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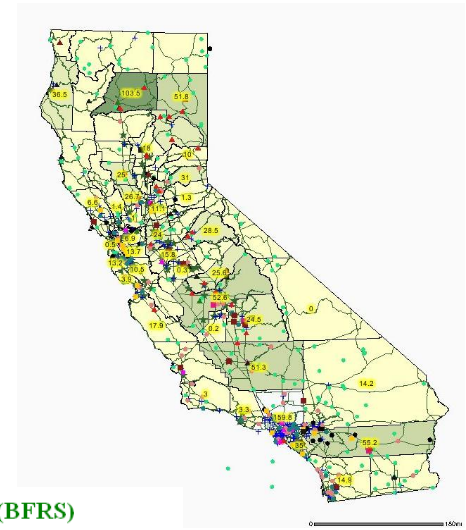
Biomass Feedstocks and Their Technical Potential

Joint IEPR and Renewables Committee Workshop on Biopower in California

Steve Kaffka , Quinn Hart,
Nathan Parker, Peter Tittman,
Rob Williams, Bryan Jenkins

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.

Data Query

Select Category :
Select County :
Select Year :

Retrieve data | View Map

California Biomass Facilities Reporting System (BFRS)
Resource 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.

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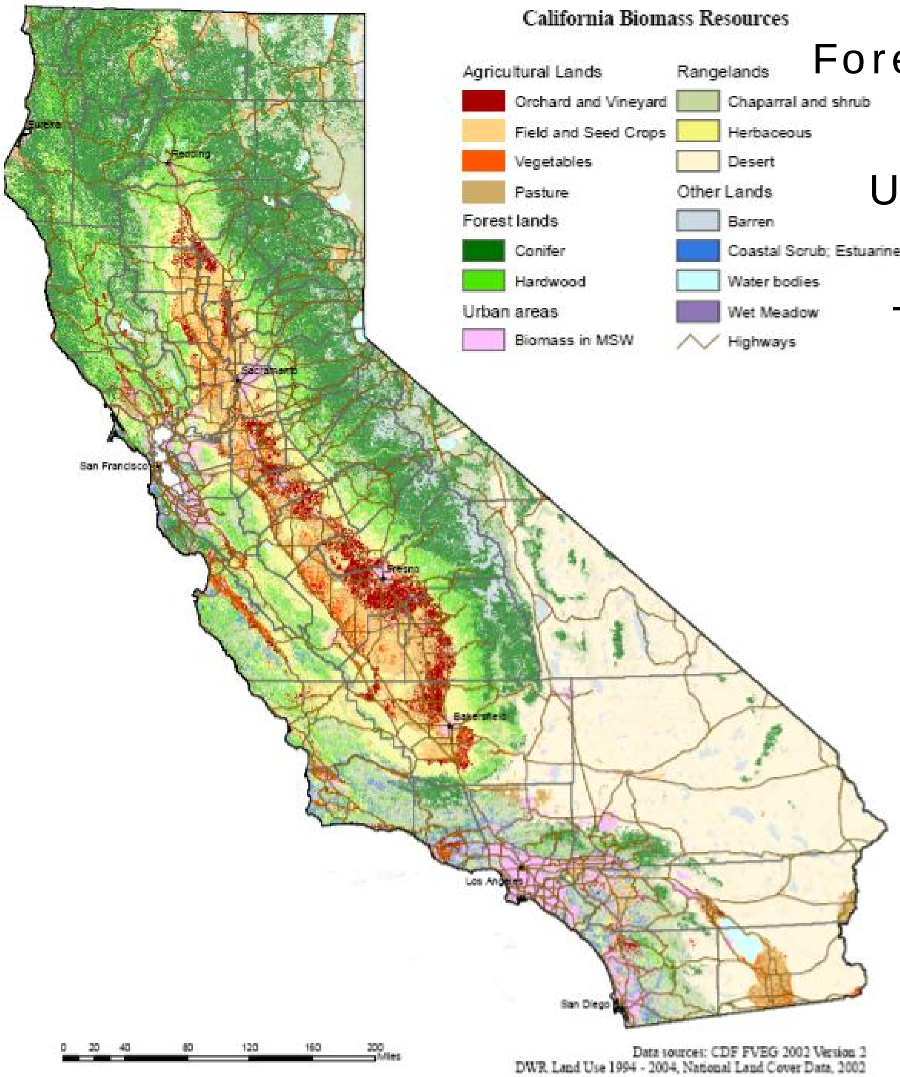
Select County :
Select Year :

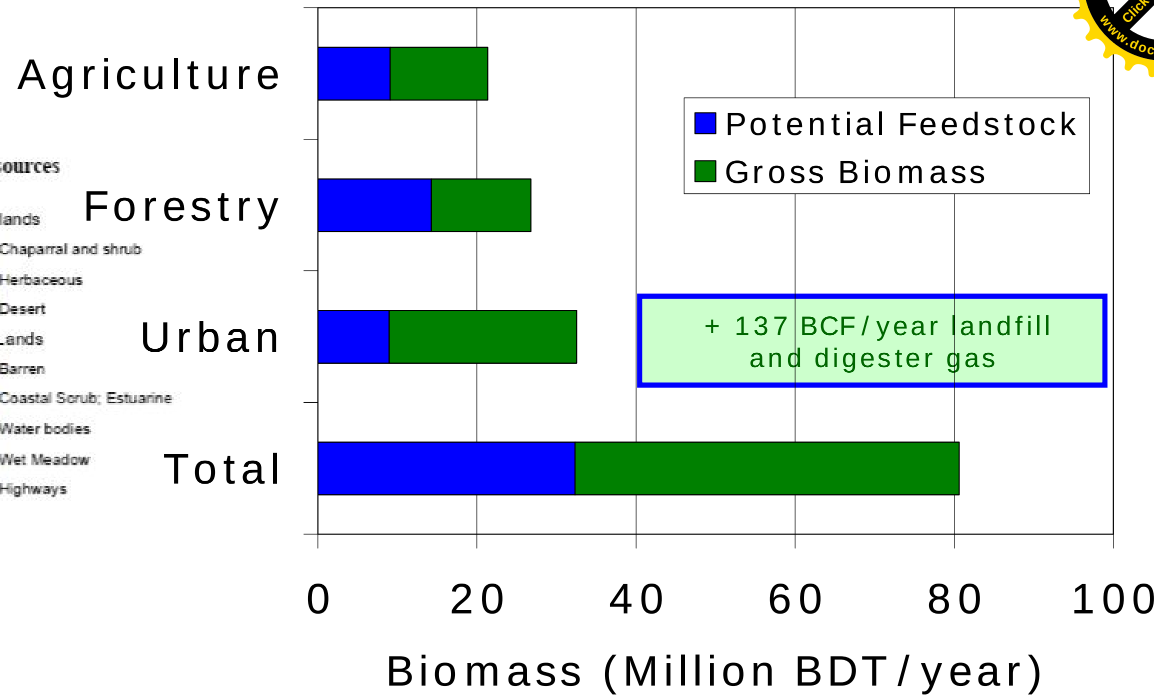
Retrieve data | View Map

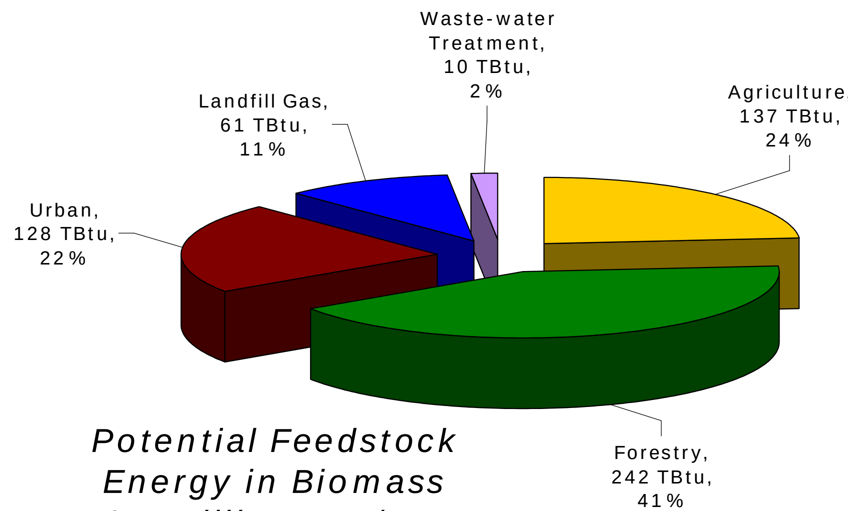
http://biomass.ucdavis.edu
Email: biomass@ucdavis.edu

Overview

1. Technical potential of biopower technologies
2. Competition for feedstocks between the biopower and biofuel industries







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

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Principal Biomass Conversion Pathways

- Production
- Collection
- Processing
- Storage
- Transportation

- Thermochemical Conversion
  - Combustion
  - Gasification
  - Pyrolysis
- Bioconversion
  - Anaerobic/Fermentation
  - Aerobic Processing
  - Biophotolysis
- Physicochemical
  - Heat/Pressure/Catalysts
  - Refining
  - Makes e.g. Esters (Biodiesel), Alkanes

- Energy
  - Heat
  - Electricity
- Fuels
  - Solids
  - Liquids
  - Gases
- Products
  - Chemicals
  - Materials

Total Bioenergy Potentials by Category in California (Ligno-cellulosic sources)

Category	Biomass (Million BDT/year)	Energy in Product (Trillion Btu/year)	Total Capacity
Electricity CHP Heat	32	118 (35 TWh) 230	4,650 MWe 9,050 MWt
Biochemical Biofuel	32	188	1.5 BGY gasoline equivalent
Thermochemical Biofuel	27*	250	1.7 BGY diesel equivalent
Biomethane	5 + Landfill gas and WWTP	106	106 BCF/y methane
Hydrogen (bio + thermal)	32	305	2.5 Million tons/y

* *Tonnage for thermochemical biofuel assumed to be constrained by moisture content.*

Current California consumption:

16 billion gallons gasoline + 4 billion gallons diesel = 2,500 Trillion Btu/year direct energy content

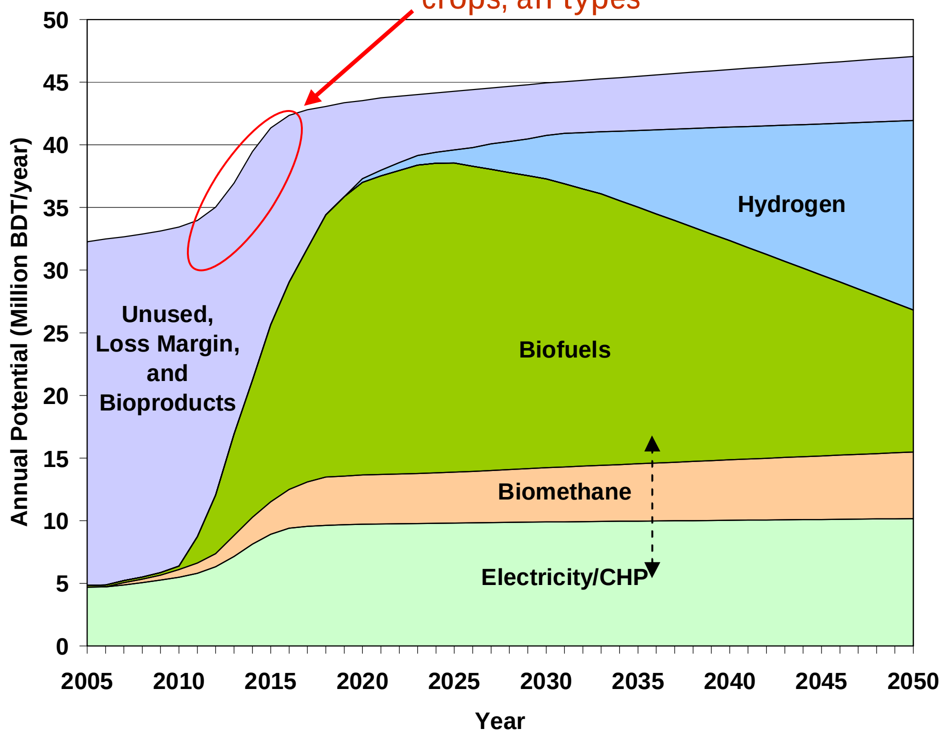
300 TWh/y electrical energy = 1,024 Trillion Btu/year direct energy

