Biomass: Building a California Bioeconomy with Hulls and Shells

December 7, 2016

california almonds

Almond Board of California

Biomass: Building a California Bioeconomy with Hulls and Shells

Karen Lapsley, Almond Board of California (Moderator)

Bill Orts, USDA Albany

Dr. Glenda Humiston, UC Davis

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Almond Board of California

Karen Lapsley,
Almond Board of California

Bill Orts,
USDA Albany





Adding Value to Almond Co-Products

William Orts – Research Leader, Bioproducts

December 7, 2016

Our USDA Research Mission:

Add value to agricultural products to help the rural economy

Agricultural Research Service

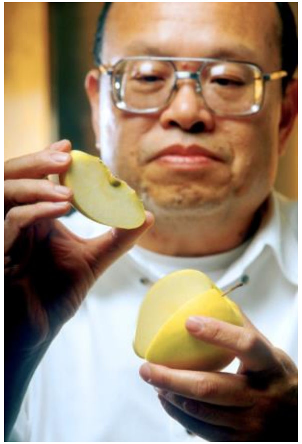
USDA Western Regional Research Center

Albany, California

~450 people
~50 in Biofuels/
& Bioproducts

Known for biotechnology, especially crop biotech.

Packaged Fruit Slices



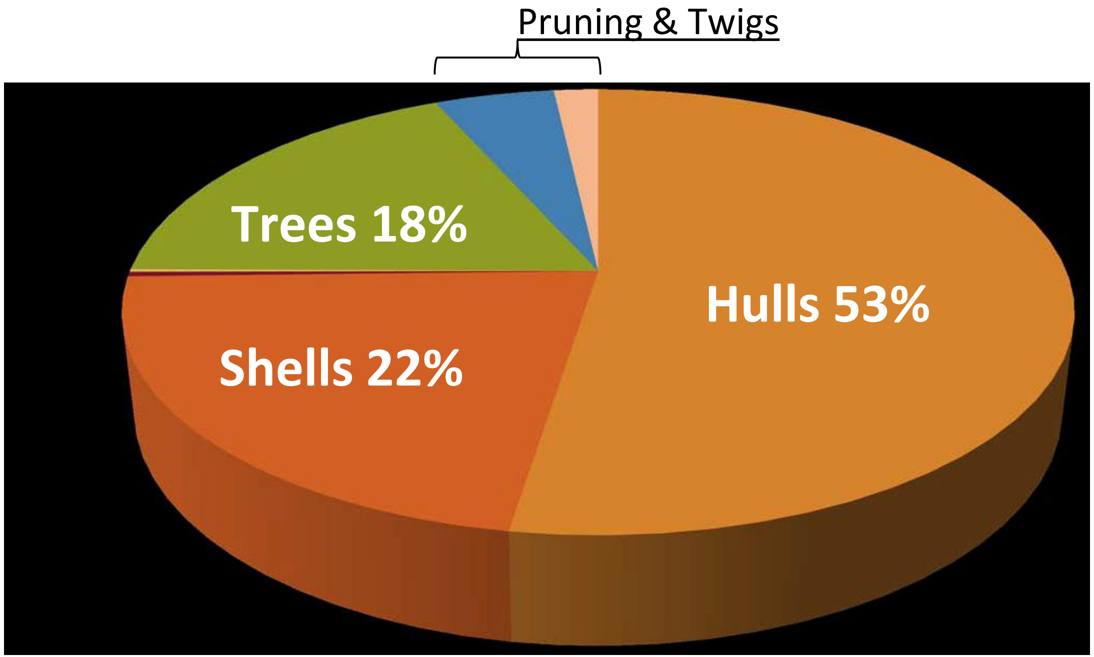
Mantrose-Haeuser Co., Inc.

McDonald's sells 65 million lbs/yr of apples in the U.S.

USDA continues to collect royalties

Almond Co-Products

Almond Biomass ⇔ 2.4 million Tons/yr



SOURCE: Guangwei Huang, CA Almond Board, 2015 data, dry mass basis

Biomass from Shellers/Hullers

	Wet Mass (MT)	Dry Mass (MT)
Hulls	1,416,413	1,235,112
Shells	538,174	520,414
Twigs	66,972	42,192
Totals	2,021,558	1,797,718

SOURCE: Guangwei Huang, CA Almond Board, 2015 data, dry mass basis

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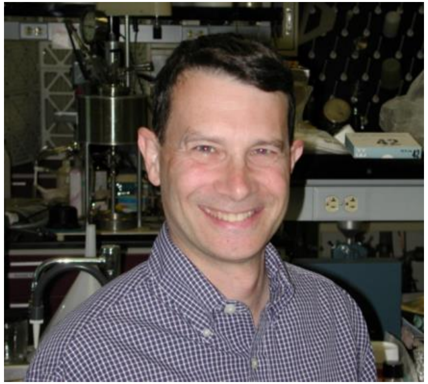
Ethanol Production from Hull Sugars?

Kelly Covello

Offeman, R.D., Holtman, K.M., Covello, K.M., Orts, W.J. Almond hulls as a biofuels feedstock: Variations in carbohydrates by variety and location in California. *Industrial Crops & Products* 54: 109-114, 2014.



Rick Offeman

Kevin Holtman

★ Locations of hulling plants providing samples from 2012/13 season

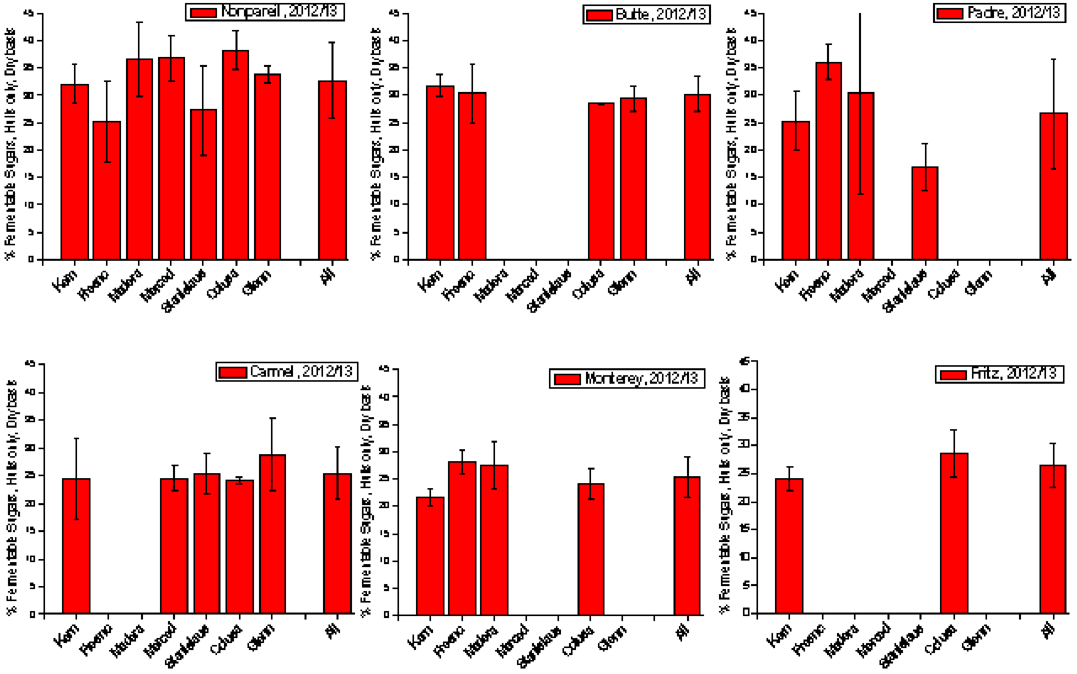
Sugars in Almond Hulls

	% Sucrose	% Glucose	% Fructose	% Fermentable sugars	% Xylose	% Inositol	% Sorbitol	% Total sugars
Non-Pareil	3.84	17.61	15.04	36.49	1.03	2.36	4.37	44.24
Butte/ Padre	0.38	12.87	12.55	25.80	0.77	0.99	2.84	30.40
Cali-fornia	0.14	6.79	3.53	10.46	0.64	1.89	1.76	14.75

