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Resource Planning Under High Renewable Penetrations

California Energy Commission
IRP Workshop

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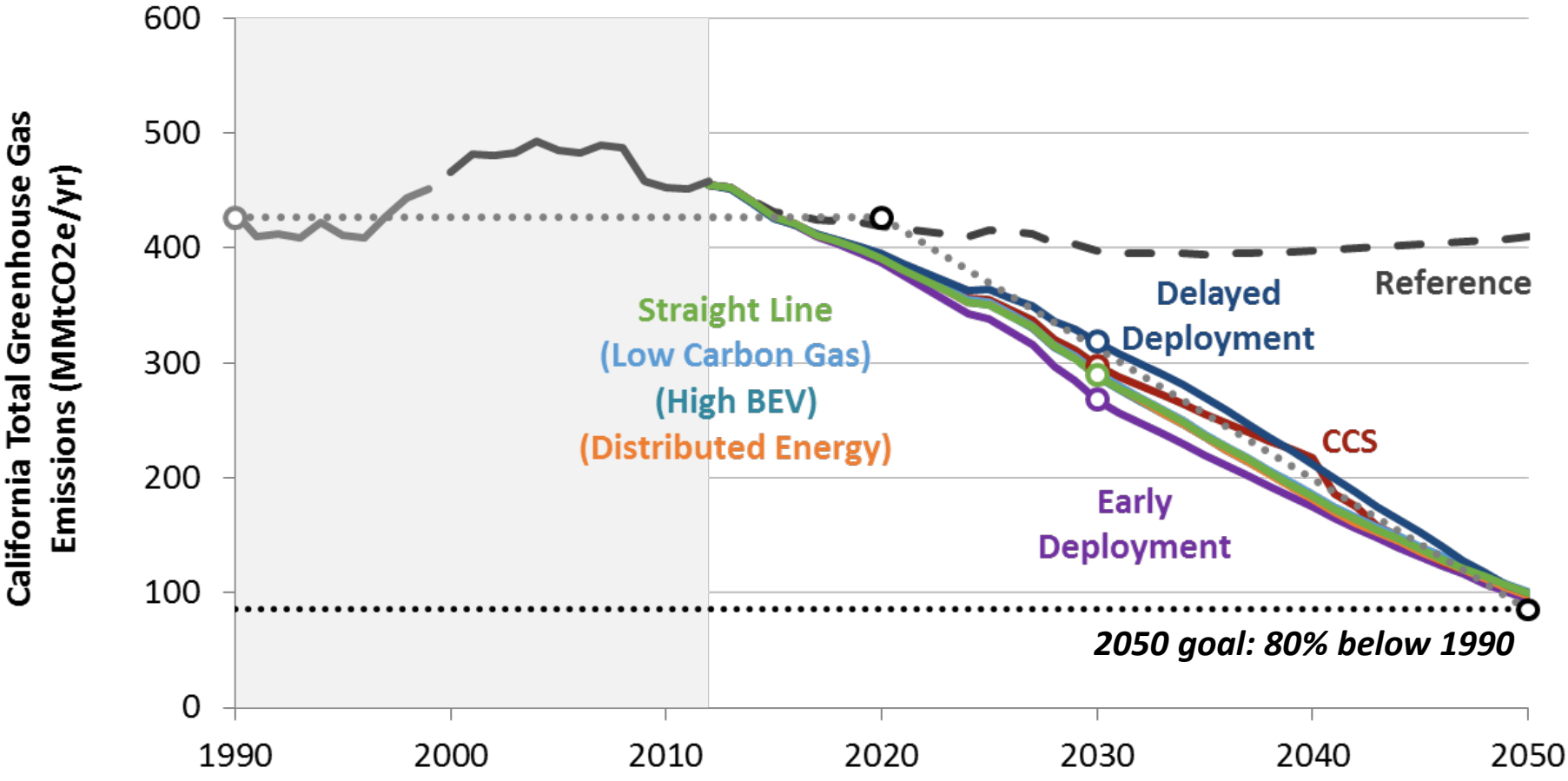
About E3

