Guayule bagasse as a biomass feedstock for liquid fuels

USDA Agricultural Research Service
U.S. DEPARTMENT OF AGRICULTURE

Colleen McMahan
Western Regional Research Center
Albany, CA
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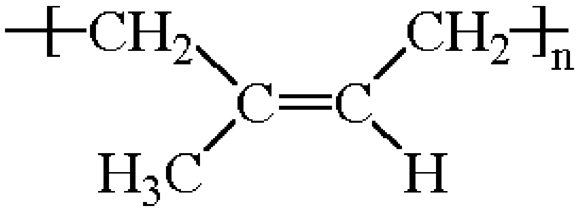
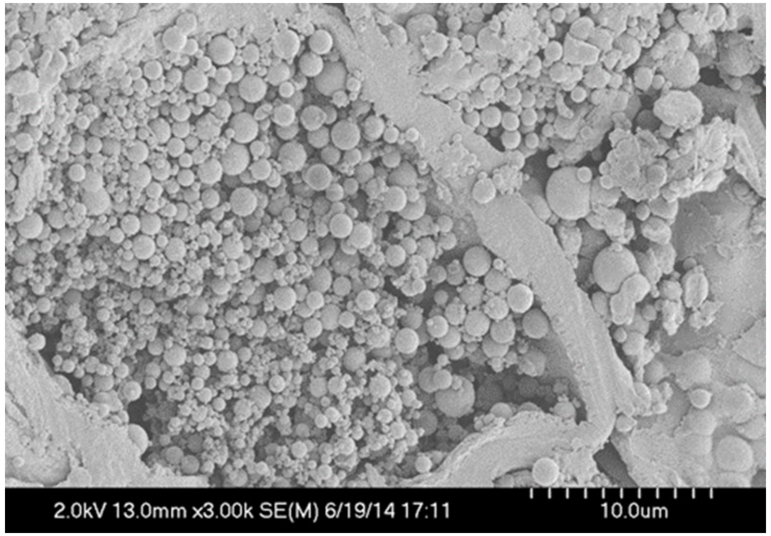
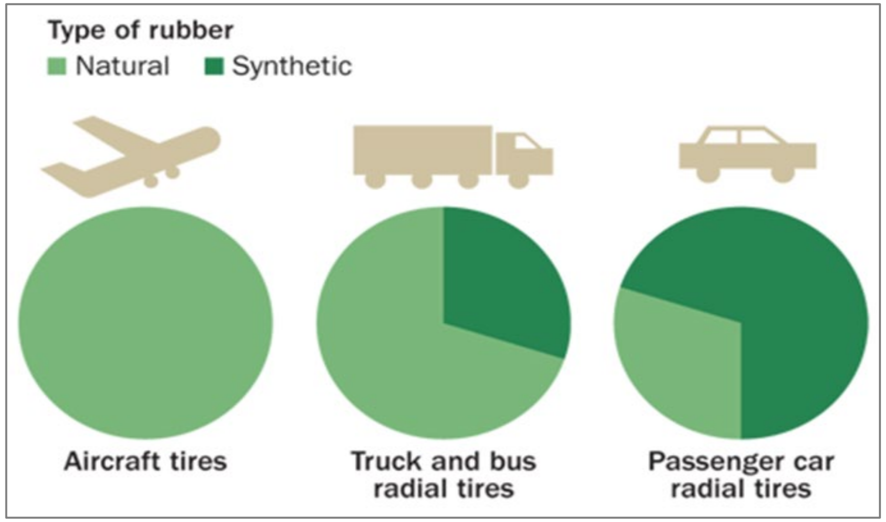
Domestic Natural Rubber

Natural rubber is a US **Critical Agricultural Material** (PL 95-592 & 98-284) required for industry, medicine, and defense. The U.S. is 100% dependent on imported natural rubber.



Guayule (*Parthenium argentatum*) is a perennial desert shrub under development as a crop for the Southwestern U.S. for natural rubber, organic resins, and biomass production. Long term climate models predict **increasing drought** in the western U.S. increasing the need for low-water use crops. Recent studies show cultivation is possible with under 2 acre-feet applied irrigation water.





