

# California's Low Carbon Fuel Standard and the Prospects for Biofuel Supplies

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January 27, 2010

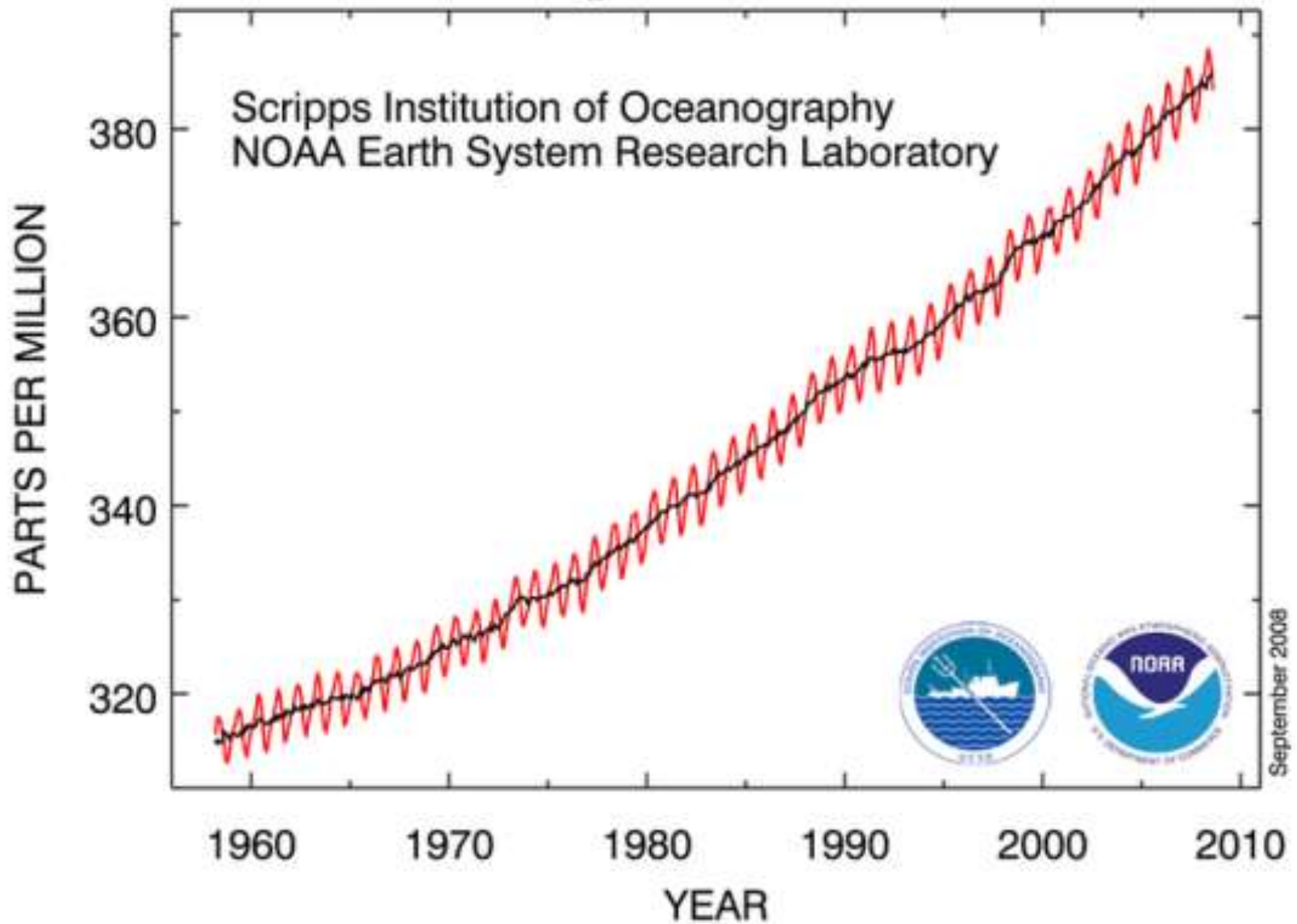


# California's LCFS

- State policy is based on the notion that climate change will be damaging.
- Initial estimates of feed stocks and bio-energy
- The Low Carbon Fuel Standard
- Possible effects of LCFS on biofuel sources and supply
- Policy considerations



# Atmospheric CO<sub>2</sub> at Mauna Loa Observatory

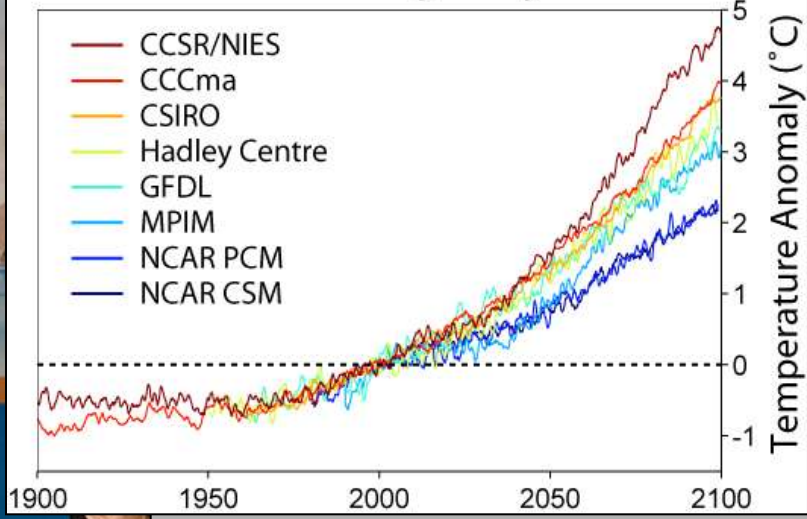


# 27ª Sesión Plenaria del Grupo Intergubernamental de Expertos sobre el Cambio Climático

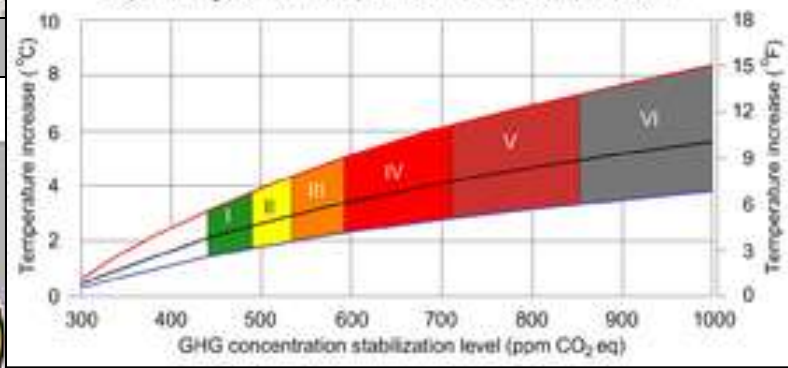
Valencia, 12-17 de Noviembre de 2007



## Global Warming Projections

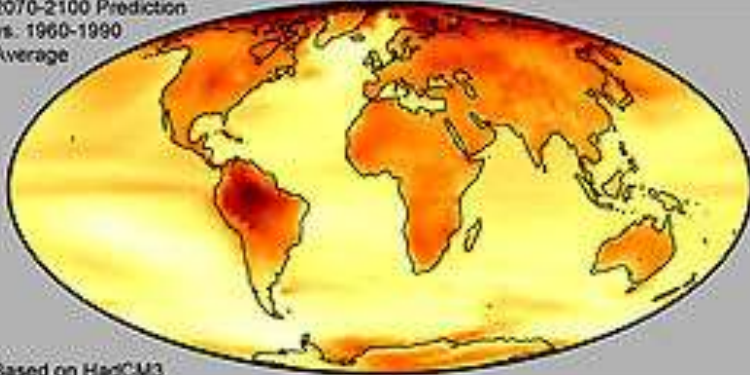


Equilibrium global mean temperature increase above preindustrial



## Global Warming Predictions

2070-2100 Prediction vs. 1960-1990 Average



Based on HadCM3



CA is particularly vulnerable to the costs associated with unmitigated climate change. A warming climate would generate more smoggy days, ozone, and foster more large brush and forest fires... by late century, CA will lose 90% of the Sierra snow pack, sea level will rise by more than 20 inches, and there will be a 3x to 4X increase in heat wave days. This will lead to increased flood damage, diverse economic losses and substantial public health costs. AB 32 Scoping Plan (Executive Summary).

| <b>Annual Damage Estimates in 2006 USD (billions)</b> |            |             |                       |
|---|------------|-------------|-----------------------|
|   | <b>LOW</b> | <b>HIGH</b> | <b>ASSETS AT RISK</b> |
| <b>Water</b>  | <b>N/A</b> | <b>0.6</b>  | <b>5</b>              |
| <b>Energy</b>   | <b>2.7</b> | <b>7.5</b>  | <b>21</b>             |
| <b>Tourism and Recreation</b>                         | <b>0.2</b> | <b>7.5</b>  | <b>98</b>             |
| <b>Real Estate</b>                                    | <b>0.3</b> | <b>3.9</b>  | <b>2500</b>           |
| <b>Agriculture, Forestry, Fisheries</b>               | <b>0.3</b> | <b>4.3</b>  | <b>113</b>            |
| <b>Transportation</b>                                 | <b>N/A</b> | <b>N/A</b>  | <b>500</b>            |
| <b>Public health</b>                                  | <b>3.8</b> | <b>24.0</b> | <b>N/A</b>            |
| <b>TOTAL</b>  | <b>7.3</b> | <b>46.6</b> |                       |

Fredrich and Roland-Holst (2008)

## Signing AB 32: The Global Warming Solutions Act

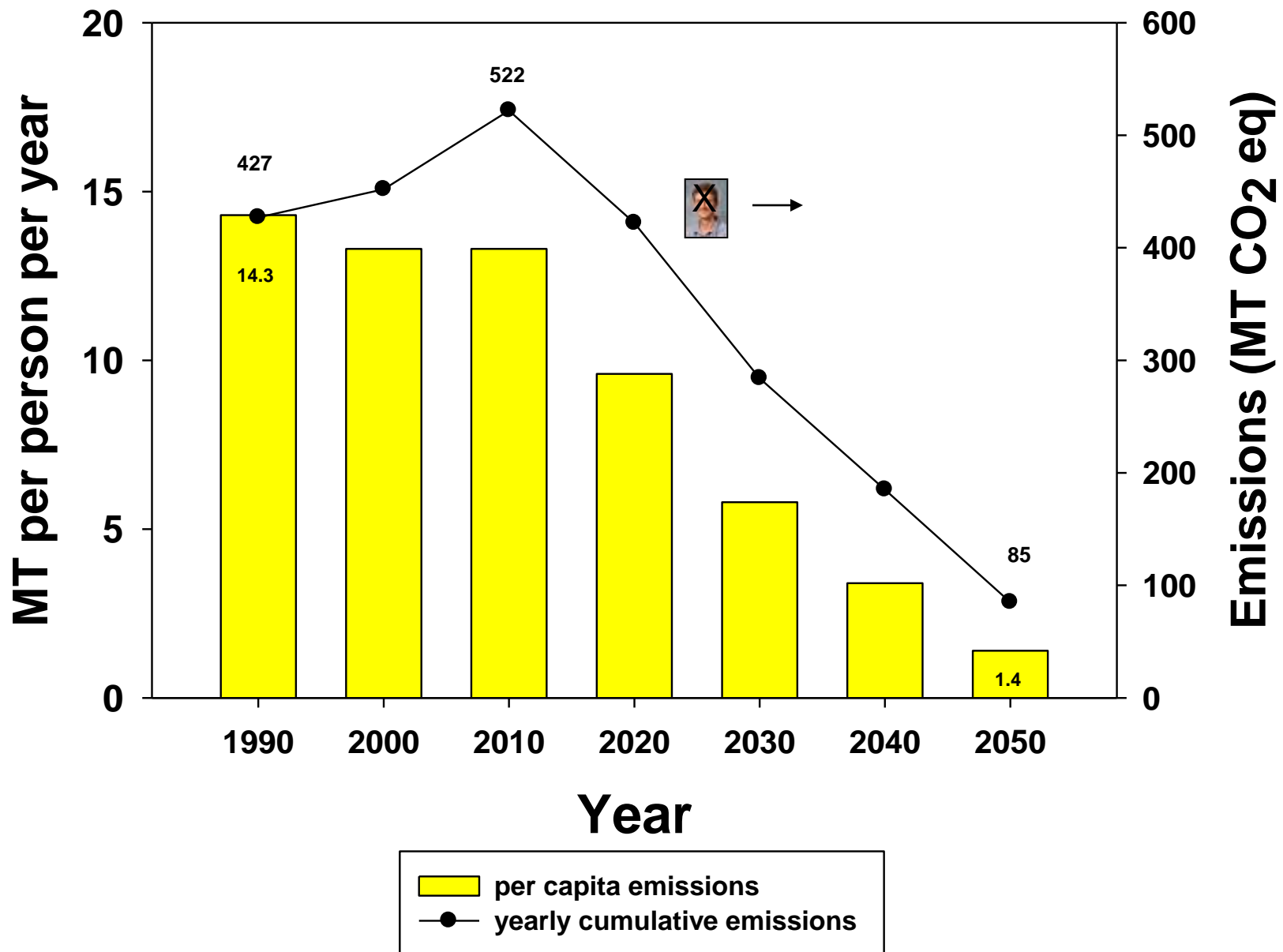


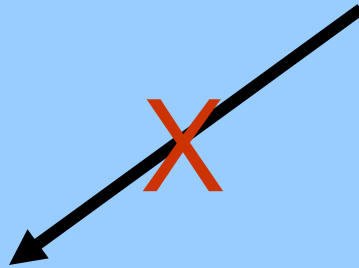
# Important recent regulations

- Global Warming Solutions Act (AB 32, Nunez)
- Low Carbon Fuel Standard (Jan. 1, 2010)
- Vehicle Greenhouse Gas Emission Standards (AB 1493, Pavley)
- Alternative and Renewable Fuel, Vehicle Technology, Clean Air, and Carbon Reduction Act (AB 118, Nunez)



