Energy+Environmental Economics

Reliance on Renewables: A California Perspective

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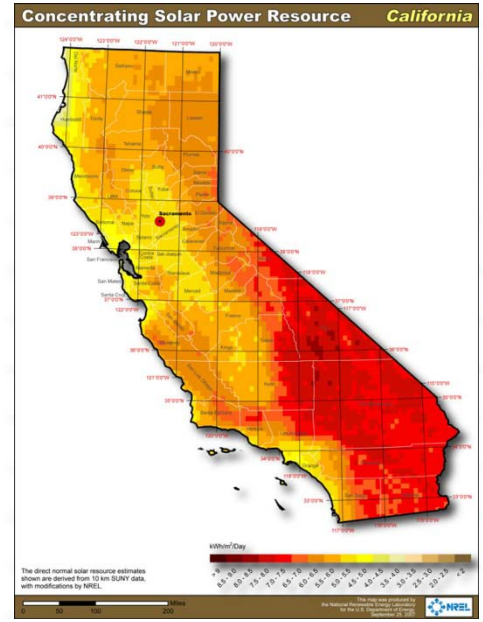
California's Current and Expected Renewable Energy Achievements

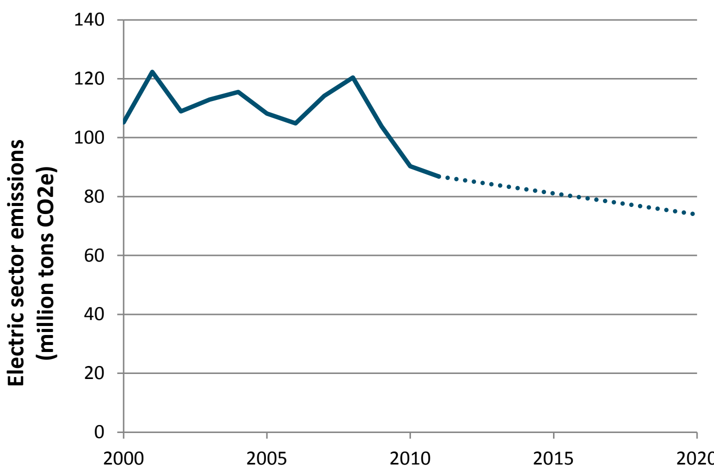
Today:

- **20% RPS achieved** by IOUs in 2012
- **20% reduction** in electric sector GHG emissions in 2011, 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%)
- **32% reduction in electric sector GHG emissions,** relative to 2005
- Projected rate impact: **6-8% increase** by 2020