Domestic Natural Rubber

USDA-ARS and partners

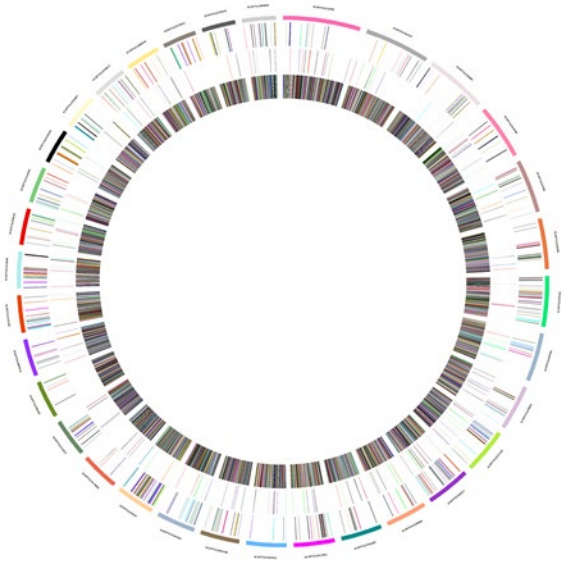
USDA-ARS published the first guayule DNA assembly and hosts the genomics resources website.

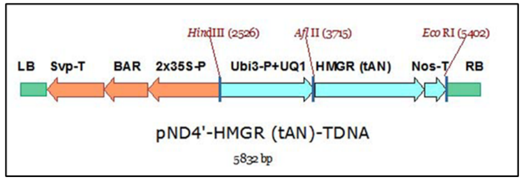
Crop biotech studies have demonstrated up to four-fold increases in rubber content in the lab.

The biochemical impacts of latex proteins, amino acids, and lipids has been established for Hevea and guayule.

Tire demonstration project was completed with Cooper Tire.

Biomass coproduct has been converted to ethanol, pyrolysis fluid, and liquid transportation fuels.

