Energy+Environmental Economics

Envision the *Grid Beyond 2030*

Big or Small?

Low Emissions Solutions Conference
September 11, 2018

Dr. Ren Orans
Managing Partner, E3

Agenda

- **Industry Trends**
  - Technology
  - Policy
  - Democracy
- **The Case for a Big Grid**
  - California cases demonstrate that diversity enables a low cost decarbonized grid
  - Hawaii shows us that without diversity, they have to rely on large amounts of storage

Energy+Environmental Economics

Industry Trends

Theme

- **Broad changes are sweeping through society that will have lasting impacts on the electricity sector**

  1. **"Technology":** Technological change in data processing, communications and manufacture are making new technologies available and cost-effective
  2. **"Policy":** Climate change and the need to decarbonize our economy will require the development of massive quantities of low-carbon electricity
  3. **"Democracy":** Consumers are increasingly wishing to take control of their own destiny, decentralizing the locus of decision-making

- **The role of utilities will need to continue to evolve to respond to these changes in ways that preserve value for their shareholders and ratepayers**

Energy+Environmental Economics

“Technology”

Renewables

+ **Solar PV costs have declined tremendously in the last decade**
+ **Wind and solar are now cost-competitive with conventional resources in many markets —*even without subsidies!***
+ **Rooftop solar can be installed at below the embedded cost rate in some jurisdictions**

Solar PPA Prices Over Time

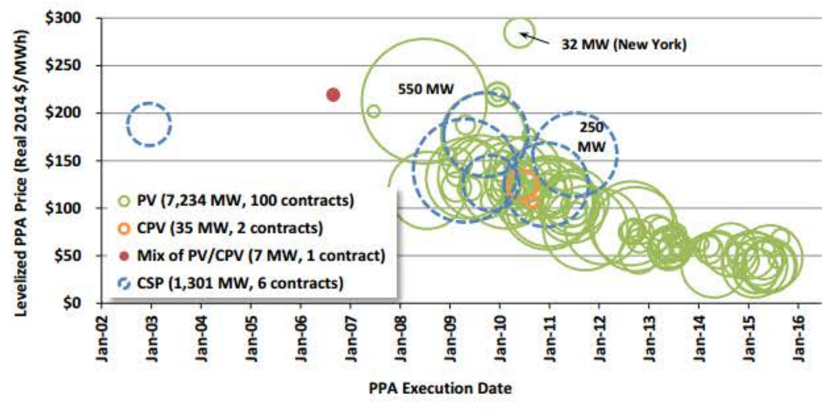


Figure 15. Levelized PPA Prices by Technology, Contract Size, and PPA Execution Date

Source: Utility Scale Solar 2014 (LBNL, 2014)

Energy storage

- There is increasing interest in grid-connected energy storage for renewable integration and investment deferral
- Battery costs are declining rapidly with manufacturing scale-up and technology advances
- Lithium-ion appears to be following the photovoltaic path

IT and communications

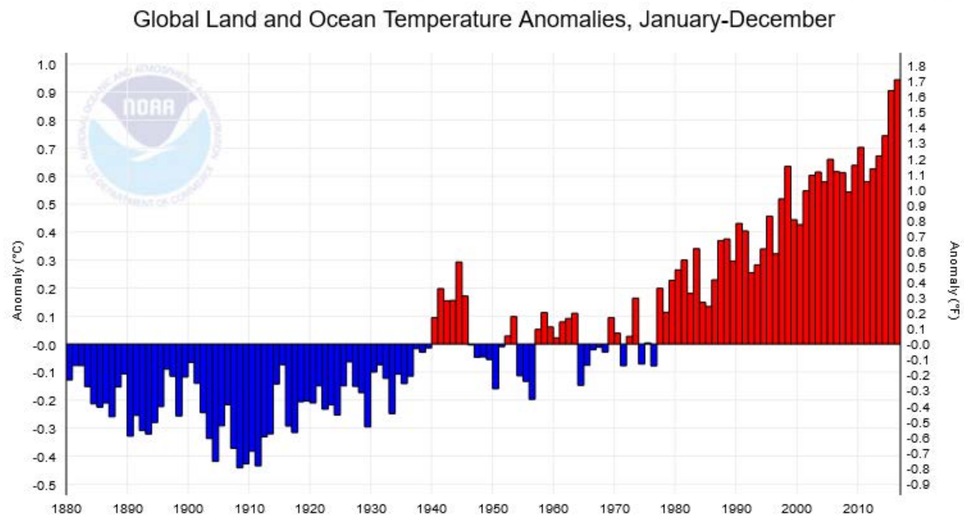
- Smart devices and advanced communications networks provide new mechanisms to facilitate customer response
- Improved access to data and control systems will enable response to occur seamlessly and with little effect on consumer experience