Fig . 6: Emission Trajectory Towards 2050





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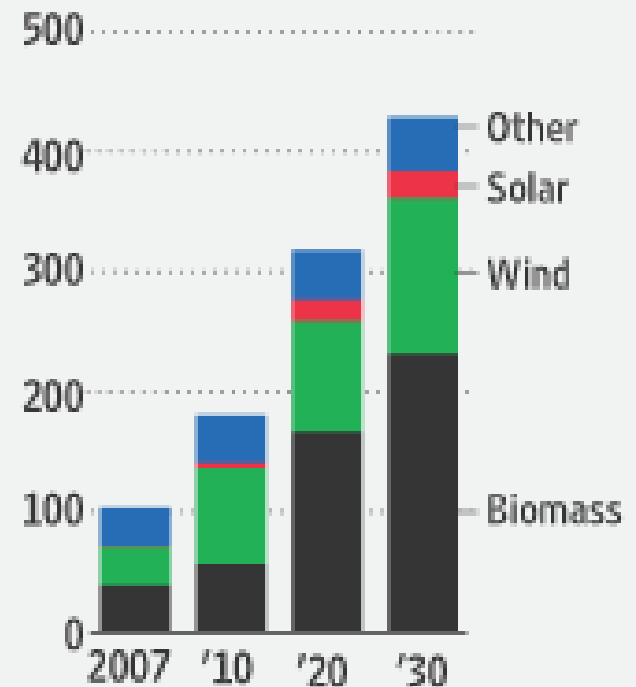
# The end of oil?

By 2025, every source of energy for transportation fuels will be needed...

---VP for Research,  
Chevron

## New Energy

Projected renewable electricity generation by energy source, in billions of kilowatthours



Source: Energy Information Administration

# California Biomass Collaborative

- Statewide biomass coordinating group
- Biomass Facilities Reporting System
- Biomass resource assessments
- Technology assessments
- Planning Functions/Policy
  - Needs Assessment
  - Roadmap for biomass development
- Coordination with State Bioenergy Interagency Working Group



## California Biomass Facilities Reporting System (BFRS) Power Generation Assessments

The BFRS database contains Biomass power plants and related facilities, including thermal station power plants, digesters, landfill gas systems, fermentation plants, bio refineries, other biomass energy converters, material handling and processing operations, and storage units with technical and environmental performance. Gross and technical resources, estimates of electricity capacity and energy from biomass for year 2003, 2005, 2007, 2010 and 2017 are included in this database.

Specific information can be retrieved by following steps.

<http://biomass.ucdavis.edu>  
Email: [biomass@ucdavis.edu](mailto:biomass@ucdavis.edu)

## California Biomass Facilities Reporting System (BFRS) Resource Assessments

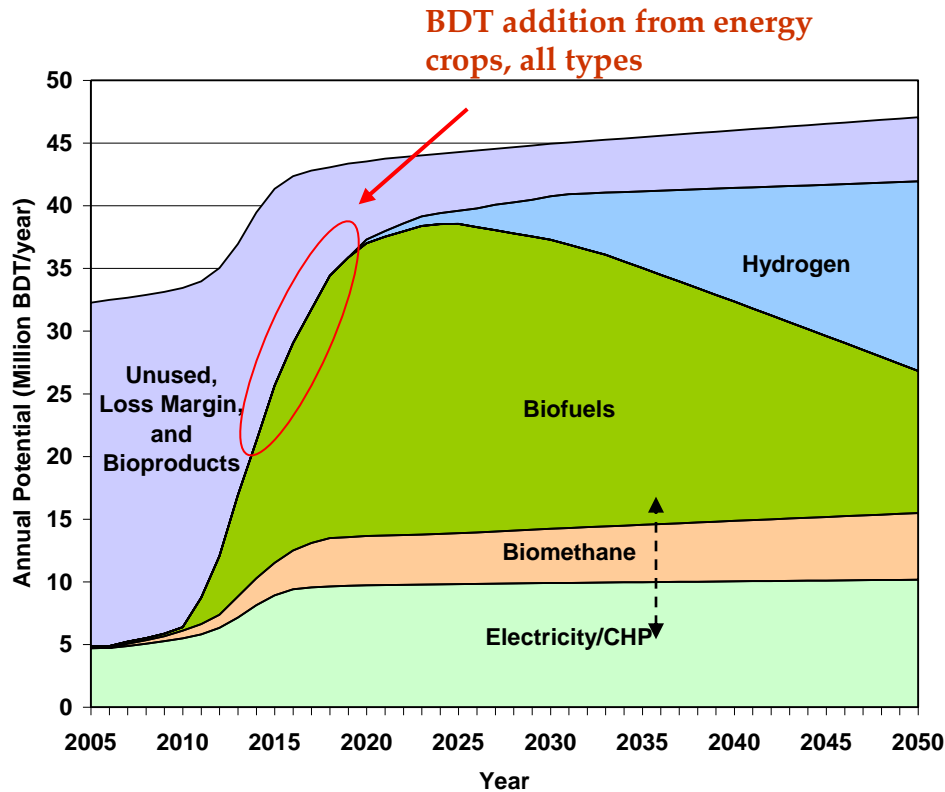
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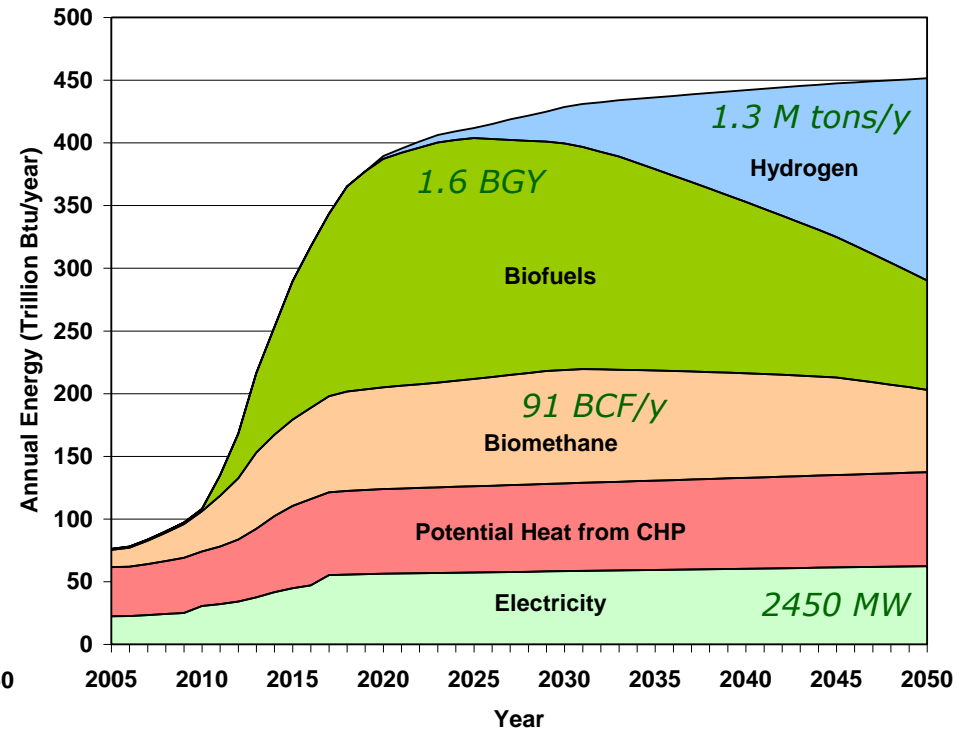
# One development scenario for California biomass (1.5 billion dry tons utilized through 2050)

## In-state tonnage



About 5 of the 32 million BDT are currently utilized. Assumes 10 million BDT from dedicated energy crops ultimately available; ramping up from 2012 to 2018.

## Energy



Potential technical recovery, not including economic costs

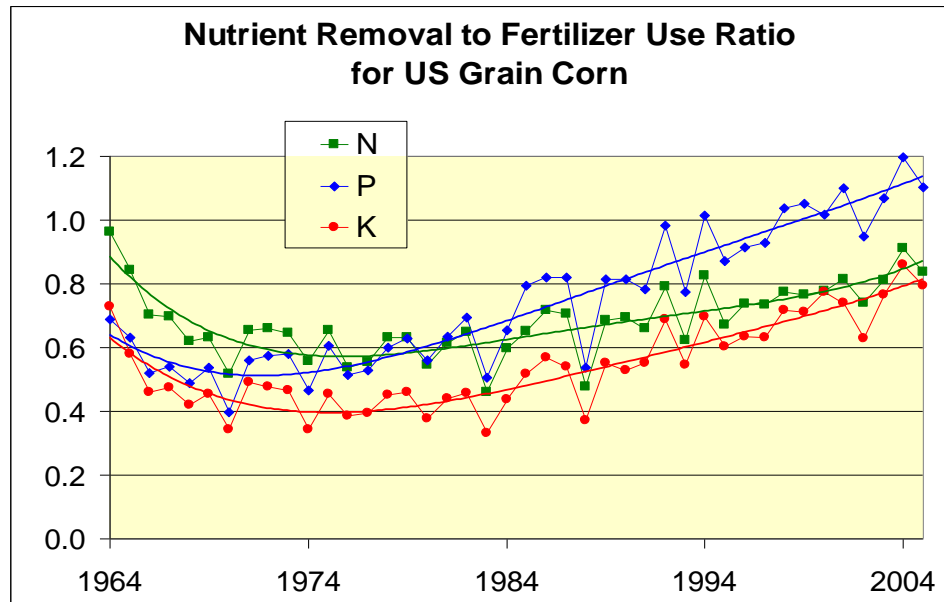
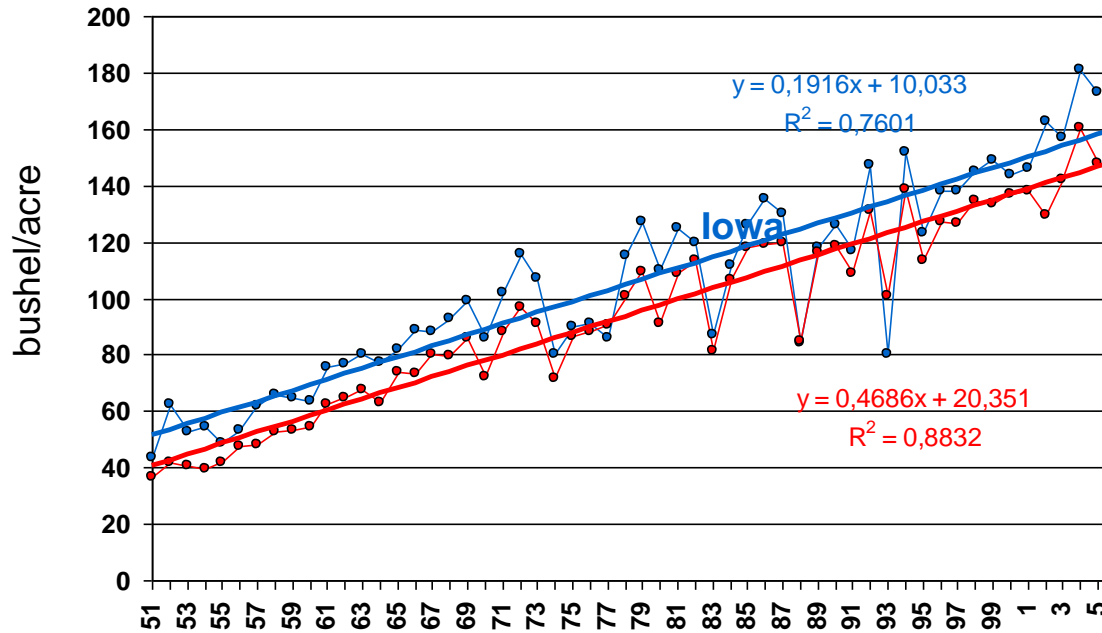
Jenkins et al. (2006) A roadmap for the development of biomass in California



**25 MGY Corn Ethanol Facility, Goshen, CA  
(now closed due to bankruptcy)**



# Corn yields in Iowa and the USA as a whole (1951-2005)



# Corn Sustainability Improvements 1987-2007

| Land Use | Soil Loss | Irrigation | Energy | Climate |
|----------|-----------|------------|--------|---------|
|----------|-----------|------------|--------|---------|

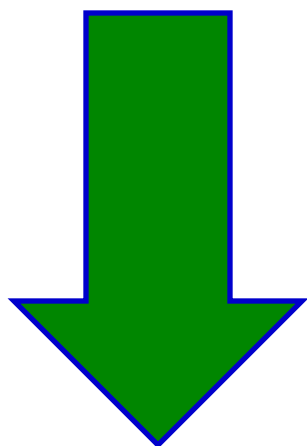
Amount of land to produce one bushel of corn