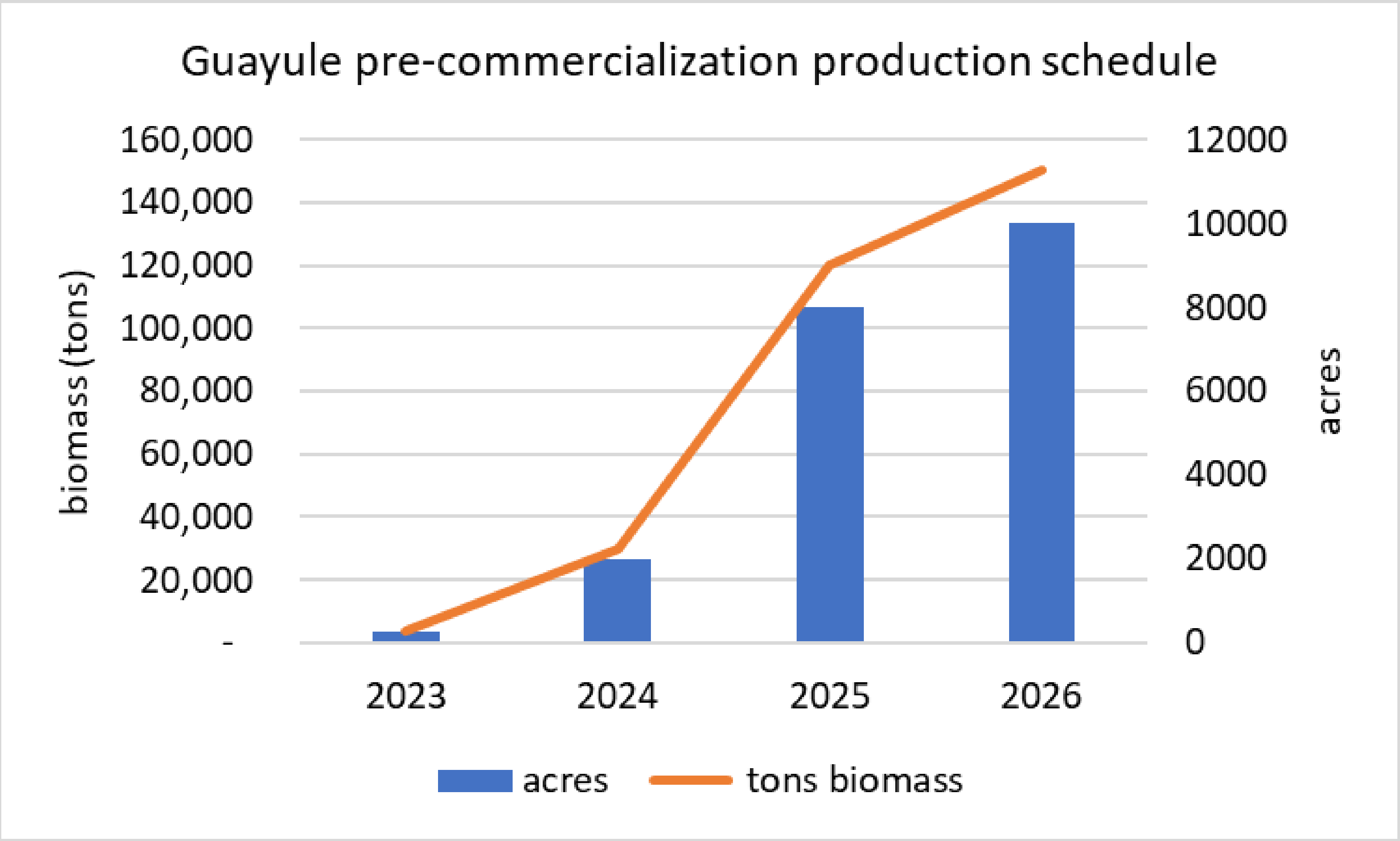




Public and private investment: ten years of progress

Bridgestone Americas Investment: Over $100M → Guayule technology package validated at demonstration scale

