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Energy+Environmental Economics

# Turning the World Upside Down: How Renewable Energy Will Impact Western Power Markets

Mid-C Seminar

July 27, 2016
Wenatchee, Washington

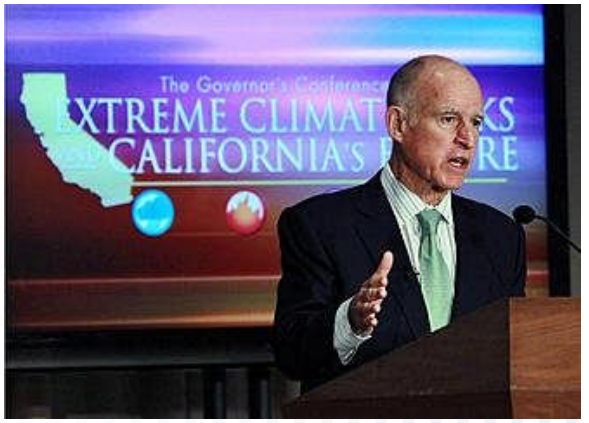
*Arne Olson, Partner*

# About E3

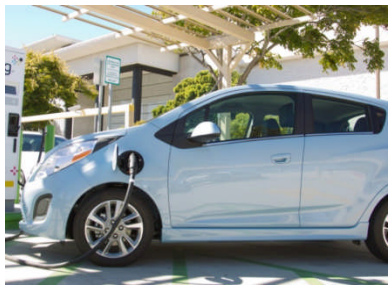
- San Francisco-based consultancy with 40 professionals focusing on electricity sector economics, regulation, planning and technical analysis
- Leading consultant to California agencies governing renewables, energy efficiency, demand response, and distributed generation programs
- Consultant to many of the world's largest utilities and leading renewable developers
- Our experience has placed us at the nexus of planning, policy and markets


# CALIFORNIA'S COMING SOLAR BINGE

# California policy is driving significant renewable adoption

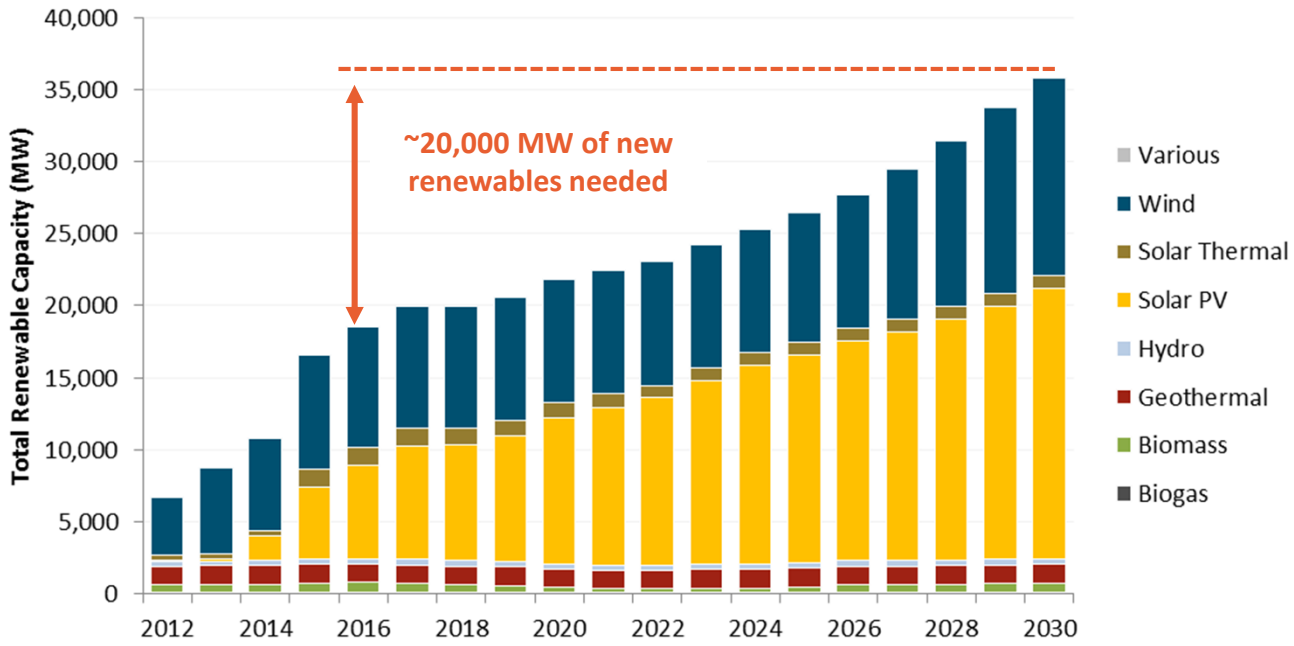



- **Gov. Brown's GHG goals: 40% reduction in economy-wide emissions, relative to 1990 levels, to be accomplished with:**
  - **50% renewable electricity**
  - Up to **50% reduction in petroleum use** in cars and trucks
  - **Doubling of energy efficiency savings** in existing buildings
- **Net energy metering decision will drive significantly more adoption of rooftop PV**