Soil loss per bushel, above a tolerable level

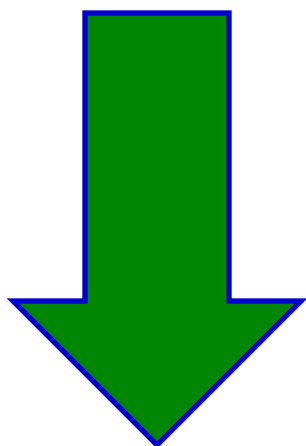
Irrigation water use per bushel

Energy used to produce one bushel

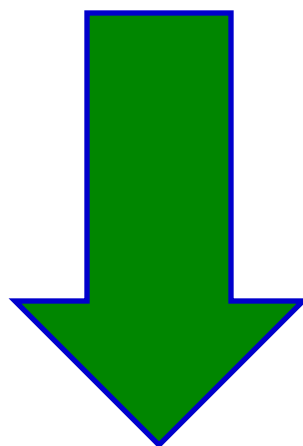
Emissions per bushel



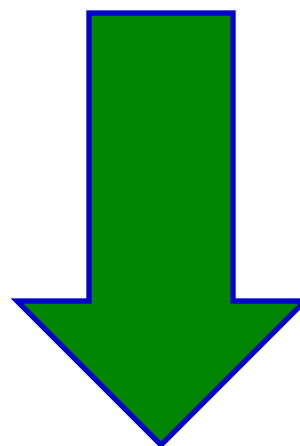
**37%**



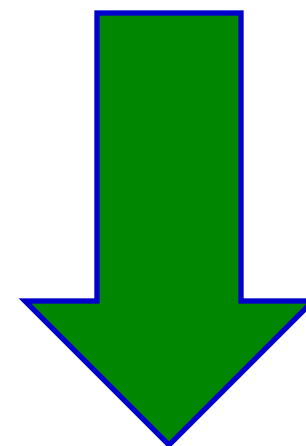
**69%**



**27%**



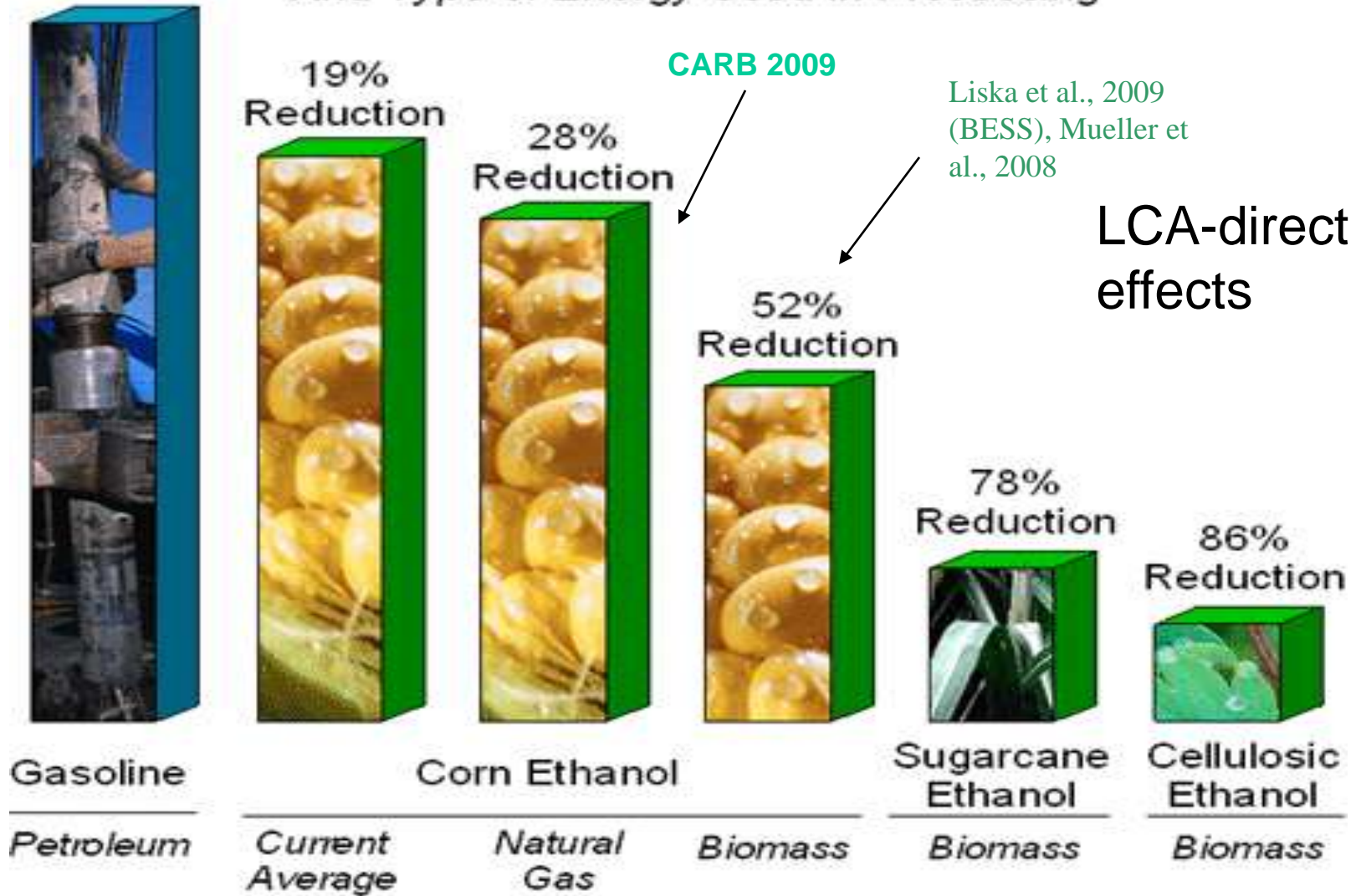
**37%**



**30%**

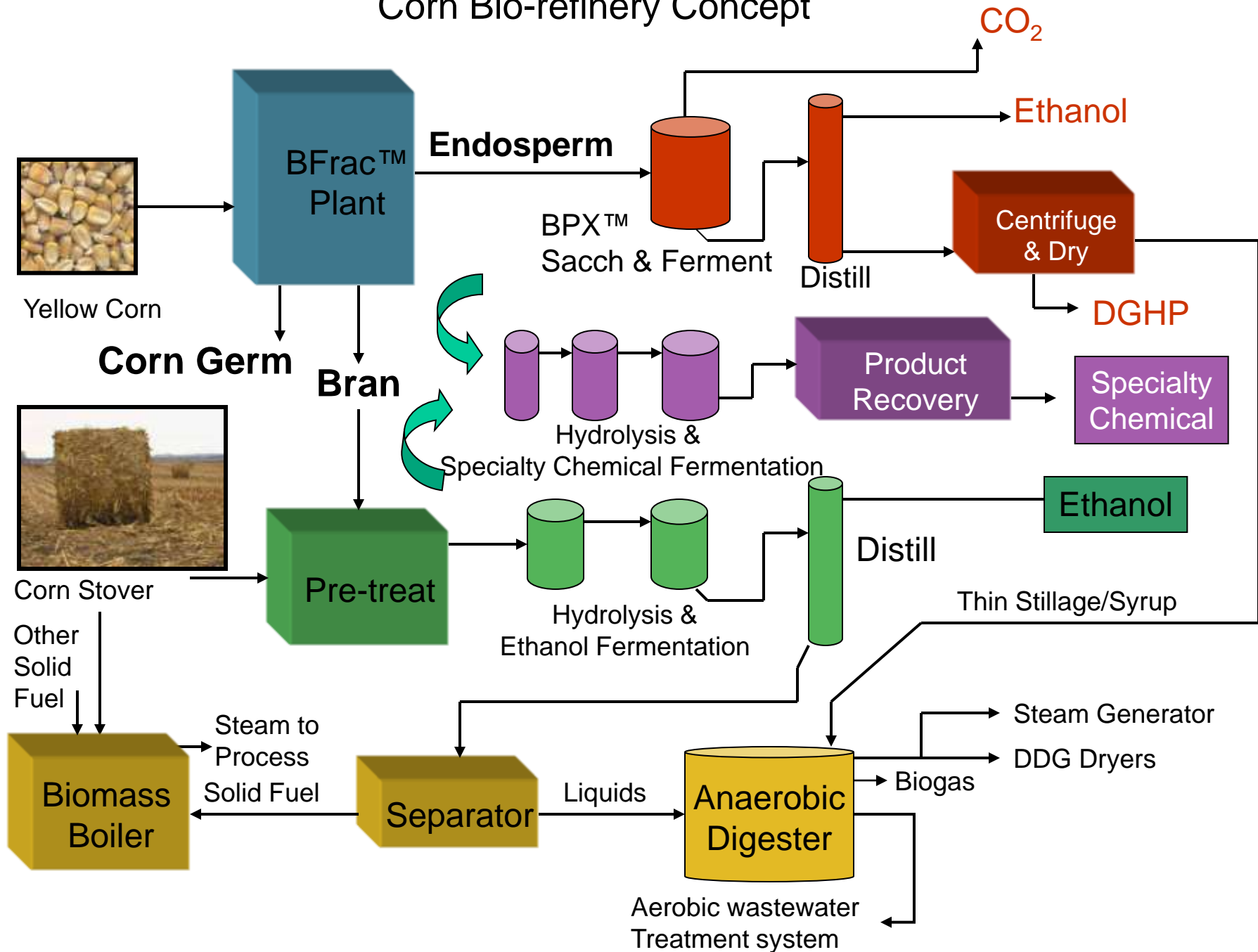
Source: Field to Market

# Greenhouse Gas Emissions by Transportation Fuel And Type of Energy Used in Processing



Sources: Wang et al, *Environ. Research Letters*, May 2007; Wang et al, *Life-Cycle Energy Use and GHG Implications of Brazilian Sugarcane Ethanol Simulated with GREET Model*, Dec. 2007

# Corn Bio-refinery Concept



# California's LCFS

- State policy is based on the notion that climate change will be damaging.
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# Low Carbon Fuel Standard

- **California Air Resources Board**
- **Reduce GHG intensity of transportation and fuels by 2020 to 2050**
- **A performance based standard (?)**

# Low Carbon Fuel Standard

- Goal is a 10% reduction in the carbon intensity (CI) of transportation fuels and emissions by 2020.
- Petroleum and biofuel providers are the regulated parties (others can opt-in: Electricity, H<sub>2</sub>, CH<sub>4</sub>).
- Can be met with a mixture of fuels and purchased/banked credits.

# Low Carbon Fuel Standard

- Creates a framework for transition to low carbon fuels. **Described as a performance standard.**
- Establishes a regulatory precedent or model for others.
- **Encourages technology innovation.**
- Allows for biofuel providers and others to assert **alternative Carbon Intensities**, but these are subject to CARBS' review and approval. (CA-GREET, GTAP)

# CARB asserts that the LCFS:

- Will increase the use of low carbon corn or sugarcane ethanol, cellulosic ethanol, renewable diesel and biodiesel, electricity, H<sub>2</sub> and CH<sub>4</sub>
- Will decrease the use of **high carbon biofuels** and petroleum

# ARB mandates for biofuels sources

| Year | Displaced Petroleum (bgge) | Sources  |
|------|----------------------------|--|
| 2009 | 0.6                        | Conventional biofuels (100%)   |
| 2020 | 3.0                        | Conventional biofuels (20%)<br>CNG, electricity, H2: (10%)<br><b>Advanced biofuels: (70%)*</b> |

\*MSW, Forestry Wastes, other ?

