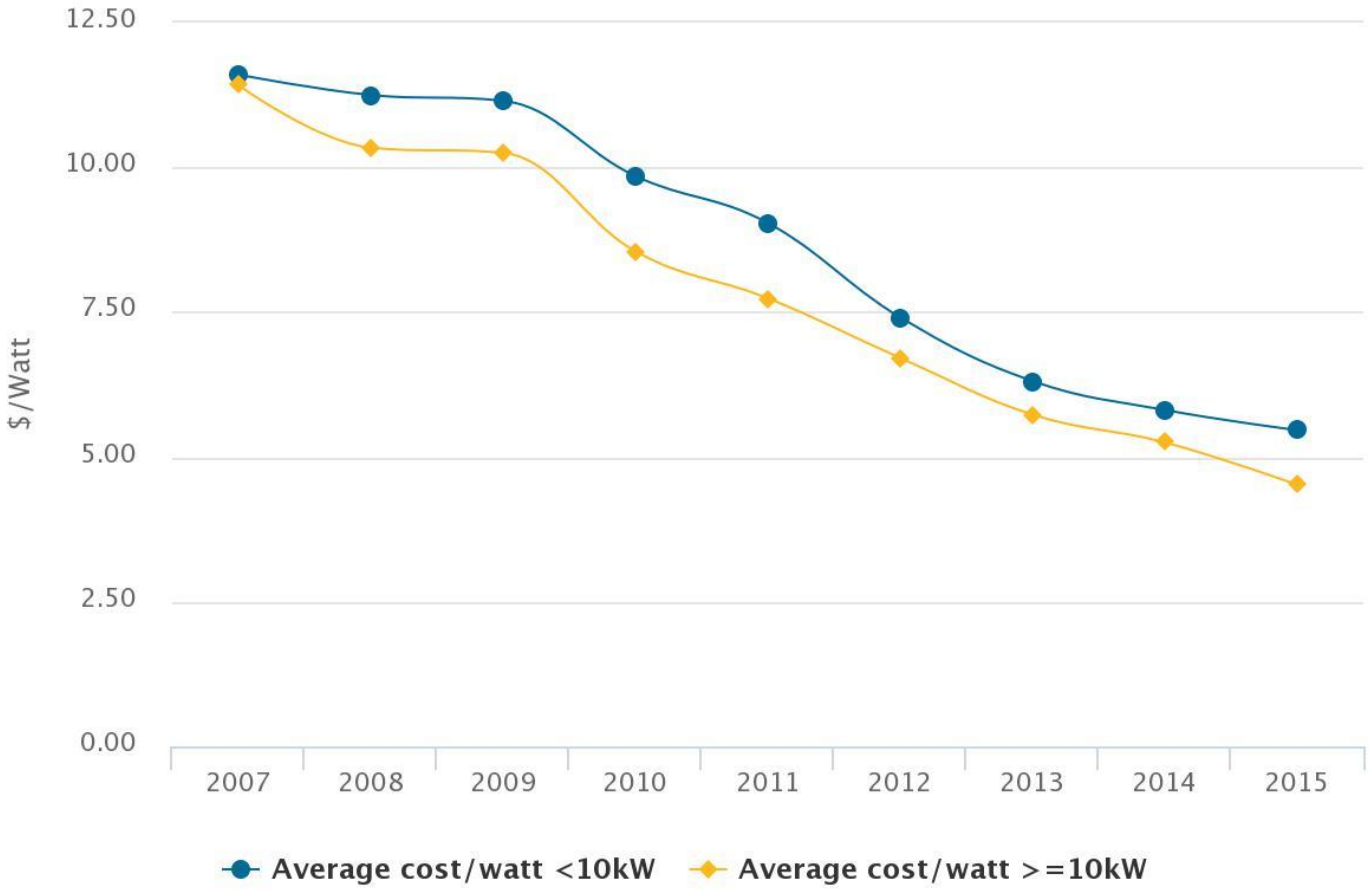
Performance-Based Incentive (PBI):
Larger systems – larger than 30 kW (applications between 10 and 30 kW can choose)
Intended for large commercial, government, & non-profit customers.

CSI: S-Curve Pattern of Capacity Installations by Year



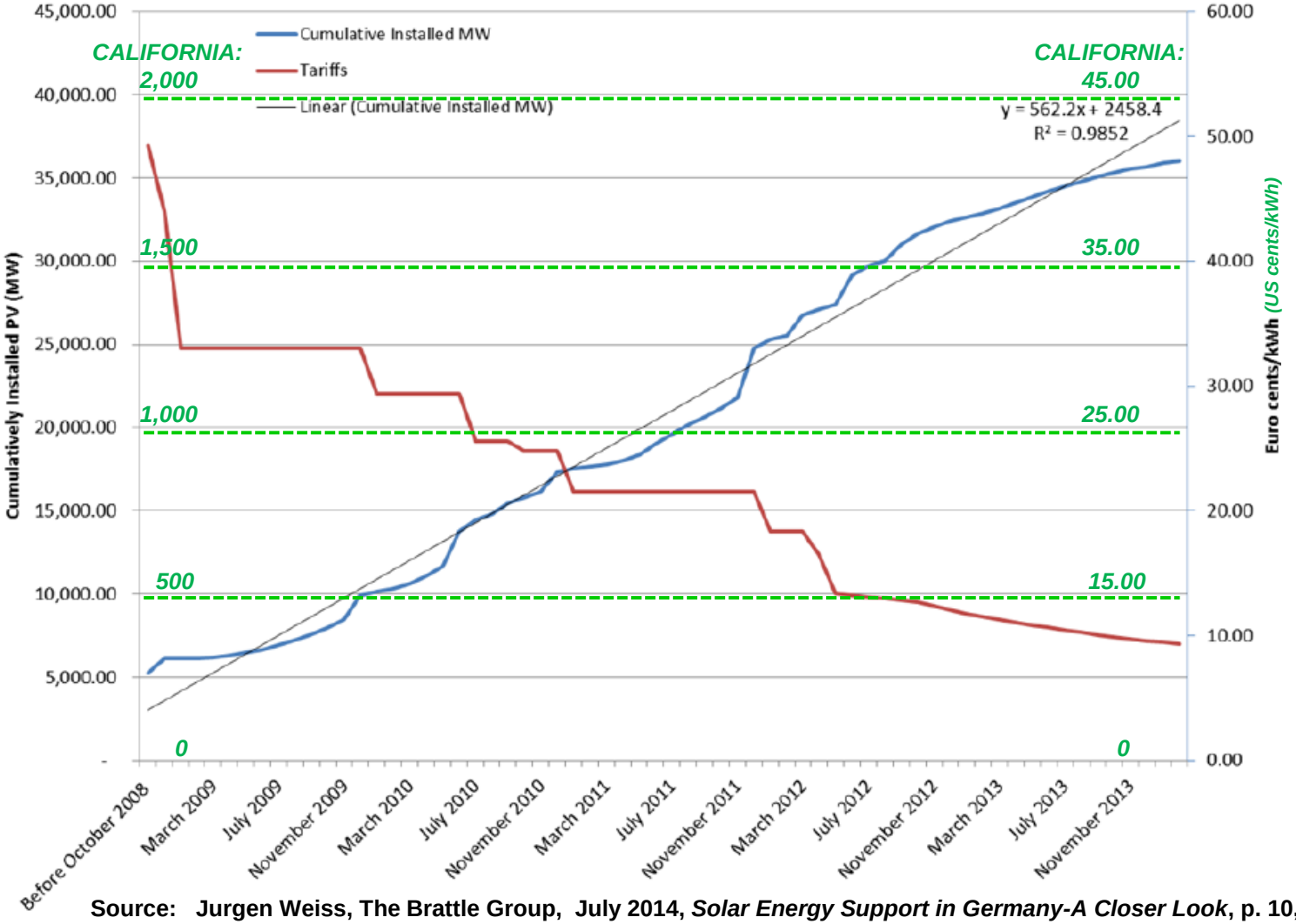
Source: California Distributed Generation Statistics, https://www.californiadgstats.ca.gov/charts/csi. Projects are bucketed by the First Incentive Claim Request Review Date which is used as the best proxy for an *installed* date in the CSI program. **Data current through 2018-02-21.**

