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Getting to 2050

Pathways to deep reductions in GHG emissions

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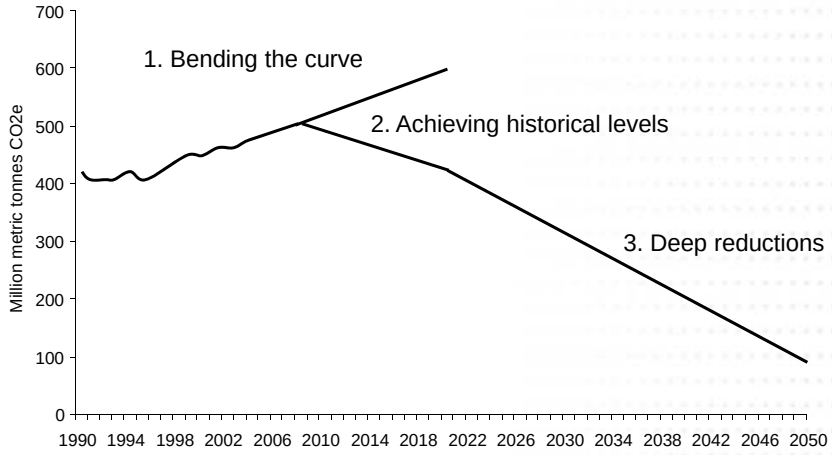
Energy and Environmental Economics, Inc.

Defining the long term path



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Energy and Environmental Economics, Inc.

- San Francisco-based consulting firm since 1989
- Deep expertise in electricity sector
- Experienced in linking technical-economic analysis to policy decision-making and public process
- Skilled at placing near term energy choices in long-term, transformational perspective

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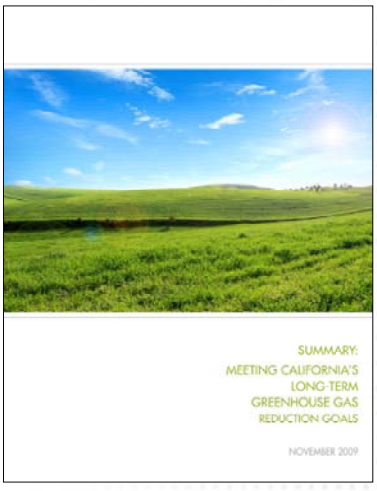
California 2050 Study

- **Key question**
  - What does California need to do to meet the 2050 GHG reduction goal?
- **Infrastructure modeling approach**
  - Multi-sector, stock roll-over model
  - Integrated electricity grid dispatch algorithms
  - Use standard projections of CA population, economic growth
  - Consistent w/ AB32 Scoping Plan
- **Independent study sponsored by Hydrogen Energy International (HEI)**



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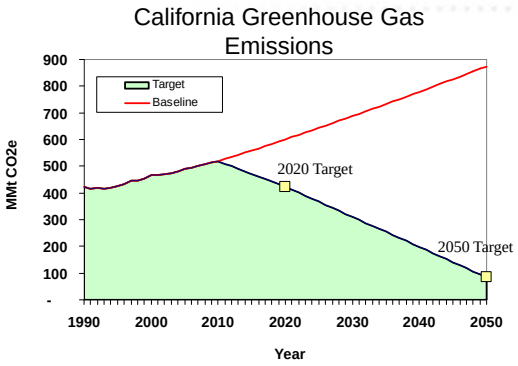
"Back-casting" Scenario Approach

- **'Baseline' (875 Mt)**
  - Business-as-usual GHG projection
- **'2050 Compliant' Scenarios (85 Mt)**
  - Mitigation measures by sector constrained to meet emissions target
- Residential, Commercial, Industrial, Agriculture, Petroleum, Transportation, and Other (Non-Fuel/Non-CO_2) Sectors