- 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

Multiple Scenarios Are on a Consistent Trajectory to Meet 2050 GHG Goal

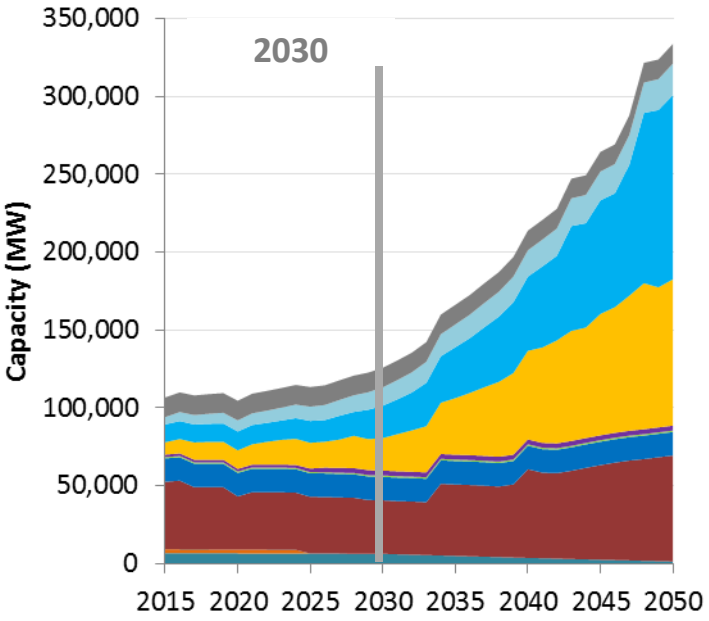


Governor Brown's 40% goal is closest to Early Deployment scenario in 2030

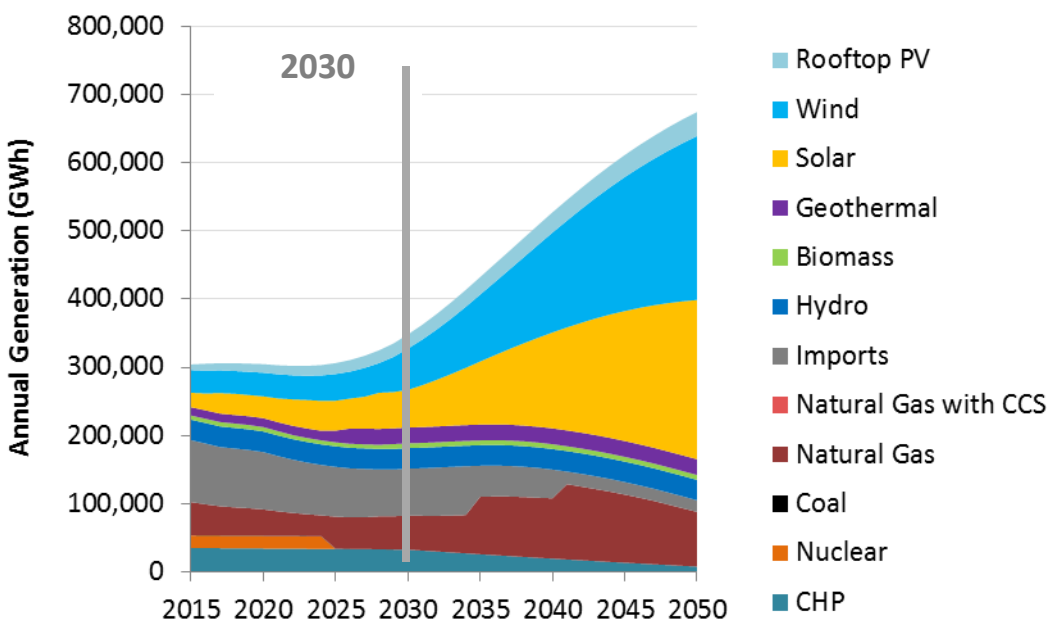
Renewables Are the Best Option to Decarbonize Electricity

- **Low-carbon electricity is primarily provided by solar and wind resources, natural gas generation continues to provide energy when solar and wind are not available**
- **Electric loads increase significantly between 2030 – 2050 due to fuel switching in buildings, industry & transportation**