Commercialization Plan
University of Arizona seminar, April 2023

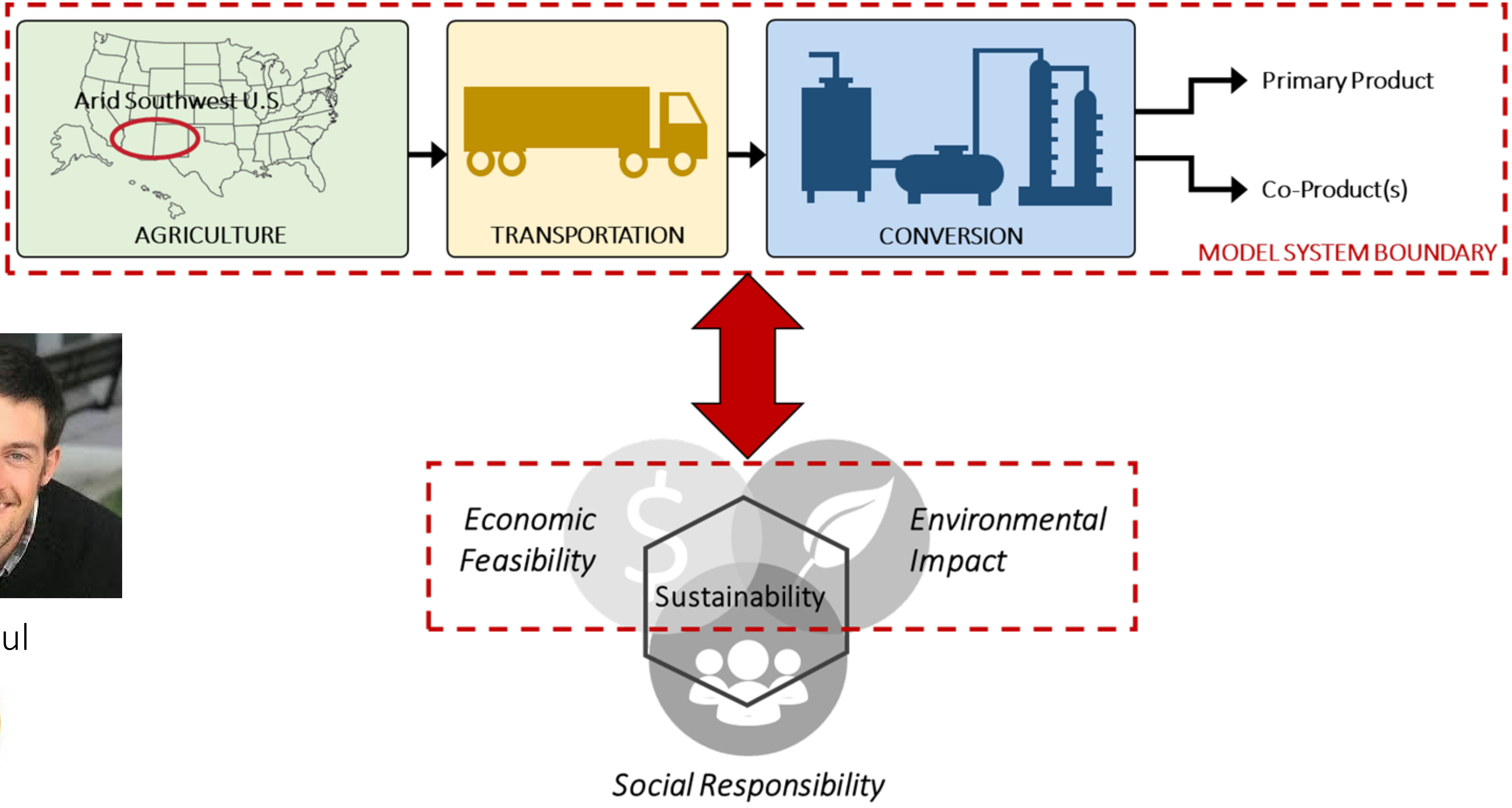


Guayule bagasse as a biomass feedstock

Biofuel feedstock advantages:

1. Ag and harvest costs borne by rubber production
2. Finely divided dry solid
3. High density
4. High energy content – over 20K MJ/kg (9000 btu/lb)
5. Harvested 12 months/year
6. Flexible feedstock for biochemical and thermochemical processes
7. Cash flow positive coproduct?

Integrated LCA/TEA Model



Jason Quinn, Evan Sproul

United States Department of Agriculture
National Institute of Food and Agriculture

E. Sproul, H.M. Summers, C. Seavert, J. Robbs, S. Khanal, V. Mealing, A.E. Landis, N. Fang, O. Sun, J.C. Quinn, "Integrated Techno-Economic and Environmental Analysis of Guayule Rubber Production," Journal of Cleaner Production, July 2020

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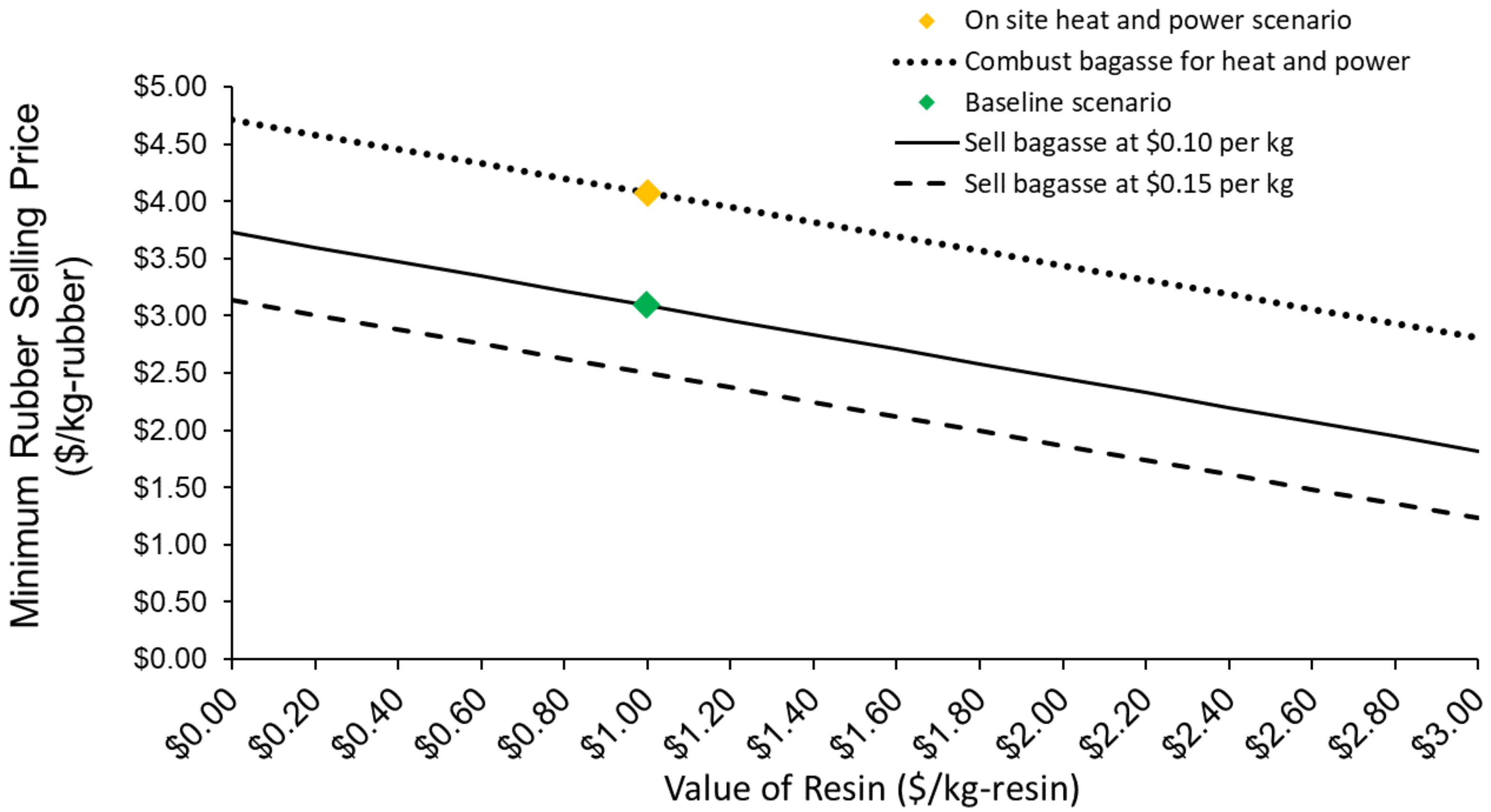
FOR ARID REGIONS