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# Agriculture

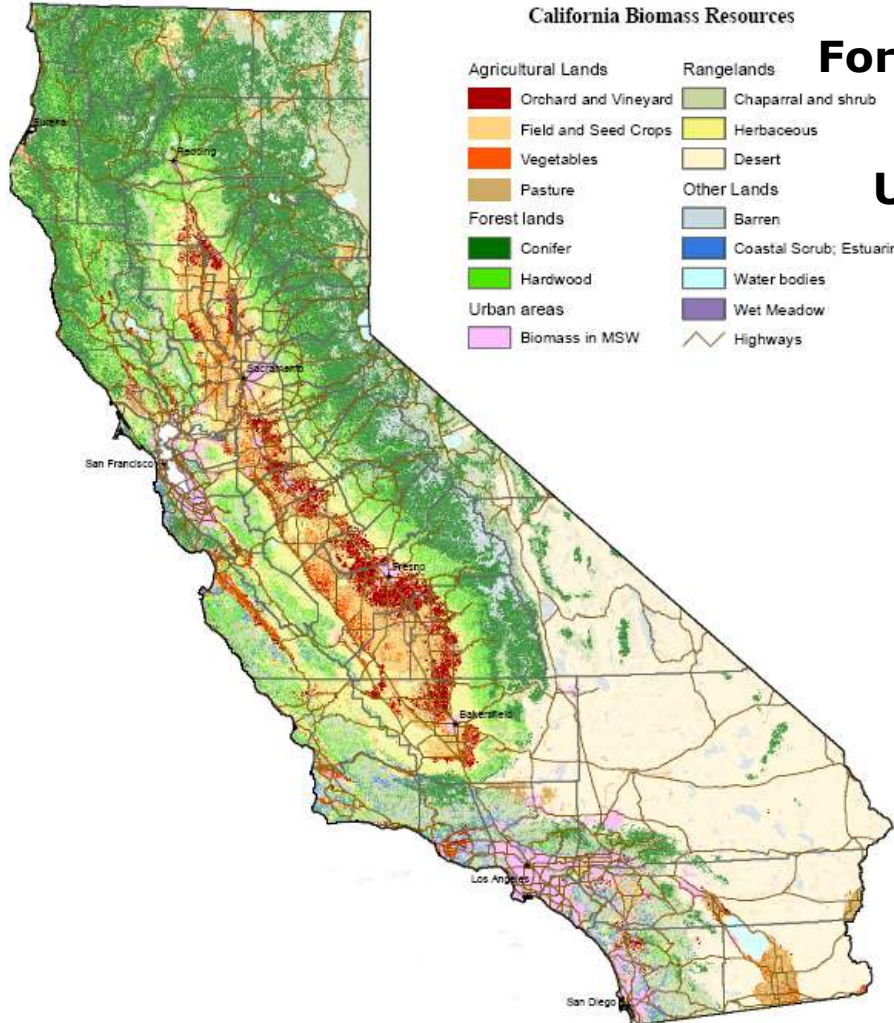
# Forestry

# Urban

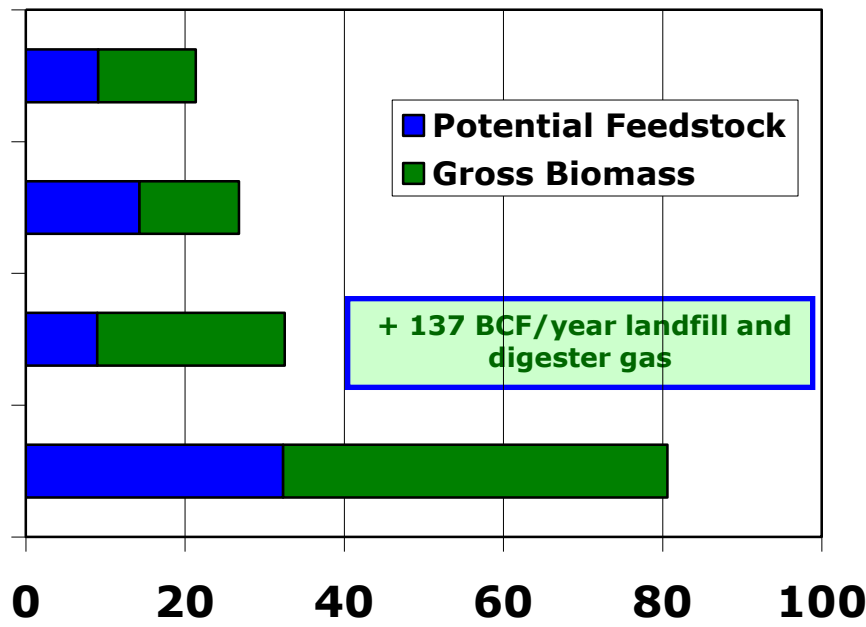
# Total

California Biomass Resources

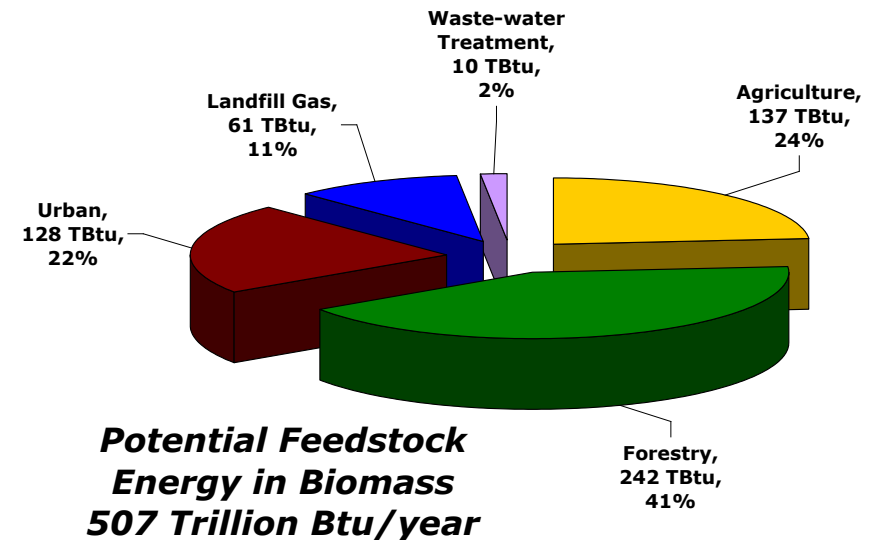
- |                           |                          |
|---------------------------|--------------------------|
| <b>Agricultural Lands</b> | <b>Rangelands</b>        |
| Orchard and Vineyard      | Chaparral and shrub      |
| Field and Seed Crops      | Herbaceous               |
| Vegetables                | Desert                   |
| Pasture                   | <b>Other Lands</b>       |
| <b>Forest lands</b>       | Barren                   |
| Conifer                   | Coastal Scrub; Estuarine |
| Hardwood                  | Water bodies             |
| <b>Urban areas</b>        | Wet Meadow               |
| Biomass in MSW            | Highways                 |



Data sources: CDF FVEG 2002 Version 2  
DWR Land Use 1994 - 2004, National Land Cover Data, 2002



Biomass (Million BDT/year)



Potential Feedstock Energy in Biomass  
507 Trillion Btu/year



# California Biomass Resources

Jenkins et al. (2006) A roadmap for the development of biomass in California



University of California, Davis

## Gross Ethanol Potential from Cellulosic Residues in California---Williams et al, (2007)-AB 118 Report

| Biomass Source<br>(residues)             | Potential<br>Feed stock<br>(MBDT/yr) | Potential<br>Ethanol<br>(Mgal/yr) | Gasoline<br>equivalent<br>(Mgge/yr) |
|--|--------------------------------------|-----------------------------------|-------------------------------------|
| Field and seed crops                     | 2.3                                  | 160                               | 105                                 |
| Orchard/vine prunings                    | 1.8                                  | 125                               | 83                                  |
| Landfills: mixed paper                   | 4.0                                  | 320                               | 213                                 |
| Landfills: wood& green<br>waste with ADC | 2.7                                  | 216                               | 144                                 |
| Forest thinning                          | 14.2                                 | 990                               | 660                                 |
| <b>Total estimates</b>                   | <b>24.9</b>                          | <b>1,814</b>                      | <b>1,205*</b>                       |

\*1.5 M acres of dedicated cellulosic energy crops could add 400 to 900 Mgge to potential. These are not estimates of economically recoverable or sustainable biomass.

# Annual technically available forest biomass in CA\*

| Ownership | Slash & thinnings (BDT) | Mill Waste (BDT) | Shrub (BDT) | Total (BDT)       | %      |
|-----------|-------------------------|------------------|-------------|-------------------|--------|
| Private   | 5,870,000               | 1,391,611        | 1,211,457   | 8,473,069         | 59.4   |
| Federal   | 2,385,689               | 1,907,786        | 1,296,354   | 5,589,892         | 39.2** |
| State     | 101,777                 | 29,771           | 71,905      | 203,453           | 1.4    |
| Total     | 8,357,466               | 3,329,168        | 2,579,716   | <b>14,266,351</b> | 100    |
| %         | 58.6                    | 23.3             | 18.1%       | 100               |        |

\* CBC/CDFFP data and assumptions; \*\*excluding federal reserves, wilderness areas, parks, etc.,

# ECONOMIC POTENTIAL OF CALIFORNIA BIOMASS RESOURCES FOR ENERGY AND BIOFUEL

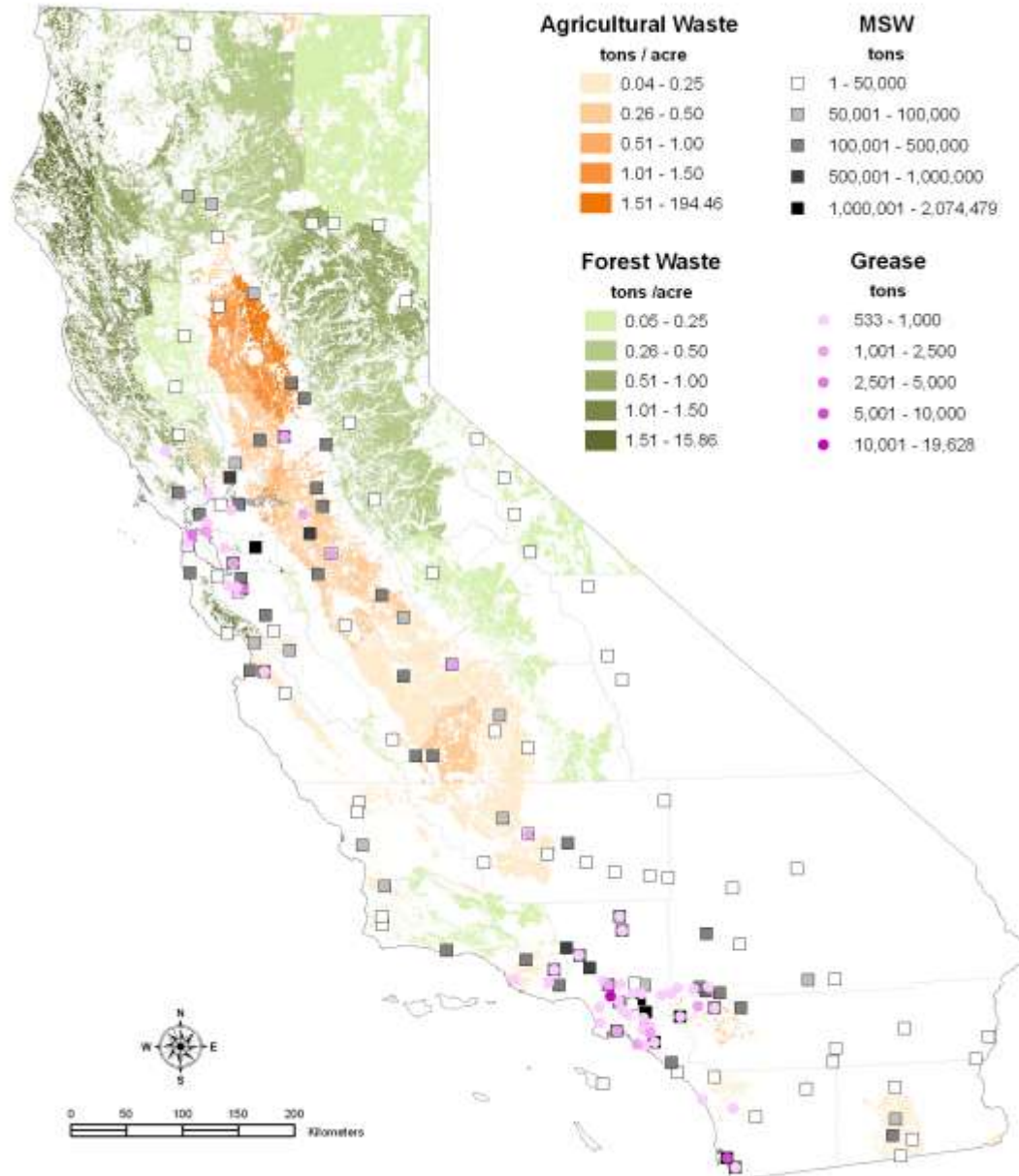
## PIER Collaborative Report

Peter Tittman, Nathan Parker, Quinn  
Hart, Mui Lay, Bryan Jenkins  
September 2008

*Also part of a research project  
carried out for the Western  
Governors Association*