Almond Hull Sugars

% Fermentable Sugars

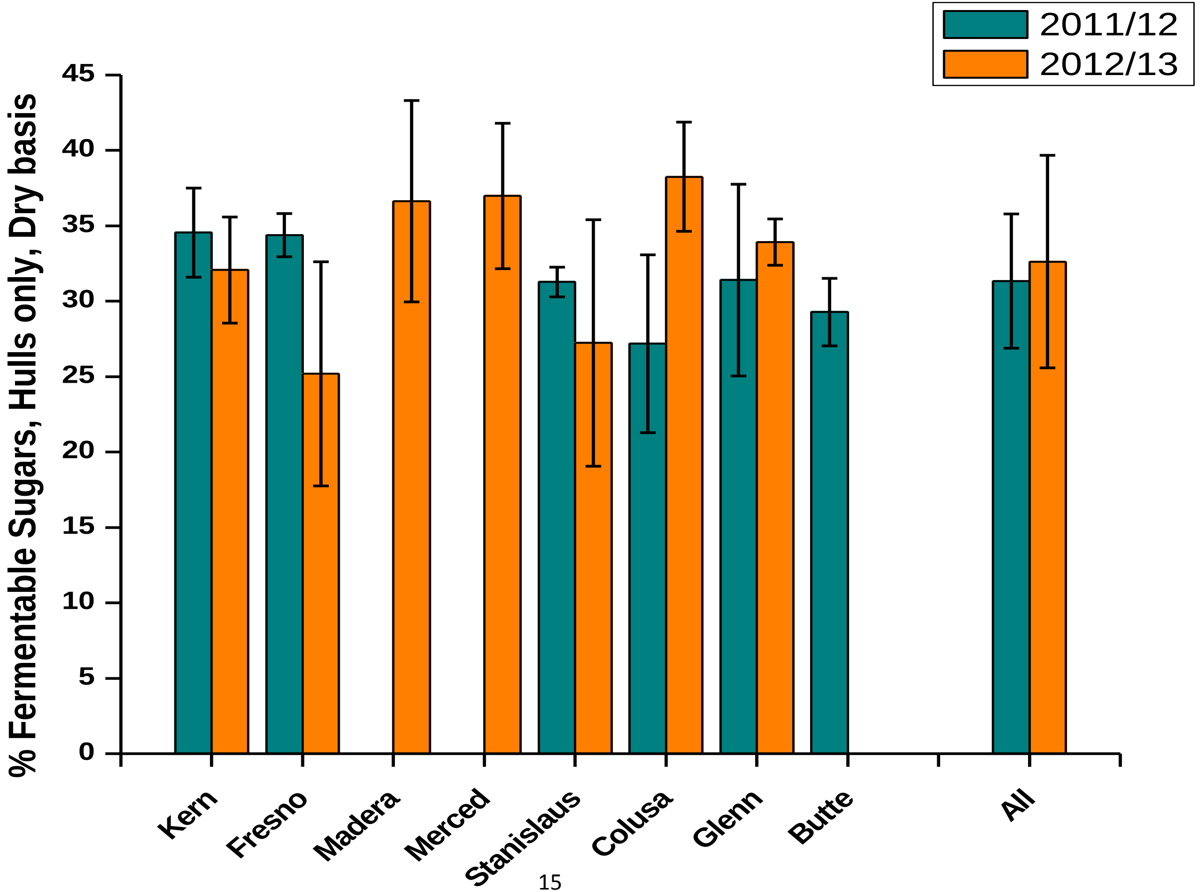
By variety and county - hulls only, dry basis, 5 samples per bar



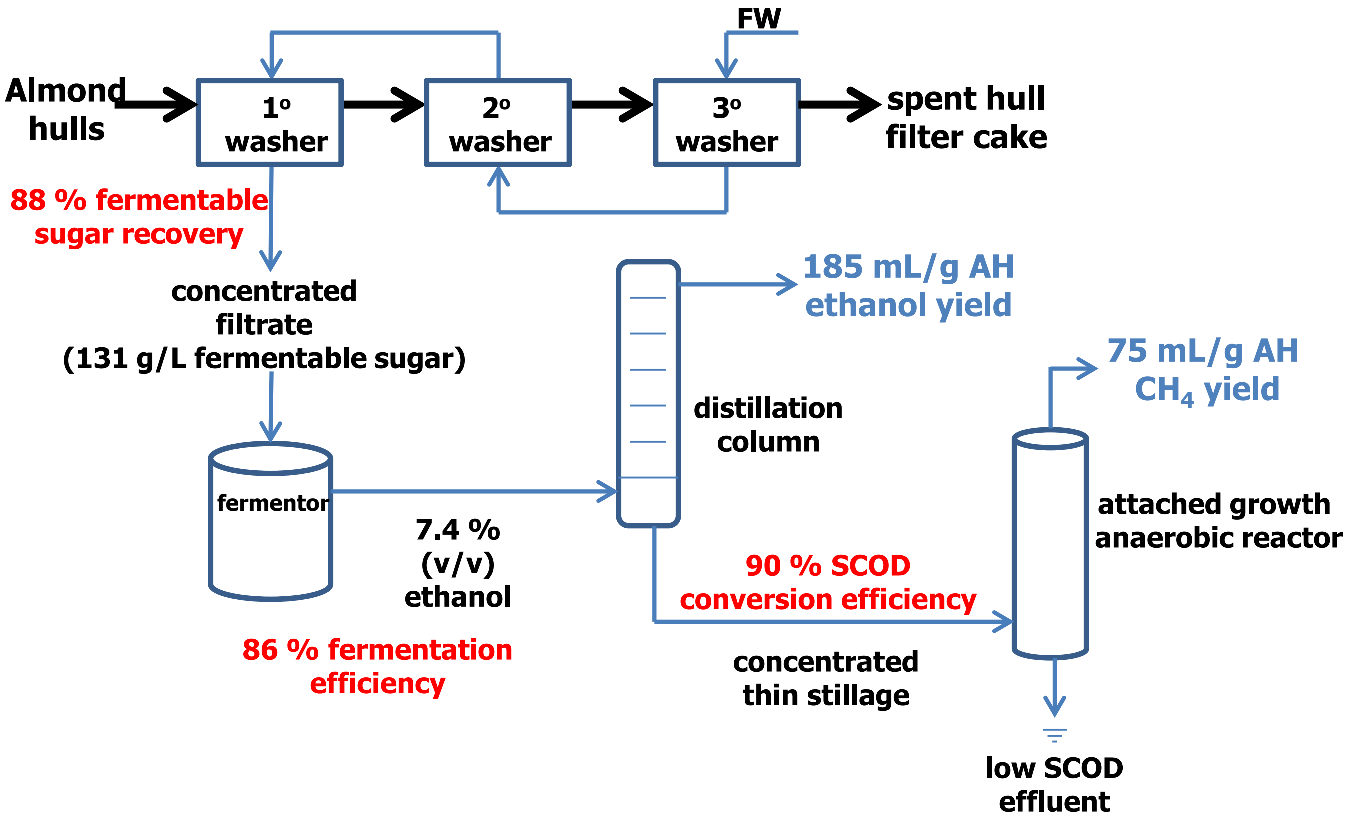
SOURCE: Offeman, Holtman *et al. (2014)* Ind. Crops & Prod. 54:109-114

Nonpareil, 2011/12 Season vs. 2012/13 Season

% Fermentable Sugars, Dry Basis (ave 5 samples each county)



Integrated Ethanol Plant



Ethanol Production from Hull Sugars?

Raw Feed	$/ton	% sugar	Sugar (lbs)	Ethanol (gal)	$/gal Ethanol
Corn kernels	132		1286	95	1.38
Sugar beets	39	18.5	370	27	1.42
Molasses (feed)	180	79.5	1590	118	1.52
Sugar cane	39	14	280	21	1.88
Almond hulls	**150**	**31**	**624**	**40**	**3.83**

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Almond Hulls vs. Sugar Beet Cossettes

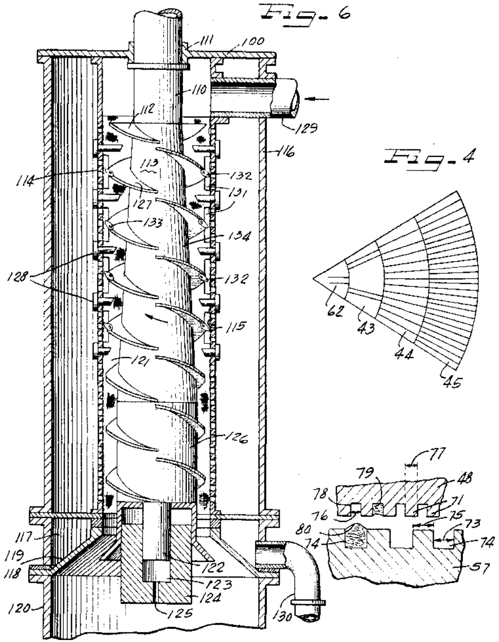
Almond Hulls
30 % fermentable sugar

Beet Cossette
15 % fermentable sugar

Sugar Beet Extraction ⇔ Hull Extraction?

cossette mixer

diffusion tower



From US Patent # 3,477,873

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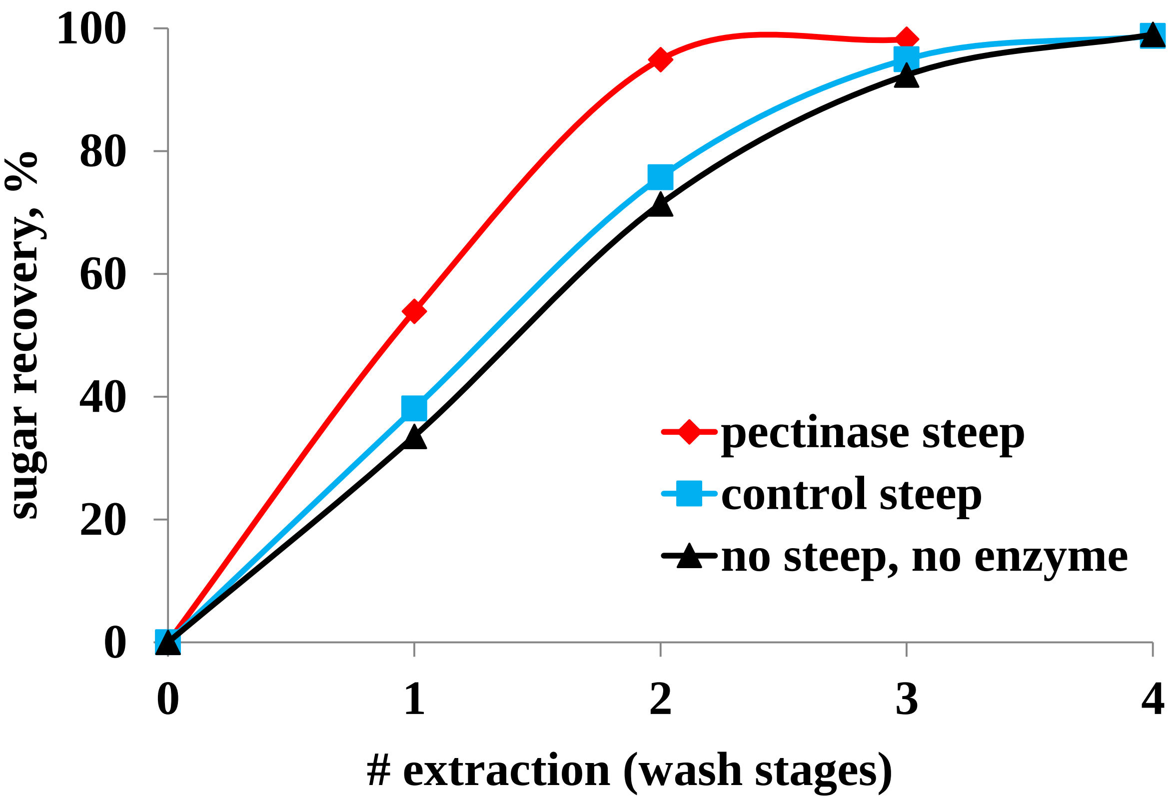
Comparison of Extraction Approaches



Processing Hulls to Sugars

- ONE IDEA: Make a concentrated sugar syrup
  - Countercurrent extraction with hot water
  - Concentrate syrup with multiple effect evaporators

- ETHANOL?
  - Ship to existing ethanol plant to co-feed with corn

- FOOD OR FEED SYRUP: ????