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

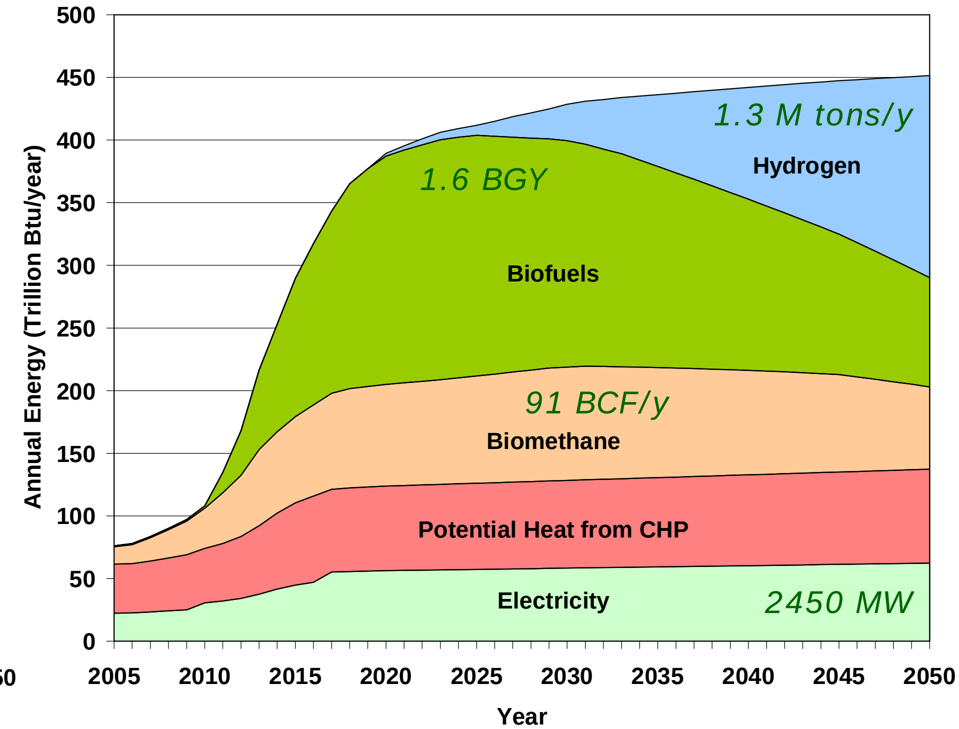
One development scenario for California biomass (1.5 billion dry tons utilized through 2050)

In-state tonnage

BDT addition from energy crops, all types



Energy

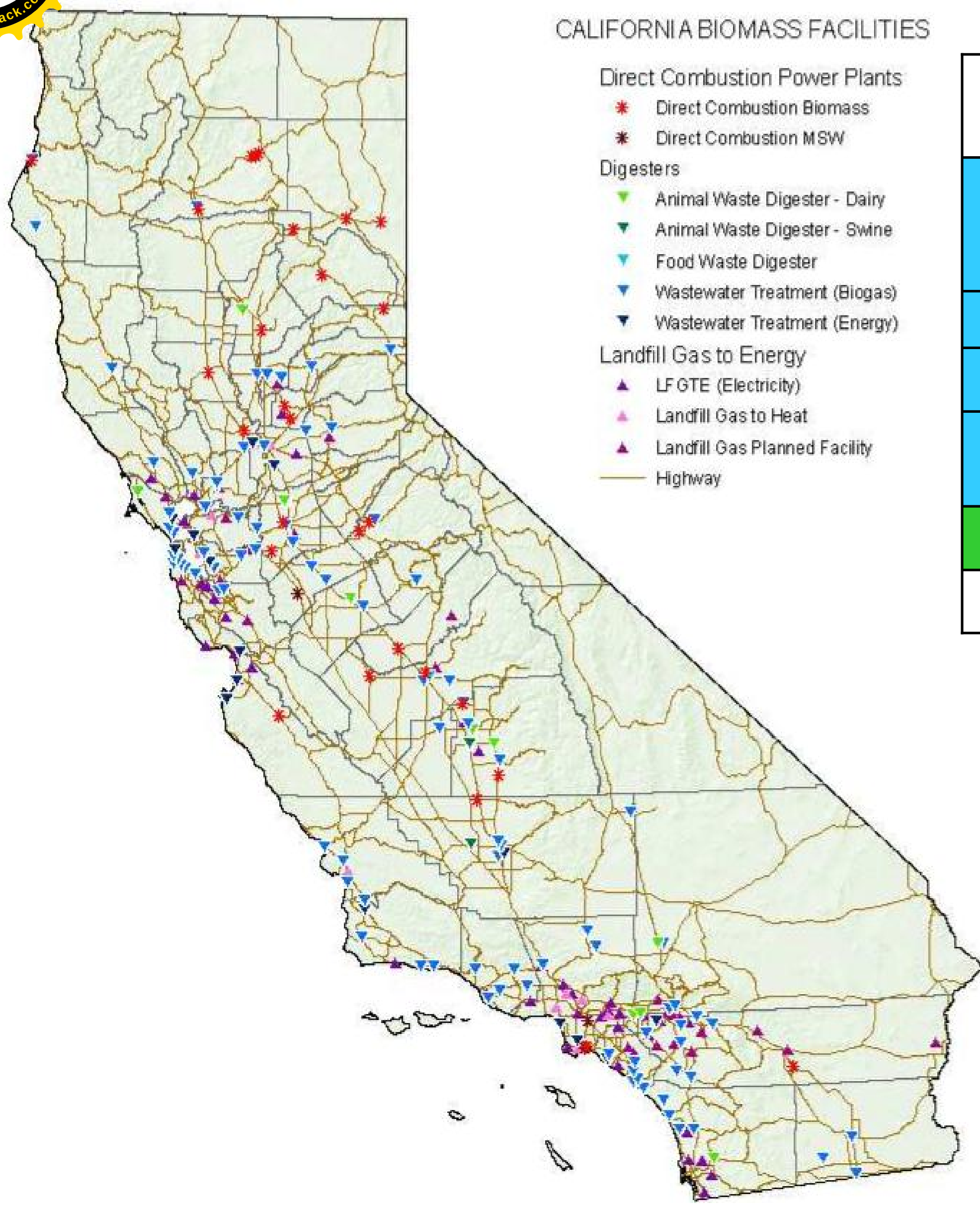


About 5 of the 32 million BDT are currently utilized.

Assumes 10 million BDT from dedicated energy crops ultimately available; ramping up from 2012 to 2018.

Potential technical recovery, not including economic costs

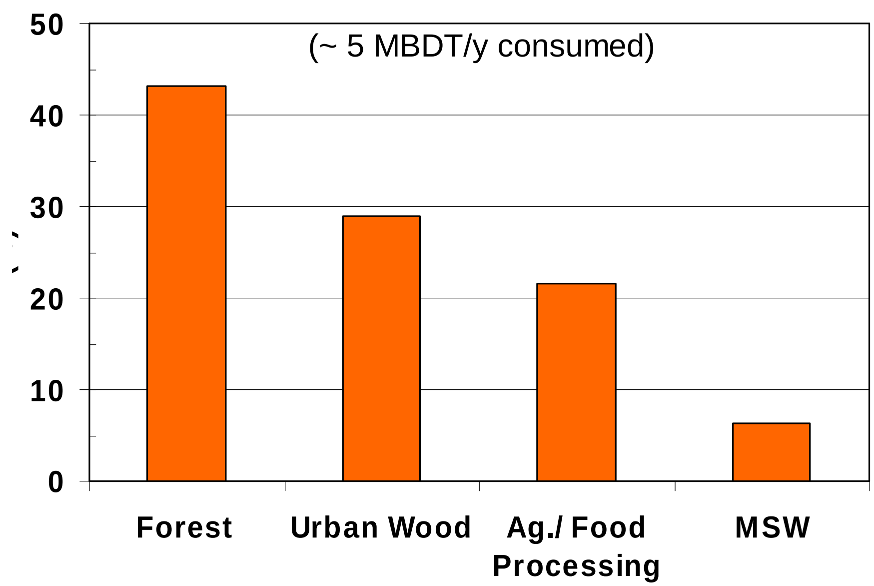
Jenkins et al. (2006) A roadmap for the development of biomass in California



~2006 Biomass Power Capacity in California

Technology/ Fuel Source	Number of facilities	Gross Capacity (MW)
Solid Fuel Combustion (includes 3 MSW facilities)	**30 -33**	**640**
Landfill gas-to-energy	**60**	**275**
Wastewater treatment *	**20**	**64**
Animal and food waste digester	**22**	**5.7**
Totals*	**132**	**985**
*** Suspect - Probably higher**		

Solid Combustion Fuel Sources



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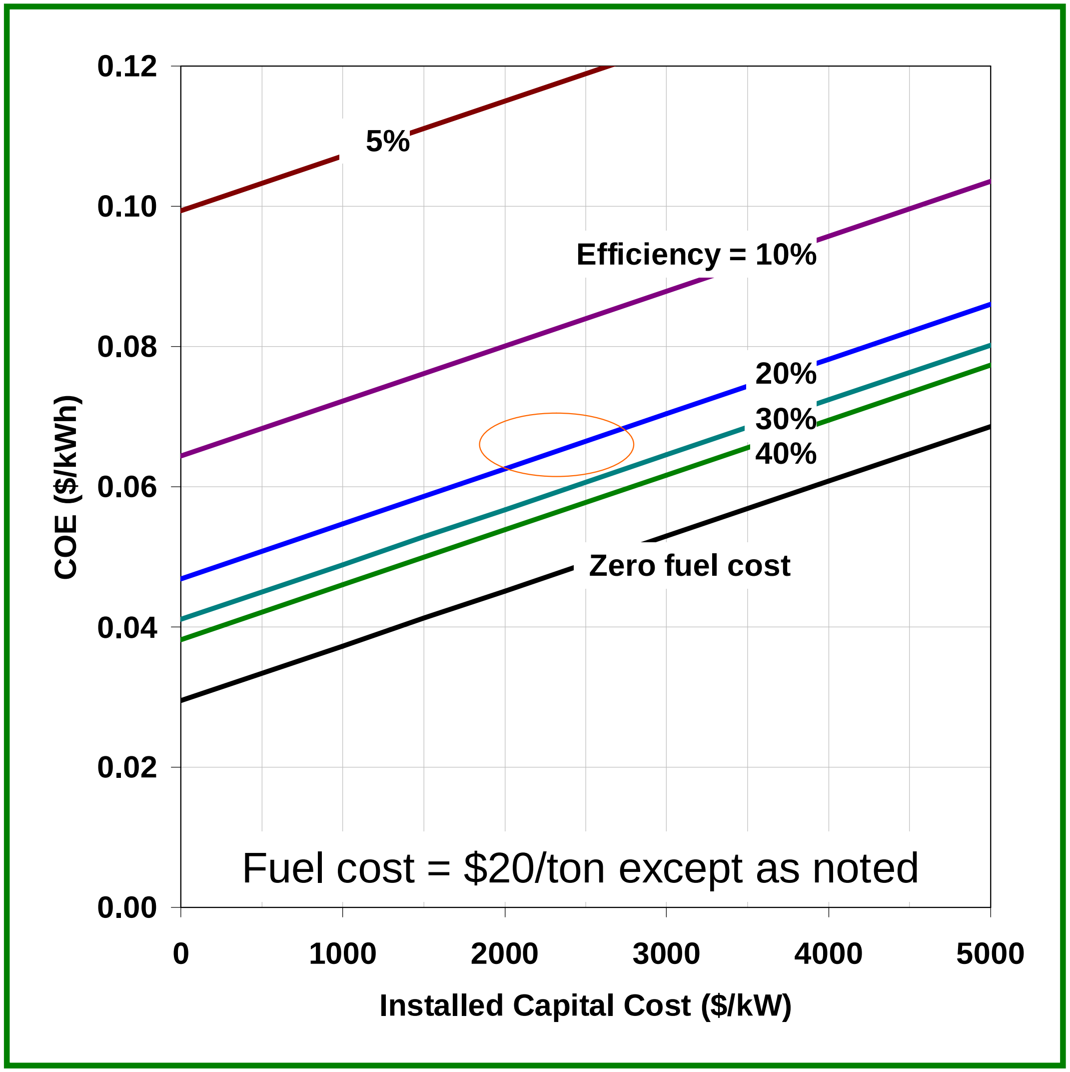
Electricity Generation– To meet Governor's goal of 20% of renewables from Biomass – Shown for accelerated RPS in 2010 and 2020

