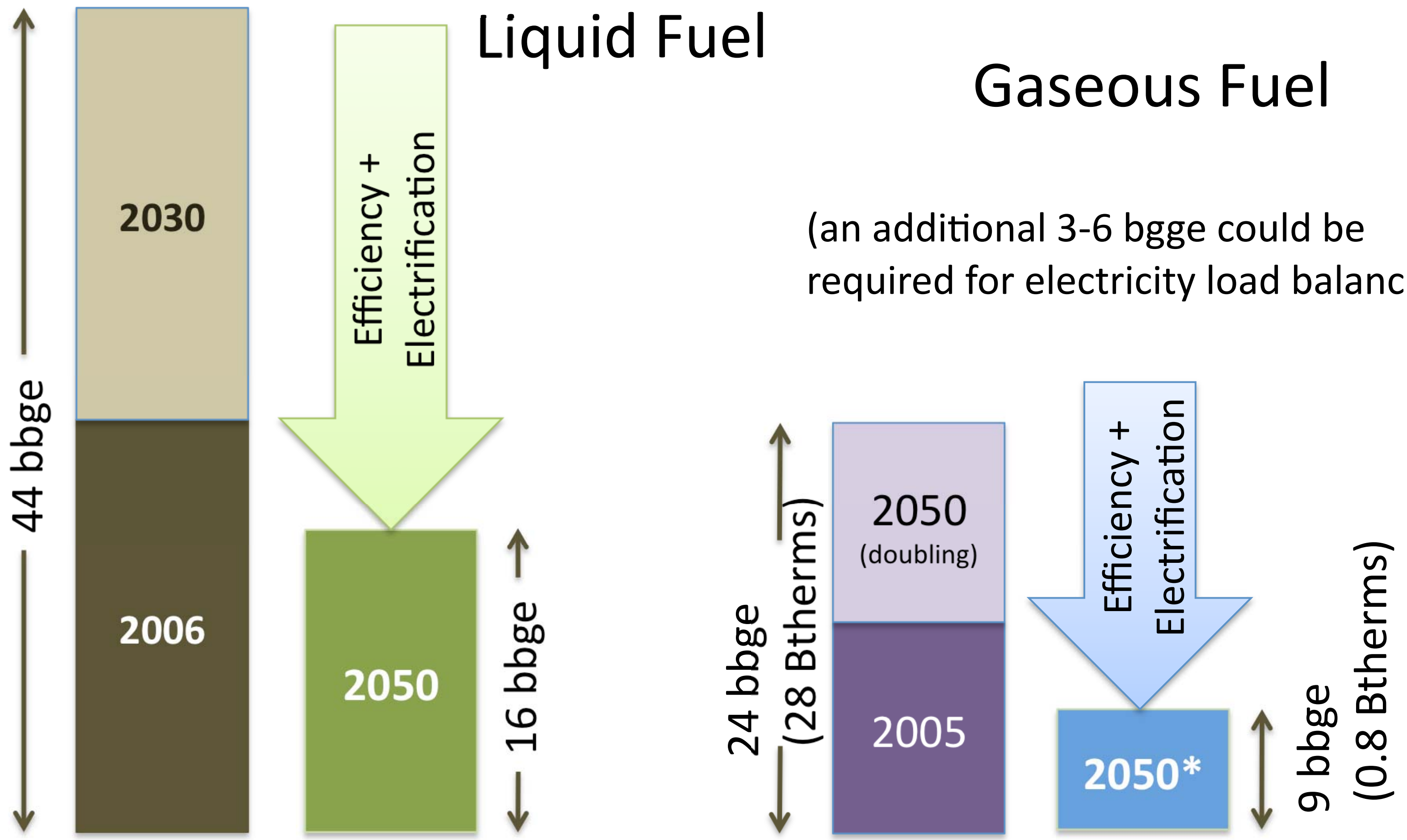
California Biofuels in 2050

Heather Youngs
Chris Somerville
Chris Field

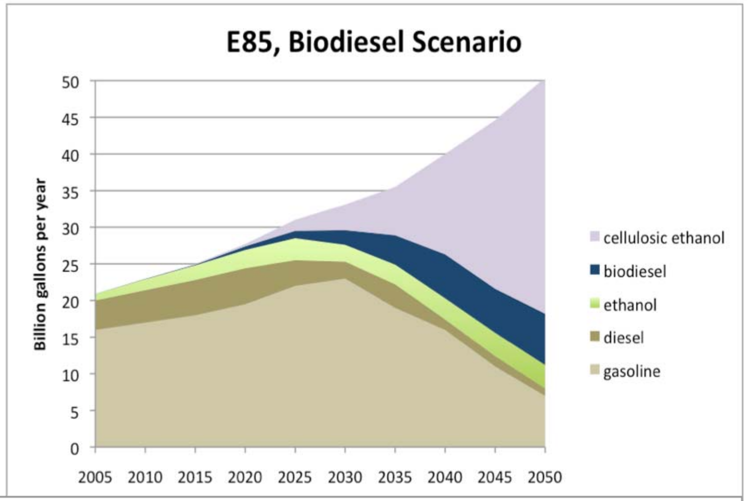
Energy Biosciences Institute

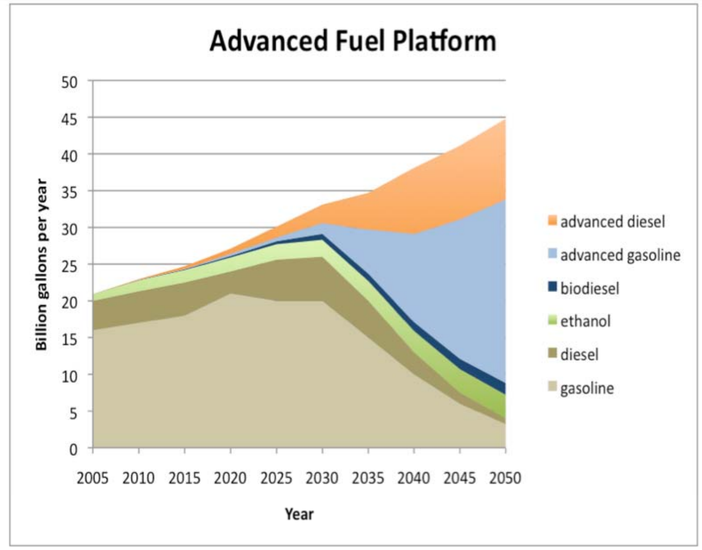
GCEP

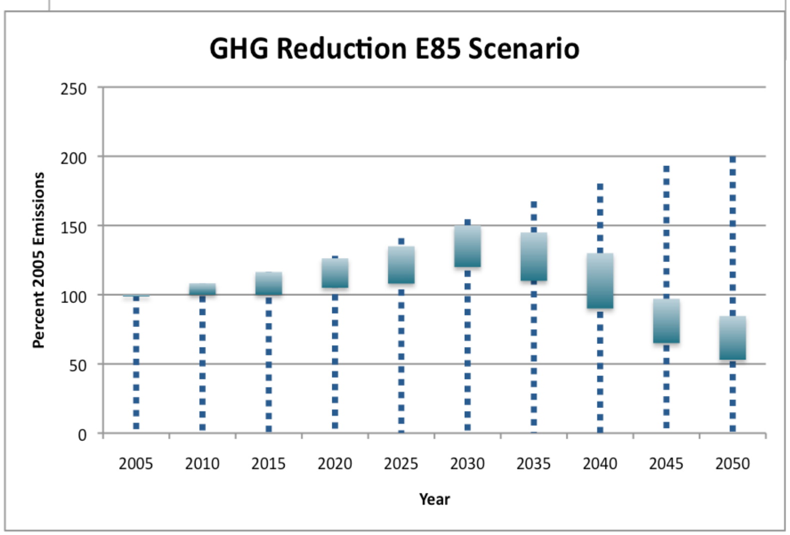
California Fuel Demand High Efficiency/Electrification: 25 bgge

