Getting to 2050
Pathways to deep reductions in GHG emissions

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Energy and Environmental Economics, Inc.

Defining the long term path

1. Bending the curve
2. Achieving historical levels
3. Deep reductions
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

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)
"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-CO₂) Sectors

Greenhouse Gas Savings for 2050

Source: Energy and Environmental Economics, Inc 2009
Emissions Reductions by Source

Types of Change

Behavioral Change

Technological Change
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

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
**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

![Graph showing electricity demand by year and sector]

**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

![Graph showing load profiles for 2050 Baseline and Compliant cases]

"Peaky" demand in 2050 Baseline  
"Flat" load profile in 2050 Compliant case
Low-Carbon Generation

1. High Renewable Case
2. High Nuclear Case
3. High CCS Case
4. Blended Case

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

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Capital Investment (Billion 2008$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline Case</td>
<td>$100</td>
</tr>
<tr>
<td>Reference Case</td>
<td>$200</td>
</tr>
<tr>
<td>Blended Scenario</td>
<td>$400</td>
</tr>
<tr>
<td>High Nuclear Case</td>
<td>$500</td>
</tr>
<tr>
<td>High Renewables</td>
<td>$550</td>
</tr>
<tr>
<td>High CCS Scenario</td>
<td>$600</td>
</tr>
</tbody>
</table>
**Generation Capacity in 2050**

- Gas CT
- Biomass
- Geothermal
- Solar Thermal
- Solar PV
- Wind
- Nuclear
- Storage - 4 Hour
- Gas w/ CCS
- Coal w/ CCS
- Coal
- Combined Cycle
- Hydro

**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
### Additional Scenario Characteristics

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. High Renewable Case</td>
<td>Long-line transmission needs, Large land footprint needs</td>
</tr>
<tr>
<td>2. High Nuclear Case</td>
<td>Nuclear waste disposal, Safety and proliferation concerns</td>
</tr>
<tr>
<td>3. High CCS Case</td>
<td>Commercialization needs, Long-term verification of storage</td>
</tr>
<tr>
<td>4. Blended Case</td>
<td>Depends on commercialization of multiple technologies</td>
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### Technology Wish List

<table>
<thead>
<tr>
<th>Category</th>
<th>Technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency</td>
<td>Zero net energy buildings, Extensive building retrofits</td>
</tr>
<tr>
<td>Electrification</td>
<td>Batteries for electric vehicles, Smart charging for electric vehicles</td>
</tr>
<tr>
<td>Biofuels</td>
<td>Zero carbon ethanol, Zero carbon algal fuels</td>
</tr>
<tr>
<td>Zero Carbon Gen</td>
<td>Carbon capture and storage, Large scale energy storage, Nuclear waste storage</td>
</tr>
</tbody>
</table>
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…

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
Thank You

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California 2050 Study Available at: