Balancing California's Energy Needs with its Environmental Goals

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Motivation for Talk

- California policy--Provide more energy using less fossil fuels
  - Greenhouse gas (GHG) emissions reduction goals
    - AB 32 requires reducing GHG emissions to 1990 levels by 2020
- Two mechanisms that have been considered to achieve these goals create special challenges
  - Renewable energy
  - Energy efficiency
- Third approach not considered also has significant challenges as well as substantial potential
  - Carbon capture and sequestration

Motivation for Talk

- Renewable energy
  - Intermittent—Energy can be produced only when wind and sunlight exists
  - Non-dispatchable—Can only obtain energy that is available
  - Location specific—Resource only exists at specific locations
  - Zero variable cost—No input fuel cost
- Energy efficiency
  - Reduce amount of fossil fuel or electricity necessary to produce given energy service
    - Heating, lighting, appliances
  - More efficient utilization of existing energy resources
    - Price-responsive final demand

Motivation for Talk

- What must California's future energy infrastructure look like to support these goals?
  - Enhanced transmission network
    - Support renewable generation
    - Enhance competitiveness of wholesale electricity market
  - Hourly meters for all final consumers
    - Default pass-through of hourly wholesale price in hourly retail price
  - Substantial investment in energy storage technologies
- Purpose of Talk—Identify major challenges that California faces in achieving the goal of a reliable supply of significantly less GHG emissions-intensive energy

California's RPS

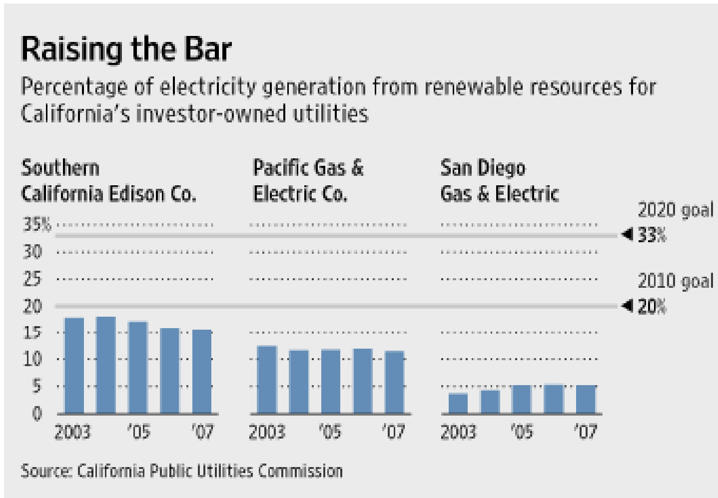
SB 1078 established the State's Renewable Portfolio Standard (RPS).

- By the year 2010, 20% of electricity consumed in California must come from renewable resources
  - Investor-owned utilities (IOUs), community choice aggregators, and energy service providers (ESPs) all subject to RPS
  - Publicly owned utilities not subject to 20 percent goal but must implement their own RPS
- Governor has set a goal of 33% of the electricity coming from renewables by 2020
- Renewable Resources include:
  - Wind
  - Solar
  - Geothermal
  - Biomass
  - Small hydro (less than 30 MW)

What an RPS Does

- Displace energy from GHG emissions-producing generation units with renewable energy
  - Reduces GHG emissions intensity of electricity consumed
  - Because energy is produced at zero variable cost, if it is physically feasible to deliver electricity, units will operate
- Assumes that renewable technologies that qualify for RPS are least-cost approach to achieving California's GHG emissions reductions goals
- Alternative approach to reducing GHG emissions intensity of electricity is to set a positive price for GHG emissions
  - All technologies can compete to supply electricity subject to paying for their GHG emissions

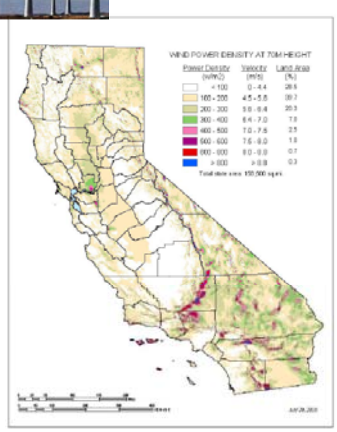
Since implementation of SB 1078 in 2002 there has been little progress towards goal



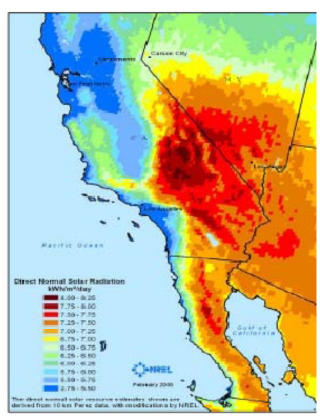
California Renewable Resource Areas

Wind Generation

Solar



California Wind Resource Map



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Forecast Generation by Technology

(MW of Nameplate Capacity)

	2007	20% RPS 2012	33% RPS 2020
Biomass	787	1,008	1,778
Wind	2,688	7,723	12,826
Geothermal	1,556	2,620	3,970
Concentrated Solar	466	1,412	3,166
PV Solar	25	533	2,860
Small Hydro LT 30MW	822	822	822
Hydro	8,464	8,464	8,464
Nuclear	4,550	4,550	4,550
Fossil	27,205	29,100	33,000

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Wind Generation Regions in CA

Solano County

Altamont Pass

Pacheco Pass

Tehachapi Mount./ Mojave Desert

San Gorgonio

Barriers to Meeting Goals

- Transmission lines needed to access major renewable regions
  - Tehachapi region has close to 4,500 MW wind potential
    - Transmission capacity from region inadequate for resource potential
  - Imperial Valley region has significant geothermal and solar resource potential
    - Transmission capacity from region inadequate for resource potential

Barriers to Meeting Goals

- Extremely difficult to obtain permit and cost recovery for transmission expansions in California
  - Transmission expansion process subject to unnecessary delays
    - Many due to NIMBY concerns
  - California process for transmission expansion assessment ill-suited to current wholesale market regime
    - Ignores state-wide and regional benefits of expansion
  - Embedded cost of California's transmission network is less 10 percent of delivered price of electricity
    - Cost of expansions should not be a major factor in decisions
    - Transmission expansions increase competitiveness of wholesale market
      - Wolak, F.A., "The Benefits of an Electron Superhighway" see web-site

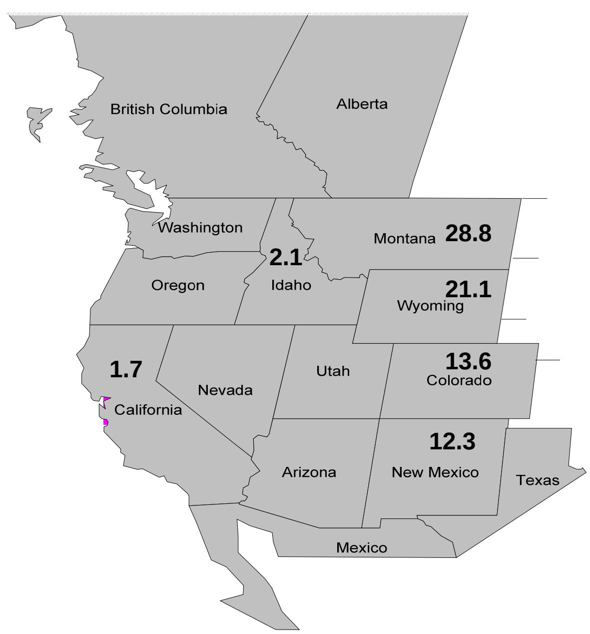
Regional Barriers

- Enormous potential for wind generation outside of California in remainder of Western System Coordinating Council (WSCC)
- Transmission expansion across state boundaries even more difficult
  - Federal government does not have siting authority that it has for natural gas pipelines
- Energy Policy Act of 2005 gave Federal Energy Regulatory Commission (FERC), wholesale market regulator, authority to designate strategic transmission corridors and order transmission lines be built
  - Palo Verde/Devers 2 line proposed by Southern California Edison is test case for this authority

Potential Wind Generation in West

Wind Generation by 2030

State	Installed Gigawatts	Energy Production Millions of MWHrs
Montana	28.8	1020
Wyoming	21.1	747
Colorado	13.6	481
New Mexico	12.3	435
Idaho	2.1	73
California	1.7	59
Total	79.6	2815



