UNIVERSITY OF CALIFORNIA, MERCED

Bioenergy policy should be resilient to climate change

in California *and* around the world

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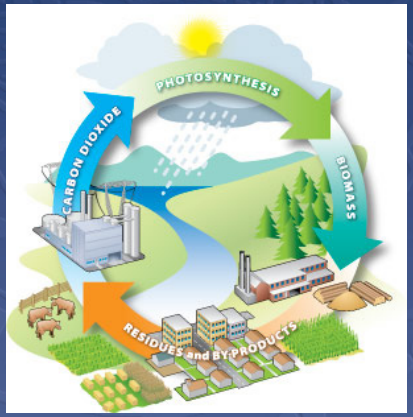
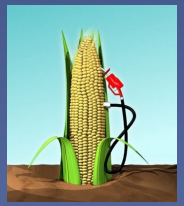
What is bioenergy?



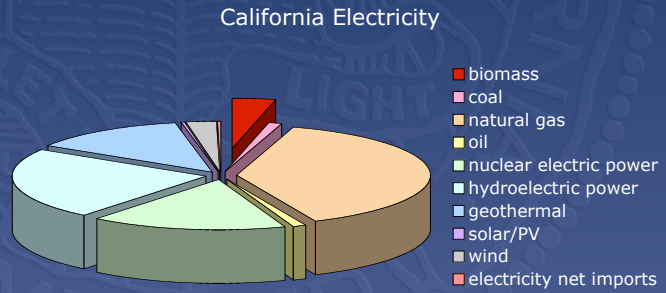
- Solar energy recently captured by plants converted to useable fuel (liquid, pellets, gas)
- Lower energy densities than fossil fuels



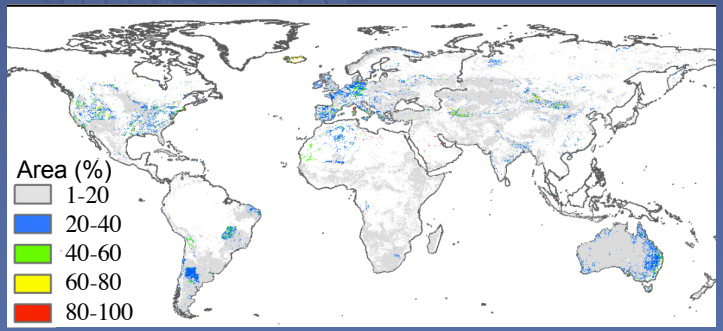
- Sources
  - Dedicated crops (e.g., corn for ethanol)
    - both annual and perennial
  - Agricultural or forestry waste (e.g., crop residue for ethanol*)
  - Municipal waste (e.g., landfill biogas)

* not yet commercially viable

Facts and figures



Source: *Energy Information Administration (May 2009)*



Source: *Campbell et al. 2008*

- 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

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Pros and cons of bioenergy

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

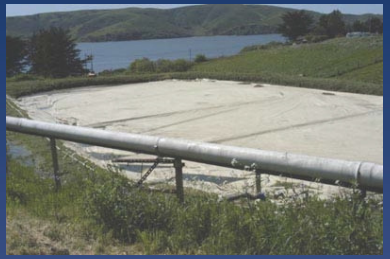
-

- 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*

Short rotation poplar

Corn field



Methane digester

How will climate change affect bioenergy resources?

Perennial grass (Miscanthus)

Biodiesel refinery

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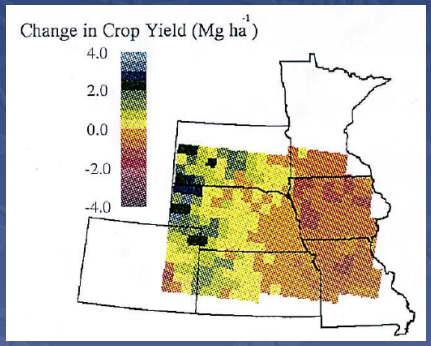
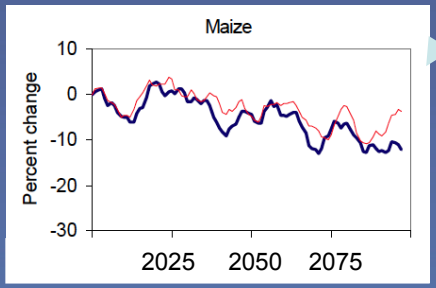
Climate change will alter biofuel crop productivity