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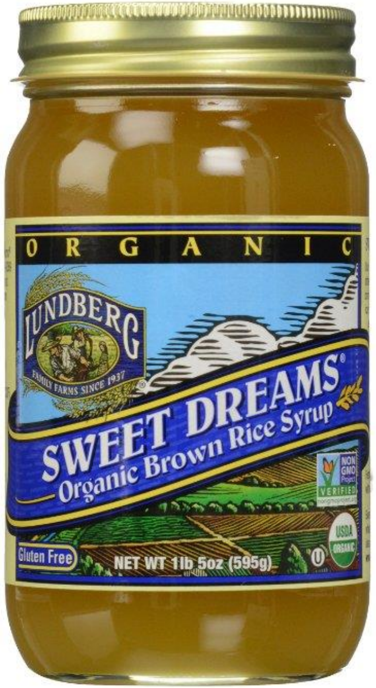
Comparison of Extraction Approaches



PHOTOS: AP, NUTRAVISTA.COM

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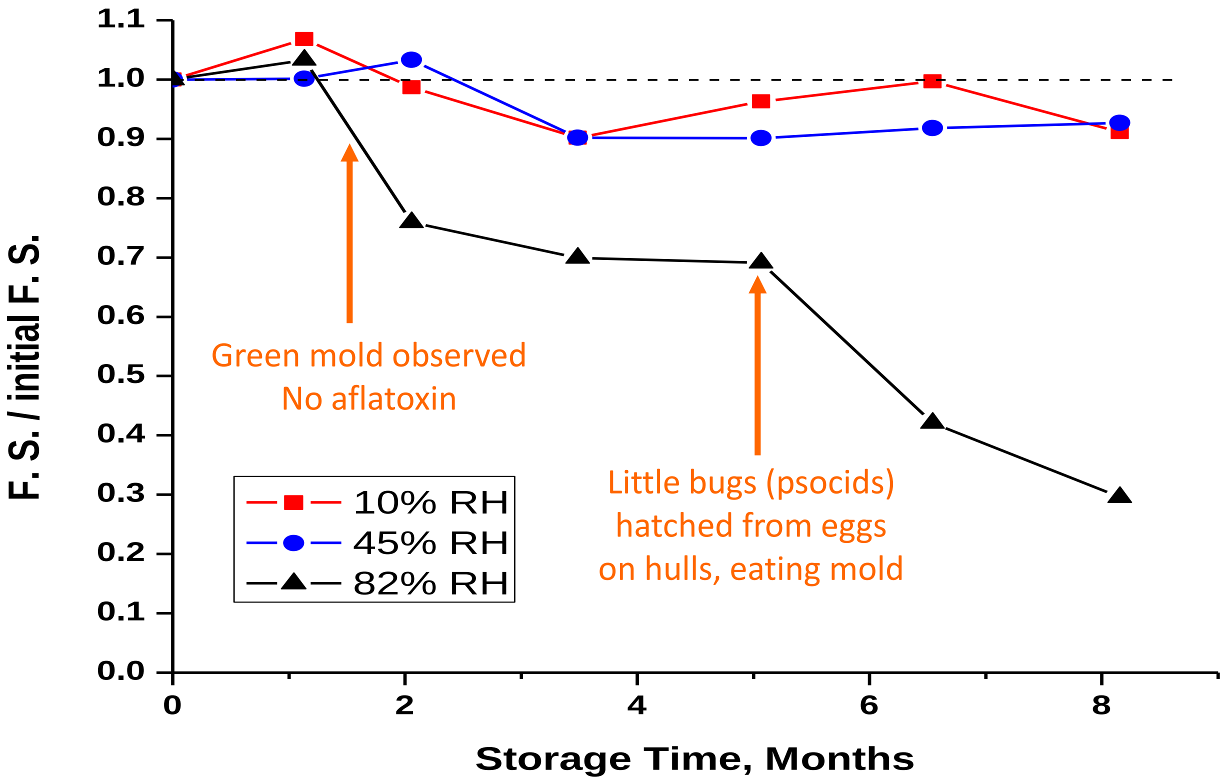
Nonpareil Lab Storage Tests

Normalized to starting concentrations

Each point average of 3 samples (North State, Cortina, Central hulls)



Spent Hulls ⇔ Uses?

Key issue: Not practical to ferment hulls directly

- Hulls absorb 4-8 times weight of water
  - Highest stirrable slurry is ~15% hulls in water.

Water: 90% 80% 70% 60% 50%

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Possible Outlets for Spent Hulls

Characteristics

- High in cellulose, lignin, hemicellulose; no sugars
- Milled to < 8 mesh, and full of water **(~93% moisture!)**

Cattle feed

- Feed value of dry spent hulls low (UC Davis analysis)
- As wet spent hulls, no monetary value
- Cost to dry the wet spent hulls too high: ~$150/ton

Anaerobic digestion to biogas

- Compressed natural gas (CNG) for local use
- BMP ~150 mL CH_4/T spent hulls
- ~50% methane, balance carbon dioxide. Upgrading needed

Boiler fuel or gasification for heat/power

- Same drying issue

Hydrothermal carbonization????

- Process suited specifically for high moisture wastes
- Produces biochar material

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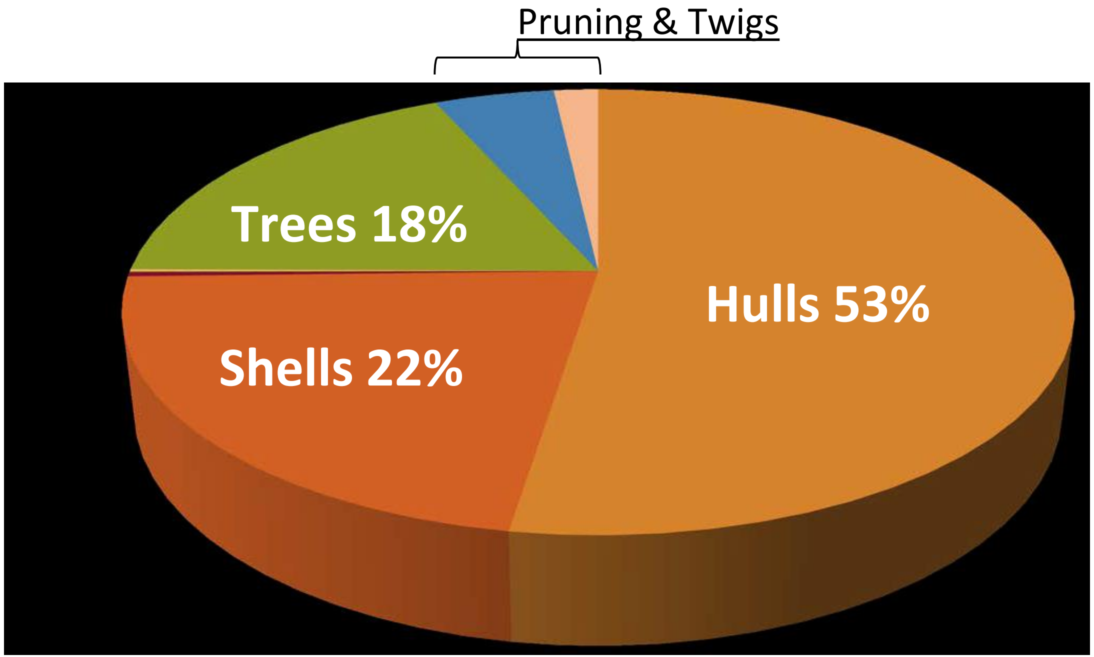
Almond Co-Products

Almond Biomass ⬄ 2.4 million Tons/yr



SOURCE: Guangwei Huang, CA Almond Board, 2015 data, dry mass basis

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Almond Shell Characterization

Previous work at USDA

Fraction	Average (g/kg)	Std dev.
Ash	34	0.07
Hot water extractives (100°C)	105	0.35
Klason lignin	237	0.53
Glucan	228	0.48
Xylan	329	0.45
Galactan	45	0.04
Others	24	0.05
Mass balance	1002	0.11

***Gong, D.C.; Holtman, K.M.; Franqui-Espiet, D.; Orts, W.J.; Zhao, R.** *Biomass and Bioenergy* 35 (10): 4435-4441 (2011).