Generating capacity by fuel type



Annual Generation by fuel type



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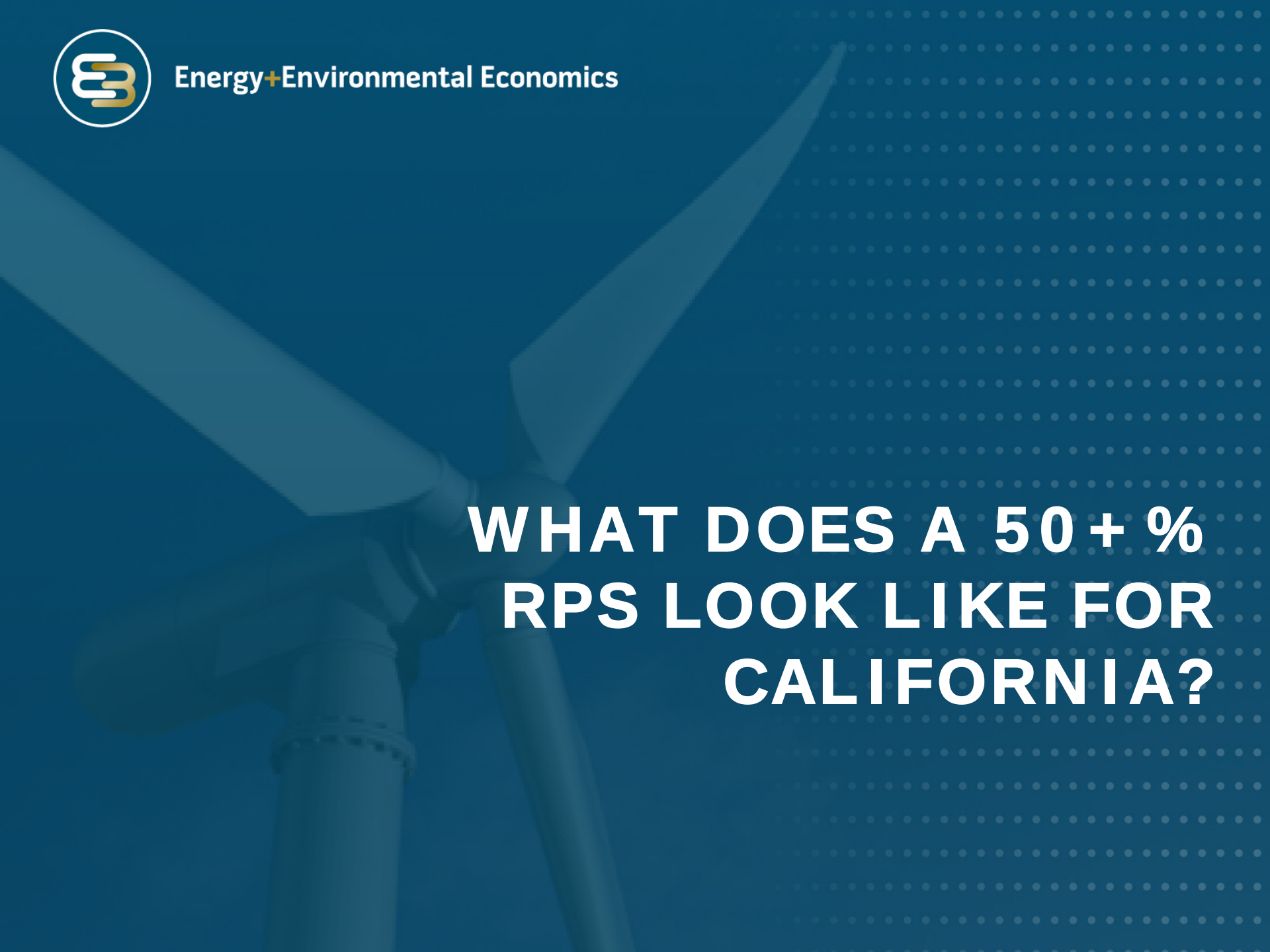