Coproduct Scenarios

Evaluated relationship between rubber, resin, and bagasse co-products.

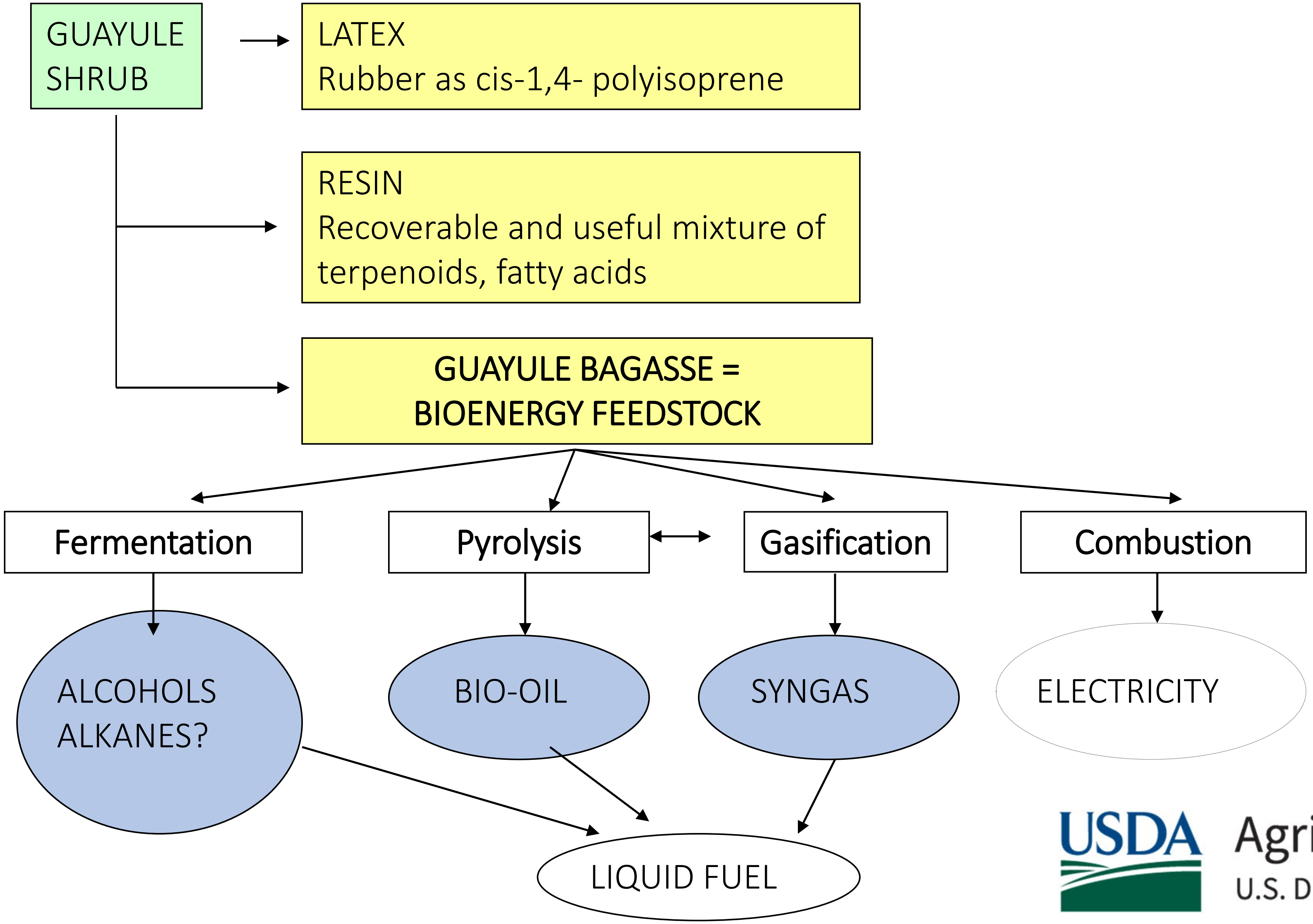
E. Sproul, H.M. Summers, C. Seavert, J. Robbs, S. Khanal, V. Mealing, A.E. Landis, N. Fang, O. Sun, J.C. Quinn, "Integrated Techno-Economic and Environmental Analysis of Guayule Rubber Production," Journal of Cleaner Production, July 2020