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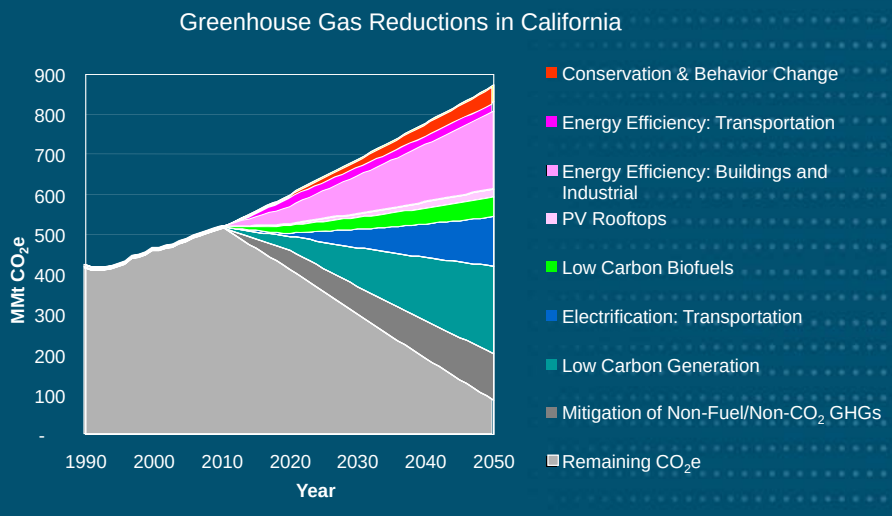
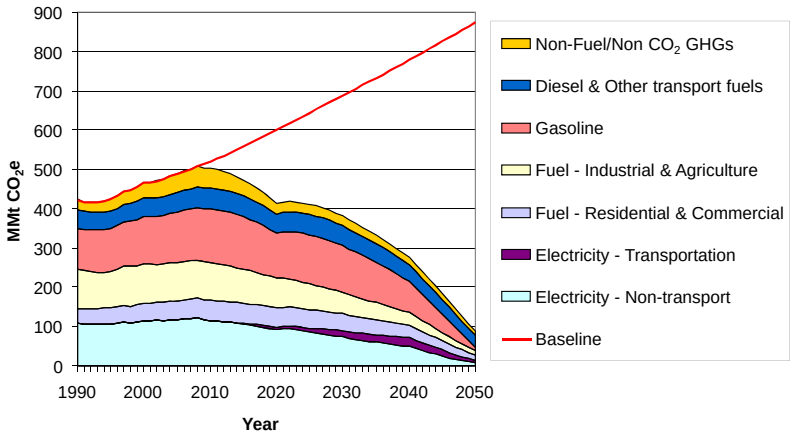
Greenhouse Gas Savings for 2050



Source: Energy and Environmental Economics, Inc 2009

Emissions Reductions by Source



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Types of Change

Behavioral Change

Technological Change

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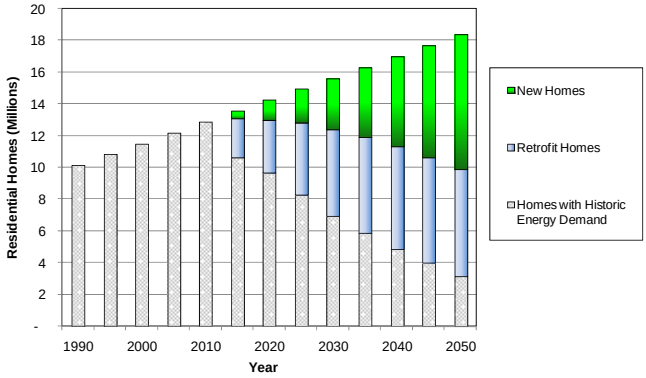
Conservation & Energy Efficiency

- **"Smart Growth" 10% reduction in vehicle miles traveled relative to baseline**
- **Unprecedented levels of energy efficiency**
- **Transition to zero net energy homes by 2020**
- **Extensive retrofits of existing buildings**



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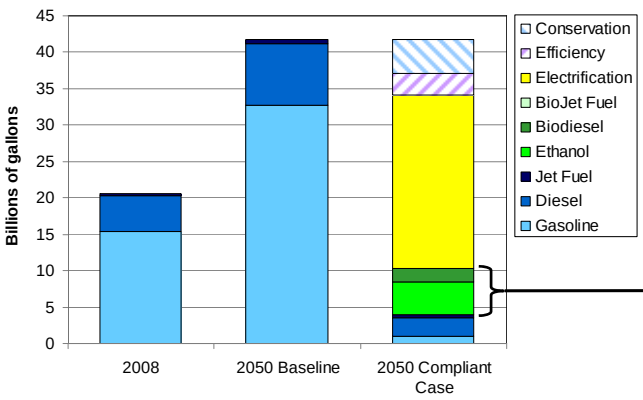
Low-Carbon Biofuels