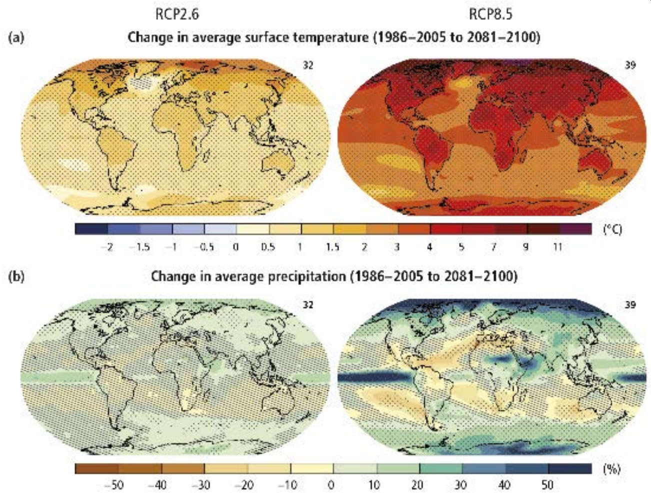
“Policy”

Deep reductions in greenhouse gas emissions are called for globally

- **The 2016 Paris agreement committed industrialized nations to 80% reductions below 1990 levels by 2050**
  - Roughly consistent with IPCC/UNFCC goal of keeping global average temperature rise within 2°C to avert catastrophic climate change
- **If current trends continue, 2°C aggregate warming will be exceeded**

Source: NOAA, https://www.ncdc.noaa.gov/monitoring-references/faq/indicators.php Global annual average temperature measured over land and oceans. Red bars indicate temperatures above and blue bars indicate temperatures below the 1901-2000 average temperature.

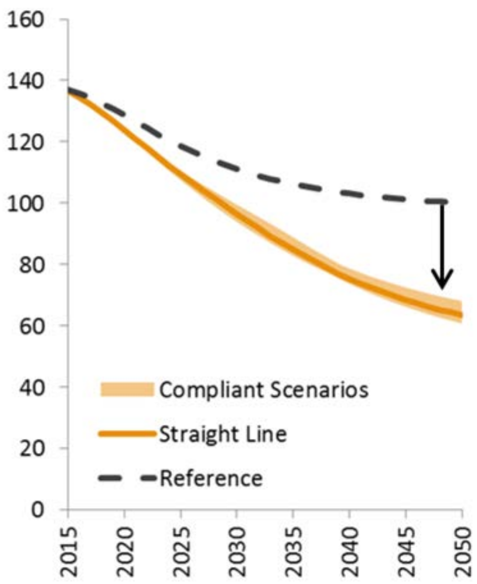




Source: IPCC Global Assessment Report 5, SPM.07

1. Doubling of current energy efficiency goals & reduced vehicle miles traveled

Energy use per capita (MMBtu/person)



+ Higher Efficiency in Buildings & Industry

- Approximate doubling of current plans for EE savings
- Largest EE savings assumed to come from commercial LED lighting, more efficient equipment & appliances

+ Higher Efficiency of Vehicles and Reduced Demand for Transportation Services

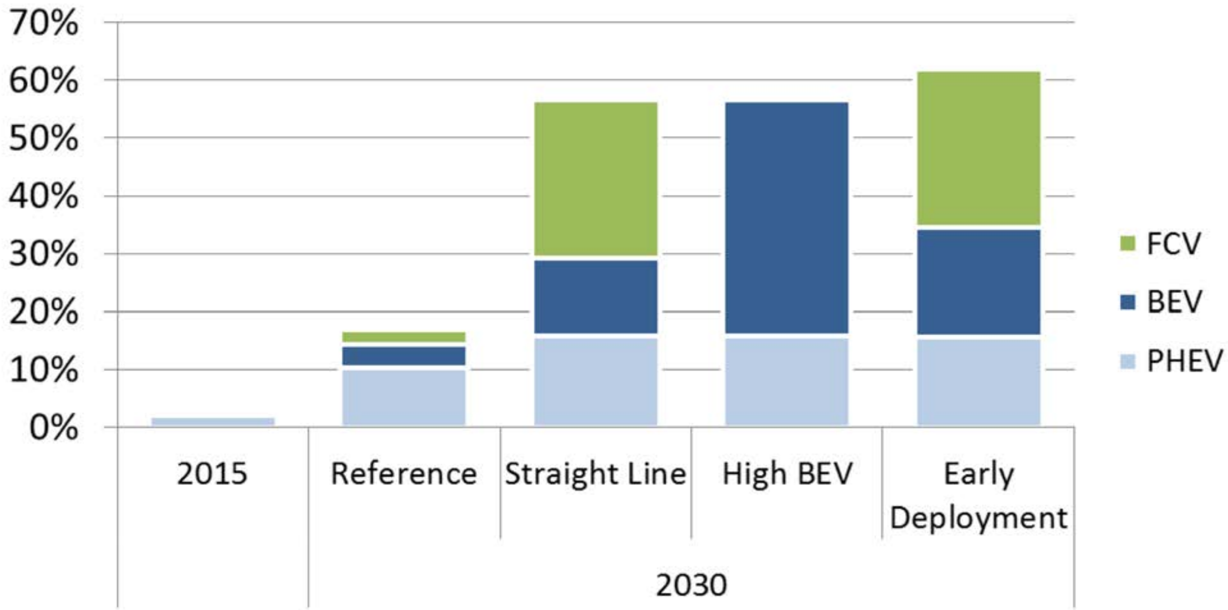
- 8% reduction in vehicles miles traveled through smart growth policies and demographic trends by 2030
- Sustained vehicle efficiency improvements
- Petroleum refining and oil & gas extraction energy use decline proportionally with demand for liquid fossil fuels

