Producing Mixed Alcohols from Biomass

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Goals

- Provide an economically feasible alternative to oil
- Provide a sustainable energy source
- Provide a use for municipal waste materials
- Provide a smaller "Carbon Footprint™" than oil production

What are Mixalcs?

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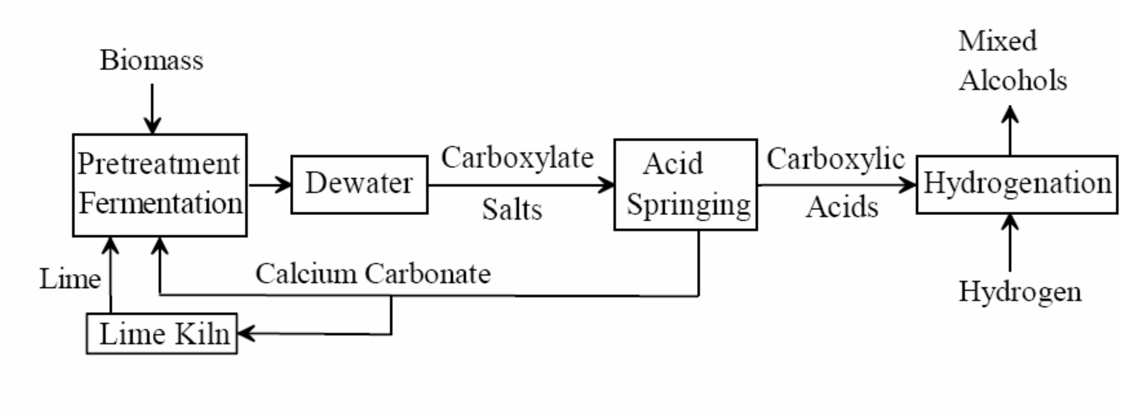
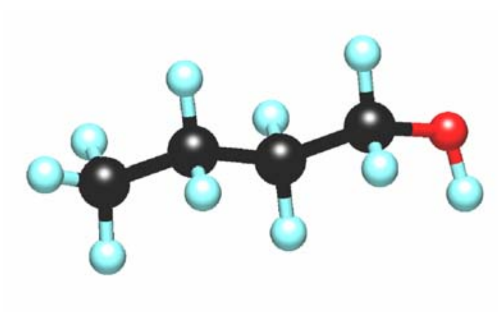
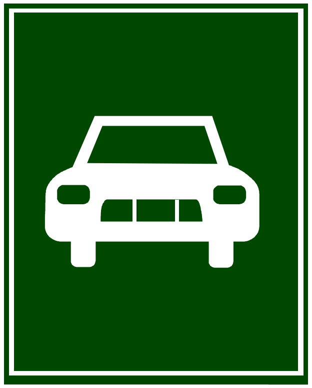
- Dr. Mark T. Holtzapple
  - Texas A&M University
  - Developed MixAlco Process



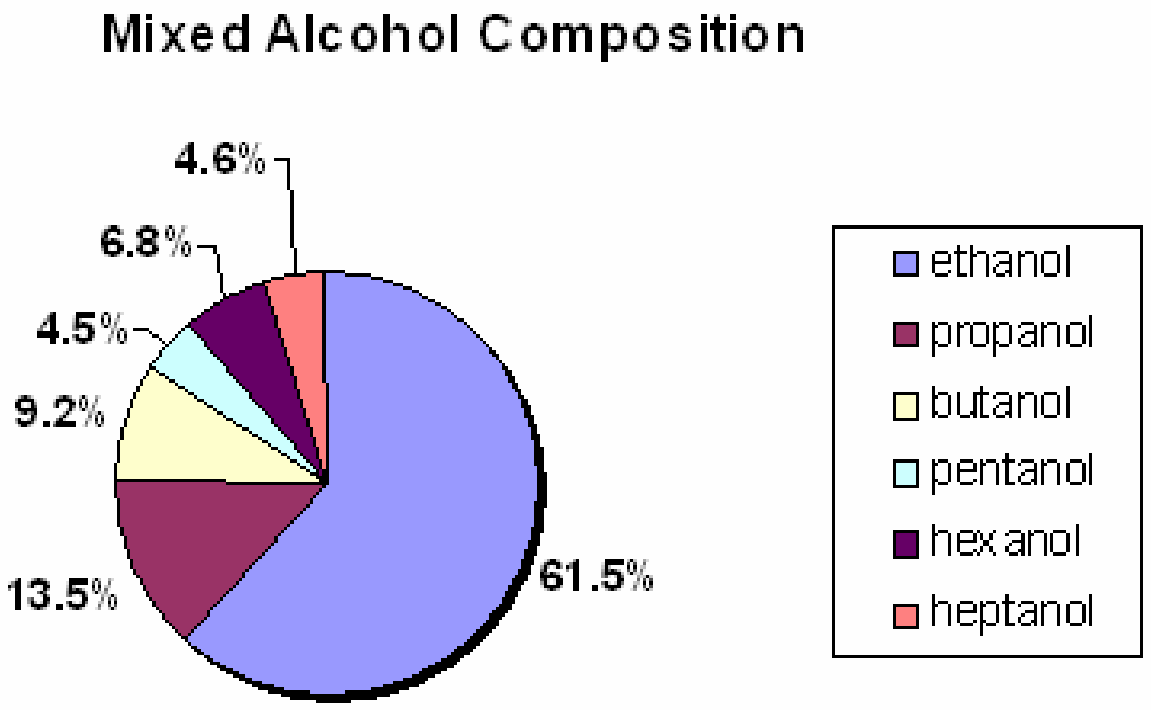
What are Mixalcs?

- Mixalcs are a mixture of short chain alcohols such as; ethanol, butanol, propanol, pentanol an hexanol
- A mix of heavier alcohols can use existing technology





What are Mixalcs?



How can Mixalcs be used?

- Mixalcs can be used as a “neat” fuel or blended in almost any proportion into gasoline
- Can even blend with heavier hydrocarbons to improve emissions

Fuel	Energy Content (BTU/gallon)
Gasoline	***125,000***
Mixed Alcohols	***104,000***
Ethanol	***84,300***

Where do mixalcs come from?

- Wide variety of feedstocks
  - Sweet Sorghum, Energy Cane
  - Municipal waste materials
  - Anything that decomposes!



Why are mixalcs so great?

