LSU AgCenter Research & Extension

A Regional Program for Production of Multiple Agricultural Feedstocks and Processing to Biofuels and Biobased Chemicals

USDA-NIFA AFRI Sustainable Bioenergy Grant

Grant Award No. 2011-69005-30515

subi SUSTAINABLE BIOPRODUCTS INITIATIVE

Personnel and Partners

- LSU AgCenter – Drs. Aita, Alison, Aragon, Attaway, Baisakh, Blazier, Bollich, Day, Dorman, Ehrenhauser, Gravois, Han, Harrell, Hoy, Kimbeng, Legendre, Lovelady, Russin, Salassi, Tubana, Viator and Vlosky
- USDA-ARS – Drs. Grisham, Hale, Johnson, Webber and P. White
- Ceres, Dupont, John Deere, MS Processes International, Optinol, Sugar Cane Growers Coop. of Fla., SynGest, and Virent
- 7 University System

Renewable Fuel Standard Program

- Under the Energy Independence and Security Act (EISA) of 2007, the RFS program increased the volume of renewable fuel required to be blended into transportation fuel from 9 billion gallons in 2008 to 36 billion gallons by 2022.
- For 2014, it is ***proposed*** that about 10% of all fuel used would be from renewable sources (only .01% cellulosic biofuel) – ***this proposal for standards is currently delayed*****.**
- EISA required EPA to apply lifecycle greenhouse gas performance threshold standards to ensure that each category of renewable fuel emits fewer greenhouse gases than the petroleum fuel it replaces.

Definition of Biofuels

- Conventional biofuel – ethanol derived from corn starch
- Advanced biofuels – other than ethanol derived from corn starch and include cellulosic biofuels and biomass-based diesel (50% GHG emissions reduction)
- Cellulosic biofuels – derived from any cellulose, hemicellulose or lignin that is derived from renewable biomass (60% GHG emissions reduction)

Year-round Feedstock Production Model

Month	Feedstock Source			
Jan		Energy cane		
Feb		Energy cane		
Mar		Energy cane		
Apr				Bagasse
May				Bagasse
Jun				Bagasse
Jul	Sweet sorghum			
Aug	Sweet sorghum			
Sep	Sweet sorghum	Energy cane		
Oct	Sweet sorghum	Energy cane	Sugar/Syrup	
Nov		Energy cane	Sugar/Syrup	
Dec		Energy cane	Sugar/Syrup	

Defined Tasks

- Feedstock development (yield/cold tolerance)
- Feedstock production (low-input/marginal soil)
- Feedstock logistics and pre-processing
- Feedstock conversion and refining
- Economics of production and processing
- Education
- Extension


Sweet sorghum

Planting hybrids of different maturity (90-days to 150-days) from early April to June allowed for the harvesting from late July through October

Comparison of 90-day hybrid to 120-day hybrid

Comparison of 90-day hybrid to 150-day hybrid

Harvesting initiated at hard-dough stage

- Across all planting dates and hybrids the average fiber was **23%** (**4.7 tons dry matter**) , **juice yield** of over **10 tons per acre**, and total fermentable sugar average was **5100** pounds per acre for sweet sorghum harvested with no extractor fans on

Scheduling required to provide 1000 tons of sweet sorghum biomass to a mill facility on a daily basis

Planting date	Maturity group	Fresh wt. tons/acre	Acres planted	Harvest period
April	Early Medium	18.6 31.5	753 444	July 15 – Aug. 1 Aug. 1 – Aug. 15
May	Medium Late	42.9 38.9	326 360	Aug. 15 – Aug. 31 Sept. 1 – Sept. 15
June	Medium Late	32.1 30.0	436 <u>467</u> **3000 acres**	Sep. 15 – Sept. 30 Oct. 1 – Oct. 15

Energy cane

Photo courtesy of Rich Johnson

Energy cane Objectives

Extend geographic range of production by breeding for cold tolerance and investigation of cultural practices that impact survivability

- Dates of harvest effects
- Fertilizer protocols
- Depth of cover
- Cellulose content