# Renewable Needs to Meet 50%

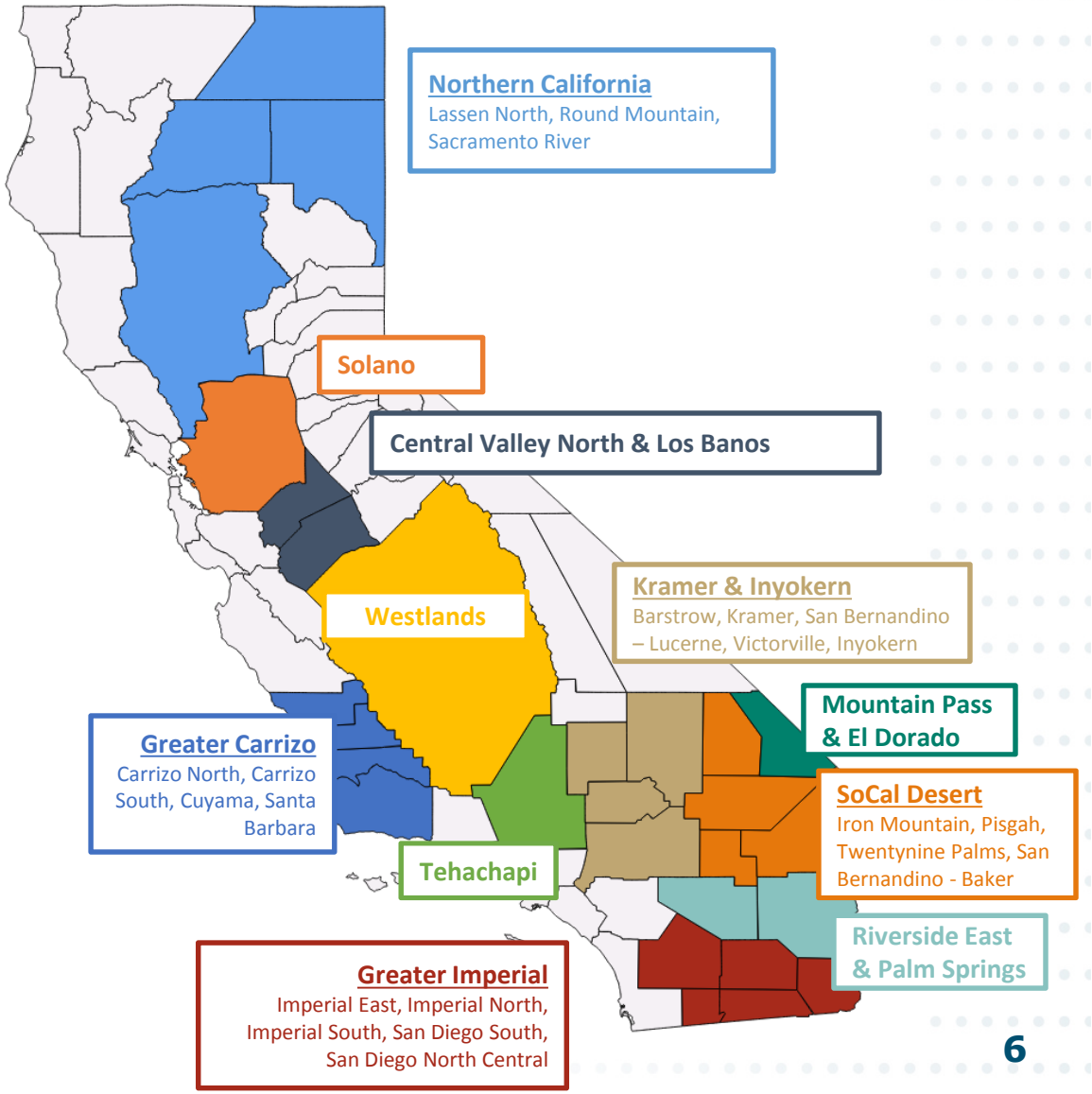
- **In 2015, California is achieving ≈25% RPS**
  - Some resources out of state
  - California resources will need to double by 2030 to reach a 50% RPS




**Source: CPUC RPS Calculator (v.6.1)**

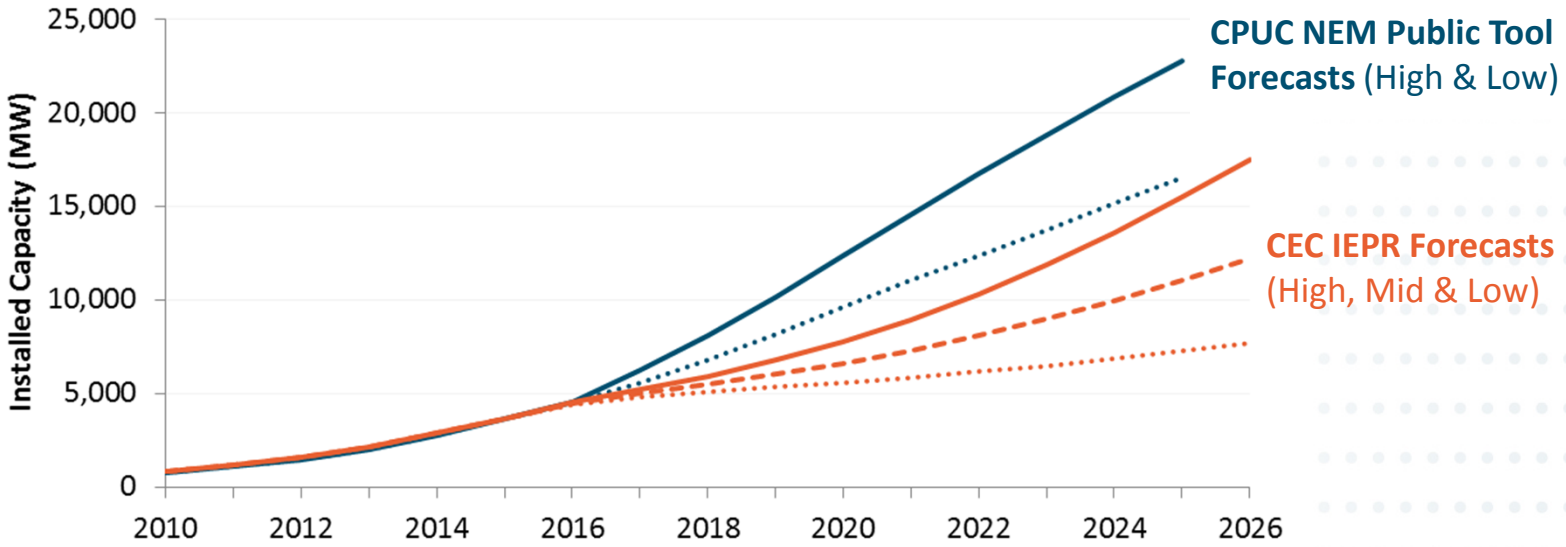
# In-state resource potential is largely solar