- Renewable
- Cleaner than gasoline
- Higher energy content than ethanol
- Lower volatility than ethanol
- Lower heat of vaporization than ethanol

Carbon Footprint™

- Gasoline produces 19.4 lbCO_2/gal
  - This only includes combustion
- Mixalcs produce 14.6 lbCO_2/gal
  - This only includes combustion
- Gasoline produces 20% more energy
- ~17.5 lbCO_2/gal

Business Plan

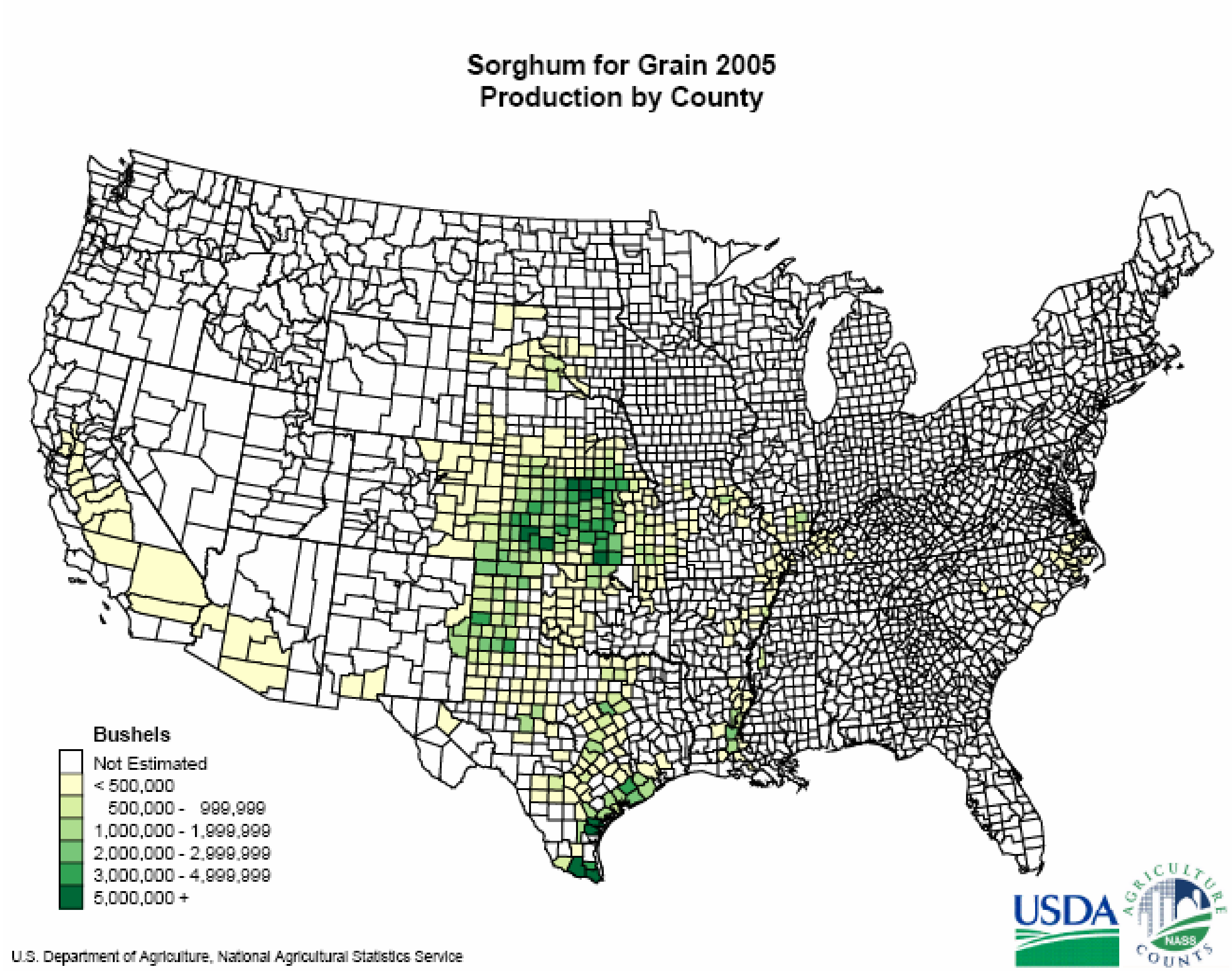
Strategy

- Start Slow – Allow supply and demand to adapt
  - First sell mixalcs as addative
  - Then sell mixalcs as a substitute for gasoline
  - Finally expand at a rate agriculture can keep up with

Logistics

- Ideal location: Agrarian rural location with plenty of livestock waste, access to oil infrastructure, and cheap real estate
- Western Kansas

Logistics



Sorghum for Grain 2005
Production by County
Bushels
Not Estimated
< 500,000
500,000 - 999,999
1,000,000 - 1,999,999
2,000,000 - 2,999,999
3,000,000 - 4,999,999
5,000,000 +
U.S. Department of Agriculture, National Agricultural Statistics Service