Test for Minimum Cellulose Content

Fiber/ Fiber + Brix $\geq$ 75%

Energy cane experiments averaged over 75%

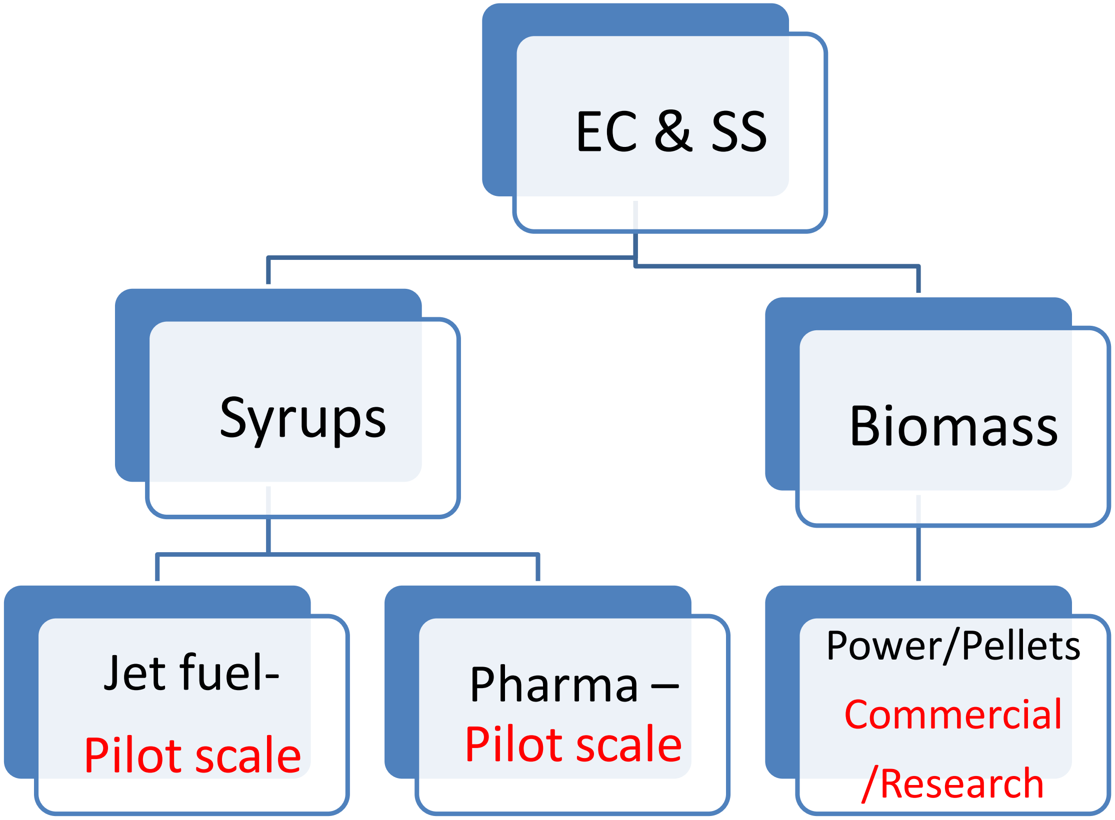
Energy cane Summary

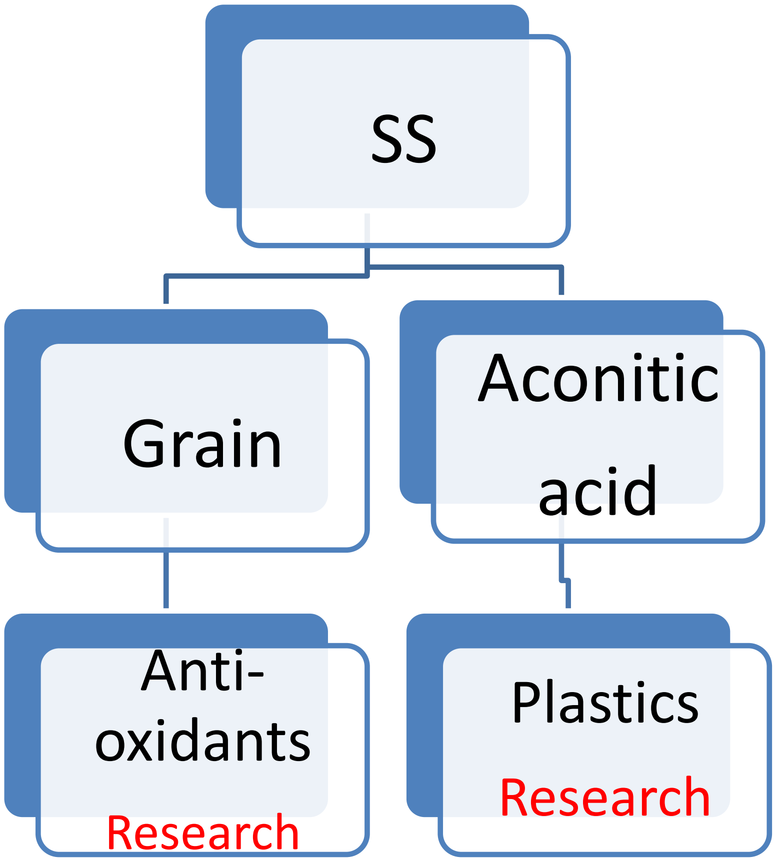
- **Dry matter yields of 9 tons/acre achievable with minimal inputs on marginal land and 15 to 17 tons of juice per acre (higher DM and juice yields were measured elsewhere)**
- **7 out of 12 months deliverable feedstock**
- **Most energy canes tested pass EPA cellulose limits**
- **Cold tolerance genetic markers identified and hundreds of cross made to provide genotypes to select for cold tolerance**

Cost of Production

- Each dry ton of energy cane cost from $95 to $110 to produce.