Year	Incremental Capacity (MW at 85% CF)	Cumulative Capacity (MW at 85% CF)
2007	-	900
2010	600	1,600
2020	1,550	2,450

Biomass Power– Levelized cost of electricity (COE)/solid-fuel thermal systems (2006)



- Current biomass steam plants typically installed for $2,000-2,800/kWe
- Net efficiencies from 15-25%
- Fuel costs range 0 - $50/dry ton, average $28/dry ton in California
- Tipping (disposal) fees available in some cases, reduce COE
- Benchmark comparison for California: Natural gas combined cycle with heat rate of 7,000 Btu/kWh (49% efficiency)—at $9/MMBtu gas price COE=$0.074/kWh (fuel cost = $0.063/kWh or 85% of COE)

UCDAVIS CALIFORNIA biomass

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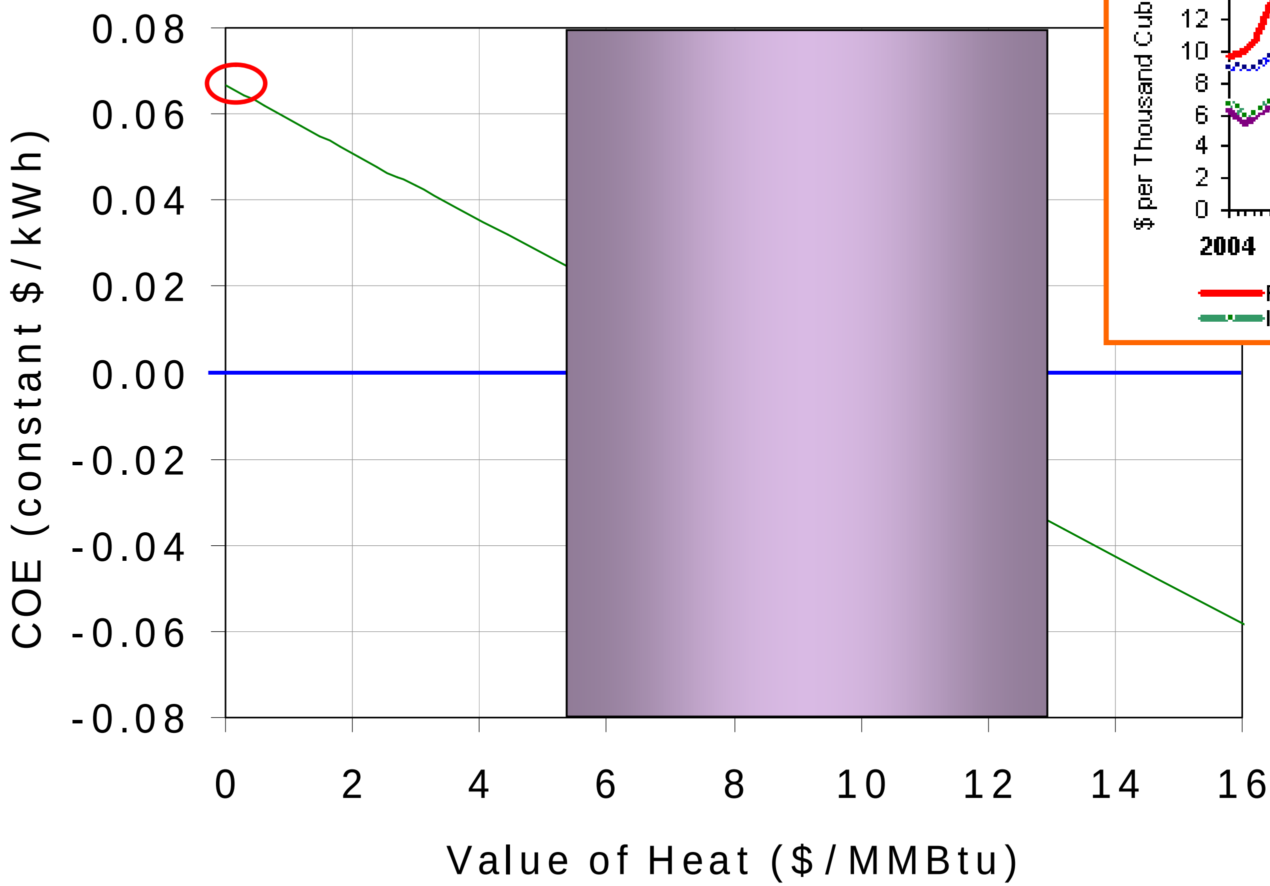
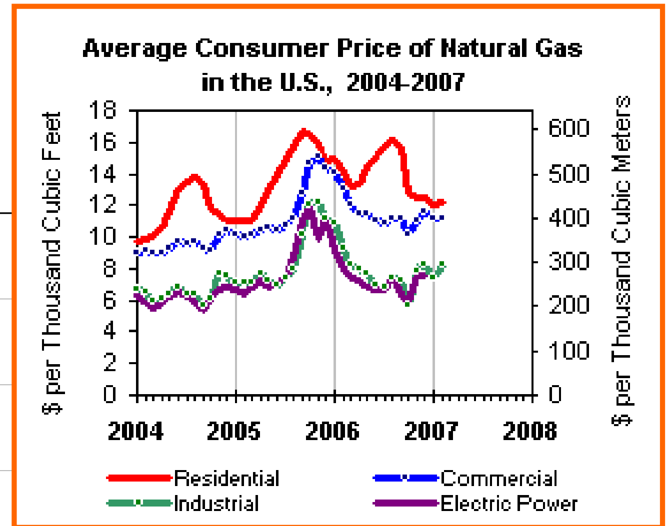
Cost of Electricity: Biomass Combined Heat and Power





- CHP provides opportunities for low cost power
- Long utilized in forest products industry
- Matching generator to thermal host often difficult for large scale development

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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

Assumptions for evaluating biomass potential

"Economically available" biomass depends on:

- Value of products that can be made
- Cost and efficiency of conversion to products
- Engineering/economics of acquisition of biomass

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Model Limitations

- The status and development of the included technologies is highly uncertain…
- Relies heavily on biomass resource assessments that currently lack their own economic modeling…
- No feedback between siting and resource…

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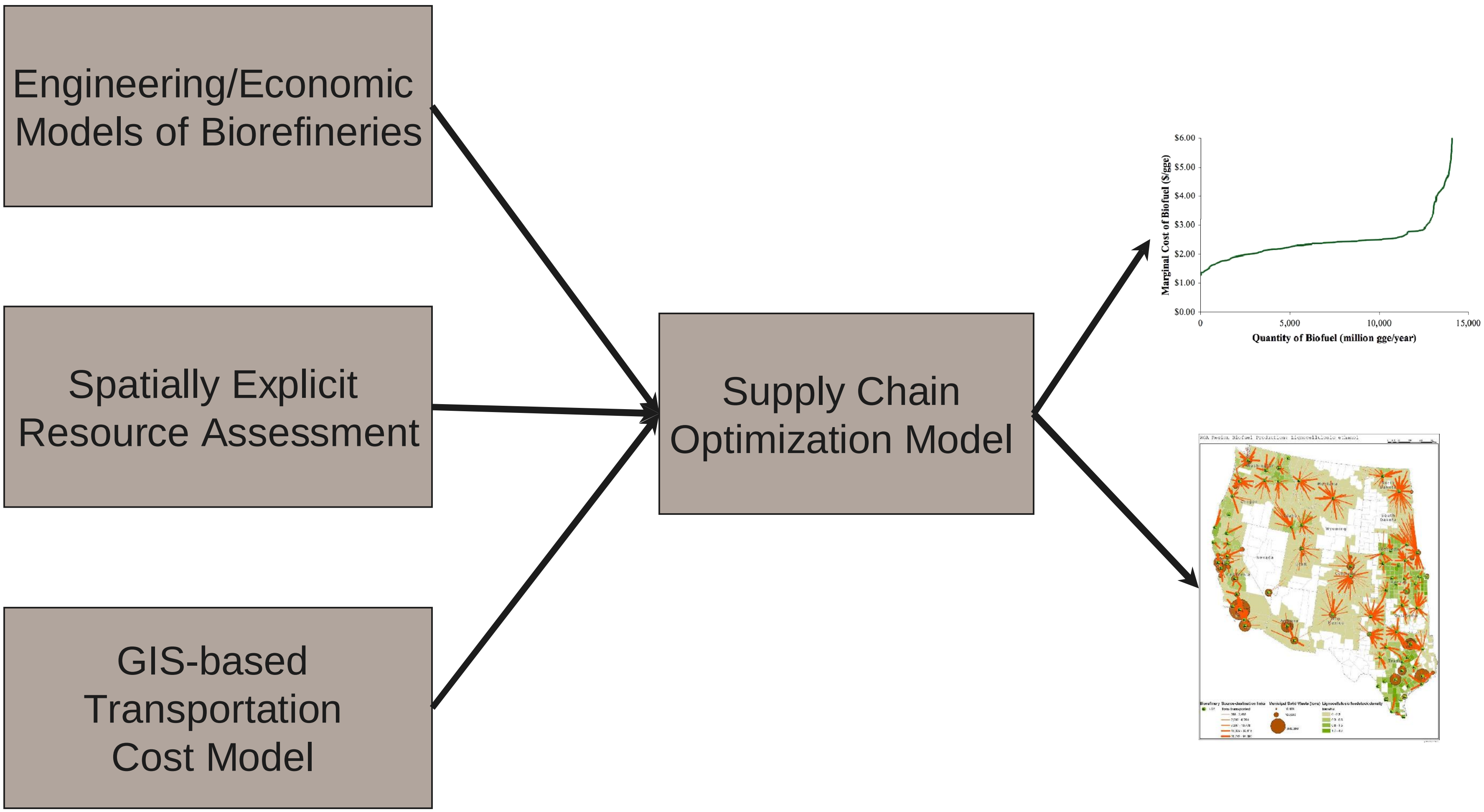
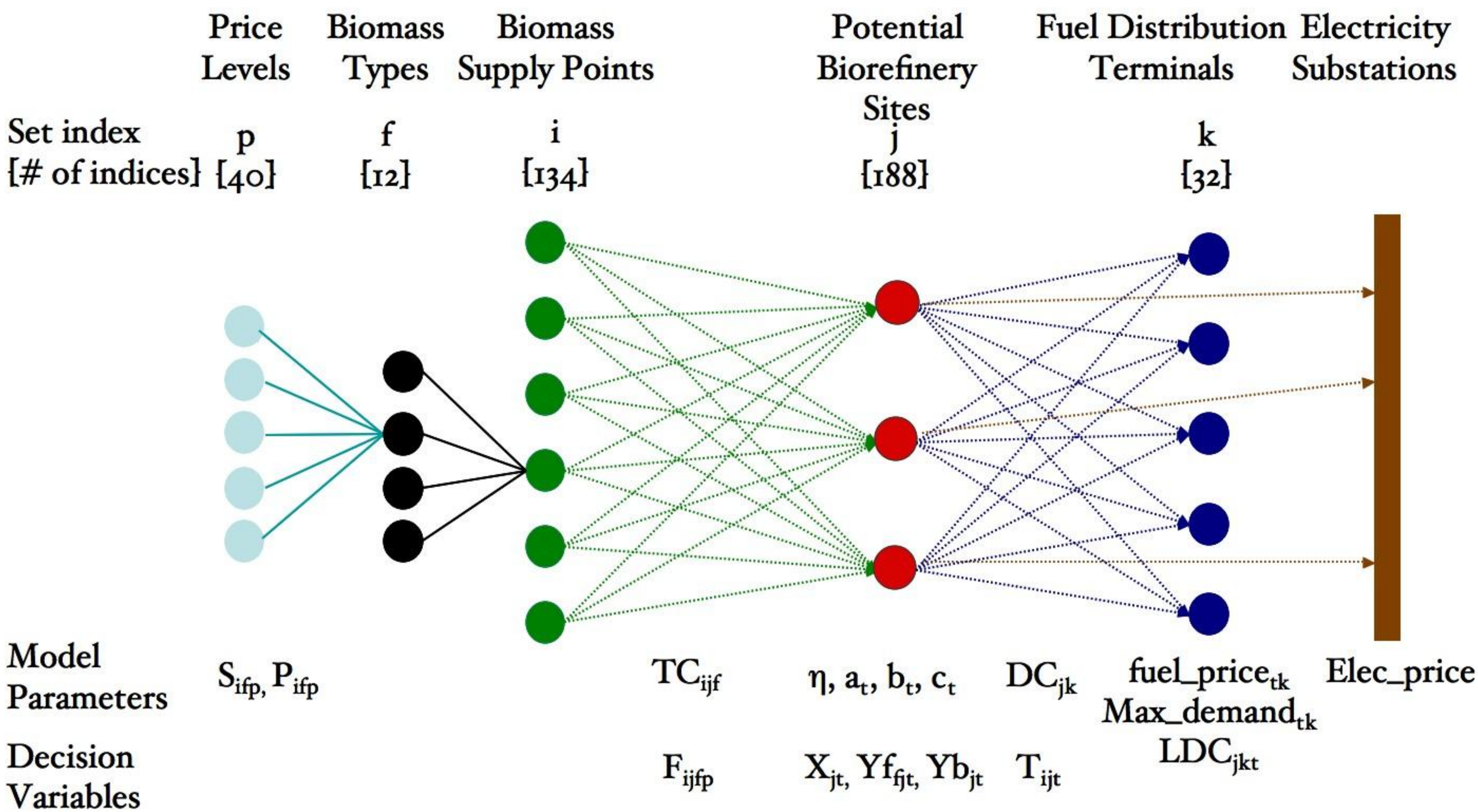
Modeling Approach