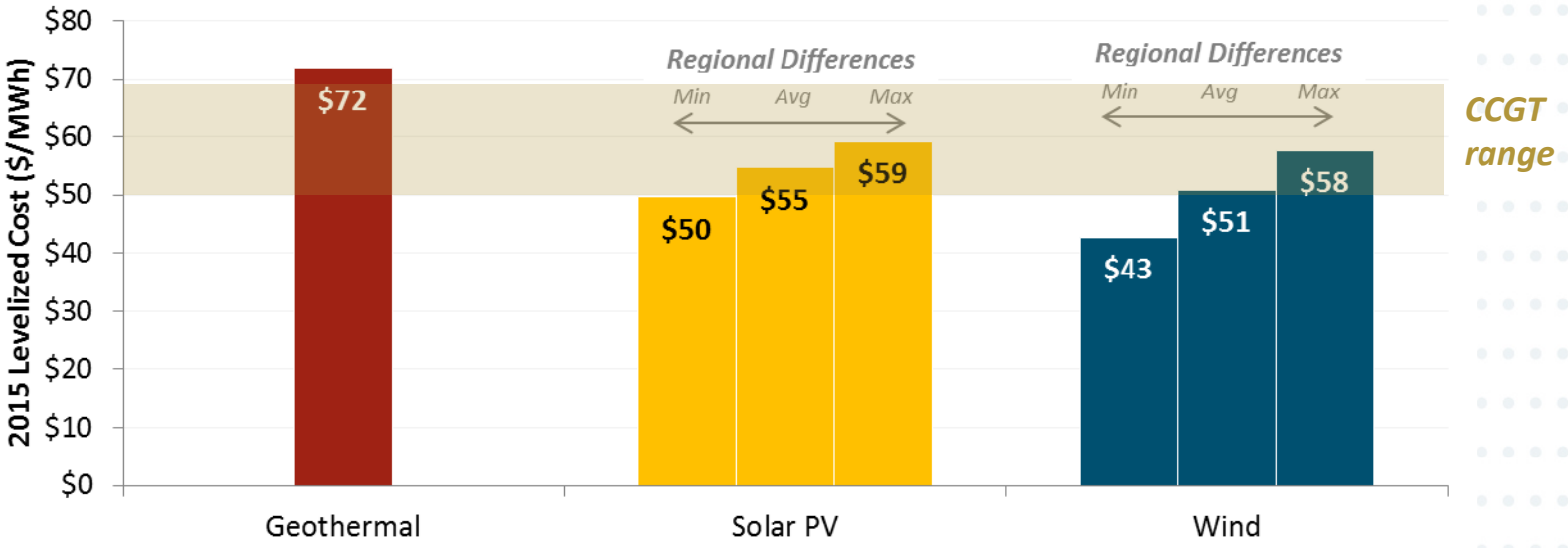
WHAT DOES A 50+% RPS LOOK LIKE FOR CALIFORNIA?

50+% RPS is a New Challenge

- **California does not yet have operating experience at 33% RPS**
- **Few other large countries or states have achieved an equivalent RPS at or above 30%:**
  - **Germany:** 28% renewables in 2014
    - 10% wind, 7% solar
  - **Spain:** 31% renewables in 2014
    - 22% wind, 6% solar
  - **Portugal:** 35% renewables in 2014
    - 26% wind, 1% solar
  - **Denmark:** >40% wind in 2014
    - Assisted by interconnections with Germany & Norway
- **50+% RPS is achievable but there may be some bumps in the road**

Renewables Are Cost-Competitive With Conventional Resources

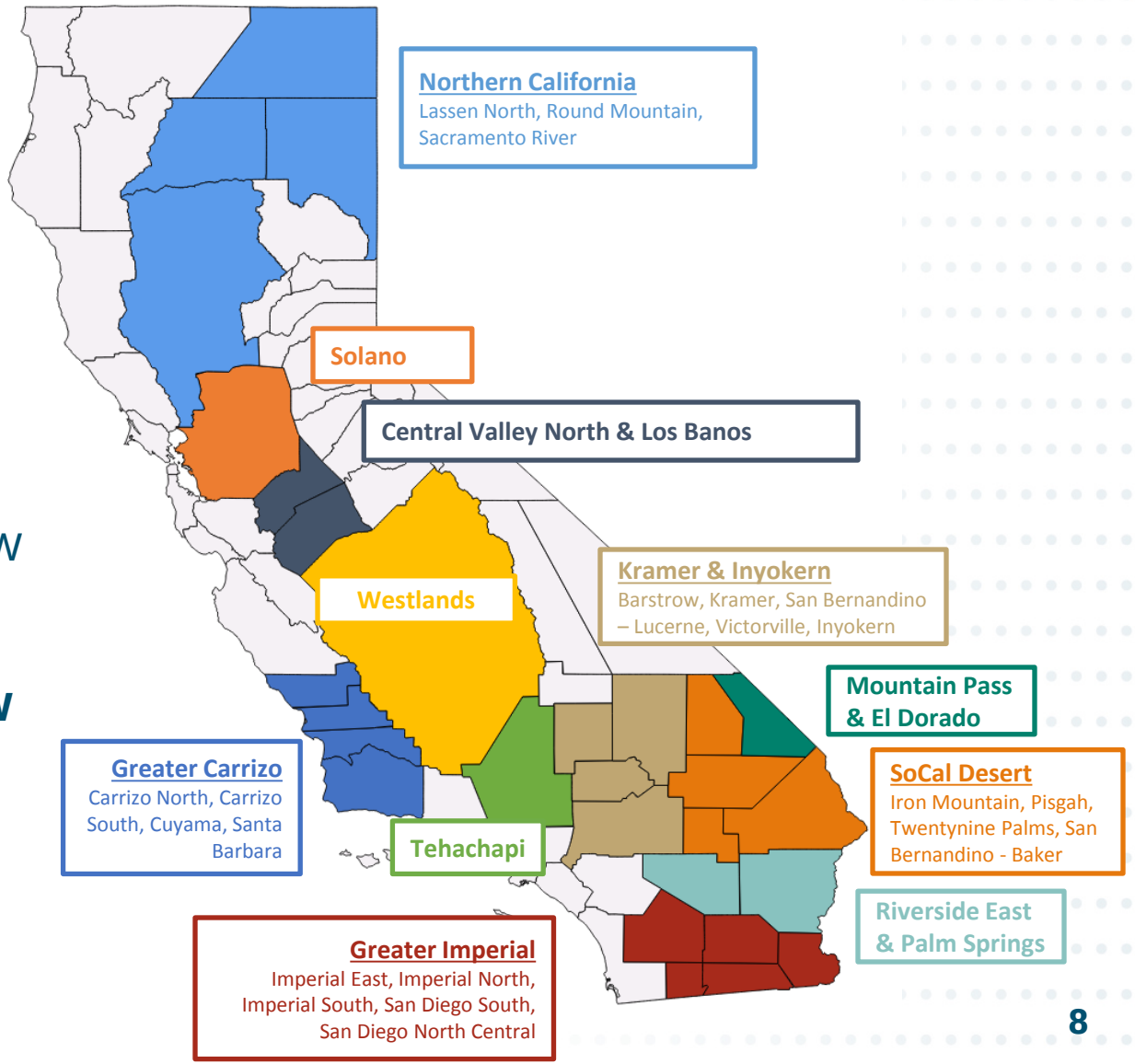
- Cost of solar and wind in 2016: $40-60/MWh
- Cost of gas combined-cycle plant: $50-70/MWh
- Cost of wind and solar continues to decline