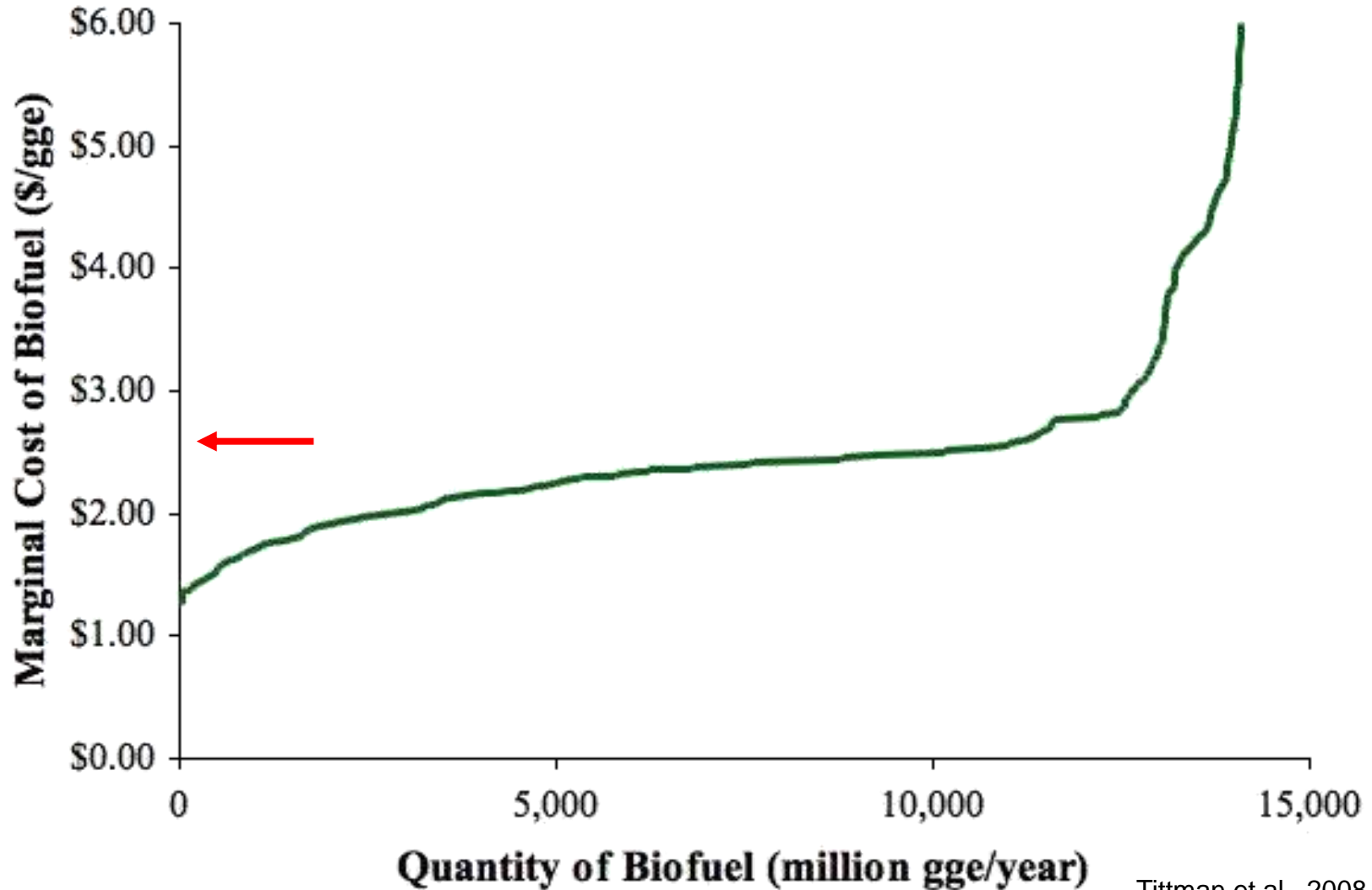


# Distribution of biomass “waste” and approximate amounts



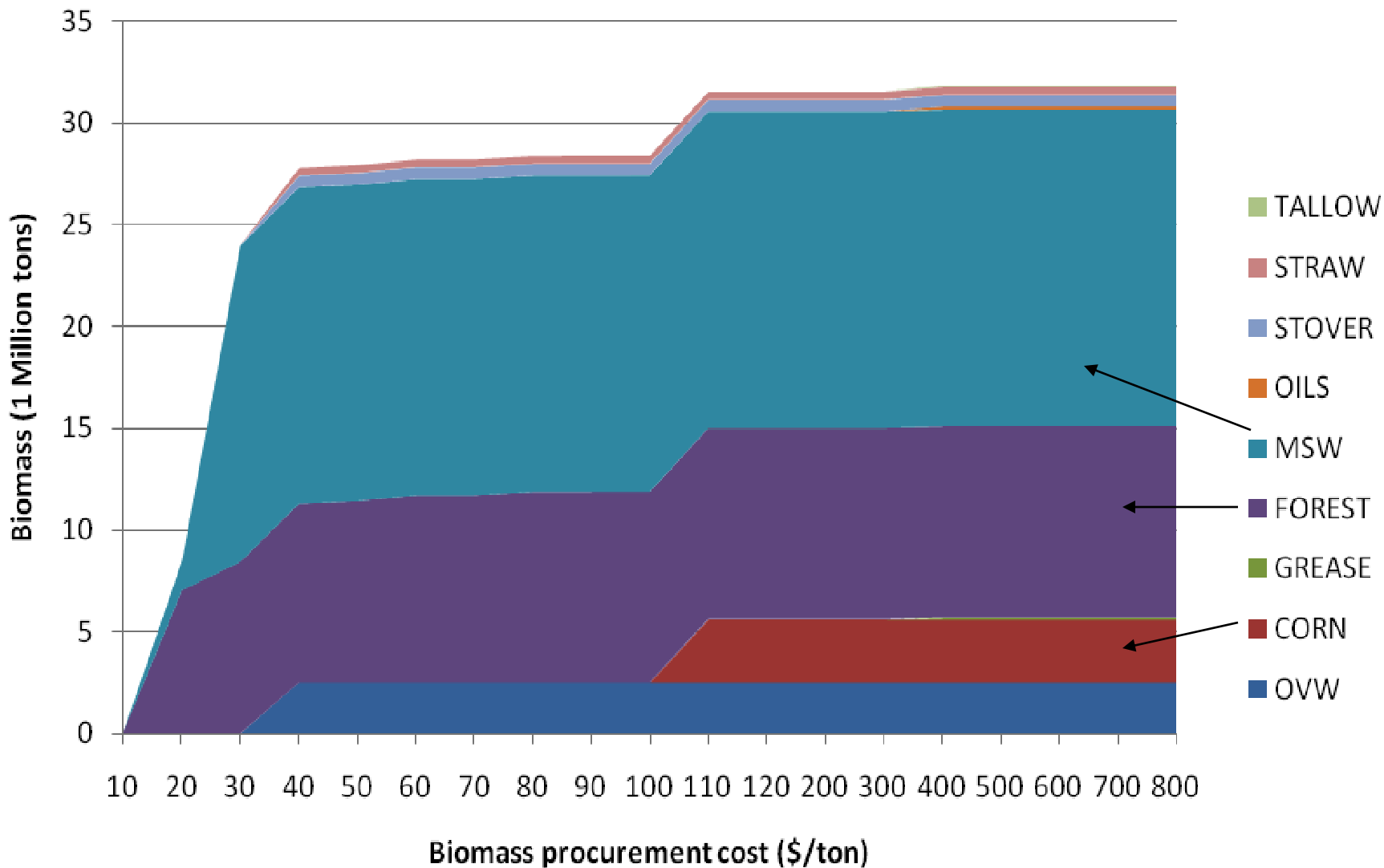
Tittman et al, 2008

# Supply Curve for All Biofuels Combined



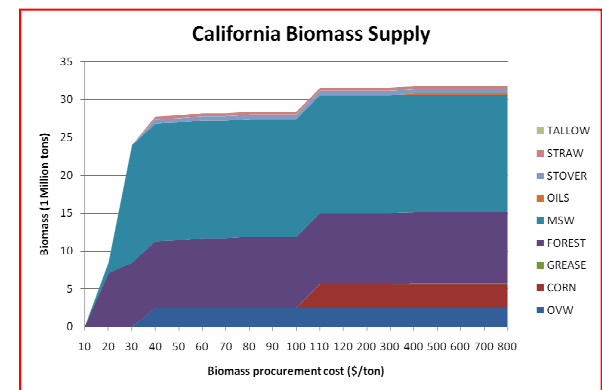
Tittman et al., 2008

# California Biomass Supply

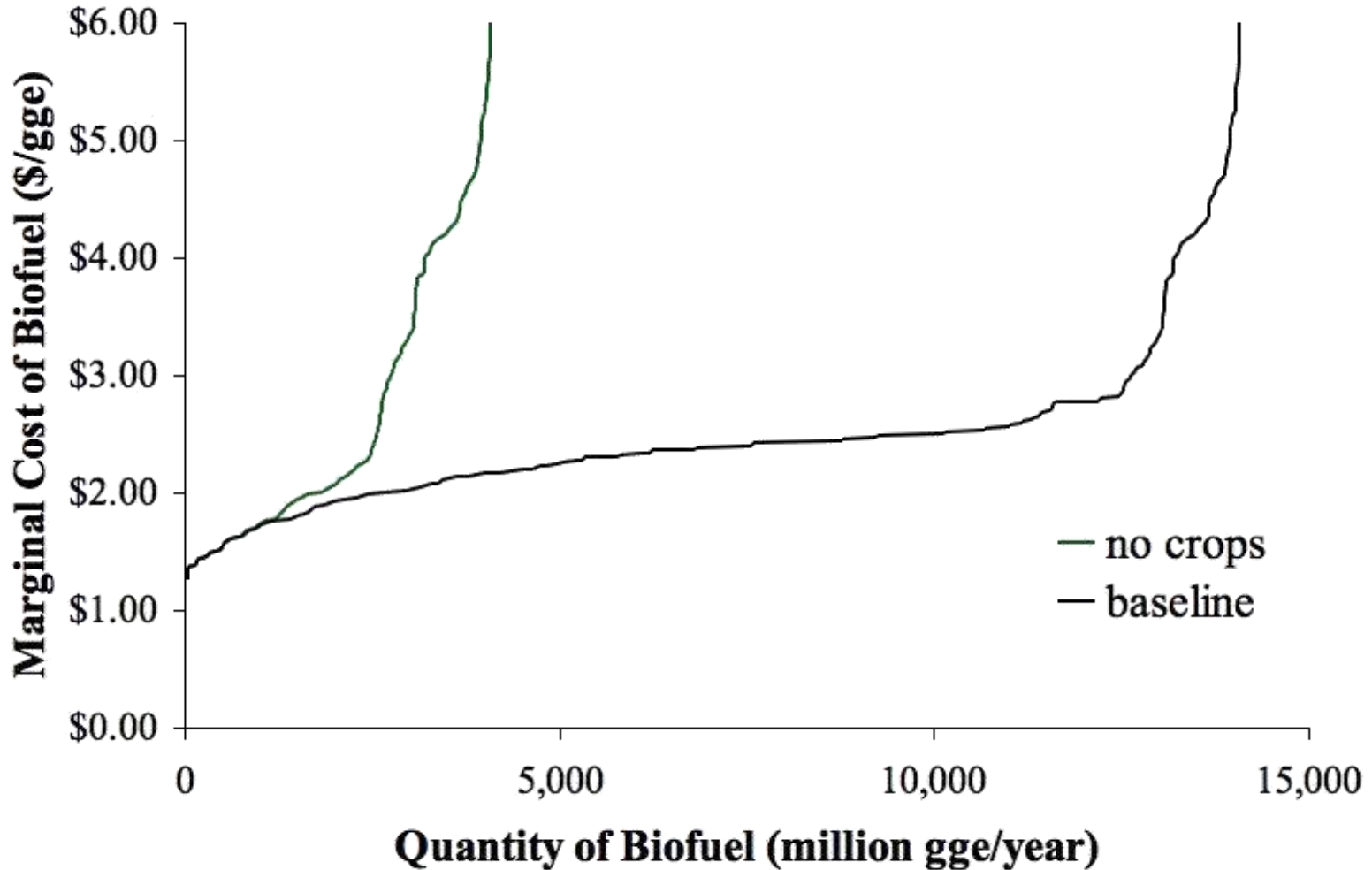


# The state-wide supply in CA is most sensitive to:

- The development of low-cost, cellulosic ethanol (LCE) technology or a technology with similar performance to LCE as modeled,
- The demand for biomass for the production of electricity,
- Availability of low-cost cellulosic feedstock from Natural Forest Stands



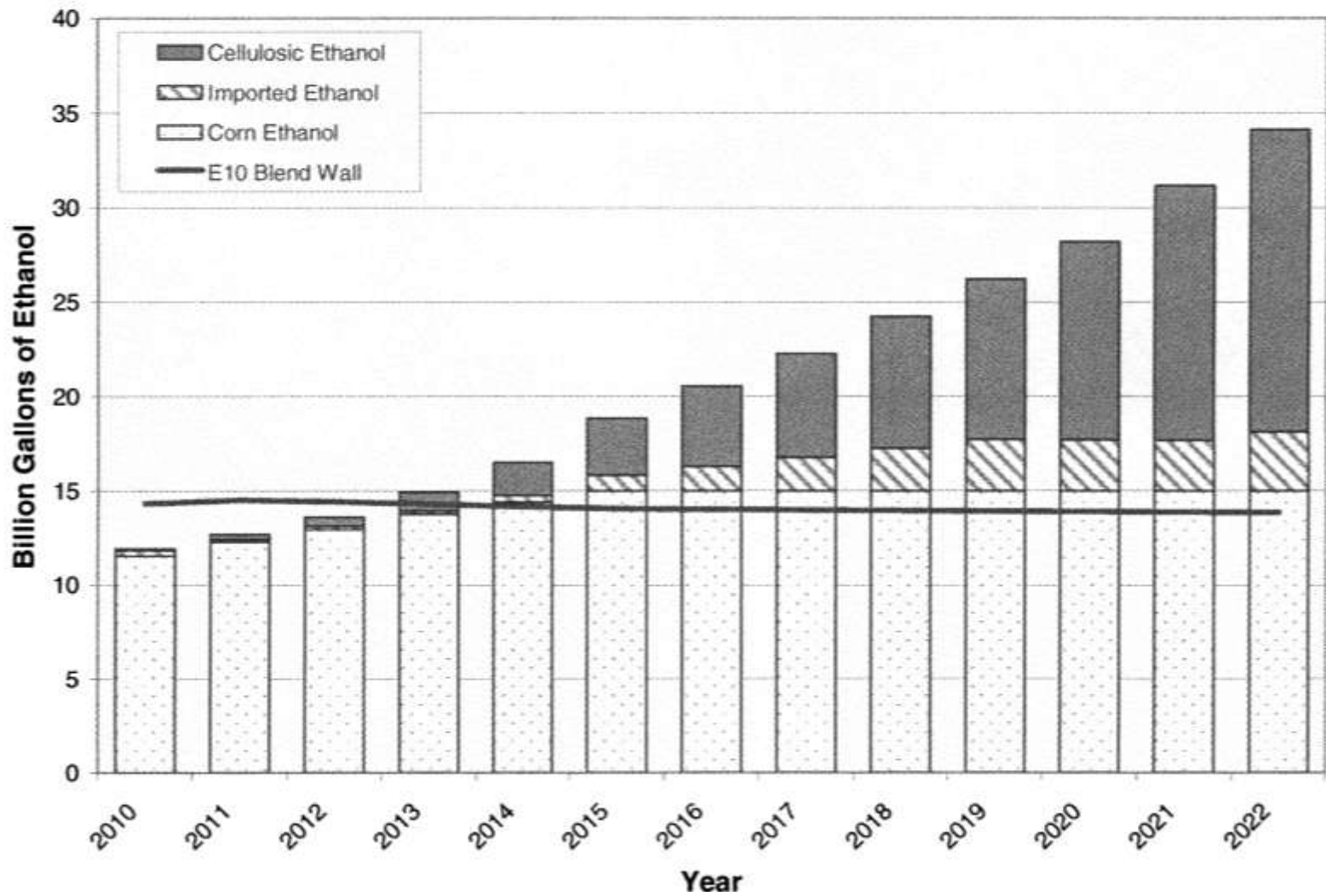
# Biofuel Supply without Dedicated Crops (WGA region)