CSI: Cost per Watt Dropped as Installed Capacity Grew



Source: California Distributed Generation Statistics, https://www.californiadgstats.ca.gov/charts/csi. Projects are bucketed by the First Incentive Claim Request Review Date which is used as the best proxy for an *installed* date in the CSI program. 142,464 project(s) were included for the generation of this chart. **Data current through 2018-02-21 and are not adjusted for inflation.**

German Feed-In Solar Tariff: 52 GW Cap vs. CSI's 3 GW Goal

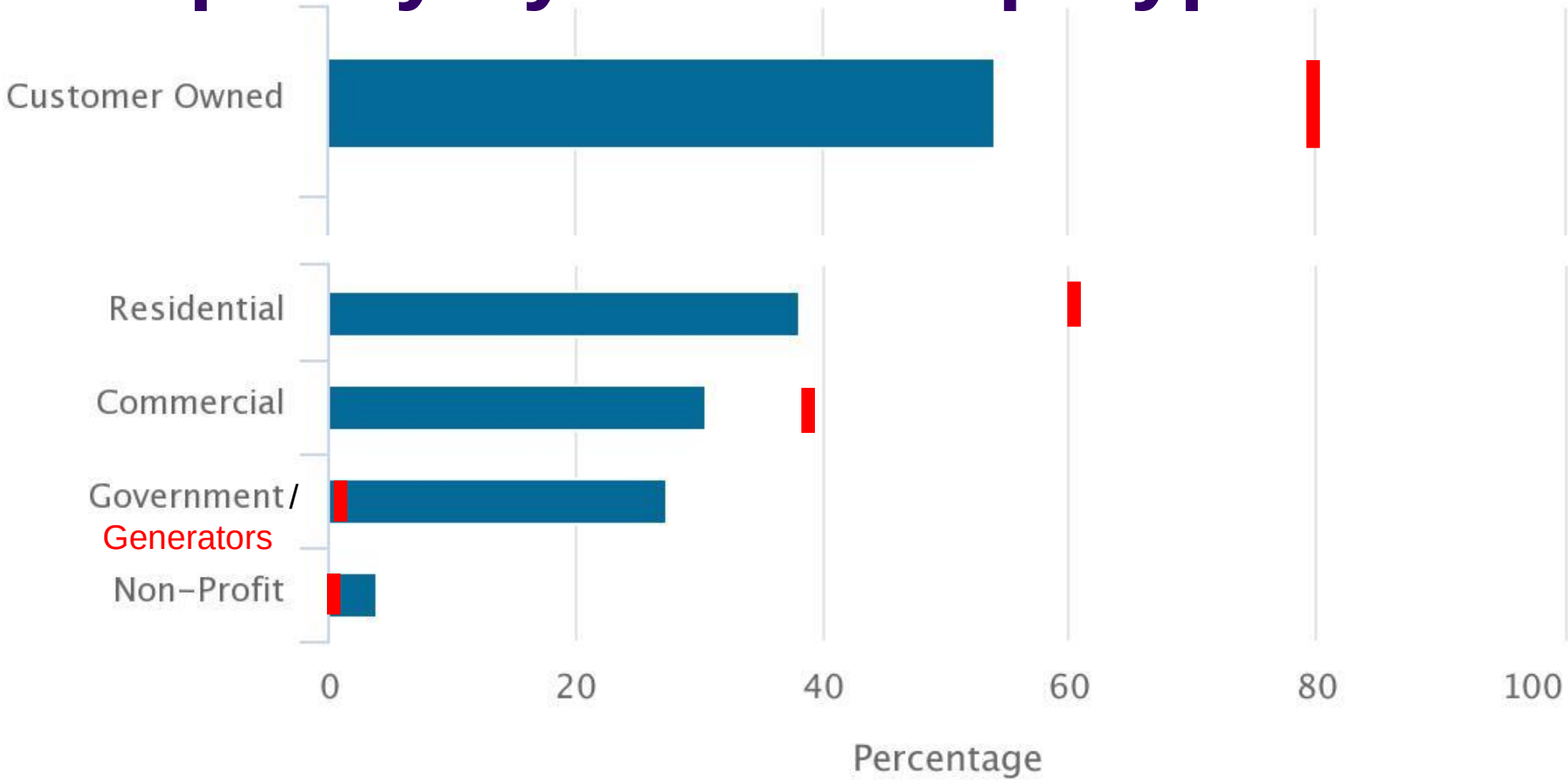


German Energiewende uses feed-in tariffs, with a 52 GW solar cap.

- Starting PV FIT level > CSI PBI
- Capacity tranches much larger
- Costs recovered through a RE levy that today makes up almost 24% of total residential electricity rates; 2018 surcharge = €0.06792/kWh
- Costs socialized across the country vs. being limited to recovery by specific investor-owned utilities (as is done for the CSI).

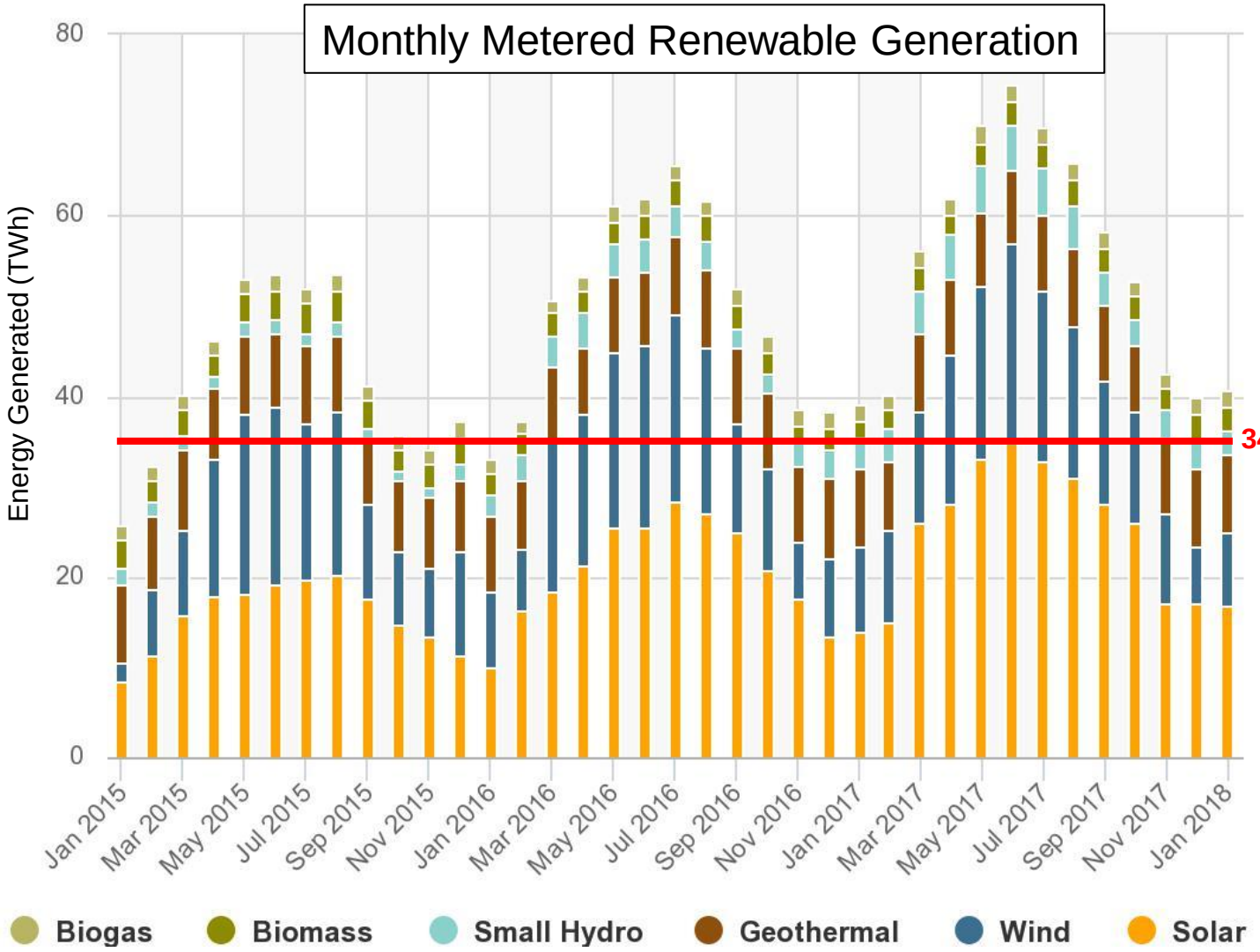
Source: Jurgen Weiss, The Brattle Group, July 2014, *Solar Energy Support in Germany-A Closer Look*, p. 10, https://www.seia.org/sites/default/files/resources/1053germany-closer-look.pdf.