Logistics

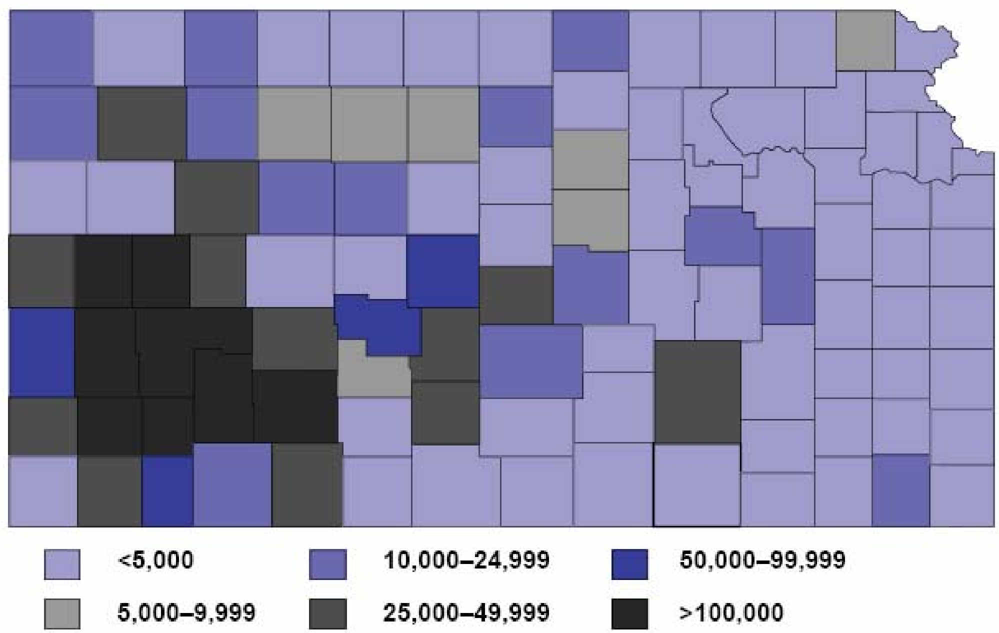
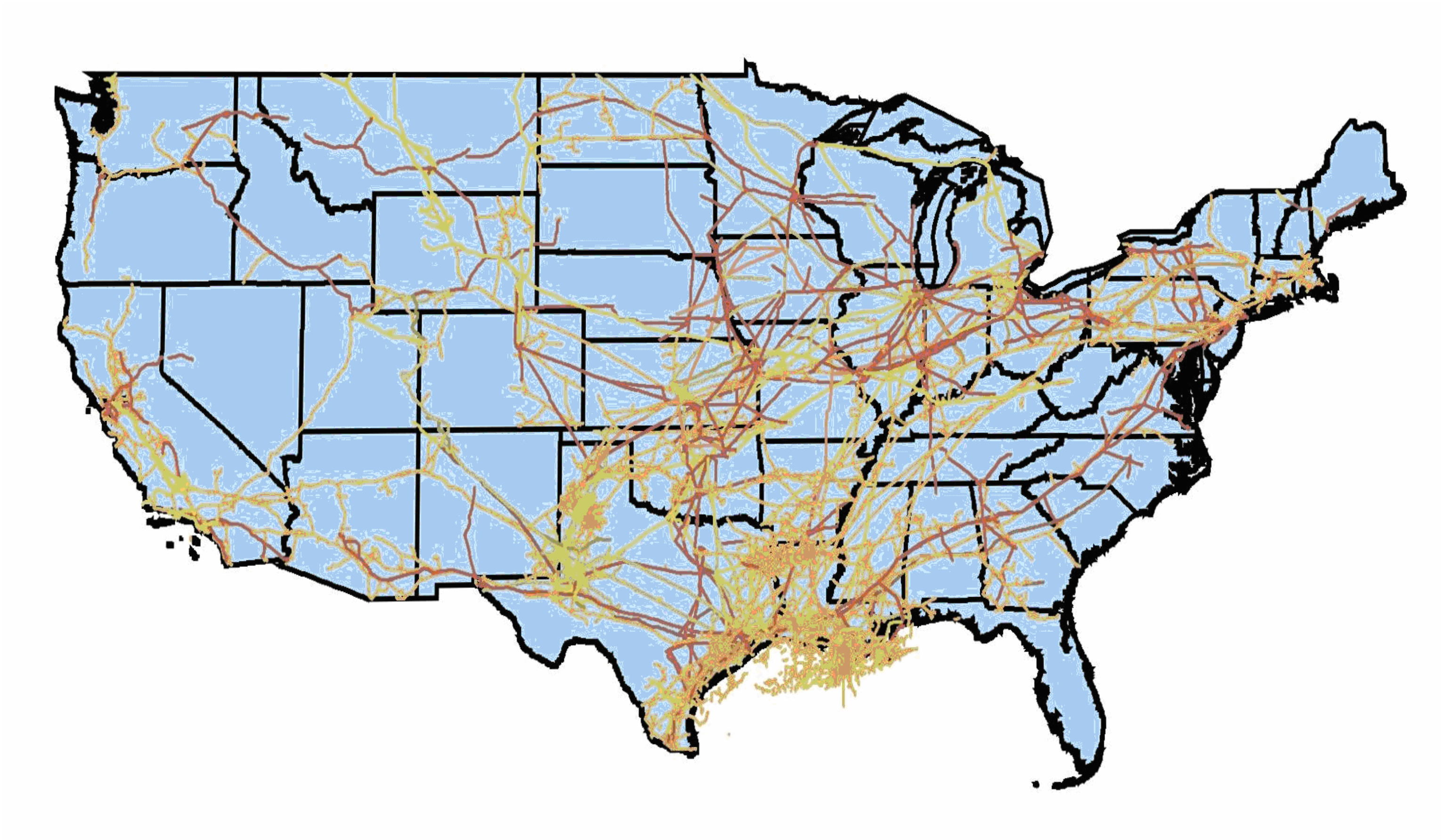


Figure 11. *Geographic Distribution of Cattle on Feed in Kansas, January 1, 1997 (2.22 million head)*

Logistics



TCI

- 40 tonne unit was selected to do cost estimation
- Lang factors were used to scale the process to different capacities

Biomass Capacity	TCI
MT/h	$
2	$ 3,123,089
10	$ 9,057,245
40	$ 23,142,670
160	$ 78,116,150
800	$ 340,875,275

Numbers from Holtzapple

TCI

Equipment Costs for all sizes of Mixalc plants

Code	Item	Qty	Unit Cost	Unit Cost(unce	Equipment Cost(r	Lang Factor	Exp 2&10	Exp 160&800	2 Installed Cost	10 Installed Cost
A-1	Biomass loader	1	50,000	$ 50,000	50,000	4.28	0.57	0.57	$ 38,800	$ 97,105
A-2	Lime screw conveyor	1	5,500	$ 5,500	5,500	4.28	0.56	0.56	$ 4,398	$ 10,831
A-3	Biomass/lime mixer	1	50,000	$ 50,000	50,000	4.28	0.57	0.57	$ 38,800	$ 97,105
A-4	Fermentor	4	537,474	$ 537,474	2,149,896	4.28	0.67	1.00	$ 1,236,435	$ 3,634,804
A-5	Saturator tank	1	20,000	$ 20,000	20,000	4.28	0.57	0.57	$ 15,520	$ 38,842
A-6	Air blower	1	3,000	$ 3,000	3,000	4.28	0.59	0.59	$ 2,193	$ 5,667
A-7	Carbon dioxide blower	1	4,000	$ 4,000	4,000	4.28	0.59	0.59	$ 2,923	$ 7,556
A-8	Circulating pump	4	18,000	$ 18,000	72,000	4.28	0.33	0.33	$ 114,666	$ 195,028
A-9	Heat exchanger	4	4,300	$ 4,300	17,200	4.28	0.50	0.50	$ 16,461	$ 36,808
B-1	Compressor	1	120,000	$ 120,000	120,000	5.04	0.79	0.79	$ 56,728	$ 202,295
B-2	Gas Turbine	1	280,000	$ 280,000	280,000	5.04	0.79	0.79	$ 132,366	$ 472,021
B-3	Steam Turbine	1	90,000	$ 90,000	90,000	5.04	0.79	0.79	$ 42,546	$ 151,721
B-4	Condenser	1	16,250	$ 16,250	16,250	5.04	0.60	0.60	$ 13,573	$ 35,649
B-5	Rankine Pump	1	1,330	$ 1,330	1,330	5.04	0.33	0.33	$ 2,494	$ 4,242
B-6	Heat Exchanger	1	75,000	$ 75,000	75,000	5.04	0.60	0.60	$ 62,643	$ 164,534
B-7	Evaporator	1	228,299	$ 228,299	228,299	5.04	0.75	1.00	$ 121,664	$ 406,808
B-8	Sensible Heat Exchanger 1	1	40,874	$ 40,874	40,874	5.04	1.00	1.00	$ 10,300	$ 51,501
B-9	Sensible Heat Exchanger 2	1	21,897	$ 21,897	21,897	5.04	1.00	1.00	$ 5,518	$ 27,590
B-10	Evaporator Pump	1	12,000	$ 12,000	12,000	5.04	0.33	0.33	$ 22,505	$ 38,276
B-11	Evaporator Turbine	1	12,000	$ 12,000	12,000	5.04	0.33	0.33	$ 22,505	$ 38,276
B-12	Lime Mixing Tank	1	9,000	$ 9,000	9,000	5.04	0.57	0.57	$ 8,224	$ 20,583
B-13	Solids Separator	1	40,000	$ 40,000	40,000	5.04	0.67	0.67	$ 27,089	$ 79,636
B-14	Lime Conveyor	1	10,000	$ 10,000	10,000	5.04	0.67	0.67	$ 6,772	$ 19,909
B-15	Noncondesible Stripper Column	1	14,000	$ 14,000	14,000	5.04	0.62	0.62	$ 11,013	$ 29,873
C-1	Reactive Distillation	1	42,000	$ 42,000	42,000	5.04	0.62	0.62	$ 33,040	$ 89,620
C-2	Reactive Distillation Reboiler	1	50,000	$ 50,000	50,000	5.04	0.62	0.62	$ 39,333	$ 106,690
C-3	Countercurrent Heat Exchanger	1	16,000	$ 16,000	16,000	5.04	0.62	0.62	$ 12,587	$ 34,141
C-4	Switching Distillation Column	1	46,000	$ 46,000	46,000	5.04	0.62	0.62	$ 36,187	$ 98,155
C-5	Reboiler Heat Exchanger 1	1	7,000	$ 7,000	7,000	5.04	0.62	0.62	$ 5,507	$ 14,937
C-6	Reboiler Heat Exchanger 2	1	7,000	$ 7,000	7,000	5.04	0.62	0.62	$ 5,507	$ 14,937
C-7	Reboiler Heat Exchanger 3	1	6,000	$ 6,000	6,000	5.04	0.62	1.00	$ 4,720	$ 12,803
C-8	Condenser	1	11,000	$ 11,000	11,000	5.04	0.62	0.62	$ 8,653	$ 23,472
C-9	Mixer	1	10,000	$ 10,000	10,000	5.04	0.69	0.69	$ 6,379	$ 19,365
C-10	Filter	1	100,000	$ 100,000	100,000	5.04	0.69	0.69	$ 63,785	$ 193,646
C-11	Filter Pump	1	6,000	$ 6,000	6,000	5.04	0.33	0.33	$ 11,252	$ 19,138
C-12	Evaporator	1	56,388	$ 56,388	56,388	5.04	0.75	1.00	$ 30,050	$ 100,478
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Numbers from Holtzapple