Note: costs include effect of state and federal tax incentives

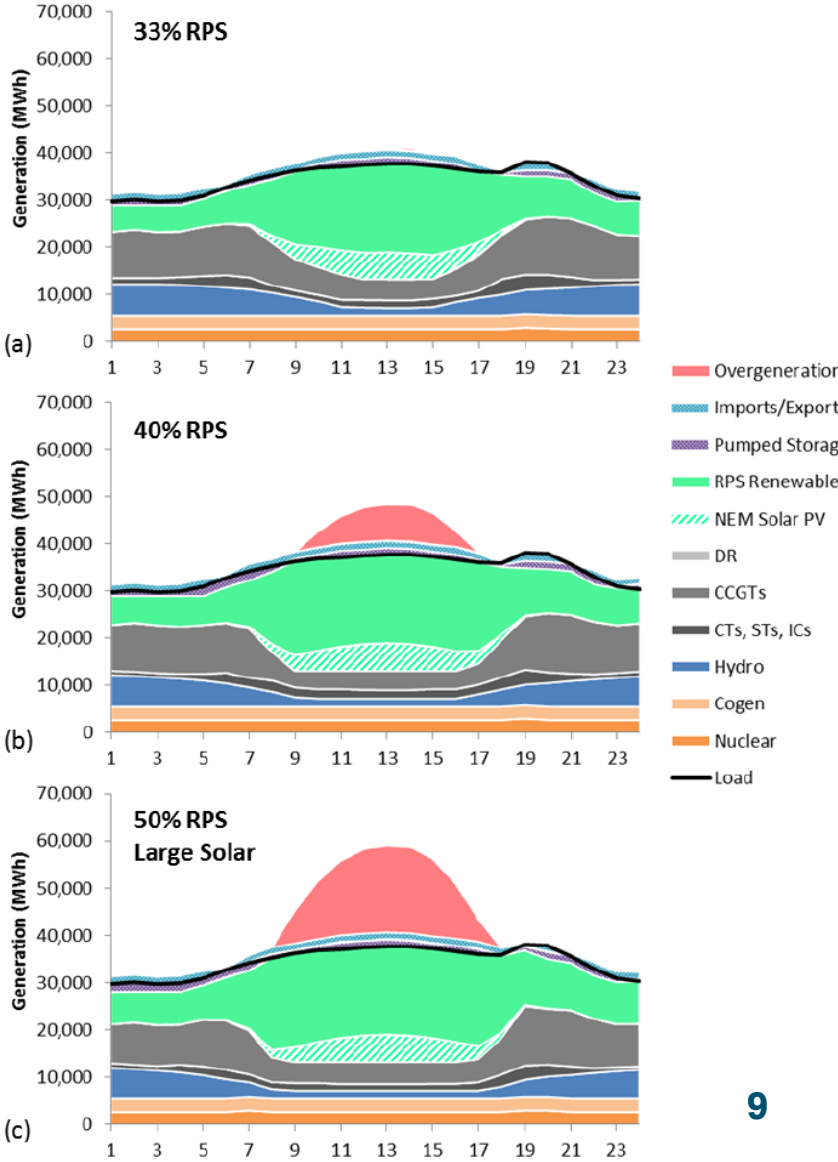
In-state Resource Potential is Largely Solar