- **"Bucket 1" resources must be 75% of RPS portfolio by 2020**
  - Must interconnect to or be dynamically scheduled to a California BA
  - Applies to LSEs, CCAs
- **Developable in-state potential:**
  - Geothermal: 1800 MW
  - Wind: < 3000 MW
  - Solar: **100,000+ MW**



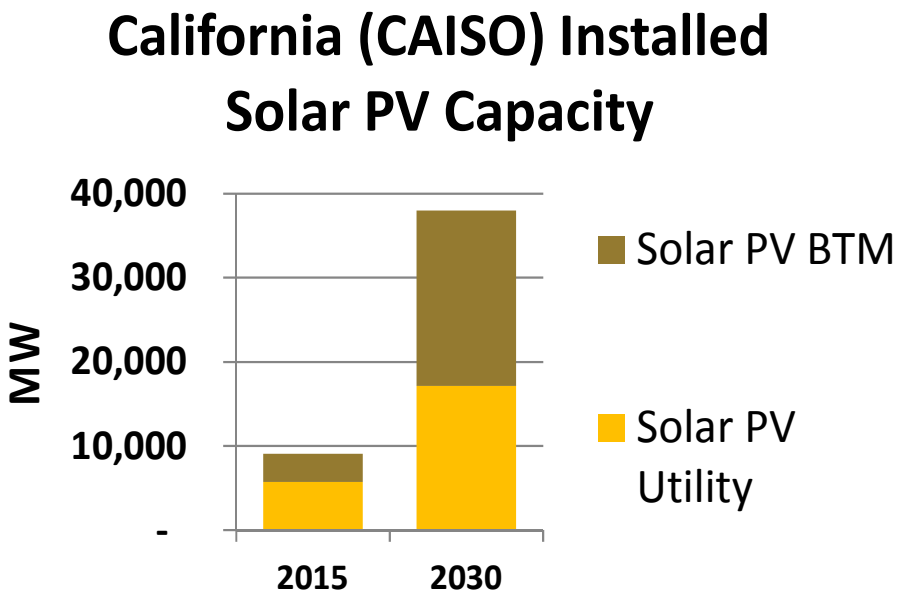
# Predicted Growth of Customer-Adopted Solar PV

- **Recent CPUC decision on NEM successor tariff ensures a significant rooftop solar market in California**
- **Future adoption is highly uncertain, but most projections suggest 10-20 GW of customer PV by 2025**



# 40 GW of solar expected in California by 2030

- **Unless procurement practices are changed, total solar installations in IOU service areas could reach 35–39 GW by 2030**
  - 15-20 GW utility scale
  - 15-20 GW customer-owned
  - Additional 2-5 GW from muni service areas (SMUD, LADWP)
- **Non-solar renewables will add another 15-20 GW**




*Source: CPUC's NEM 2.0 Public Tool*
*https://www.ethree.com/public_projects/cpucPublicTool.php*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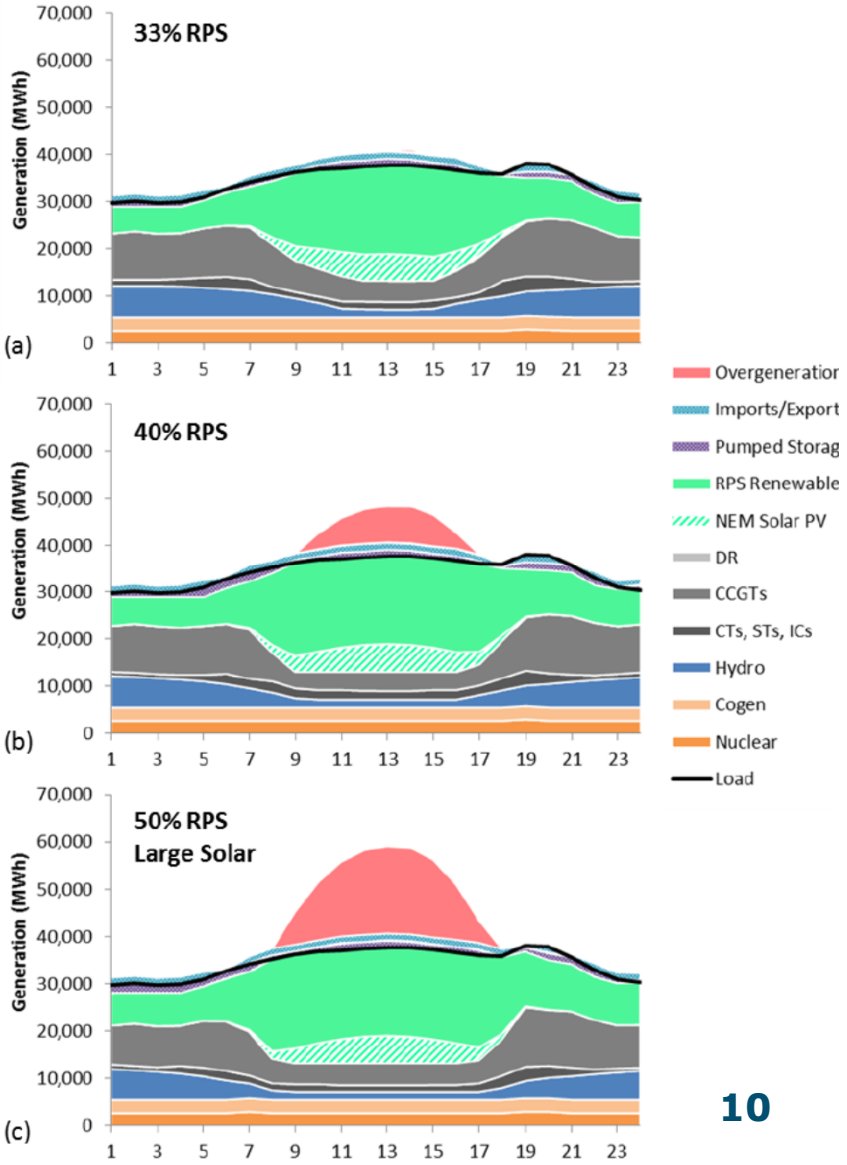
WHAT WILL THIS MEAN FOR THE MARKET?

