Northwest **Power** and **Conservation** Council

March 4, 2014

MEMORANDUM

TO: Council Members

FROM: Charlie Black, Power Planning Division Director

SUBJECT: Investigating a 50 Percent Renewable Portfolio Standard in California

Arne Olson, lead investigator and partner at Energy+Environmental Economics, will report to the Council on his firm's recently-completed study on the implications of moving to a 50 percent renewable portfolio standard in California. This study was commissioned by the five largest electric utilities in California, including PG&E, SCE, SDG&E, LADWP and SMUD.

The E3 study addresses operational, cost and other impacts of increasing the California RPS from 33 percent to 50 percent. It also identifies and examines potential methods to mitigate the impacts.

The study's recommendations include diversifying renewable generation and increasing inter-regional regional coordination as promising ways for California to meet a 50 percent RPS.

The E3 study has been receiving significant attention within California and more broadly. It provides timely ideas and relevant information, including about the growing importance of inter-regional linkages between the California and Pacific Northwest power systems.

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Energy+Environmental Economics

Investigating a 50 Percent + Renewables Portfolio Standard in California

Northwest Power and Conservation Council
Portland, Oregon
March 12, 2014

Arne Olson, Partner

About the Study

+ Study sponsors:

- Los Angeles Dept. of Water & Power
- Southern California Edison Co.
- Pacific Gas and Electric Co.
- San Diego Gas & Electric Co.
- Sacramento Municipal Utility District
- Technical input from California ISO

Analysis team: Energy + Environmental Economics (E3) with support from DNV KEMA & ECCO International

+ Advisory panel:

- Dr. Dan Arvizu – Director and CEO of National Renewable Energy Laboratory
- Dr. Severin Borenstein – Director of the University of California Energy Institute and Co-Director of the Energy Institute at Haas School of Business, UC Berkeley
- Dr. Susan Tierney – Managing Principal at Analysis Group Inc., Boston, MA
- Mr. Stephen Wright – Retired Administrator, Bonneville Power Administration; General Manager, Chelan County Public Utility District

Available at: http://www.ethree.com/public_projects/renewables_portfolio_standard.php

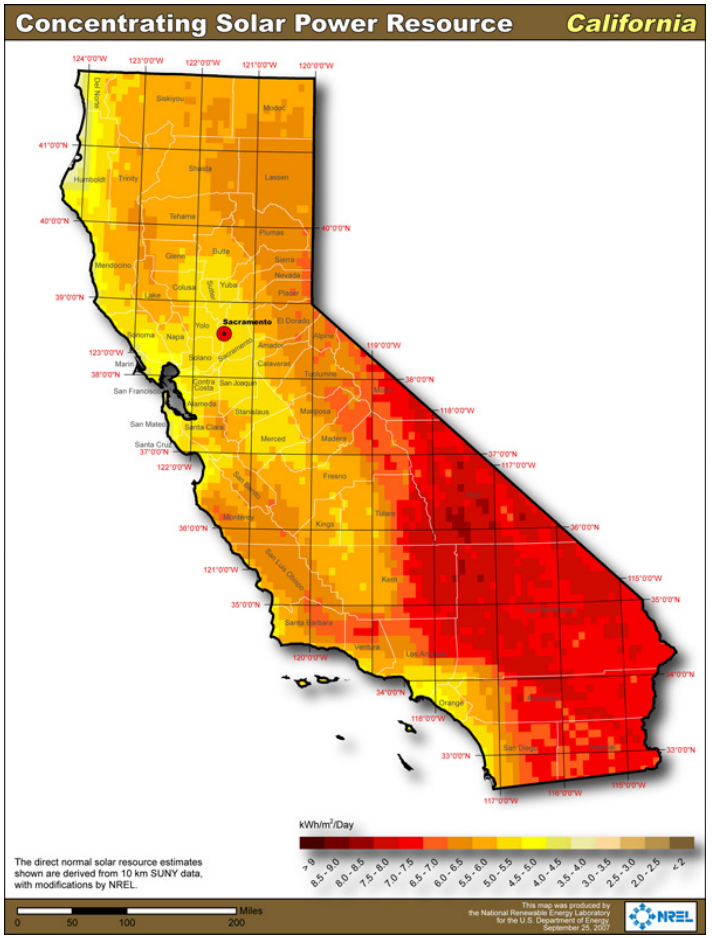
California's Renewable Energy Achievements To Date

+ Today:

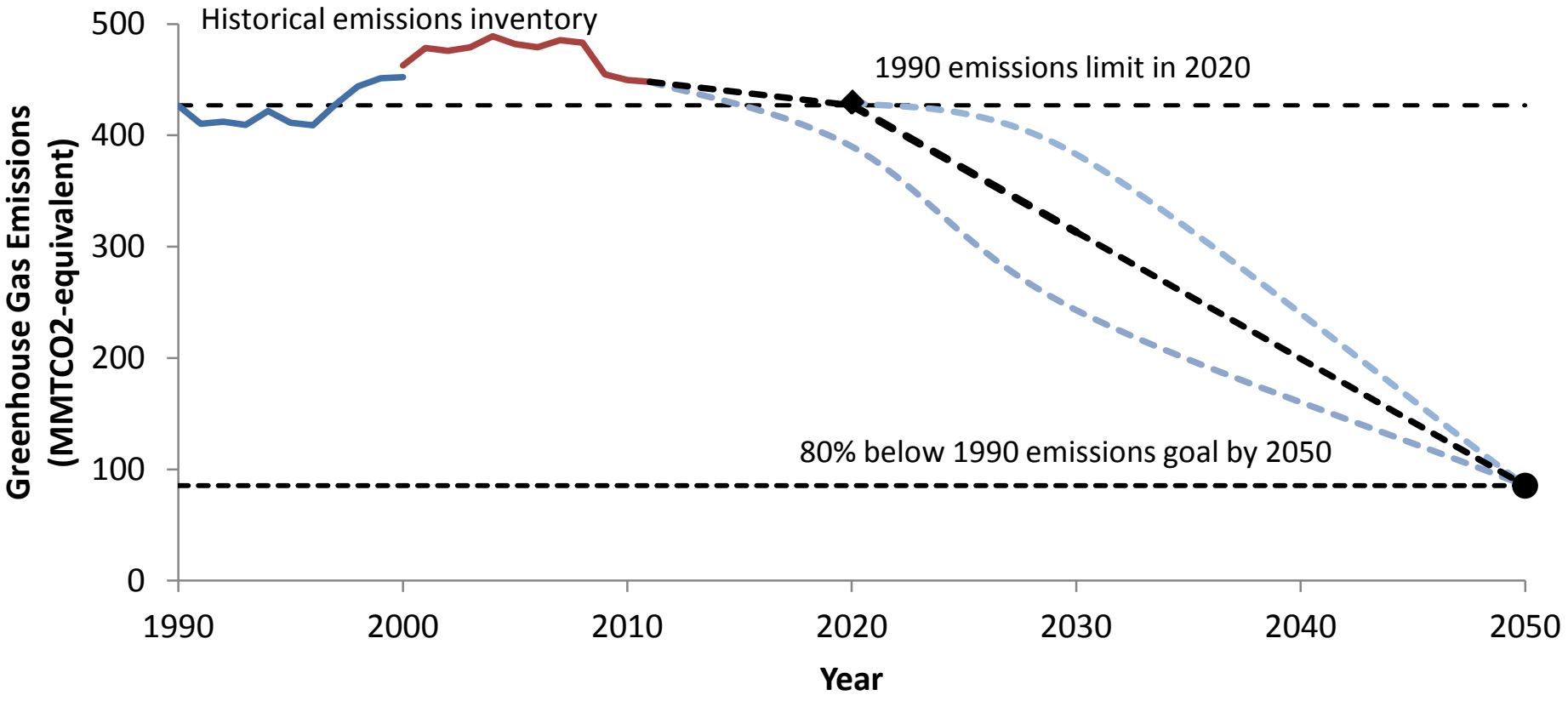
- **20% RPS achieved** by IOUs in 2012
- **15% reduction in electric sector GHG emissions** relative to 2005