California and Germany: PV Capacity by Ownership Type



Source: California Distributed Generation Statistics, https://www.californiadgstats.ca.gov/charts/csi. 143,084 project(s) were included for the generation of this chart. **Data current through 2018-02-21; German percentages derived from Fraunhofer ISE, 2018, Recent Facts about Photovoltaics in German, pp.28-29, https://www.ise.fraunhofer.de/content/dam/ise/en/documents/publications/studies/recent-facts-about-photovoltaics-in-germany.pdf**

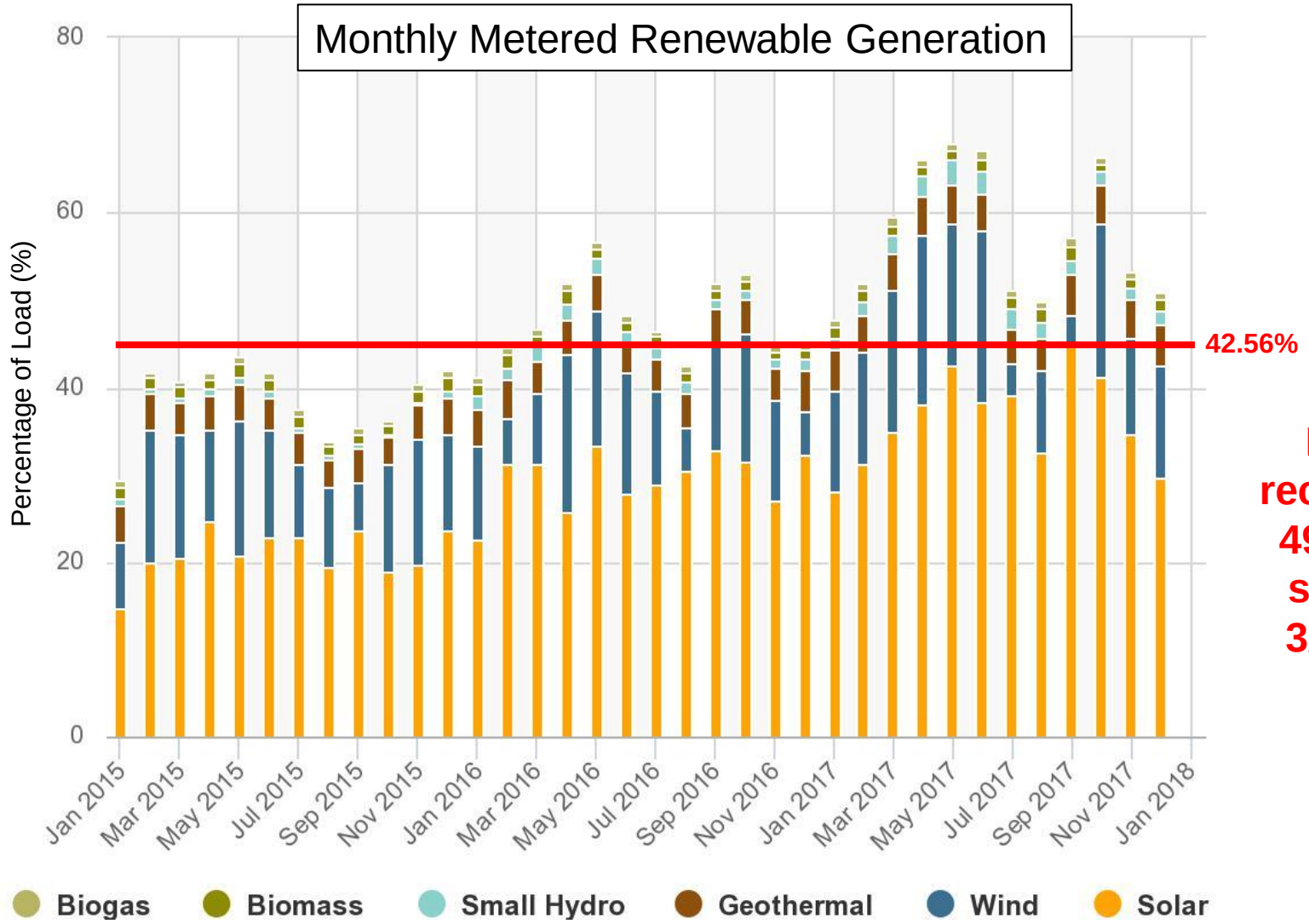
California PV Generation is Growing in Absolute Terms…



New record of 10,411 MW set on 3/5/18.

Source: http://www.caiso.com/Documents/MonthlyRenewablesPerformanceReport-Jan2018.html, accessed on 3/8/18.

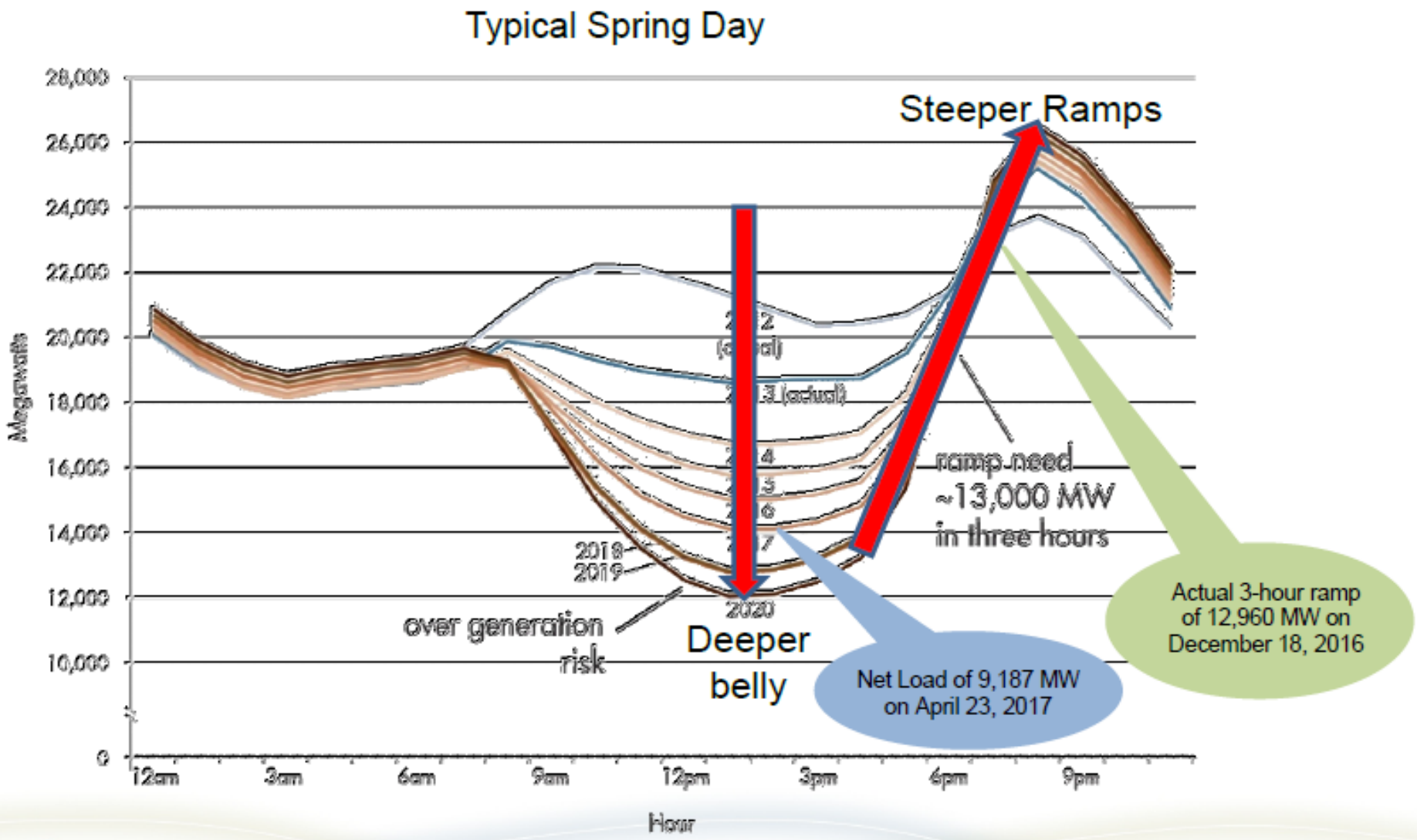
And as a Percentage of CAISO Net Load (= Load Served).