Product Cost

- Product cost was heavily dependent on Raw Materials cost
- Biomass feedstock cost will be highly dependent on market conditions
- Used a 4% inflation rate to do future calculations
- Royalties to Holtzapple were assumed to be 3% of gross sales

Numbers from Holtzapple

Product Cost

	Plant Consumptions		Cost per rate or quantity		2007
Plant Specifications					Calculated values, $
Capacity, MT sorghum/h:	40				
Capacity, gal mixed alcohols/	45100000				
Fixed Capital Investment (FC	19671269				
Product Price $/gal	2.00				
Raw Materials					
1 Sorghum	320000	MT/yr	$40.00	USD/MT	$12,800,000.00
2 Hydrogen	9,039,012	kg/yr	$0.81	USD/kg	$7,321,600.00
3 Lime	32000	MT/yr	$44.00	USD/MT	$1,408,000.00
4 Inhibitor	53,333	kg/yr	$6.00	USD/kg	$320,000.00
Labor (table 6-14)	8000	work-hr/year	$173.75	USD/hr op	$1,390,000
Utilities (table 6-14)					
Electricity	5.94E+05	kWh/yr	$0.05	$/kWh	$31,467
790-kPa Steam	207680	MT/yr	$6.00	$/MT	$1,246,080
Natural Gas	288320	GJ/yr	$4.00	$/GJ	$1,153,280
Cooling Water	2.23E+07	m3/yr	$0.05	$/m3	$1,004,400
Solid Fuel	-1.18E+06	GJ/yr	$2.00	$/GJ	($2,368,000)
Maintenance and repairs	0.04	of FCI			786850.76
Operating supplies	0.15	of maintenance and repairs			118027.614
Laboratory charges	0.15	of labor			$208,500.00
Royalties (if not on lump-sum basis)	0.03	of mixed alcohol sales			$2,706,000.00
Depreciation - calculated separately below				**Total variable production costs:**	**$28,126,205.11**
Taxes (property)	0.03	of FCI			590138.07
Financing (interest)	0	of FCI			0
Insurance	0.007	of FCI			137698.883
Rent	0	of FCI			0
				Fixed charges (without depreciation):	727836.953
				Plant overhead costs	$2,308,323.37
				Administrative costs	$208,500.00
				Distribution + marketing costs	$577,080.84
				Research and Development	$1,442,702.10
				Total general expenses	$4,536,606.31
				Total product cost (w/o D) C:	**$33,390,648.37**

Numbers from Holtzapple

Profitability

- All processes can be profitable at reasonable mixalc prices
- Even if oil prices come down, mixalcs can be competitive

Mt/h	Break even price for 8% ROI
2	$ 2.02
10	$ 1.09
40	$ 0.86
160	$ 0.80
800	$ 0.78

Profitability

Return on Investment		
ROI = profit/TCI = R-D-(R-dIf)*t		
ROI		19
Rate of Return based on discounted cash flow		
function = sumCF(1+i)^(n-k) + 0.15FCI + (TCI-FCI)-TCI(1+i)^10		
function	$	567,239,693.48
i		0.08
n		10
Net Present Worth		
NPW = sum(CFk/((1+i)^k)+(CFn+Vs+Iw)/((1+i)^n)-TCI		
i		0.08
NPW		$262,741,732
Pay Out Time		
POT = (FCI-0.15*FCI)+TCI*i*n/average cash flow annually		
Average Cash Flow		$43,247,008
i		0.08
POT		0.814731856