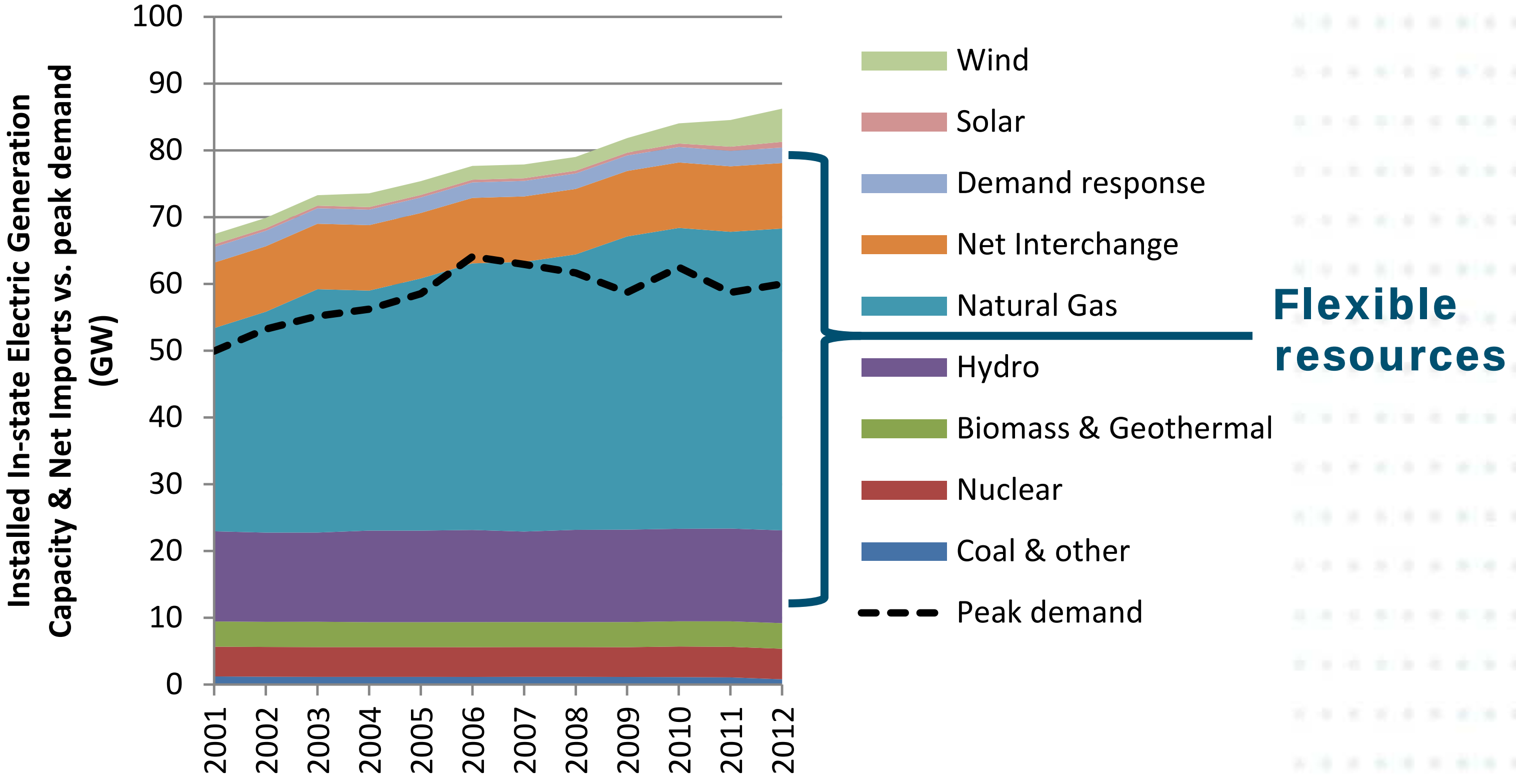


Key Factors in California's Success

- **Access to high-quality resources**
  - Excellent solar, wind and geothermal resources
  - Access to low-cost natural gas
- **Strong state policy support**
- **Very active developer market**
- **Steep decline in solar PV prices**
- **Complementary fleet of flexible natural gas and hydro resources**
- **Federal tax incentives and loan guarantees**

California's Generation Mix

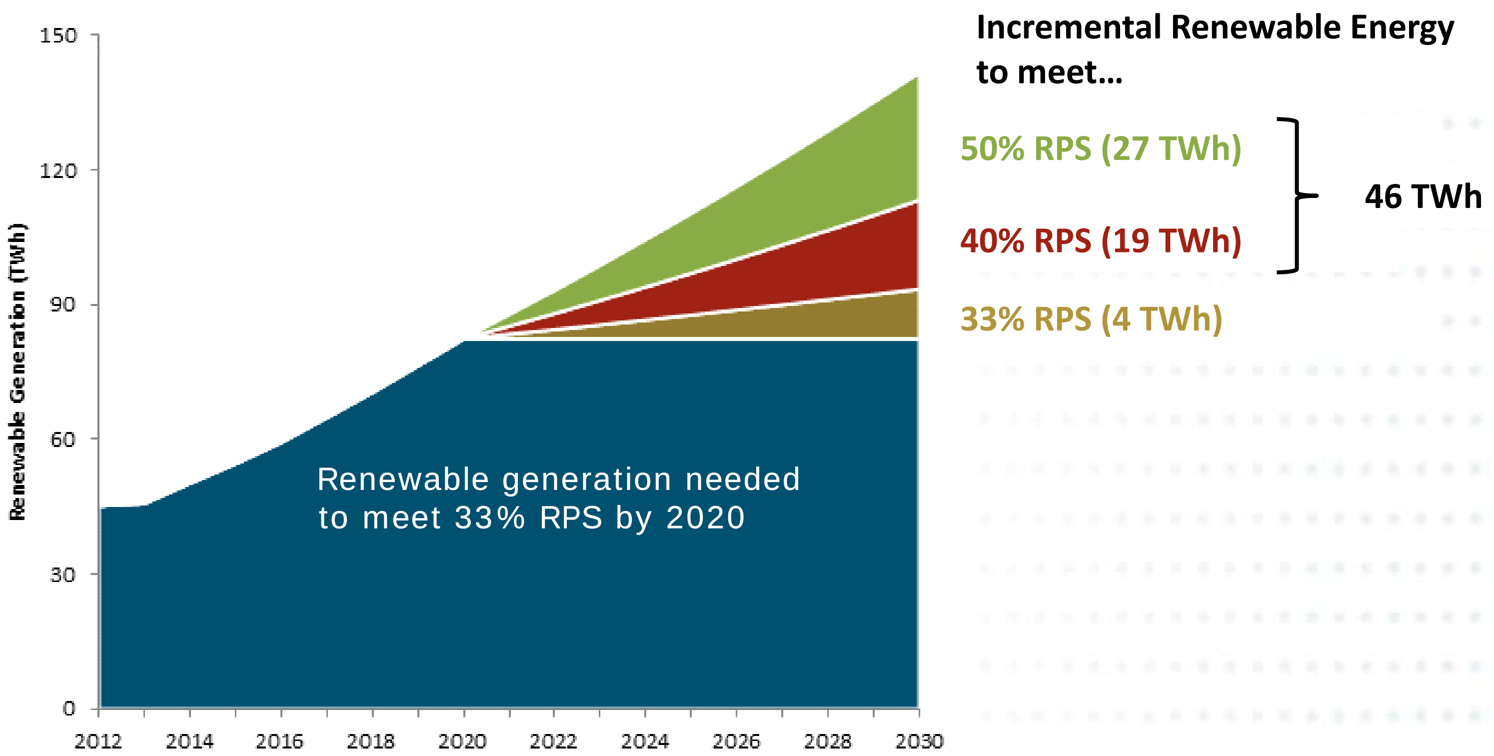
+ **California generation mix includes significant flexibility to integrate variable resources with its large natural gas fleet and relatively small amounts of must-run baseload generation**



