Bioenergy policy should be resilient to climate change in California and around the world

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What is bioenergy?

- Solar energy recently captured by plants converted to useable fuel (liquid, pellets, gas)
- Lower energy densities than fossil fuels

Sources
- Dedicated crops (e.g., corn for ethanol)
  - both annual and perennial
- Agricultural or forestry waste (e.g., crop residue for ethanol*)
- Municipal waste (e.g., landfill biogas)

* not yet commercially viable
Facts and figures

- 3.6% of CA electricity and 2.3% of CA transportation fuel were from biomass in 2006
  - most corn ethanol, grown outside of CA
- Executive Order for 20% of biofuel to be produced in CA and 20% of renewable electricity to be biomass by 2010
- Area to grow bioenergy crops uncertain - 8.9 million acres in CA

Source:
- Energy Information Administration (May 2009)
- Campbell et al. 2008
Pros and cons of bioenergy

+ -

• Can reduce GHG emissions
• Productive use of marginal cropland
• Decrease waste from urban, ag land
• No intermittency problems like with solar, wind*

• Life cycle accounting required to assess GHG reductions
• Competes with other land uses
• Some crops resource intensive
• Vulnerable to climate variability* & change

* Variability in resource months --> decades
How will climate change affect bioenergy resources?

- Short rotation poplar
- Perennial grass (Miscanthus)
- Corn field
- Methane digester
- Biodiesel refinery
Climate change will alter biofuel crop productivity

- Rainfed corn
  - $\uparrow$ CO$_2$ $\uparrow$ yield
  - $\uparrow$ rainfall $\uparrow$ yield

- Irrigated corn
  - $\uparrow$ temperature $\downarrow$ yield, except in far north

- Crop dependent effects

- Climate variability and extreme events affect yields, volatility in supply and price

Source: Lee et al. 2009, Tubiello et al 2002
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Source: Lee et al. 2009, Tubiello et al. 2002
Climate change will alter where bioenergy crops are grown

- Suitable climate may shift geographically
  - alters fuel transport distance
  - transport affects fuel life cycle performance

- Regions where corn yields borderline are improved or become unsuitable
  - changes in distribution of marginal cropland available to biofuel crops

- European assessment found northward shift for bioenergy crops

(Tuck et al. 2006)
Climate change will affect crop water supply and demand

Bioenergy crops most sustainable without irrigation; California mostly irrigated cropland
Decrease in water available for irrigation in California
Higher temperatures increase plant water use
  - water requirements are crop specific
Water required by refineries and power plants
  - 4 - 9.5 gal H₂O per gal biofuel vs 0.4 gal H₂O per gal gasoline

Table 14. Water use by region (in TAF/yr)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Sacramento</th>
<th>San Joaquin</th>
<th>Tulare</th>
<th>Southern California</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2050 Standard</td>
<td>6,149.8</td>
<td>5,772.6</td>
<td>3,655.5</td>
<td>8,856.0</td>
<td>24,433.9</td>
</tr>
<tr>
<td>2050 Climate Change</td>
<td>4,623.4</td>
<td>4,490.0</td>
<td>2,794.7</td>
<td>7,460.8</td>
<td>19,368.9</td>
</tr>
<tr>
<td>% Change</td>
<td>-24.82</td>
<td>-22.22</td>
<td>-23.55</td>
<td>-15.75</td>
<td>-20.73</td>
</tr>
</tbody>
</table>

Source: Howitt et al. 2009
Mitigation & adaptation policies may alter bioenergy landscape

- Carbon sequestration requires biomass to remain on site
  - native grass system better for C storage or fuel?
- Crop management adaptations (e.g., erosion prevention) may require crop residue
- Forest thinning for wildfire management --> more woody biomass
- Biofuel accounting & mandates

Source: http://www.afdc.energy.gov/afdc/sabre/sabre.php
Conclusions

- Bioenergy resources are diverse - some are vulnerable to climate change.
- Uncertainties in climate change impacts include
  - emissions pathways, federal and state policies
  - regional precipitation and temperature changes, and
  - varying resource sensitivities (e.g., corn vs switchgrass).
- Bioenergy commodities are subject to national and international pricing and supply, making climate change in remote areas relevant to California.
Research needs

• How will biofuel water demand and yields change with climate change in CA and other source regions?
• Where will water availability limit the sustainability of bioenergy sources?
• How will changes in land use, climate, and in mitigation and adaptation policies influence where bioenergy crops are grown?
• Can bioenergy compliment other renewable but intermittent energy sources?
• What would a resilient bioenergy system look like?