- **Eliminate consumption of gasoline by 2050 replacing it with some mix of low-carbon electricity and low-carbon fuels**
- **Aggressive biofuel assumptions don't meet all transportation energy needs – biofuels likely to become premium fuel**



California Biofuel Availability

100% of California's biomass feedstock for ethanol plus 7% of US feedstocks (DOE EIA 2007)

Feedstocks include Ag Residues, Grasses and Forest Trimmings

7% assumes a distribution proportional to fuel consumption across all 48 States

Assumes 1.8 billion gallons per year of algal biodiesel and bio-jet fuel

Sufficient to meet 25% of biodiesel and 10% of bio-jet fuel demand in 2050 compliant case

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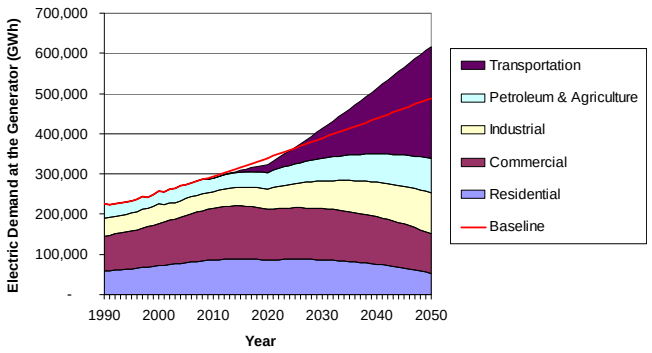
Electrification & Electricity Demand

- **Electricity demand could nearly double by 2050**
- **Increase in demand driven by electric vehicles**
- **Nearly all electricity must be from low-carbon generation**



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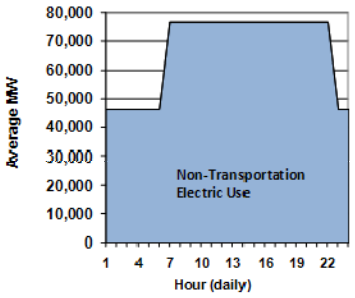
Electrification and Loads

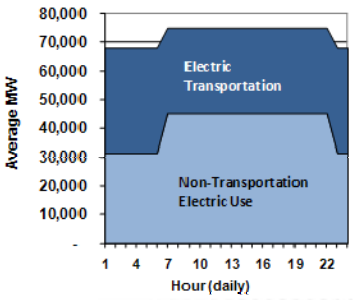
- **High levels of energy efficiency help to decrease demand and flatten the demand profile**
- **Off-peak electric vehicle "smart charging" & electrification will flatten load shape, increase overall demand & need for baseload generation**

2050 Baseline Case



"Peaky" demand in 2050 Baseline

2050 Compliant Case



"Flat" load profile in 2050 Compliant case

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Low-Carbon Generation

1. High Renewable Case

2. High Nuclear Case

3. High CCS Case

4. Blended Case

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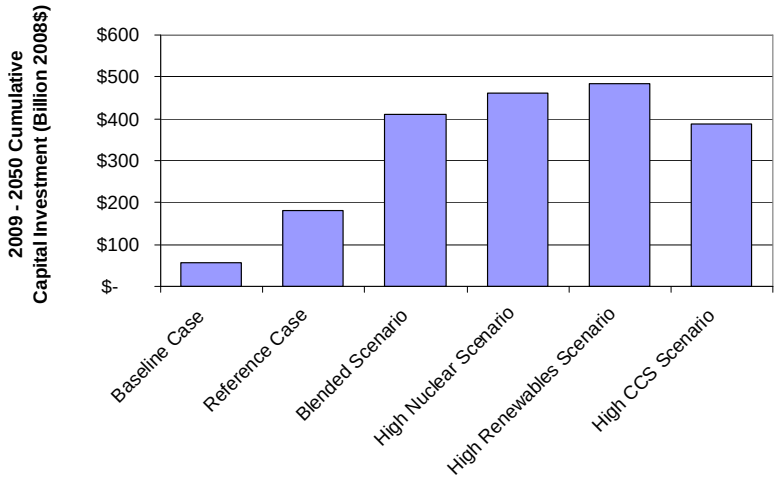
Investments to decarbonize electricity are significant in all low-carbon cases