- Consensus opinion is that yield must increase for profitability.


EC & SS
Syrups
Biomass
Jet fuel-
Pilot scale
Pharma –
Pilot scale
Power/Pellets
Commercial
/Research


SS
Grain
Aconitic acid
Anti-oxidants
Research
Plastics
Research

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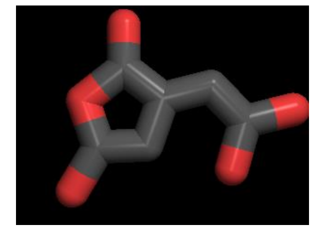
Continuation Research

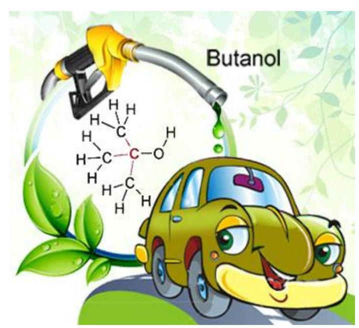
Biomass

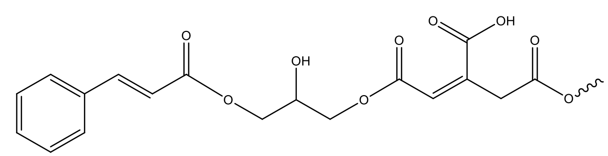
Sugar

Syrups

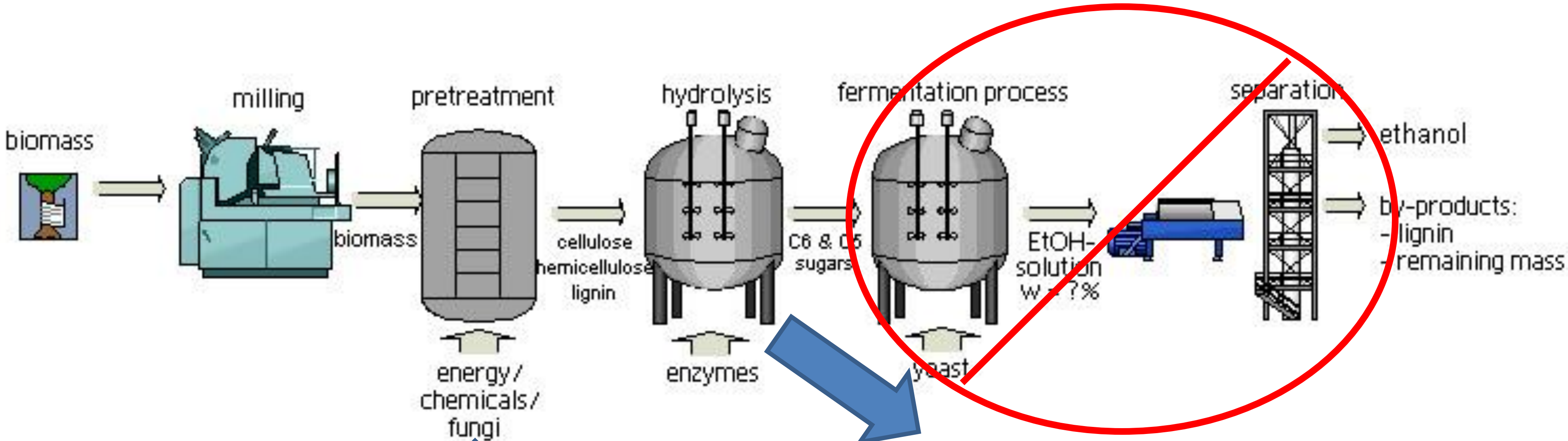
Organic acids





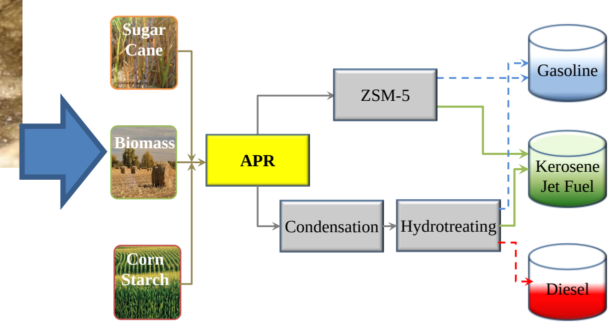


Idealized Process



Pretreatment

Syrup



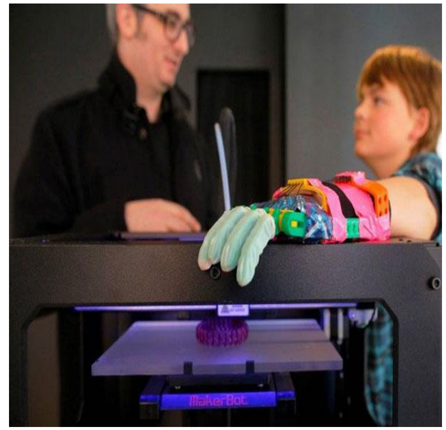
Estimated Energy Cane Total Production Costs

Energy Cane Variety	Ho 02-144	Ho 02-147	Ho 06-9001	Ho 06-9002	HoCP 72-114
			($/ton)		
Variable cost per wet ton	16	11	17	19	14
Fixed cost/rent per wet ton	10	7	10	11	8
Total grower cost per wet ton	26	18	27	30	22
Variable cost per dry ton	70	61	61	70	62
Fixed cost/rent per dry ton	42	36	37	41	37