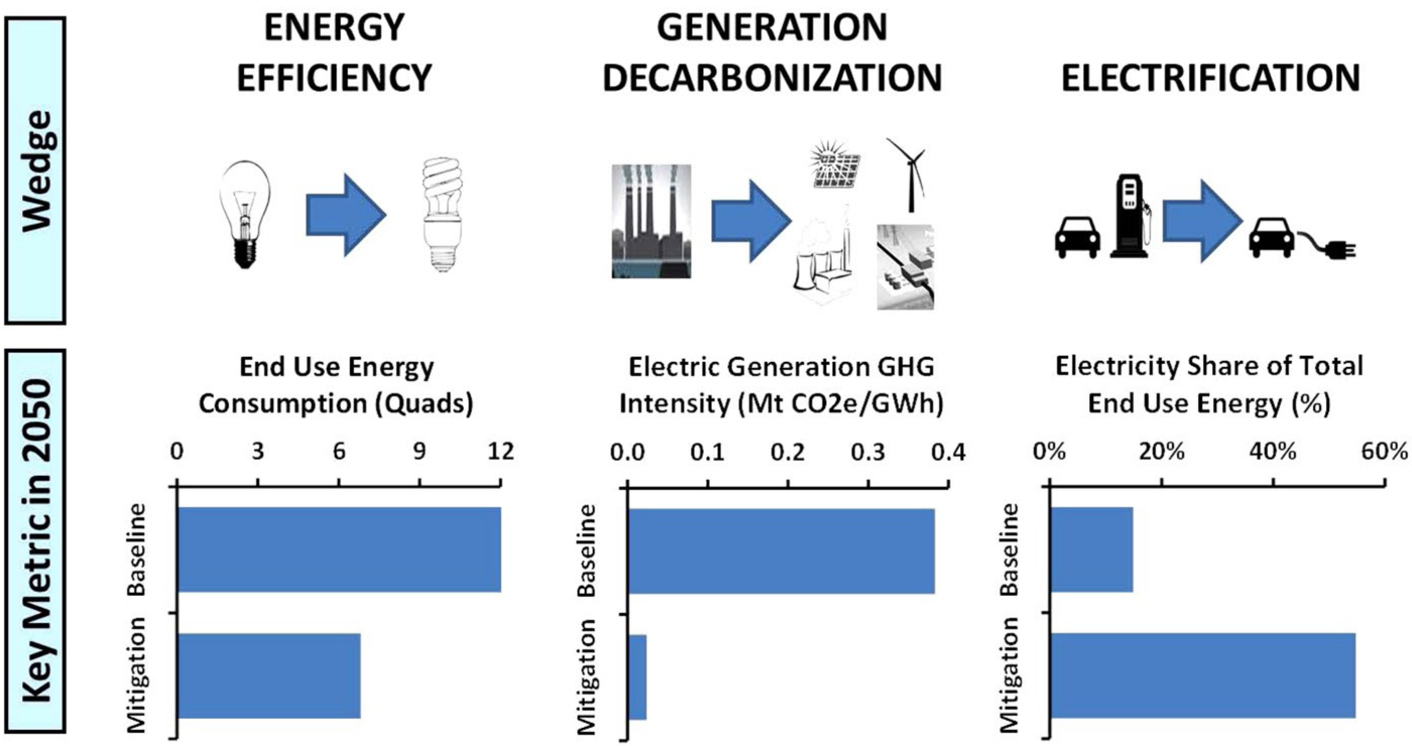
Source: CEC, California Installed In-State Electric Generation Capacity by Fuel Type (MW), 2001 – 2012. http://energyalmanac.ca.gov/electricity/electric_generation_capacity.html Net interchange and demand response resources estimated from CAISO 2013 Summer Loads and Resource Assessment.

