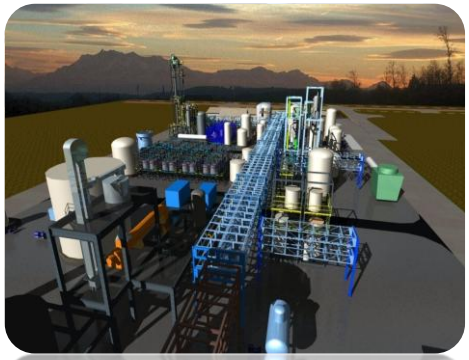
ARKENOL

BlueFire RENEWABLES



SucreSource

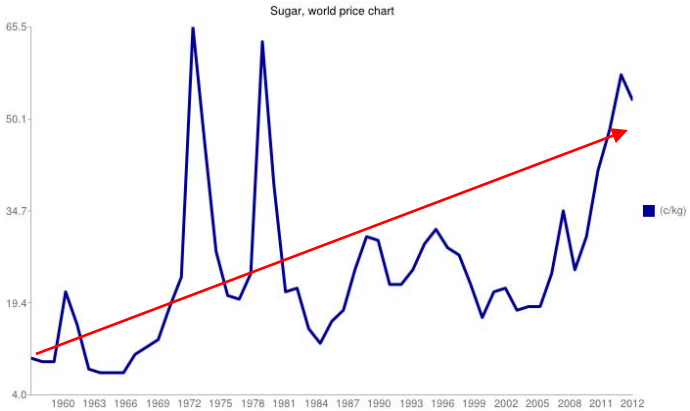
The Future of Biorenewables

DOE BIOMASS 2012

2012

U.S. and World Sugar Prices Are Fluctuating Wildly

U.S. Commodity prices peaked at $35/100 lbs in mid 2010 and have fallen to $24/100 lbs recently but the trend is clear.



World Commodity prices peaked at $65/100 kgs in mid 1975 and have seen similar costs in 2012 at $57/100 kgs recently and the trend is also clear.

With ever greater pressure on this food commodity, what is the near and longer term answer?

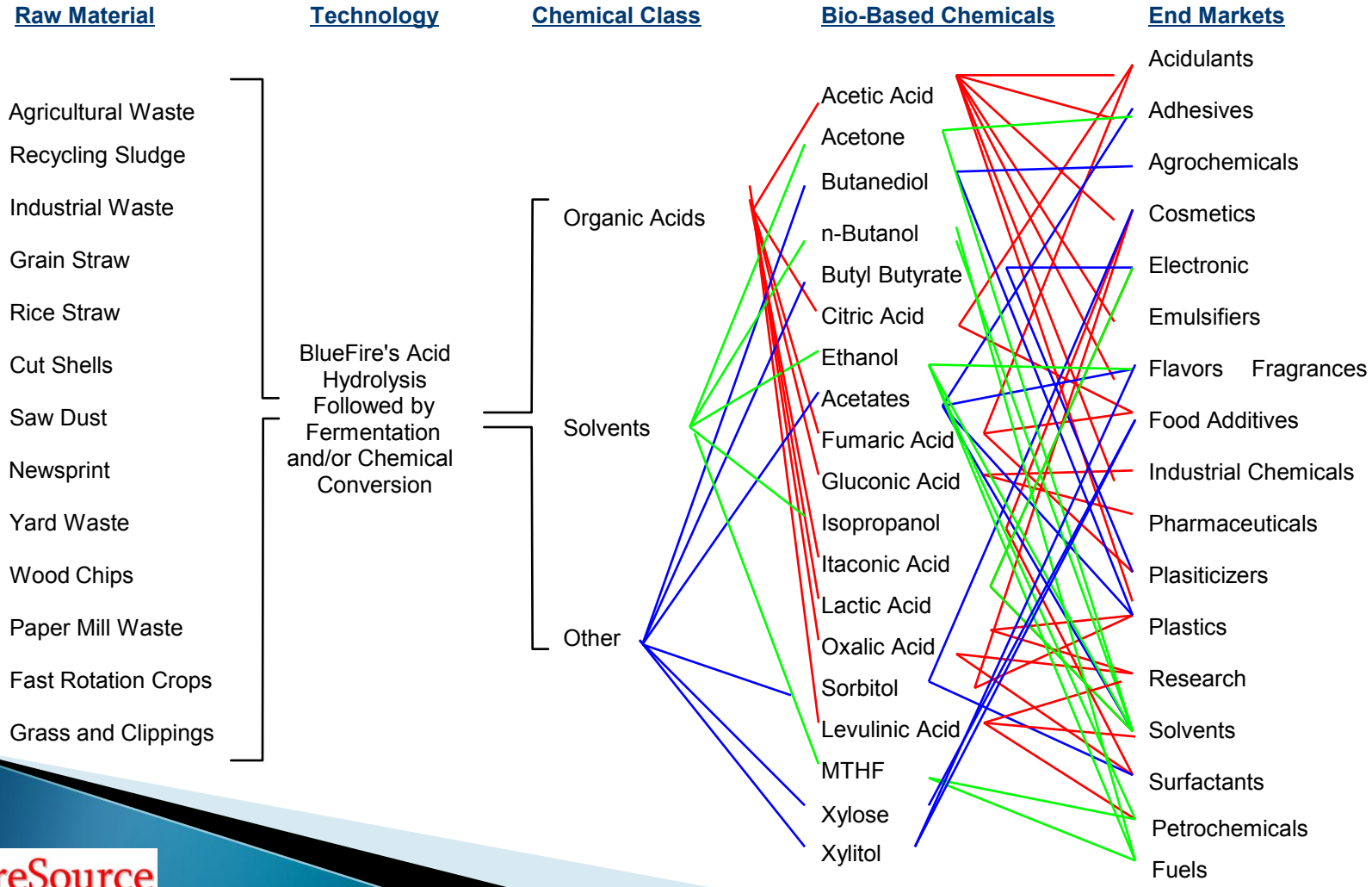
Cellulosic Sugars for metabolic conversion to higher value products!

With Biofuel values in the $3/gal volumetric range (~$20/100 lbs), higher value solvents, biochemicals and plastic precursors can be valued several times this price.

SucreSource

BlueFire/SucreSource Technology Provides Competitive Entry into Bio-based Chemicals and Target Market Segments

Arkenol technology has been used to produce the bio-chemicals shown below. Over 140 common chemicals were produced through fermentation commercially prior to 1940 and can be again with competitively priced cellulosic sugars.



SucreSource

Typical Biopathways to Future Bio-Chemicals

SucreSource produced cellulosic sugars are clear (no solids), concentrated (~12-18%), contain low inhibitors (<1%) and will typically feed microbial metabolics better than laboratory sugar standards (~10-20% improvement). Chemical hydrolysis approach allows transformation of lowest cost mixed biomass feedstocks for lowest sugar production costs (~$10-15/100 lbs).

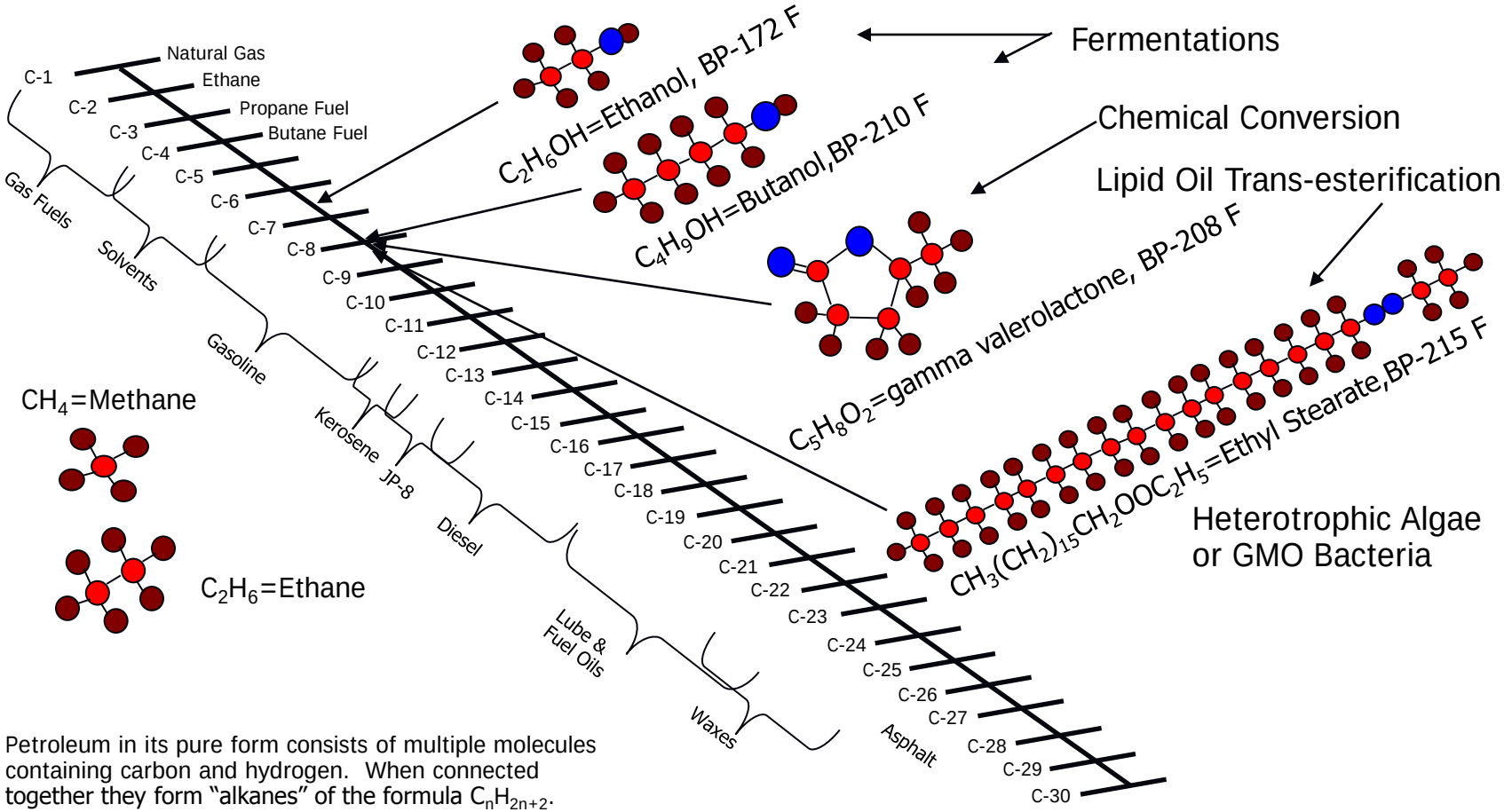
Identification of Actual and Potential Pathways to Building Blocks from Sugars