+ By 2020:

- **On track to meet (or exceed) 33% RPS** by 2020
  - ≈ 50% if counting rooftop PV (5%) and large hydro (13%)
- **20% reduction in electric sector GHG emissions** relative to 2005
- **6-8% rate increase** due to 33% RPS



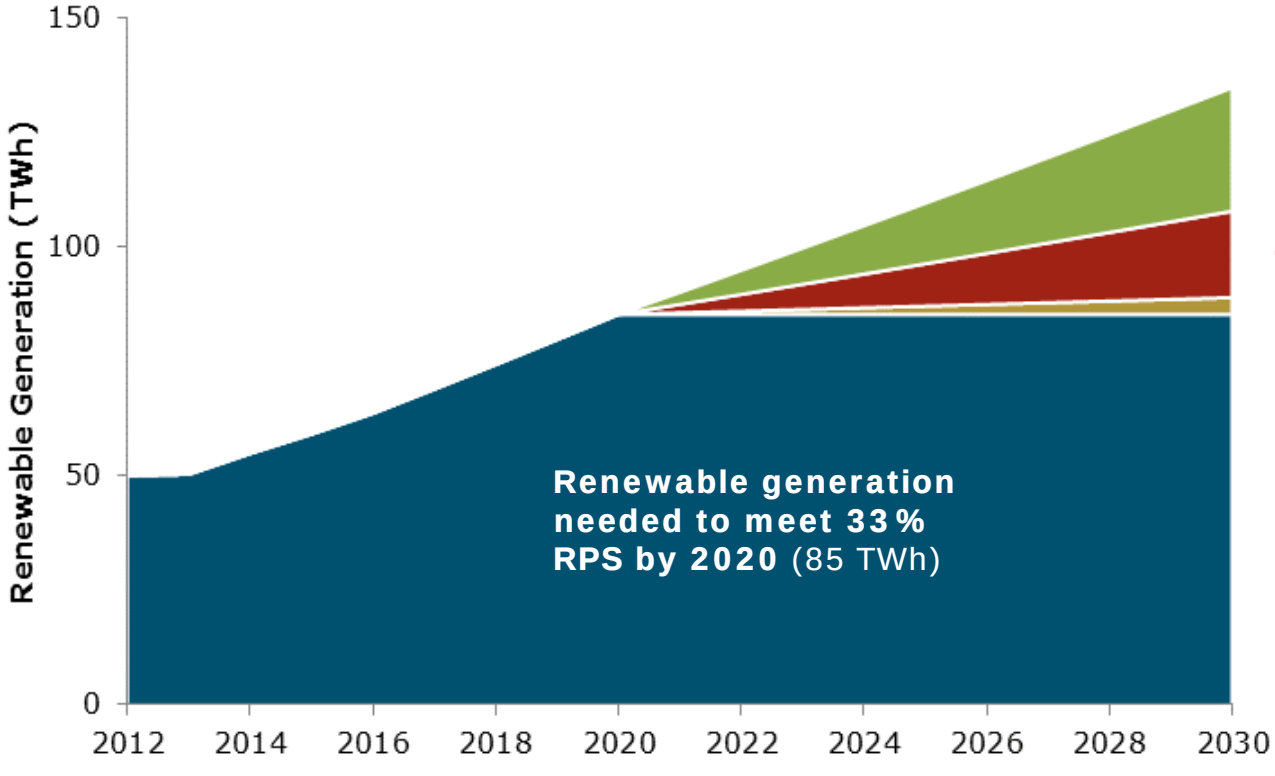
California's GHG Goals



+ **Meeting CA's GHG goal could require 90% zero-carbon generation by 2050** (Williams et al, *Science* 2012)

Key Study Questions

- **What are the requirements, operational challenges, potential solutions, costs and consequences of integrating 50% RPS by 2030 in California?**



50% RPS is a New Challenge

- **California still does not have operating experience at 33% RPS**
- **No other country or state has achieved an equivalent RPS above 30% anywhere in the world**
  - Germany: 22% renewables in 2012
    - 7.4% wind, 4.5% solar
  - Spain: 24% renewables in 2012
    - 18% wind, 4% solar
  - Denmark: 30% wind in 2012
    - Assisted by interconnections with Germany & Norway
  - Norway, New Zealand & British Columbia achieve higher renewable penetrations with large hydroelectric resources which do not count towards RPS in California

Renewable Integration Challenges

1. Downward ramping capability

Thermal resources operating to serve loads at night must be ramped downward and potentially shut down to make room for a significant influx of solar energy after the sun rises.

2. Minimum generation flexibility

Overgeneration may occur during hours with high VER production even if thermal resources and imports are reduced to their minimum levels. A system with more flexibility to reduce thermal generation will incur less overgeneration.

3. Upward ramping capability

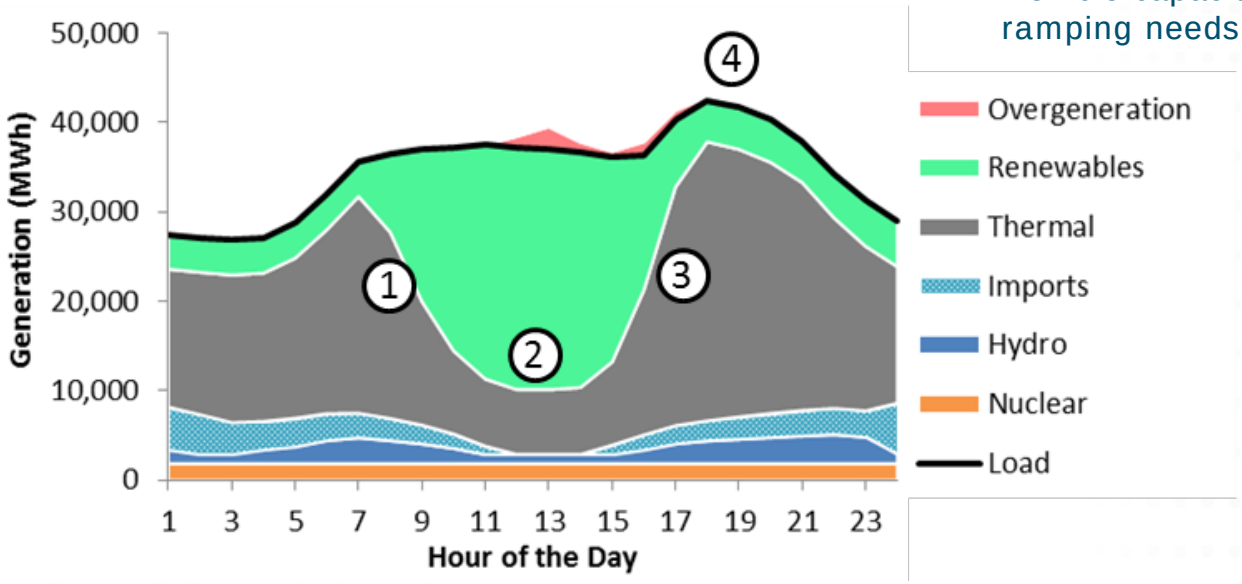
Thermal resources must ramp up quickly from minimum levels during the daytime hours and new units may be required to start up to meet a high net peak demand that occurs shortly after sundown.