Higher RPS in CA post-2020?

- 50% RPS by 2030 would maintain current trajectory for renewable penetration



Three Key Energy System Transformations Needed by 2050



Constraints

ENERGY EFFICIENCY

- Max feasible rate of improvement: 1.3% y^{-1}
- Fundamental changes in the built environment
- Limitations on changes in human behavior

GENERATION DECARBONIZATION

- Grid operability requires some natural gas usage
- Large infrastructure investment required
- Facility and transmission siting challenges

ELECTRIFICATION

- Smart charging
- Battery technology and cost
- Low-carbon source of electricity

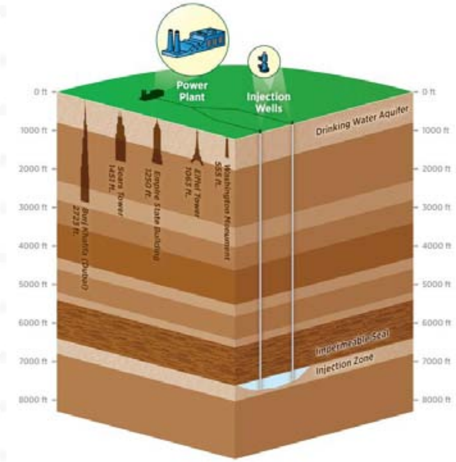
Source: "The Technology Path to Deep Greenhouse Gas Emissions Cuts by 2050: The Pivotal Role of Electricity," Williams et al, Science (2012)

Options for Electric Sector Decarbonization

1. **Nuclear**

   - State law prohibits construction of new nuclear facilities until the federal government has designated a permanent nuclear waste repository

2. **Fossil generation with carbon capture and sequestration (CCS)**



   - No commercial projects in service; proposed projects and are struggling to make it to the finish line due to cost overruns and political opposition

3. **Renewables**

   - Current default option

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**

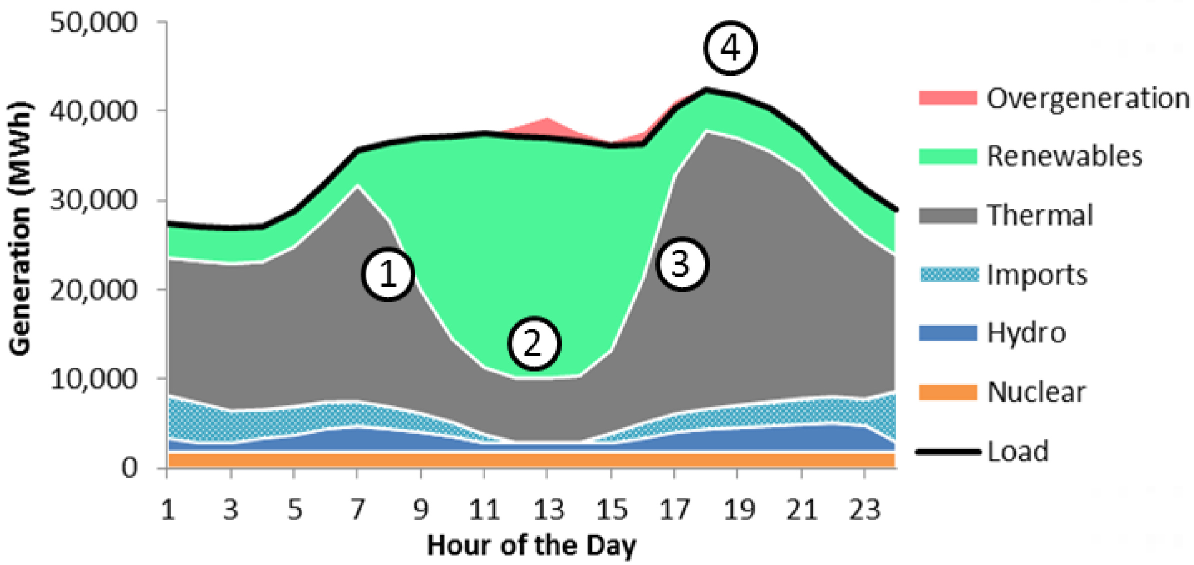
   Thermal resources must ramp up quickly from minimum levels during the daytime hours and new units may be required to start up to meet a high net peak demand that occurs shortly after sundown.