Corn



Source: *Brown et al. 2000*



Source: *Lee et al. 2009*

- Rainfed corn
  - ↑ CO_2 ↑ yield
  - ↑ rainfall ↑ yield
- Irrigated corn
  - ↑ temperature ↓ 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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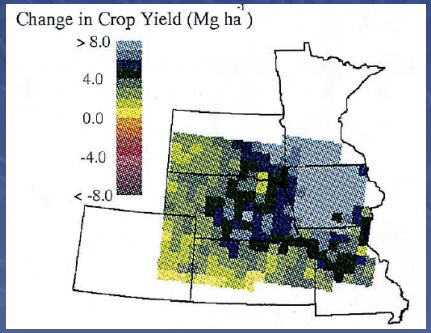
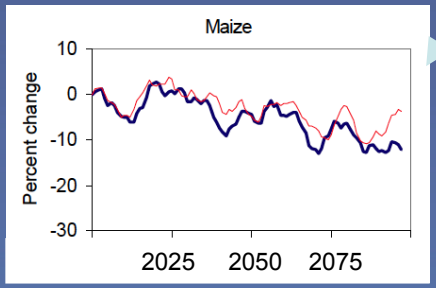
Climate change will alter biofuel crop productivity

Switchgrass



Source: *Brown et al. 2000*



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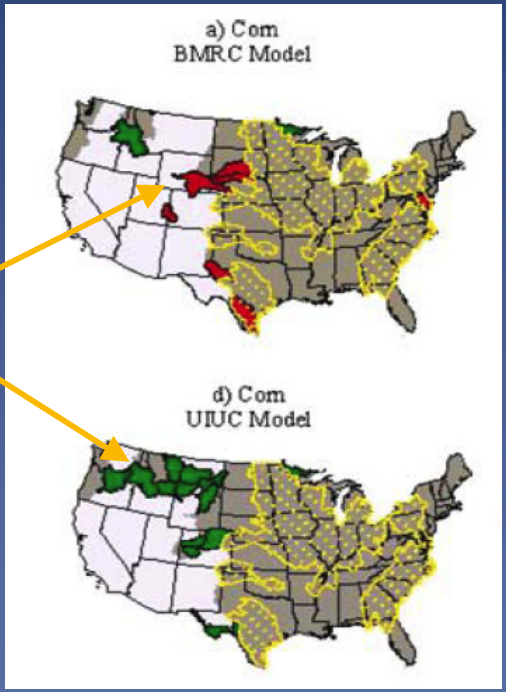
Climate change will alter where bioenergy crops are grown

- 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)



Source: *Thomson et al. 2005*

Climate change will affect crop water supply and demand

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

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

Source: *Howitt et al. 2009*

- 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 H_2O per gal biofuel vs 0.4 gal H_2O per gal gasoline

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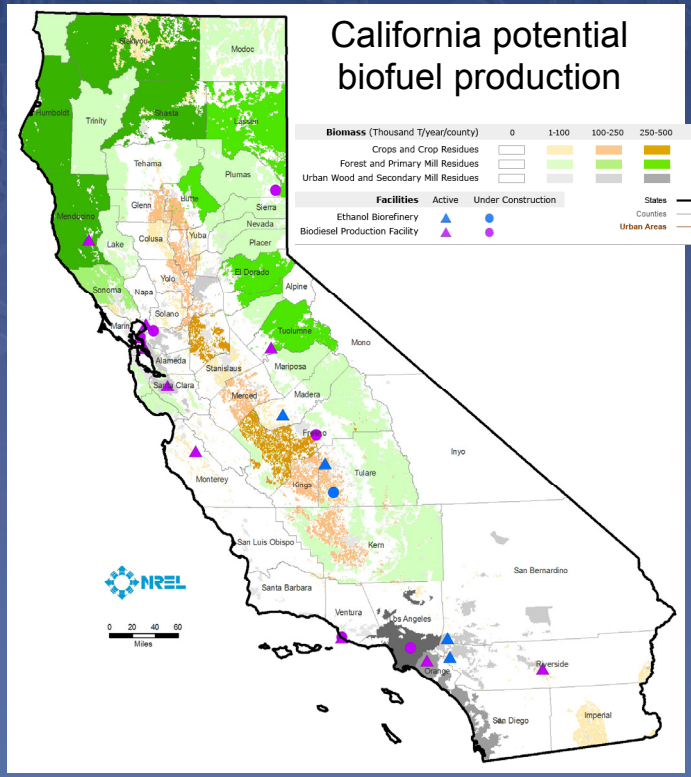
Mitigation & adaptation policies may alter bioenergy landscape



- 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

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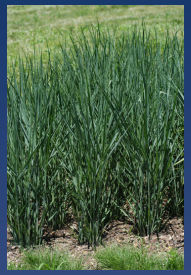
Conclusions

- Bioenergy resources are diverse - some are vulnerable to climate change.
- Uncertainties in climate change impacts include
  - emissions pathways, federal and state polices
  - 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?