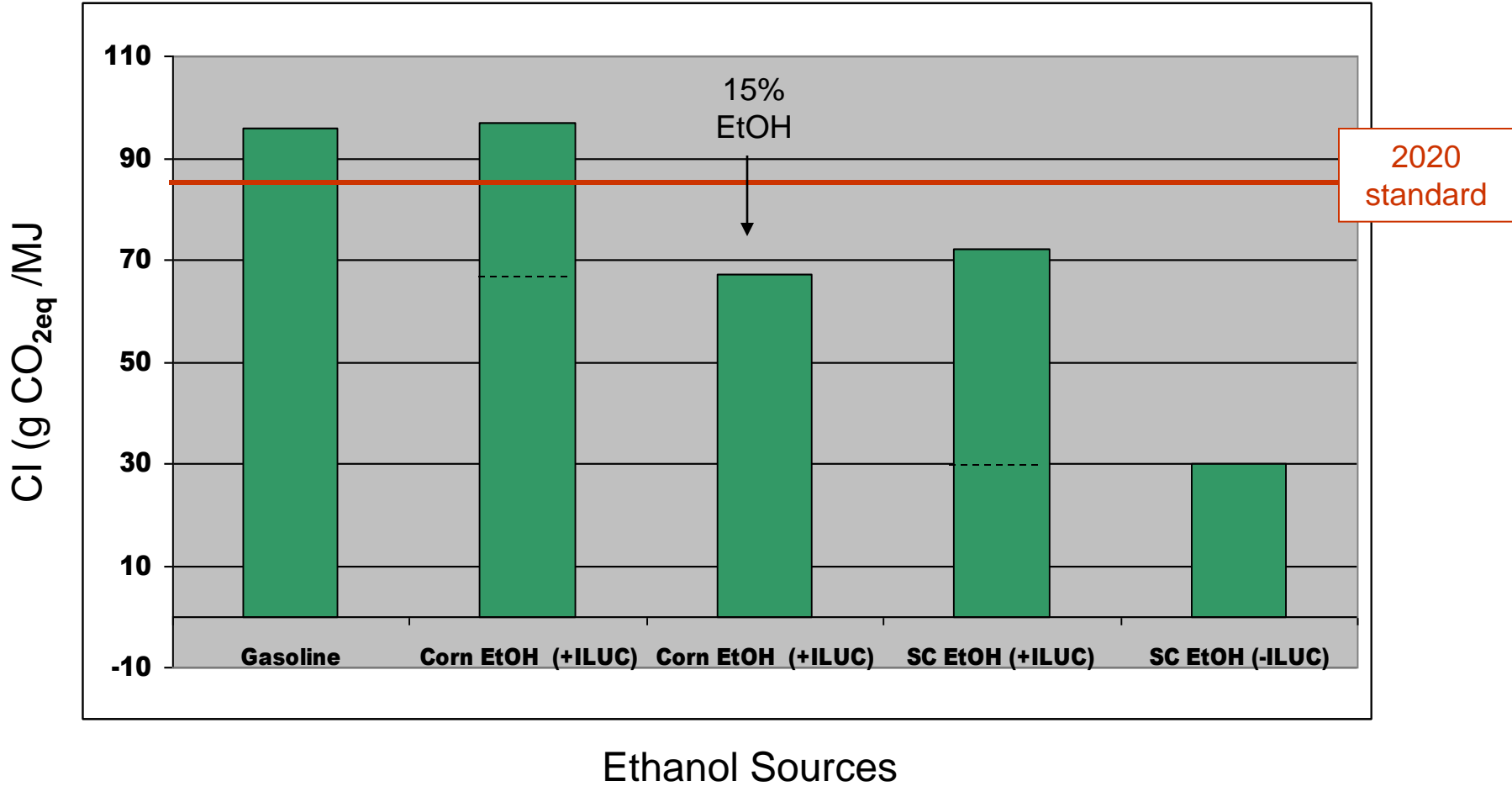
# LCFS/Life Cycle Analysis of Alternative Fuels (g CO<sub>2eq</sub> /MJ)

| Source               | Gasoline |    | Corn Ethanol           |      |
|----------------------|----------|----|------------------------|------|
| Feed stock           | Oil well | 7  | Corn field             | 36   |
| Transport            |          | 1  |                        | 2    |
| Refining             |          | 14 |                        | 38   |
| Distribution         |          | 1  | Blend with gasoline    | 3    |
| Combustion (Offsets) |          | 73 |                        | 0    |
| Co-products          |          |    | DDGS to cattle         | (12) |
| ILUC ←               |          |    | Loss of forest/pasture | 30   |
| Total                |          | 96 |                        | 97   |

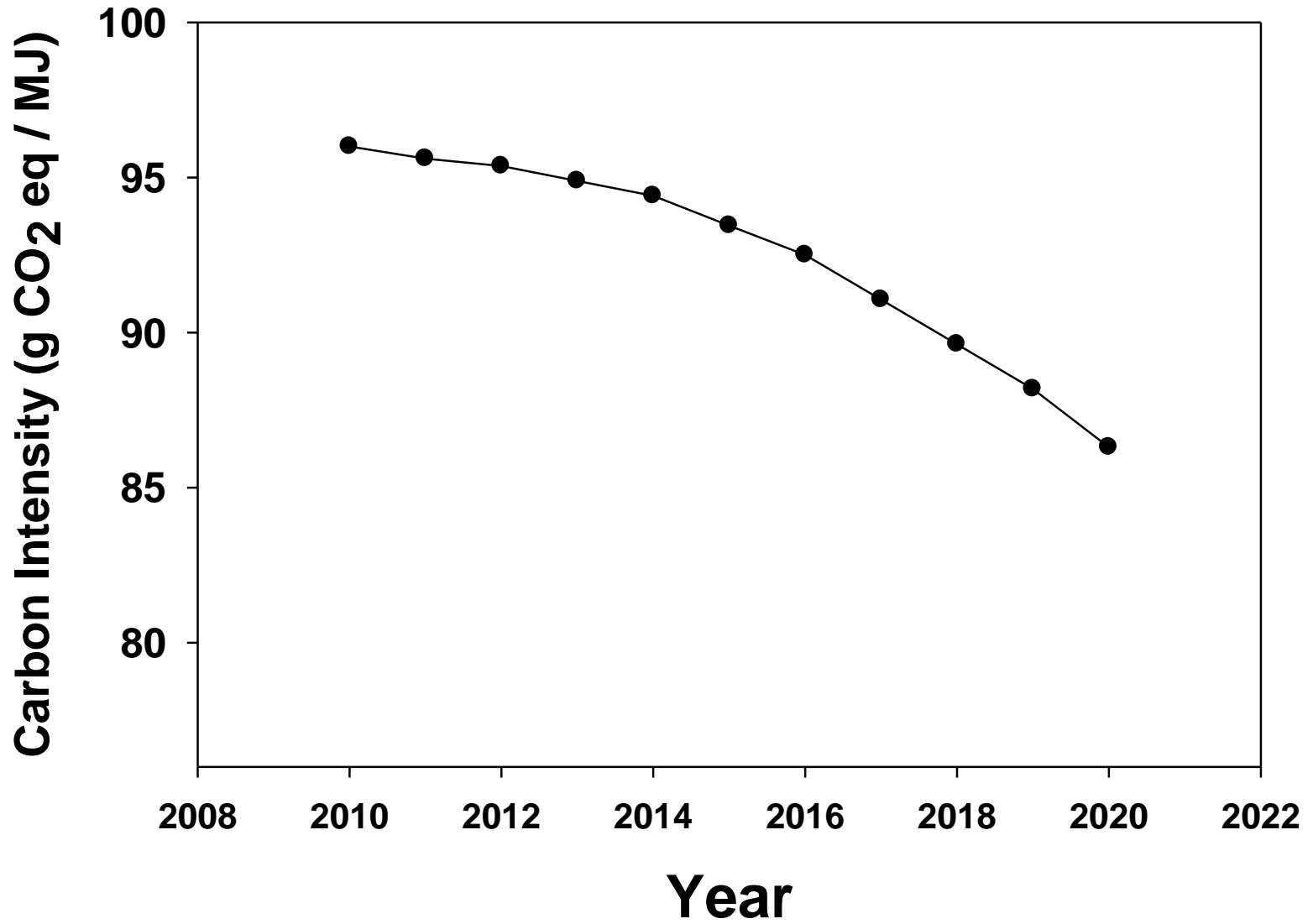
Figure V.D.2-1  
Max E10 Ethanol Consumption Compared to RFS2 Requirements<sup>212</sup>



# Comparison of Carbon Intensity of Corn and Sugar Cane Ethanol with and without indirect Land Use Intensity



# LCFS Implementation Schedule, CARB



# California's LCFS

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- **Policy considerations**

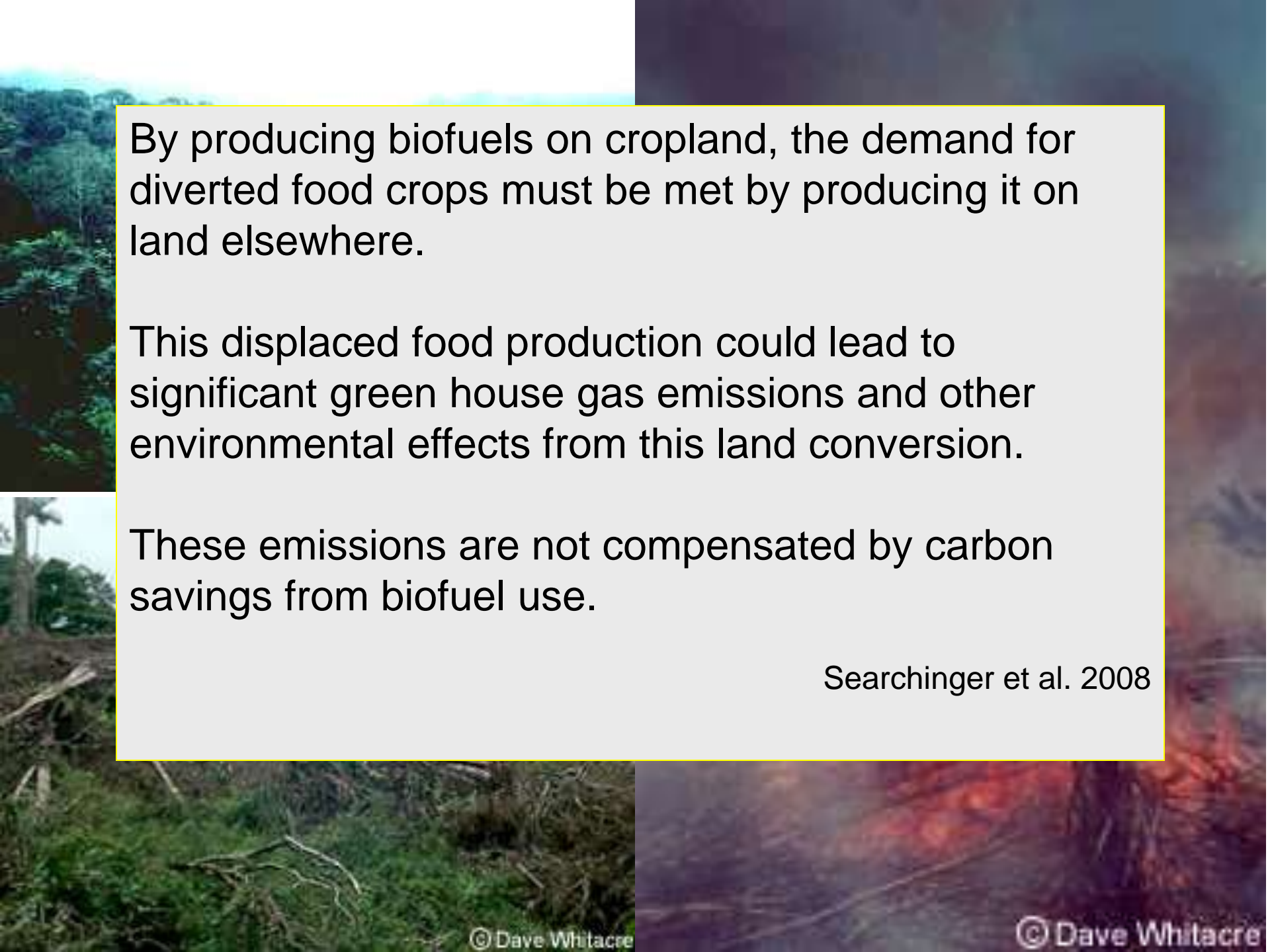


“...the fuel vs. nature question is vexed because the agriculture vs. nature question is vexed...the 1<sup>st</sup> difficulty...is the question of when and where we can develop ... rationales for nature preservation that transcend human-use values. ... The 2<sup>nd</sup> difficulty arises culturally...Americans tend to see nature and agriculture (*and forestry?*) in diametrical opposition.”