4. Peaking capability

The system will need enough resources to meet the highest peak loads with sufficient reliability

5. Sub-hourly flexibility (not shown in chart)

Flexible capacity needed to meet sub-hourly ramping needs



Study utilized E3's Renewable Energy Flexibility (REFLEX) Model to investigate flexible capacity needs under high renewables

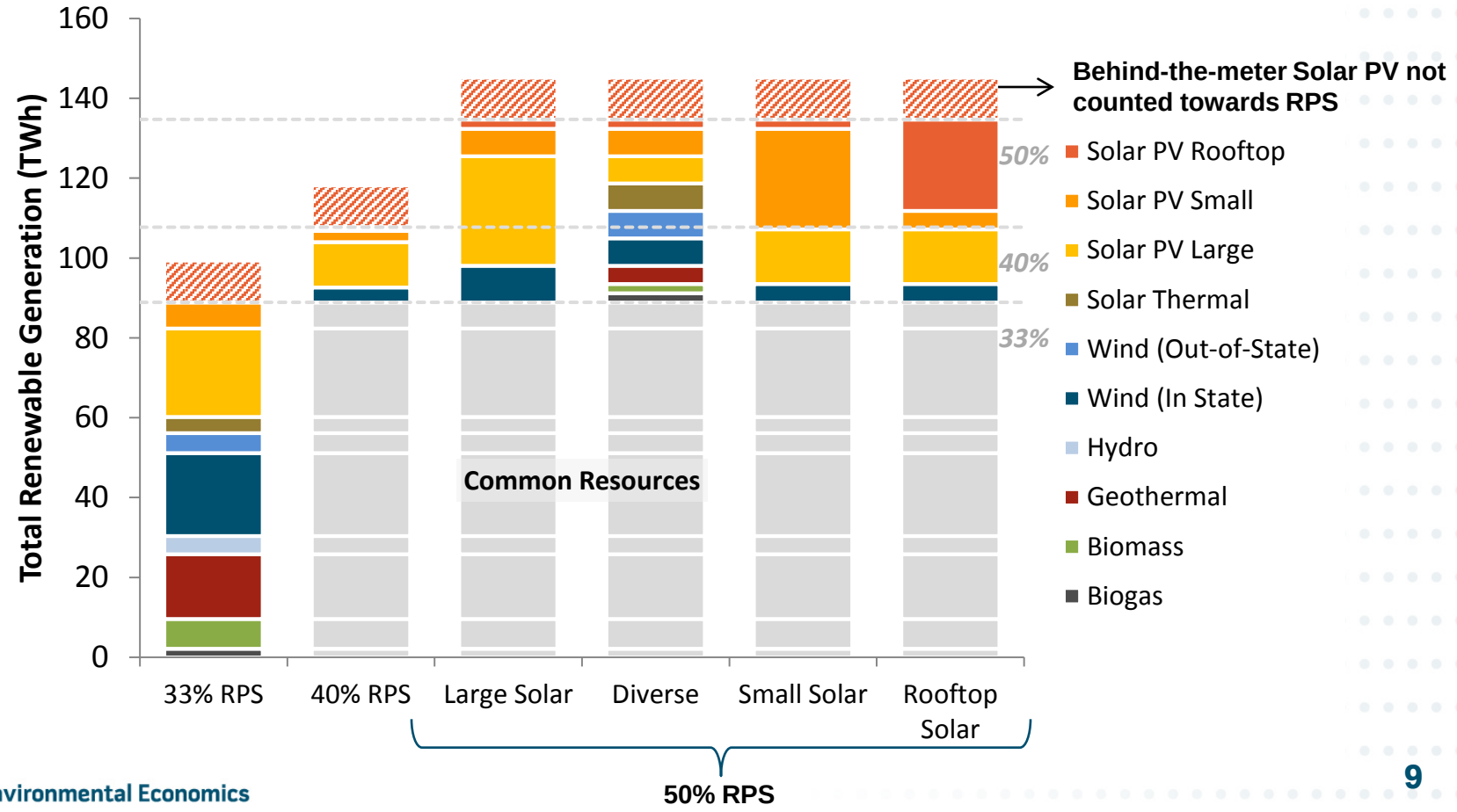
REFLEX: Stochastic Production Simulation Modeling

- **REFLEX answers critical questions about flexibility need through stochastic production simulation**
  - **Captures wide distribution of operating conditions** through Monte Carlo draws of operating days
    - 63 years of load conditions, 42 years of hydro, 3 years of solar, 3 years of wind
  - **Illuminates the significance of the operational challenges** by enabling calculation of likelihood, magnitude, duration & cost of flexibility violations
  - **Creates an economic framework** to guide choices between operational strategies and investments

Implemented on the Plexos for Power Systems and ProMaxLT production simulation platforms

2030 Study Scenarios

- Study considered a 33% RPS scenario plus five high RPS scenarios with resource incremental to 33% RPS resources
- All portfolios include 7,000 MW of behind the meter solar PV that does not count toward RPS: "physical" renewable penetration of 50% RPS scenarios is 54%

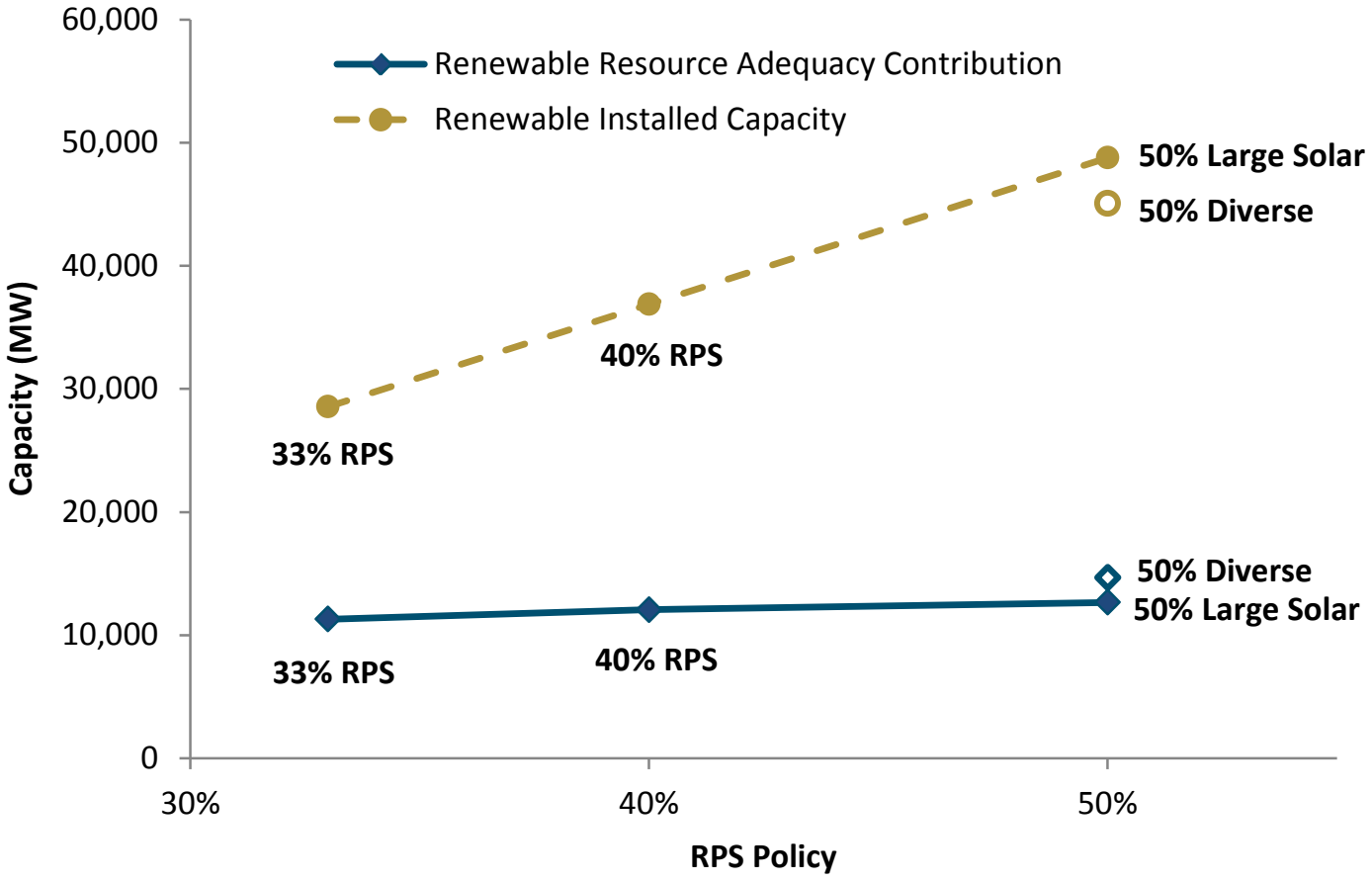


Key Assumptions

- **Study Area is the three Balancing Authority Areas: SMUD, LADWP and CAISO**
- **All renewable generation is balanced by California grid operators**
  - Study investigates whether it is physically possible to achieve RPS levels of 50% and higher
- **Study assumed retirement of 19,000 MW of coal, nuclear and once-through cooled gas steam turbine power plants by 2030**
  - These plants were replaced with 11,000 MW of new gas-fired CCGT and CT units
  - Local reliability constraints met (e.g., 25% of SDG&E load and 40% of SCE load served with thermal generation)
- **Up to 1500 MW of exports allowed in base case**