2. Greater reliance on electricity in buildings & zero emission vehicles

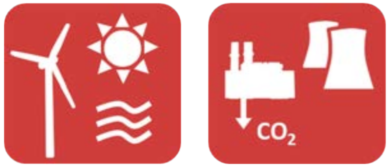
- Switching to electric space conditioning & water heating in buildings
- Electric processes in industry
- Rapid ramp up of battery electric and/or fuel cell vehicles

- 6-7 million ZEVs and PHEVs on the road by 2030

Share of New Vehicle Sales by Year and Technology



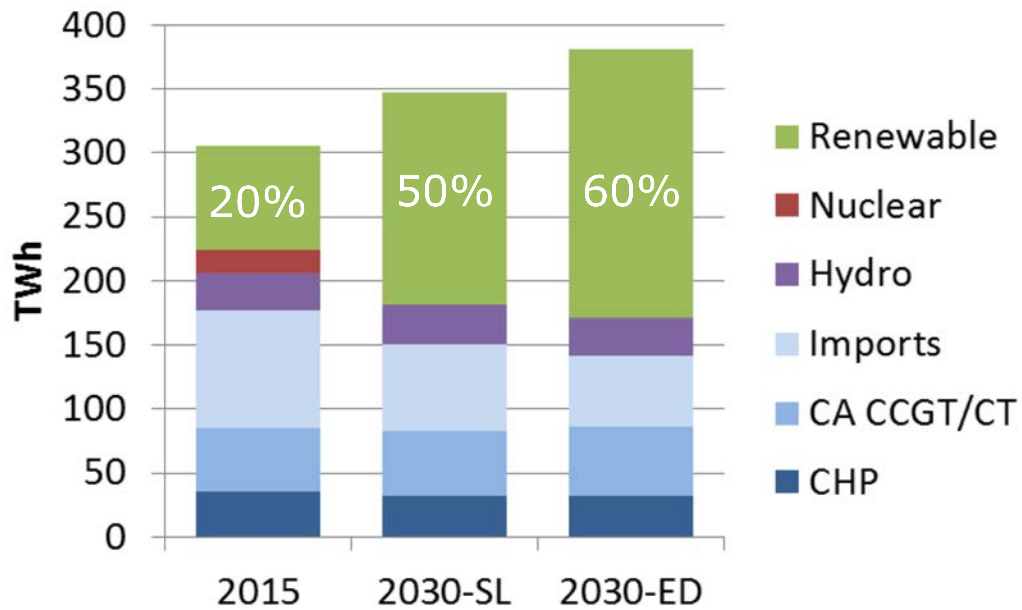
3. Renewables account for 50-60% of annual energy use by 2030



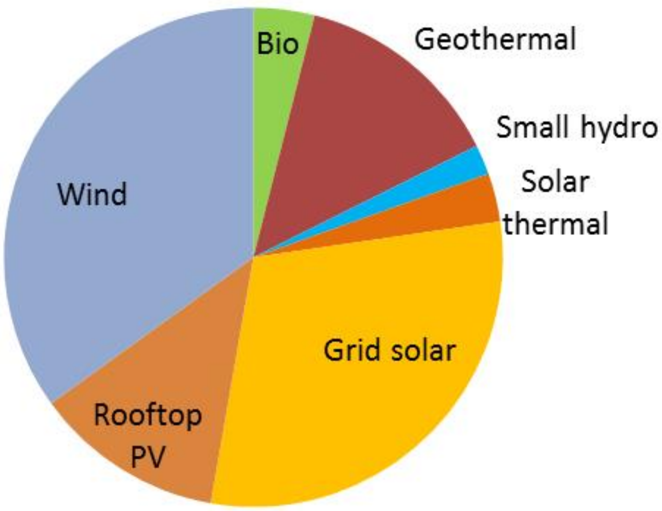
+ **Average renewable additions are ~2,400 MW/year (plus rooftop PV) through 2030, mostly solar and wind resources.**

+ **Integration solutions are needed in all high renewables cases:**
  - regional coordination, renewable diversity, flexible loads, more flexible thermal fleet, curtailment energy storage, flexible fuel production for ZEVs

Annual Energy



2030 Renewable Generation by Type (%) – Straight Line



Energy+Environmental Economics

“Democracy”