Agricultural biofuels: Two ethical issues.\_P. Thompson, 2008.

# Swidden agriculture in the tropics





By producing biofuels on cropland, the demand for diverted food crops must be met by producing it on land elsewhere.

This displaced food production could lead to significant green house gas emissions and other environmental effects from this land conversion.

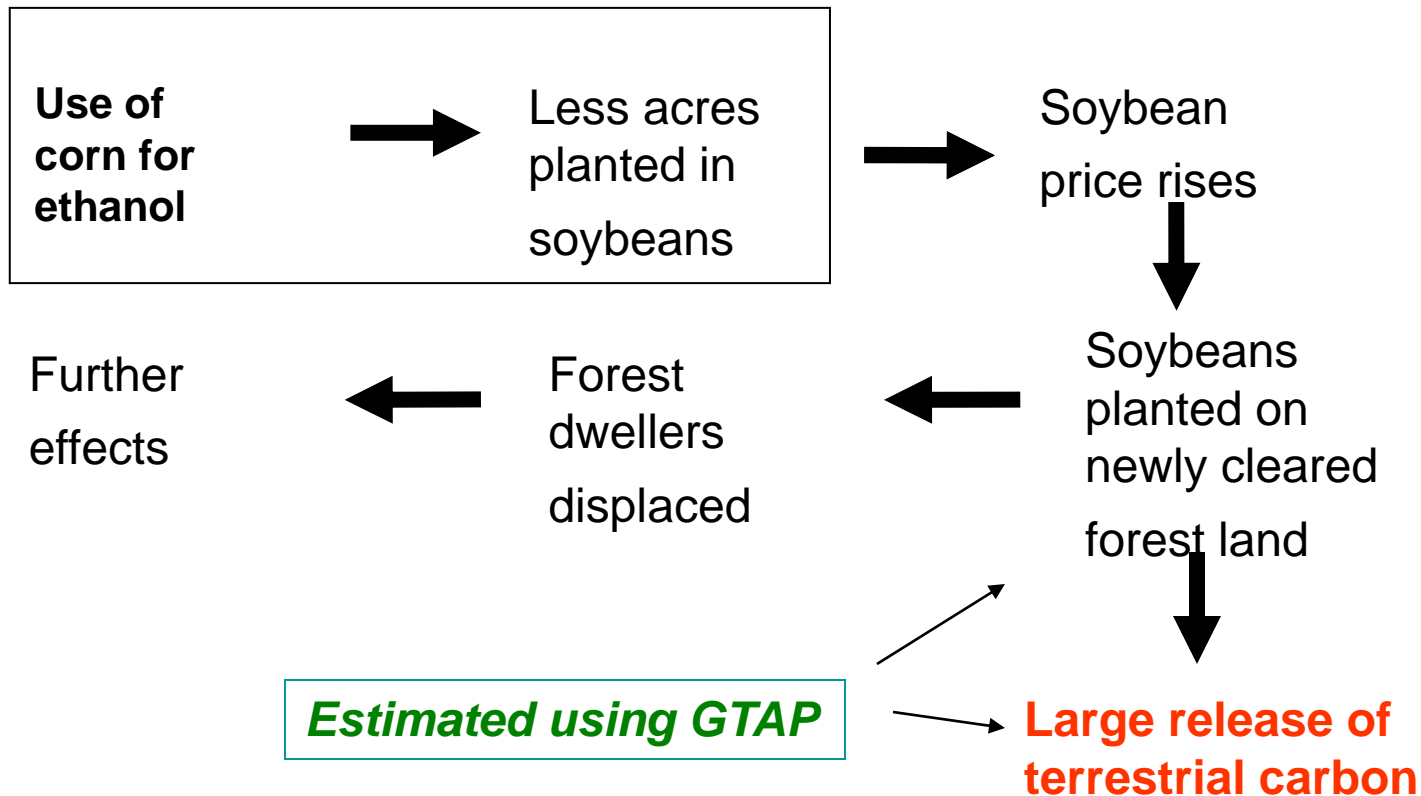
These emissions are not compensated by carbon savings from biofuel use.

Searchinger et al. 2008

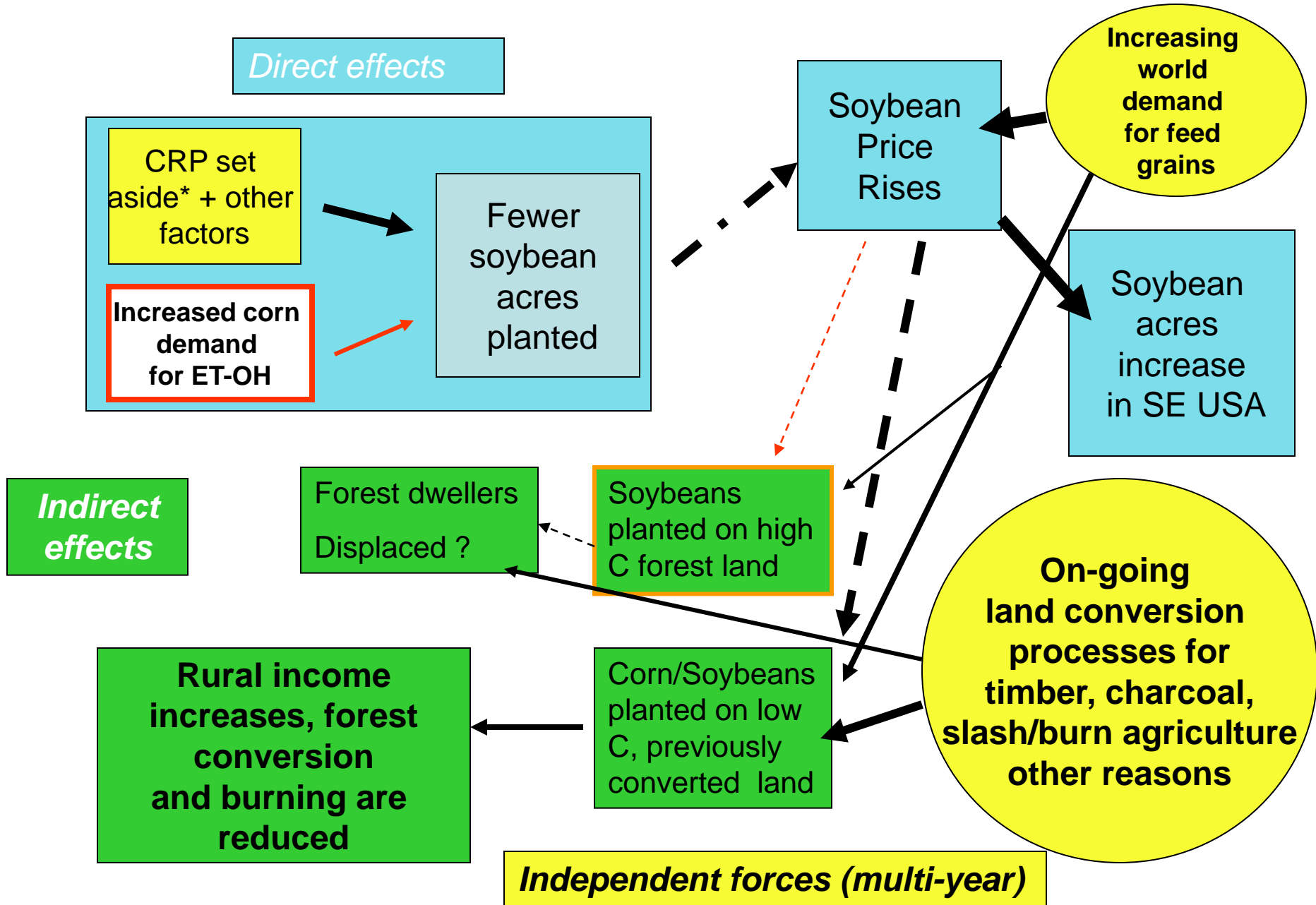
# Market Mediated Effects:

- **Market-mediated or Indirect Land Use Change (iLUC):**

## Direct effects



# Market Mediated Effects of Corn Ethanol Use on Indirect Land Use Change



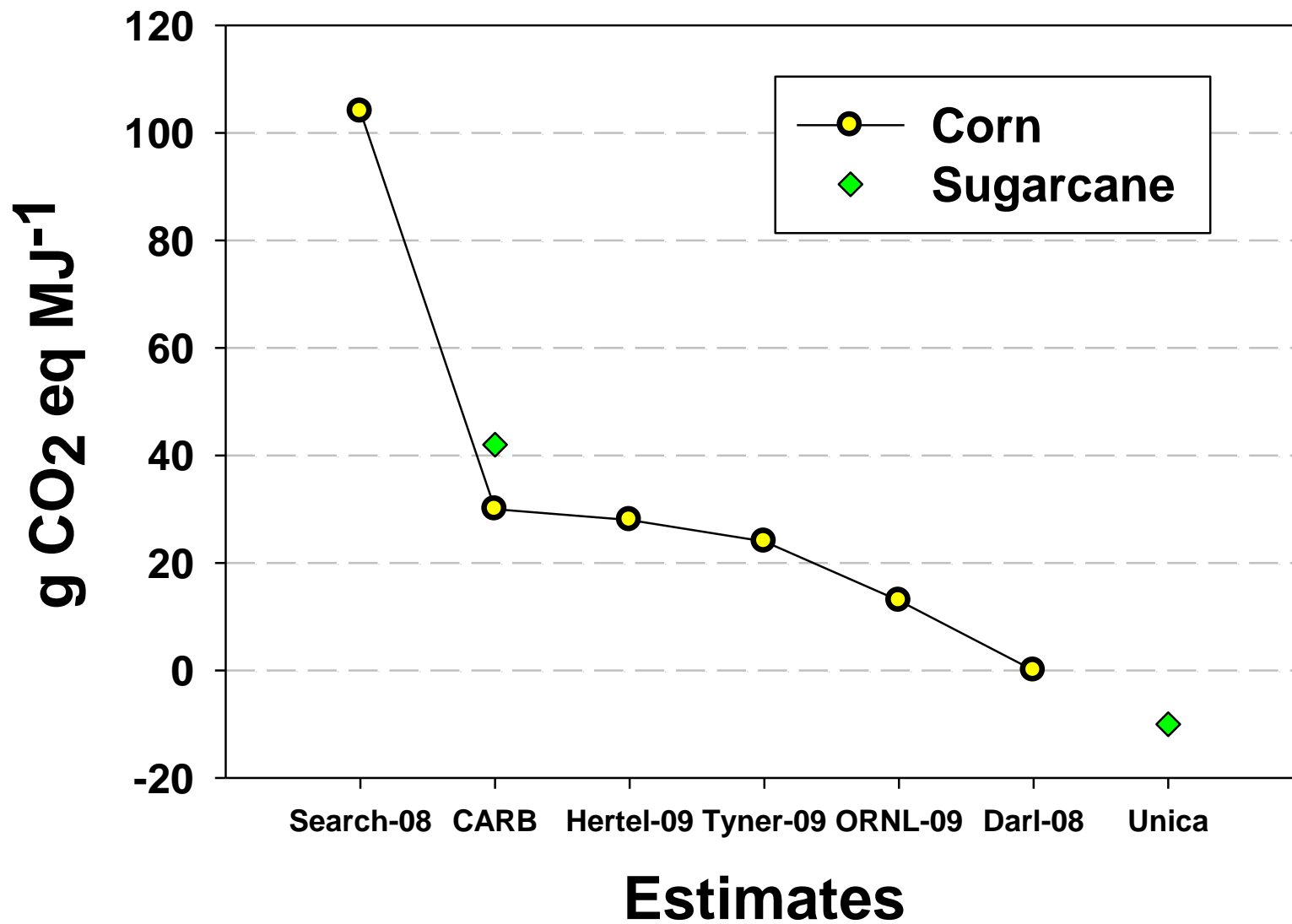


Mahogany logs seized by Brazilian authorities are seen in this 2002 photo: Illegal logging is responsible for much deforestation in the Amazon. Der Spiegel, 2009

## Oak Ridge National Lab GTAP-based Simulations: Oladosu and Kline, (2009)

- Export/production data show little or no indirect impact from corn grain use for ethanol
- Trade and export fluctuations are similar to previous periods prior to ethanol development
- Currently, nearly 9 bgal/yr ethanol in US = 2/3 of EISA requirement
- There is less US cropland planted in 2009 than in 2001 (-1%)
- All this means that there is little evidence to suggest that ethanol has forced crops out of production in ways needed to drive the “indirect” effects modeled.