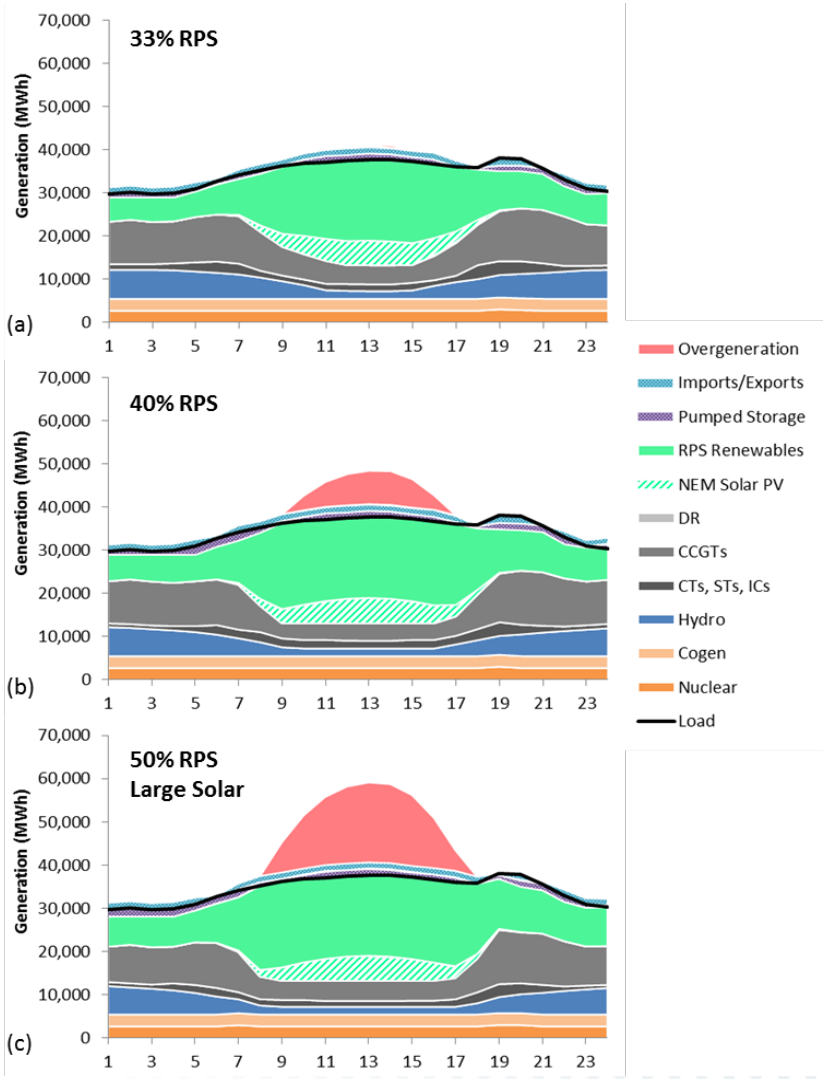
Capacity Value of Renewables Declines Significantly Above 33%

- As the installed renewable capacity increases, the effective capacity of renewables diminishes



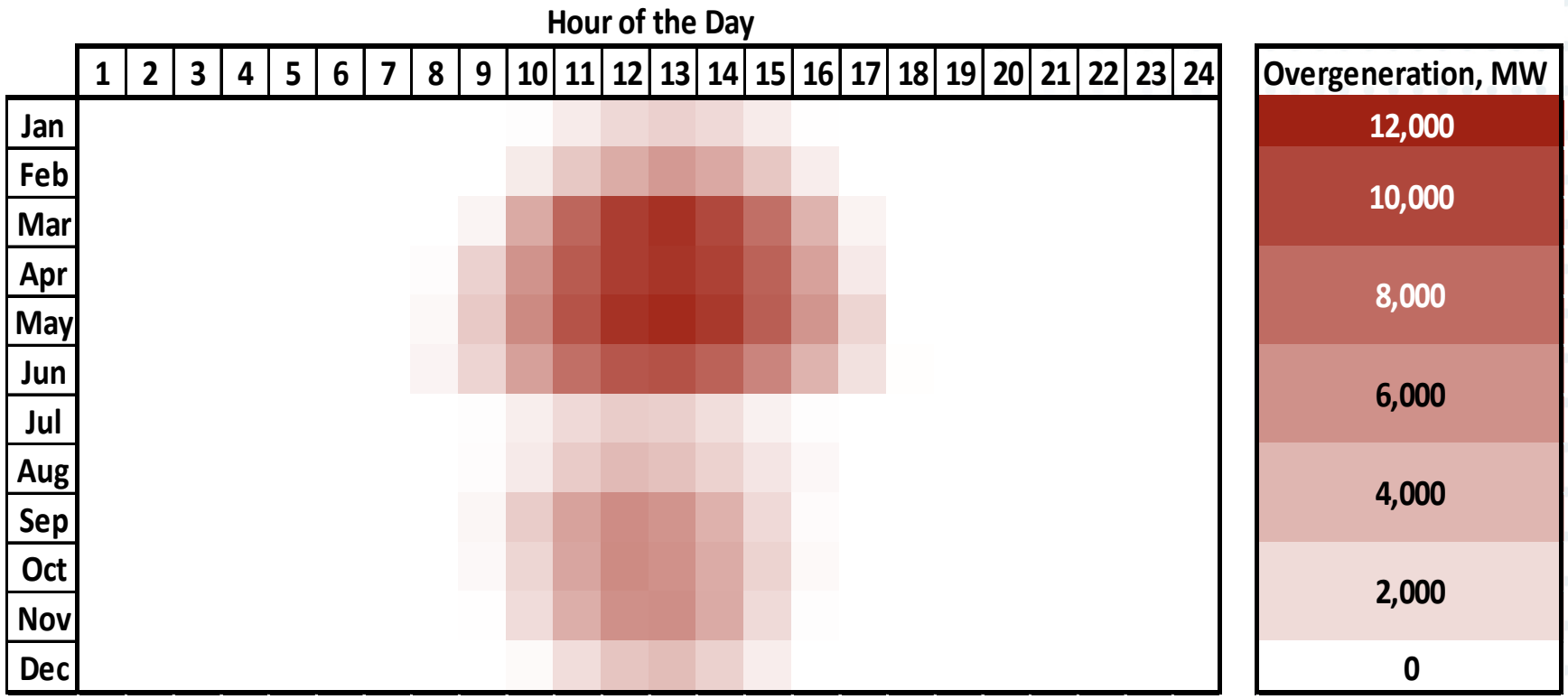
Example Day in April under 33%, 40% and 50% RPS

- **Chart shows increasing overgeneration above 33%**
  - Overgeneration is very high on some days under the 50% Large Solar case
  - Fossil generation is reduced to minimum levels needed for reliability
- **Renewable curtailment is a critical strategy to maintain reliability**
  - Reduces overgeneration
  - Mitigates ramping events



Overgeneration Is Extensive and Can Occur in Any Month

Average overgeneration (MW) by month-hour, 50% Large Solar Case:



Overgeneration Statistics

Overgeneration is minimal at 33% RPS, but increases to nearly 9% of available renewable energy under the 50% RPS Large Solar scenario

Overgeneration Statistics	33% RPS	40% RPS	50% RPS Large Solar
Total Overgeneration			
GWh/yr.	190	2,000	12,000
% of available RPS energy	0.2%	1.8%	8.9%
Overgeneration frequency			
Hours/yr.	140	750	2,000
Percent of hours	1.6%	8.6%	23%
Extreme Overgeneration Events			
99th Percentile (MW)	610	5,600	15,000
Maximum Observed (MW)	6,300	14,000	25,000