Consumer empowerment is resulting in a decentralization of decision-making

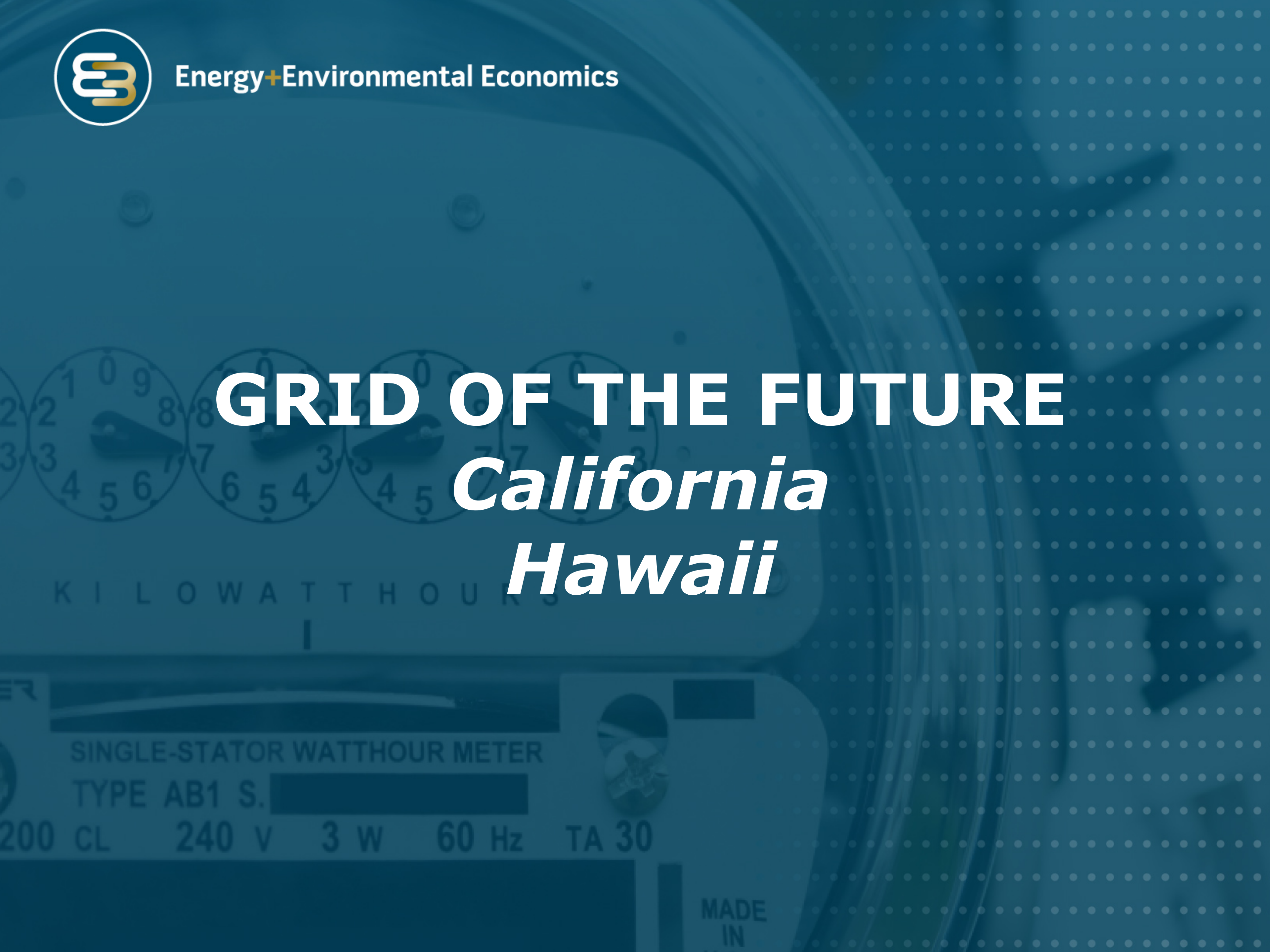
+ **Restructuring of the electric utility industry in the 1990s invited new entities into the industry**
  - Direct access (DA), electric service providers (ESPs), independent system operators (ISOs)
+ **Municipalization and community-choice aggregation (CCA) allow local control of energy decisions**
+ **Rooftop solar and demand response empower small customers**
+ **More difficult to justify large, centralized infrastructure investments**

Traditional utility view has little room for customer response

- Rates are set as part of a careful, political process designed to produce equitable outcomes
- Customer response, also called "bypass", upsets this balance
  - Customers are motivated to minimize their bills through consumption decisions
  - Direct access and net energy metering are the most extreme examples of this
  - Utilities respond with fixed monthly charges and "ratchet" demand charges

Economists prefer taxes that are non-distortionary, i.e., they do not change behavior of consumers or producers