4. **Peaking capability**

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

5. **Variability and uncertainty**

   The system will need flexible capacity to meet sub-hourly ramping needs

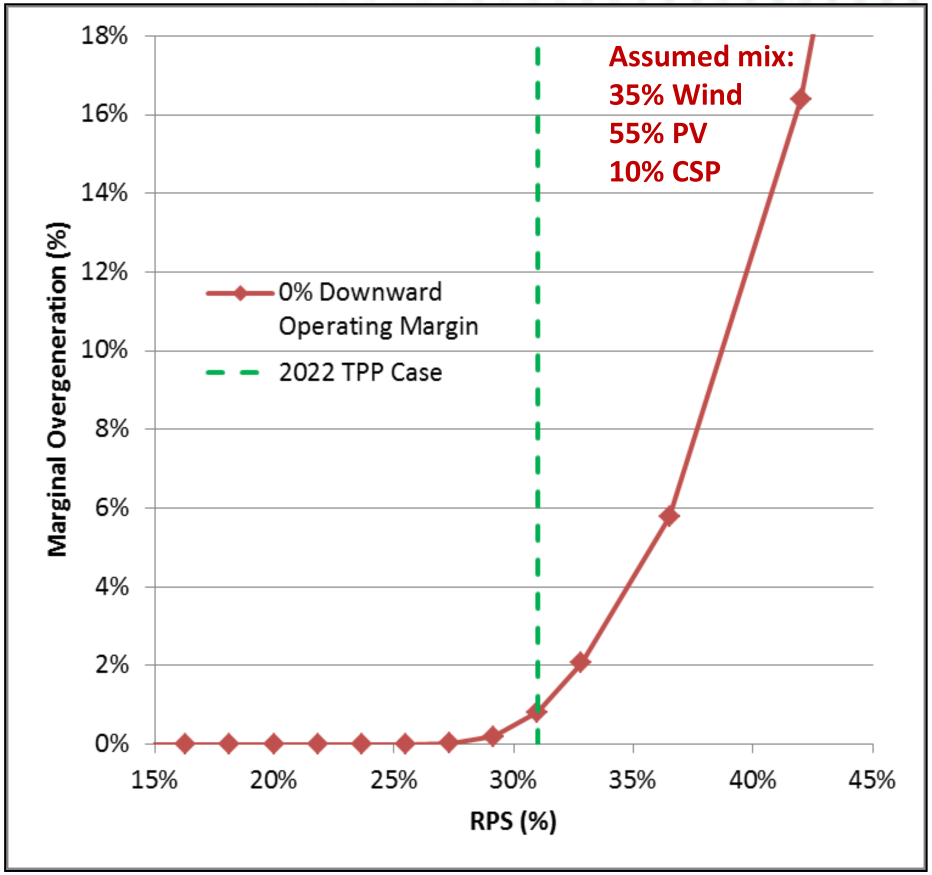


E3 is using our Renewable Energy Flexibility (REFLEX) Model to investigate flexible capacity needs under high renewables for California entities

Marginal Overgeneration Increases Exponentially as RPS Increases

+ **REFLEX model shows that the potential for over-generation becomes significant starting at around 33% RPS**
+ **California will need to find ways to use, export or store surplus renewable energy**
+ **Solutions will have a big impact on GHG reductions and cost**

Marginal Overgeneration (Percent of the next MWh of RPS resources curtailed)



Integration Solutions Will Be Critical to Success

+ **Increased regional coordination**
  - Make best use of latent flexibility in current system
+ **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**
  - Deep-draw (diurnal) storage is important

Conclusions

- California is on track to achieve its 2020 RPS and GHG goals at reasonable cost
- California is investigating the appropriate role of renewables in meeting further GHG reductions

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Thank You!

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