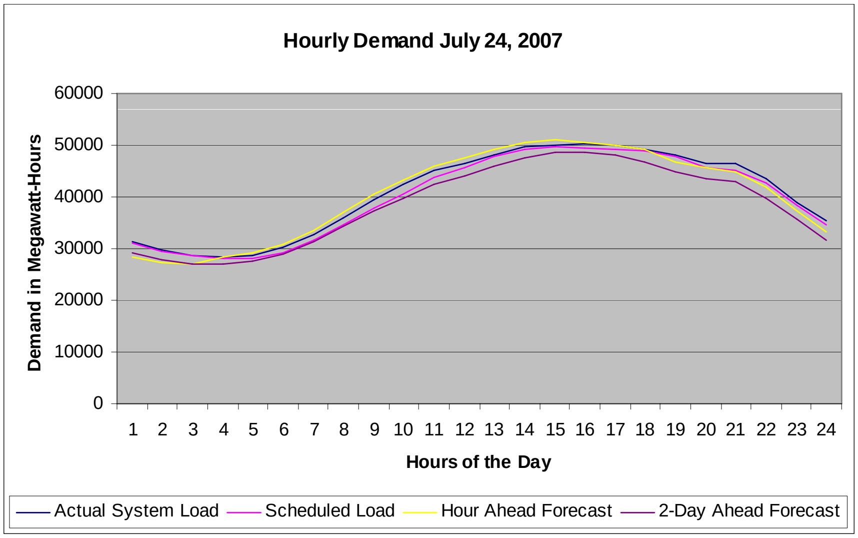
Managing Intermittency

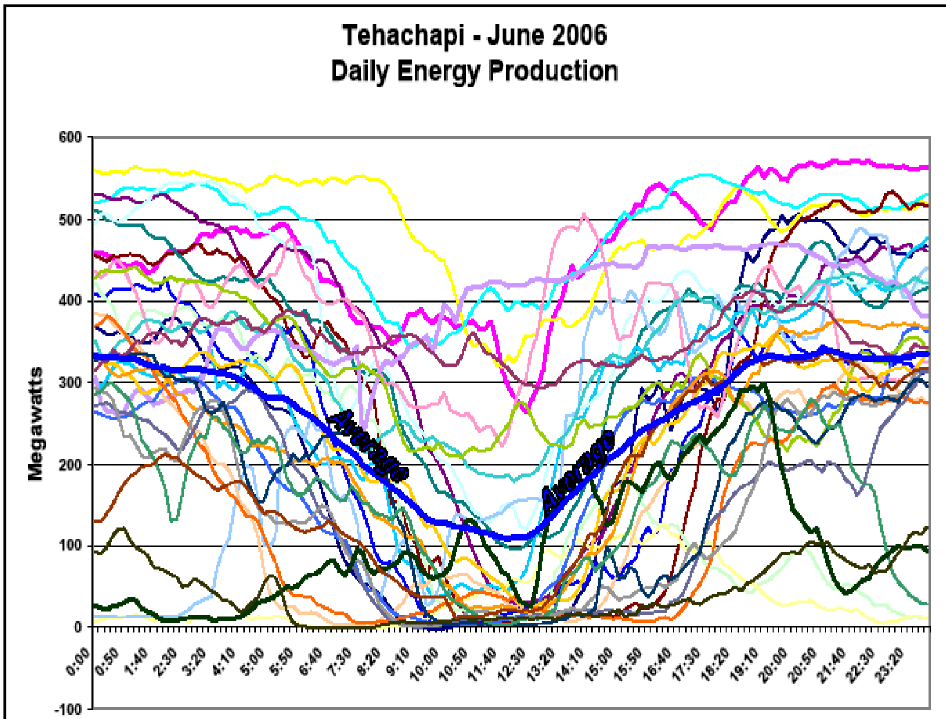
- Electricity supply must equal demand at every instant in time at all locations in transmission network
  - Some units must follow second-to-second instructions from system operator—Automatic Generation Control (AGC)
    - AGC only provided by fossil-fuel units in California
  - Requires units to turn on and off and ramp up and down to meet load increases and decreases through day
    - Wind and solar units cannot provide this service
- Similar to operating automobile, starting and accelerating fossil-fuel units is very costly in terms of fuel efficiency, GHG emissions, and other pollutants