New record of 49.95% set on 3/4/18.

Source: http://www.caiso.com/Documents/MonthlyRenewablesPerformanceReport-Jan2018.html, accessed on 3/8/18.

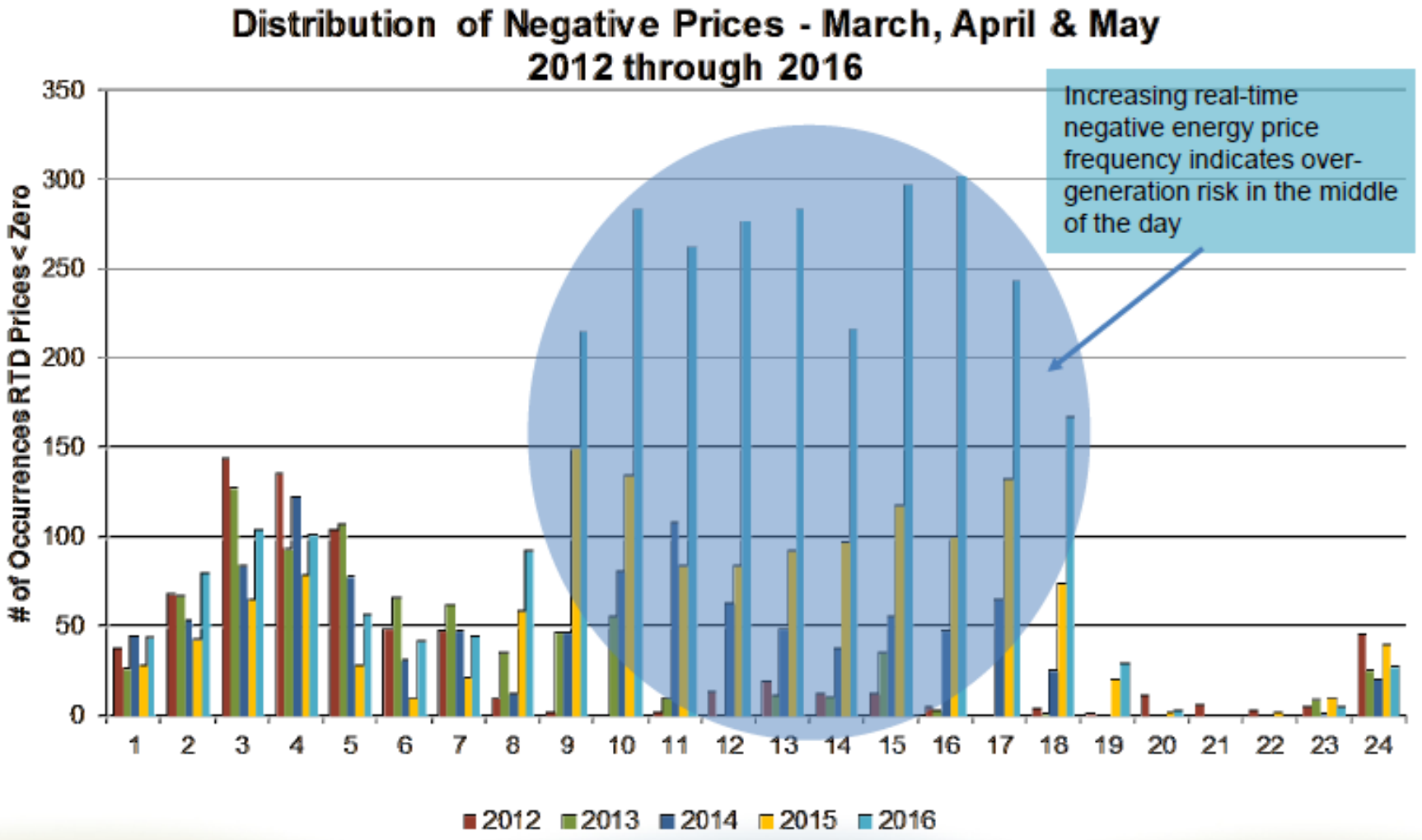
Actual net-load and 3-hour ramps are approximately four years ahead of ISO's original estimate



California ISO

Source: CAISO, Mark Rothelder, 5/12/17,Renewable Integration, California Energy Commission, IEPR Workshop, http://www.caiso.com/Documents/RenewableIntegrationUnlockingDividends.pdf.

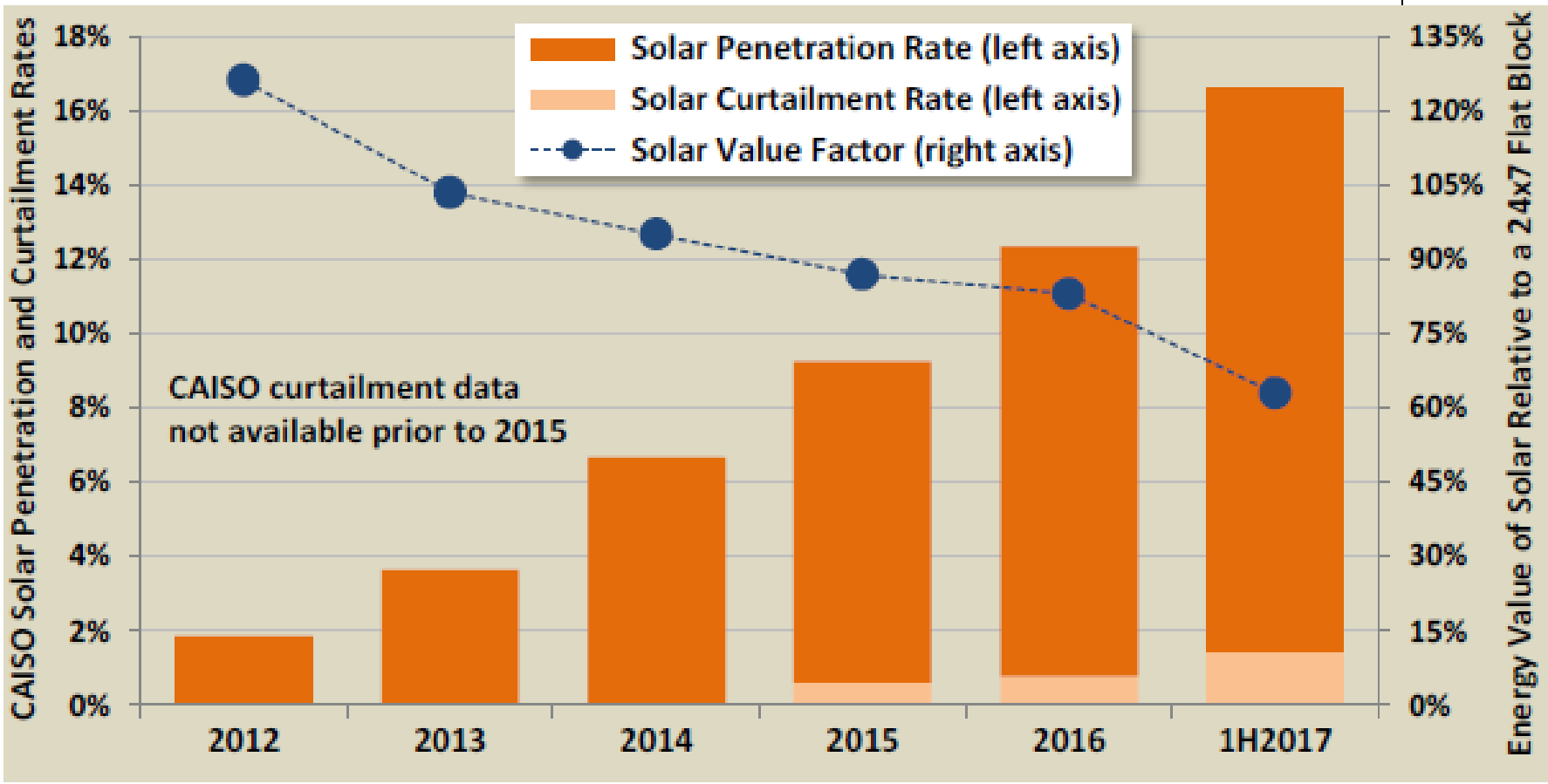
Low Net Load Affects CAISO Wholesale Electricity Pricing…