Supply Chain Optimization Model

- Objective: maximize total industry annualized profit
- Formulated as mixed integer-linear programming model
- Locates and sizes biorefineries based on distribution of biomass resource
- Chooses which technology to use
- Allocates resource and demand to each biorefinery

Overview of optimization



Feedstock Class	Specific Feedstock	Geography	Source
Agricultural Resources			
Residues	Corn stover, small grain straws	County	Dr. Richard Nelson, Kansas State University [1] and CBC [2]
Grains	Corn	County	
Forest Resources			
Forest Thinnings	Public and Private lands includes juniper and pinyon pine	County	USFS Forest Products Lab [1] and CBC [2]
Residues and Byproducts			
Animal Fats & Waste Greases	Beef Tallow, Pork Lard, Yellow Grease	County & municipality (waste greases)	Dr. Richard Nelson, Kansas State University [1]
Municipal Solid Waste (MSW)	Wood residues, paper, yard waste, etc	municipality	SWIS [3]
Woody Residues	Orchard and vineyard waste	County	CBC [2]

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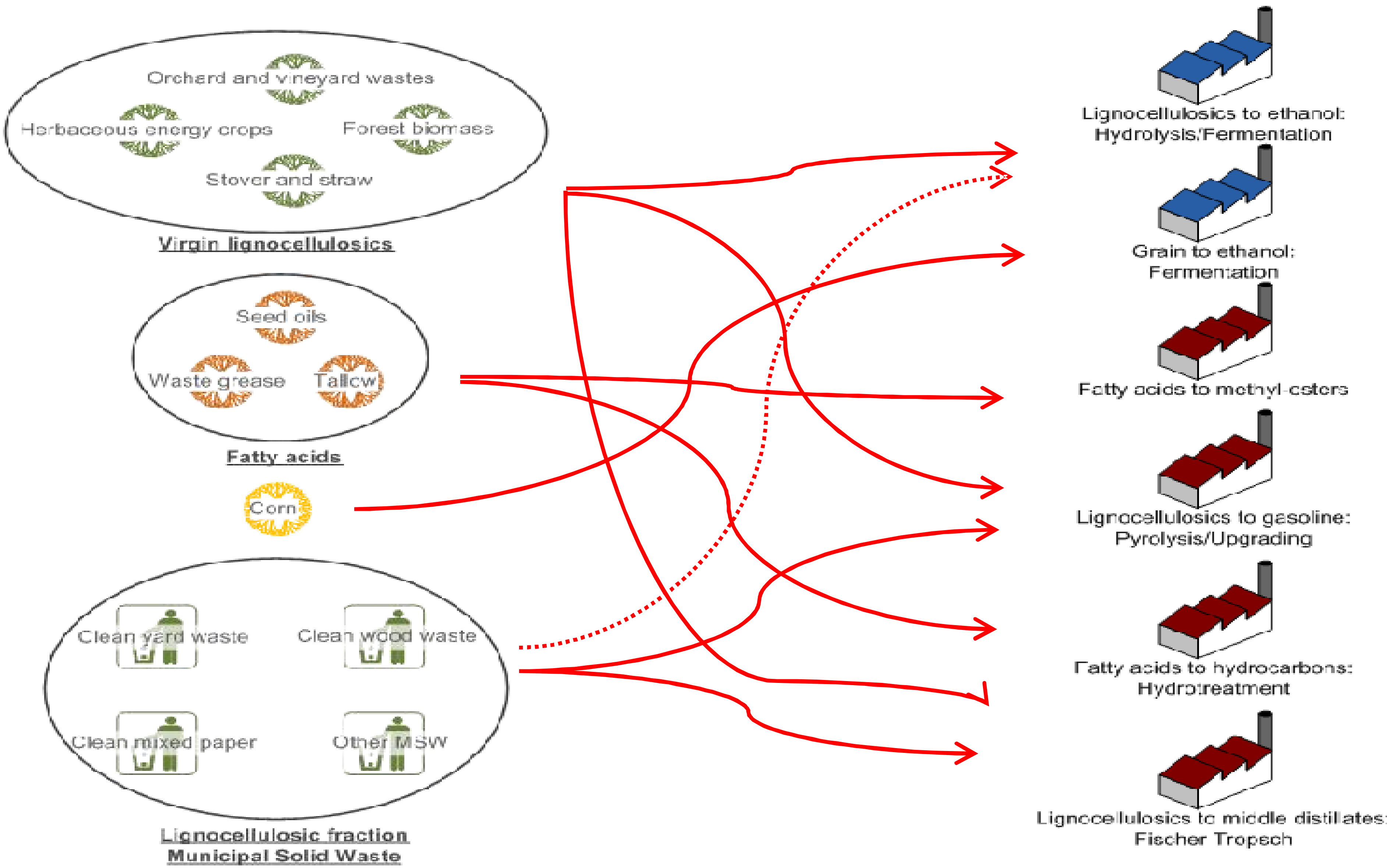
Feedstock Conversion Pathways

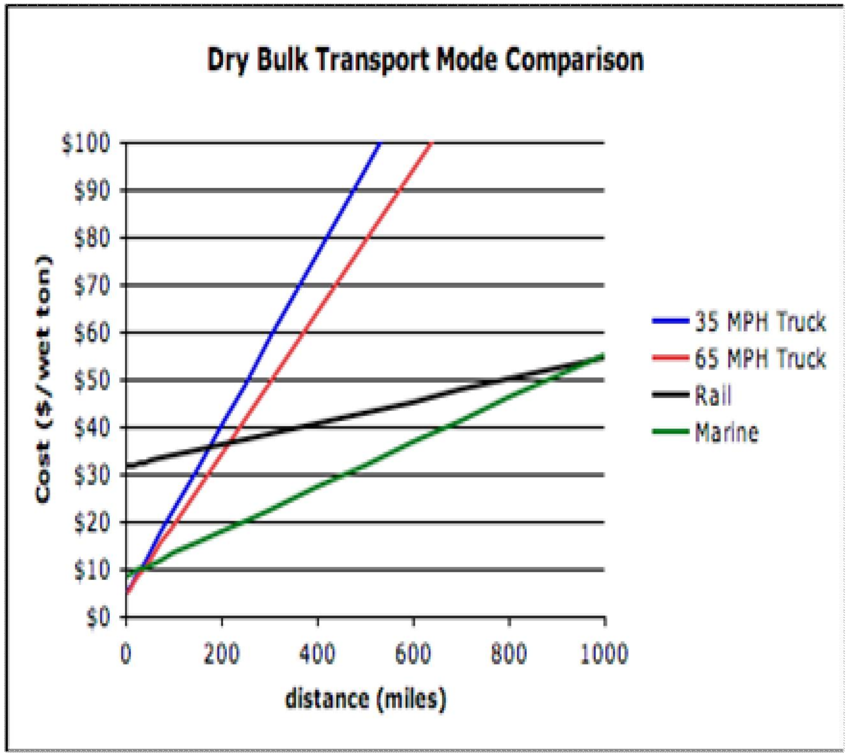


Summary of Conversion Cost Model

- Biorefineries are assumed to operate at design capacity for an economic lifetime of 20 years.
- Cost curves are fitted to match the economies of scale from the detailed model of conversion costs.
- The cost functions of each technology depend on either feedstock input or fuel product or both.
- Biorefineries are modeled to consume a constant mix of feedstock for the entire production period. The feedstock mix designates the conversion costs.

Why geography is important

- Dispersion of potential biomass resource affects delivered biomass costs
- Adjusts value of products due to market access