Total grower cost per dry ton	112	97	98	111	99

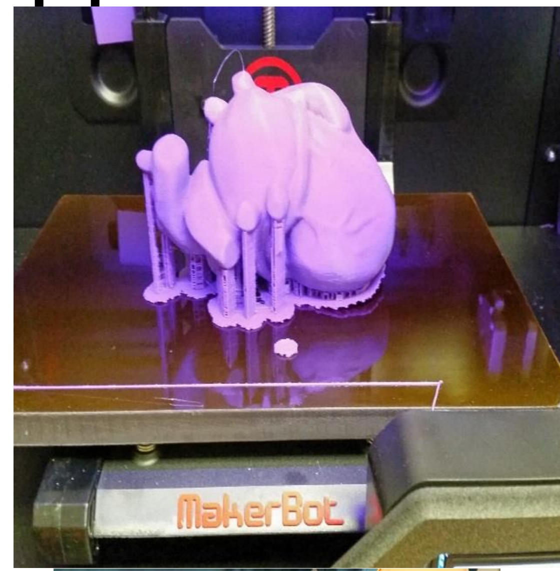
Variable costs estimated using 2014 values. Fixed equipment costs = $145/acre, land rent = 16.7% of breakeven price x yield.
Dry ton costs estimated using an average fiber content of each variety.
Crop cycle through harvest of 4th stubble.
Total grower cost represents an estimate of breakeven price per ton.

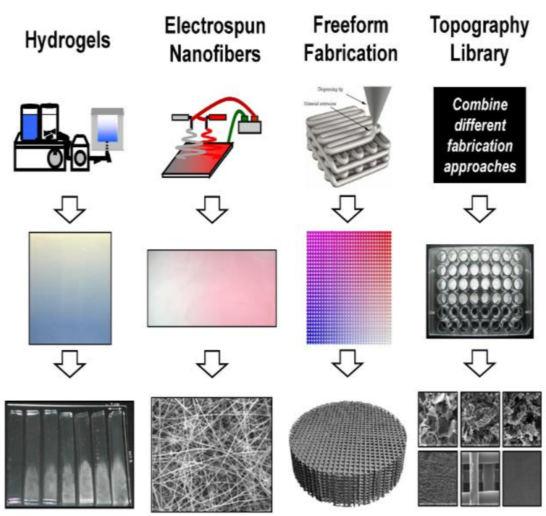
3D Printing provides new applications.

- Tissue Scaffolding
- Replacement organs
- Rapid Prototyping



Henn, S. and Carpien, C. 3-D Printer Brings Dexterity To Children With No Fingers. NPR.org, Jun 18, 2013.



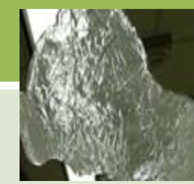
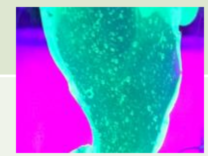


NIST: http://www.nist.gov/mml/bbd/biomaterials

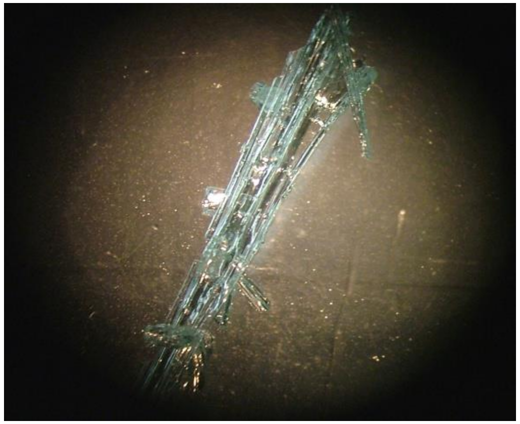
Windpipe implant for baby. USA Today: http://www.usatoday.com/story/news/nation/2013/05/22/3d-printer-implant-baby/2348091/