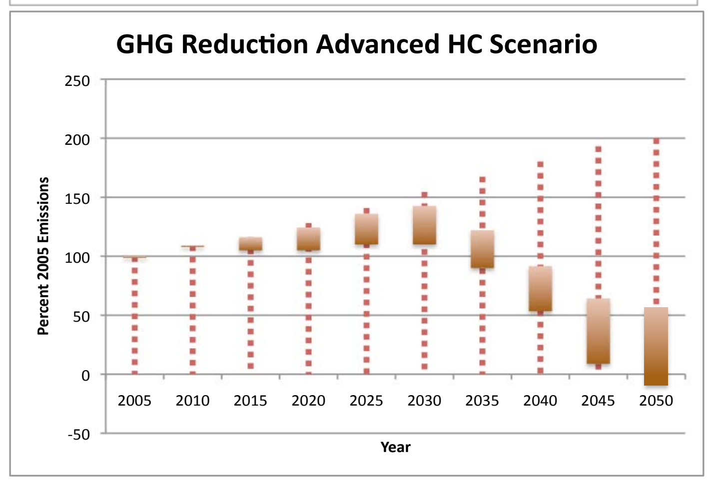


Need deep replacement of fuels to meet the GHG Goals





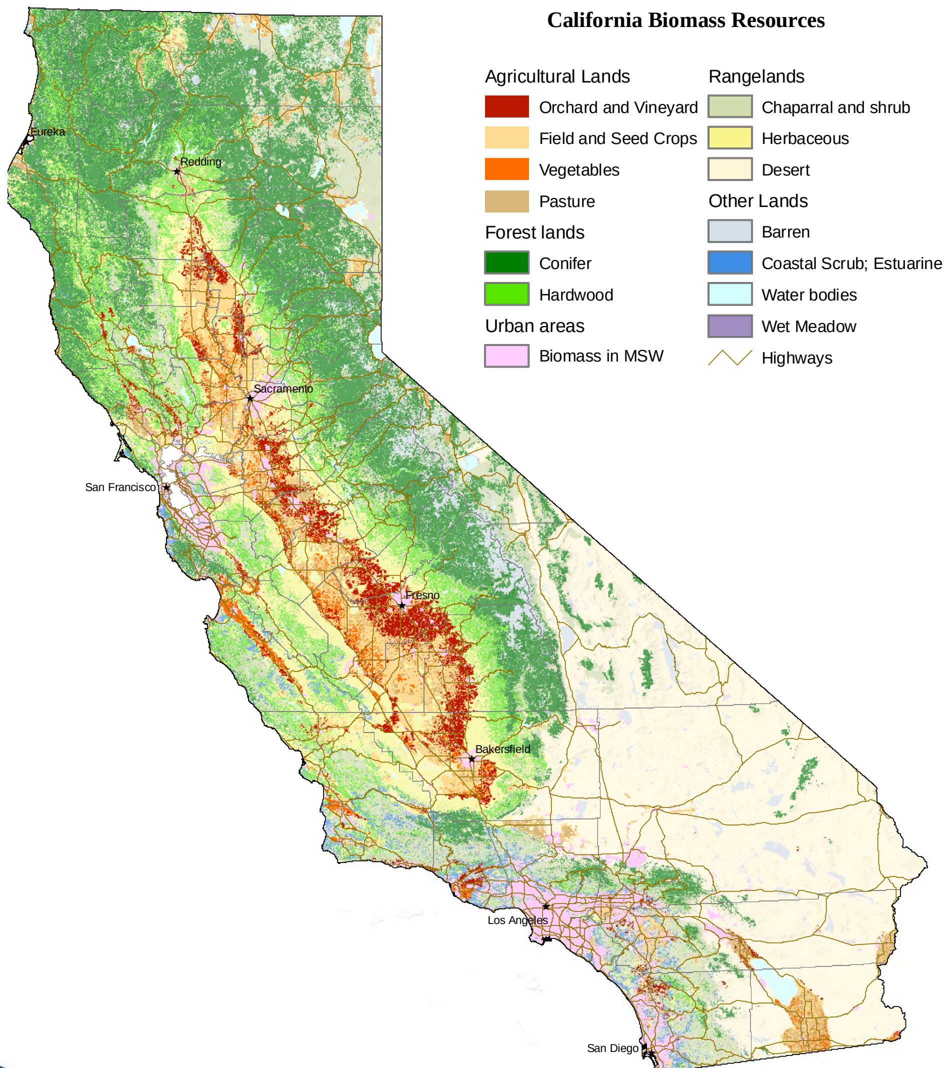




Assumptions behind decarbonizing fuel

- Decarbonizing fuel could be resource limited
  - Policy goal is 75% in-state production by 2050
  - 60% available biomass residues are used (ag, forest, MSW)
  - Limited energy crop production to 50% of abandoned ag land and 50% unused timber land
  - Imported biofuels are limited to equal the in-state supply

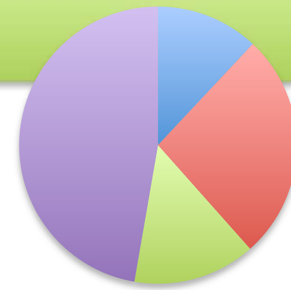
California Biomass



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

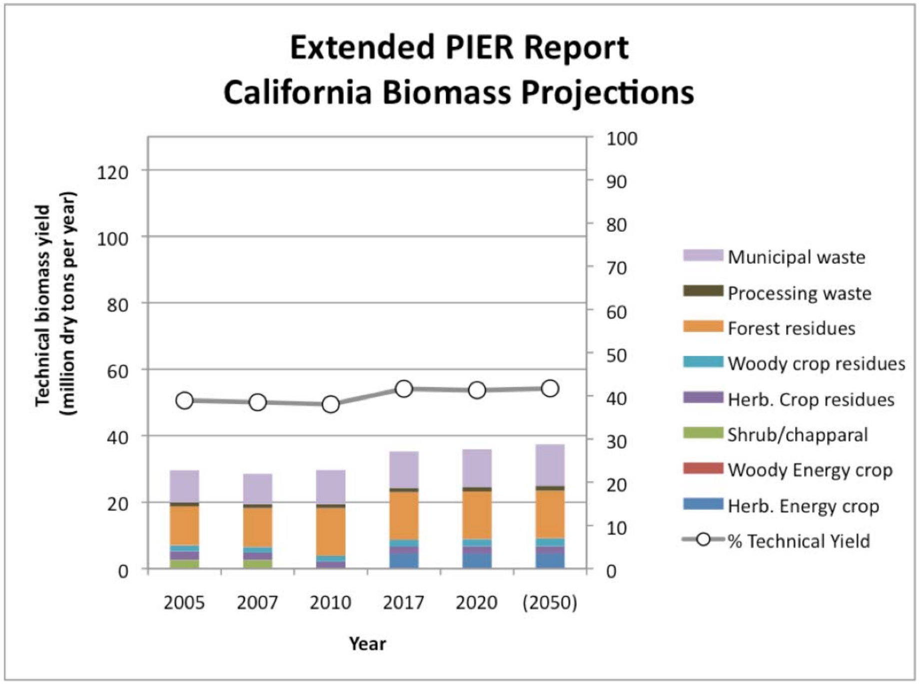
CA Waste Biomass

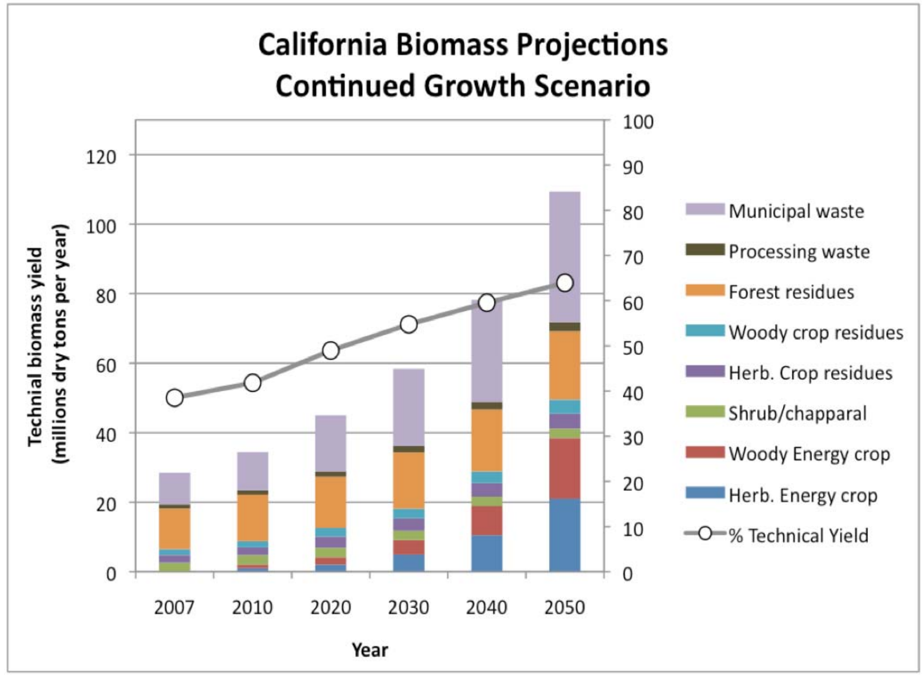
Gross production 100 mtons



Lignocellulosic feedstocks	
Wastes	
Agriculture	nut and fruit hulls
	vineyard trimmings
	corn stalks and straw
	thinnings
	food processing waste
Forestry	forest thinnings
	sawdust
	mill waste
Communities	tree trimmings
	grass clippings
	paper waste
	wood construction waste
Energy crops	
Perennial grasses	miscanthus
	switchgrass
Trees	farmed poplar
	pine
	eucalyptus
	willow coppice
Other fibrous crops	sisal agave
	sorghum