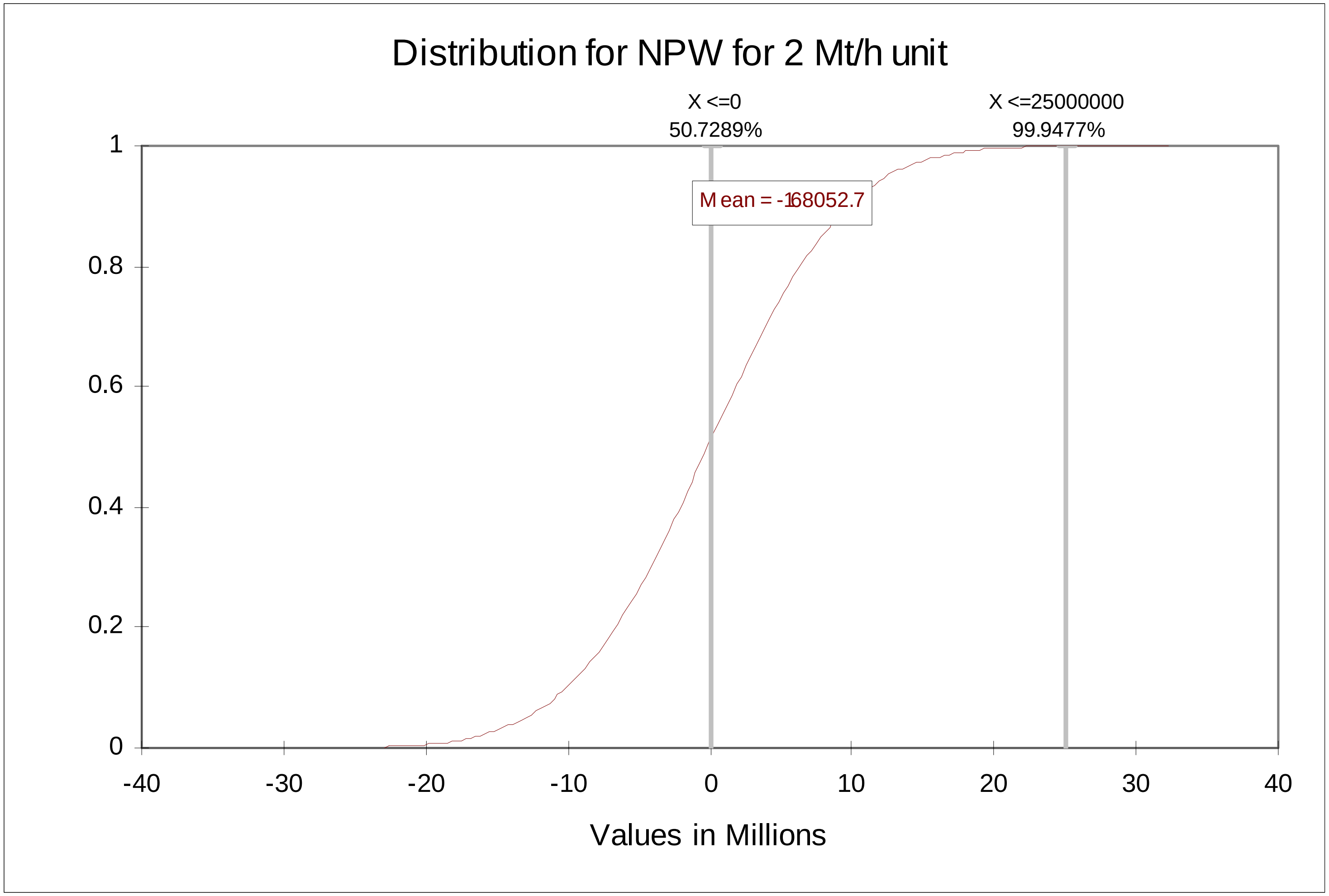
Profitability

Year	Mixalcs Produced Gallons/year	MixalcPrice USD/gallon	Annual sales (USD/year)	Production costs (USD/year)	Depreciation (USD/year)	Gross profit, GP (USD/year)	Net profit, Np (USD/year)
2007	45,100,000	2.00	$90,200,000	$33,390,648	$1,672,058	$55,137,294	$35,839,241
2008	45,100,000	2.08	$93,808,000	$34,726,274	$1,672,058	$57,409,668	$37,316,284
2009	45,100,000	2.16	$97,560,320	$36,115,325	$1,672,058	$59,772,937	$38,852,409
2010	45,100,000	2.25	$101,462,733	$37,559,938	$1,672,058	$62,230,737	$40,449,979
2011	45,100,000	2.34	$105,521,242	$39,062,336	$1,672,058	$64,786,848	$42,111,451
2012	45,100,000	2.43	$109,742,092	$40,624,829	$1,672,058	$67,445,205	$43,839,383
2013	45,100,000	2.53	$114,131,775	$42,249,822	$1,672,058	$70,209,895	$45,636,432
2014	45,100,000	2.63	$118,697,046	$43,939,815	$1,672,058	$73,085,173	$47,505,363
2015	45,100,000	2.74	$123,444,928	$45,697,408	$1,672,058	$76,075,463	$49,449,051
2016	45,100,000	2.85	$128,382,725	$47,525,304	$1,672,058	$79,185,363	$51,470,486