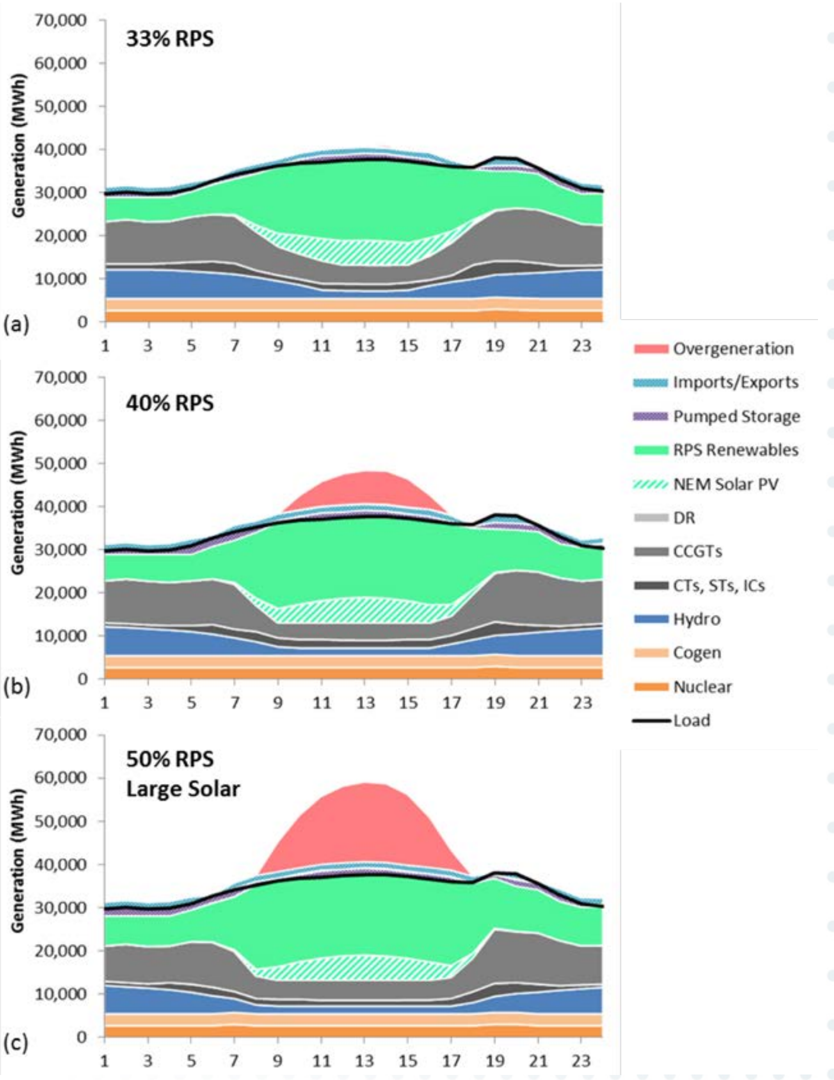
Energy+Environmental Economics



GRID OF THE FUTURE
California
Hawaii

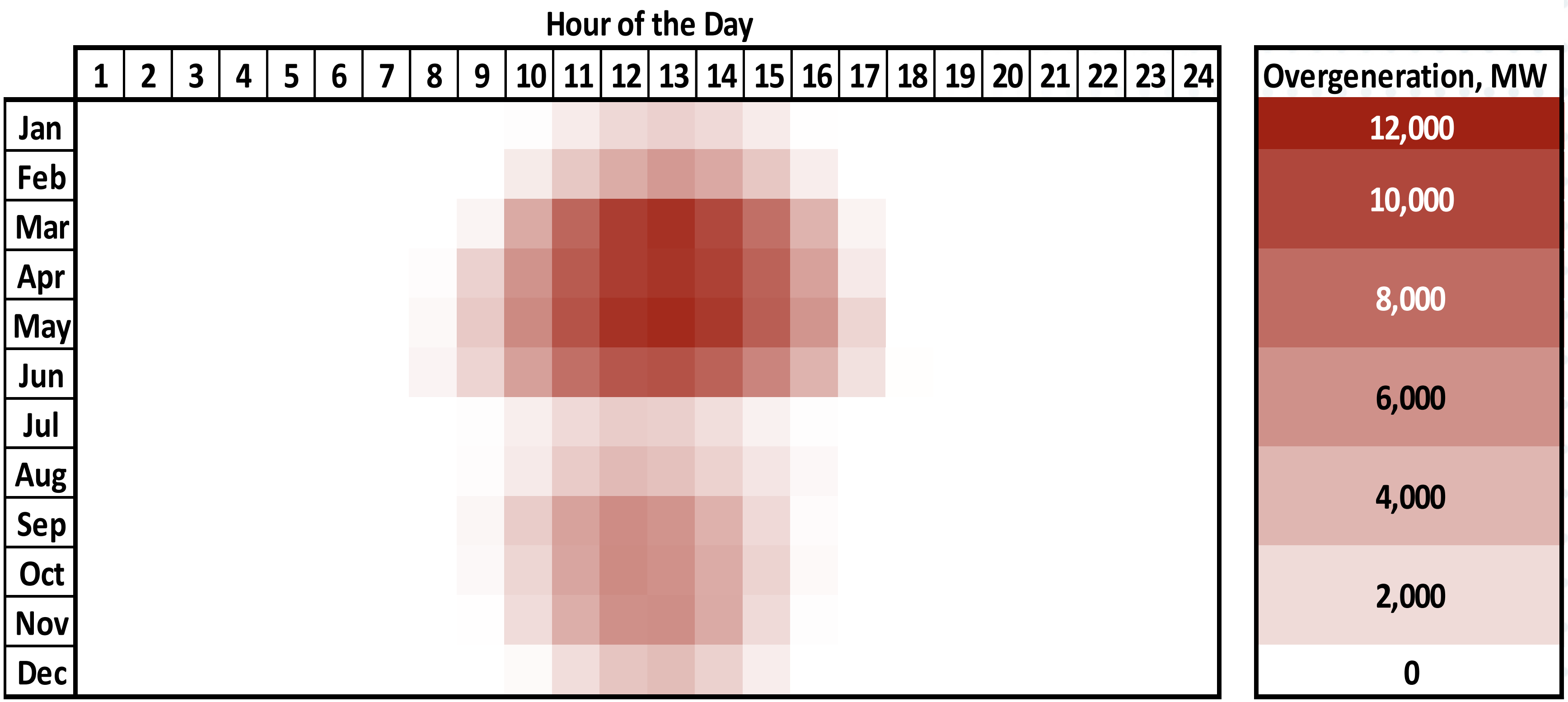
Example Day in April under 33%, 40% and 50% RPS in California