Skull implant for 22-year-old woman. http://www.umcutrecht.nl/research/news/2014/03/3d-printed-skull-implanted-in-patient.htm

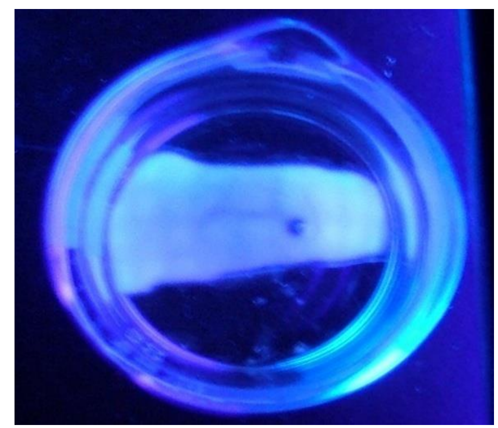
Our current bioplastic formulations.

Properties	Monomers Used	Additives / Notes	Picture
Hard, Brittle, Translucent	**Citric Acid, Cinnamic Acid, Glycerol**		
Hard, Brittle, Translucent, Fluorescent	**Citric Acid, Cinnamic Acid, Glycerol**	**Fluorescein**	
Hard, Tough, Opaque	**Citric Acid, Cinnamic Acid, Glycerol**	**Plaster**	
Rubbery, Tough, Translucent	**Citric Acid, Sebacic Acid, Glycerol**	**Substitute 1% sebacic acid for some of the citric acid**	