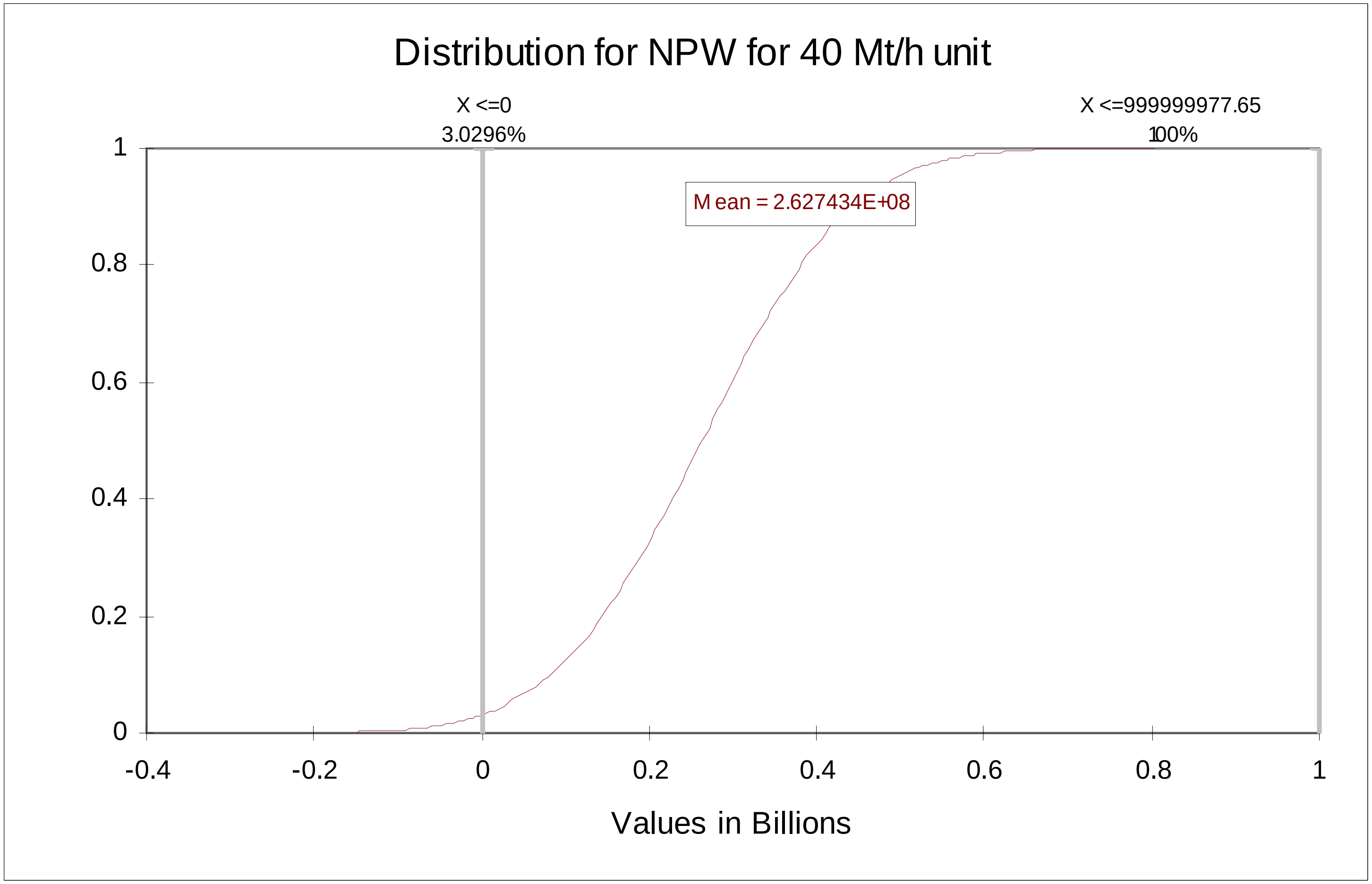
Uncertainty

- An uncertainty of 30% was applied to all equipment prices, raw material prices, and product price
- @Risk was used to evaluate the variation in NPW at this uncertainty
- 30% uncertainty was chosen in order to cover all possible inaccuracies in pricing

Uncertainty



Uncertainty



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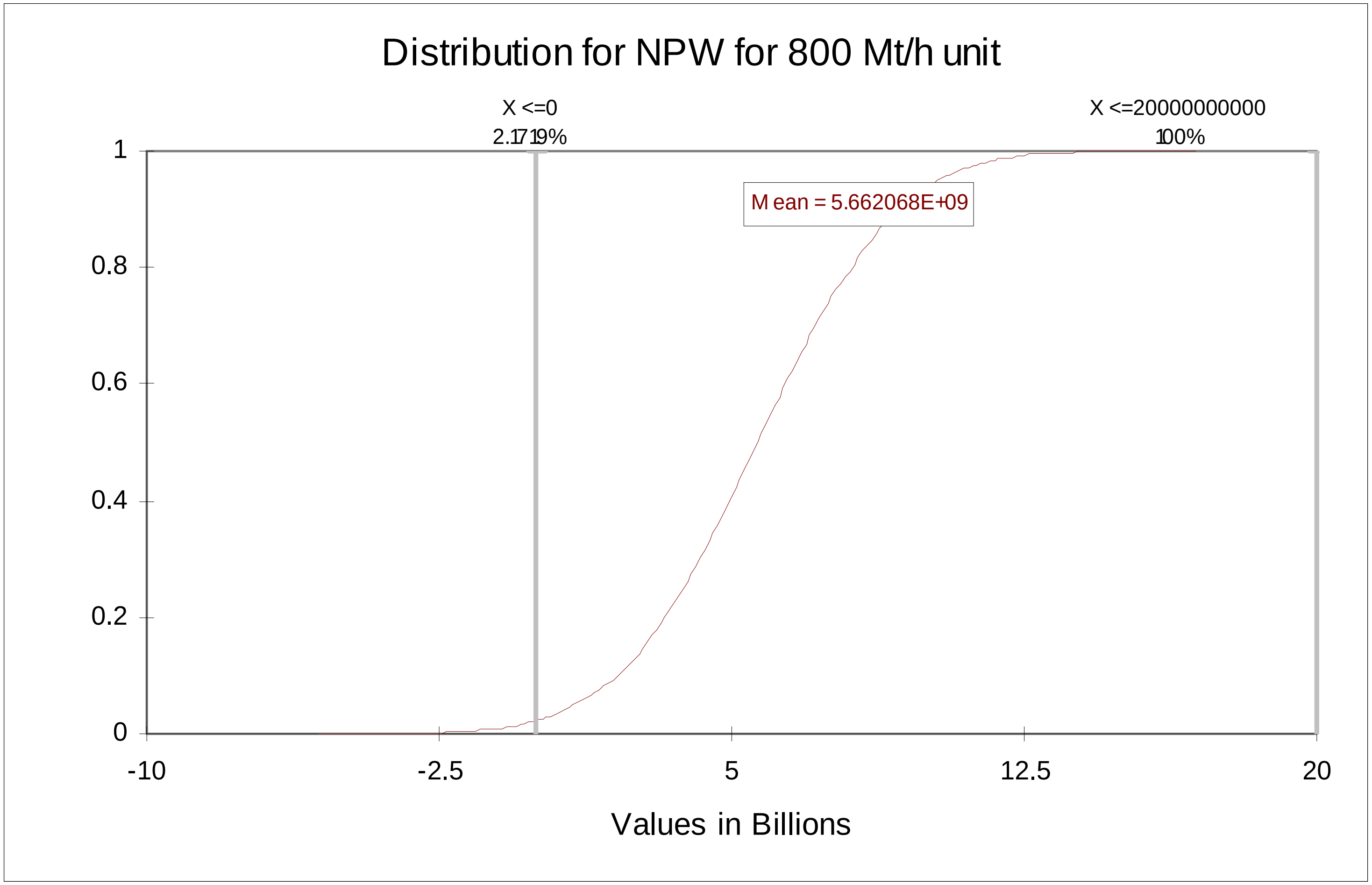


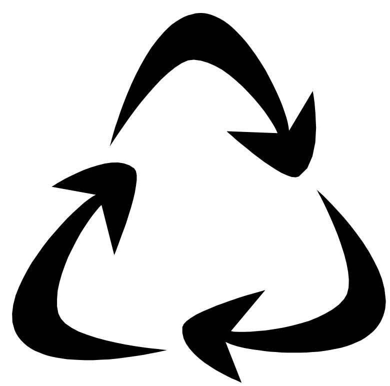
Uncertainty

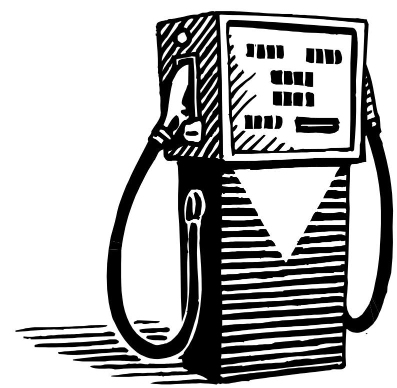
- Agricultural prices will vary with demand
- This process and other biofuels processes will put huge demands on agricultural production
- The impact that the biofuels industry will have on the agricultural industry will affect prices and supply in the future