Marginal Overgeneration

- **Marginal overgeneration = the fraction of the next increment of renewables that would result in overgeneration**
  - Varies by renewable technology based on the generation profile of the renewable resource compared to load shape
- **50% RPS Diverse scenario results in less overgeneration than 50% RPS Large Solar scenario**

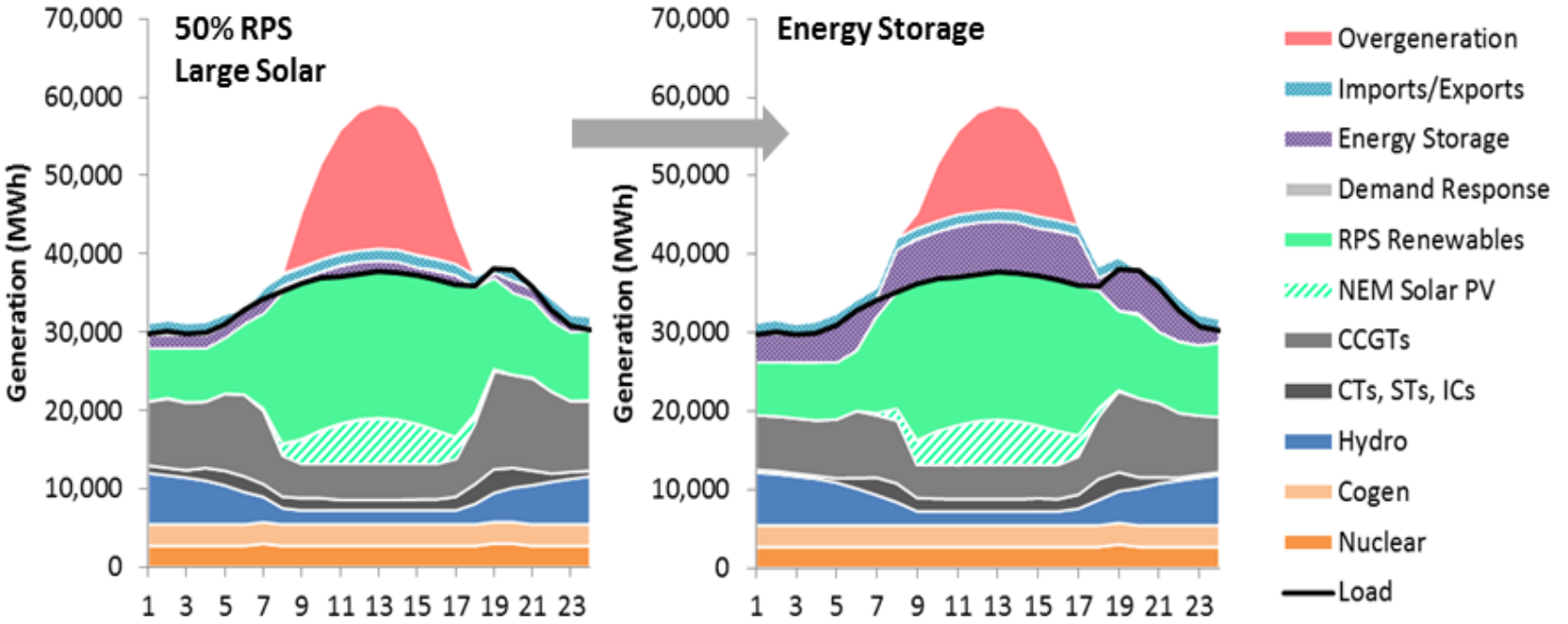
Technology	33% RPS	40% RPS	50% RPS Large Solar	50% RPS Diverse
Geothermal	2%	9%	23%	15%
Wind	2%	10%	22%	15%
Solar PV	5%	**26%**	**65%**	**42%**

Potential Integration Solutions

- **Default solution to maintain reliability: Managed, compensated curtailment of renewables**
  - Curtailed renewable energy replaced to ensure compliance with RPS
- **Five potential integration solution cases are analyzed as alternatives to curtailment**
  1. Diverse renewable resource portfolio
  2. Enhanced Regional Coordination
  3. Conventional Demand Response (down only)
  4. Advanced Demand Response (up and down)
  5. Energy Storage
- **Study tested 5,000 MW of each solution by 2030**
  - Did not explore combinations or try to develop an optimal portfolio

Potential Integration Solution: Energy Storage Case

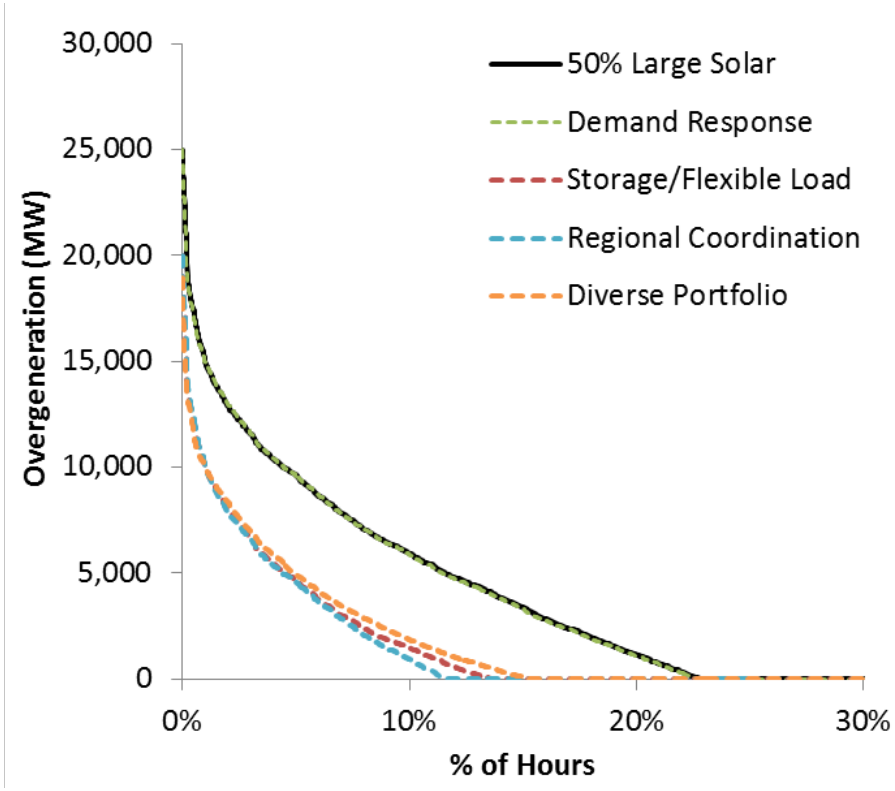
- **Assuming 5,000 MW of diurnal energy storage in CA reduces overgeneration from 9% in the 50% RPS Large Solar case to 4% of total renewable energy. Storage charges during the day & discharges at night.**