Building Blocks	Yeast or Fungal	Bacterial	Yeast or Fungal	Bacterial	Chemical & Catalytic Processes	Biotrans-formation
	AEROBIC FERMENTATIONS		ANAEROBIC FERMENTATIONS		CHEM-Enzyme TRANSFORMATIONS	
3 Carbon	Commercial Product - C	Commercial Product - C	Commercial Product - C	Commercial Product - C	Commercial Product - C	Commercial Product - C
3-Hydroxy propionic acid	X	X				
Glycerol	X	X	X	X	C	
Lactic acid	X		X	C		
Malonic acid	X				X	
Propionic acid				X		
Serine	X	C				C
4 Carbon						
3-Hydroxy butyrolactone					X	
Acetoin	X	X		X		
Aspartic Acid	X	X				X
Fumaric Acid	X	X			X	
Malic acid	X	X				
Succinic acid	X	X		X		X
Threonine	X	C				
5 Carbon						
Arabitol	X		X		C	X
Furfural					C	
Glutamic	X	C				
Itaconic Acid	C					
Levulinic acid					X	
Xylitol	X		X	X		C
6 Carbon						
2,5 Furan dicarboxylic acid					X	
Aconitic acid	X					
Citric acid	C					
Glucaric acid	X	X			X	
Gluconic acid	C	X				X
Levoglucosan					X	
Lysine	X	C				
Sorbitol	X	X			C	X
Number in each Pathway category*	21	14	4	6	11	7
Commercial processes	3	4	0	1	4	2

*DOE, "Top Value Added Chemicals from Biomass, Vol 1, August 2004,DOE/GO-102004-1992"

SucreSource

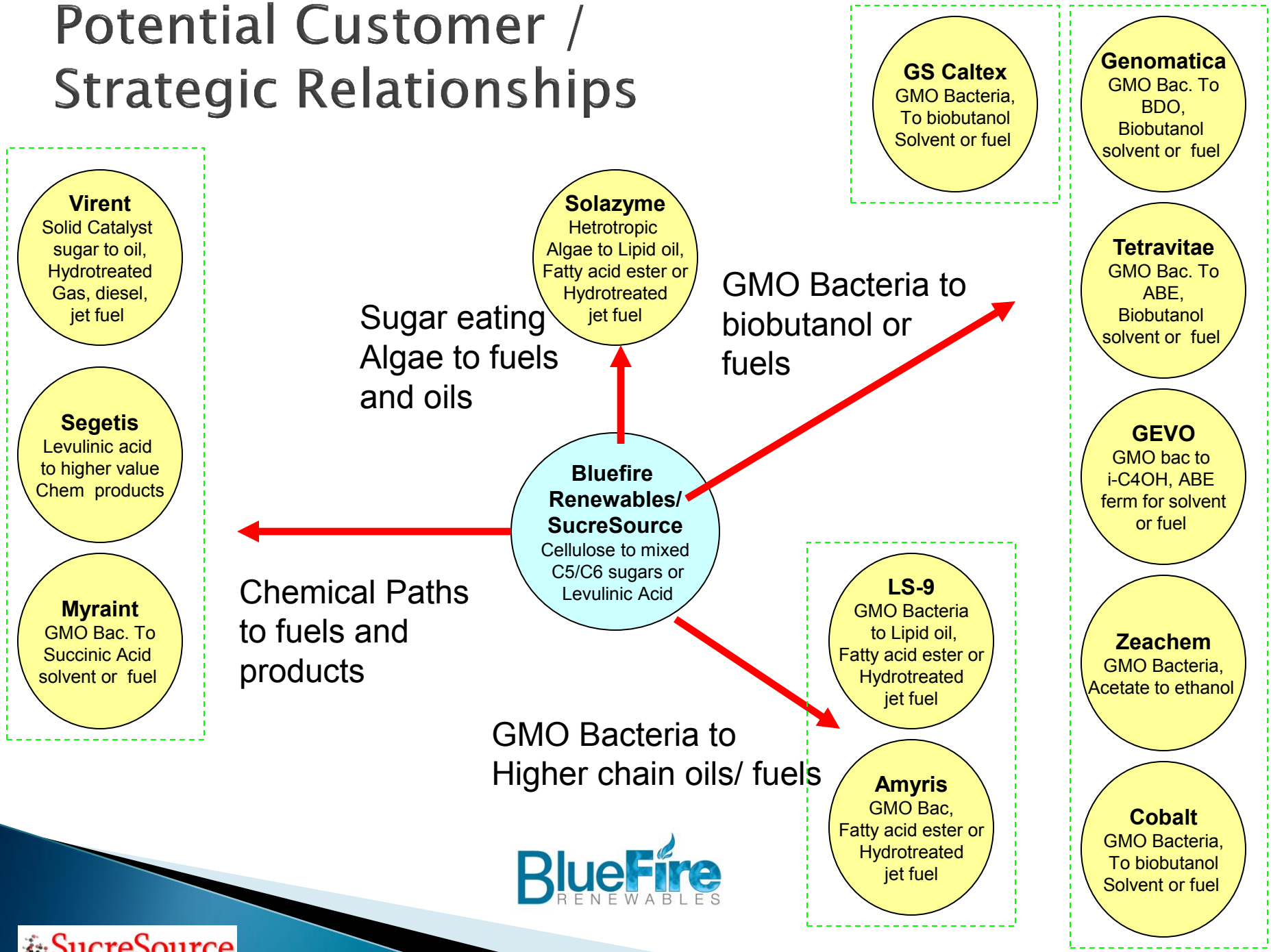
Biofuels Beyond Ethanol & BioButanol



Petroleum in its pure form consists of multiple molecules containing carbon and hydrogen. When connected together they form "alkanes" of the formula C_nH_{2n+2}. Groups of Alkanes are separated by boiling points to form product "cuts".

SucreSource

Potential Customer / Strategic Relationships



BlueFire RENEWABLES

SucreSource

Biomass Opportunities for Sugars

Component	Percent Dry Weight
Cellulose	40-60%
Hemicellulose	20-40%
Lignin	10-25%

Typical levels of cellulose, hemicellulose and lignin in biomass

Material	Six-Carbon Sugars	Five-Carbon Sugars	Lignin	Ash
Hardwoods	39-50%	18-28%	15-28%	0.3-1.0%
Softwoods	41-57%	8-12%	24-27%	0.1-0.4%
Ag Residues	30-42%	12-39%	11-29%	2-18%
Grasses	30-42%	30-39%	17-20%	4-5%
Bagasse	**44.8%**	**36.7%**	**17.61%**	**0.82%**

Sugar and Ash Composition of Various Biomass Feedstocks (Weight Percent)

Mean deviation from best to worst waste mix is :

Material	Six-Carbon Sugars	Five-Carbon Sugars	Lignin	Ash
Mean Feed	42.1%	22%	21.4%	1.5%
Deviation	+/- 4%	+/- 8%	+/- 2%	+/-0.3%

SucreSource

U.S. Department of Energy
Energy Efficiency and Renewable Energy

Feedstock Flexibility

Tier 1
Minimal Cost Per Ton

Municipal Waste

- Non-Recyclable Paper
- Tree pruning's
- Grass clippings
- Lumber
- Wood Chips
- Landscaping Residue
- Construction & Demolition Debris (woody portion)

Tier 2
$15-$50 Per Ton

Forestry Waste

- Wood Chips
- Harvesting Slash
- Saw Mill Waste
- Paper Mill Waste
- Disease/Beetle Infested Trees

Tier 3
$35-$125 Per Ton

Agricultural Waste

- Corn Stover
- Switch Grass
- Energy Cops
- Cereal Straws
- Sugar Cane Bagasse

SucreSource

Starch vs. Cellulosic Sugars

Starch

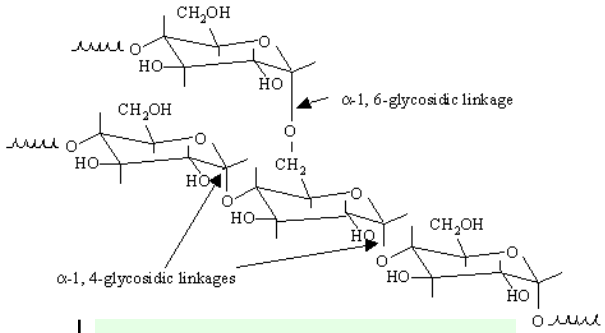
Sugars are more commonly found in the form of biopolymers that must be chemically processed to yield simple sugars. In the United States, today's fuel ethanol is derived almost entirely from the starch (a biopolymer of glucose) contained in corn. Starch consists of glucose molecules strung together by a-glycosidic linkages. These linkages occur in chains of a-1,4 linkages with branches formed as a result of a-1,6 linkages.

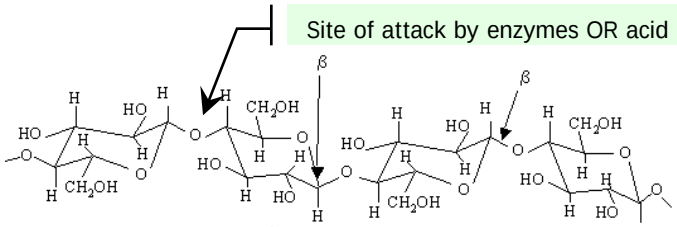
Cellulose

Cellulose, the most common form of carbon in biomass, is also a biopolymer of glucose. In this case, the glucose moieties are strung together by ß-glycosidic linkages. The ß-linkages in cellulose form linear chains that are highly stable and much more resistant to chemical attack because of the high degree of hydrogen bonding that can occur between chains of cellulose. Hydrogen bonding between cellulose chains makes the polymers more rigid, inhibiting the flexing of the molecules that must occur in the hydrolytic breaking of the glycosidic linkages.

Lignin

Lignin or lignen is a complex phenolic chemical compound most commonly found in wood, and an integral part of the secondary cell walls of plants. It is one of the most abundant organic polymers on Earth, exceeded only by cellulose, sequestering 30% of non-fossil organic carbon and constituting from a quarter to a third of the dry mass of wood. As a biopolymer, lignin is unusual because of its heterogeneity and lack of a defined primary structure. Its most commonly noted function is the support through strengthening of wood cells in trees.





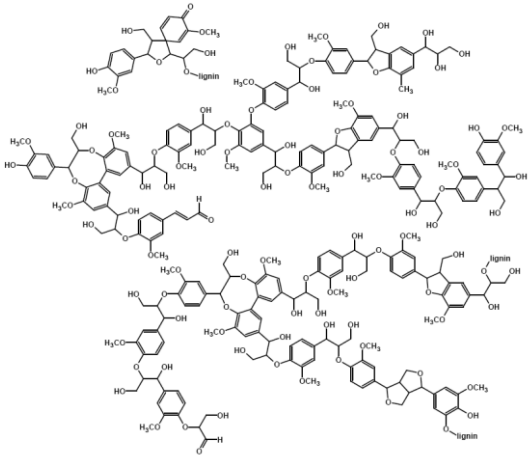


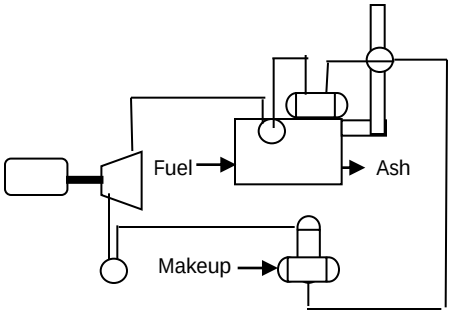
Figure 3 - Structural Motifs of Softwood Lignin

U.S. Department of Energy
Energy Efficiency and Renewable Energy

SucreSource

Leading Biomass Conversion Processes:

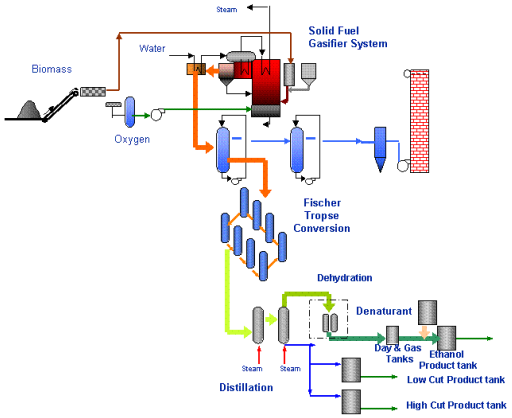
Biomass to Power



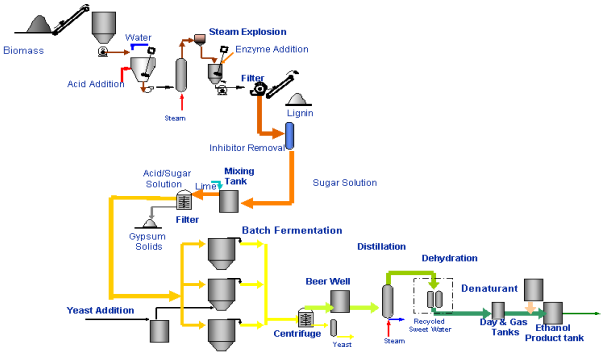
- Conventional combustion produces ~$1.8 /ton of feed

Biomass Thermochemical Decomposition

100 gal/ton alkane or alcohol mixed products no sugars



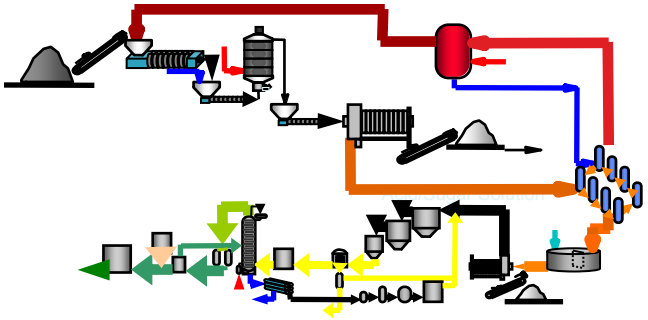
Biomass Enzymatic Conversion to Sugars



60 gal/ton ethanol ~ 950 lbs sugars ~ $18/ton feed

Biomass Chemical Conversion to Sugars

80 gal/ton ethanol ~1200 lbs sugars ~ $26/ton feed



SucreSource

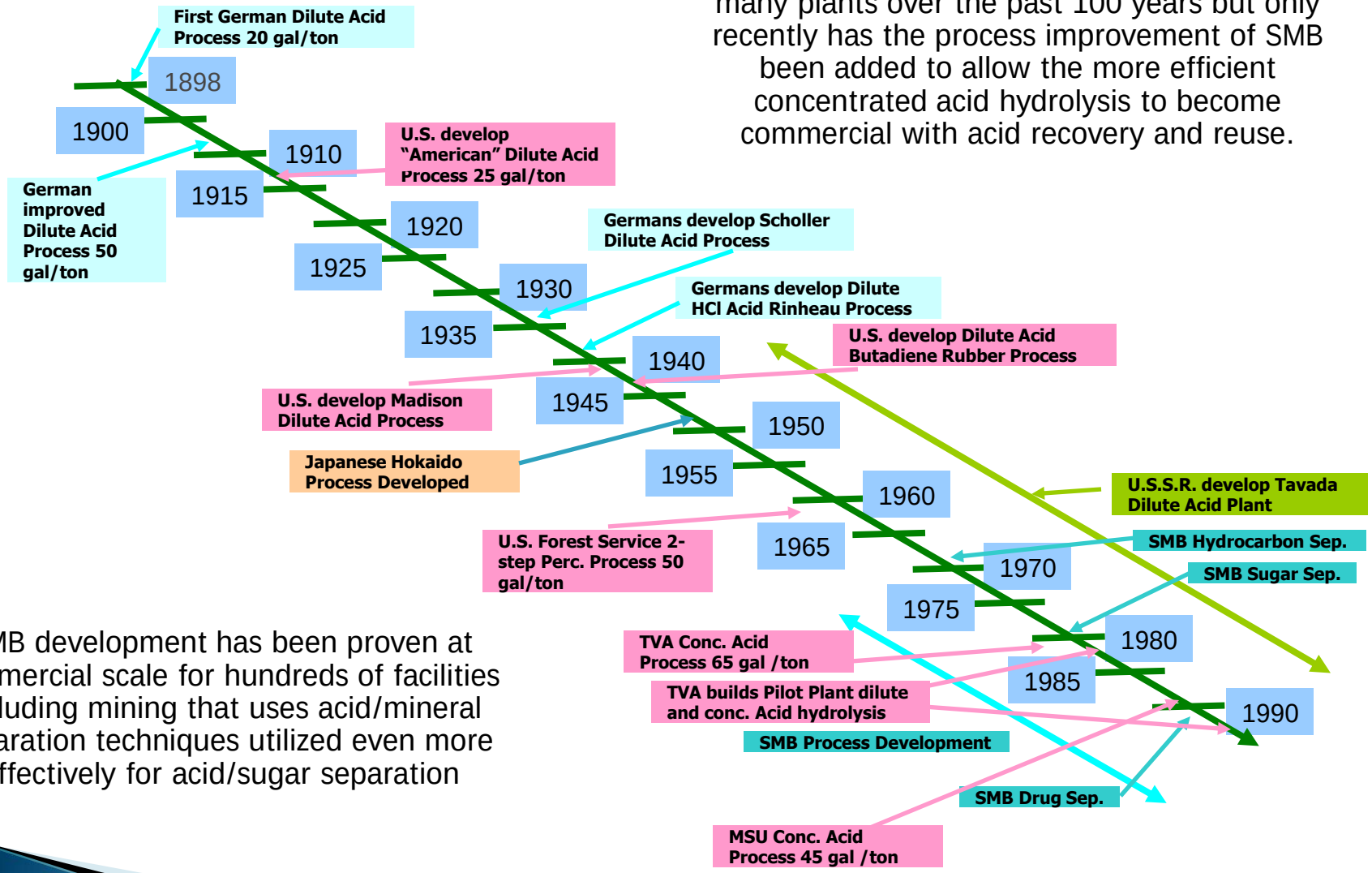
Technology Feasibility Checklist

Issues	Ideal Hydrolysis Technology	Enzymatic Hydrolysis	Weak Acid Hydrolysis	Strong Acid Hydrolysis	Concentrated Acid Hydrolysis	Gasification	Pyrolysis
Capital Cost (55 MMGPY Size)	low	$15-20/gal	$12-15/gal	$10-15/gal	$8-10/gal	$5-20/gal	$8-15/gal
Energy Usage	low	97kBTU/gal	83kBTU/gal	88kBTU/gal	105kBTU/gal	167kBTU/gal	137kBTU/gal
Feedstock Flexibility	high	1-genus,10var	All Genus same Decryst	All Genus same Decryst	All Genus	All Genus need H2:CO ratio	All Genus need H2:CO ratio
Sugar Selectivity	high	40-50% C6, 10-20% C5	40-50% C6, 10-20% C5	50-60% C6, 15-25% C5	70-80% C6, 60-70% C5	N/A	N/A
Sugar Yield	high	30-50 gal/BDT	30-50 gal/BDT	40-60 gal/BDT	70-80 gal/BDT	80-100 gal/BDT	50-70 gal/BDT
Production of Inhibitors	low	C5 Deg , Furfural, HMF	C5 Deg , Furfural, HMF	C5 Deg , Furfural, HMF	<1% Organic Acids	CO2, Catalyst Deactivators	PCBs
Potential Health Hazard	low	Enzyme Sensitivity	Volatile organic acids	Volatile inorganic acids	Low Volatility, Most Common Chem	High Temp, High Pres. Flamable Gas	Carcinogens
Op Cost Gross Margin	high	$0.5/gal Enzyme, -10% IRR	$0.5/gal Chem, -10% IRR	$0.4/gal Chem, -5% IRR	$0.85/gal All in, 25% IRR	$0.6/gal Chem & Cat, 5% IRR	$0.3/gal Waste, -5% IRR

SucreSource

Acid Hydrolysis Process Development Timeline

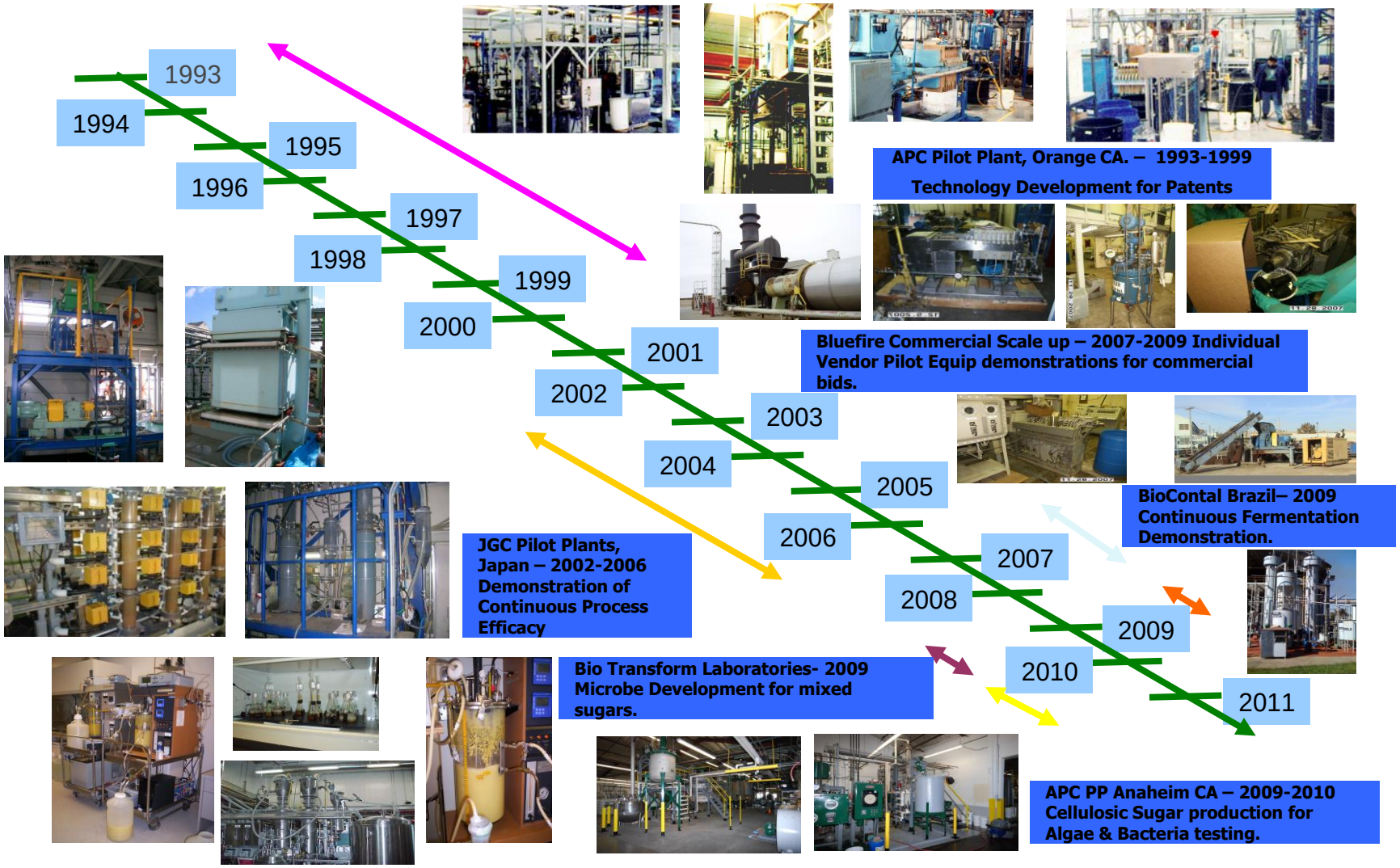
Acid Hydrolysis has been commercialized in many plants over the past 100 years but only recently has the process improvement of SMB been added to allow the more efficient concentrated acid hydrolysis to become commercial with acid recovery and reuse.