- **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



Overgeneration Is Extensive and Can Occur in Any Month in California

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



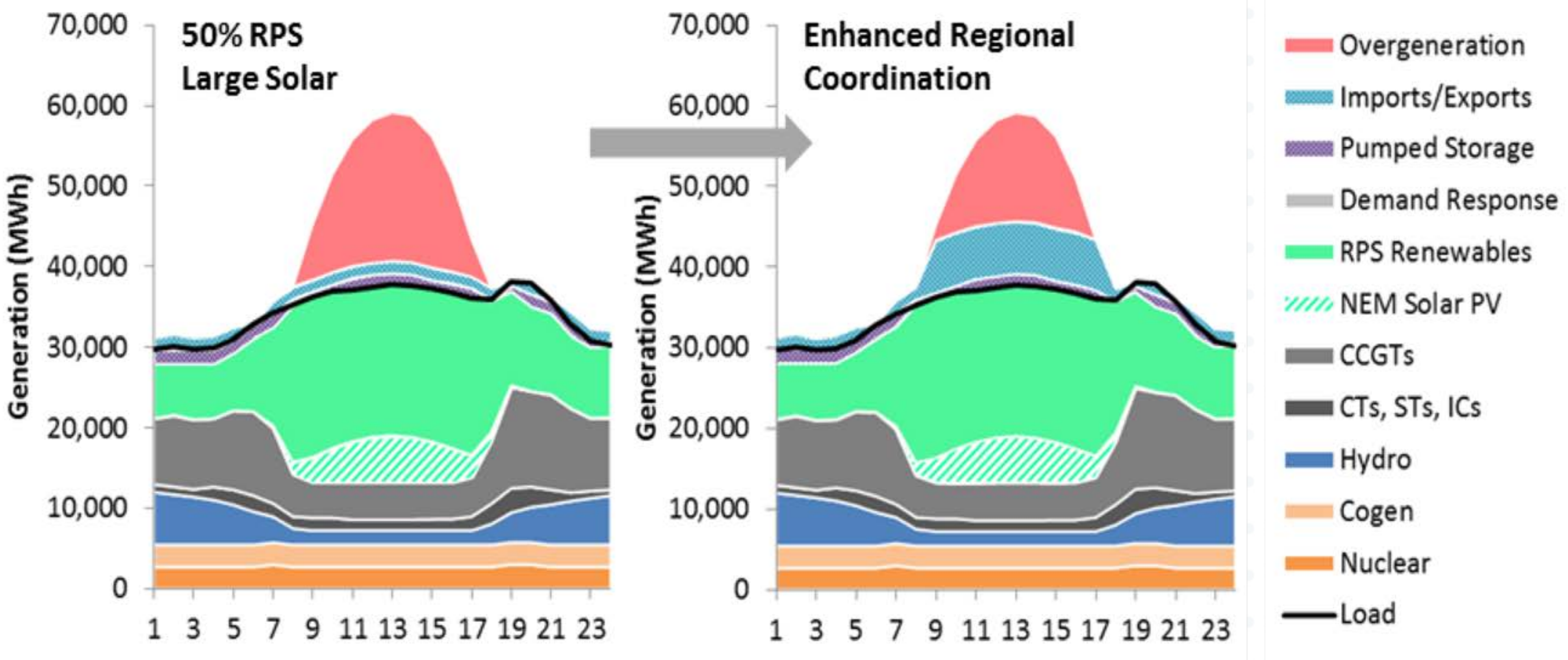
Marginal Overgeneration in California

+ **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 Solution: Enhanced Regional Coordination Case