California Biomass Technical Availability Scenarios (no economics)





Scenario Differences

- Improved residue recovery (up to 62% from 40%
- Increase in MSW production to correlate with population growth
- Growth of additional energy crops (woody and herbaceous) on abandoned ag. and non-productive forest lands

Fuel Yield

3-12 billion gallons gasoline equivalent

40-100 mtons = 3.2-8 bgge residues
5-40 mtons = 0.5-3.2 bgge energy crops

Detail on Productivity and Yields

Table 5. Projected biomass yield in 2050 (million dry tons per year).

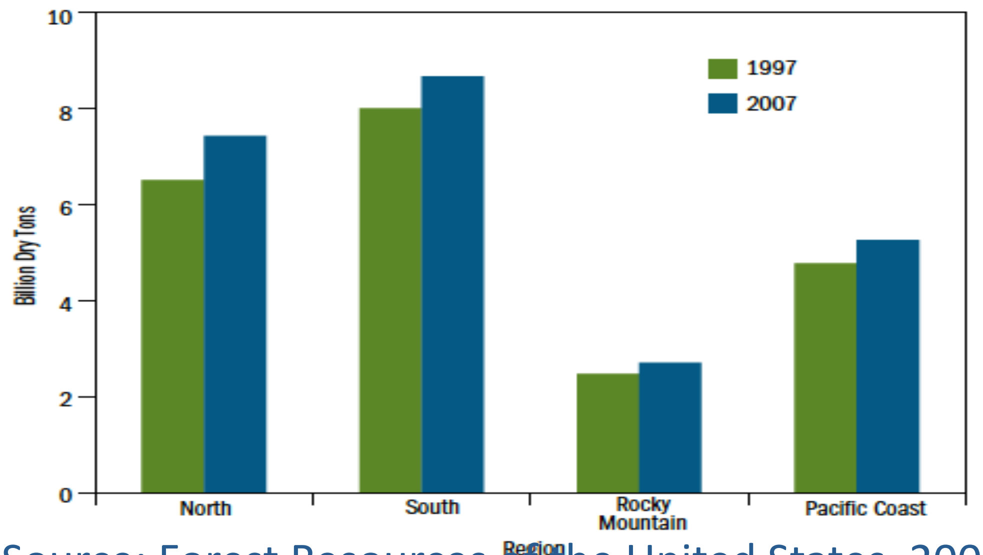
Biomass Source	Scenario A Productivity (Gross Biomass)	Scenario A Technically Recoverable Yield	Scenario A Percent Recovery	Scenario B Productivity (Gross Biomass)	Scenario B Technically Recoverable Yield	Scenario B Percent Recovery
Primary						
Herb. Energy Crop	5	4.5	90	30	21	70
Woody Energy Crop	0	0	0	25	17.5	85
Shrub/chaparral*	0	0	0	4.9	2.7	55
Secondary						
Herb. crop residue	6.5	2.1	33	8.6	4.3	50
Woody crop residue	3.5	2.4	70	5.4	4.0	75
Forest residue	26.8	14.3	53	39.2	19.6	50
Tertiary						
Processing waste	1.8	1.4	80	3.3	2.6	80
Animal waste	15.8	5.5	35	15.0	9.0	60
Municipal waste	41.7	10.4	25	53.7	37.6	70
Total	**101.1**	**40.6**	**40**	**185.1**	**118.4**	**64**

*Previous estimates for shrub and chaparral in 2007 was 4.9 million dry tons per year with a 55% recovery[1,4]

Jenkins BM (2005) Biomass in California: Challenges, opportunities, and potentials for sustainable development. In PIER Collaborative Report California Biomass Collaborative, California Energy Commission.; Jenkins BM (2006) A preliminary roadmap for the development of biomass in California." In PIER Collaborative Report CEC-500-2006-095-D: California Biomass Collaborative, California Energy Commission.