- **New resources needed for 50% RPS:**
  - 15,000 MW
- **Developable potential:**
  - Geothermal: 1,800 MW
  - Wind: < 3,000 MW
  - **Solar: 100,000+ MW**



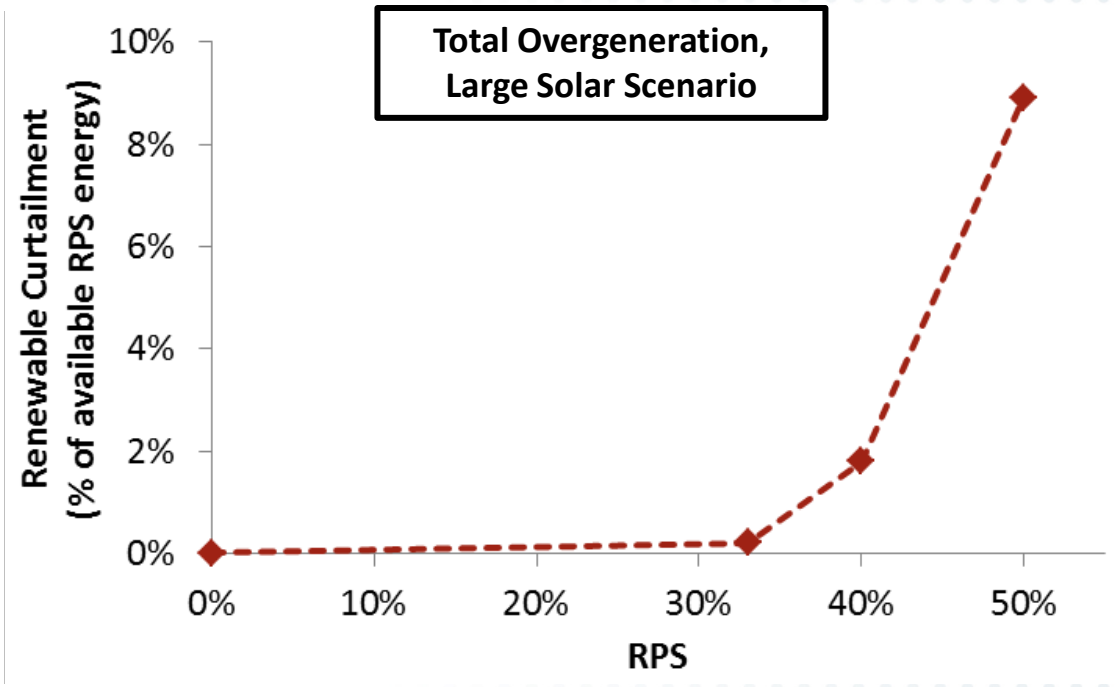
Principal Challenge at 50+% RPS is Solar-Driven Oversupply

- Studies show that the potential for over-generation becomes significant at higher renewable penetrations
- Solar energy production is concentrated during relatively few hours of the year
- California will need to find ways to use, export or store surplus renewable energy



Oversupply Challenge Grows Rapidly at Higher Penetrations

- **Significant increase in solar PV installations under current policy**
  - 15-20 GW for RPS
  - 12-21 GW of rooftops under NEM 2.0
  - 15-20 GW of wind and geothermal
- **Curtailment of wind and solar will become commonplace**