California ISO

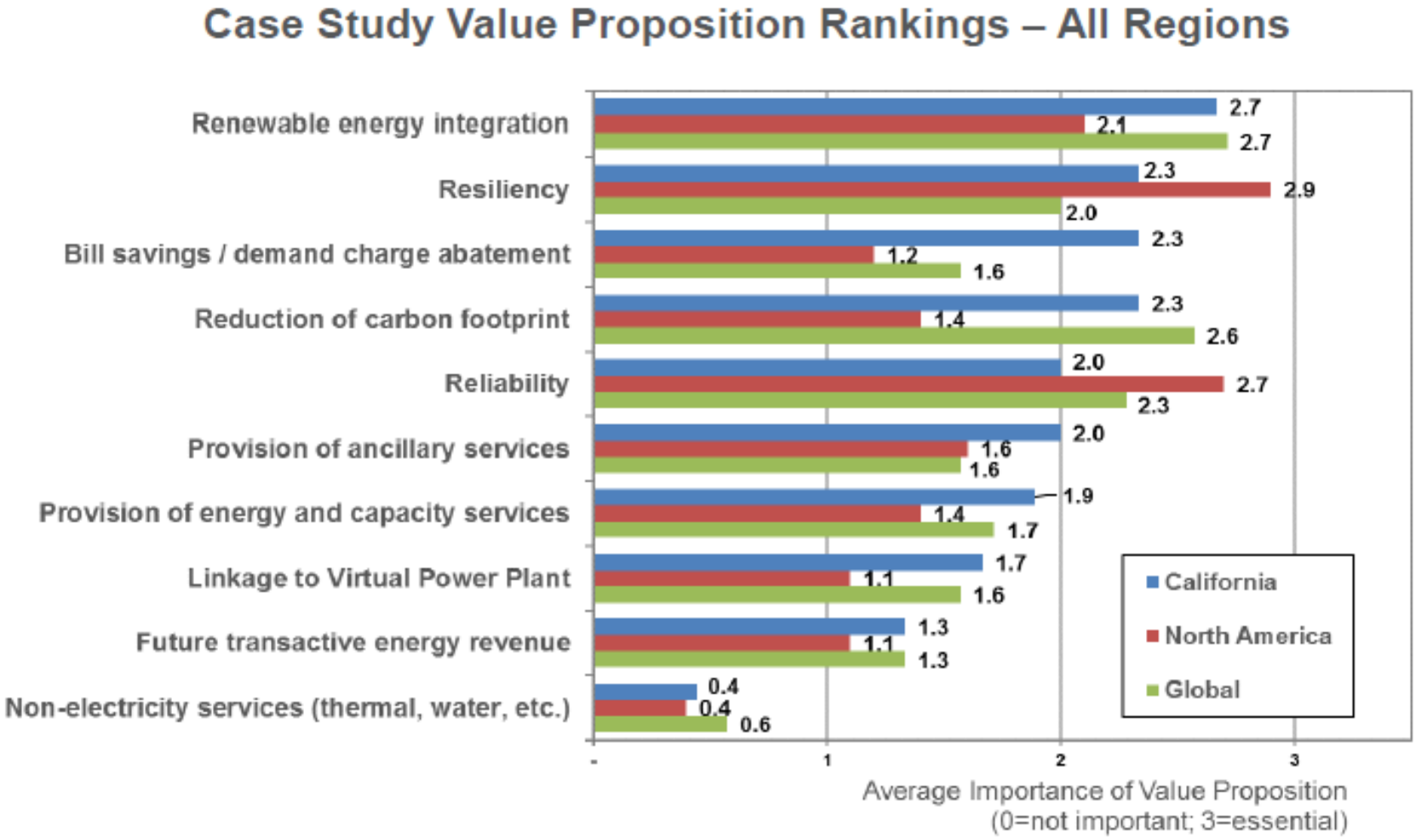
Source: CAISO, Mark Rothelder, 5/12/17,Renewable Integration, California Energy Commission, IEPR Workshop, http://www.caiso.com/Documents/RenewableIntegrationUnlockingDividends.pdf.

And Solar Value Factor as Solar Curtailments Increase.



Source: Lawrence Berkeley Lab, September 2017, *Utility-Scale Solar 2016: An Empirical Analysis of Project Cost, Performance, and Pricing Trends in the United States*, p.35, http://eta-publications.lbl.gov/sites/default/files/utility-scale_solar_2016_report.pdf

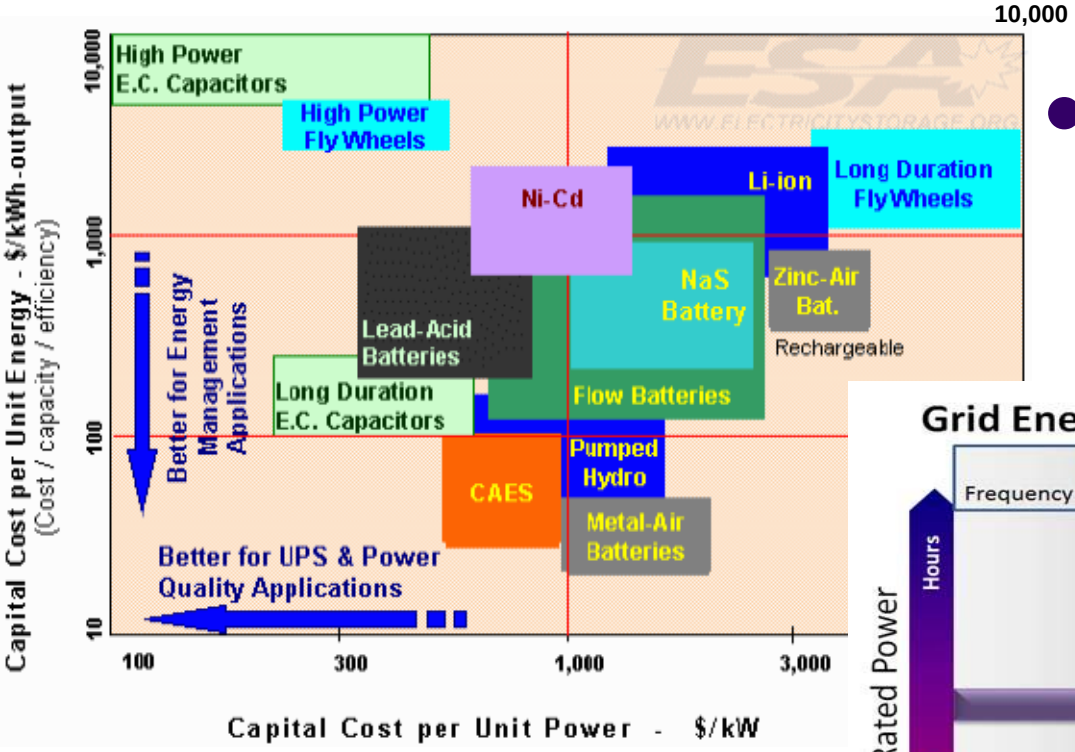
VALUE PROPOSITIONS DRIVING MICROGRIDS TODAY



Source: Navigant, 10/2/17, *California Energy Commission Microgrid Research Roadmap: Global Case Studies & Summary*, http://www.caiso.com/Documents/NavigantPresentation-CaliforniaEnergyCommissionMicrogridResearchRoadmap.pdf.