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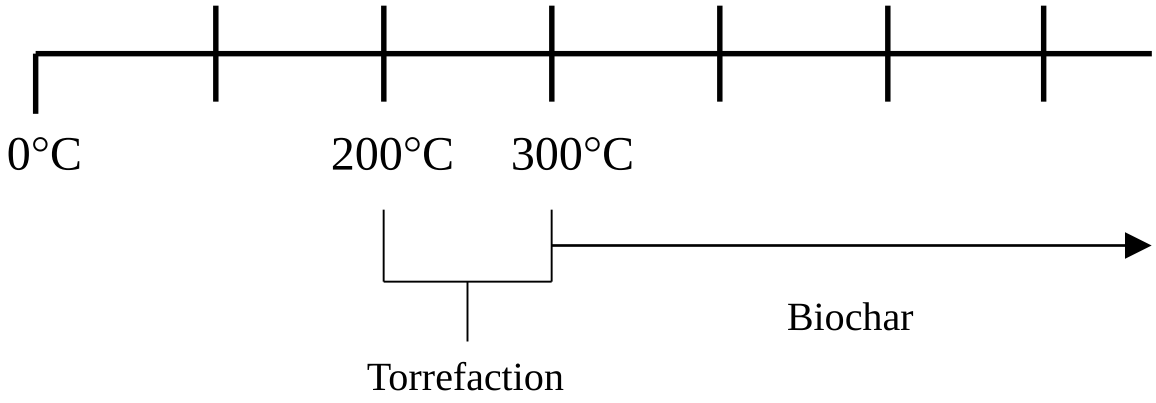
TORREFIED FILLERS FOR PLASTICS

TO STUDY THE EFFECTS OF TORREFIED FILLERS ON THERMAL AND MECHANICAL PROPERTIES OF PP

Torrefaction ⇔ "Burning" in Limited Oxygen



- Torrefaction: 200ºC to 300ºC under inert atmosphere
- Removes moisture and volatiles → stable to microbial attack
- Densify torrefied biomass → cheaper to transport
- Energy value ~ low rank coal

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Torrefaction: Conversion of Biomass to "Biocoal"

RENEWABLE FUEL TECHNOLOGIES

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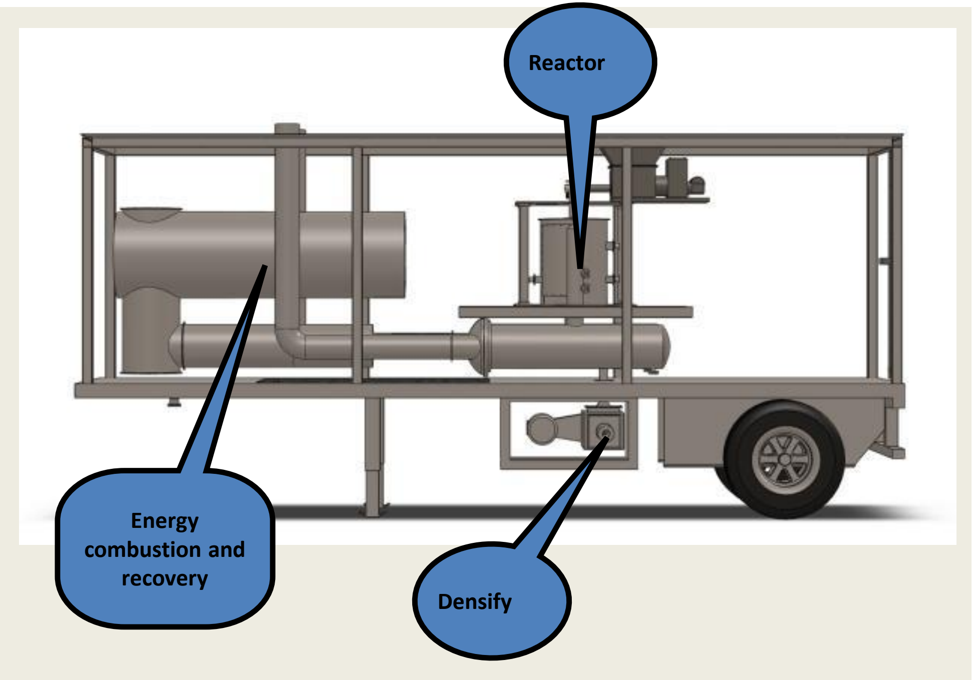
Built a portable 8 tons/day unit to produce BioCoal on location.

The 28' unit is mounted on an 18-wheel trailer

Almond hullers processing plant, Los Banos, CA



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RENEWABLE FUEL TECHNOLOGIES

http://renewablefueltech.wordpress.com/

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Torrefied Almond Shells

230º C

260º C

290º C

60 min 80 min 100 min

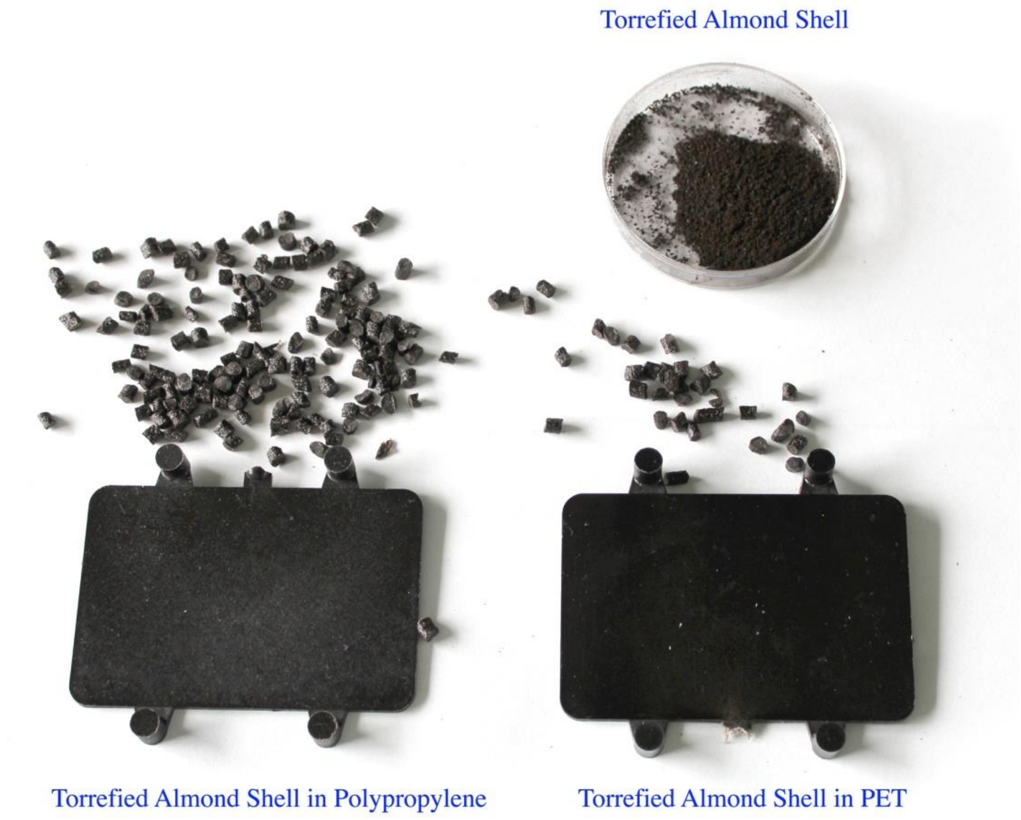
Making plastic parts with almond shell additives

Torrefied biomass:

- Almond shells at 280°C
- Wood at 280°C
- Almond shells at 300°C

Polymer: Polypropylene

Torrefied Biomass-Polymer Composites

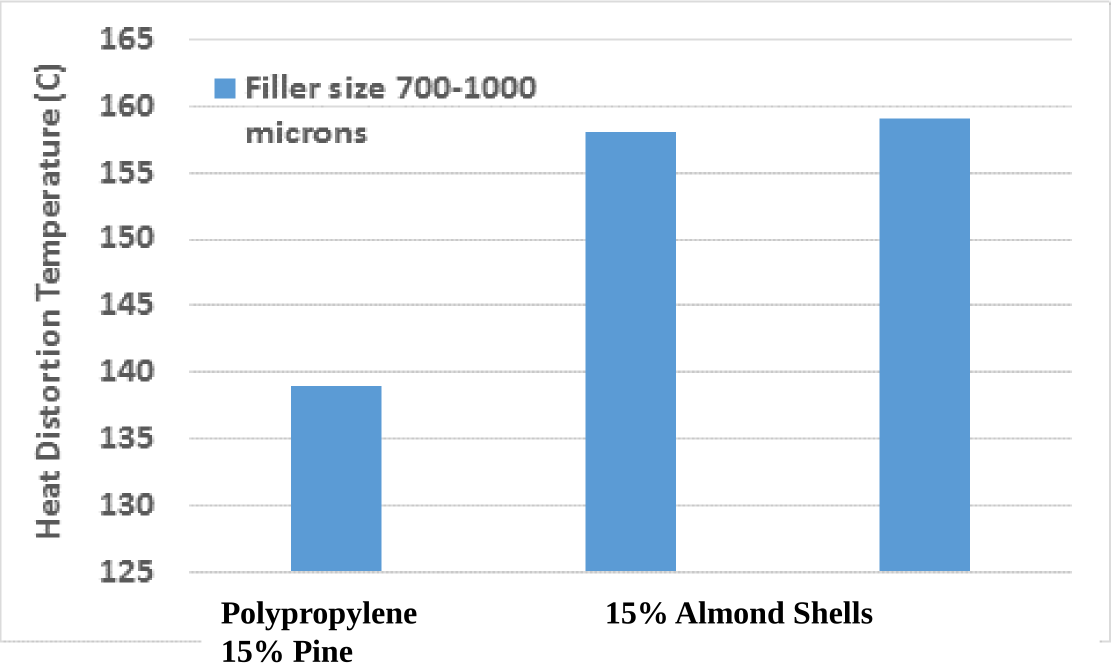


– Alternative to wood-polymer composites

Heat Distortion Temperature

a.k.a. ⇔ the softening point

Temperature at which material deforms under specific load



Heat Distortion Temperature

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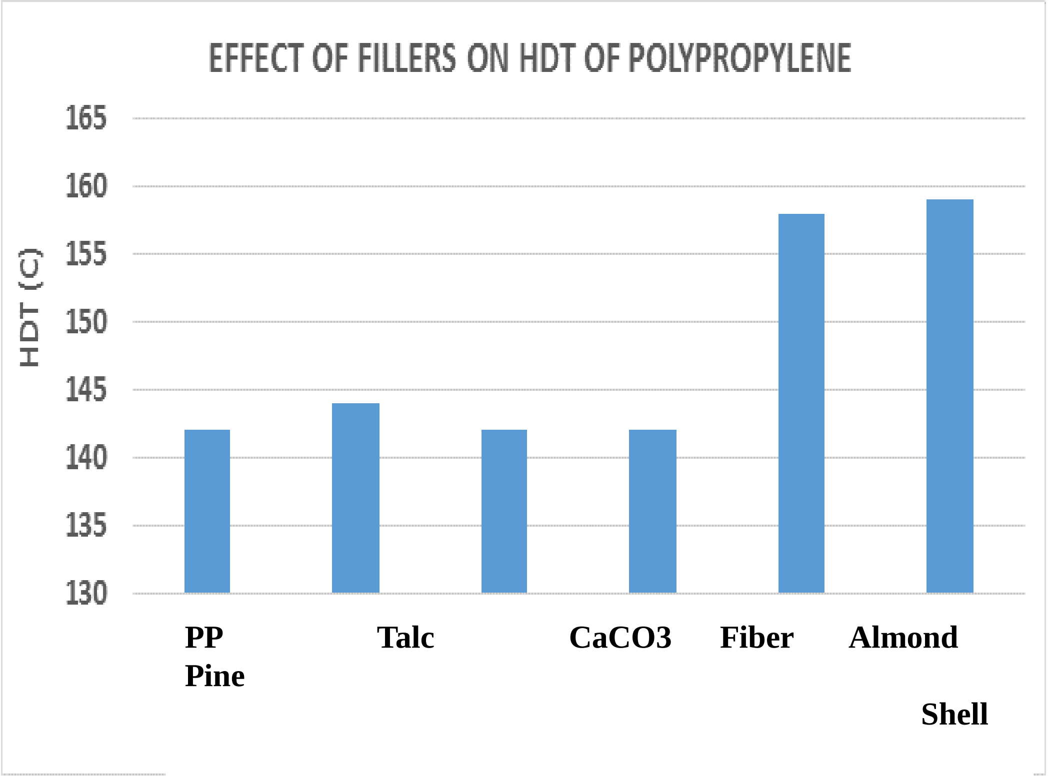

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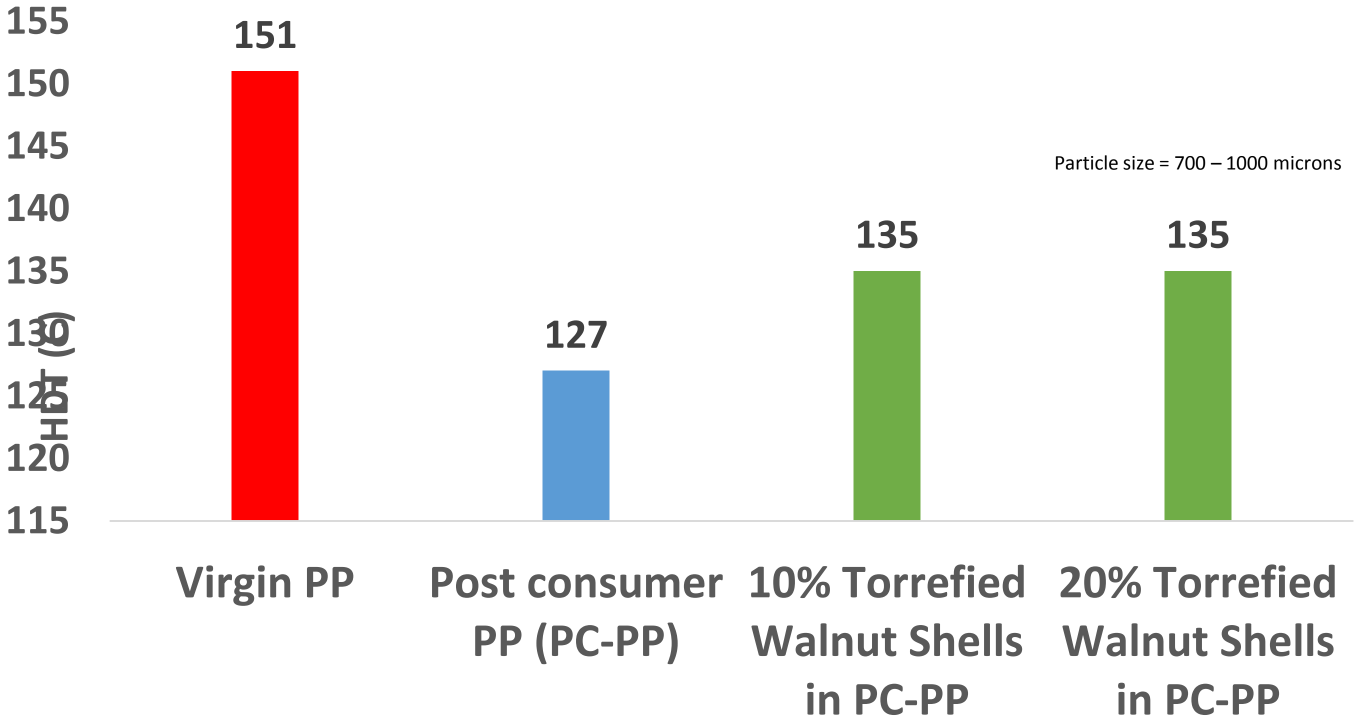
EFFECT OF TORREFIED FILLERS ON HEAT DEFLECTION PROPERTIES OF PP



- SIGNIFICANT DIFFERENCE IN HDT BETWEEN VIRGIN AND RECYCLED PP
- ADDITION OF TORREFIED FILLERS IMPROVED THE PROPERTY OF RECYCLED PP

PP grades provided by Kevin Stevenson, FDS MFG

Torrefied Biomass in Plastics

F-D-S Manufacturing Co.
Since 1950

THERMALLY TREATED BIOMASS FOR OTHER APPLICATIONS

TIRE INDUSTRY, FILTERS, SOIL ADDITIVES, BIOENERGY

ELEMENTAL ANALYSIS OF CARBON BLACK & TORREFIED BIOMASSES

SAMPLE	% C	% H	% O	% N	% Si
CARBON BLACK	88.48	0.91	4.74	0.19	<0.05
TORREFIED WALNUT SHELLS	62.51	5.68	28.84	0.49	1.06
TORREFIED RICE HULL	40.70	4.22	26.14	0.45	10.77

Torrefied biomasses are <u>oxygen-rich</u>

Torrefied rice hull <u>contains</u> ~ 11% silica

ELEMENTAL ANALYSIS OF BIOMASS

TORREFIED BIOMASS	% C	% H	% O	% N	% Si
SORGHUM	54	3	20	1	5
ALMOND	54	6	36	1	1
WALNUT	63	6	29	0.5	1
PISTACHIO	65	5	32	0.4	0.2
RICE HULL	41	4	26	0.5	11

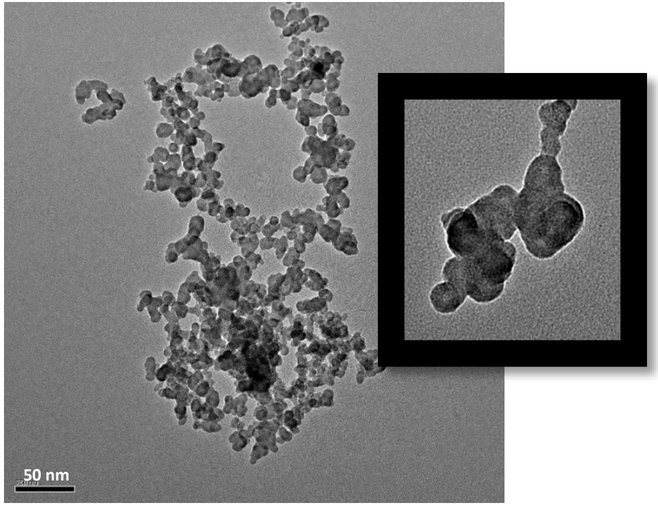
- TORREFIED BIOMASS RETAIN FUNCTIONALITY AFTER PRETREATMENT
- SORGHUM AND RICE HULL CONTAINED SILICA

PARTICLE SIZES

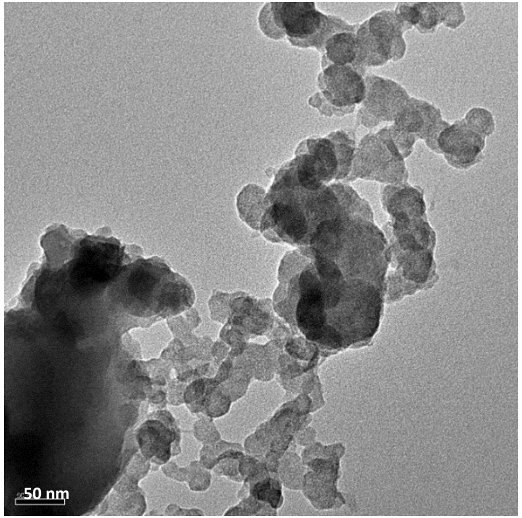
TORREFIED BIOMASS	AVERAGE PARTICLE SIZE (microns)
SORGHUM	3
ALMOND	150
WALNUT	150
PISTACHIO	150
RICE HULL	250

- SAMPLES WERE GROUND USING THE CRYO-GRINDER
- SORGHUM WAS TORREFIED AT ANOTHER LOCATION. IT MAY HAVE BEEN TORREFIED AT A HIGHER TEMPERATURE, THUS INCREASING IT'S GRINDABILITY

TEM OF CARBON BLACK & TORREFIED SORGHUM



CARBON BLACK



TORREFIED BIOMASS

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CONFIDENTIAL

CALORIFIC VALUES

BIOMASS	BEFORE TORREFACTION (J/g)	AFTER TORREFACTION (J/g)
SORGHUM	No value from Joe James	18,928
ALMOND	17,319	21,205
WALNUT	18,574	23,810

- HOUSE COAL HAS A CALORIFIC VALUE **30,000 J/g**
- ENERGY DENSITY OF INCREASES AFTER TORREFACTION

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The New York Times

Making Tires From a Desert Shrub Found in the U.S.