System design for cellulosic ethanol

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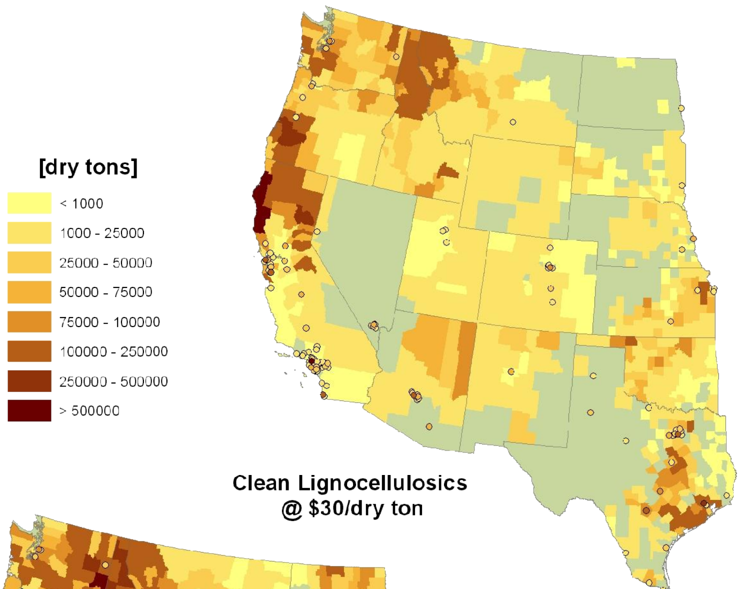
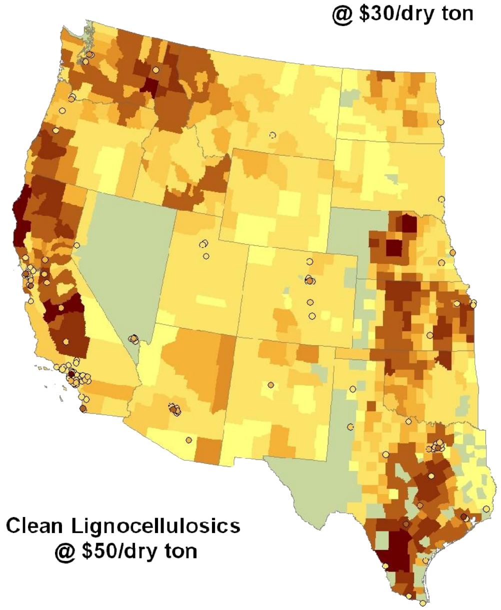
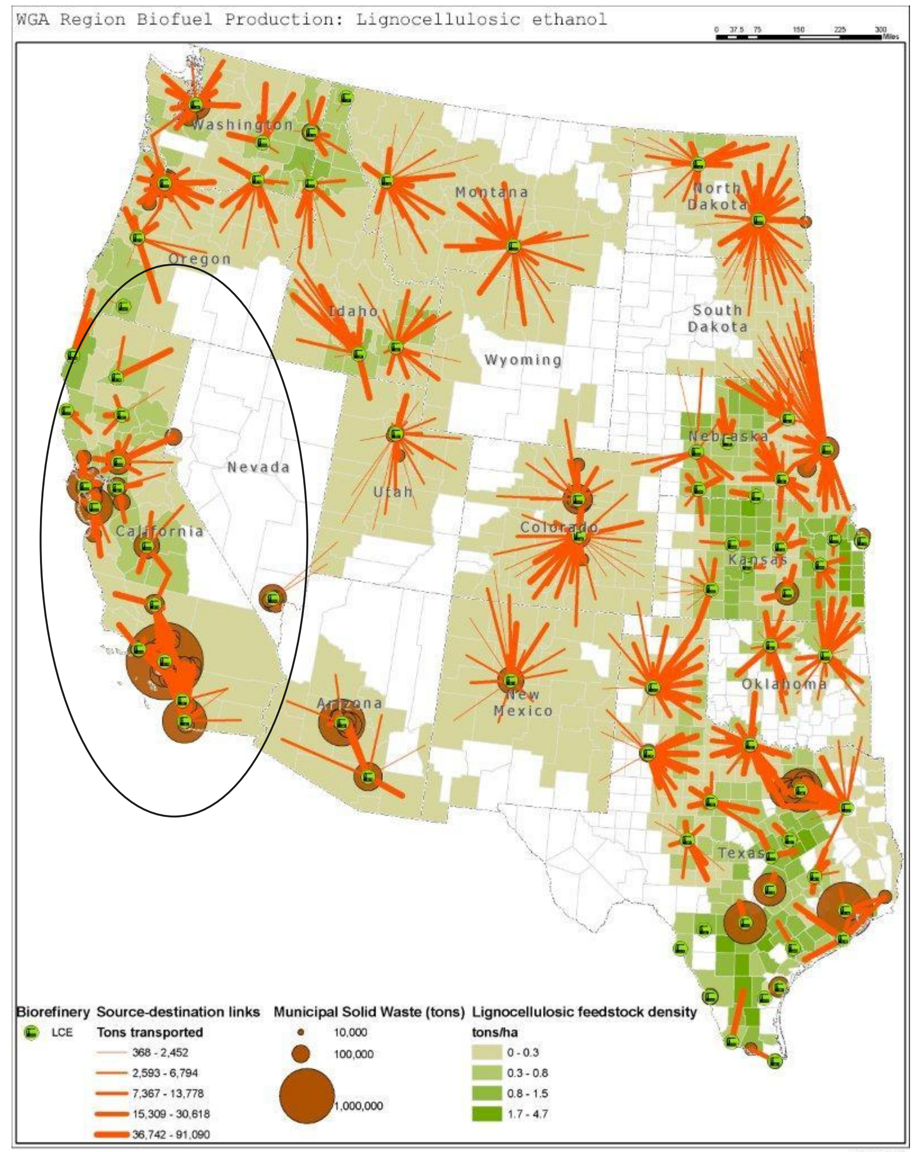


Clean Lignocellulosics
@ $30/dry ton



Clean Lignocellulosics
@ $50/dry ton



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Example of detailed model

Inputs

Feedstock Type	**Poplar**
Economic Lifetime of Plant (Years)	20
Weighted Cost of Capital	12%

	Short Term (2010)	Mid Term (2015-2020)	Long Term (2025+)
Applicable Feedstocks	clean herbaceous feedstocks (agricultural residues and grasses) and de-barked wood chips		
Applicable Size Range (MGY)	25 - 60	60 - 150	60 - 300
Feedstock Input (dry ton/yr)	500,000	1,225,000	2,500,000
Feedstock Input (MMBtu/yr)	9,000,000	22,050,000	45,000,000
Yield - Dilute Acid (gal/dry ton)	76.9	85.9	91.9
Yield - Advanced Tech (gal/dry ton)	--	81.2	98.6
Conversion efficiency (HHV)	36%	38%	46%
Ethanol Production (MGY)	**38**	**99**	**246**
Pretreatment Technology	Dilute Acid	Steam Explosion	LHW
Capital Cost ($/gallon)	7.13	3.06	3.62
Consumables and By-Products			
CO2 Stream (ton/yr) (1)	121,800	315,100	780,800
Water Consumption (1000 gal/yr) (2)	267,100	654,400	1,335,400
Net Electricity Production (kWh/gal) (3)	2.62	6.33	2.11
Ethanol Production Costs			
Fixed O&M ($/yr) (3)	$ 10,421,977	$ 17,598,813	$ 24,219,933
Fixed O&M ($/gal/yr)	$ 0.27	$ 0.18	$ 0.10
Variable O&M ($/gal/yr) (3)	$ 0.25	$ 0.21	$ 0.09
Electricity Value ($/gal/yr) (4)	$ (0.15)	$ (0.36)	$ (0.12)
Net Electricity Value ($/yr) - credit	$ 5,732,921	$ 35,870,896	$ 29,629,081
Annual Operating Cost ($/yr)	***$ 14,119,838***	***$ 2,907,821***	***$ 17,499,764***
Total Capital Cost ($) (5)	$ 274,189,133	$ 304,400,977	$ 891,873,839
Economic Lifetime (Years)	20	20	20
Weighted Cost of Capital	12%	12%	12%
Annual Payment ($/gal/yr)	$ 0.95	$ 0.41	$ 0.48
Annual Payment ($/yr)	***$ 36,708,107***	***$ 40,752,831***	***$ 119,402,981***
Non-Feedstock Ethanol Production Cost ($/gal)	**$ 1.32**	**$ 0.44**	**$ 0.56**

Technology is expected to change over time, with increasing efficiency and lower overall costs per unit. All potential changes are estimated.

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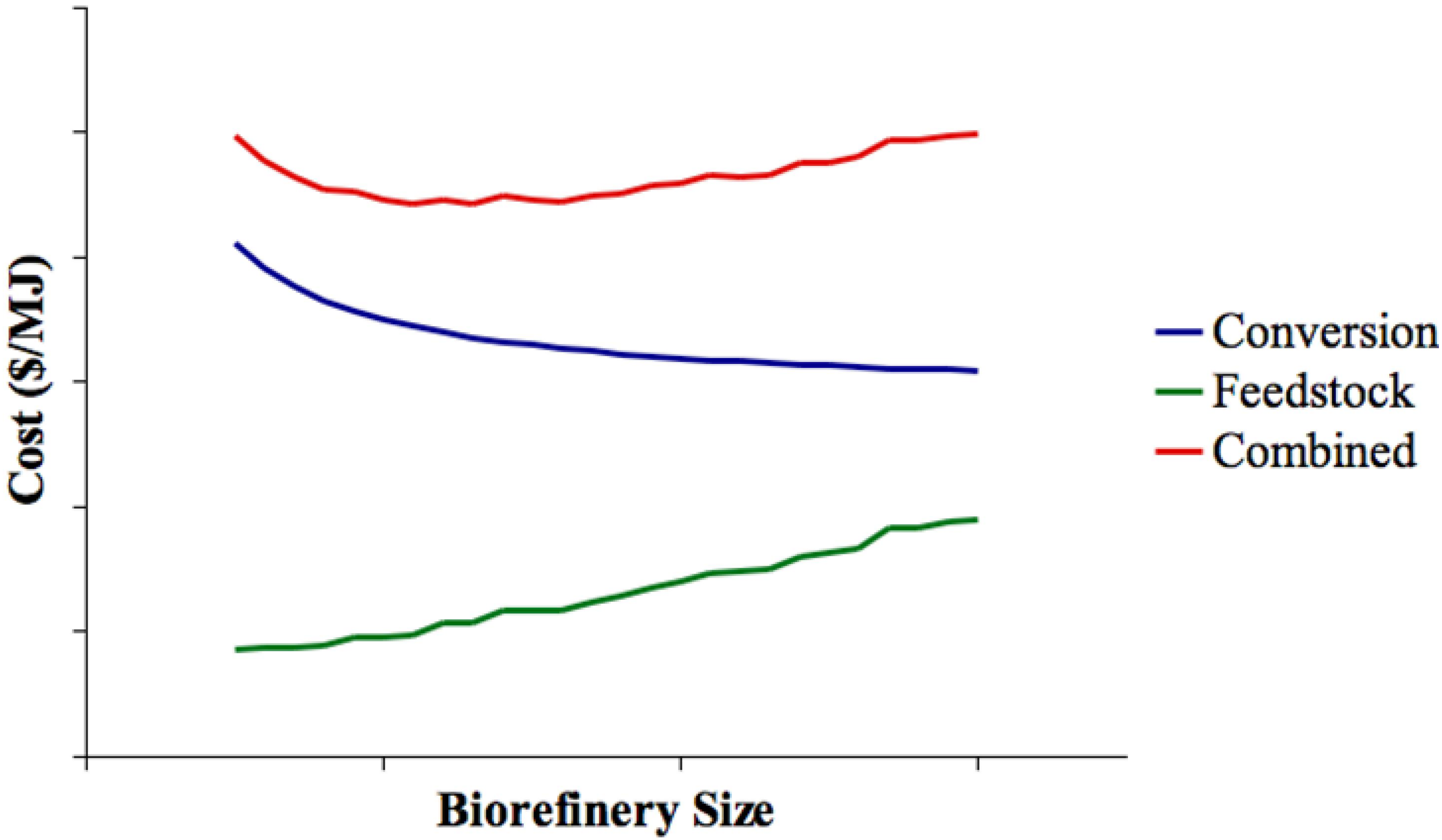
Importance of biorefinery size