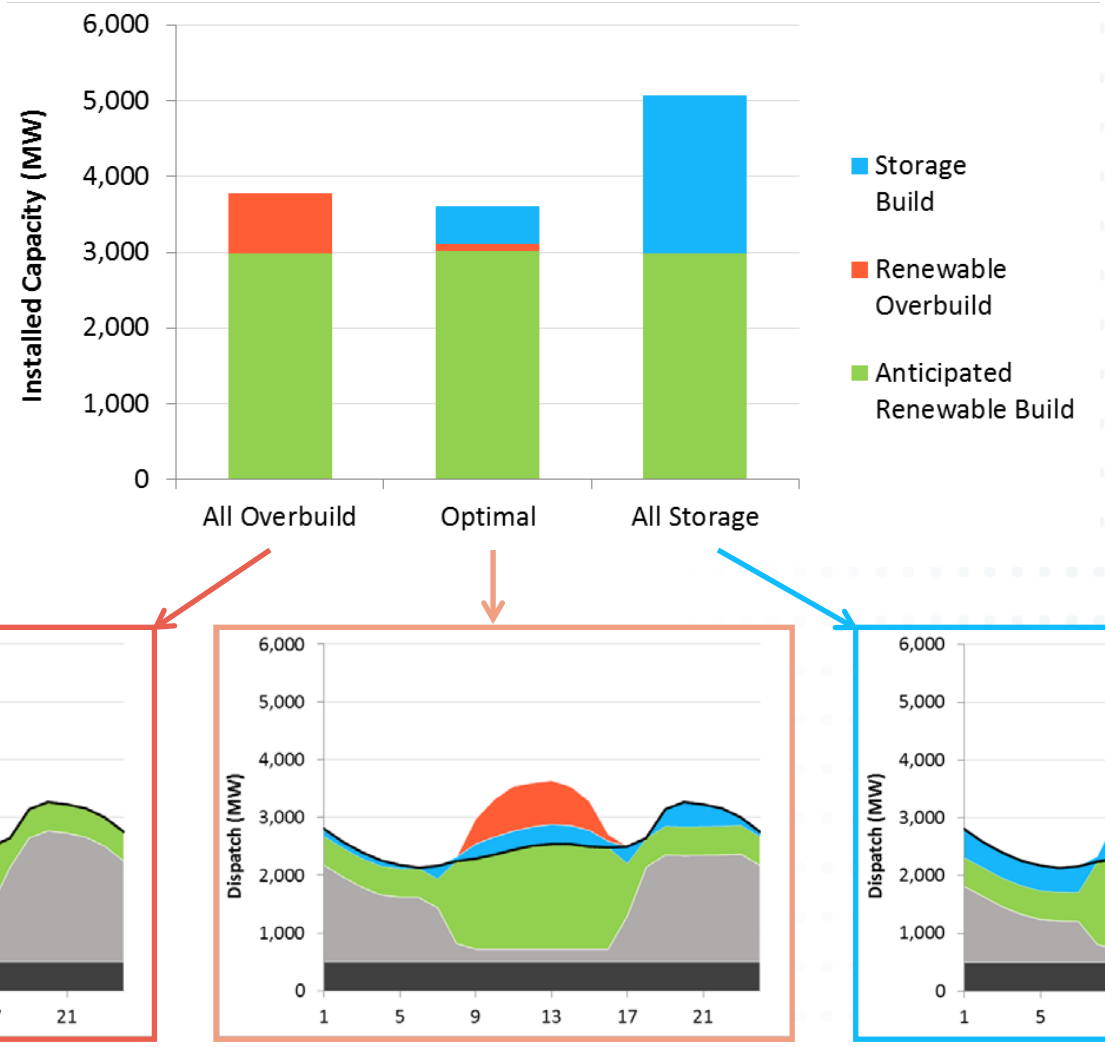


Overgeneration Statistics	33% RPS	40% RPS	50% RPS, Large Solar
Total Overgeneration (GWh/yr.)	190	2,000	12,000
% of hours with overgeneration	1.6%	8.6%	23%
% of available RPS energy	0.2%	1.8%	8.9%
Marginal overgeneration for Solar PV	5%	26%	65%