Net biomass stocks are increasing

Live tree biomass

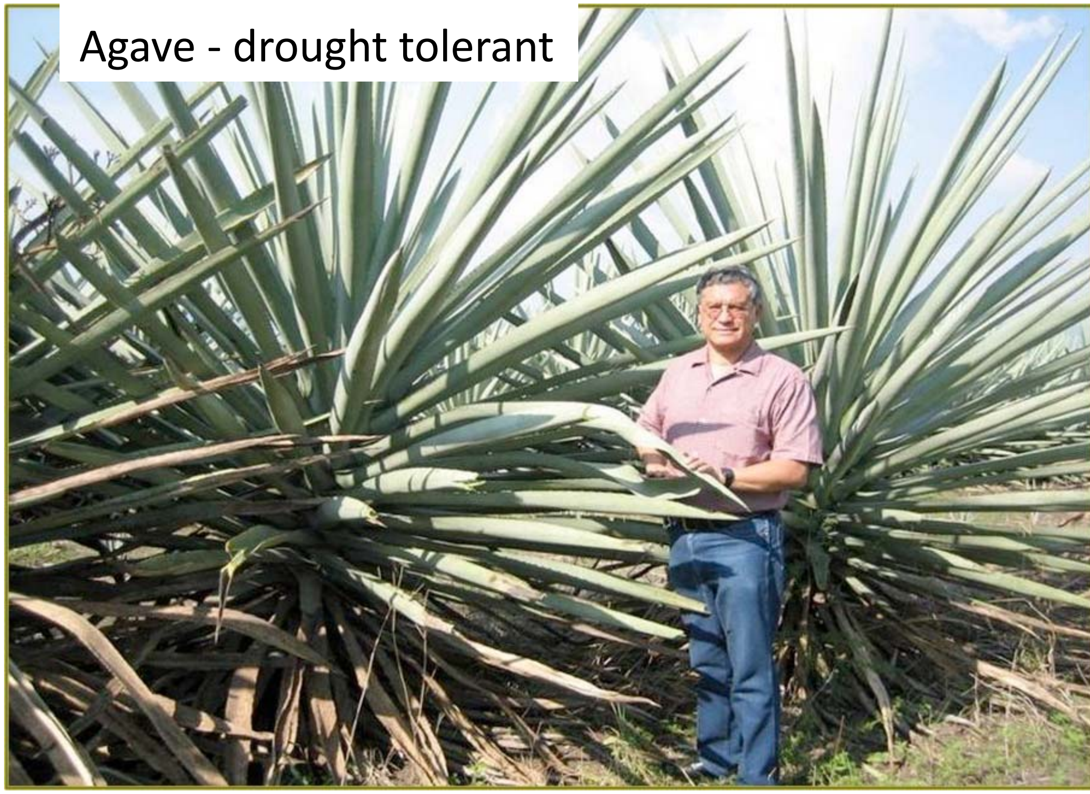


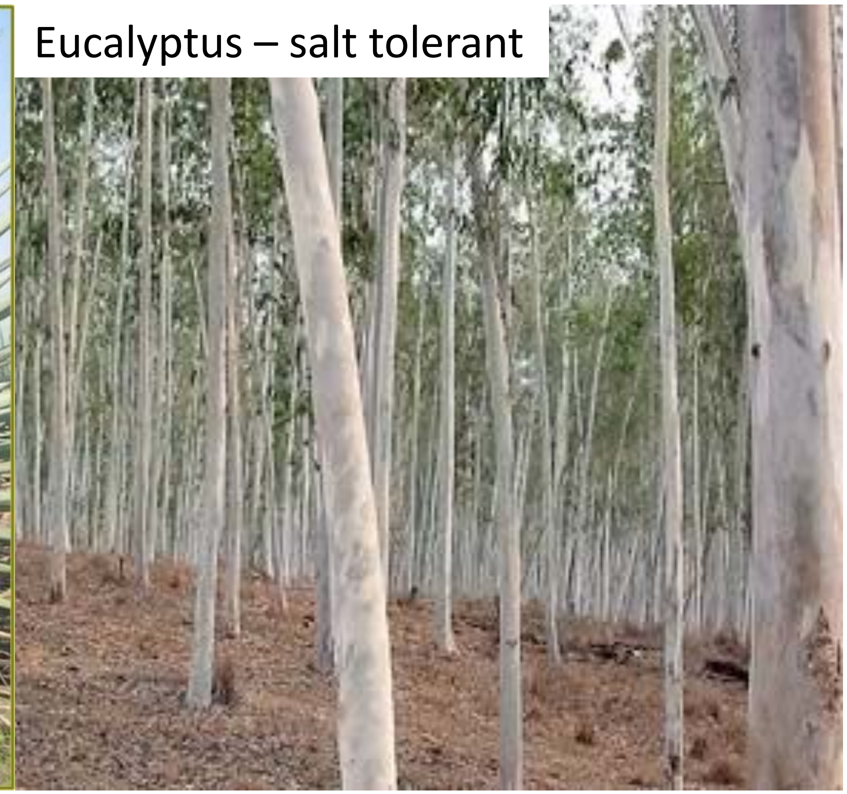
- Forest biomass in the U.S. and Canada increased 10% from 1997 to 2007. We harvest 1% of total forest biomass, <60% annual growth

Source: Forest Resources of the United States, 2007 GTR_WO78

- Agricultural biomass per acre has increased with development of high density cropping varieties
- Input use has declined. Environmental awareness, rising fertilizer cost, no-till, better management, more robust varieties (trees and crops)

Yields



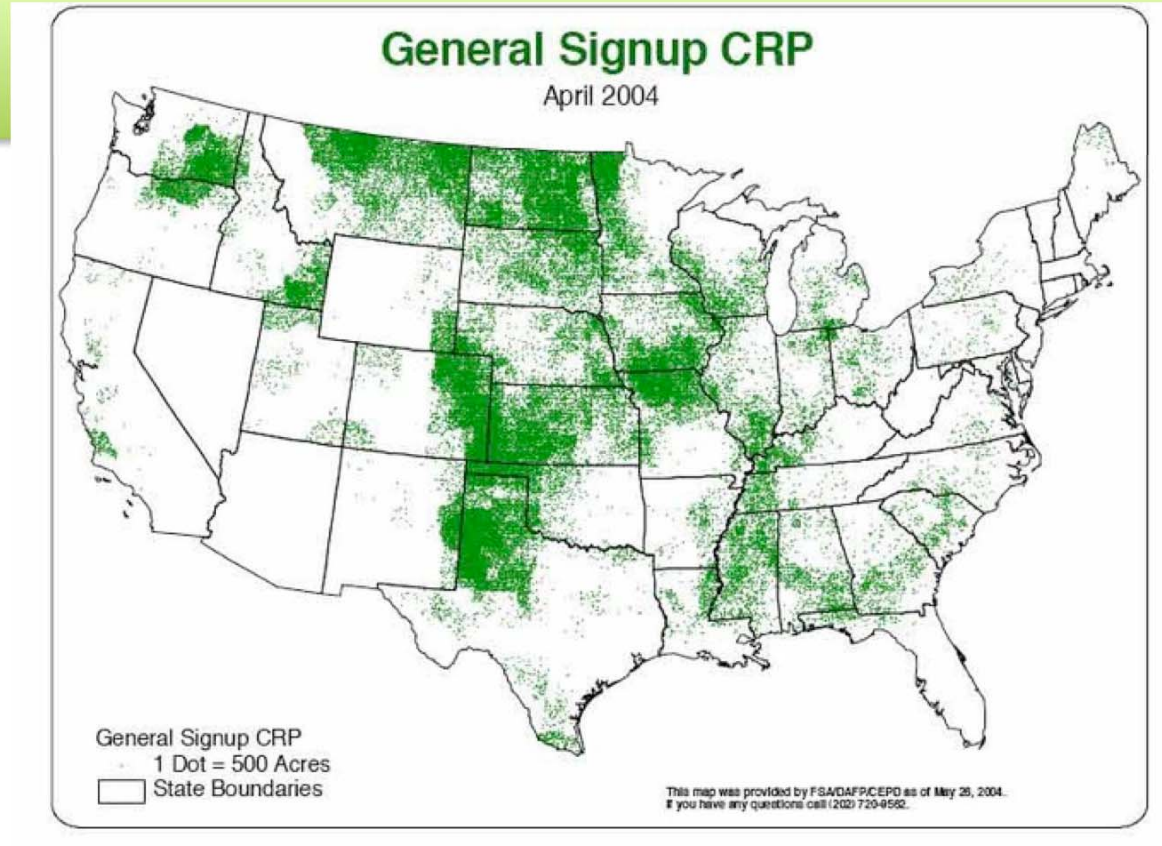


10-34 tonnes/ha/yr = 4.5-15 tons/acre/yr
5 year life cycle, 10-30 inches rain/yr

6-22 tonnes/ha/yr in California
Can coppice or leave standing for additional growth 30-100 inches of rain

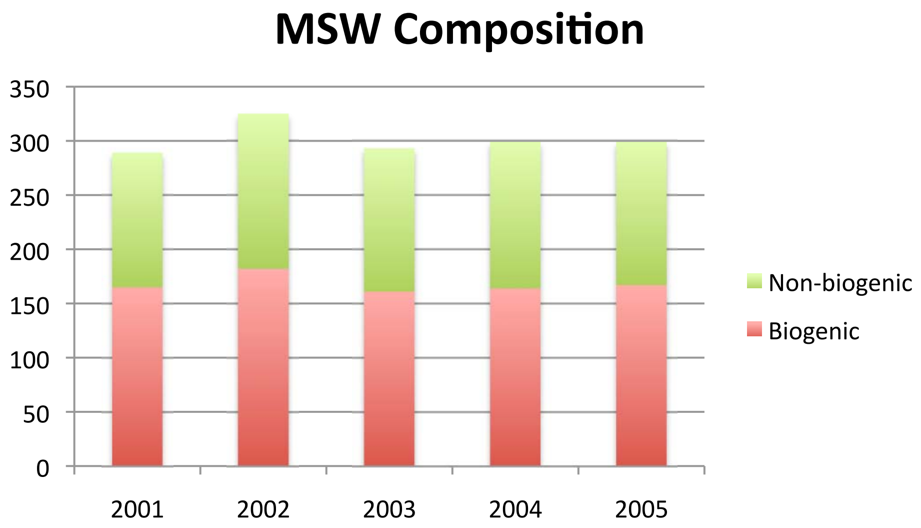
1 ha = 2.47 acre, 1 tonne = 1.12 tons

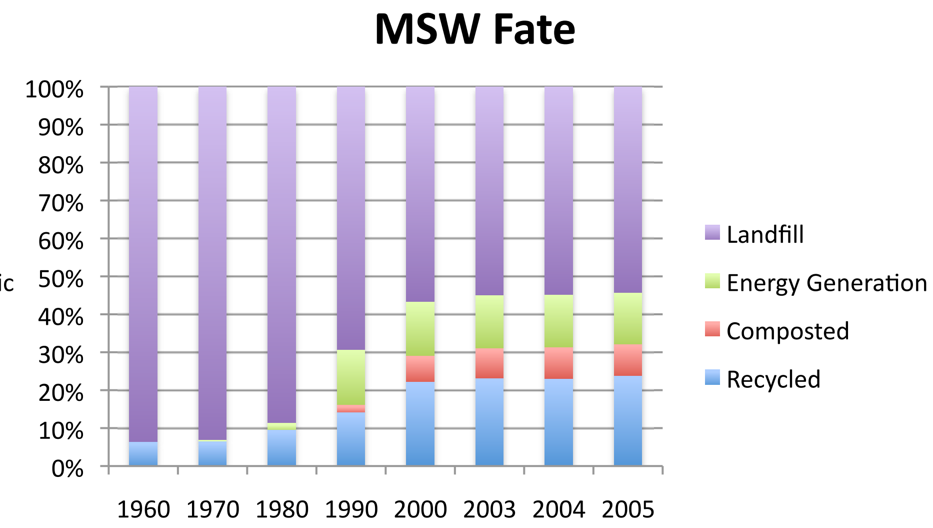
Land Availability



- 8.9 million acres CRP
- 4.5-8 million acres timberland no longer in production
- 9 million acres grazing land could be combined with forestry