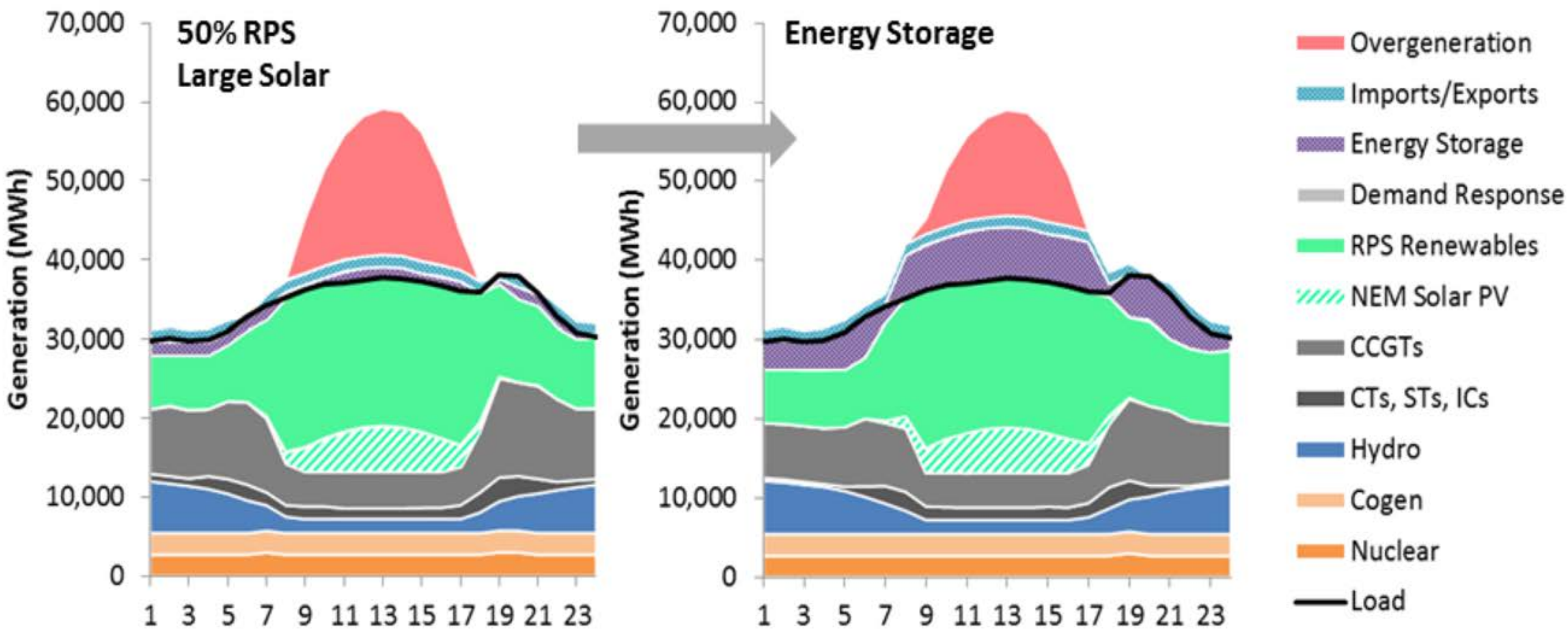
+ **Increasing California's export capability by 5,000 MW (6,500 MW total) reduces overgeneration from 9% in the 50% RPS Large Solar case to 3% of total renewable energy**



Example April day

Potential Integration Solution: Energy Storage Case

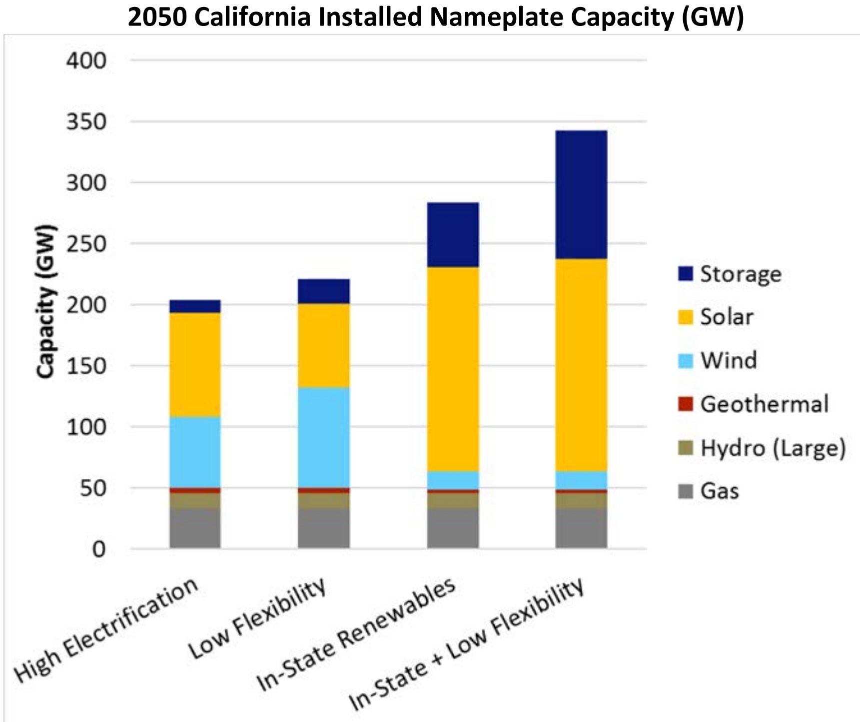
+ **Assuming 5,000 MW of diurnal energy storage in CA reduces overgeneration from 9% in the 50% RPS Large Solar case to 4% of total renewable energy. Storage charges during the day & discharges at night.**