# California is going to have more solar energy than it can use

- Studies show that the potential for over-generation becomes significant at higher renewable penetrations
- Renewable energy production is concentrated during relatively few hours of the year
- California will need to figure out what to do with a large surplus of renewable energy during many hours of the year



# What do you do when you have too much energy?

- **Try to sell some to your neighbors!**
  - Construction of California-Oregon interties has led to mutually beneficial exchanges
  - Benefits are due to load and resource diversity between the regions
  - Surplus energy flows south during most of the year
  - Surplus capacity available for S-N flow during wintertime

# Try to sell some to your neighbors!

Surplus solar for sale! All you can eat!

Fong Wan, PG&E

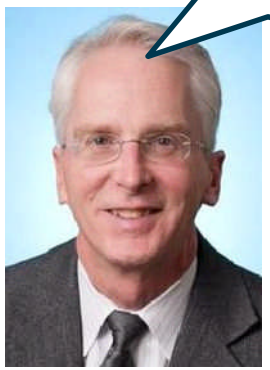
Stu Hemphill, SCE

Jim Avery, SDG&E

No thanks, I'm kind of full!

Elliot Mainzer, BPA

No thanks, I'm <u>really</u> full!



Steve Wright, Chelan PUD

I'll take some!

Pat Reiten, PacifiCorp

# What do you do if you still have too much energy?

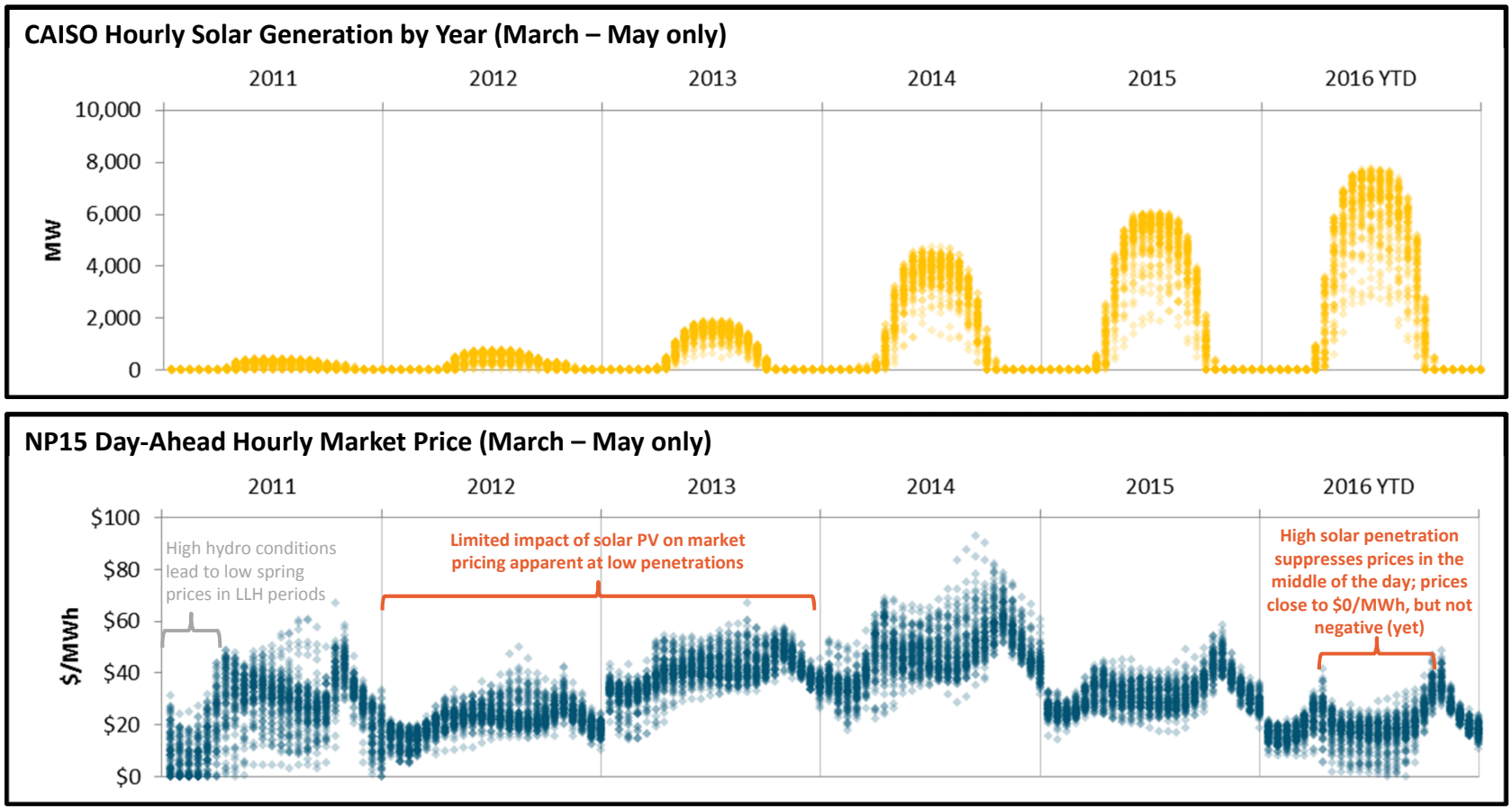
- Hydro spill is a reality at every hydroelectric facility
- It is not cost-effective to build the power system to absorb all of the available hydropower
- Curtailment of solar will become routine and commonplace