USDA United States Department of Agriculture
National Institute of Food and Agriculture

Sfier et al, (2014), Snoeck et al (2015) found similar results.

The guayule biorefinery: bioproducts + bioenergy



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Source	biomass from guayule	glucan	hemicellulose (xylans +)	lignin	ash
Chundawat et al Ind Crops Prod 2011	shrub above ground	19	17	35	5.4
Holtman, 2011	shrub above ground	31	18	30	
Boateng et al Fuel 2009	shrub above ground	15	19	19	12.5
Chow et al Ind Crops Prod 2008	shrub (wood and bark)	32-47	9-13	32-42	1-6
Chundawat et al Ind. Crops Prod. 2011	bagasse (defoliated, latex extraction)	27	20	36	1.8
Holtman, 2011	bagasse (defoliated, latex extraction)	37	23	33	
Boateng et al Fuel 2009	bagasse (defoliated, latex extraction)	23	26	30	3.2
Chow et al Ind Crops Prod 2008	bagasse	41	11	25	9.8
Srinivasan & Ju Biores. Tech. 2010	bagasse	19-34	5-18	49-60	
Holtman, 2011	leaf stream	27	14	26	
Srinivasan & Ju Biores. Tech. 2010	leaf	31	29	37	

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Table 2
Proximate, elemental and biochemical analysis, and energy content of guayule bagasse (GB) and whole shrub (GW).