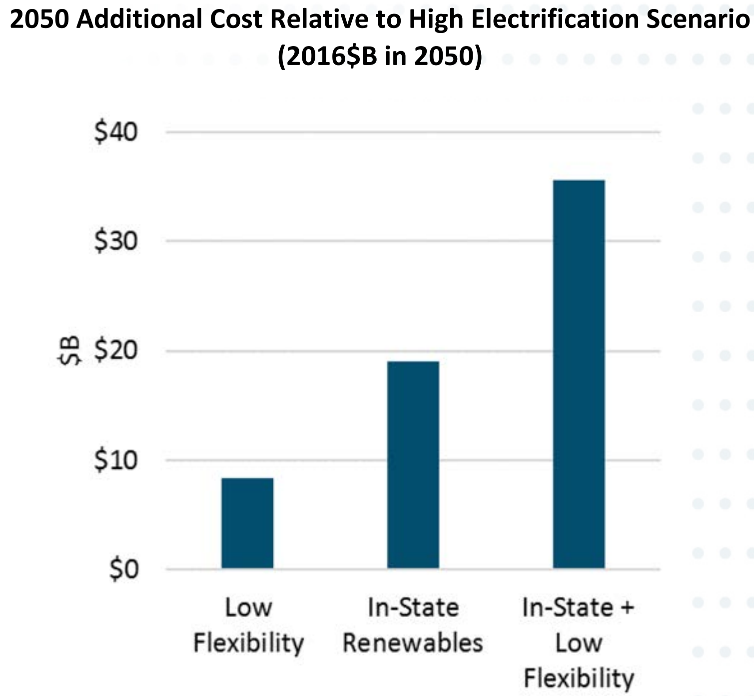


Example April day

Without renewable integration solutions, 2050 electricity costs are 9% – 40% higher

2050 High Electrification Case with 95% zero-carbon electricity sector emissions (8 MMT CO2) RESOLVE model results:

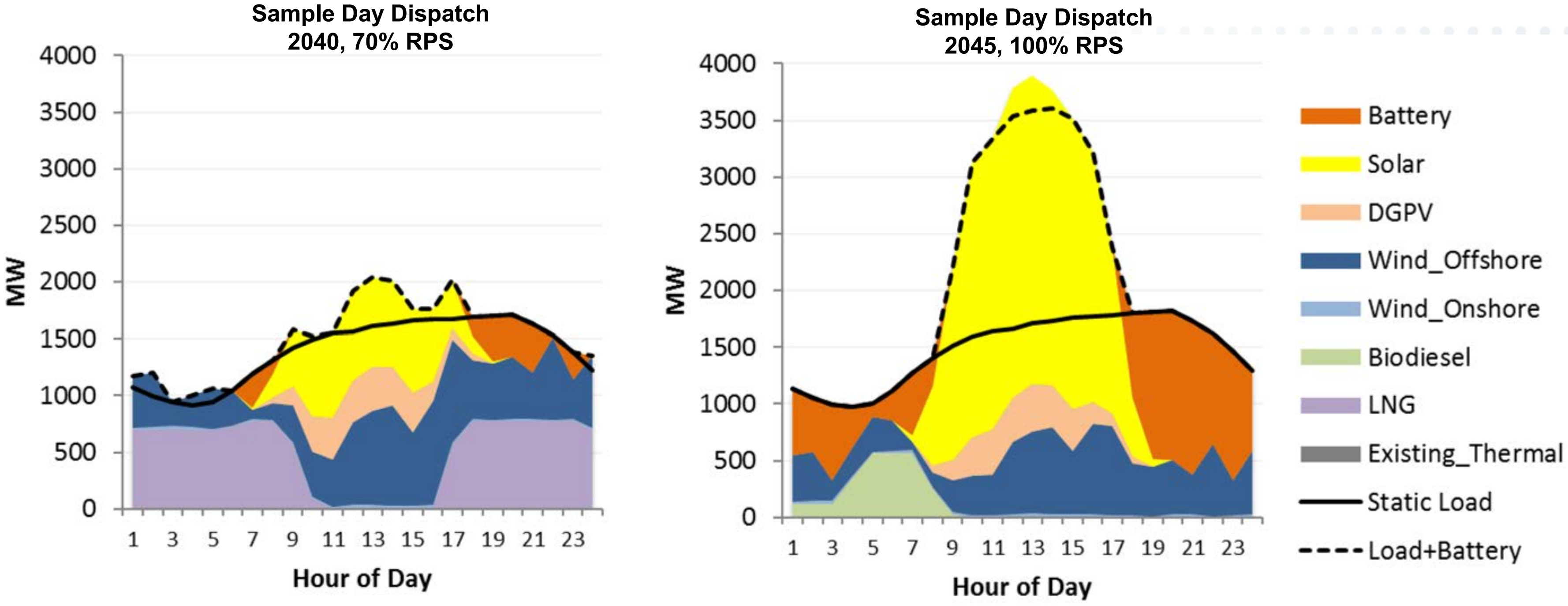




- High Electrification includes "best case" renewable integration solutions including a diverse renewable portfolio (44 GW of OOS wind)
- The land area required for new utility-scale solar PV in the "In-state + Low Flexibility" scenario exceeds ~1700 square miles (~1% of state land) vs. ~600 square miles in the High Electrification case

Renewable Integration Solutions are Needed in Hawaii

- Batteries are used to store solar energy during the day and dispatch that energy to help meet load when the sun is not shining
- Stored solar energy complemented by offshore wind and biofuels



Summary

- **Decarbonization of power, and electrification of transportation and buildings will require both modernization and new investments in a large bulk power grid.**
- **Microgrids, DER’s and and modernized sensing and switching equipment will become part of this large grid and can be used to increase reliability and resilience of the grid.**
  - Value based planning will make cost effective use of microgrids
- **“Regionalization” is the lowest cost way to expand the effectiveness of the bulk power system and to integrate large amounts of renewable resources**

Energy+Environmental Economics

Thank You!

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

Ren Orans, Managing Partner (ren@ethree.com)