Noxon Hydro Electric Facility Courtesy of Avista Utilities

- E3 market simulations show overgeneration, and negative pricing, in over 20% of hours by 2030

# Solar generation is already suppressing market prices

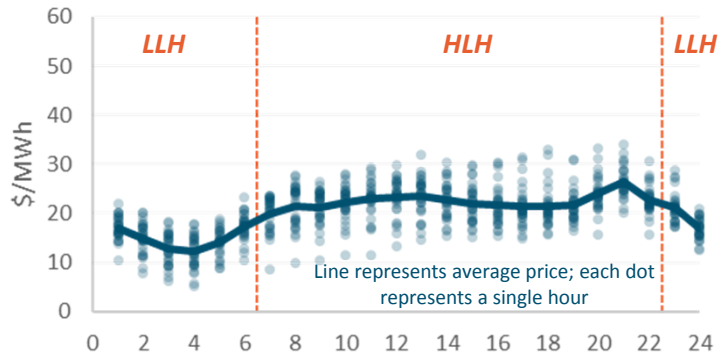
- **Rapid increase in solar buildout has clearly begun to suppress daytime market prices—but negative pricing has not yet been observed in the day-ahead market**



# Daytime prices now frequently lower than nighttime prices

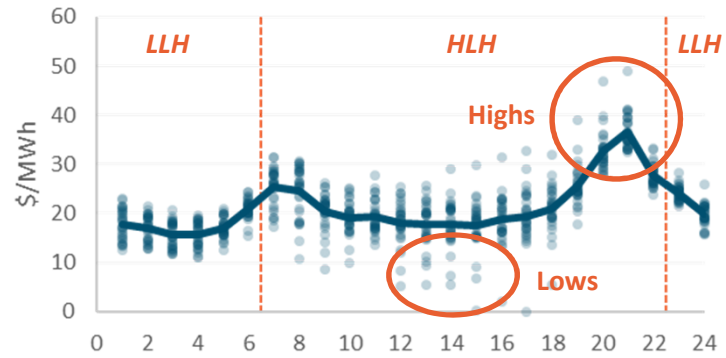
## + Changes in market dynamics driven by solar buildout may require a reevaluation of the standard HLH/LLH trading product

**NP15 Hourly Prices, April 2012**




- Prices relatively uniform within HLH, LLH periods
- Highest prices observed in HLH periods, lowest prices observed during LLH

**NP15 Hourly Prices, April 2016**

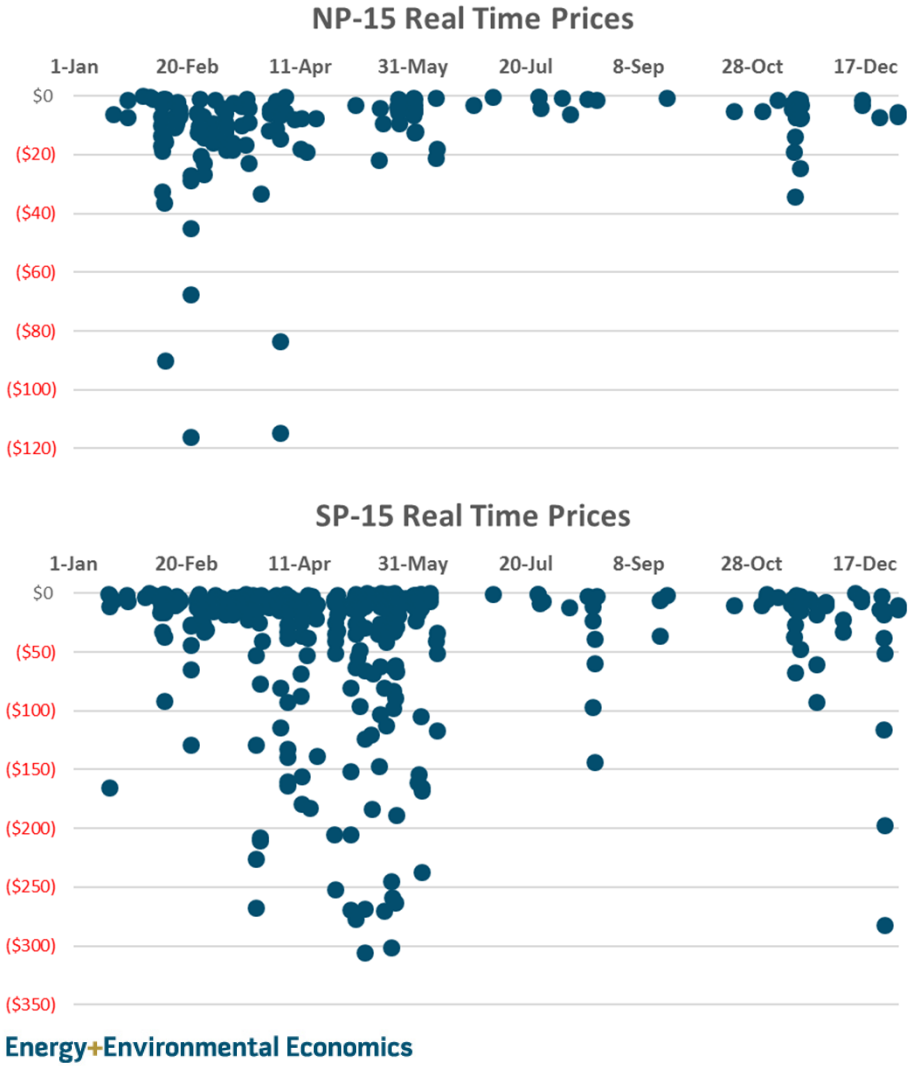



- Prices vary significantly within HLH and LLH periods
- Highest hourly prices observed during solar ramps, lowest prices observed in middle of day