Example April day

Frequency of Flexibility Violations: Solution Cases

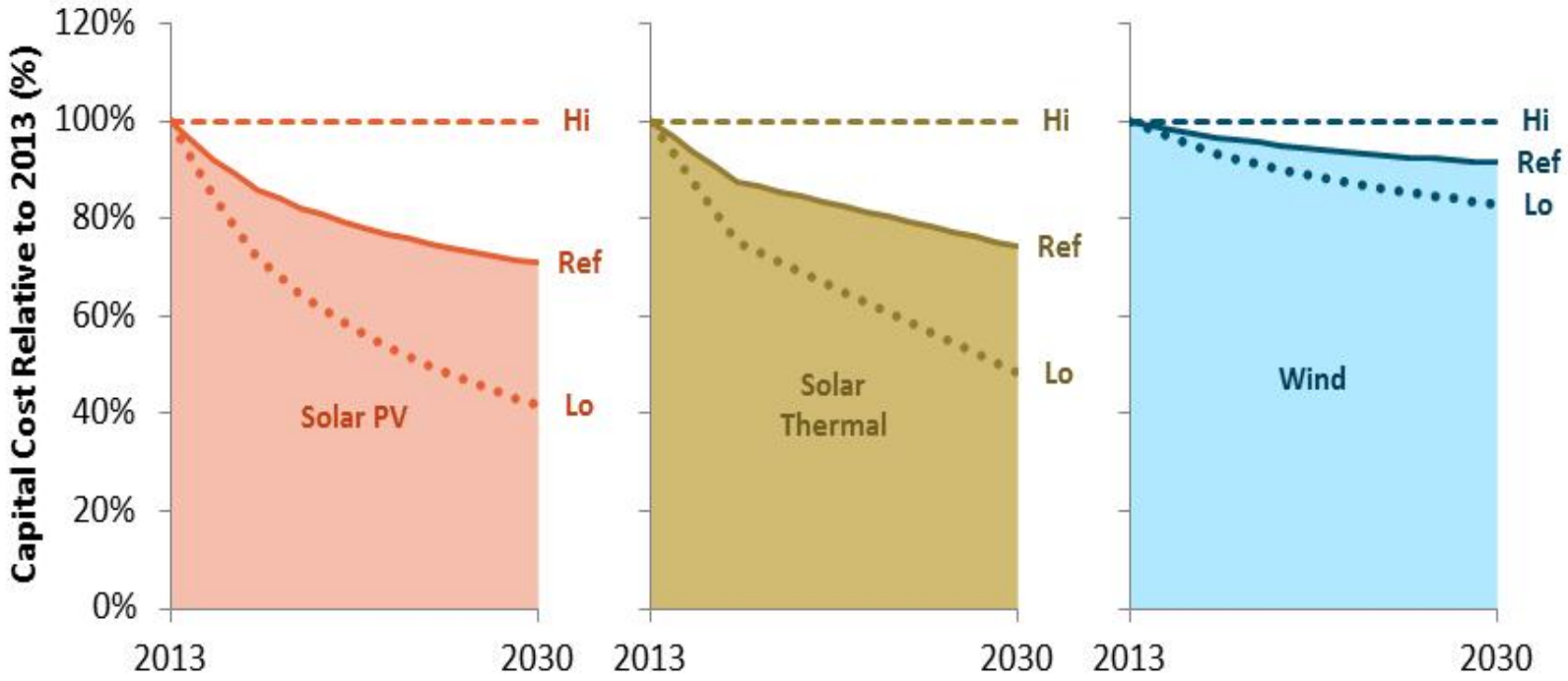
- **Only solutions that provide downward flexibility (storage, flexible load, and increased export capability) reduce overgeneration**



Solution	Overgen (GWh/yr)
None	12,000
Demand Response	12,000
Storage/ Flexible Load	5,000
Regional Coordination	4,700
Diverse Portfolio	5,400

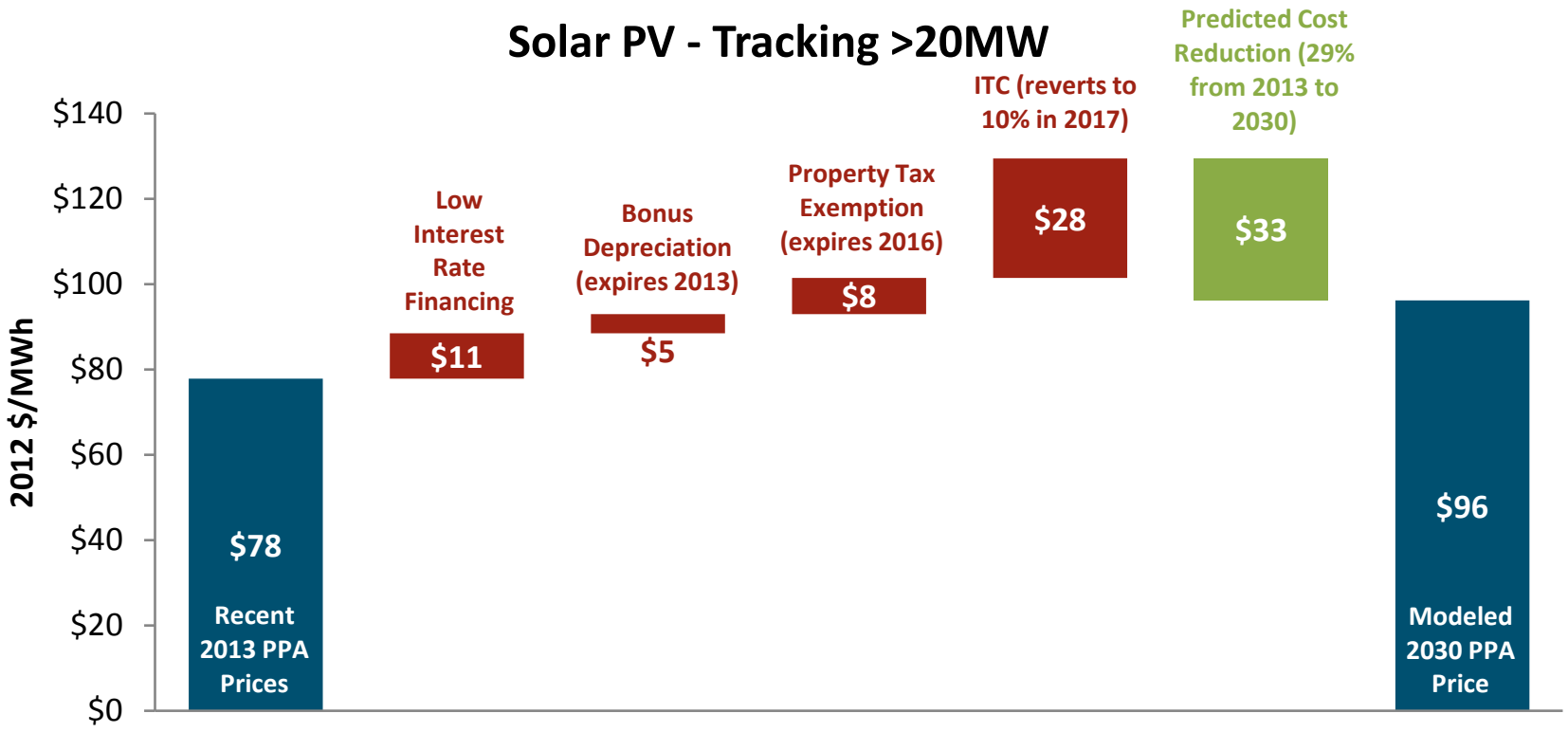
Renewable Capital Cost Reduction Assumptions through 2030

- "Learning curves" are utilized to project capital cost reductions for solar PV, solar thermal and wind by 2030