SMB development has been proven at commercial scale for hundreds of facilities including mining that uses acid/mineral separation techniques utilized even more effectively for acid/sugar separation

SucreSource

Arkenol-Bluefire Ethanol Development Timeline

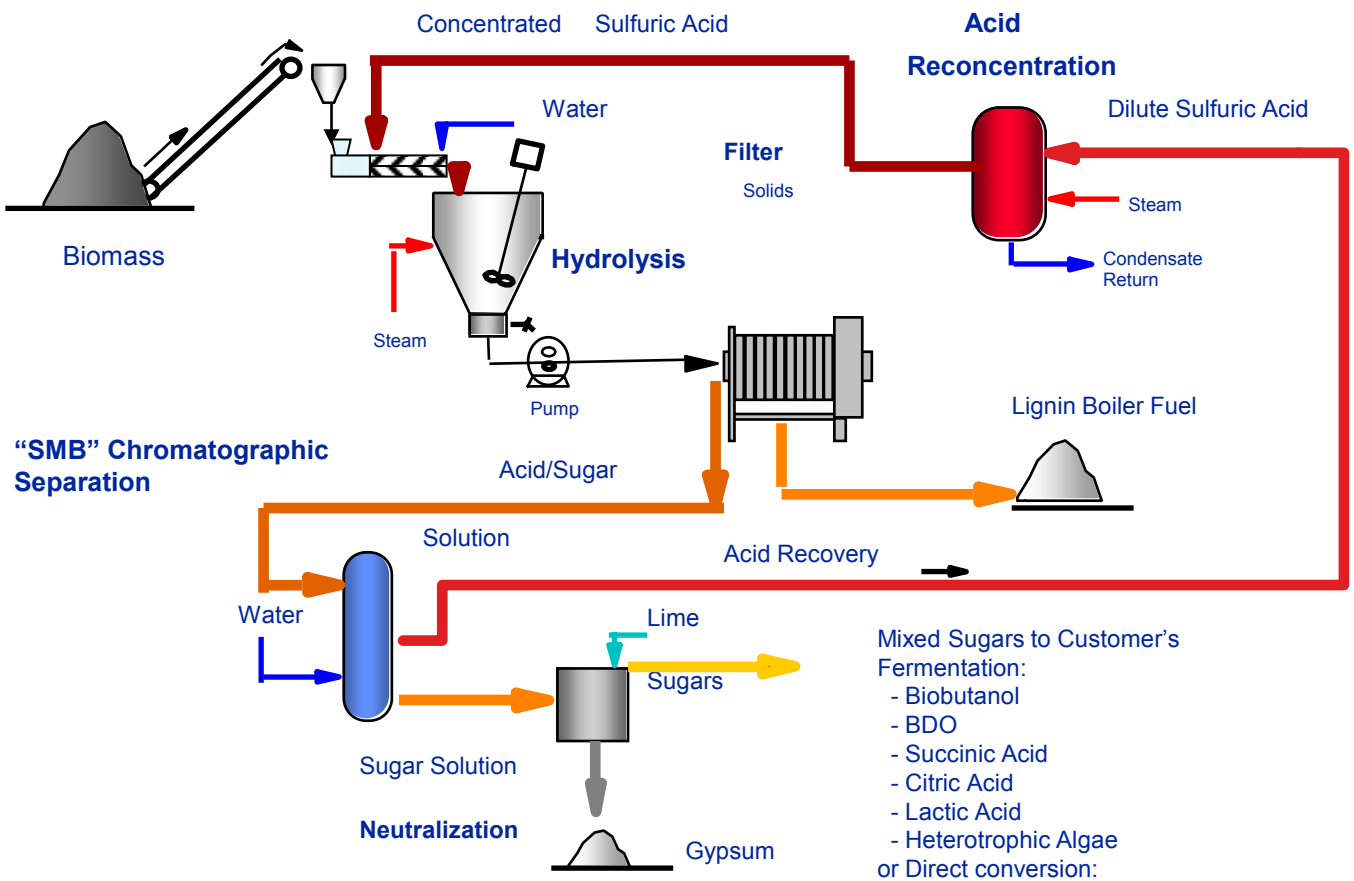


Pilot plants built for IP development and patent protection, third party validation of technology, commercial scale-up confirmation and cellulosic sugar production for customer testing with > 5,000 hrs operation.

SucreSource

SucreSource™ Conversion of Cellulosic Biomass to Mixed Sugars

*** Using Arkenol's Concentrated Acid Hydrolysis Process**



Mixed Sugars to Customer's Fermentation:
- Biobutanol
- BDO
- Succinic Acid
- Citric Acid
- Lactic Acid
- Heterotrophic Algae

or Direct conversion:
- Hydrogenation
- Thermal conversion

SucreSource

ARKENOL Concentrated Acid Hydrolysis of Cellulosic Feedstock to Fermentable Sugars Process-1 Bone Dry Ton Breakdown

Feedstock –
1-ton, 2,000 lbs.
60% - 1,200 lbs Cellulose
25% - 500 lbs. Hemicellulose
12% - 240 lbs. Lignin
3% - 60 lbs. Ash
0% - 0 lbs. Water

- 0% Ash processing

Decrystallization (Pretreatment) –
1,200 lbs Cellulose
500 lbs. Hemicellulose
240 lbs. Lignin
60 lbs. Ash
700 lbs. Water
2,100 H2SO4

Water

Chemical Hydrolysis -
290 lbs Cellulose
90 lbs. Hemicellulose
1,280 lbs C6+
180 lbs C5+
80 lbs. inerts
240 lbs. Lignin
2,760 lbs. Water
2,100 H2SO4

66 lbs 93%
Makeup H2SO4

SMB- Extract
2 lbs C6+
0 lbs C5+
1 lbs. inerts
10,020 lbs. Water
2,038 H2SO4

Water

Filtration Lignin Cake-
289 lbs Cellulose
89.5 lbs. Hemicellulose
55 lbs C6+
12 lbs C5+
79 lbs. inerts
239 lbs. Lignin
800 lbs. Water
20 H2SO4

Filtration Liquor-
1 lbs Cellulose
0.5 lbs. Hemicellulose
1,225 lbs C6+
168 lbs C5+
0.5 lbs. inerts
1 lbs. Lignin
5,510 lbs. Water
2,080 H2SO4

SMB- Extract
2 lbs C6+
0 lbs C5+
1 lbs. inerts
10,020 lbs. Water
2,038 H2SO4

SMB- Raffinate
1,223 lbs C6+
168 lbs C5+
4 lbs. inerts
9,320 lbs. Water
42 H2SO4

Neutralizer
1,217 lbs C6+
160 lbs C5+
1 lbs. Gypsum
9,560 lbs. Water

Neutralizer
6 lbs C6+
8 lbs C5+
58 lbs. Gypsum
43 lbs. Water

76% recovery of Cellulose, 82% Hemicellulose
81% conversion of feed to sugars by wt.
12.6% Sugar (11% C6, 1.5% C5)
97% Recovery of H2SO4
17% lowest conc. H2SO4
Batch Filtration run in parallel w/surge vessels
SMB Acid Recovery 98%, Sugar Recovery 100%
<24-hr feed to product, 1-min pretreatment, 45-min Hydrolysis, 1.5 hr SMB, 6 hr ferm to ETOH
Hydrolysis yields based on temp, decryst, acid, time
Lignin (~3500 BTU/lb), soil or plastics feedstock

ARKENOL

SucreSource

Typical SucreSource Questions and Answers:

(Actual Customer Questions)

- 1. Could you provide some actual data including
- – Hydrolysis yields of cellulose and hemicellulose (%)? *The cellulose and hemicellulose contained in the biomass feedstock must be separated from the lignin (pretreatment) before being broken down to monomer sugar components. The conversion of 76% cellulose and 82% hemicellulose in the feed to soluble polymers attackable by hydrolysis is achieved by our concentrated acid decrystallization.*
- – Sugar recovery yield and final concentration (%)? *Sugars are created from cellulose (92-100% C6) and hemicellulose (50-60% C5, 40-50% C6) polymers using chemical hydrolysis where there is enough water present in an acid solution to cleave monomer sugars and complete the molecule with water weight gain. 81% of the available cellulose and hemicellulose is recovered as monomer sugars but weight of sugars is 110% of initial cellulose and hemicellulose due to water weight gain.*
- – Recovery yield of sulfuric acid (%)? *With all of the sulfuric acid loses considered, 97% of the acid is recovered and reused in the process.*
- – The lowest concentrations of hydrolyzed sugar and sulfuric acid in the entire process? *The lowest concentration of sugars is 12.6% (depending on feedstock) in the product stream with 17% acid concentration being the lowest in the SMB extract stream to the reconcentrator.*

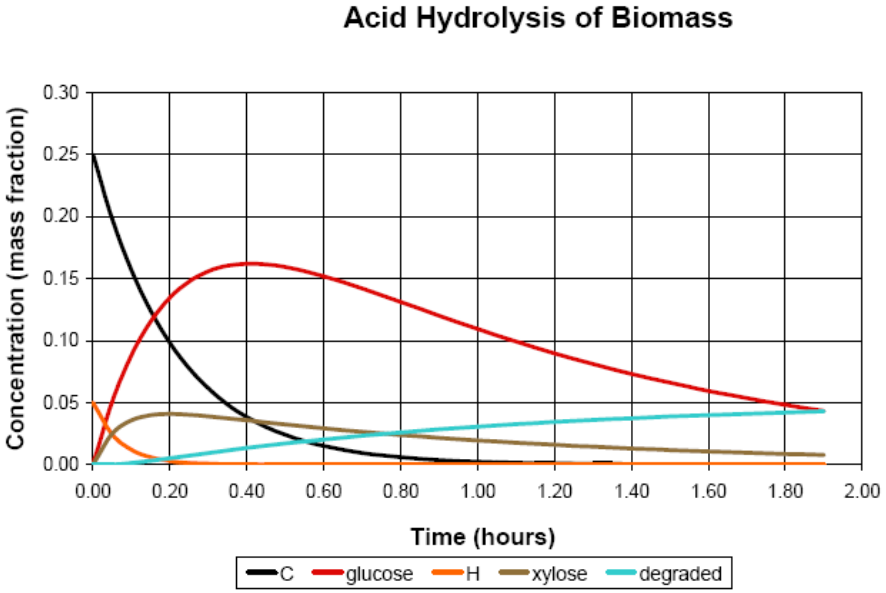
SucreSource

Typical SucreSource Questions and Answers:

(Actual Customer Questions)

- 2. Are overall steps continuous process? If there were any step of batch process, which is the step? *The entire process is continuous with the exception of filtration. Multiple filters are used in batch mode with feed and product surge vessels so that filtration times do not affect continuous flow of processing.*
- 3. Is it possible to increase the recovery yield of sugar and sulfuric acid in the SSMB step? *Yes, but the economic returns don't justify adding capacity to improve on 98% acid recovery and 100% sugar recovery currently achieved.*
- 4. What kind of mixing method is applied to the first hydrolysis step? How long time does wood pieces stay in the extruder? *Solid wood pieces are pushed into a twin barrel kneader to be mixed with the concentrated acid. The resulting biomass paste containing solubilized cellulose and hemicellulose is pushed by the extruder into the hydrolyser pump within 60 seconds to be mixed with water and hydrolyzed.*
- 5. What do you think about the major factor that determines the hydrolysis yield of biomass in the scale-up concern?