Some Results: ECONOMIC POTENTIAL OF CALIFORNIA BIOMASS RESOURCES FOR ENERGY AND BIOFUEL

PIER Collaborative Report

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September 2008

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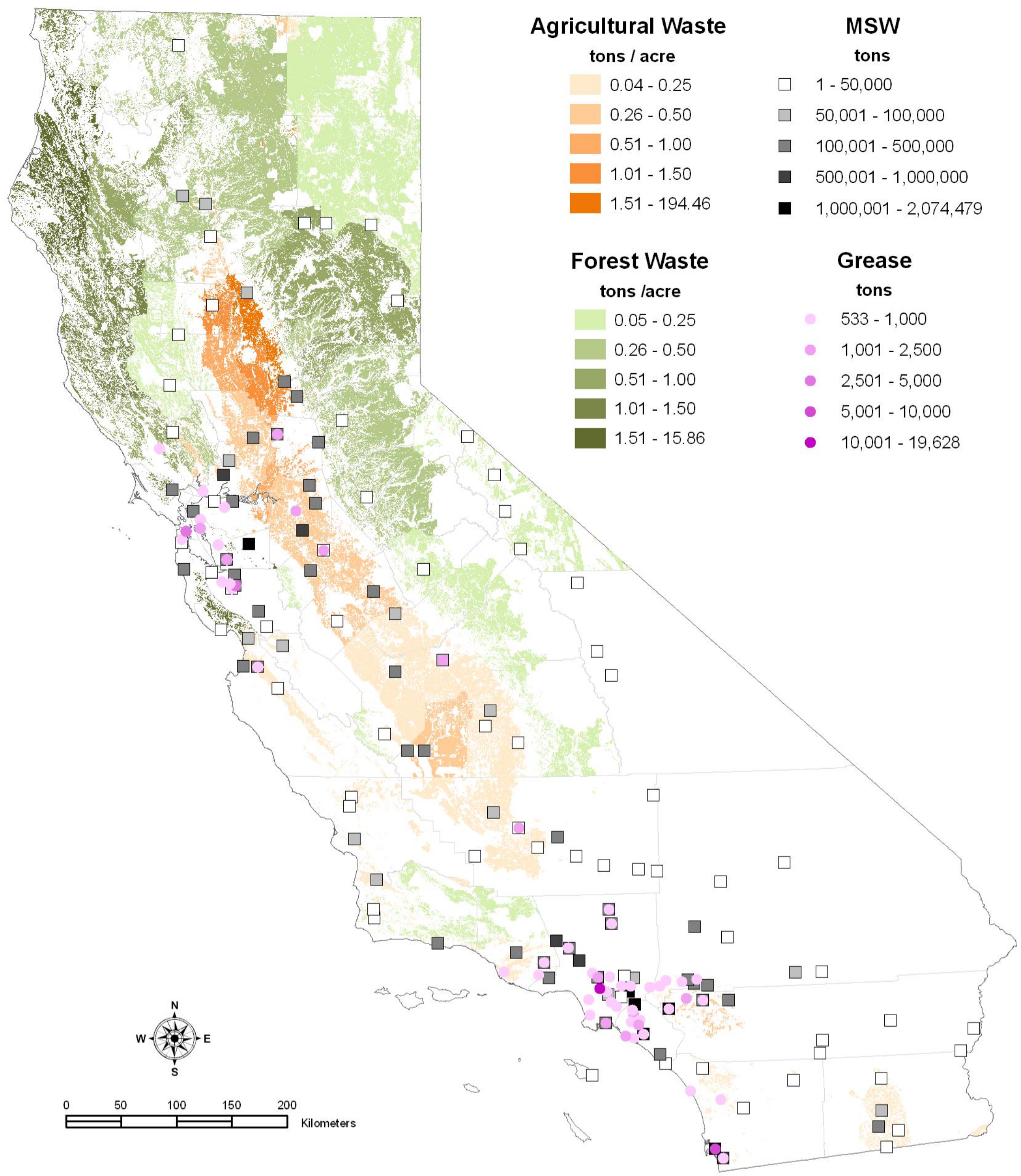
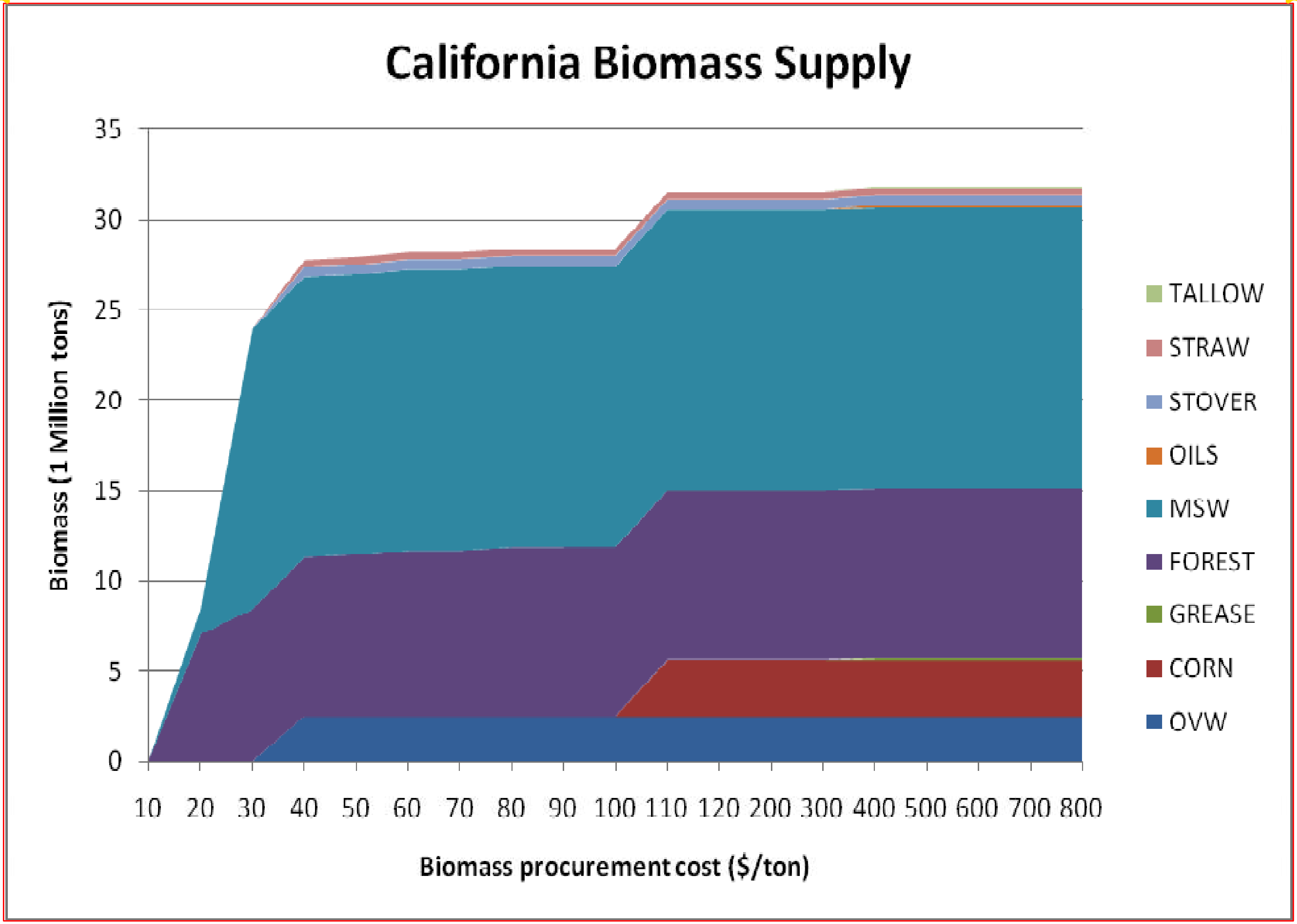
Distribution of biomass "waste" and approximate amounts





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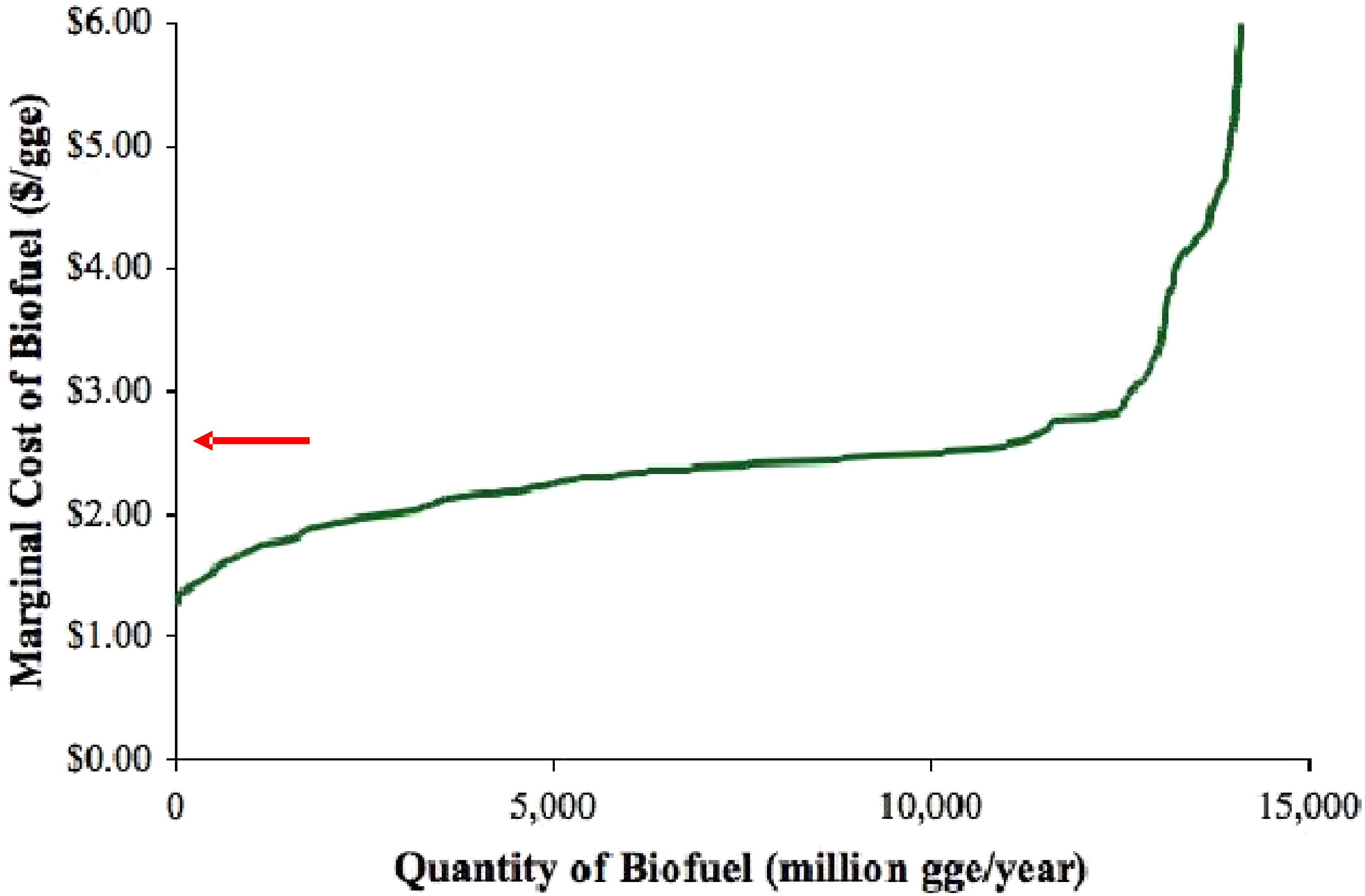
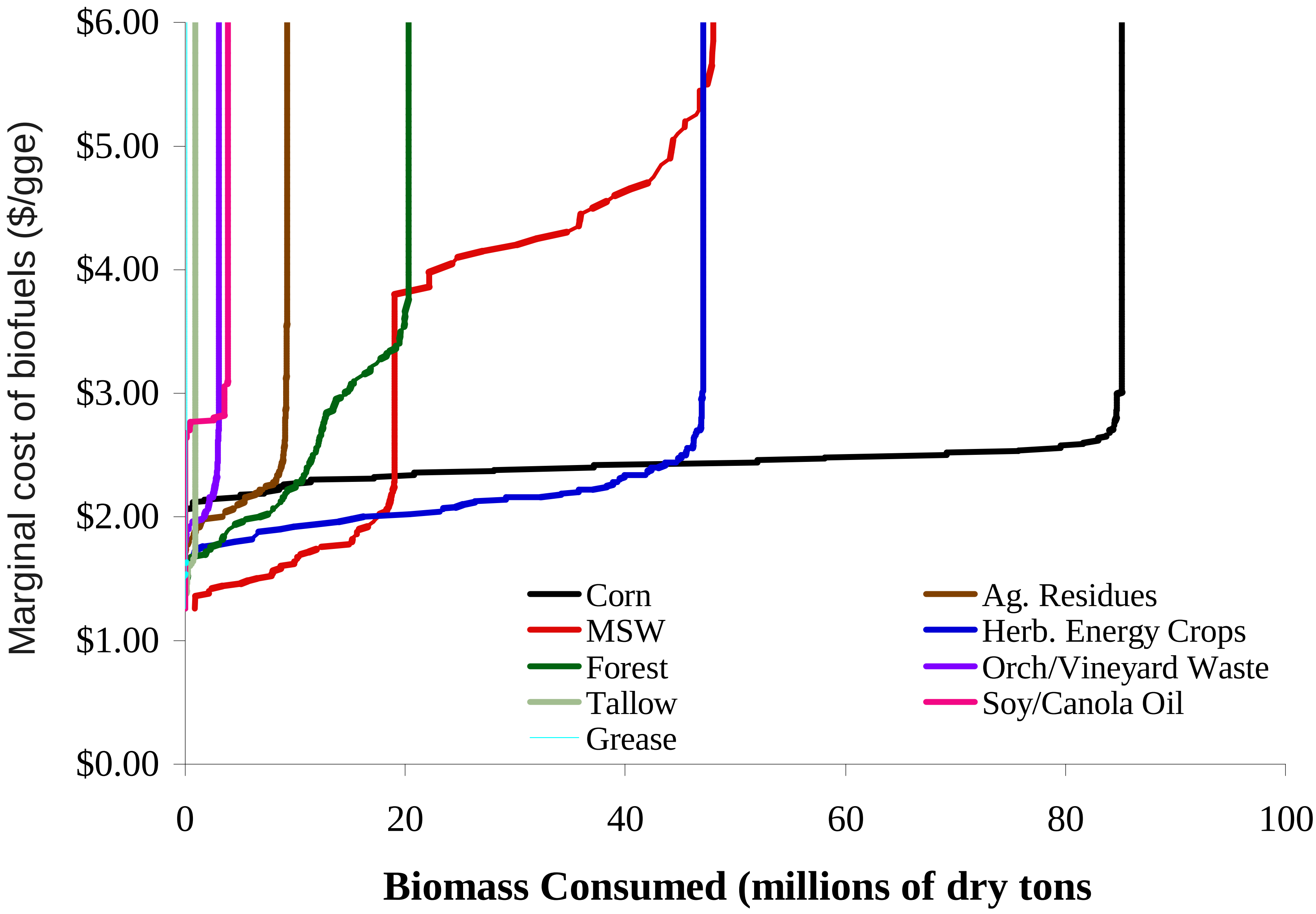
Supply Curve for All Biofuels Combined