BIO-PLASTICS
MATRICES FROM ACONITIC ACID



Biodegradable and photolithotrophic plastics from Energy crops



Harvesting

- Sweet Sorghum

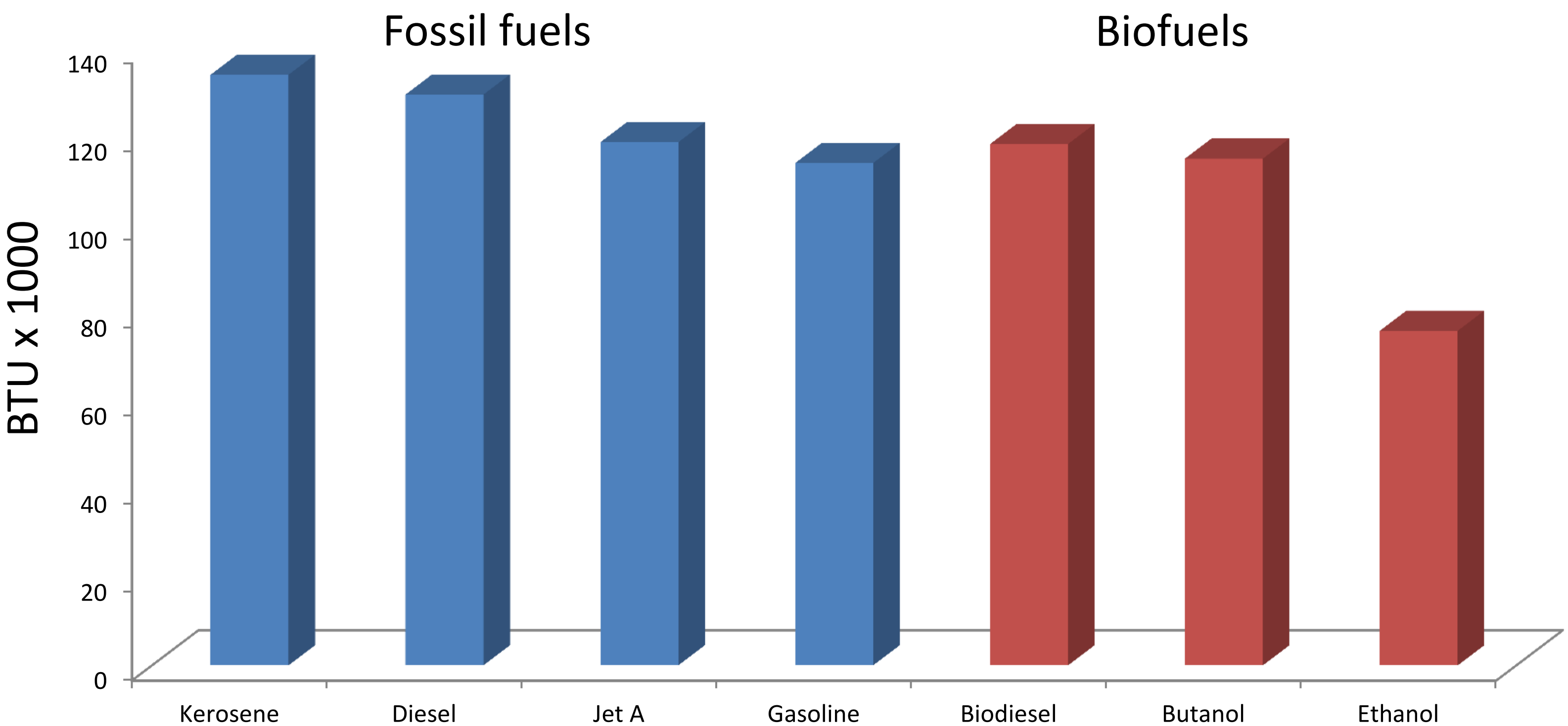
- Energy cane

Weight loss- 6-7% over 72 hr. period on harvesting
3 trials, one acre lots (about 18 rows)
8 inch billets, 3 different fan speeds evaluated

7-9% weight loss over a 72 hr. period. Same design.
Harvesting in October

Butanol as a Fuel

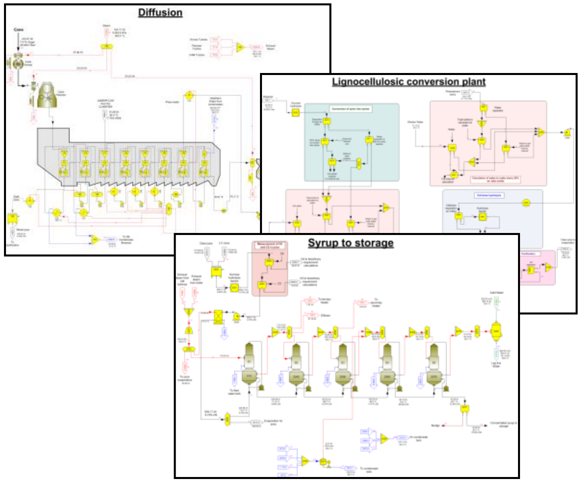
Energy Equivalents- Liquid Fuels



A transportation fuel requires high energy density per unit weight

Co-generation

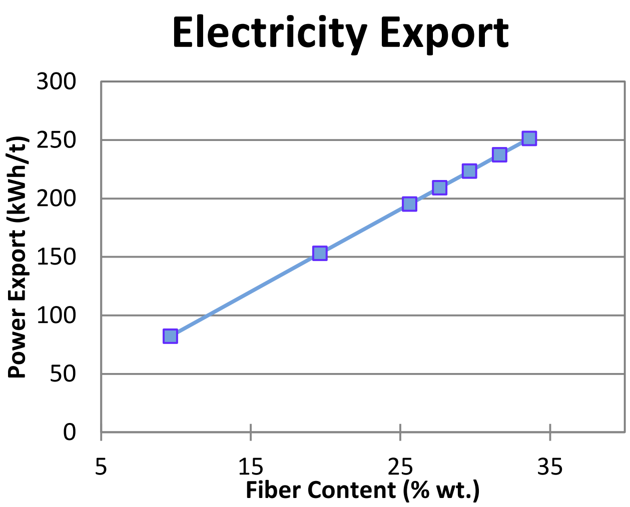
- Model developed in SUGARS™
  - Extraction by diffusion
  - Diluted acid pretreatment for lignocellulosic conversion

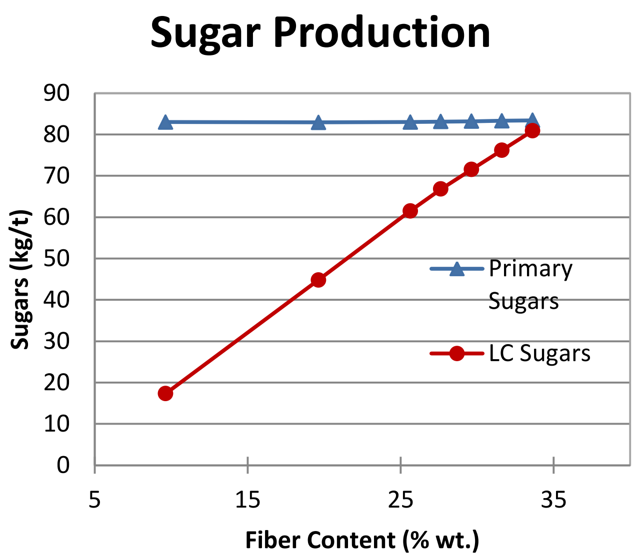


Annual production of fermentable sugars, excess bagasse, electric power and syrup