Acid hydrolysis sugar production and degradation kinetics depend on operating temperature, acid concentration, solubilized cellulose and hemicellulose and residence time in that order. Scaleup is affected by plug flow reactor axial back mixing and radial mixing to uniformity. Temperature rise during reaction is negligible and heat loss minimal due to low thermal conductivity of hydrolysate.

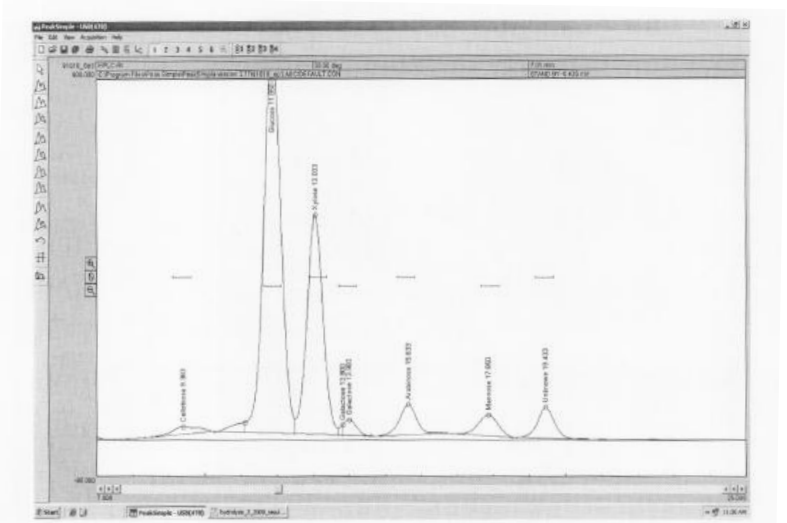


SucreSource

Typical SucreSource Questions and Answers:

(Actual Customer Questions)

- 6. Is there any other use of lignin else burning? *Polymorphic Lignin can be extracted from lignin cake and converted to adhesives, plastics or phenolic solvents, used as a soil amendment or fuel (~8,500 BTU/lb dry).*
- 7. In lignin stream, is there any additional recovery of sugar and sulfuric acid? *The filter cake uses a 4 x counter current wash that removes all but ~1% acid and 2% sugar content by weight of cake using only 1.x cake volumes of rinse water.*
- 8. What is the composition of the recovered sugars (% of dextrose/ Xylose/galactose/arabinose/mannose %? Dimmers? Oligomers%)? *Typically <3% dimmers, < 0.5% trimers and no oligomers.*
- 9. What is the amount of HMF/furfural/lignin derivatives/organic acids in the final sugar product? *Typically <1% furfural and organic acids going to SMB with <10% of that in raffinate product (<0.10%).*



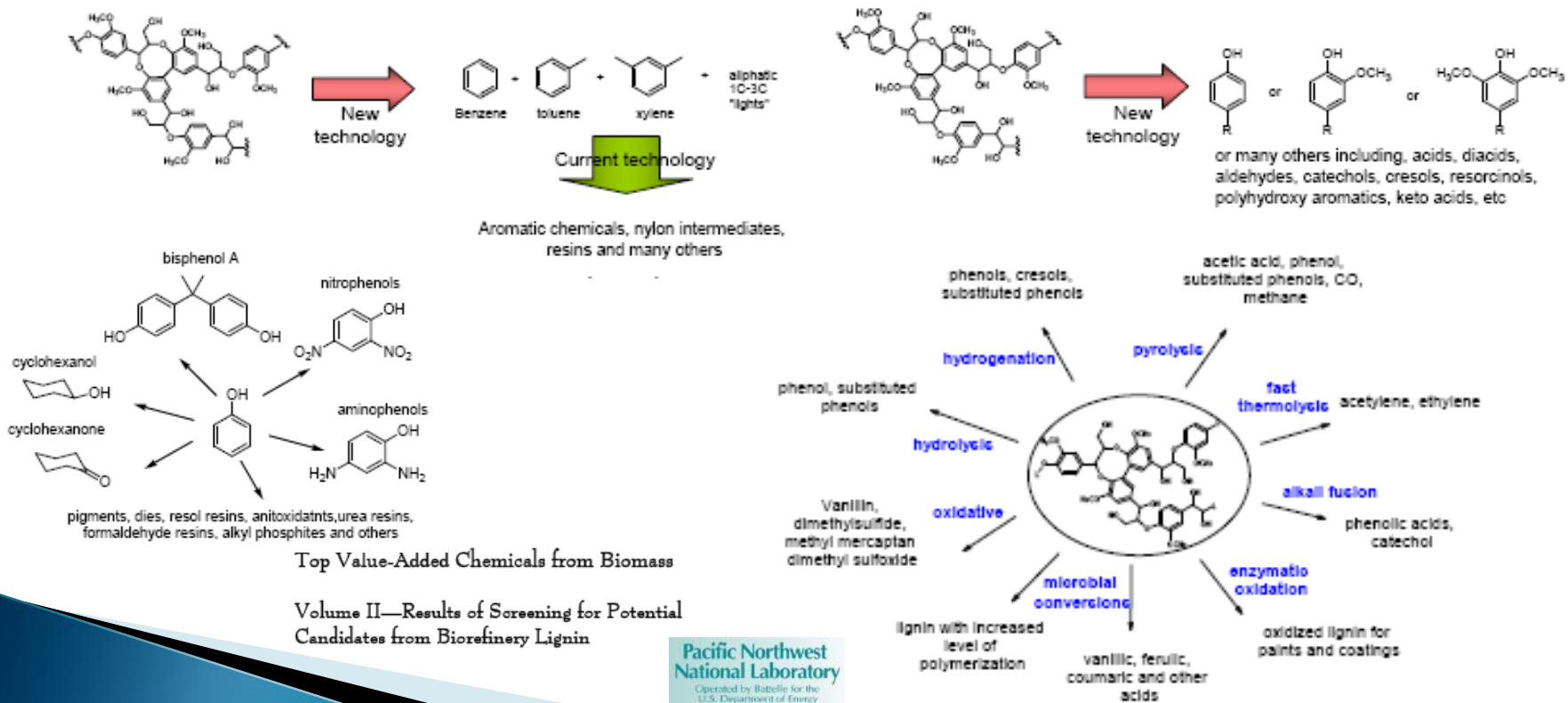
Number	Component	Retention	Area	Sugar Standard curves	X	% Sugar
1	Cellobiose		871.56	Y= 20330X – 9.578; R = 0.9999	0.04	0.69
2	Glucose	11.85	28319.9	Y = 19640X – 16.72; R2 = 1	1.44	22.95
3	Xylose	13.03	14899.6	Y = 18630X – 29.07 R2 = 0.9996	0.8	12.75
	Galactose	13.98	856.41	Y = 17350 X – 22.41 R2 = 0.916	0.05	0.81
5	Arabinose	15.63	1763.41	Y = 19700 X – 34.99 ; R2 = 0.999	0.09	1.45
6	Mannose	17.85	6746.4	Y = 19010 X – 22.95 ; R2 = 0.9998	0.36	5.67
					Total % sugar =	44.32

SucreSource

Arkenol Concentrated Acid Hydrolysis Technology Bio-Chemicals

Concentrated Acid Hydrolysis Technology can Transform Lower Value Biomass Mixed Wastes into Fermentable Sugars, Lignin, Gypsum and Residual C5 Sugars. The Fermentable Sugars can be Fermented or Chemically converted to Biofuels, Solvents, Plastic Feedstocks or Other Higher Value Products:

Lignin Pathway to Phenolic Chemicals



Top Value-Added Chemicals from Biomass

Volume II—Results of Screening for Potential Candidates from Biorefinery Lignin

Pacific Northwest National Laboratory
Operated by Battelle for the U.S. Department of Energy

SucreSource

SucreSource™
Acid Hydrolysis Hydrolysate Sugars

Analysis of hydrolyzate samples for oligosaccharides.

Chromatographic analysis was carried out by HPIC on an anion exchange column, eluted with dilute sodium hydroxide, with pulsed amperometric detection of carbohydrates. With this system, monosaccharides elute first and higher saccharides elute in the general order of number of saccharide units. In the case of fructooligosaccharides, for example, peaks for oligosaccharides with up to 30 - 40 saccharide units can be distinguished readily. Three hydrolyzate samples were analyzed: (1) #25, 12/17/07, 35 min.; (2) 12/18/07, 35 min.; (3) material composited and filtered at ARi. No significant peaks beyond trisaccharides were obtained in any of the samples. The following table gives analytical values for the observed peaks although these values should be considered approximate since the standards used did not necessarily correspond with the sugars present. Standard carbohydrates were: glucose and fructose for monosaccharides; sucrose for disaccharides; and kestose (fructosyl sucrose) for trisaccharides. All results are given in percent by weight of sample.

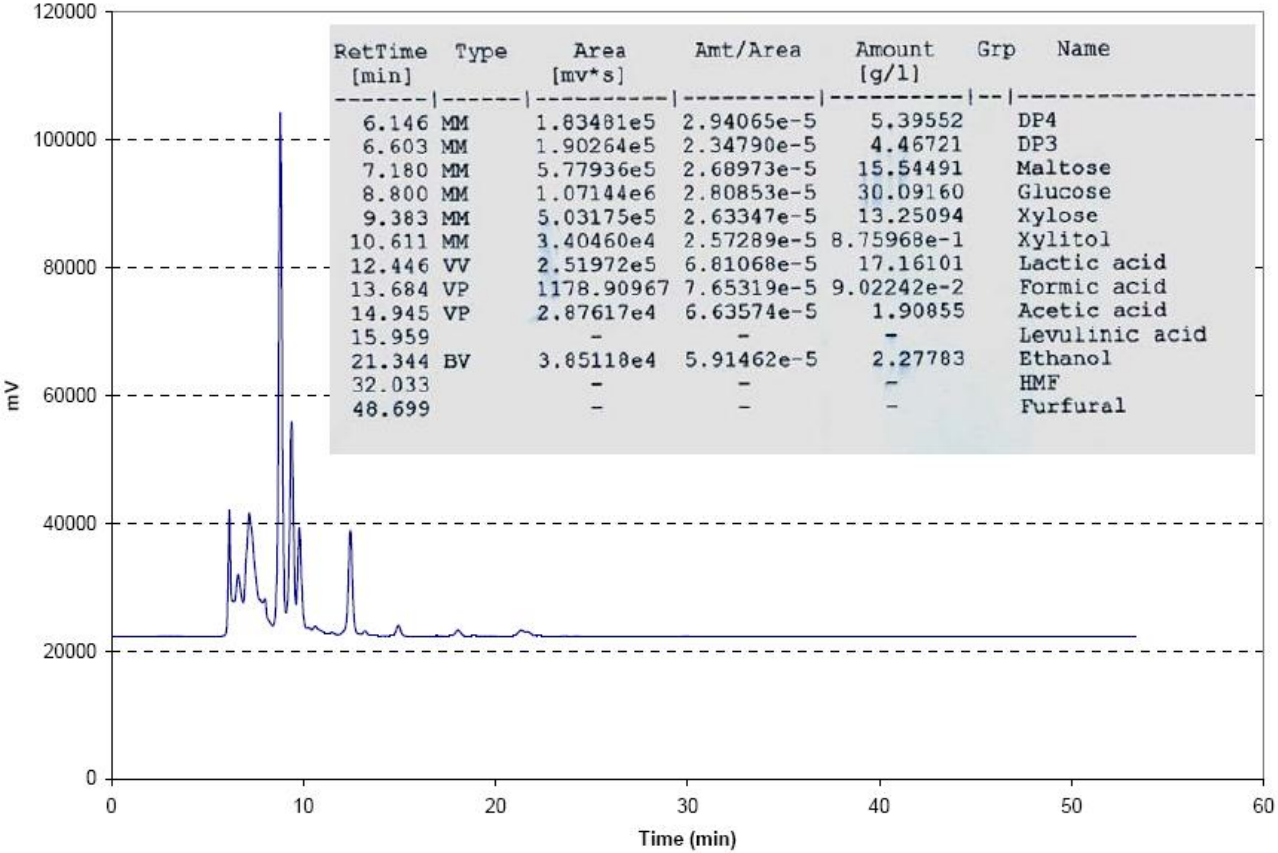
Sample	Monosaccharide	Disaccharide	Trisaccharide
#1 (12/17, 35 min)	9.47	0.30	0.57
#2 (12/18, 35 min)	8.88	1.29	0.34
#3 (composite)	8.44	1.37	0.53