## + Disconnect between hourly market prices and standard trading products will become more exaggerated with increasing solar buildout

# Negative prices observed in real-time market

**Negative prices have been observed in the real-time market in 2015**




+ **Negative prices seen more frequently in spring**
  - Combination of low loads and high solar generation resulting in negative net loads may be a key driver
+ **Negative price magnitudes and frequency are higher in SP-15**
+ **Day ahead markets have still not experienced negative prices**
  - We anticipate the real time and day ahead markets will both have considerable number of hours with negative prices with increasing solar

# How low can negative prices go?

- **Market should clear at the renewable "replacement cost" – the net cost of procuring additional renewable resources to ensure compliance with RPS targets**
- **Price that California LSEs should be willing to pay to deliver their resources to the market**
  - Can also be described as the "marginal cost of RPS compliance" or the long-run REC value

$$\text{Replacement Cost [\$/MWh]} = \frac{\text{PPA Price [\$/MWh]}}{\text{1 - Marginal Curtailment [\%]}} - \text{Energy Value [\$/MWh]}$$

PPA price grossed up to reflect the fact that only a portion of the marginal resource's output can be delivered to the grid

Netted from PPA price to capture reduced fuel & O&M

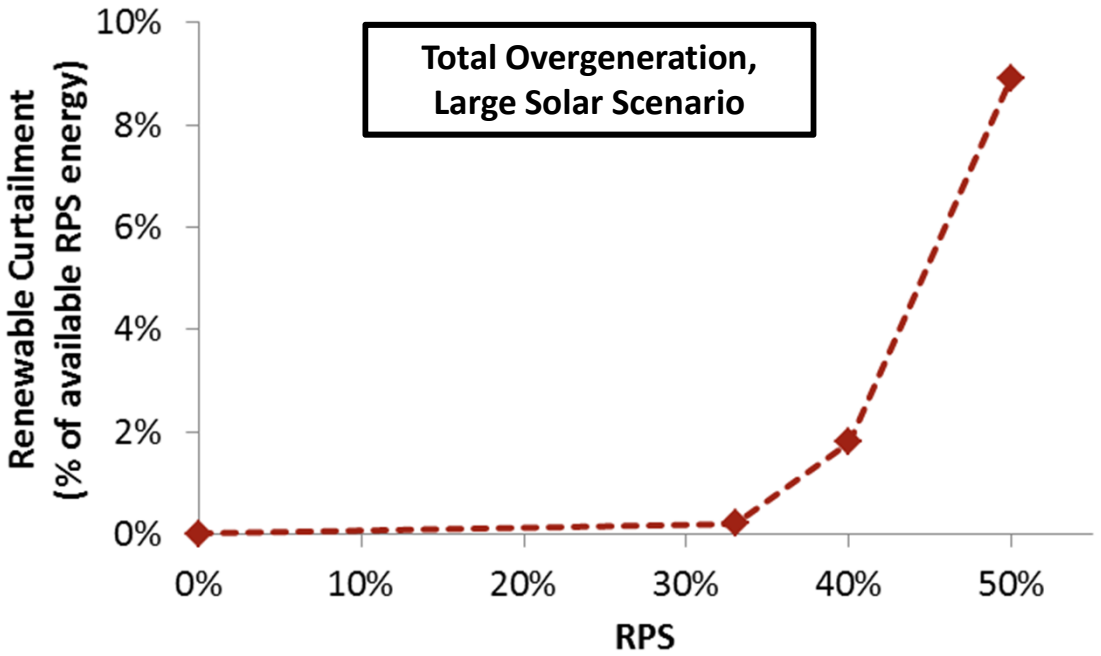
***Replacement cost can range from $20-150/MWh***

# Marginal curtailment increases quickly once saturation is reached

- **Marginal solar curtailment may exceed 65% in 2030**
- **Marginal solar cost may exceed $100/MWh**
  - $50/MWh PPA price