By DIANE CARDWELL AUG. 18, 2015

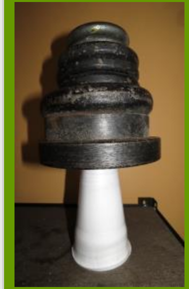
USDA researchers are partnering with tire companies to provide a domestic source of rubber to make US-produced rubber tires.

Colleen McMahan

USDA

Grow Plastics Technology in Packaging

Better



Equivalent/Superior Strength

Thermally Stable

Greener

100% Bio Based

Up to 80% CO_2 Reductions from Materials

Lower Cost

Beat Solid Plastics on Price by up to 40%

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1/21/2014 9:18am

Next Steps….

- Work to isolate sugars from hulls for
  - Feed? Ethanol? Food?
  - Explore synergies with sugar beet
- Find new uses for spent hulls.
- Explore new uses for torrefied shells,
  - Plastics
  - Rubber tires!
- Take advantage of the fact that the hulls and shells are aggregated, in California…..

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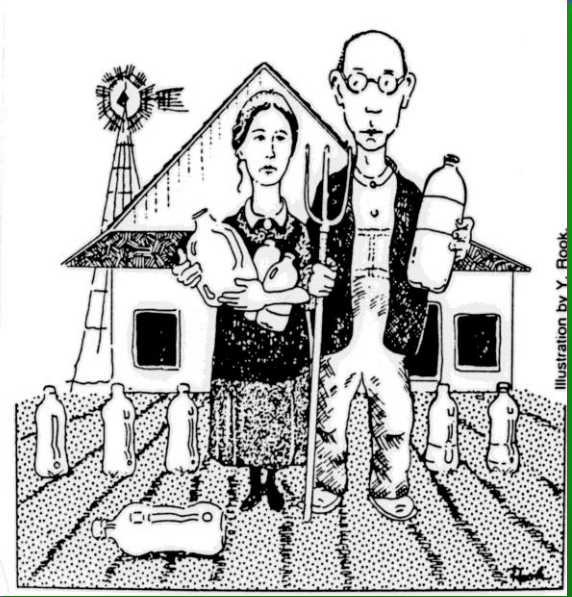
Acknowledgements

- California Department of Food and Agriculture (Grant # SCB11021)

- RPAC Almonds for donating almond shells



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Oils and Rubber

- Colleen McMahan
- Grace Chen
- Ken Lin
- Tom McKeon

Biofuels

- Kevin Holtman
- Charles Lee
- Kurt Wagschal
- Dominic Wong

Bioproducts

- Greg Glenn
- Bor-Sen Chiou
- De Wood
- A player to be named

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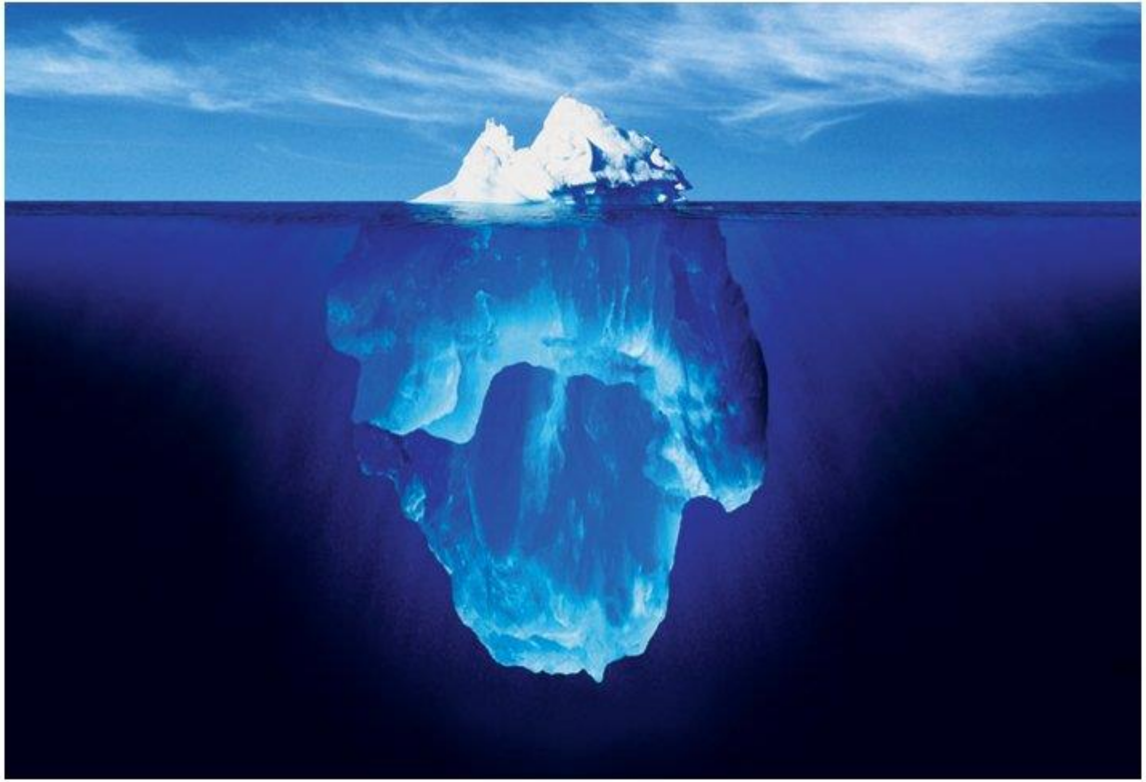
"a date which will live in infamy"
December 7th 1941
Pearl Harbor

Partnerships



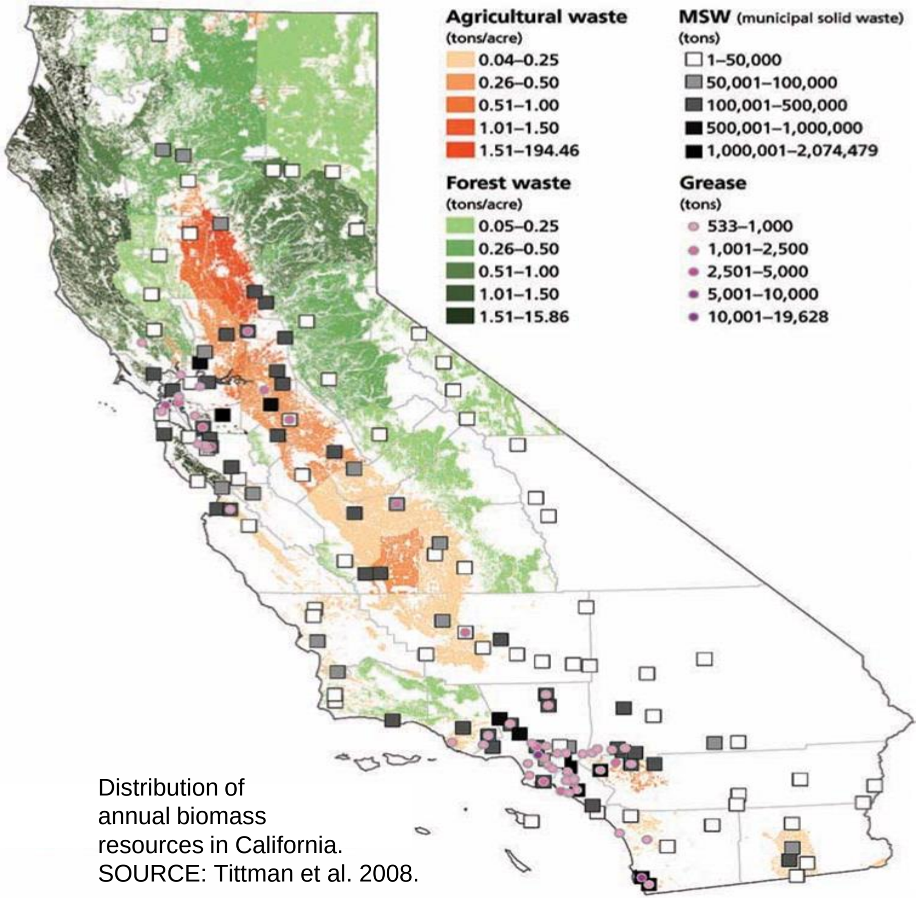
Dr. Glenda Humiston, UC Davis

Growing the Bio-Economy

Energy ~ Products

Dr. Glenda Humiston, Vice President
Agriculture and Natural Resources
University of California

California has many sources and very high volumes of biomass – this is both a challenge and an opportunity!