Analysis of CSP Hydrolysate for Sugars by ARI

SucreSource

SucreSource™
Acid Hydrolysis Hydrolysate Sugars

Figure 1: HPLC Analysis of the Hydrolysate (60 min run time)



RetTime [min]	Type	Area [mv*s]	Amt/Area	Amount [g/l]	Grp	Name
6.146	MM	1.83481e5	2.94065e-5	5.39552		DP4
6.603	MM	1.90264e5	2.34790e-5	4.46721		DP3
7.180	MM	5.77936e5	2.68973e-5	15.54491		Maltose
8.800	MM	1.07144e6	2.80853e-5	30.09160		Glucose
9.383	MM	5.03175e5	2.63347e-5	13.25094		Xylose
10.611	MM	3.40460e4	2.57289e-5	8.75968e-1		Xylitol
12.446	VV	2.51972e5	6.81068e-5	17.16101		Lactic acid
13.684	VP	1178.90967	7.65319e-5	9.02242e-2		Formic acid
14.945	VP	2.87617e4	6.63574e-5	1.90855		Acetic acid
15.959		-	-	-		Levulinic acid
21.344	BV	3.85118e4	5.91462e-5	2.27783		Ethanol
32.033		-	-	-		HMF
48.699		-	-	-		Furfural

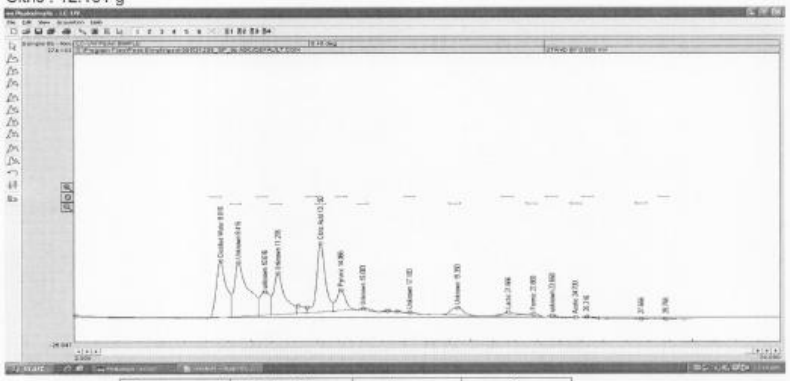
Despite Lactobacillus contamination of sample, BTR Analysis of CSP Hydrolysate Sugars showed virtually no HMF or Furfural inhibitors.

SucreSource

SucreSource™
Acid Hydrolysis Hydrolysate Sugars

Column : Alltech IOA-1000 Organic Acids
Serial No.: 05510327 Lot no. 056-29 300 mm x 7.8 mm Part No: 9646 Bin : G45
Hardware Type: Female (B)
Temperature: 40.0ºC Flowrate: 0.4 ml/min ========> Pressure: 66 - 70 psi
Detector: UV / Wavelength: 210 nm
Software : PEAK SIMPLE CHROMATOGRAPHY DATA SYSTEM

03/13/09
Rxn - 31209
Sample 6 @ 12:10 p.m
Wt. Sample : 0.685 g
Citric : 12.131 g

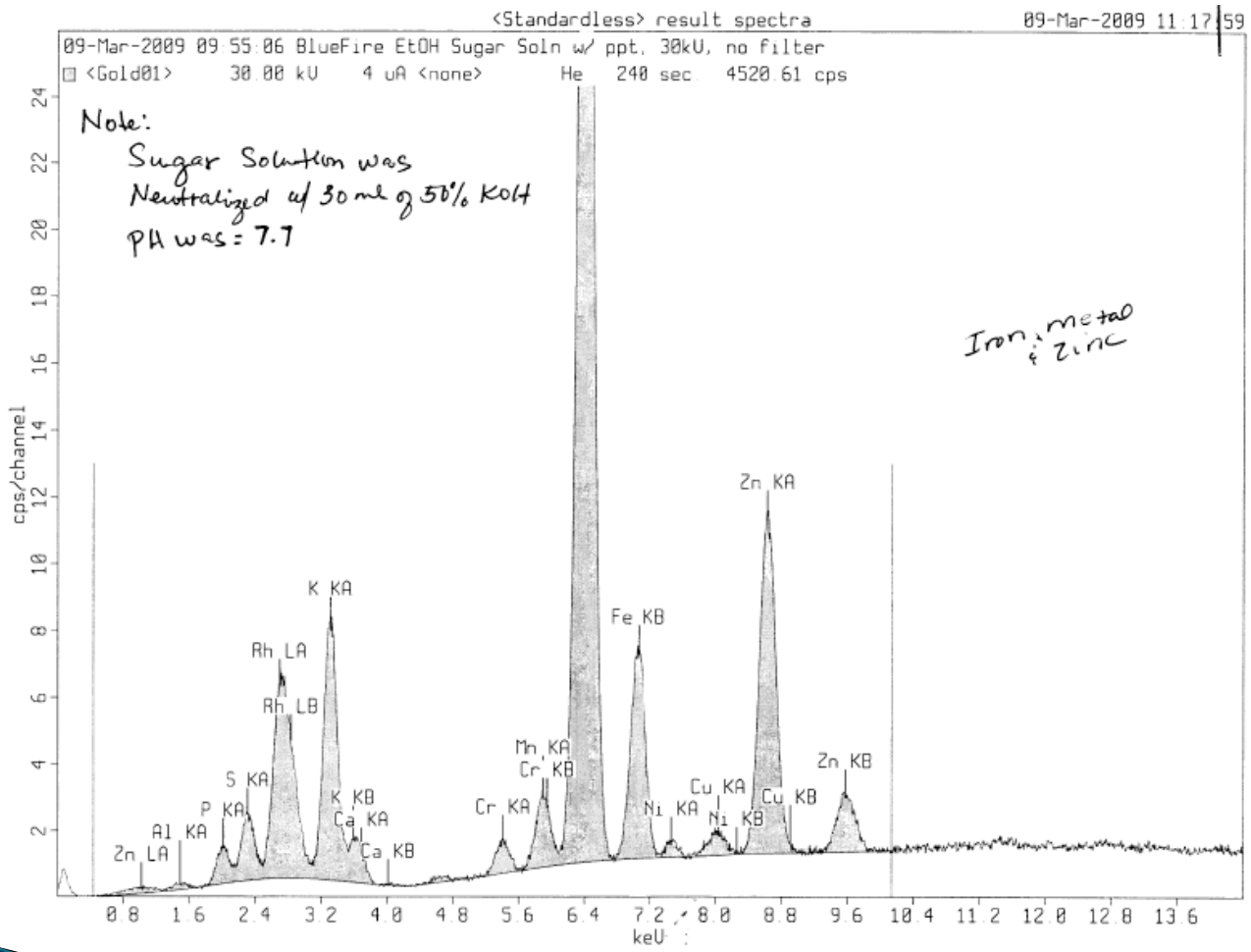


Component	Retention	Area	%
Distilled Water	8.62	1946.11	
Unknown	9.42	2446.02	
unknown	10.62	728.84	
Unknown	11.22	1462.16	
Citric Acid	13.15	1920.8	
Pyruvic	14.07	601.12	0.03
Unknown	15.08	64.09	
Unknown	17.18	21.08	
Unknown	19.35	304.25	
Lactic	21.67	122.08	0.11
Formic	22.8	56.29	0.04
unknown	23.65	48.16	
Acetic	24.7	6.03	0.06
		Total Acid	**0.24**

Pilot Plant Sugar Concentrate Organic Acid Analysis by APC for Customer showed little organic acid generation at low temperature pretreatment and hydrolysis conditions.

SucreSource

SucreSource™
Acid Hydrolysis Hydrolysate Sugars



Pilot Plant Hydrolysate Mineral Content by BTR of CSP Sugars for Nutrient Assessment

Metal	ppm
K	2000
Al	277
P	496
S	429
Ca	118
Cr	82
Mn	185
Fe	3,672
Ni	47
Cu	77
Zn	1,017

SucreSource

SucreSource™
Acid Hydrolysis Hydrolysate Sugars

Table 1: Results of fermentations with hydrolysate

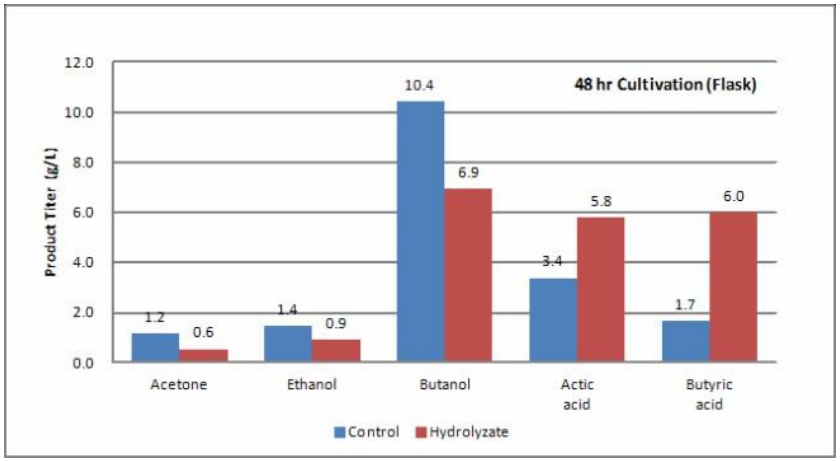
Hydrolysate Fermentations Testing Sterilization Procedures	Thermosacc S. cerevisiae Hydrolysate "as is" pH adj	Thermosacc S. cerevisiae Hydrolysate "pasteurized" pH adj	Thermosacc S. cerevisiae Hydrolysate "autoclaved" pH adj
YMXA: Aerobic Xylose only (20 g/L)			
glucose initial (g/L)	30.0916	30.12684	30.8101
glucose final (g/L)	10.34098	16.97947	15.93271
xylose initial (g/L)	13.2509	13.3315	13.4710
xylose final (g/L)	12.6078	12.1572	12.5925
Cell biomass:			
foil&filter (t=0)	1.1214	1.0873	1.1600
foil&filter&dry biomass, 5ml (t=0)	1.1220	1.0876	1.1604
cell biomass initial (g/L)	0.1200	0.0600	0.0800
foil&filter (t=19hr)	1.1405	1.0562	1.0604
foil&filter&dry biomass, 5ml (t=19hr)	1.1468	1.0599	1.0650
cell biomass final (g/L)	1.2600	0.7400	0.9200
cell biomass growth (g/L dry wt.)	1.1400	0.6800	0.8400
ethanol initial (g/L)	2.2778	2.2158	1.9715
ethanol final (g/L)	5.3932	4.0636	3.8474
pH initial	4.48	4.45	4.4
pH final	4.23	4.34	4.27
Glucose utilization (%)	**66**	**44**	**48**
Xylose utilization (%)	**5**	**9**	**7**
$Y_{cell/X}$ ***(g/g)***	0.058	0.052	0.056
$Y_{EtOH/X}$ ***(g/g)***	0.158	0.141	0.126

Pilot Plant Hydrolysate BTR Fermentation Test shows superior metabolic utilization of raw (pH adj) hydrolysate sugars by Sc yeast against treated and Laboratory Standard sugar media for growth and production.