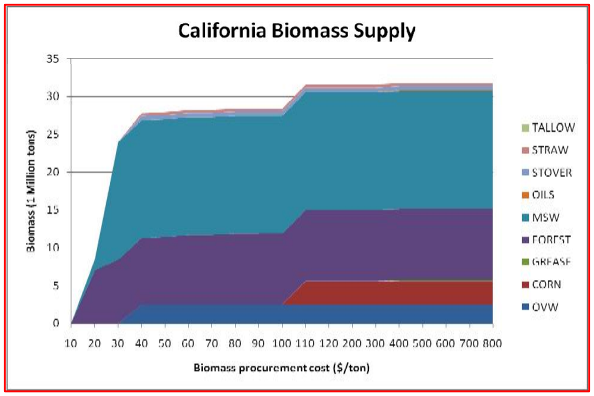


Type of Biomass Consumed

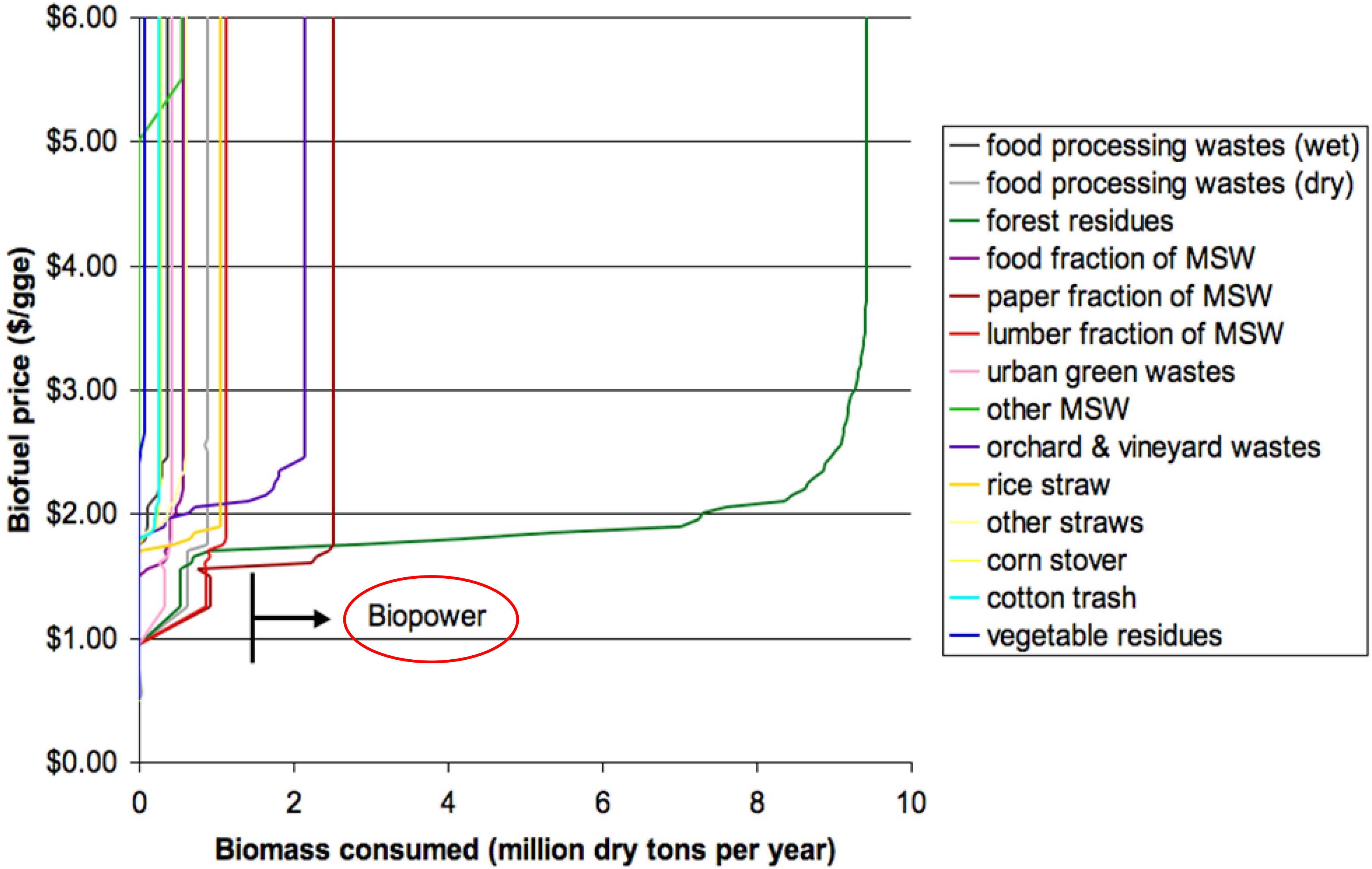


The state-wide supply in CA is most sensitive to:

- 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



Consumption of lignocellulosic biomass for energy production



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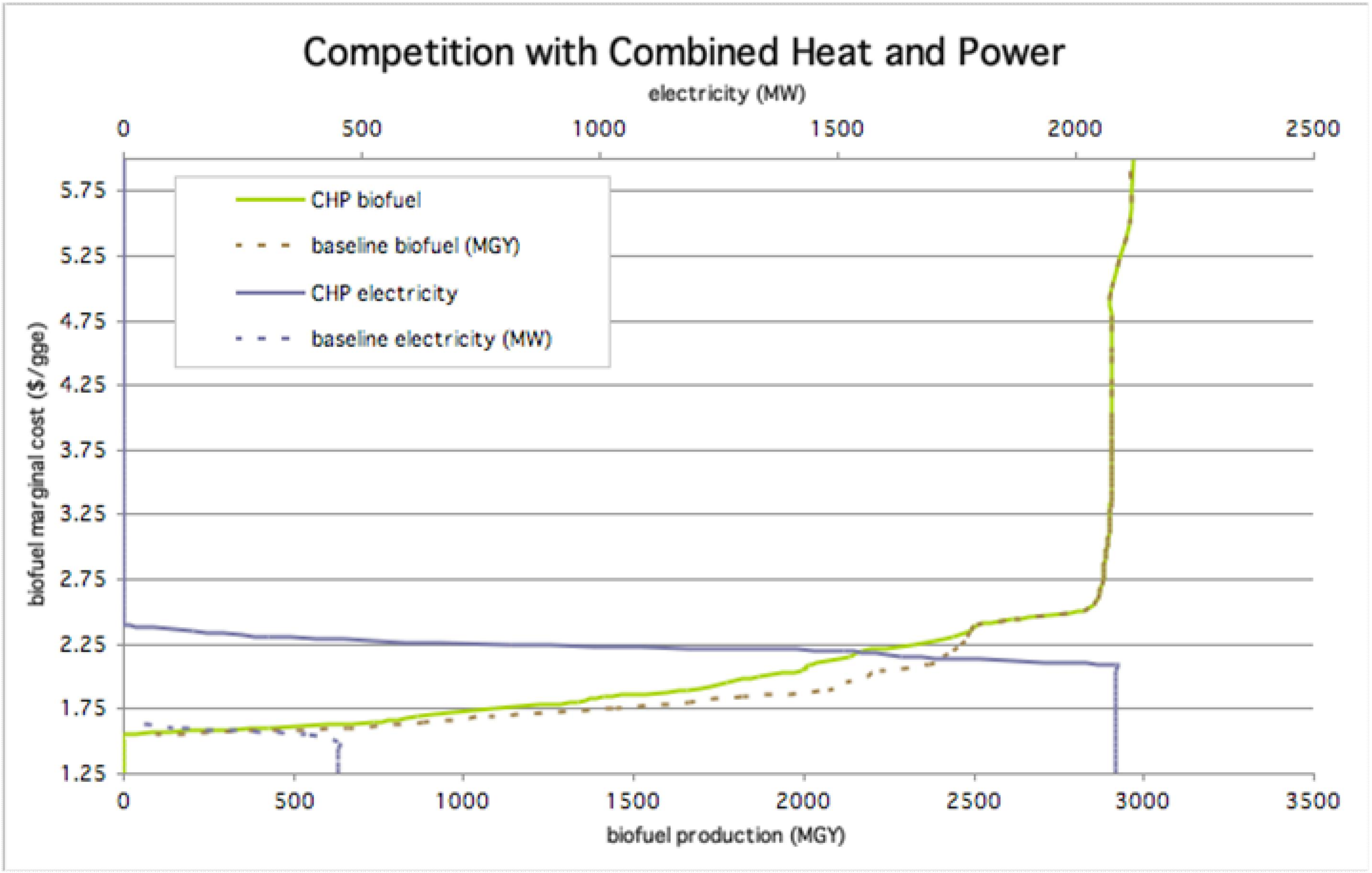
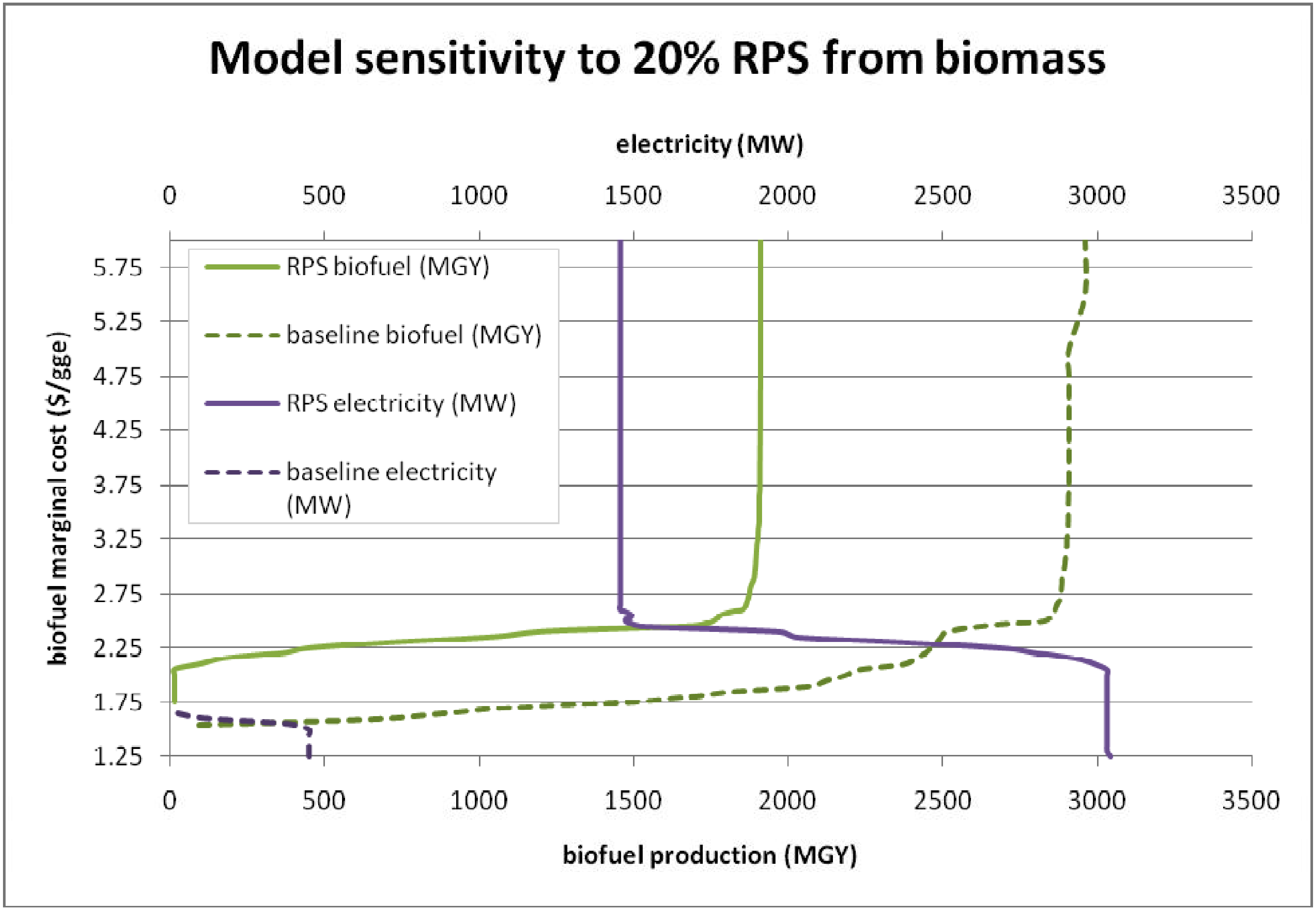
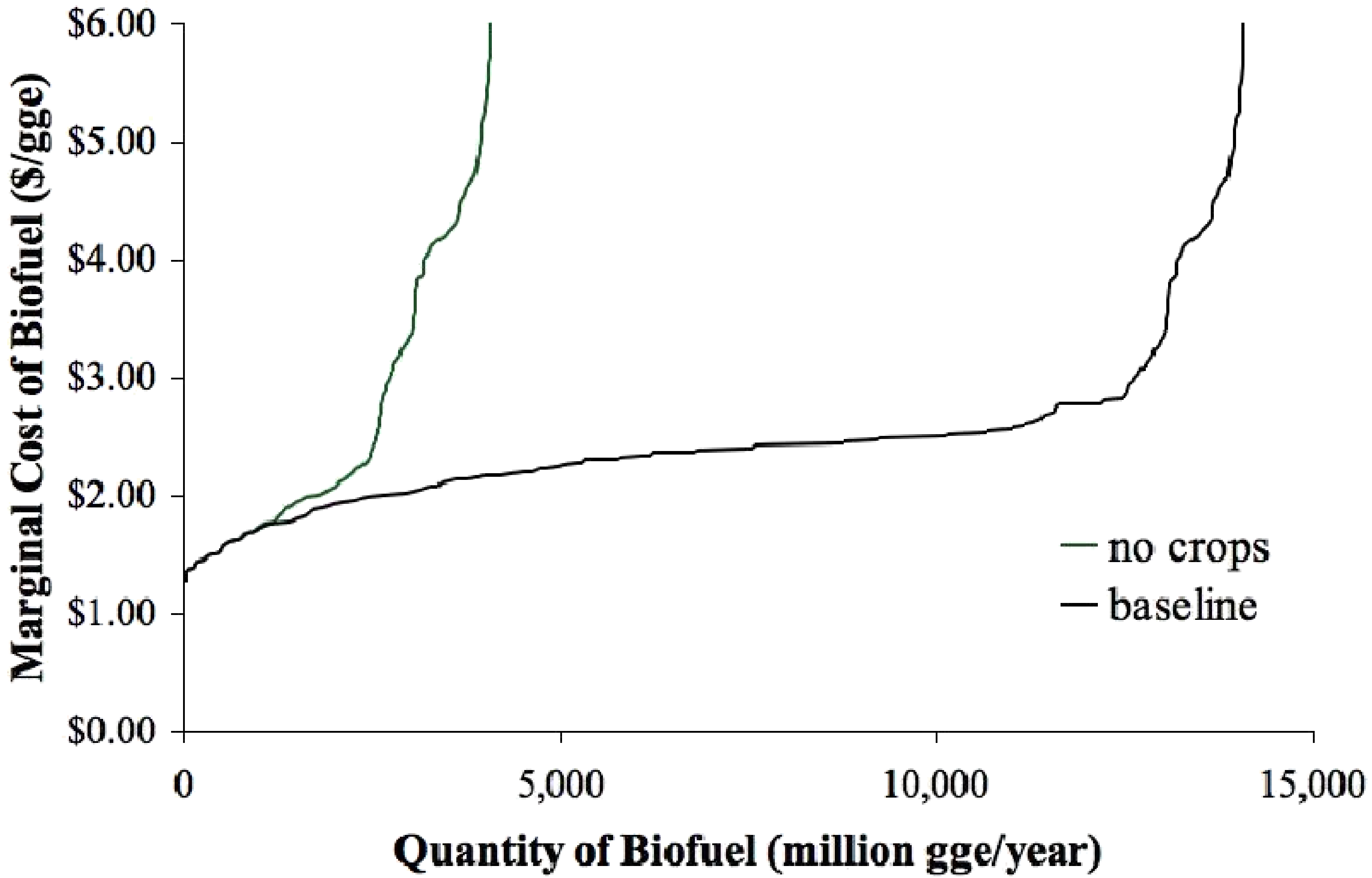
Competition between biofuels and biopower