2030 Resource Cost Assumptions After Scheduled Tax Code Changes

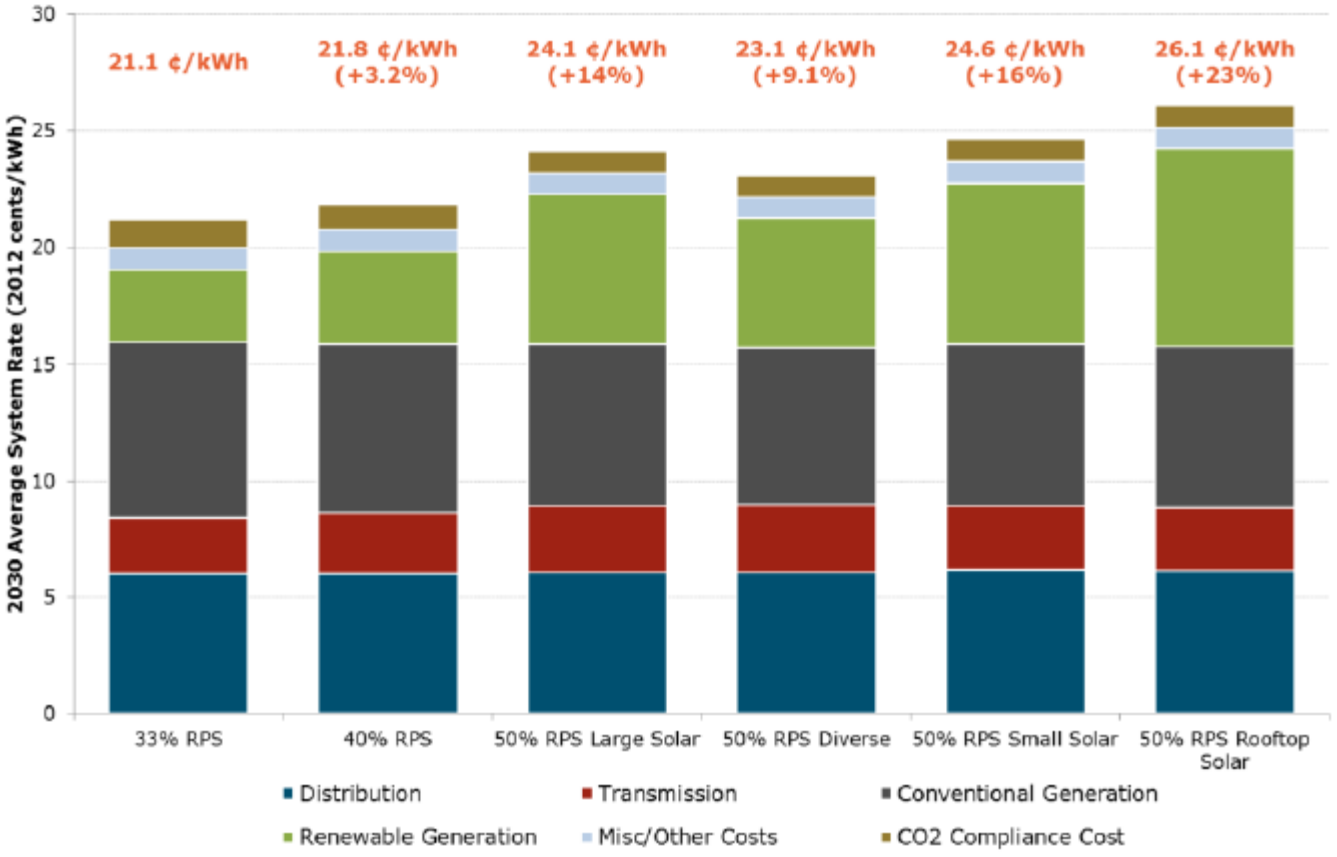
+ **2030 large solar PV: $96/MWh**
+ **2030 in-state wind: $99/MWh**
+ **2030 Base Case CCGT: $96/MWh***



*Base Case assumptions: $6/MMBtu gas, $50/ton CO2

2030 System Average Rate Impacts ($2012/kWh)

- 50% RPS scenarios result in a 9% - 23% increase in system average rates relative to a 33% RPS in 2030

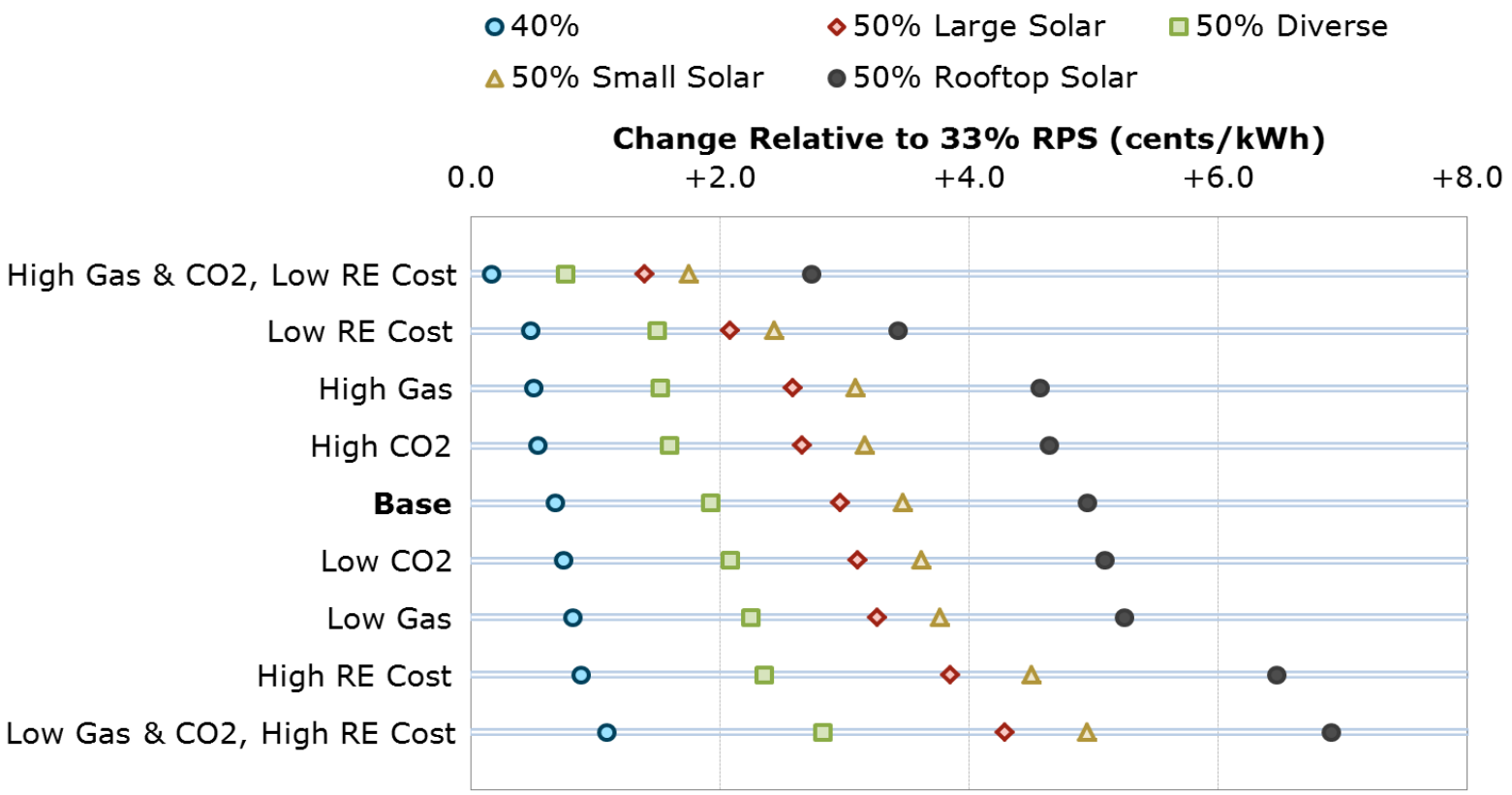


2030 revenue requirement
(2012 $ billion) % change relative to 33% RPS

Revenue Requirement Category	33% RPS	40% RPS	50% RPS Large Solar	50% RPS Diverse	50% RPS Small Solar	50% RPS Rooftop Solar
CO_2 Compliance Cost	3.2	2.9	2.5	2.4	2.5	2.5
Conventional Generation	20.3	19.5	18.7	18.1	18.7	18.6
Renewable Generation	8.2	10.6	17.1	14.8	18.5	22.8
Transmission	6.5	7.1	7.8	7.9	7.4	7.3
Distribution	16.2	16.2	16.3	16.3	16.7	16.5
Misc / Other Costs	2.5	2.5	2.5	2.5	2.5	2.5
Total	**56.9**	**58.8**	**64.9**	**62.1**	**66.3**	**70.3**
Percentage Change	n/a	3.2%	14.0%	9.1%	16.4%	23.4%