Trends in MSW use

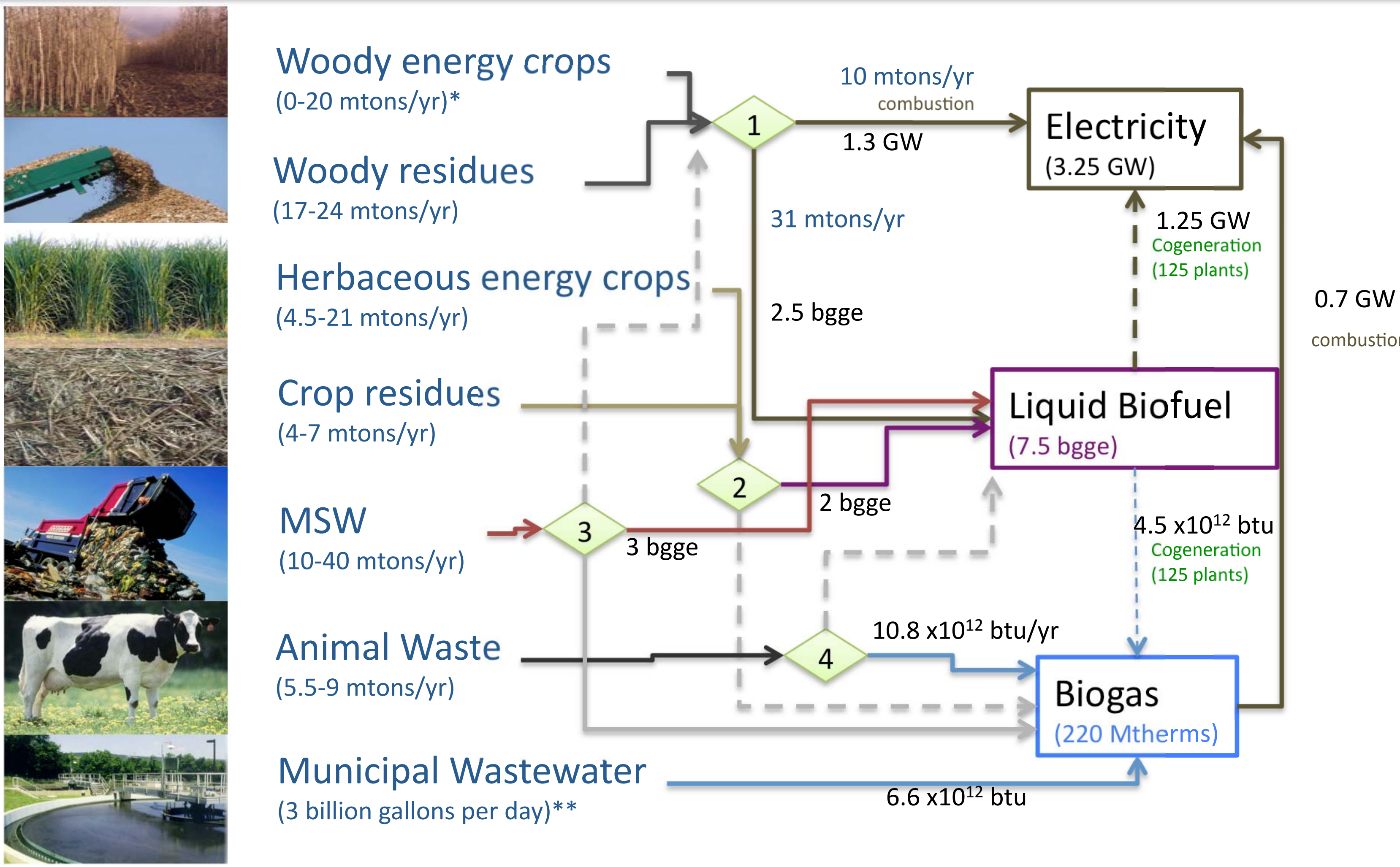




MSW is 40% of our residue biomass

Recycling and Composting can be increased but there will still be residuals (e.g. Taylor biomass – wood recycling (construction waste, etc.) – 40% of recovered material is unusable – recently completed 5 year permitting process to install a biomass gasifier unit to generate electricity)

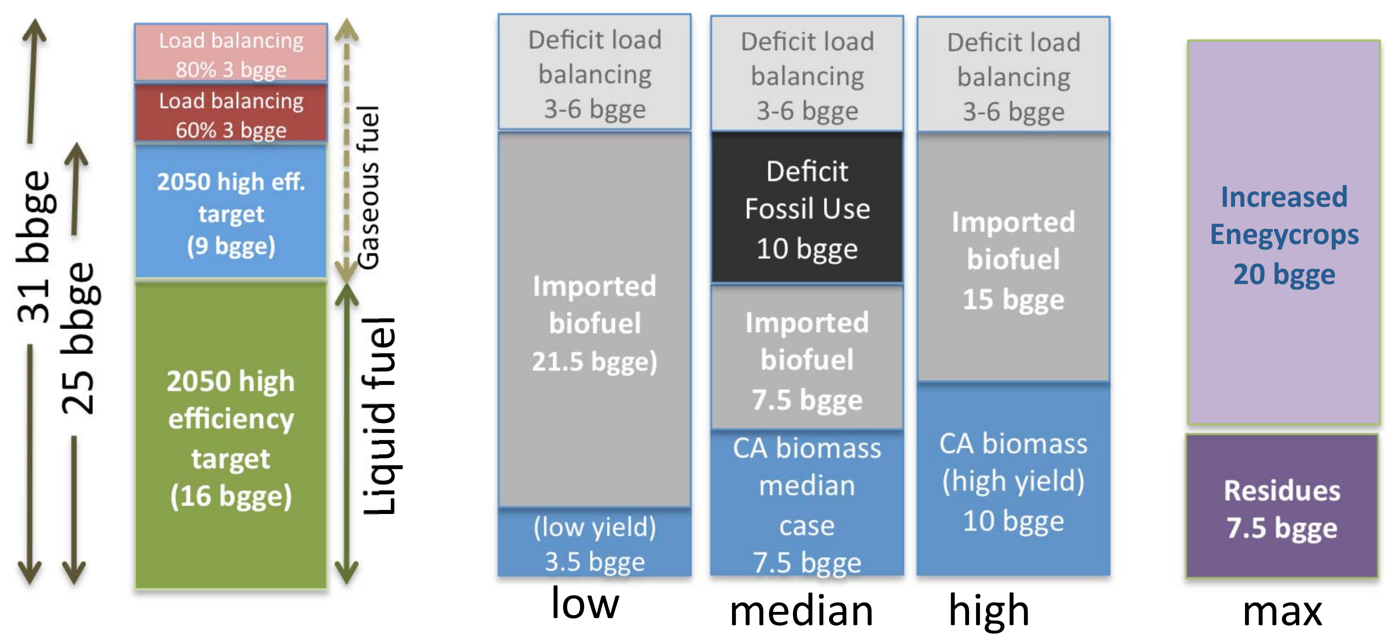
Decisions regarding biomass use



*technical recoverable yield (50-80% of gross biomass production depending on type)
**not currently used for energy production

How much biofuel can be produced from CA resources?