MixAlco™ Process

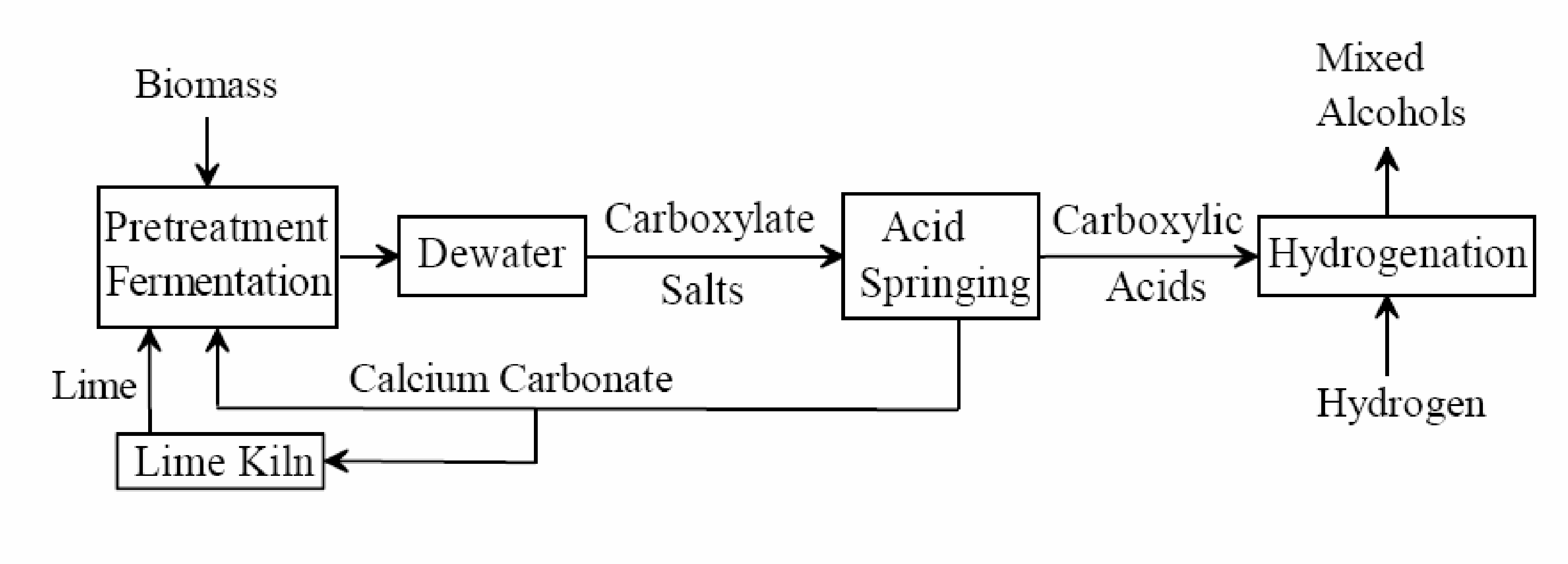
MixAlco™ Process

- Developed by Dr. Mark T. Holtzapple at Texas A&M University
- Converts biomass feedstocks into a mixture of light alcohols





MixAlco™ Process

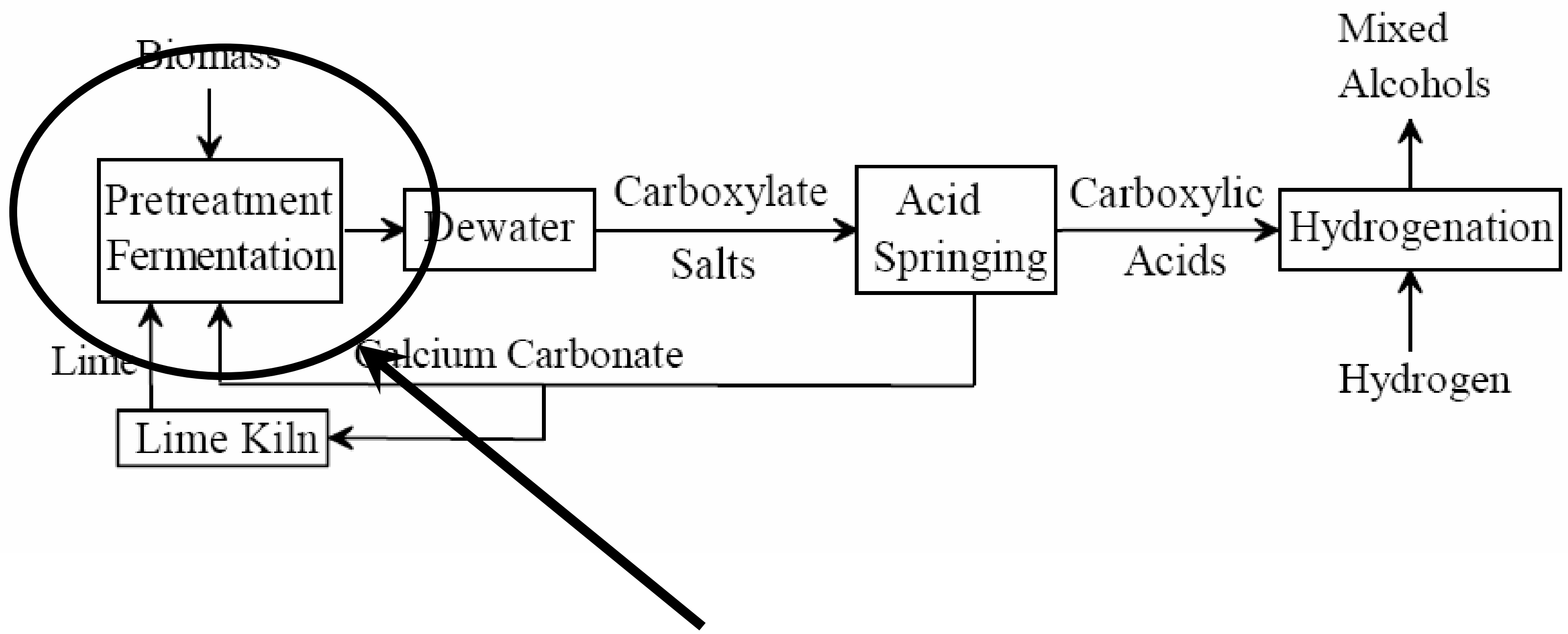


From Holtzapple p.5

Advantages

- No enzymes
- No pure cultures
- Continuous
- Highly adaptable
- Has potential to recycle various waste products