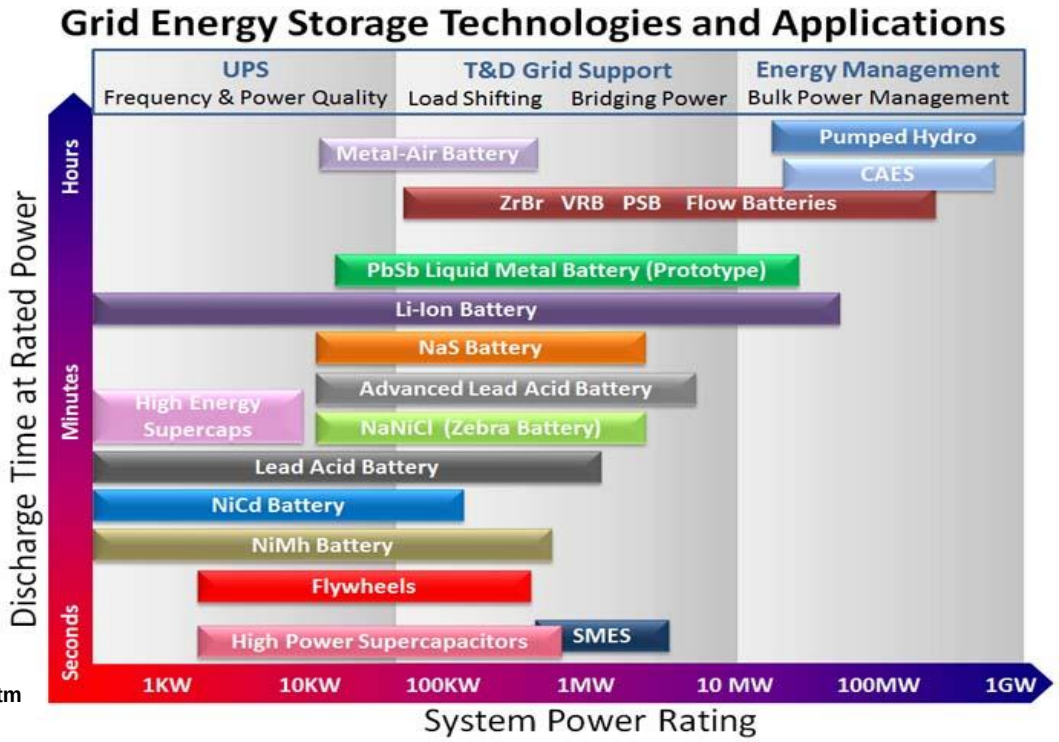
NAVIGANT

CA Microgrid Drivers Point to Increased Demand for Storage



- Best storage type depends on microgrid equipment portfolio.

- Power vs. Energy
- Capacity vs. Flow



http://www.mpoweruk.com/grid_storage.htm

LCORE Results

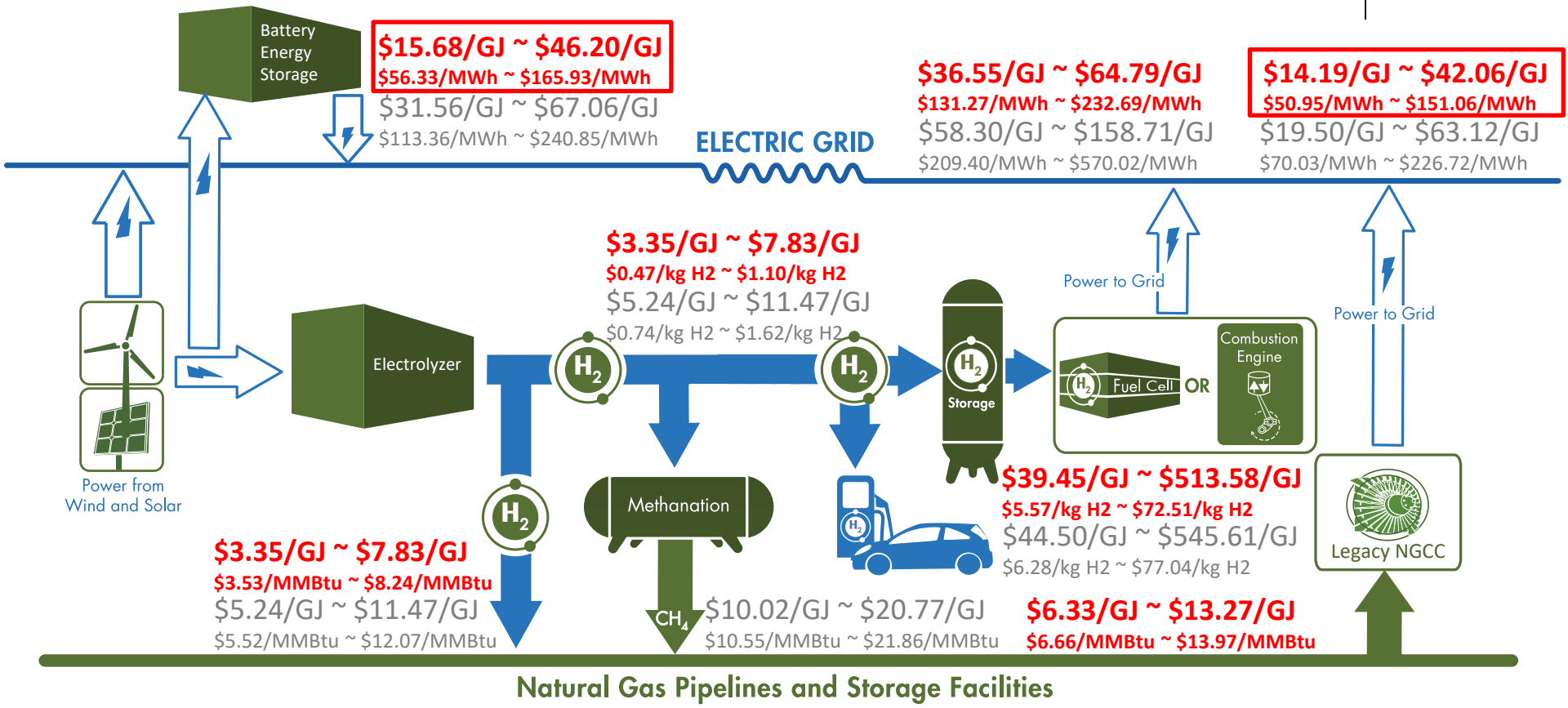
CURRENT COSTS & EFFICIENCES

45% Capacity Factor for Batteries;
90% Capacity Factor for All Other Equipment

LCORE Results

FUTURE COSTS & EFFICIENCES

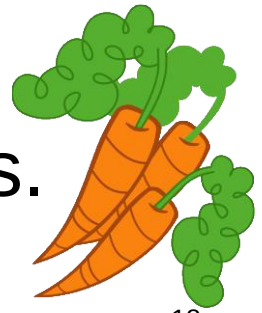
45% Capacity Factor for Batteries;
90% Capacity Factor for All Other Equipment



ALL RESULTS PRELIMARY – DO NOT QUOTE

California CSI: Lessons Relevant for Microgrids

- Almost every microgrid includes solar PV
  - Off-setting technologies required for integration
- Demonstrated value proposition is imperative
  - Homogeneity of solar PV enabled single valuation
  - Heterogeneity of microgrid design requires more project-specific quantification of value
- Cost improvements must be demonstrated as microgrid installed capacity increases
- Carrots create more positivity than sticks.



Disruptive Change is Coming… Faster than We Think

- Decentralized, block chain-enabled, peer-to-peer (“P2P”), trustless trading platform
  - Establishes digital trust via bilateral smart contracts

We believe empowering individuals and communities to co-create their energy future will underpin the development of a power system that is resilient, low-cost, zero-carbon and owned by the people of the world.

Source: https://powerledger.io/media/Power-Ledger-Whitepaper-v3.pdf

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THANK YOU!

QUESTIONS?