Many Potential Integration Solutions Exist

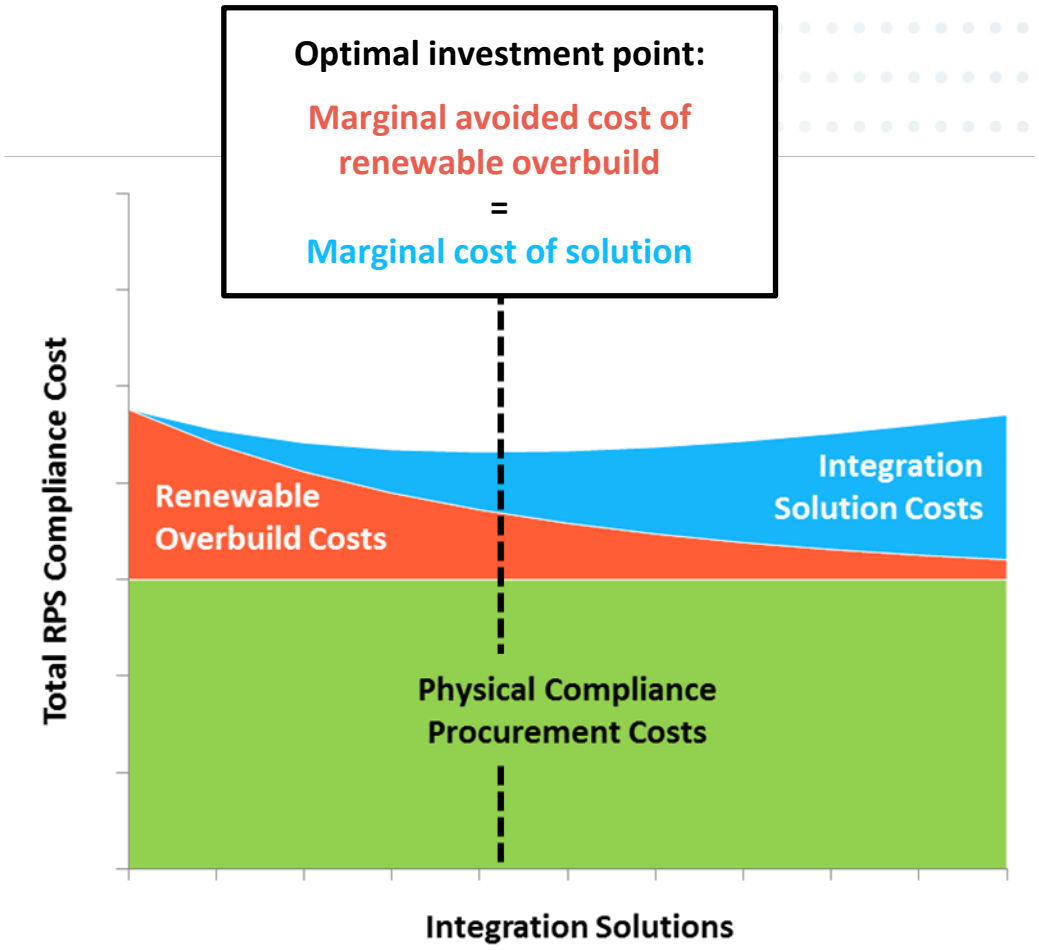
+ **Increased regional coordination**
  - Energy Imbalance Market and Regional ISO
+ **Renewable resource diversity**
  - Reduces overgeneration and need for flexible resources
+ **Flexible loads**
  - Shifting loads from one time period to another, sometimes on short notice
+ **Flexible generation**
  - Need generation that is fast ramping, starts quickly, and has min. gen. flexibility
+ **Energy storage**
  - Pumped hydro, batteries, compressed air

Optimal Solution Balances Non-Renewable Solutions with Overbuild



Integrated Planning is Needed to Balance Renewables & Solutions

- **Balancing the costs of renewable overbuild and integration solutions is a complex multidimensional optimization problem**
  - Complex interactive effects
  - Requires sophisticated model that considers both operations and investment costs
- **E3's RESOLVE model uses linear programming to solve this problem**
  - Used in CAISO's SB350 study
  - Currently in use in CPUC's IRP proceeding



Summary

- **Governor Brown's aggressive goals require large quantities of zero-carbon electricity**
  - Modeling suggests that 50% renewables is the minimum requirement to meet 40% GHG reductions by 2030
- **Integration challenges are significant above 40%**
  - Portfolio diversity and regional coordination are key solutions
- **It is possible to achieve 50-60% renewables at a reasonable cost**
  - State policymakers must ensure timely implementation of renewable integration solutions

E3's Key Renewable Integration & Decarbonization Projects

+ **Investigating a Higher Renewables Portfolio Standard in California**
  - **Clients:** PG&E, SCE, SDG&E, LADWP, SMUD
  - **Completed:** January 2014
+ **PATHWAYS: Long-Term Greenhouse Gas Reduction Scenarios**
  - **Clients:** California state agencies
  - **Completed:** April 2015
+ **Senate Bill 350 Study: The Impacts of a Regional ISO-Operated Power Market on California** (w/ The Brattle Group, Aspen Environmental Group & BEAR Inc.)
  - **Client:** CAISO
  - **Completed:** July 2016
+ **CPUC RPS Program & IRP Implementation Support**
  - **Client:** CPUC
  - **Ongoing**

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Thank You!

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