    ÷ (1-65%) curtailment

    – $40/MWh energy value

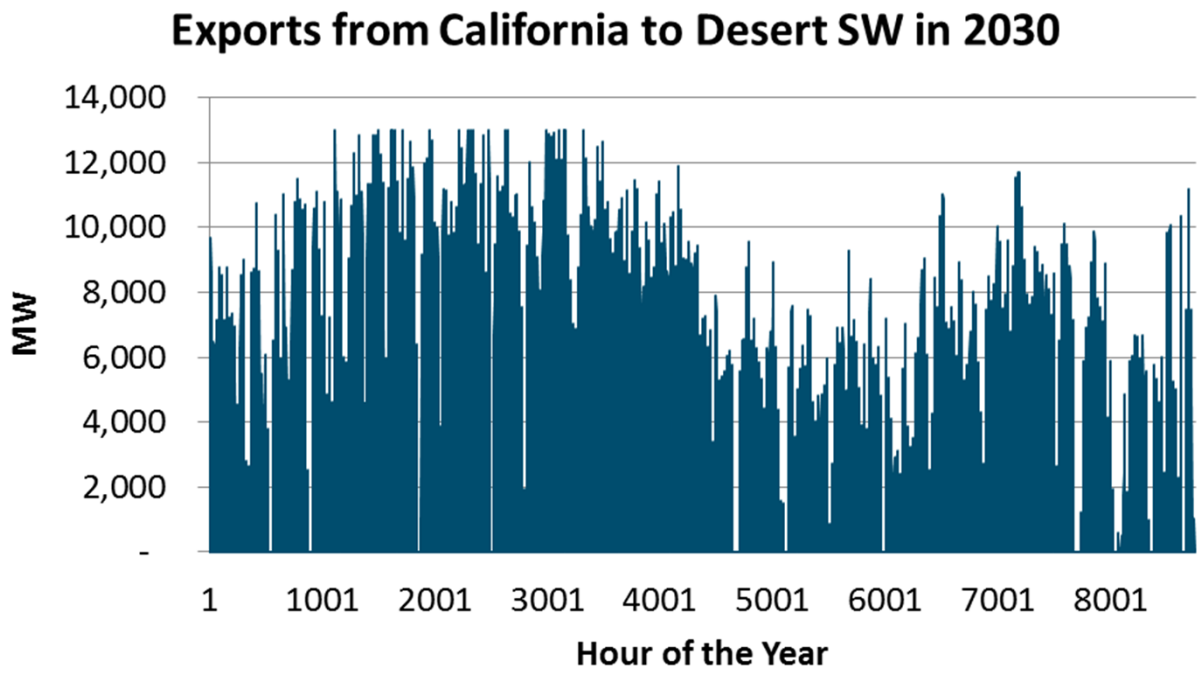



| Marginal Overgeneration | 33% RPS | 40% RPS | 50% RPS |
|---|---|---|---|
| Solar PV | 5% | 26% | 65% |
| Wind & Geothermal | 2% | 12% | 22% |

*Source: E3, Investigating a Higher Renewables Portfolio Standard for California*

# SW case study: California becomes significant exporter

- **2030 case study market simulations shows average exports of several thousand MW to the Desert Southwest under high solar cases**
  - Concentrated during springtime hours



# SW case study: negative prices spill out from California

## 2030 PV Prices under Low Price Scenario

| Month | Hour 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 34 | 34 | 33 | 34 | 35 | 38 | 48 | 46 | 39 | 20 | -35 | -44 | -47 | -42 | -16 | 36 | 43 | 52 | 50 | 49 | 50 | 47 | 37 | 34 |
| 2 | 34 | 34 | 34 | 34 | 35 | 38 | 48 | 44 | 35 | -21 | -44 | -47 | -47 | -44 | -35 | 22 | 39 | 52 | 53 | 52 | 50 | 48 | 38 | 36 |
| 3 | 31 | 31 | 31 | 32 | 33 | 37 | 45 | 37 | 15 | -45 | -47 | -47 | -47 | -47 | -45 | -18 | 33 | 46 | 52 | 52 | 48 | 45 | 33 | 32 |
| 4 | 31 | 30 | 30 | 31 | 32 | 35 | 39 | 28 | -25 | -45 | -45 | -45 | -47 | -43 | -31 | 8 | 31 | 43 | 48 | 48 | 47 | 44 | 34 | 32 |
| 5 | 31 | 30 | 30 | 31 | 33 | 33 | 30 | 28 | -11 | -43 | -50 | -50 | -45 | -33 | -7 | 30 | 39 | 48 | 52 | 53 | 50 | 47 | 35 | 32 |
| 6 | 32 | 31 | 31 | 32 | 34 | 32 | 31 | 29 | 26 | -6 | -27 | -32 | -24 | 8 | 30 | 36 | 45 | 52 | 57 | 55 | 55 | 53 | 36 | 33 |
| 7 | 39 | 38 | 37 | 39 | 41 | 32 | 36 | 33 | 31 | 29 | 22 | 20 | 24 | 32 | 38 | 45 | 50 | 54 | 60 | 59 | 56 | 52 | 44 | 40 |
| 8 | 38 | 37 | 37 | 37 | 40 | 40 | 45 | 35 | 32 | 31 | 29 | 27 | 32 | 39 | 45 | 51 | 53 | 56 | 62 | 59 | 56 | 52 | 41 | 39 |
| 9 | 34 | 34 | 33 | 34 | 36 | 40 | 44 | 35 | 30 | 18 | 0 | 3 | 8 | 30 | 40 | 47 | 49 | 59 | 62 | 60 | 53 | 49 | 37 | 35 |
| 10 | 34 | 33 | 33 | 34 | 36 | 40 | 44 | 35 | 16 | -45 | -50 | -50 | -41 | -20 | 28 | 42 | 47 | 53 | 52 | 49 | 47 | 47 | 37 | 34 |
| 11 | 35 | 34 | 33 | 33 | 35 | 38 | 45 | 40 | 31 | -34 | -37 | -45 | -45 | -32 | 20 | 37 | 49 | 49 | 48 | 46 | 47 | 47 | 39 | 36 |
| 12 | 41 | 41 | 40 | 40 | 42 | 45 | 52 | 48 | 41 | 10 | -26 | -25 | -26 | -14 | 19 | 42 | 54 | 57 | 54 | 54 | 55 | 55 | 46 | 43 |