Distribution of annual biomass resources in California.
SOURCE: Tittman et al. 2008.

Combustion for electricity is not the future…

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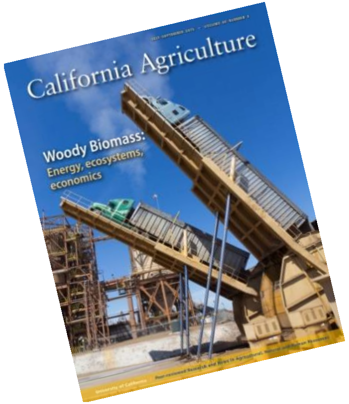
Solar is in, biomass energy is out—and farmers are struggling to dispose of woody waste



California's Homeless Biomass Problem

Biomass power generation in California is threatened by expiring contracts, low energy prices and an unlevel playing field, leaving millions of tons of biomass fuel without a use.

By Ron Kotrba | August 25, 2015

California's immense stores of waste biomass once had a plush abode in the equitably priced, long-term power purchase agreements (PPA) that stemmed from the state's aggressive interpretation of federal legislation—the Public Utilities Regulatory Policy Act of 1978—born out of the energy crisis of the early 1970s. At its peak in the early 1990s, the California biomass energy industry produced almost 4.5 billion kilowatt-hours (kWh) per year of electricity, according to the National Renewable Energy Laboratory, and each year provided a good home to more than 10 million tons of the state's solid wastes. PURPA required electric utility companies to buy privately produced power at their avoided cost of generation, in essence spawning development of the independent power industry in the U.S. High avoided cost rates, particularly in California, and favorable federal tax policy for renewable energy projects provided the impetus under PURPA for explosive growth for the state's biomass power industry.

AWAITING ACTION: Greenleaf Power idled this 17-MW biomass power plant in Tracy, California, last fall when it could not compete on an unlevel playing field with solar and wind, and low natural gas prices, the basis for pricing under new PPAs.
PHOTO: GREENLEAF POWER

California's big biomass problem

August 29, 2016

California Farm Bureau,

G+1 0 Like 1

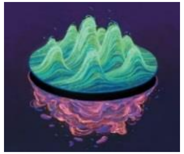
Across California, tens of millions of trees are dead, intense wildfires burn, and orchard and forest waste piles up, as more plants that convert wood waste into electricity close due to expiring contracts with utility companies.

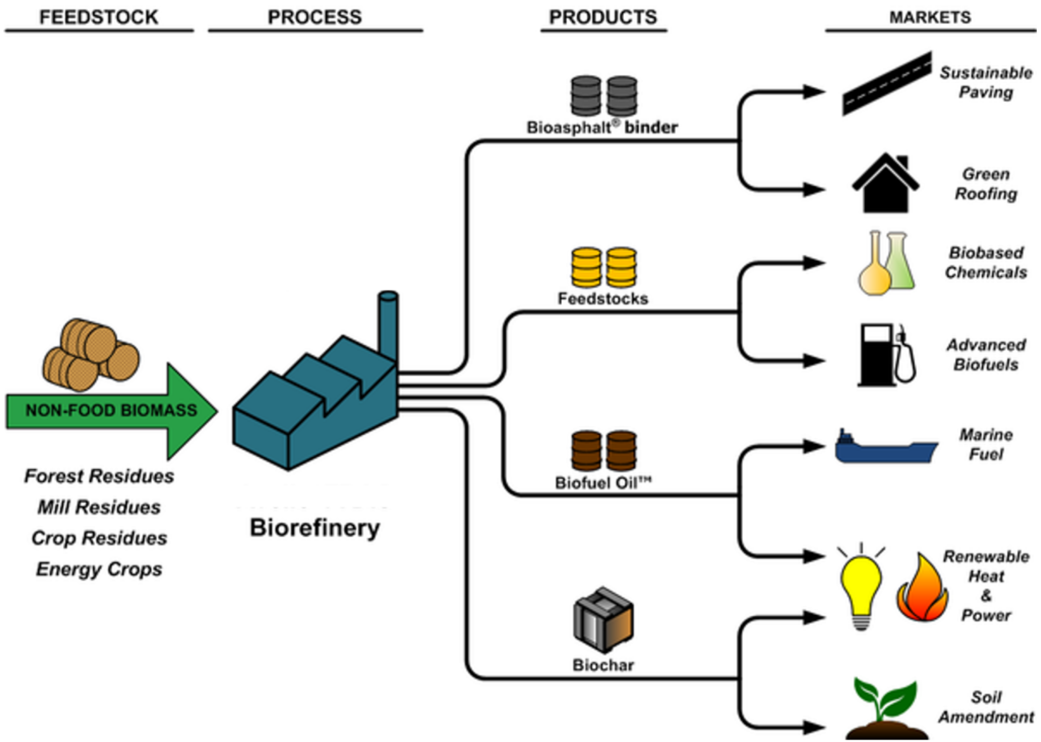
"Nothing has been done to adjust the utility rates at the California Public Utilities Commission to account for the value that biomass has; they are not keeping track of all of the avoided pollution that it affords," said Allan Krauter, senior administrative analyst for Kern County. "Unless and until the state is willing to make up the difference between the market price and the break-even price, they are going to continue to have a big biomass problem."

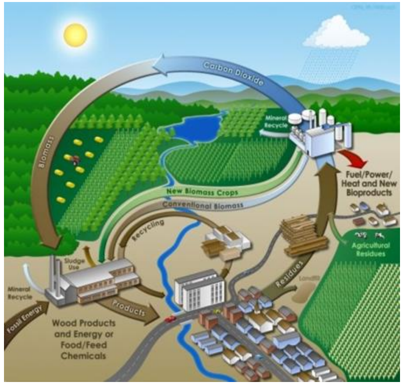
The problem centers on 25- and 30-year contracts between biomass plants and utility companies, established in the 1980s, resulting in the construction of 66 power plants with an operating capacity of almost 1,000 megawatts. Now, only 22 biomass plants remain operating, with a total capacity of 532 MW—still enough to convert 7.3 million tons of wood waste into electricity.

The plants' power-purchase contracts with utility companies that expired in recent years were not renewed, because the utilities had cheaper renewable-energy alternatives—forcing plants to close. Natural gas costs 2.9 cents per kilowatt-hour; wind and solar cost 8 cents per kWh. By contrast, a price floor of 12 cents per kWh was established for biomass when the program began.

Expanding BioProducts Requires Innovation & New Technology







Biodegradable Plastics from Biomass

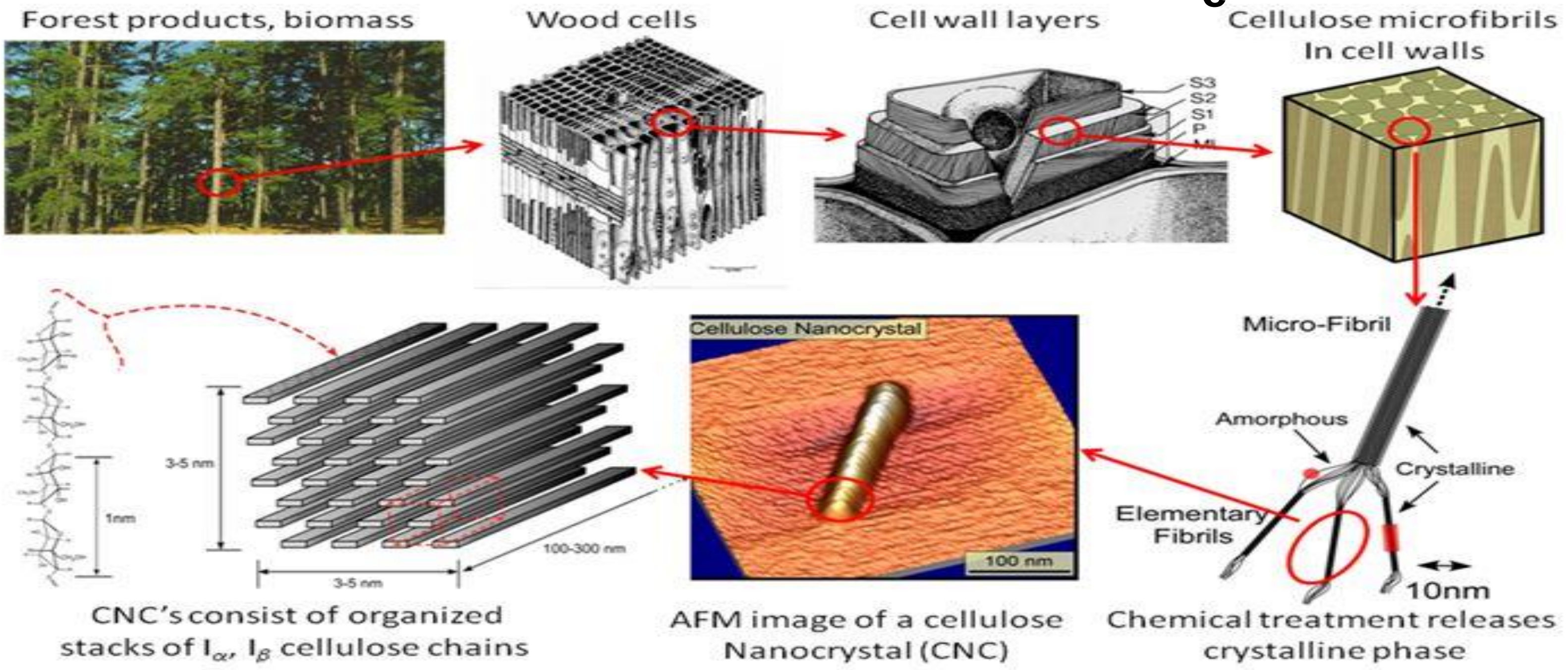
Commercial bioplastic is already made from cellulose – replacing petroleum-based plastics. Scientists developed means to ferment a broader range of cellulosic materials – enabling large scale commercial production.