- Policy goal is 75% in-state production by 2050
- Our projections indicate only 12-45% of high efficiency liquid fuel demand is possible from in-state resources without substantial effects on agriculture
- California will likely have to import biofuels
  (the state imported 73% of refined petroleum products in 2007and 96% of ethanol, mostly from the Midwest and Brazil)
- Limitations on biofuel production and import lead to fossil fuel use and increased GHG emissions



Current Limitations to Bioenergy in California are Inter-related

- Socio-Economics
  - Biomass availability, transportation costs
    - Corn from the midwest!
    - Bioelectricity feedstock cost \$20-\$60/MWh – fixed price contracts at \$45-\$70/MWh
  - Availability of financing
  - Cost of recovering waste biomass
  - Cost of establishing new energy crops
    - Interactions with current agriculture and forestry industry
  - Farmer/Forester adoption of novel energy crops
  - Biogas and pipeline interconnection standards (developer pays)

- Permitting (even in a generally policy-friendly context!)
  - Bluefire goes to Mississippi
  - Fewer than 1% dairy have functioning digestors
  - Biogas and pipeline interconnection standards

- Policy conflicts
  - Definitions of "renewable biomass"
  - Local and state policies for MSW management
  - Landfill gas flaring v. on-site electricity or pipeline injection

Public opinion

- June 2011 - Opposition to Calgren Renewables anaerobic digestor plans.
  - $4.58m from CEC for an AD unit to use local cow manure to generate biogas to replace natural gas at the 55mgy biofuels facility.
- Other communities calling for moratoria on biomass electricity
  - Thurston County WA (one year approved)
  - Protests in Massachusetts and call for three year moratorium

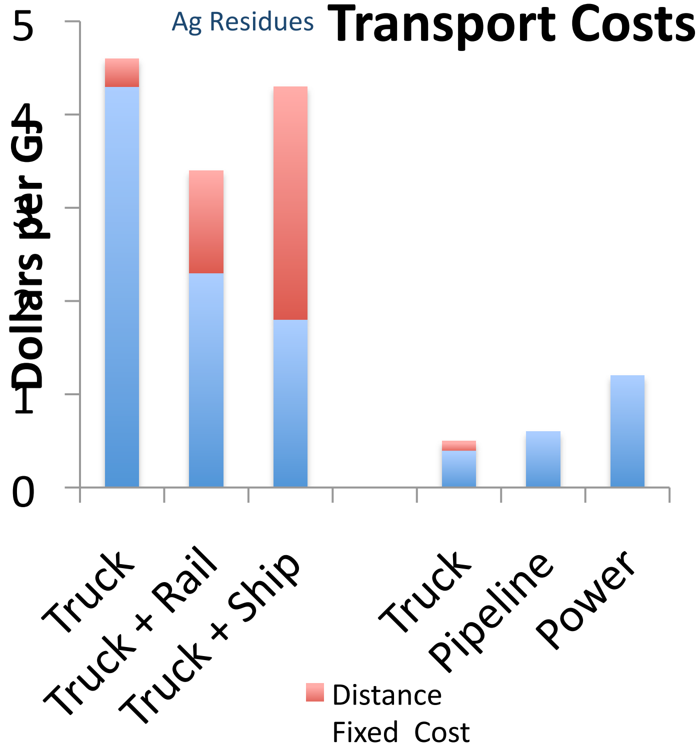
Calgren Renewables 55mgy biofuels plant in Pixley, CA

The state is funding new projects but at same time…California can't even keep it's current bioenergy capacity functioning!?!

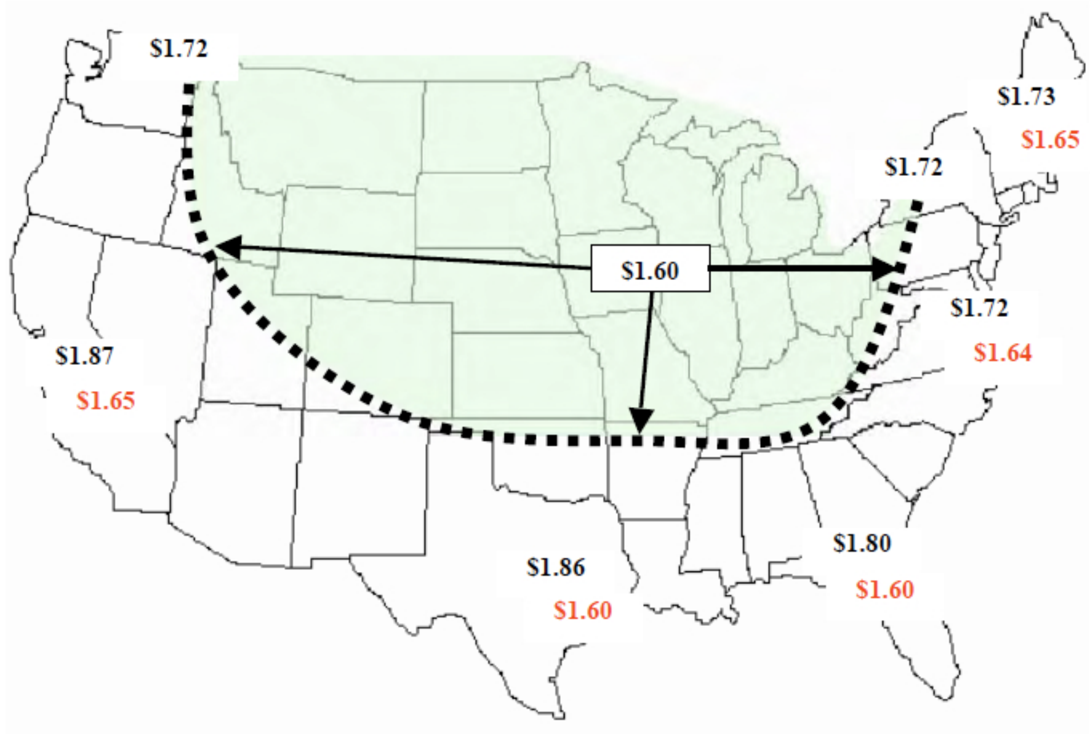
Fuels (mgge/yr)	2009 Production	Idle Capacity	Proposed Projects
Ethanol	21	221	20
Biodiesel	27	78	30
Biomethane	<1	8	6
Total	48	307	56
Biomass Electricity (MW)	**Operating Capacity**	**Idle Capacity**	**Proposed Projects**
Solid-fuel biomass	757	139	346
Landfill Gas	422	-	139
Dairy Digestors	3.9	4.6	4.3
Other Digestors	60	-	7.9
Biogas/NG cofiring facilities	210	-	359
Unrecovered MSW	75	-	455
Total	1527	144	1311