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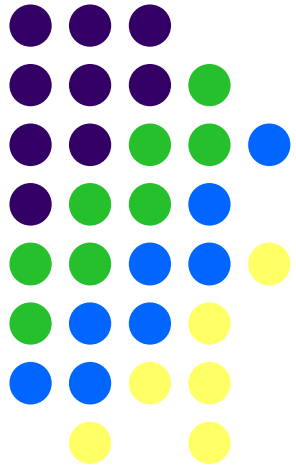

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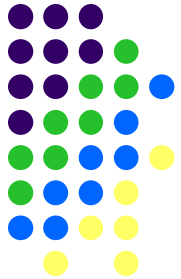
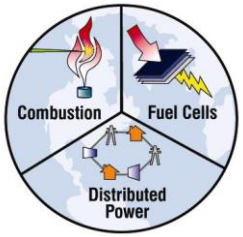
Backup Slides



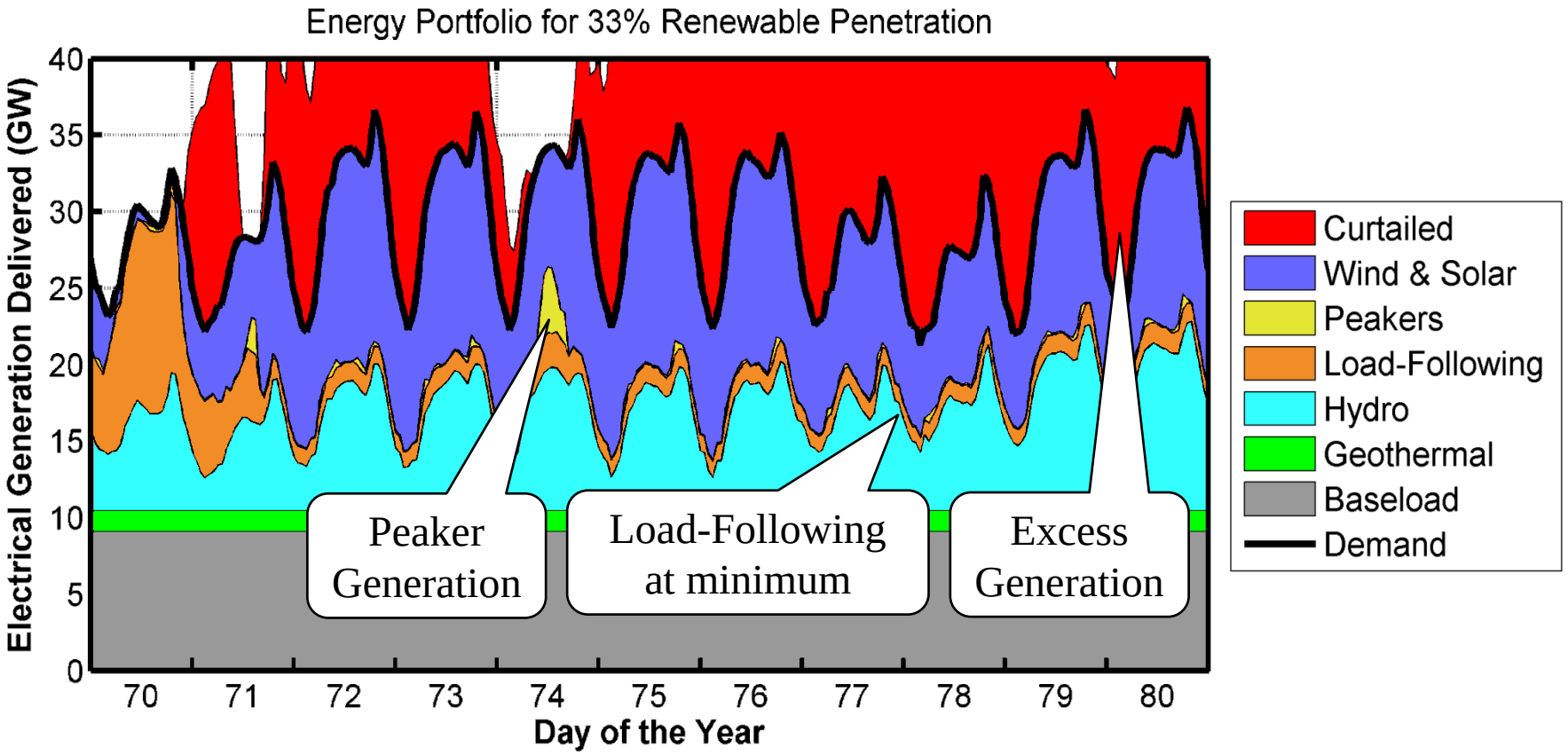
HiGRID Results: Renewables Integration

- **Task 4.1: Perform spanning analysis for different resources in California**
  - **Installation of renewables affects how other generators operate**

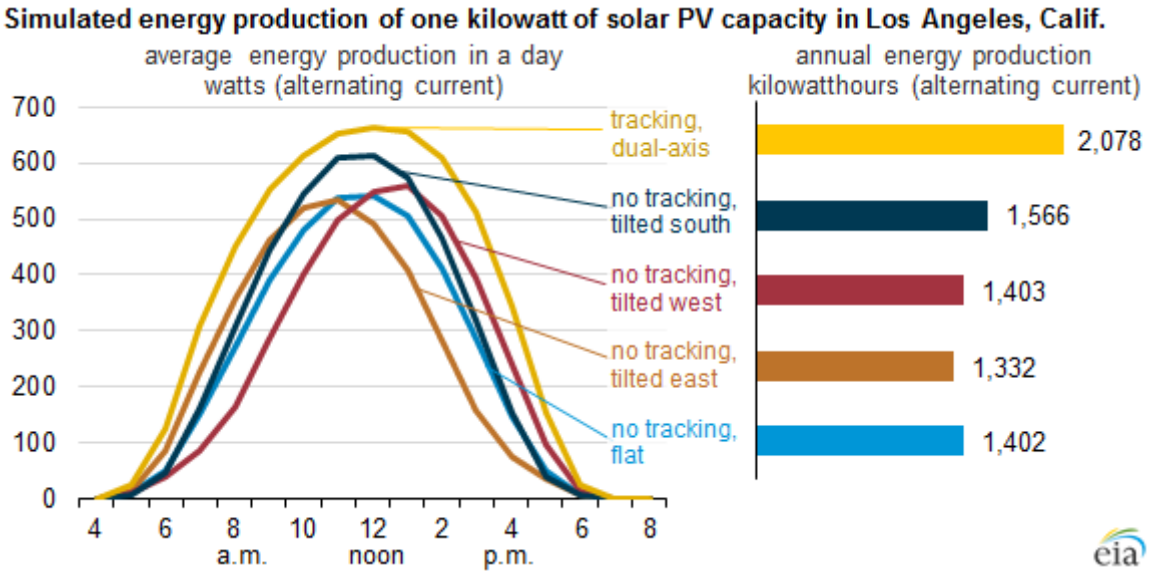


Advanced Power and Energy Program

UCIrvine | University of California



Solar PV Output Depends on Orientation, Tilt, and Tracking



Source: EIA, based on National Renewable Energy Laboratory's PVWatts, using default input values except as noted.
Note: Tilted systems are assumed to be mounted with a 20-degree tilt from horizontal. The assumed system size is one kilowatt of direct current, with output in watthours of alternating current.