	GB2017	GB2018	GB2019	GW2017	GW2019
Proximate Analysis (wt.%)[a]					
Moisture [b,e]	0.55 ± 0.15[g]	1.45 ± 0.55[g]	1.08 ± 0.05[g]	4.25 ± 0.09[h]	11.61 ± 0.02[i]
Ash [f]	4.07 ± 0.10[g]	3.69 ± 0.30[g]	3.86 ± 0.74[g]	6.50 ± 0.16[h]	4.01 ± 0.79[g]
Volatile Matter [f]	76.33 ± 0.47[g]	75.56 ± 0.03[g]	75.99 ± 0.14[g]	78.82 ± 1.07[h]	78.67 ± 0.10[h]
Fixed Carbon [f]	19.60 ± 0.48[i]	20.75 ± 0.30[i]	20.15 ± 0.75[i]	14.68 ± 1.08[g]	17.33 ± 0.79[h]
Elemental Analysis (wt.%) [a,e]					
Carbon	46.44 ± 0.20[g]	47.16 ± 0.28[g]	49.31 ± 0.22[h]	46.98 ± 0.00[g]	51.78 ± 0.50[i]
Hydrogen	6.49 ± 0.11[gh]	6.47 ± 0.05[gh]	5.18 ± 0.08[h]	5.12 ± 0.07[h]	5.45 ± 0.10[g]
Nitrogen	1.60 ± 0.07[gh]	1.79 ± 0.07[gh]	2.01 ± 0.17[h]	1.97 ± 0.05[h]	1.35 ± 0.16[g]
Sulfur	1.82 ± 0.17[g]	2.01 ± 0.26[g]	2.16 ± 0.11[g]	2.06 ± 0.02[g]	1.97 ± 0.15[g]
Oxygen [c]	39.59 ± 0.31[h]	38.88 ± 0.49[h]	37.50 ± 0.80[gh]	37.38 ± 0.18[gh]	35.46 ± 0.96[g]
Biochemical Analysis (wt.%) [a,e]					
Glucan	23.33 ± 0.40[i]	22.18 ± 0.14[i]	16.51 ± 1.06[h]	16.66 ± 0.02[h]	11.55 ± 0.68[g]
Xylan	14.60 ± 0.29[i]	13.91 ± 0.08[i]	12.73 ± 1.32[hi]	10.56 ± 0.09[gh]	9.12 ± 0.30[g]
Klason Lignin	23.03 ± 0.14[g]	22.52 ± 0.17[g]	24.17 ± 1.69[g]	28.87 ± 0.24[h]	23.08 ± 2.30[g]
Protein [d]	10.00 ± 0.44[gh]	11.19 ± 0.44[gh]	12.56 ± 1.06[h]	12.31 ± 0.31[h]	8.44 ± 1.00[g]
HHV (MJ/kg) [e]	22.80 ± 1.13[g]	22.73 ± 0.29[g]	24.10 ± 1.47[g]	25.42 ± 0.13[gh]	27.12 ± 0.44[h]

[a]Dry basis; [b] as received basis; [c] by difference; [d] protein = N content × 6.25, [e] ± = standard deviation where n = 3, [f] ± = standard deviations where n = 2, [g–i] different superscripts within the same row indicate significant differences between the means at $p < 0.05$ by Duncan's multiple range test.

Cheng et al. Industrial Crops and Products 2020

Fast pyrolysis may be the most attractive option for conversion but costs must be lowered

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1. Can be used for bagasse or leaf material
2. 60+% yield of pyrolysis fluid with ~ 38+MJ/kg
3. Demonstrated conversion to liquid fuels mixtures comprising 30.4% gasoline (C5–C7), 37% jet (C8–C12) and 24% diesel (C13–C22), albeit at high cost
4. TEA calculated minimum fuel selling price (MFSP) 1.88 $/L for gasoline, 1.84 $/L for jet fuel and 1.91 $/L for diesel fuel.

Boateng, et al. Fuel (2016) Guayule (*Parthenium argentatum*) pyrolysis biorefining: Fuels and chemicals contributed from guayule leaves via tail gas reactive pyrolysis
Boateng, et al. 2015 Guayule (*Parthenium argentatum*) pyrolysis biorefining: Production of hydrocarbon compatible bio-oils from guayule bagasse via tail-gas reactive pyrolysis. Fuel 158, 948-956.
Boateng et al. 2010 Guayule (*Parthenium argentatum*) pyrolysis and analysis by PY–GC/MS. Journal of Analytical and Applied Pyrolysis. 87:14-23.
Boateng et al. 2009 Energy-dense liquid fuel intermediates by pyrolysis of guayule (*Parthenium argentatum*) shrub and bagasse. Fuel. 88:2207–2215.
Sabaini et al. 2018 Techno-economic analysis of guayule (*Parthenium argentatum*) pyrolysis biorefining: production of biofuels from guayule bagasse via tail-gas reactive pyrolysis. Industrial Crops & Products. 112:82-89

New studies underway at Iowa State University (Brown) with NMSU (Brewer)

Thank you, CAAFI!

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