CEC Alternative Fuel Program 2011-2012 investment plan
CEC Bioenergy Action Plan

Transport Costs

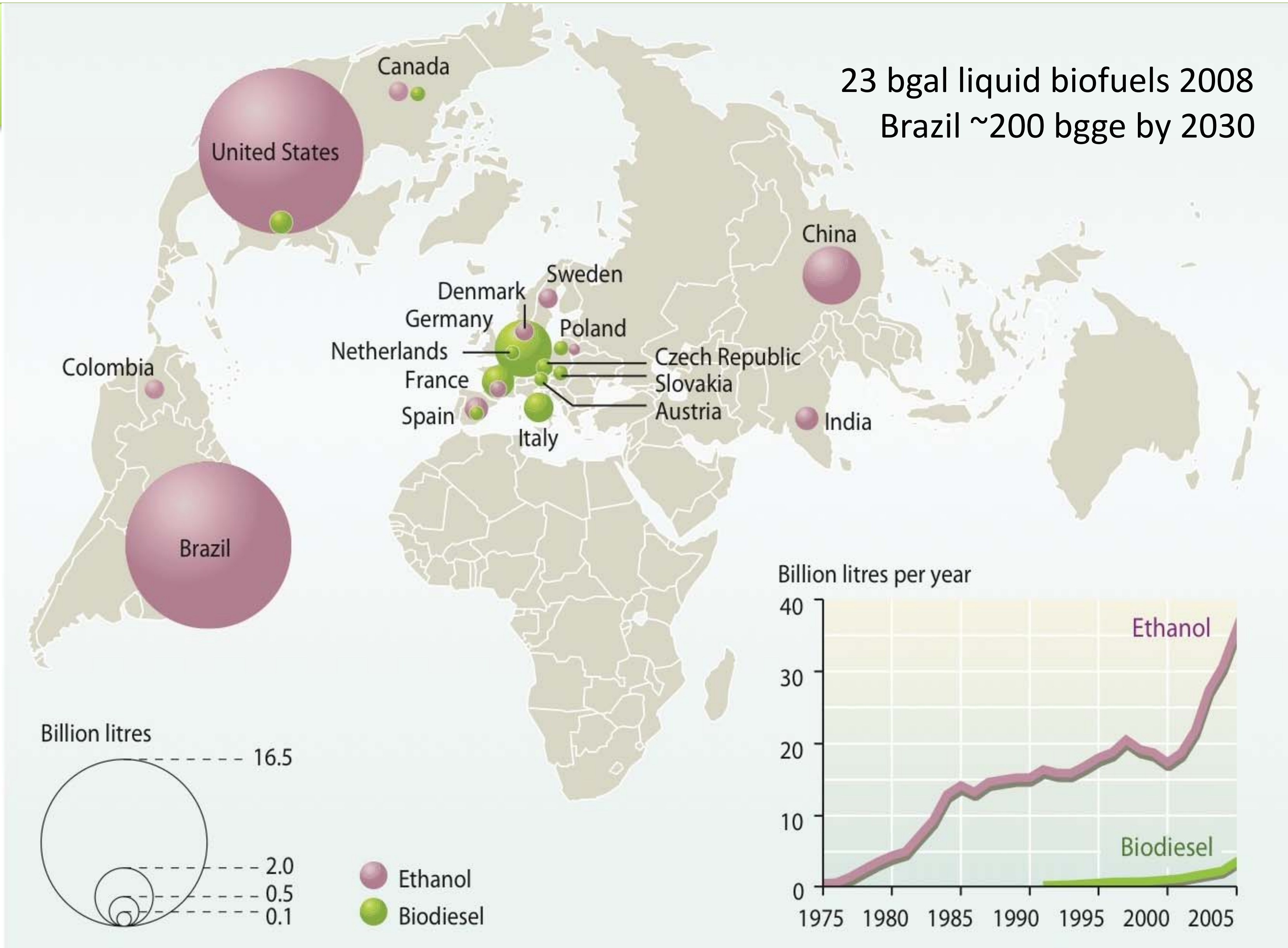


Searcy et al. 2007



James Baker Institute 2010

23 bgal liquid biofuels 2008
Brazil ~200 bgge by 2030



Sources: EarthTrends Database, REN21 2006; FO Licht's World Ethanol & Biofuels Report 2008.
Map compiled and produced by Emmanuelle Bournay.

Conclusions

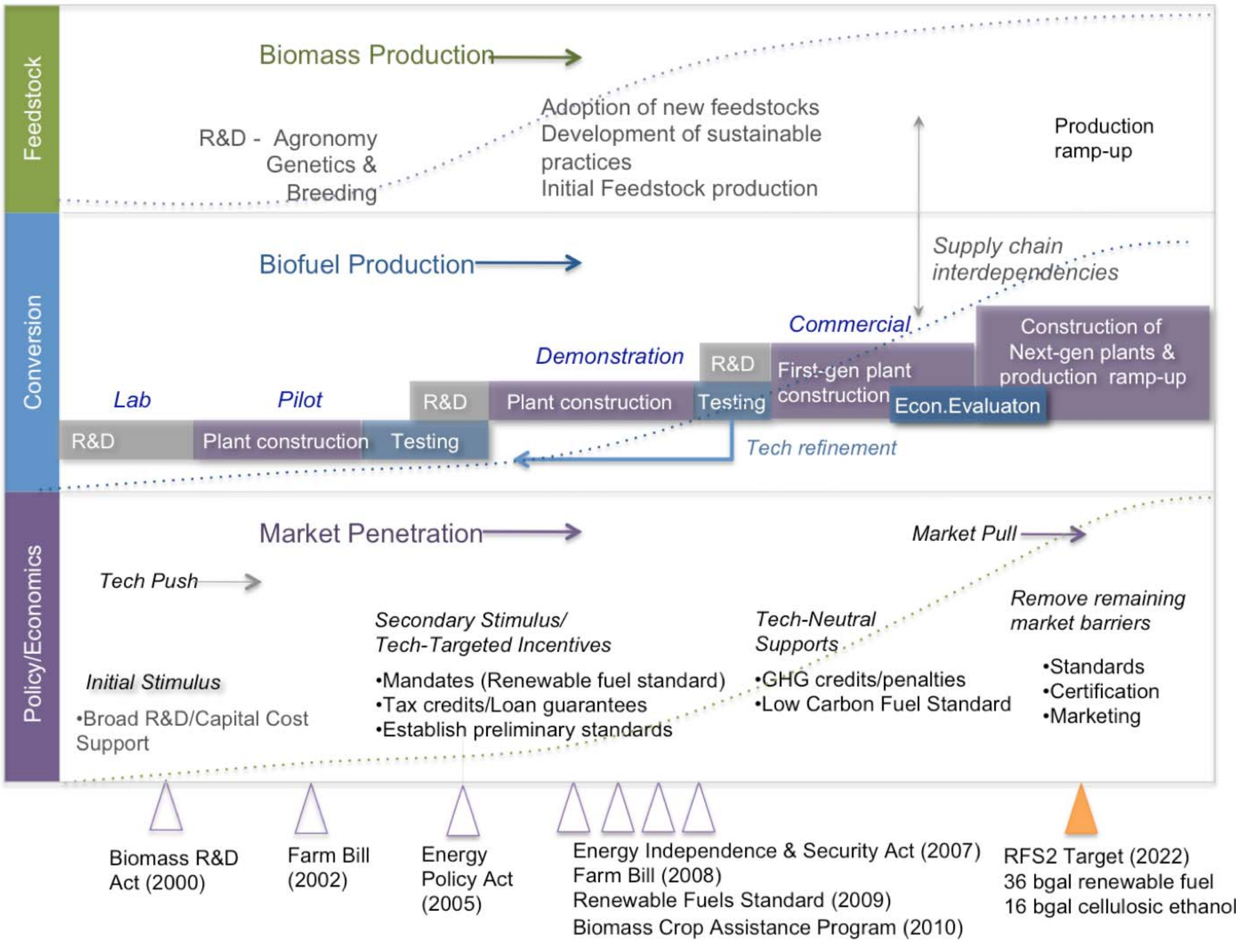
- Bioenergy is emerging as a critical player in meeting California's GHG goals
  - Required to provide baseload power if nuclear and CCS are off the table (e.g woody biomass to electricity)
  - Required as a replacement for natural gas to for industrial use and to provide firming of intermittant renewables such as wind and solar
  - Required to decarbonize fuels
    - Advanced (drop-in) biofuels from residues or low-input lignocellulosic residues do better than E85 and conventional biodiesel
    - California will likely need to import at least half its biofuel

      (the state imported 73% of refined petroleum products in 2007and 96% of ethanol, mostly from the Midwest and Brazil)

Residues Alone are Not Enough

Two Choices

- Increase in-state biomass
  - Policy Need: Supports to adopt efficient, non-food bioenergy crops on idle lands and encourage residue/waste biomass use
  - Technical Need: Improved understanding of biomass residue recovery options, multiple use decision making, conversion technologies, and CA-specific energy crops
  - Social Need: Education and communication to stakeholders
  - Risk: Inappropriate choices could have impacts on water resources, soil quality, ecosystem services, and economic consequences
- Rely heavily on imported biofuels
  - Policy Need: Establish sustainable biomass/biofuel certification standards (e.g. Council on Sustainable Biomass Production)
  - Risks: Difficult to enforce compliance and leakage (sources produce low carbon fuel for CA but increase fossil use locally)



Youngs (2011) Path to Commercialization *Bioenergy Connection* p17-19

Extra Slides

Comparing bioenergy crops

Crop	Average Productivity (Mg ha^{-1} yr^{-1})	Ethanol yield (L ha^{-1})	Seasonal Water Requirements (cm yr^{-1})	Tolerance to Drought	Nitrogen Requirements (kg ha^{-1} yr^{-1})
Corn		3,800 (total)	50-80	low	90-120
Grain	7	2,900			
Stover	3	900			
Sugarcane	80 (wet)	9,950 (total)	150-250	moderate	0-100
sugar	11	6,900			
bagasse	10	3,000			
Miscanthus	15-40	4,600-12,400	75-120	low	0-15
Poplar	5-11	1,500-3,400	70-105	moderate	0-50
Agave spp.	10-34	3,000-10,500	30-80	high	0-12