## Arizona Solar Profile

**Production concentrated in periods of low prices**

| Month | Hour 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 39% | 72% | 75% | 70% | 66% | 70% | 72% | 75% | 64% | 4% | 0% | 0% | 0% | 0% | 0% | 0% |
| 2 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 7% | 58% | 74% | 77% | 72% | 69% | 68% | 71% | 66% | 62% | 16% | 0% | 0% | 0% | 0% | 0% | 0% |
| 3 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 31% | 76% | 82% | 83% | 84% | 84% | 82% | 82% | 84% | 80% | 55% | 1% | 0% | 0% | 0% | 0% | 0% |
| 4 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 74% | 94% | 95% | 95% | 92% | 91% | 88% | 89% | 92% | 94% | 74% | 5% | 0% | 0% | 0% | 0% | 0% |
| 5 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 79% | 89% | 93% | 93% | 94% | 95% | 93% | 93% | 91% | 88% | 72% | 16% | 0% | 0% | 0% | 0% | 0% |
| 6 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 85% | 96% | 96% | 96% | 96% | 96% | 97% | 96% | 96% | 95% | 86% | 42% | 0% | 0% | 0% | 0% | 0% |
| 7 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 59% | 75% | 84% | 87% | 88% | 82% | 74% | 72% | 69% | 62% | 52% | 28% | 0% | 0% | 0% | 0% | 0% |
| 8 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 54% | 78% | 90% | 94% | 92% | 88% | 84% | 76% | 65% | 64% | 49% | 4% | 0% | 0% | 0% | 0% | 0% |
| 9 | 0% | 0% | 0% | 0% | 0% | 0% | 3% | 50% | 80% | 90% | 90% | 89% | 84% | 79% | 85% | 76% | 65% | 31% | 0% | 0% | 0% | 0% | 0% | 0% |
| 10 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 38% | 81% | 89% | 87% | 84% | 80% | 76% | 84% | 85% | 71% | 4% | 0% | 0% | 0% | 0% | 0% | 0% |
| 11 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 14% | 66% | 73% | 74% | 71% | 68% | 71% | 71% | 75% | 48% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 12 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 43% | 68% | 66% | 65% | 64% | 63% | 69% | 68% | 44% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |

## New Mexico Wind Profile

| Month | Hour 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 59% | 59% | 64% | 62% | 62% | 59% | 59% | 59% | 57% | 51% | 45% | 45% | 46% | 47% | 48% | 47% | 39% | 38% | 43% | 48% | 54% | 57% | 57% | 60% |
| 2 | 55% | 55% | 60% | 59% | 59% | 54% | 53% | 54% | 50% | 45% | 41% | 43% | 45% | 48% | 49% | 49% | 42% | 40% | 42% | 46% | 50% | 54% | 55% | 56% |
| 3 | 54% | 55% | 61% | 60% | 59% | 53% | 51% | 48% | 43% | 40% | 39% | 41% | 43% | 46% | 48% | 50% | 42% | 39% | 39% | 43% | 48% | 51% | 52% | 55% |
| 4 | 53% | 53% | 58% | 57% | 57% | 49% | 43% | 40% | 38% | 39% | 41% | 44% | 49% | 53% | 55% | 56% | 49% | 44% | 43% | 44% | 50% | 52% | 52% | 54% |
| 5 | 46% | 46% | 51% | 49% | 48% | 40% | 32% | 27% | 25% | 26% | 27% | 31% | 36% | 41% | 44% | 46% | 39% | 34% | 32% | 35% | 41% | 45% | 47% | 48% |
| 6 | 44% | 41% | 46% | 46% | 49% | 37% | 27% | 20% | 18% | 18% | 19% | 23% | 27% | 31% | 33% | 35% | 29% | 27% | 28% | 31% | 38% | 44% | 47% | 46% |
| 7 | 35% | 32% | 35% | 33% | 34% | 22% | 14% | 11% | 9% | 7% | 7% | 9% | 13% | 17% | 18% | 20% | 16% | 21% | 24% | 26% | 30% | 32% | 37% | 37% |
| 8 | 32% | 32% | 38% | 37% | 39% | 28% | 21% | 14% | 12% | 8% | 7% | 9% | 12% | 15% | 16% | 18% | 15% | 17% | 20% | 22% | 27% | 28% | 33% | 33% |
| 9 | 39% | 39% | 45% | 44% | 46% | 36% | 32% | 25% | 20% | 17% | 16% | 18% | 21% | 23% | 24% | 24% | 18% | 20% | 25% | 30% | 36% | 39% | 41% | 40% |
| 10 | 49% | 49% | 55% | 54% | 55% | 47% | 46% | 41% | 34% | 29% | 28% | 31% | 33% | 36% | 37% | 37% | 29% | 28% | 31% | 38% | 43% | 46% | 47% | 49% |
| 11 | 58% | 57% | 62% | 61% | 62% | 58% | 58% | 57% | 52% | 44% | 37% | 37% | 38% | 39% | 39% | 39% | 32% | 32% | 38% | 45% | 52% | 55% | 56% | 58% |
| 12 | 63% | 62% | 66% | 65% | 65% | 61% | 62% | 63% | 60% | 53% | 45% | 44% | 43% | 45% | 46% | 46% | 39% | 38% | 43% | 51% | 57% | 61% | 62% | 64% |

+ **Many hours of negative prices at Palo Verde in 2030**
+ **Depends of flexibility of coal fleet to ramp down**
+ **Affects economics of new and existing resources**
  - E.g., Arizona solar may have very little energy value in 2030
  - NM wind has a complementary profile and much higher energy value

*Charts show average hourly prices by month in the indicated years

# Key Questions

- **Will California policymakers re-open the door for procurement of out-of-state wind?**
  - Studies show significant benefit from WY, NM wind
- **How much solar surplus can be absorbed outside of California in the absence of a Day Two market?**
  - How many more coal plants will retire by 2030?
  - How flexibly can the remaining plants be operated?
  - How much can be stored in NW reservoirs?
- **Will California and other states agree to form a regional ISO, and how large will it become?**

Energy+Environmental Economics

# Thank You!

Energy and Environmental Economics, Inc. (E3)
101 Montgomery Street, Suite 1600
San Francisco, CA 94104
Tel 415-391-5100
www.ethree.com

Arne Olson, Partner (arne@ethree.com)