Managing Intermittency

- Wind and other renewables often unavailable during peak periods
  - July 2006 heat storm, July 24 demand in California ISO control area hit a 1 in 50 year peak of 50,200 MW
    - Less than 5 percent of installed wind capacity was operating at the time
  - Tehachapi wind energy comes primarily at night
  - Solar photovoltaic panels less efficient during very hot portion of day

Daily Load Shape in California





Managing Intermittency

- Renewable energy can disappear extremely rapidly
- Significant system operation challenges associated with large renewable energy share
  - With 20 percent renewable share, significant fraction of energy can disappear with little warning
  - Operators need to hold more operating reserves
    - Fossil fuel units running with unloaded capacity
    - Quick start combustion turbine generation units
    - Increased GHG emissions production from renewables
  - Energy storage technologies required
    - Transfer off-peak power to peak

Price Implications of Intermittency

- Intermittency and price for GHG emissions enhances electricity price volatility
  - With a significant renewable share wholesale prices are likely to be very low when these units are operate
  - With a price of GHG emissions and high fossil fuel prices, when fossil-fuel units operate wholesale prices are very high
- Creates incentive for investments in storage technologies
  - Value of storage technology is ability to turn low-priced electricity into high-price electricity
- Can create incentive for final demand to participate actively in wholesale market

Economics of Energy Efficiency

- Variation in electricity demand throughout day and year
  - On 7/24/07 demand ranged from 28,300 MW to 50,200 MW
- Average MW consumption per hour during 2006
  - Approximately 27,000 MW
  - Peak demand for 2006 is 50,200 MW
- Reducing peak demand
  - Eliminate need to construct new generation capacity
  - Can retire old inefficient units located close to large cities
- Significant fraction of generation capacity used very infrequently
  - In California approximately 5,000 MW (10 percent of peak demand) used less than 2 percent of hours of the year
  - With global climate change larger fraction is likely to be used even less frequently

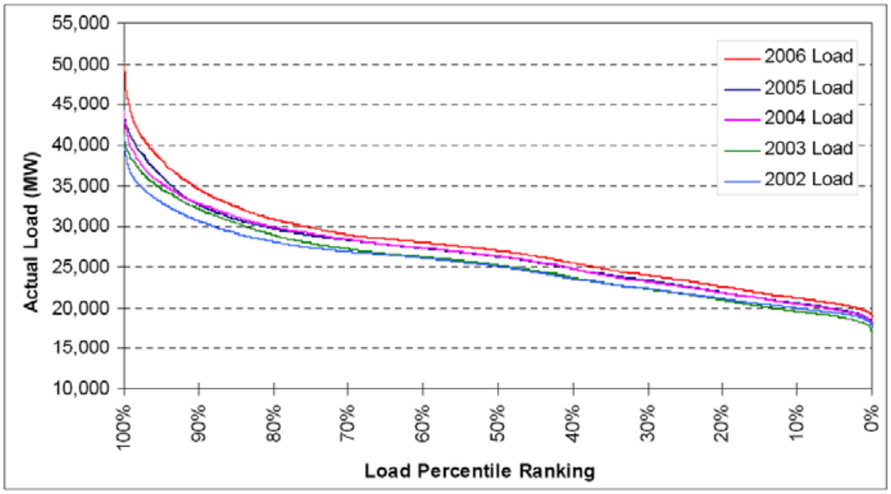
Table E.1 Load Statistics for 2003 – 2007*

Year	Avg. Load (MW)	% Chg.	Annual Total Energy (GWh)	Annual Peak Load (MW)	% Chg.
2003 Actual	26,345		230,857	42,581	
2004 Actual	27,309	3.5%	239,312	45,597	7.1%
2005 Actual	26,990	-1.2%	236,483	45,562	-0.1%
2006 Actual	27,427	1.6%	240,344	50,270	10.3%
2007 Actual	27,646	0.8%	242,265	48,615	-3.3%
2003 Adjusted	25,471		223,206	41,063	
2004 Adjusted	26,436	3.7%	231,660	44,209	7.1%
2005 Adjusted	26,477	0.2%	231,994	44,260	0.1%
2006 Adjusted	27,427	3.5%	240,344	50,198	11.8%
2007 Adjusted	27,646	0.8%	242,265	48,615	-3.3%

* Adjusted figures are normalized to account for day of week, changes in the CAISO Control Area footprint, and the 2004 leap year.