## Diverse estimates for ILUC values for corn ethanol and sugarcane ethanol



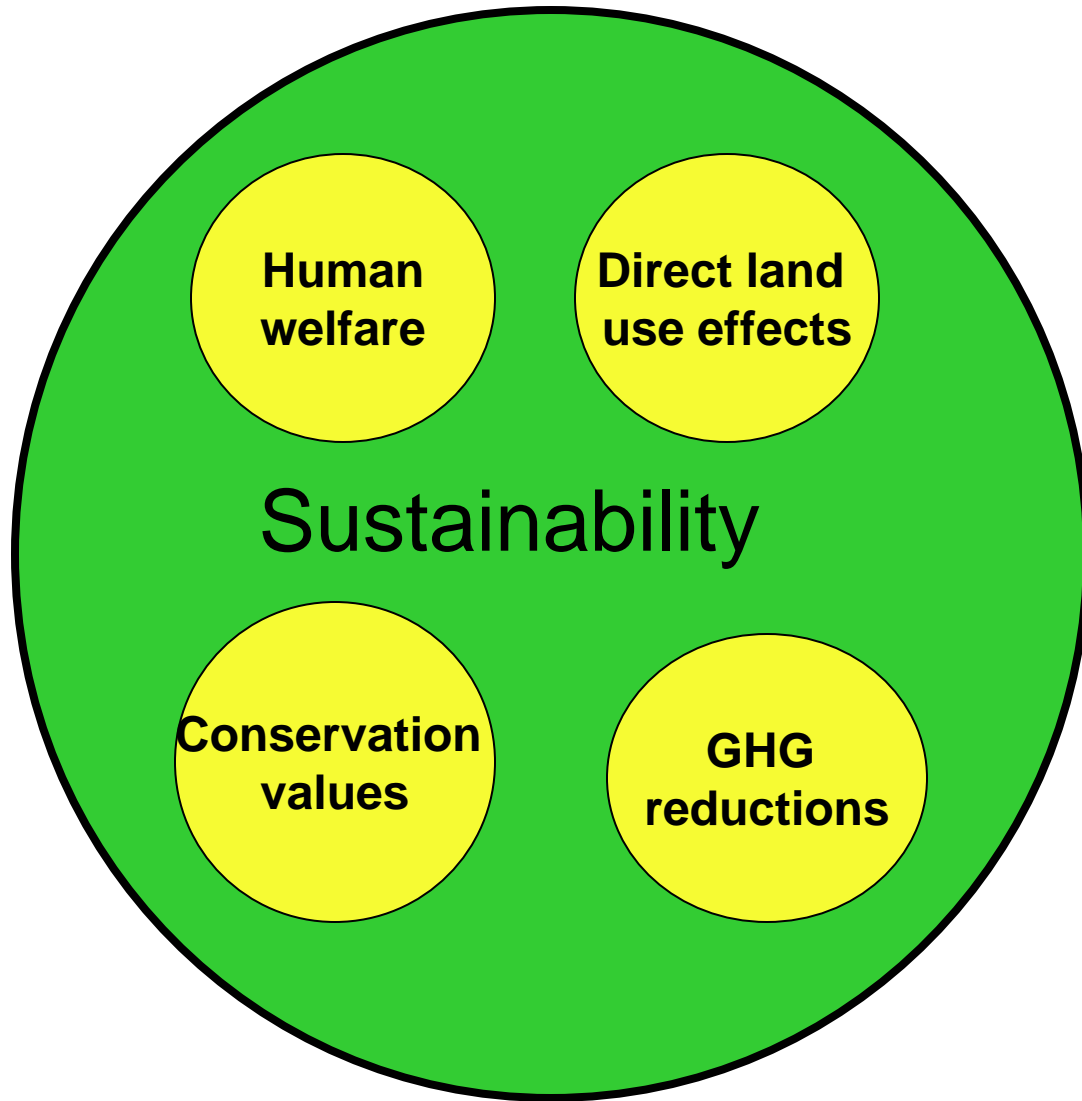


## Multiple reasons for biofuels- **AB 32 and the LCFS are not just GHG policies**

Alternative fuels from biomass will:

1. Diversify the supply of transportation fuels, provide more domestic sources and improve national security
2. Increase rural employment and wealth,
3. Reduce expensive crop surpluses
4. Distribute fuel refining
5. **Benefit the environment by reducing petroleum use for transportation and GHG increases**
6. Other benefits

*(DOE, USDA, other sources-2004)*



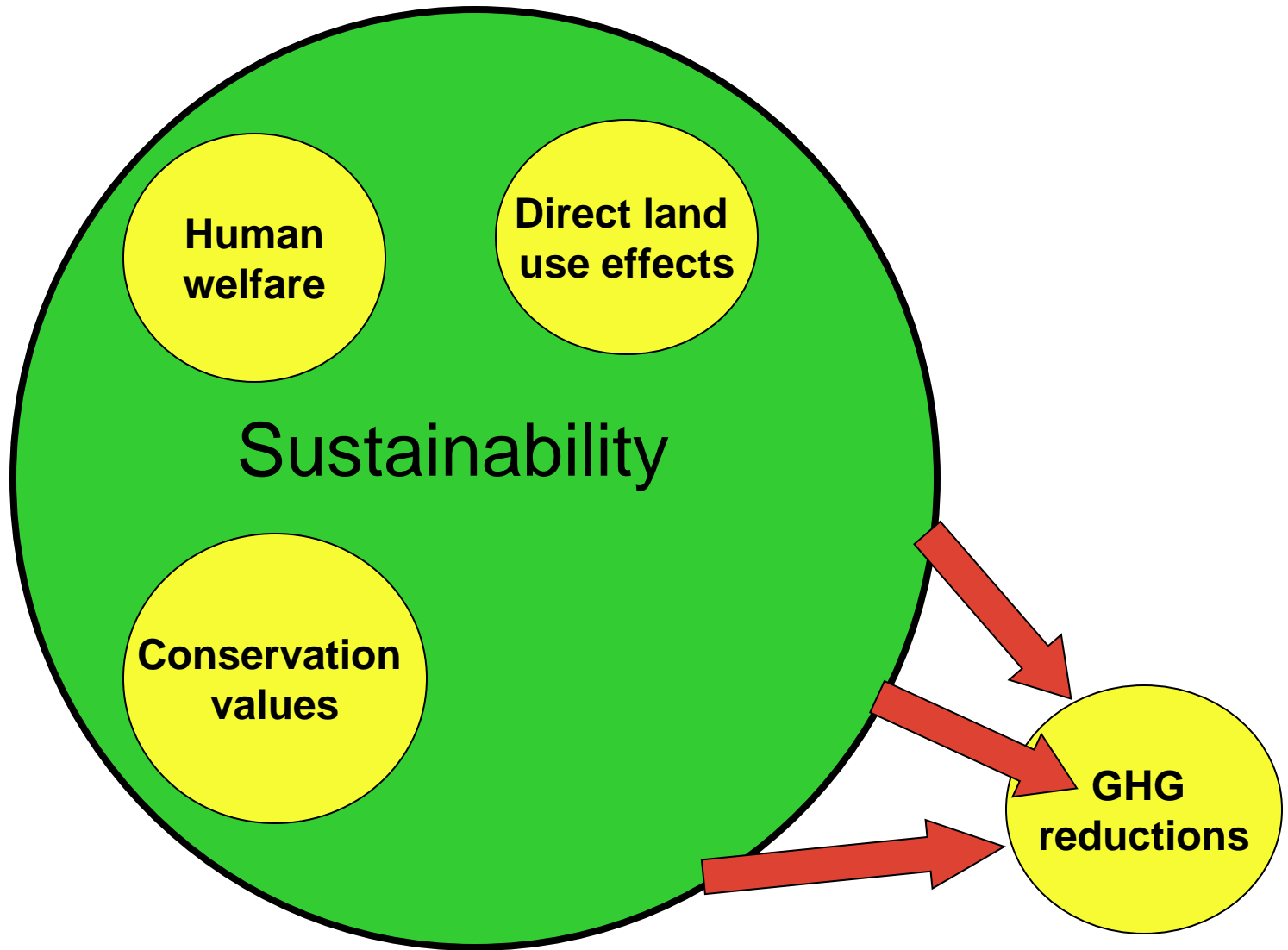
**Human  
welfare**

**Direct land  
use effects**

**Sustainability**

**Conservation  
values**

**GHG  
reductions**



The need for tradeoffs:

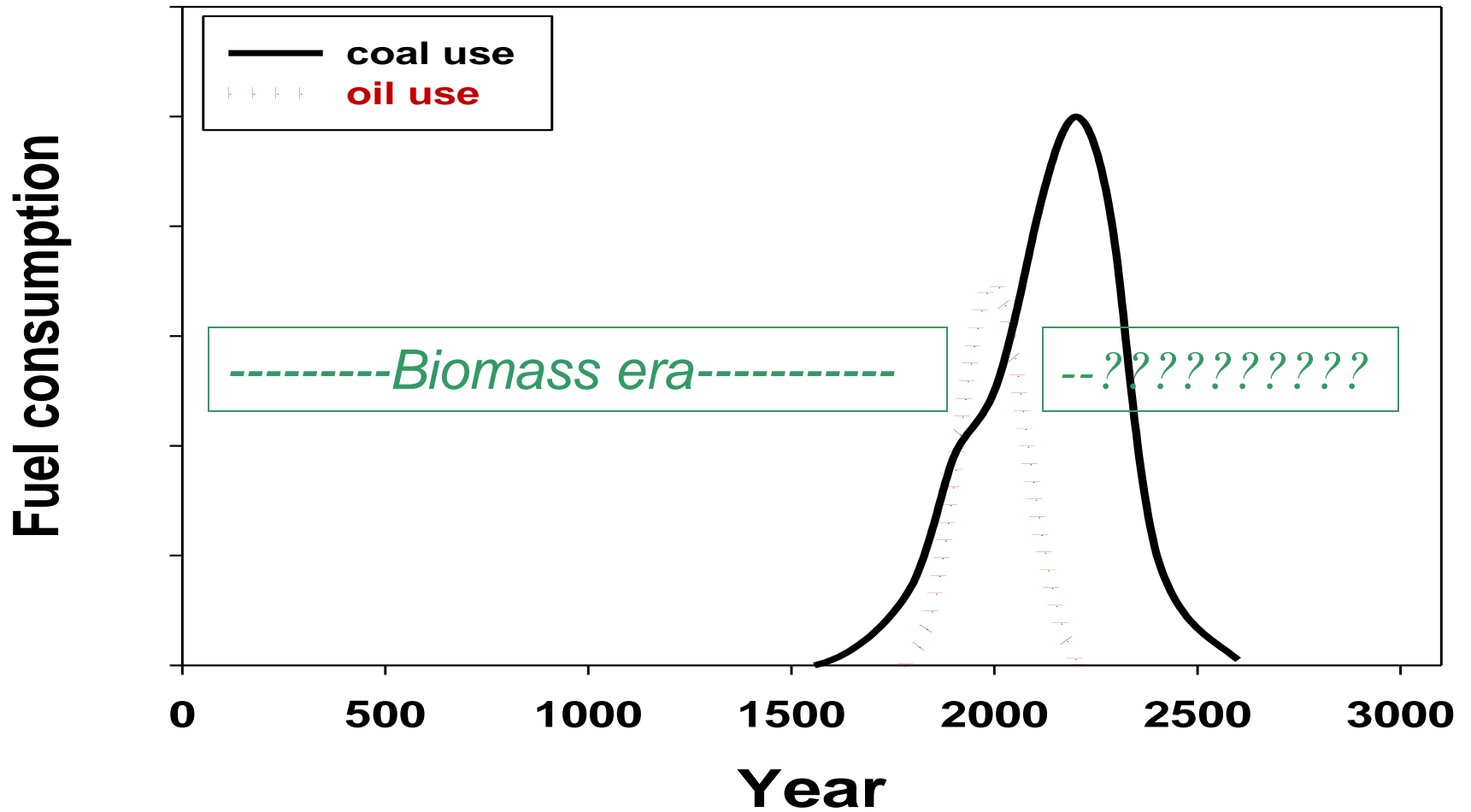
“While air quality and climate change emissions are closely related, **there are certain cases in which technology involves tradeoffs**: a certain technology may bring about a decrease in one pollutant at the cost of an increase in another. These relationships are a strong argument for coordinated emissions reduction strategies.”

***CALSTART 2009***

# California's LCFS

- The Low Carbon Fuel Standard requires reducing the Carbon Intensity of transportation fuels in CA.
- It emphasizes the use of waste resources and cellulosic feed stocks, and discourages the use of purpose grown crops, especially corn.
- It is uncertain that alternative low CI biofuels will be available in the timeframe required by the law.
- Imported biofuels may be necessary.





**Expected duration of fossil fuels (0 to 3000 AD)**

(redrawn from P.E. Hodgson, 1999)