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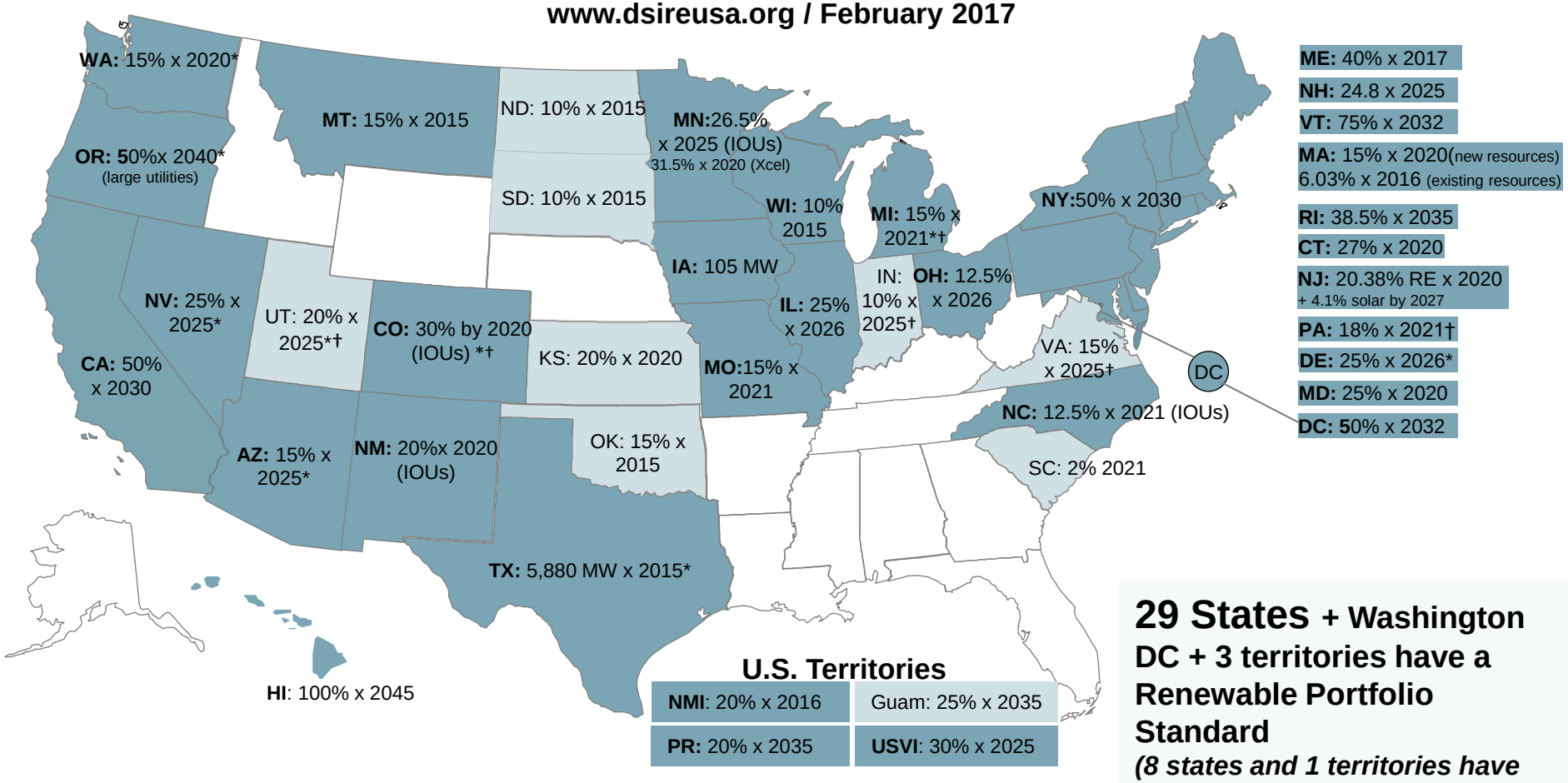
Renewable Portfolio Standard Policies

www.dsireusa.org / February 2017



ME: 40% x 2017
NH: 24.8 x 2025
VT: 75% x 2032
MA: 15% x 2020(new resources) 6.03% x 2016 (existing resources)
RI: 38.5% x 2035
CT: 27% x 2020
NJ: 20.38% RE x 2020 + 4.1% solar by 2027
PA: 18% x 2021†
DE: 25% x 2026*
MD: 25% x 2020
DC: 50% x 2032

U.S. Territories

NMI: 20% x 2016	Guam: 25% x 2035
PR: 20% x 2035	**USVI**: 30% x 2025

29 States + Washington DC + 3 territories have a Renewable Portfolio Standard
(8 states and 1 territories have renewable portfolio goals)

Renewable portfolio standard
Renewable portfolio goal

* Extra credit for solar or customer-sited renewables
† Includes non-renewable alternative resources

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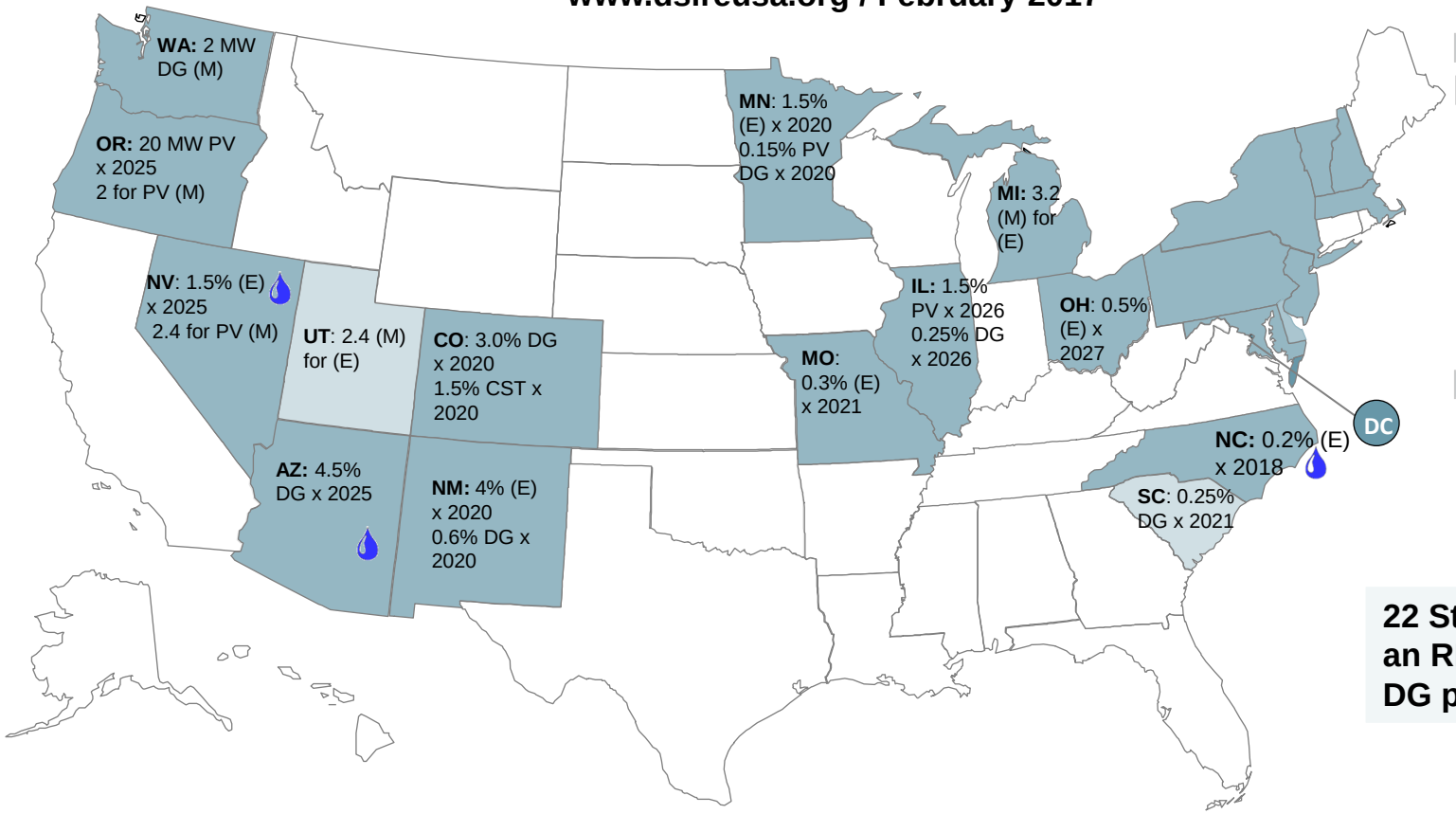
Renewable Portfolio Standards (RPS) with Solar or Distributed Generation Provisions

www.dsireusa.org / February 2017



VT: 1% DG X 2017 + 3/5ths of 1%/year until 10% X 2032

NH: 0.3% (E) x 2014

MA: 400 MW PV x 2020

NY: 0.58% customer - sited x 2015

PA: 0.5% PV x 2021

NJ: 4.1% (E) x 2028

DC: 2.5% (E) x 2023

DE: 3.5% PV x 2026 3.0 for PV (M)

MD: 2.5% (E) x 2020

22 States + DC have an RPS with solar or DG provisions

Renewable Portfolio Standard with solar/distributed generation (DG) provision

Renewable Portfolio Goal with solar/DG provision

(E): Solar Electric
PV: Solar Photovoltaic
DG: Distributed Generation
(M): Multipliers
(CST): Customer - Sited

Delaware allows certain fuel cell systems to qualify for the PV carve-out

Solar water heating counts toward solar/DG provision