SucreSource

SucreSource™
Acid Hydrolysis Pilot Plant Hydrolysate Sugars

Dilute Acid Pilot Plant Hydrolysate sugars use higher temperatures and longer residence times to produce representative hydrolysate sugars, but with higher organic acid contamination and Calcium ion levels due to reduced separation of lime neutralization and evaporative concentration.



Typical Mixed Hydrolysate Sugar Utilization

		Bluefire
	pH	7.55
g/L	Glucose	159.92
	Xylose	132.93
	Arabinose	1.21
	Maltose	-
	Succinic Acid	1.16
	Acetic Acid	24.39
	Lactic Acid	0.96
	Pyruvic Acid	-
	Malic Acid	-
	Fumaric Acid	-
	Xylulose	2.81
	Formic Acid	1.29
	Glycerol	0.07
	HMF	-
	Furfural	-
	Levulinic Acid	2.95
	Ethanol	
	Syringic Acid	0.028
	Vanillin	0.007
	Vanillic Acid	0.011
	Syringealdehyde	-
	Hydroxybenzoic acid	-
	Transferrulic Acid	
	2-Furoic Acid	
PPM	Sulfate	46.7
	Phosphate	21.7
	Chloride	527.4
	Ammonium	8.9
	As	-
	Ca	11430

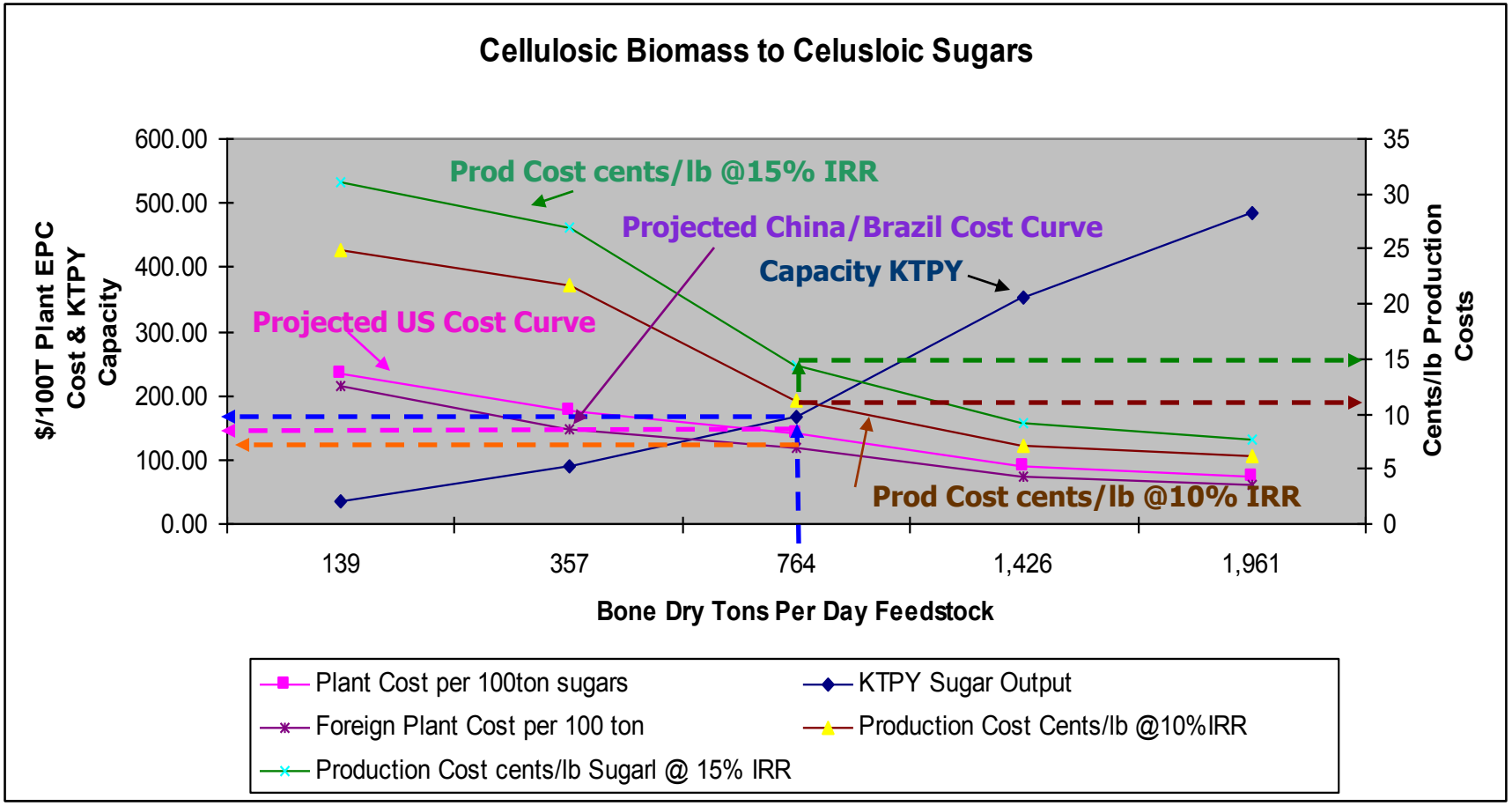
Expressed as:
g/l or ppm

	Cu	-
	Fe	2.7
	K	713.3
	Mg	1272
	Mn	17.8
	Ni	-
	Pb	-
	Zn	1.2
	Na	605.2
	Cr	-
	Asp	15.8
	Glu	115.9
	Ser	3.7
	His	2.0
	Gly	48.0
	Thr	44.2
	Arg	0.0
	Ala	94.0
	Tyr	2.6
	Val	77.5
	Met	0.0
	Phe	16.5
	Ile	25.9
	Leu	62.7
	Lys	2.3

SucreSource

Cellulosic Sugar Economics

As the plant capacity increases the cost per produced product is reduced and economics improve.

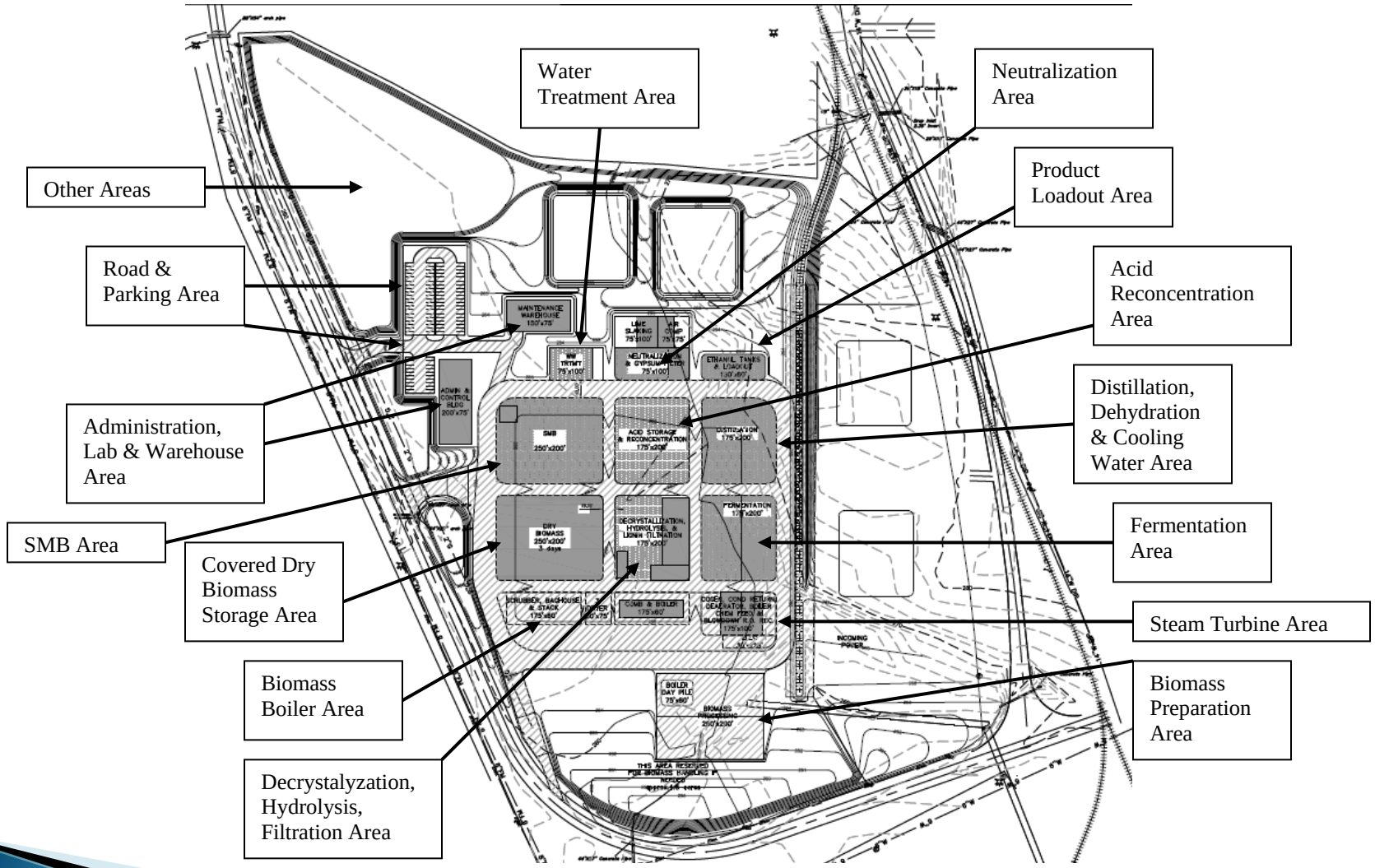


Example: 770 bdtpd biomass feedstock = 156 ktpy mixed sugars (~125 ktpy Glucose), at $150/100 ton x 1560 = $234-million EPC, ¢15 U.S. @15% IRR or ¢11 U.S @ 10% IRR 80/20 Debt/Equity

SucreSource

Fulton 18.9 MMGPY (770 bdtpd) Plant Layout –

38 acre site (~20-acres occupied by biomass to ethanol plant, ~ 16 by biomass to sugars portion of plant)



SucreSource

Statistical Validation of Predicted Plant Performance

* Using Crystal Ball® Monte Carlo Simulation Software

Assumption: E12

Normal distribution with parameters:

Mean	45.08%
Standard Dev.	4.51%

Selected range is from -Infinity to +Infinity

Cell: E12

(E12) Predicted Glucan Distribution

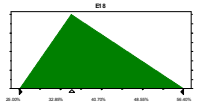
Assumption: E18

Triangular distribution with parameters:

Minimum	25.00%
Likeliest	35.00%
Maximum	56.40%

Selected range is from 25.00% to 56.40%

Cell: E18



(E18) Predicted Feed Moisture Distribution

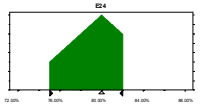
Assumption: E24

Triangular distribution with parameters:

Minimum	72.00%
Likeliest	80.00%
Maximum	88.00%

Selected range is from 75.04% to 82.03%

Cell: E24



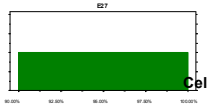
(E24) Predicted Hydrolysis Conversion

Assumption: E27

Uniform distribution with parameters:

Minimum	90.00%
Maximum	100.00%

Cell: E27



(E27) Predicted Filter Press Sugar Retention

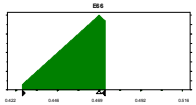
Assumption: E66

Triangular distribution with parameters:

Minimum	0.422
Likeliest	0.469
Maximum	0.516

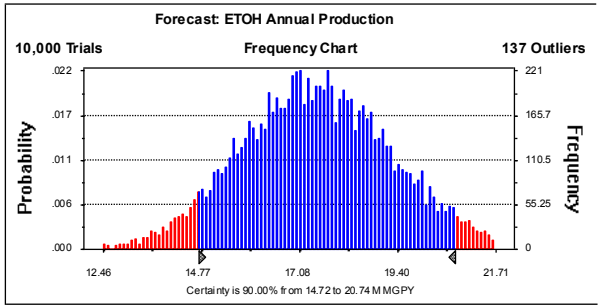
Selected range is from 0.426 to 0.472

Cell: E66

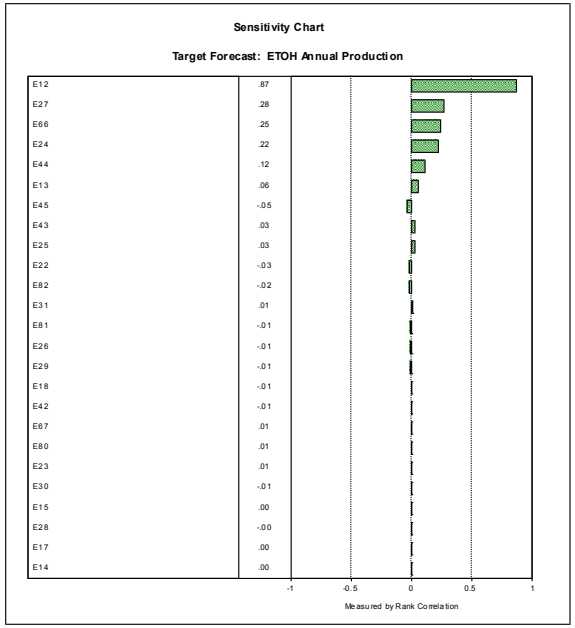


(E66) Predicted Fermenter Yeast Conversion

Plant Predicted Output (MMGPY)



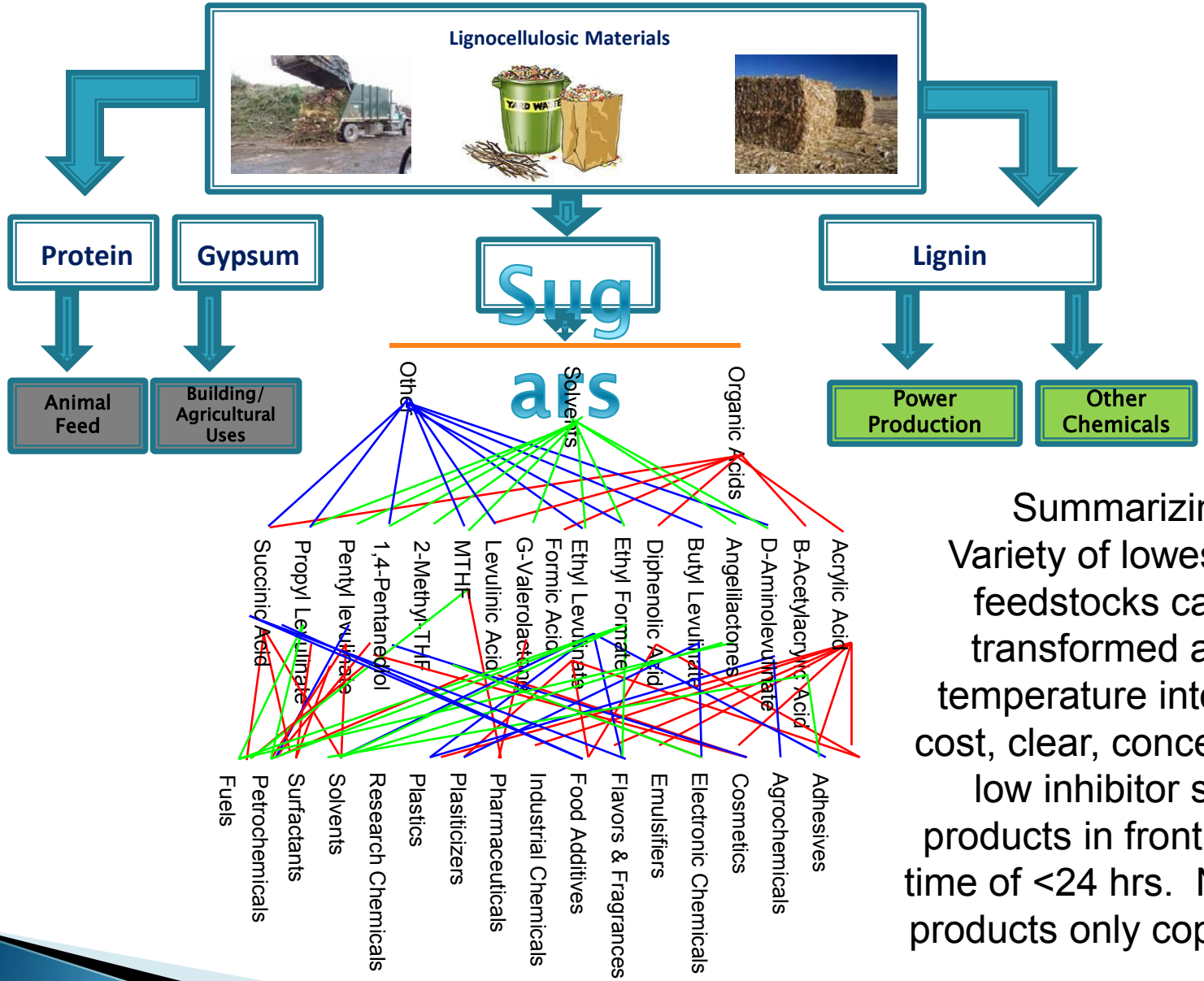
Tornado Chart of Inputs Affecting Outputs



Monte Carlo Simulation varies all inputs within a predicted value profile and depicts the resulting output as a statistical probability of performance. U.S. DOE requested Tornado diagram identifies relative impacts of different inputs on targeted output capacity (relative Risk)

SucreSource

BlueFire Technology = Maximum Flexibility in Feedstock, Products & Markets



Summarizing:
Variety of lowest cost feedstocks can be transformed at low temperature into lower cost, clear, concentrated, low inhibitor sugar products in front to back time of <24 hrs. No waste products only coproducts.

SucreSource

Sampling of Arkenol's Patents

i) Patent No. 5,562,777 for Arkenol's basic technology, "A Method of Producing Sugars Using Strong Acid Hydrolysis of Cellulosic and Hemicellulosic Materials" on October 8,1996;

ii) Patent No. 5,580,389 for "Method of Separating Acids and Sugars Resulting from Strong Acid Hydrolysis as Amended" on December 3, 1996;

iii) Patent No. 5,597,714 for "Strong Acid Hydrolysis of Cellulosic and Hemicellulosic Materials" on January 28, 1997;

iv) Patent No. 5,620,877 for "A Method of Fermenting Sugars Resulting From Strong Acid Hydrolysis As Amended" on April 15, 1997;

v) Patent No. 5,726,046 for "Method of Producing Sugars Using Strong Acid Hydrolysis" on March 10, 1998;

vi) Patent No. 5,782,982 for "Method of Removing Silica from Solids Resulting from the Strong Acid Hydrolysis of Cellulosic and Hemicellulosic Materials" on July 21, 1998;

vii) Patent No. 5,820,687 for "Method of Separating Acids and Sugars Using Ion Resin Separation" on October 13, 1998;

viii) Patent No. 5,892,107 for "Method for the Production of Levulinic Acid and Its Derivatives" on April 6, 1999.

(ix) Patent No. 6,054,611 for "Method for the Production of Levulinic Acid and Its Derivatives" on April 25, 2000;

(x) PCT International Publication Number WO 03/010339 A1 for "The Separation of Xylose and Glucose from Process Acid Hydrolysate" on February 6, 2003;

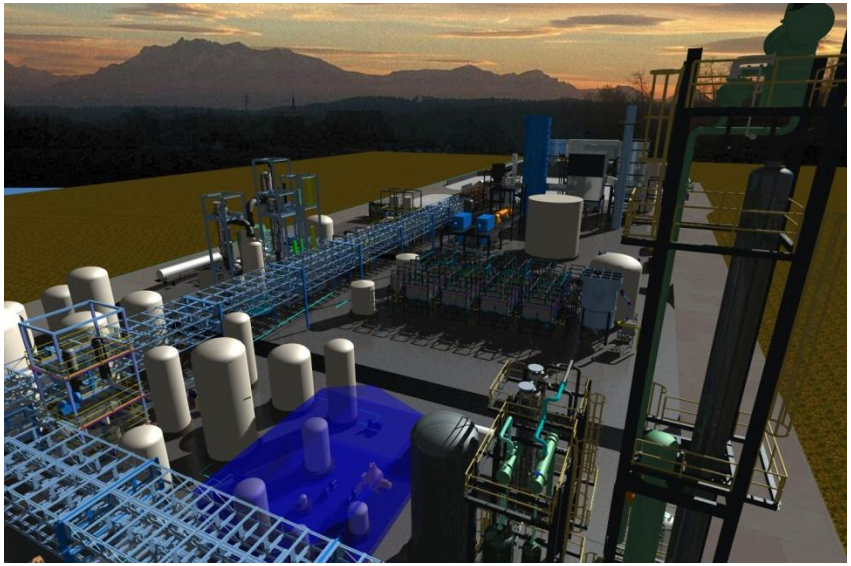
(xi) Patent No. 2,158,430 for "Method of Producing Sugars Using Strong Acid Hydrolysis of Cellulosic and Hemicellulosic Materials" on December 16, 2003; and

(xii) U.S. Patent Publication Number 2004/0173533 AI "Separation of Xylose and Glucose" on January 26, 2004.

~Patents allowed and pending on all continents~

SucreSource

Contact Information



BlueFire Corporate Offices
31 Musick
Irvine, CA 92618
main: 949-588-3767
fax: 949-588-3972
email: rgklann@bfreinc.com

Media Contact
Laura Finlayson
Beckerman Public Relations
One University Plaza, Suite 508
Hackensack, New Jersey 07601
email: lfinlayson@beckermanpr.com
phone: 201-465-8007