Somerville, Youngs, Taylor, Davis, Long (2010) Science

Agave tequiliana Harvest

Only piña are used for tequila, leaves generally discarded

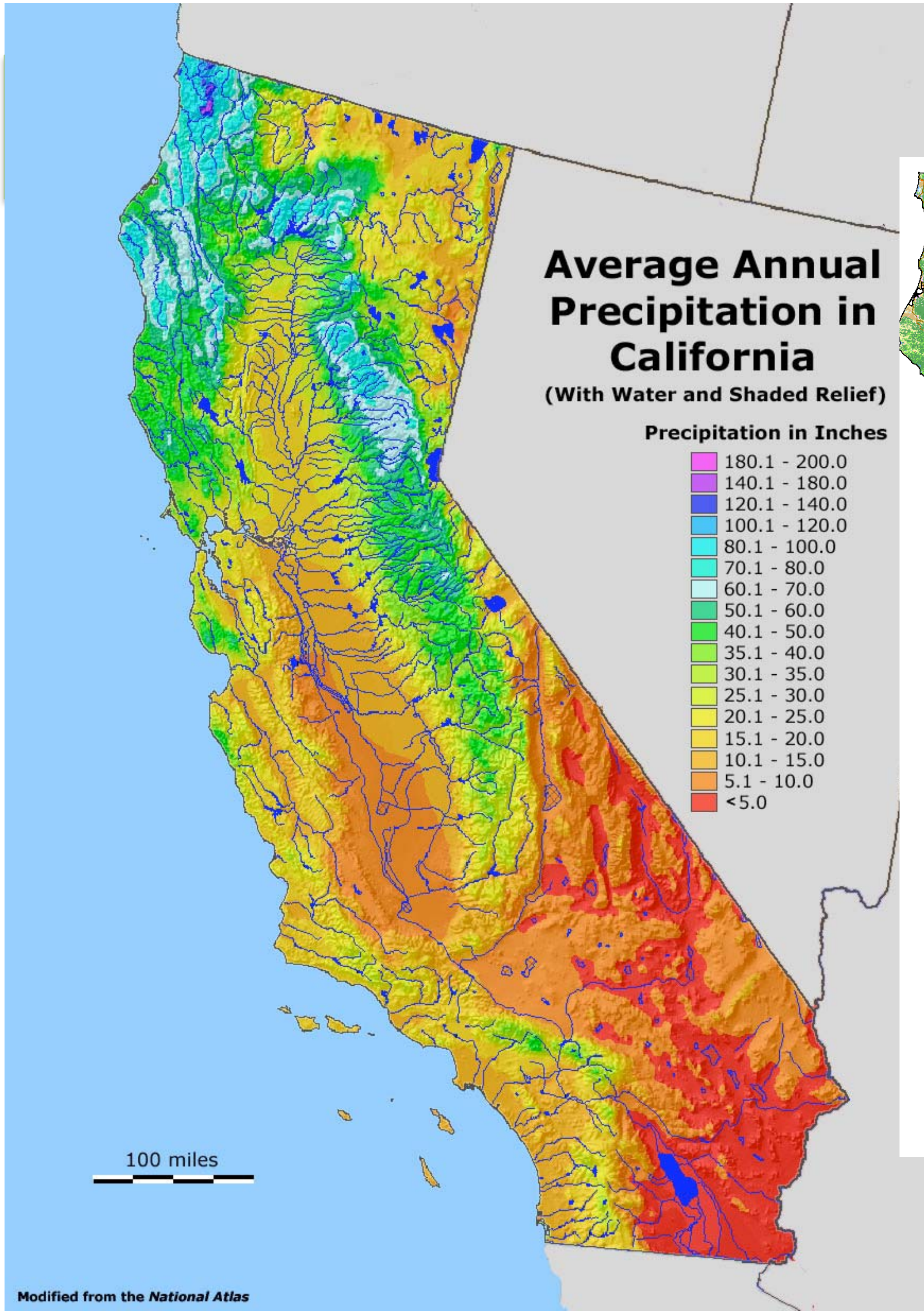
Agave sisalana

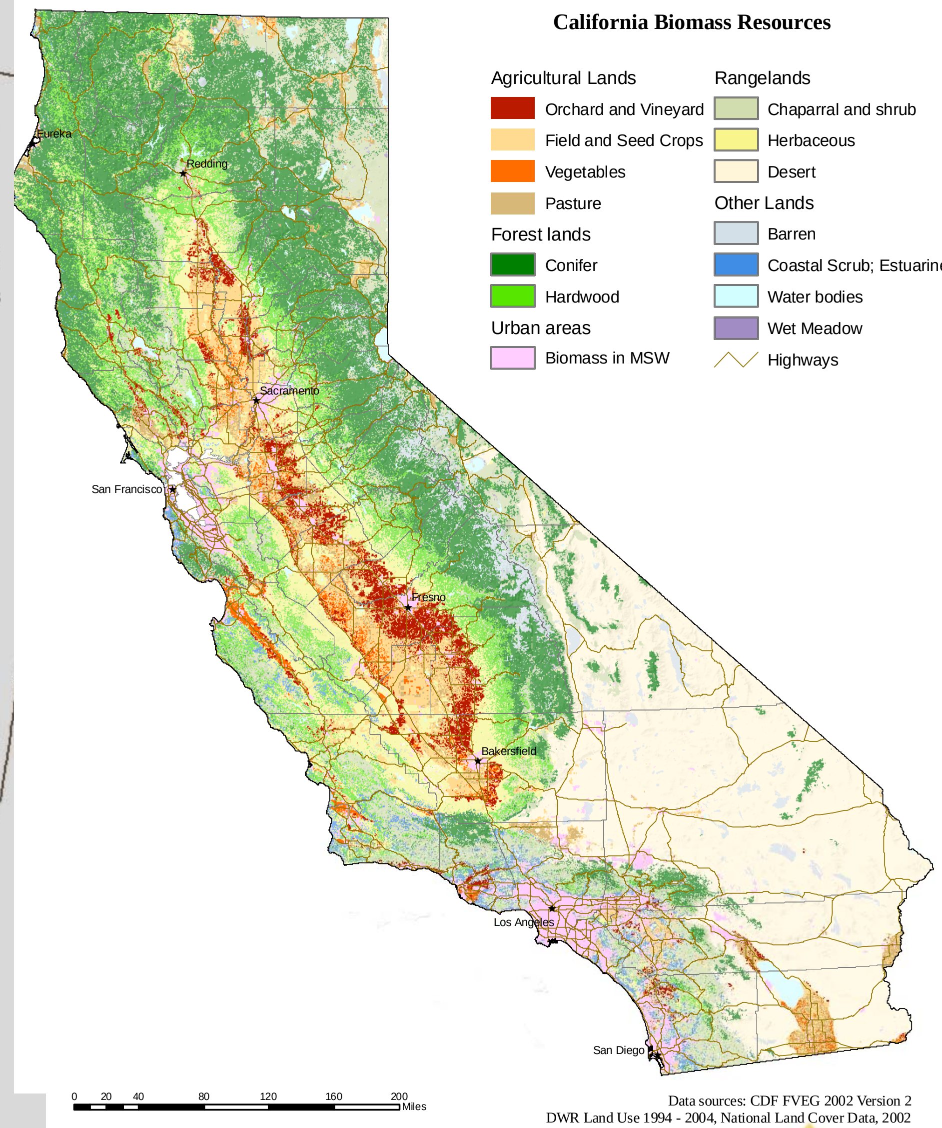
Sisal field

Sisal fibers drying

Sisal powerplant - Tanzania

Yield 10 tonnes/ha/yr – 10 year cycle
Top producers: Brazil, China, Kenya, Tanzania


Average Annual Precipitation in California
(With Water and Shaded Relief)
Precipitation in Inches
180.1 - 200.0
140.1 - 180.0
120.1 - 140.0
100.1 - 120.0
80.1 - 100.0
70.1 - 80.0
60.1 - 70.0
50.1 - 60.0
40.1 - 50.0
35.1 - 40.0
30.1 - 35.0
25.1 - 30.0
20.1 - 25.0
15.1 - 20.0
10.1 - 15.0
5.1 - 10.0
<5.0
100 miles
Modified from the National Atlas


California Biomass Resources
Agricultural Lands
Orchard and Vineyard
Field and Seed Crops
Vegetables
Pasture
Forest lands
Conifer
Hardwood
Urban areas
Biomass in MSW
Rangelands
Chaparral and shrub
Herbaceous
Desert
Other Lands
Barren
Coastal Scrub; Estuarine
Water bodies
Wet Meadow
Highways
Eureka
Redding
Sacramento
San Francisco
Fresno
Bakersfield
Los Angeles
San Diego
0 20 40 80 120 160 200
Miles
Data sources: CDF FVEG 2002 Version 2
DWR Land Use 1994 - 2004, National Land Cover Data, 2002