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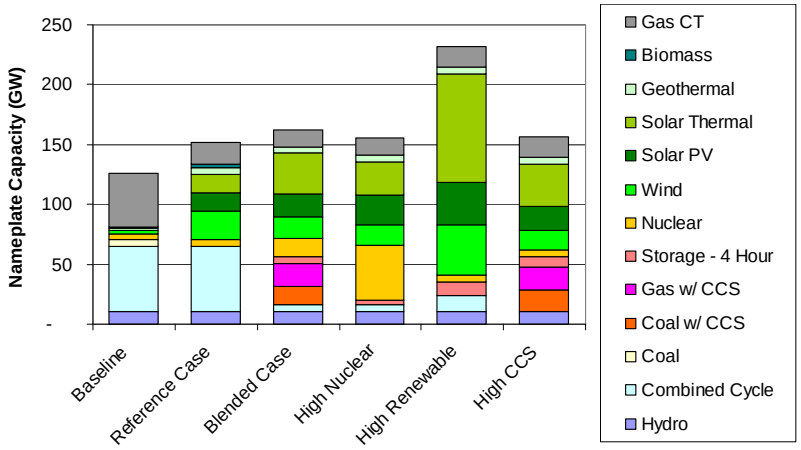
Generation Capacity in 2050



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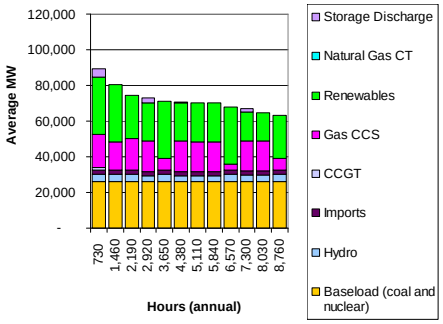
Grid Operations

- **Mix of baseload, load-following, intermittent and peaking generation makes it easiest to maintain grid reliability and low-cost**
- **High nuclear case –energy is spilled or exported in some periods**
- **High renewables – additional energy storage is needed (12,000 MW)**
- **High CCS – assume some load-following capability from gas with CCS by 2050 leads to flexible grid operations**

- **2050 load duration curve – blended case**



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Additional Scenario Characteristics

1. High Renewable Case

Long-line transmission needs

Large land footprint needs

2. High Nuclear Case

Nuclear waste disposal

Safety and proliferation concerns

3. High CCS Case

Commercialization needs

Long-term verification of storage

4. Blended Case

Depends on commercialization of multiple technologies

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Technology Wish List

Efficiency	Zero net energy buildings Extensive building retrofits
Electrification	Batteries for electric vehicles Smart charging for electric vehicles
Biofuels	Zero carbon ethanol Zero carbon algal fuels
Zero Carbon Gen	Carbon capture and storage Large scale energy storage Nuclear waste storage

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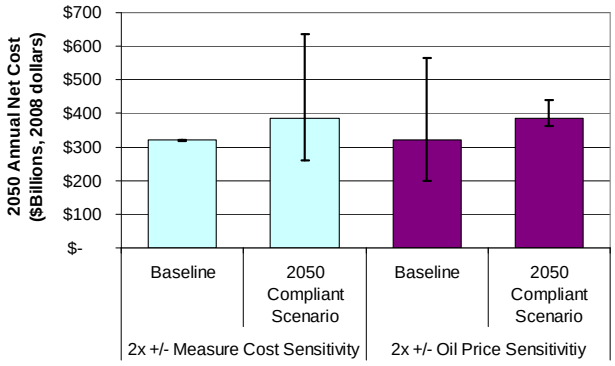
Low Carbon Technology Cost Risk vs. Oil Price Risk

- Our 'best guess' is that Compliant case costs $66 billion more than Baseline in 2050 (1.3% of California Gross State Product), with great uncertainty
- But current system is vulnerable to oil price volatility…



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Where We Focus Now

+Efficiency

- Energy use reduction through behavior change
- Deep reductions in building energy usage

+Zero-carbon Generation

- Integration of high levels of renewable generation
- Commercialization of electricity energy storage
- Commercialization of low-carbon generation technologies

+Electrification

- Transportation sector in particular

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Thank You
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