	Scenario 1 Excess bagasse used for electric power generation				**Scenario 2 Excess bagasse used for lignocellulosic sugars production**			
Feedstock	Primary sugars, million kg	Excess bagasse, million t	Power export, million kWh	Syrup, K-m3	Primary sugars, million kg	Excess bagasse, million t	Lignocellulosic sugars, million kg	Syrup, K-m3
Energy cane	99.8	600.8	268	50.5	99.8	330.2	85.8	94.1
Sweet Sorghum	49.6	164.2	119.9	24.9	49.6	147.4	38.9	44.5
Facility total	149.4	765.0	387.9	75.4	149.4	477.6	124.7	138.6

An integrated biorefinery approach based on energy cane and sweet sorghum is feasible in terms of fiber availability





2.7 kg/t more LC sugars per 1 % in fiber

7.0 kWh/t increase per 1% increase in fiber

- Simulations
  - Minimum 5% in fiber content to export generation 45.1 kWh/t
  - Minimum 3% in fiber content to produce 2.3% LC sugars/t

Enzymatic sugar production

Start

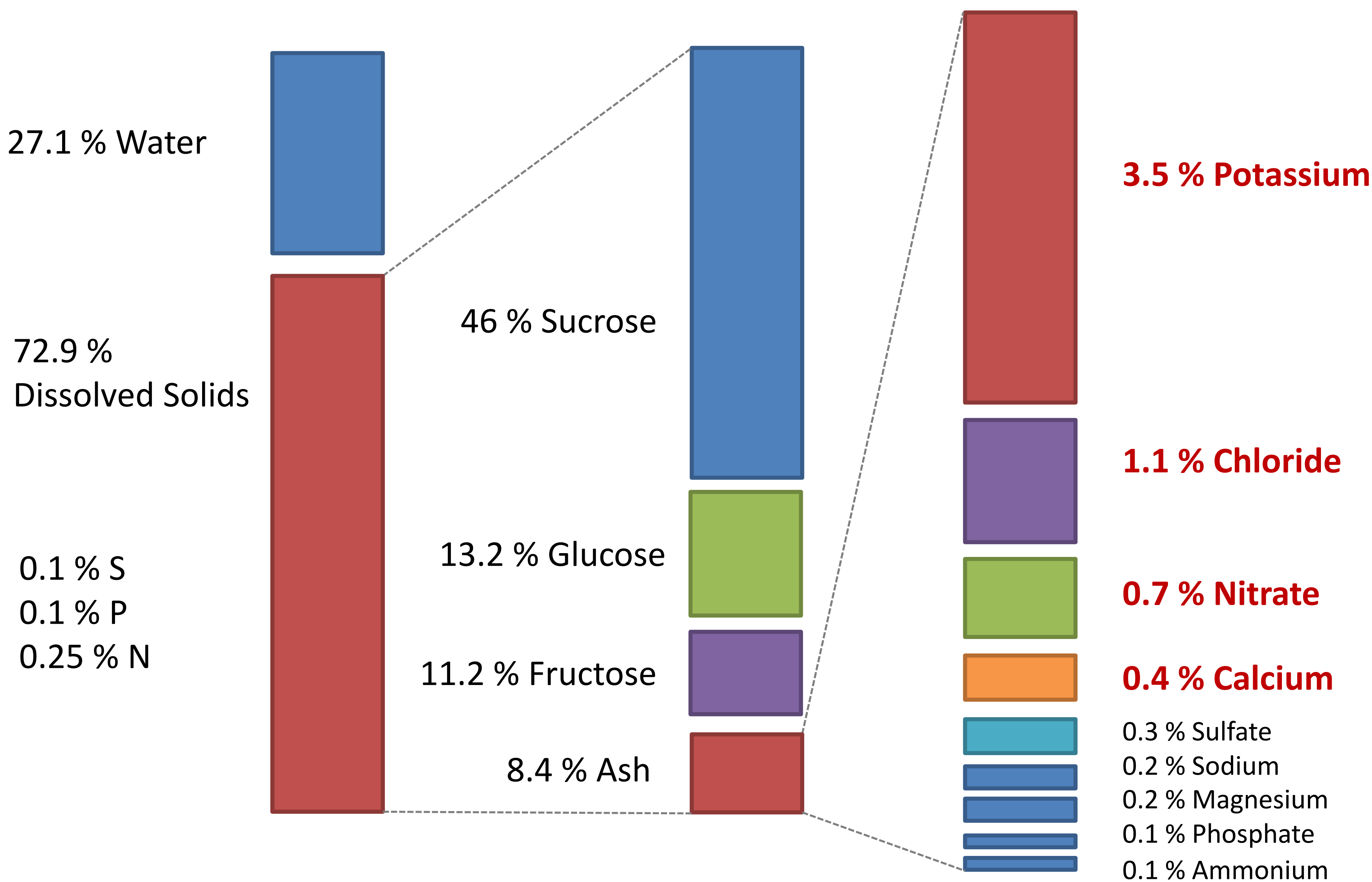
6 hours

3 hours

40 hrs

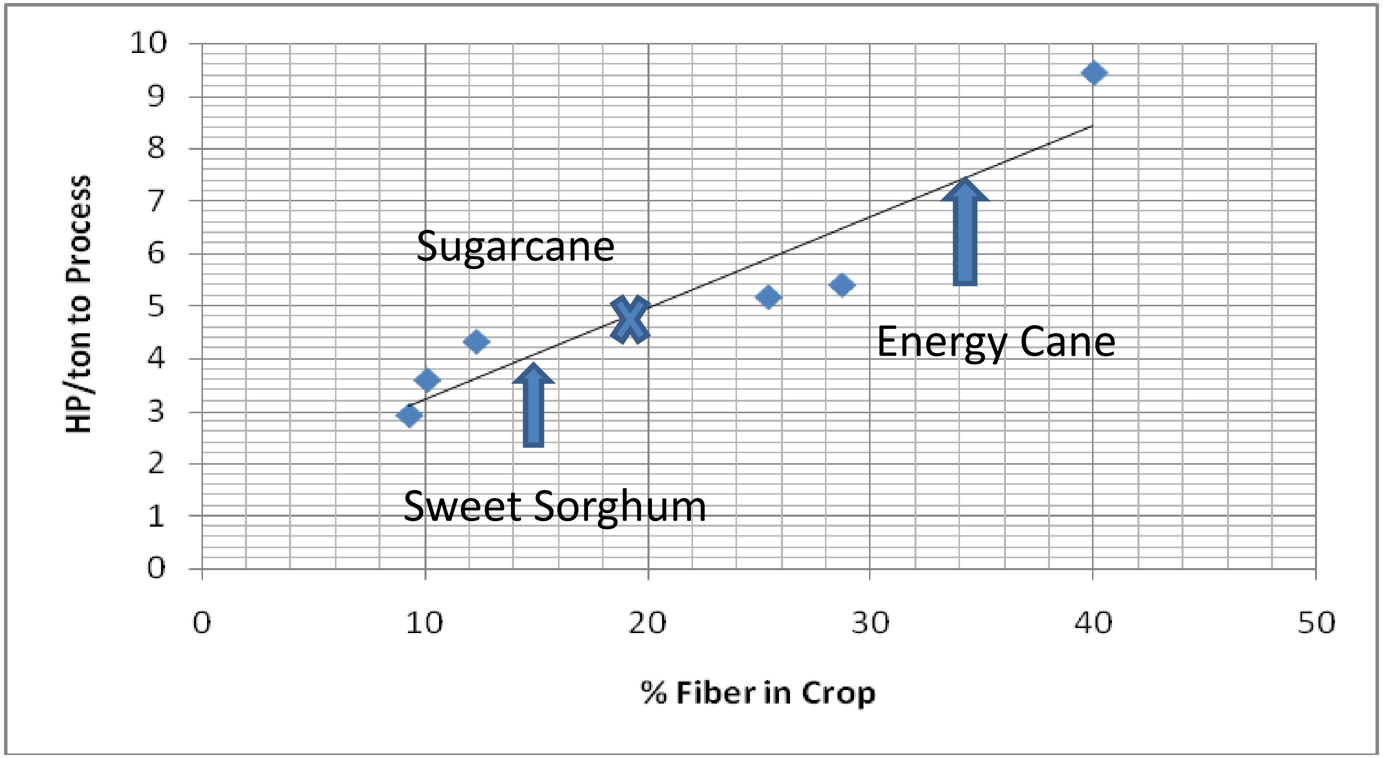
sugar yield - 70-90% of cellulose in biomass converted to fermentable sugars

Composition Sorghum Syrup



Power Requirements- Milling (Crop Dependent)

Sweet sorghum and energycane fall at different ends for fiber.



Eiland and Clarke, 2008 ASSCT, Panama City, Florida

Milling

Sweet Sorghum

Three runs of 5 ton lots. For two runs the whole plant was harvested, for one the seed heads and leaves were removed.

Feed rate low. It was not possible to mill the clean billets because of choking (**not enough fiber**).

Energy Cane

- Feed rate dependent on variety.
- Leaf removal necessary to improve efficiency.
- **Increased power requirement due to high fiber content.**