An estimated $375 billion market for chemical, plastic, and rubber products represents a huge bioeconomy opportunity.

www.milkeninstitute.org/publications/view/461

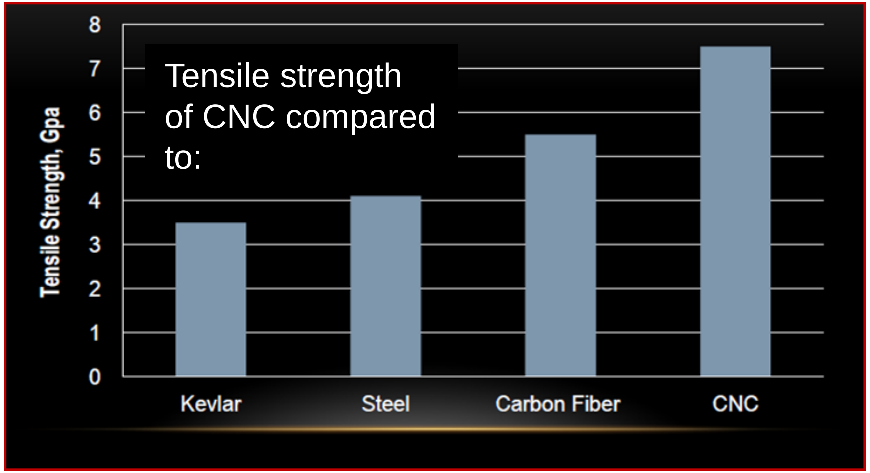
Opportunity: Cellulosic Nanomaterials (CNC)

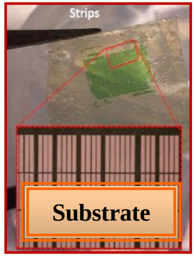
✓ Stronger ✓ Lighter ✓ Cheaper ✓ Renewable

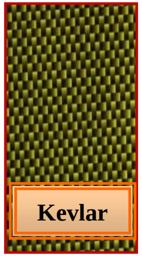


SOURCE: USFS Forest Products Laboratory 2013

Opportunity: Cellulosic Nanomaterials (CNC)







Wood pellets
$155 (100% conversion)

Fuel Ethanol
$255 (@100 gallons/ton)

High Brightness Paper
$500 ($1,000/ton - 45% yield)

Cellulose Nanocrystals
$1,350 ($6,000/ton - 23% yield)

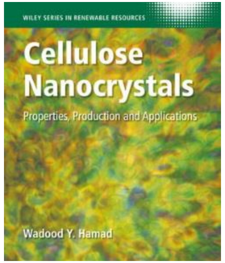
SOURCE: USFS Forest Products Laboratory 2013

Adding nanocellulose material to cement makes concrete about 22% stronger, lighter and more elastic. And, carbon is sequestered!

Siskiyou County is partnering with US Forest Service and several private sector partners on three possible applications for nanocellulose materials :

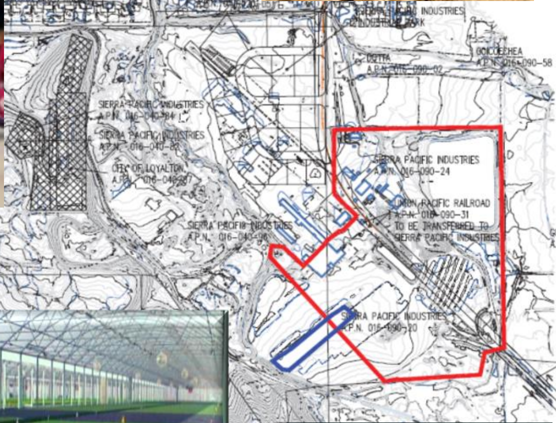
- ✓ as a cement additive to improve the structural characteristics of concrete.
- ✓ as a coating for fruit pallets to extend the usable life of wood pallets.
- ✓ as additives for bridge coverings and tennis courts (concrete and/or asphalt).

It is projected that cellulosic nanomaterial could have a market penetration as high as 3-4% across target markets building to over 24 million tons of demand.



This could create ~224,000 jobs and GDP value of over $100 billion in the US – as projected by the National Nanotechnology Initiative and National Science Foundation study.

Research on High-Value Biobased Products Supports Forest Health & Economic Development Opportunities.



…and more!

UC Cooperative Extension

- 200+ Advisors who live/work in local communities
- 130+ Campus-based UCCE Specialists

UC CE

Agricultural Experiment Station

- 650+ researchers across the entire UC system

Berkeley University of California College of Natural Resources

UC Davis College of Agricultural and Environmental Sciences

UC Riverside College of Natural & Agricultural Sciences

UC Davis Veterinary Medicine

Research & Extension Centers

RECS

- 9 locations statewide
- Over 12,000 acres

Statewide Programs & Institutes

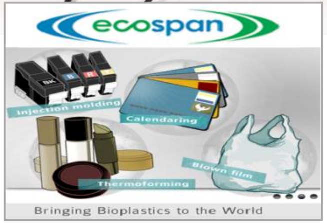
- Ag Issues Center
- Integrated Pest Management Center
- Informatics & GIS
- Nutrition Policy Institute
- Sustainable Ag Research & Education
- Water Research Institute
- Youth Development and 4-H

USDA CERTIFIED BIOBASED PRODUCT

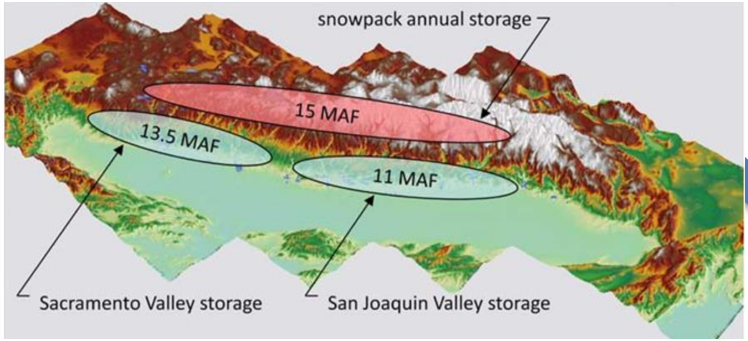
PRODUCT 95%

Over 300 California Firms Produce a Wide Array of Bio-Based Products

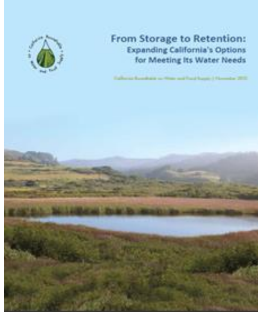
February 2012: Presidential Executive Order requires federal agencies & contractors to utilize biobased products.

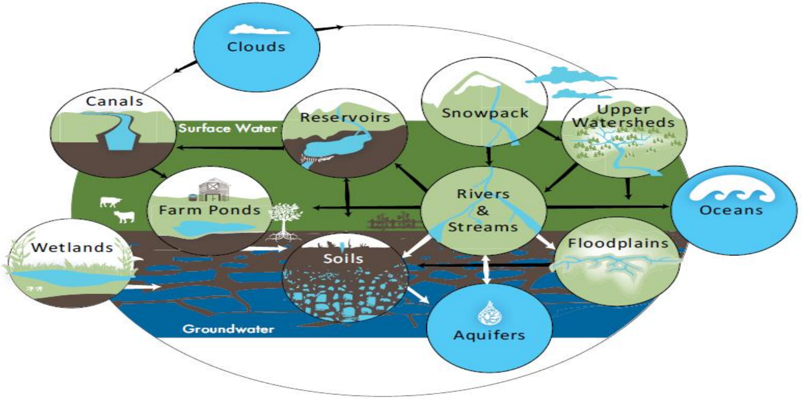


Healthy watersheds could produce 9–16% more water for California



California Roundtable on Water and Food Supply





"Effect of forest management on water yields and other ecosystem services in Sierra Nevada forests".

UCM Faculty: Roger Bales

UCB AES Faculty: Kevin O'Hara

UCCE Advisor: Susan Kocher

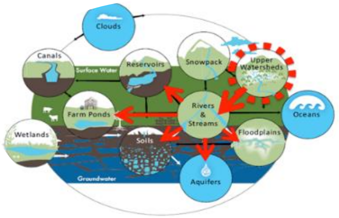
UCCE Specialist: Bill Stewart

http://aginnovations.org/images/uploads/CRWFS_Storage_FINAL.pdf

“Layers” of Funding & Economic Activity Will be Needed

Value of Biobased Products will help finance forest health activities – probably not enough.

Augment with Cap & Trade Credits



Need to monetize value of “reclaimed” water from forest health activities!

Working Landscapes

Agriculture ~ Forests ~ Fisheries ~ Mining

Watersheds ~ Energy ~ Recreation ~ Habitat

1.2 Million Jobs in California

$318 Billion Direct Sales & Exports

272,000+ New Jobs in Five Years

www.caeconomy.org/resources/entry/2013-california-economic-summit-playbook
2012 Data developed by Center of Excellence Research Office, CA Community Colleges

Synergia (Greek): creation of a whole greater than the sum of its parts.

Strategy for a Sustainable California = SYNERGY

Synergos (Greek): "working together".

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Questions?

growing
ADVANTAGE
The Almond Conference