California ISO Control Area

Figure E.5 Hourly Load Duration Curves



Economics of Energy Efficiency

- Ways to smooth demand peaks
  - Technologies for storing electricity
  - Price-responsive final demand
- Necessary infrastructure for price-responsive demand
  - Meters capable of recording hourly consumption
    - Conventional meters are read once per month
      - Monthly bill is difference between meter readings
- Retail prices that vary with real-time system conditions can smooth demand peaks
  - If consumers are required to pay these prices and benefit from it

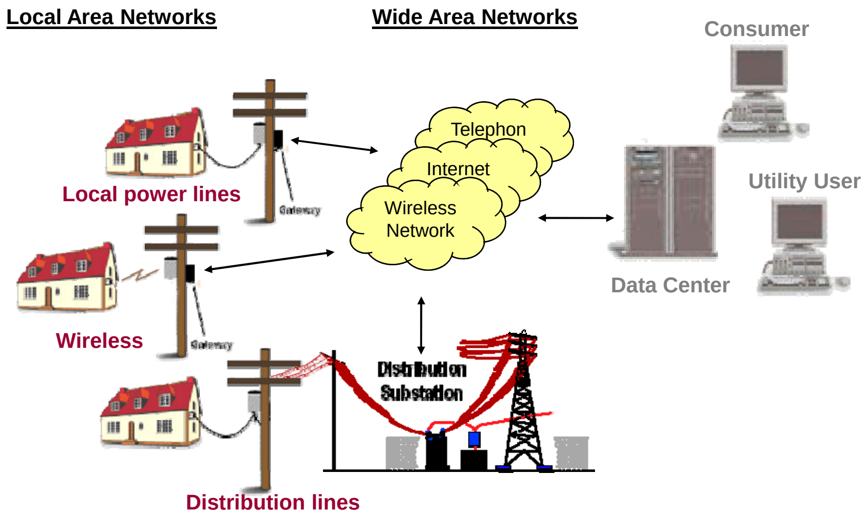
Economics of Energy Storage

- Suppose it costs 2 MWh to store 1 MWh in off-peak period to sell in peak period of day
  - If price during peak period more than twice price in off-peak there are revenues to pay for investments in energy storage technology
- If average peak price is $30/MWh and average off-peak price is $10/MWh
  - Total revenues for 1 MWh energy storage per day to sell during peak hour each day of the year is $3,650
- Larger the price differences between peak and off-peak hours make more energy storage technology investments profitable

Price-Responsive Demand

- Lack of hourly metering of final demand makes it impossible to set hourly retail prices that pass-through hourly wholesale price
  - Customer reduces monthly bill by same amount by reducing consumption by 1 KWh during hour when wholesale price is $5000/MWh as he does when price is $0/MWh
- Economics of hourly meters is rapidly changing because of technological change
  - Major cost of monthly reading for conventional meters is labor cost
  - Modern hourly meters are read remotely by wireless or wireline technology

Advanced Metering Communication Networks



Price-Responsive Demand

- Substantial state-level regulatory barriers to active demand-side participation
  - "Consumers must be protected from short-term price risk"
  - "Electricity is a right, not a commodity"
  - Wolak, Frank (2007) "Managing Demand-Side Economic and Political Constraints on Electricity Industry Re-structuring Processes," on web-site.

Price-Responsive Demand

- Interval meters have up-front installation costs and communications network cost
  - Variable cost per meter per month is less than $0.50 per meter
  - Economic case for hourly meters can almost be made based on metering cost saving alone
  - Estimated wholesale energy purchase costs savings improves economics
- A number of large retailers in the United States, Canada, Australia, Italy have or are installing universal hourly metering
  - Metering is a regulated distribution network service

Price-Responsive Demand

- Important point--Fixed-retail price does not imply customers do not pay real-time hourly wholesale price in retail prices
  - Retailers will go bankrupt if this outcome does not hold on annual basis
  - Customers just cannot benefit from lower annual bill from reducing consumption during high-priced hours

Price-Responsive Demand

- All California investor-owned utilities are installing hourly meters for all customers
  - Major barrier to active demand-side participation in California will soon be eliminated
- Remaining challenge is regulatory barrier
  - Recent empirical evidence on "politically acceptable real-time pricing" is promising
    - Methods to share risk of responding short-term prices between consumers and retailers