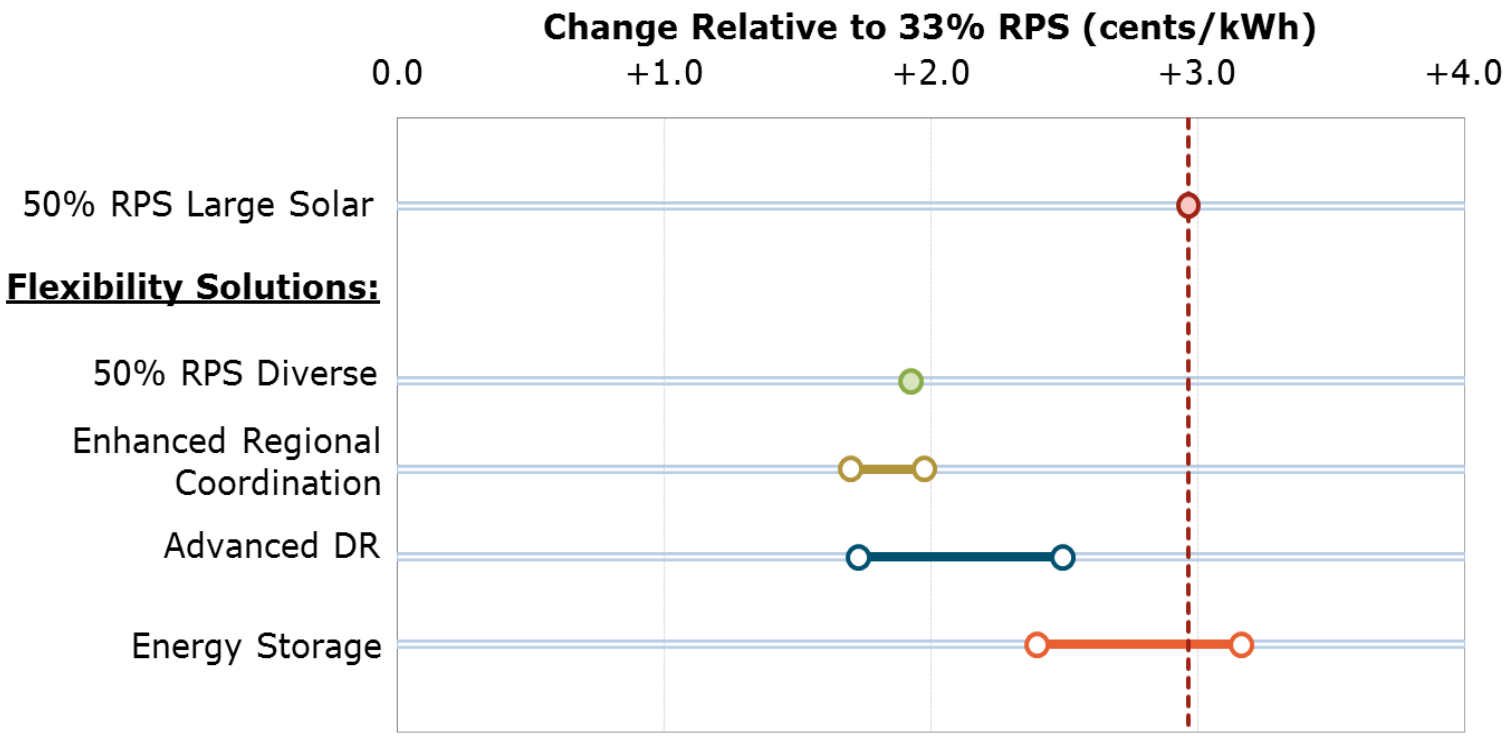
Cost differences between RPS portfolios relative to 2030 33% RPS
(2012 cents per kWh)

- **50% RPS scenarios result in higher rates relative to 33% RPS under a wide range of cost assumptions**



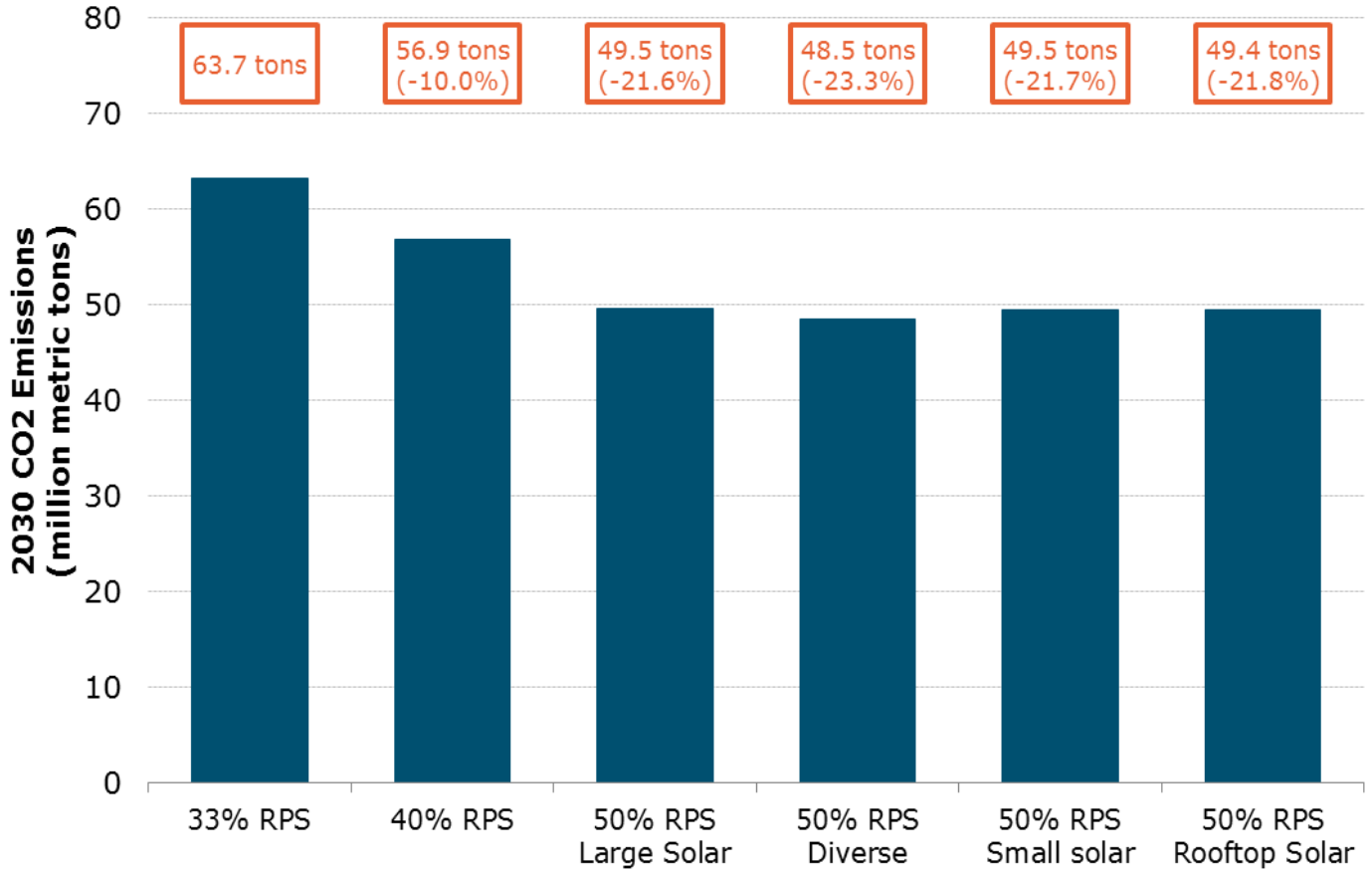
Change in Average Rates of Flexibility Solution Cases Relative to 33% RPS (2012 cents/kWh)

- **5,000 MW of flexibility solutions reduce the cost of meeting a 50% RPS in 2030, but result in higher average rates compared to the 33% RPS scenario**



2030 Carbon Dioxide Emissions

- **Electricity sector carbon dioxide emissions decrease in 2030 in all scenarios as the RPS increases**



Conclusions and Next Steps

- **Based on the assumptions made in this study, integrating 50% renewable energy in California appears to be technically feasible**
- **Renewable integration challenges, particularly overgeneration during daylight hours, are likely to be significant under a higher RPS**
- **A number of promising renewable integration solutions are identified; timely implementation of these solutions is critical to reducing costs & operational challenges**
  - Increased regional coordination and pursuing a diverse portfolio of renewable resources appear to be the most promising solutions

Energy+Environmental Economics

Thank You!

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