Model sensitivity to 20% RPS from biomass
electricity (MW)
0
500
1000
1500
2000
2500
3000
3500
5.75
5.25
4.75
4.25
3.75
3.25
2.75
2.25
1.75
1.25
biofuel marginal cost ($/gge)
RPS biofuel (MGY)
baseline biofuel (MGY)
RPS electricity (MW)
baseline electricity (MW)
biofuel production (MGY)

Biofuel Supply without Dedicated Crops (WGA region)



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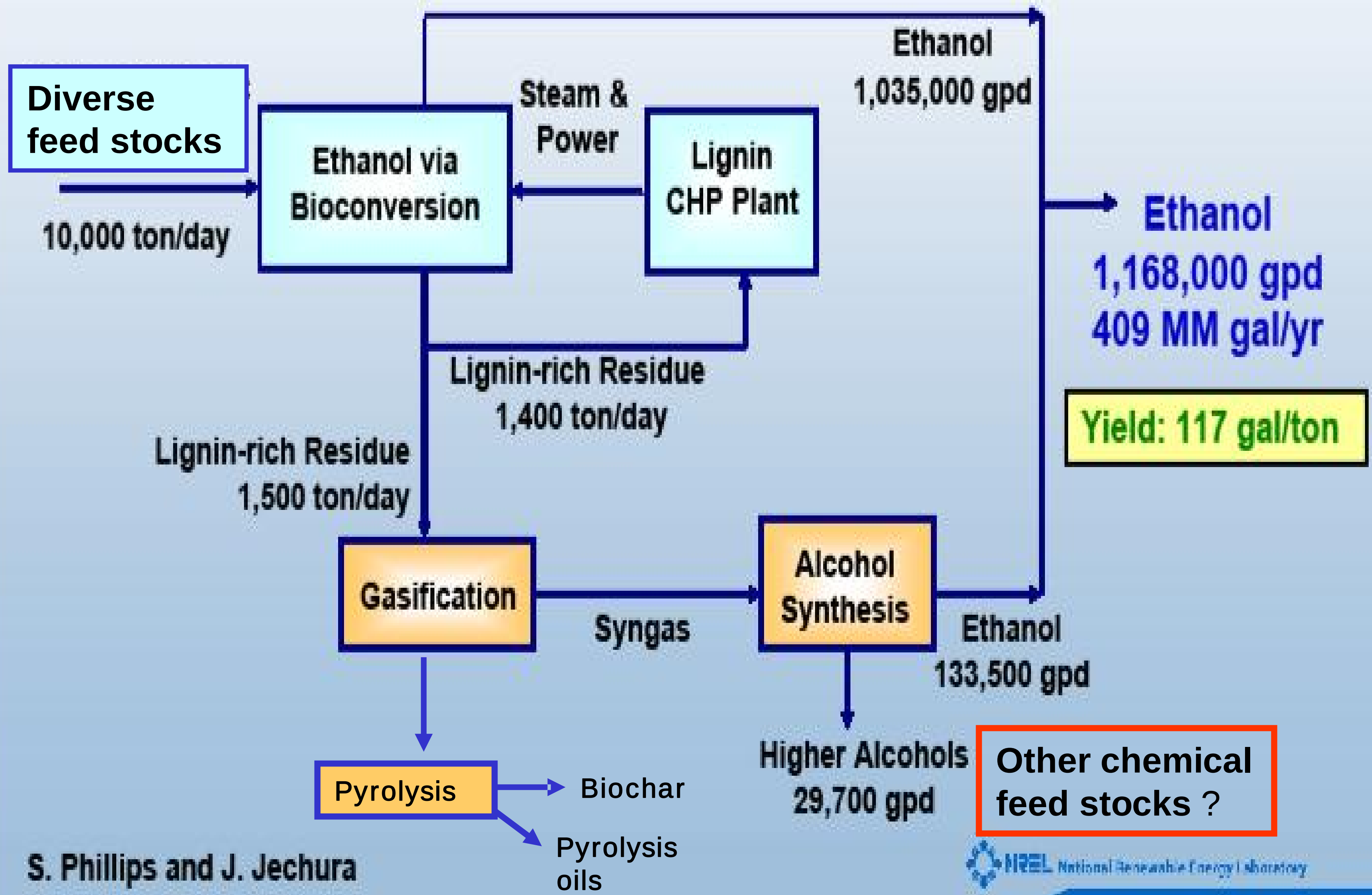
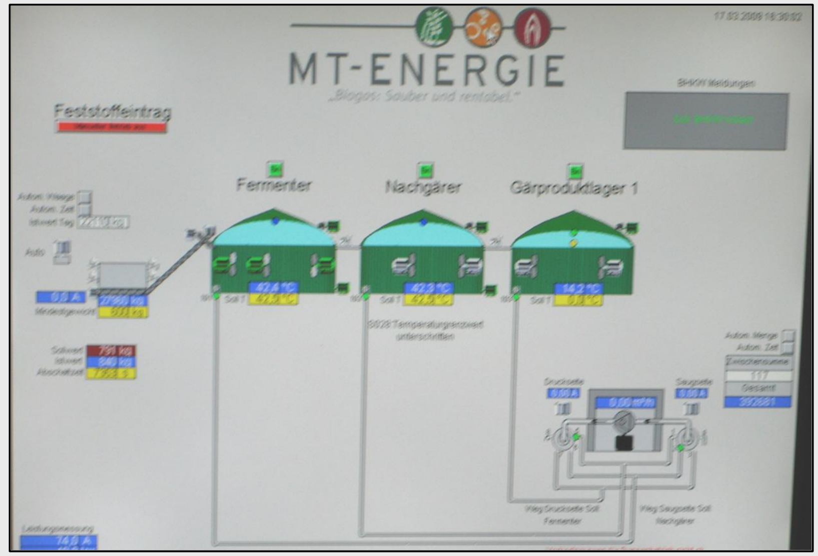
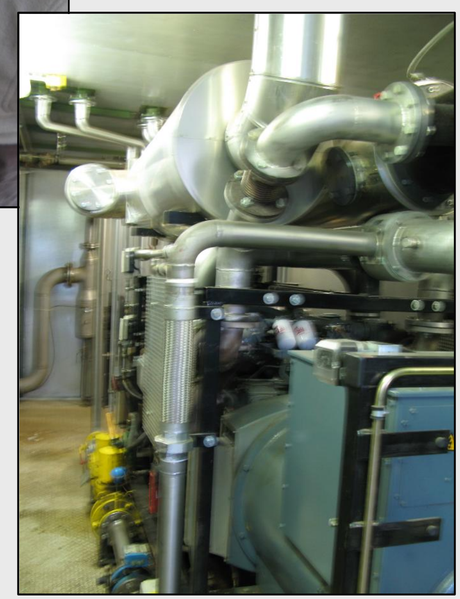
Potential future bio-refinery







Biogas to electricity facility in Germany, 2009

Summary

- At current prices and with current technology, there is a limited potential for biofuels production from biomass resources in the western U.S.
- More than two-thirds of the potential for biomass energy in the WGA region requires production of energy crops on agricultural lands, but this is not necessarily true for CA under the conditions modeled and assumptions used so far.
- The costs of production from advanced conversion technologies are still largely uncertain due to lack of commercial demonstration.
- The feed-in tariff price for electricity will strongly influence the relative competitiveness of conversion technologies.

6th Annual Forum

Evaluating the Net Environmental and Social Benefits of Biomass Energy

Cal EPA Building

(Sher Auditorium)

May 12/13, 2009

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