MixAlco™ Process

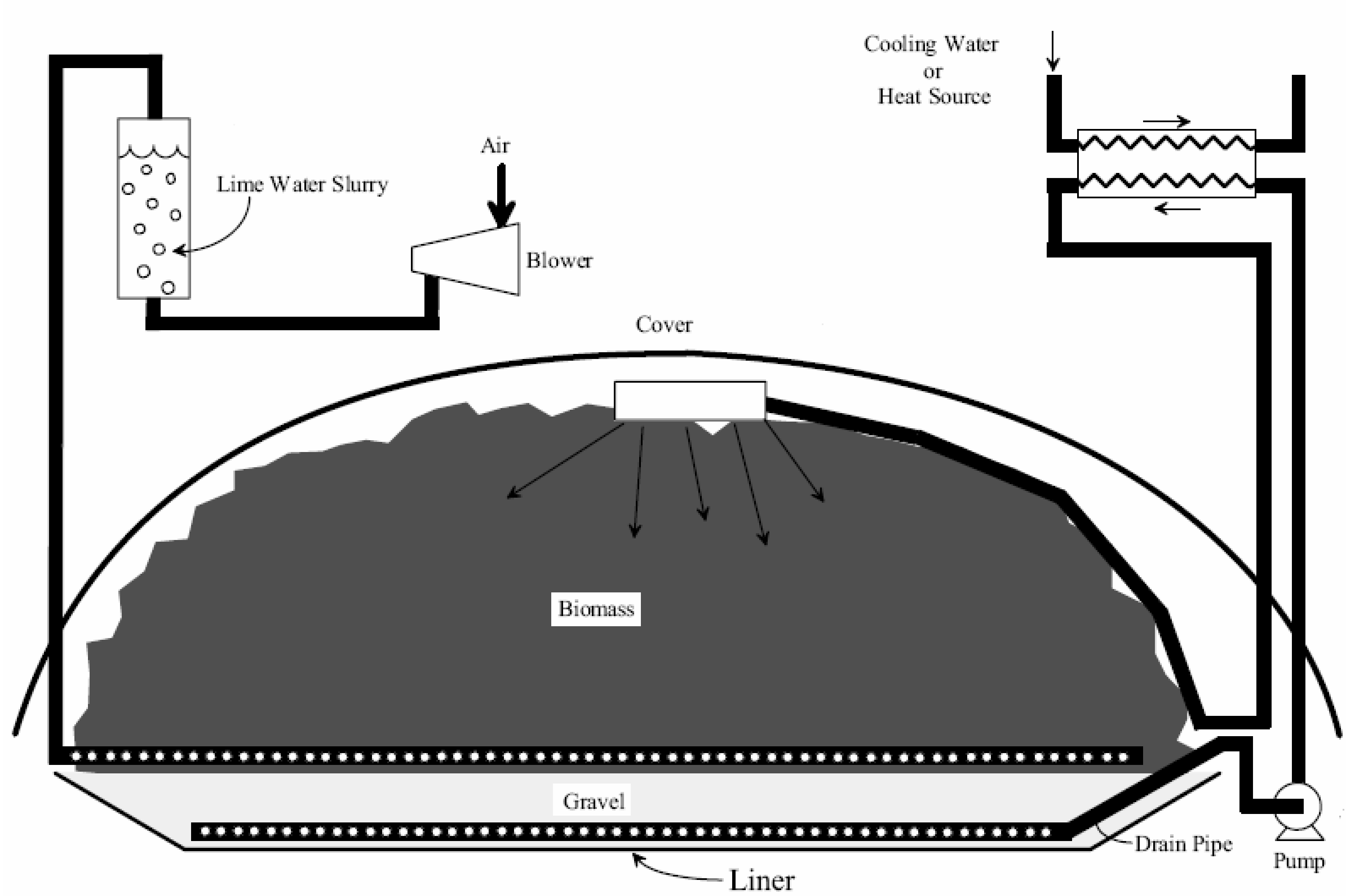


From Holtzapple p.5

Pretreatment Fermentation

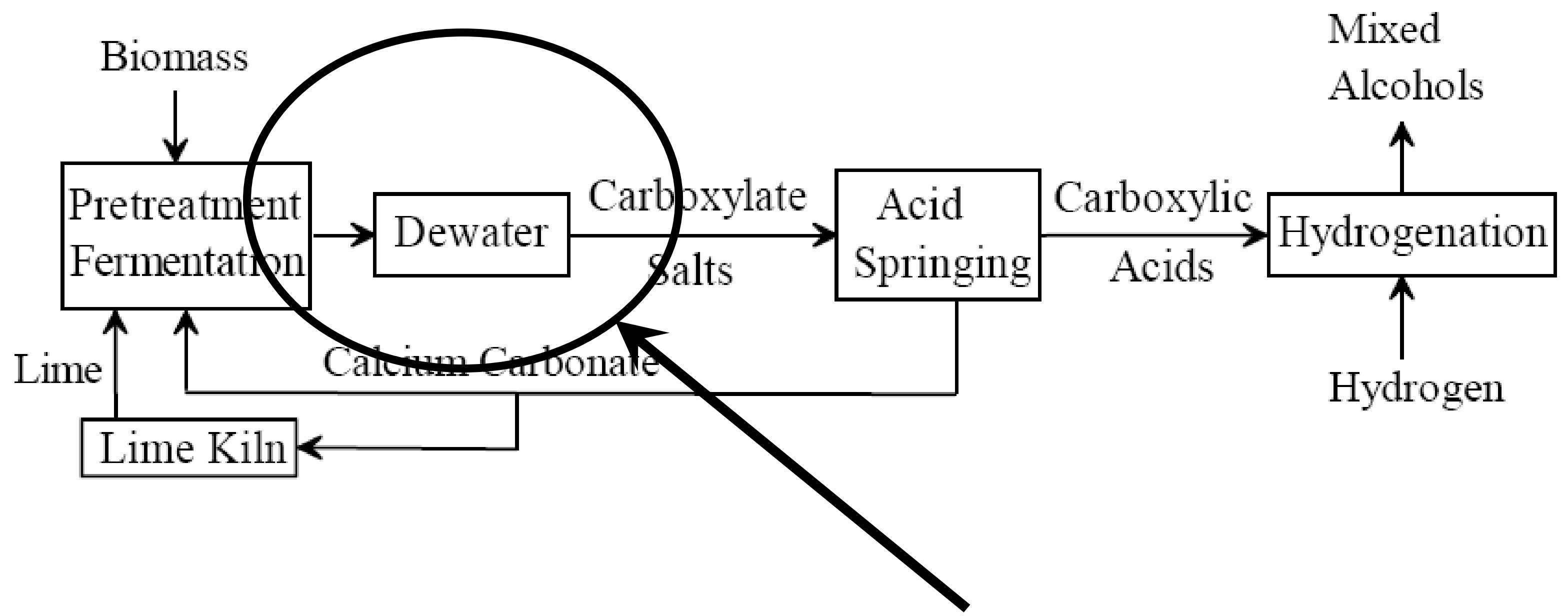
- Feedstock of 80% sorghum foliage and 20% cattle manure
- Pretreat with lime, water, and methane inhibitor
- Pretreatment removes lignin
- Add bacteria such as marine mesophilic organisms
- Bacteria digests 80% of solid biomass[1]
- ~.5g of total acids per gram of feed[1]
- 4 piles each having the volume of 43,000m^3

Pretreatment Fermentation



From Holtzapple p.9

MixAlco™ Process

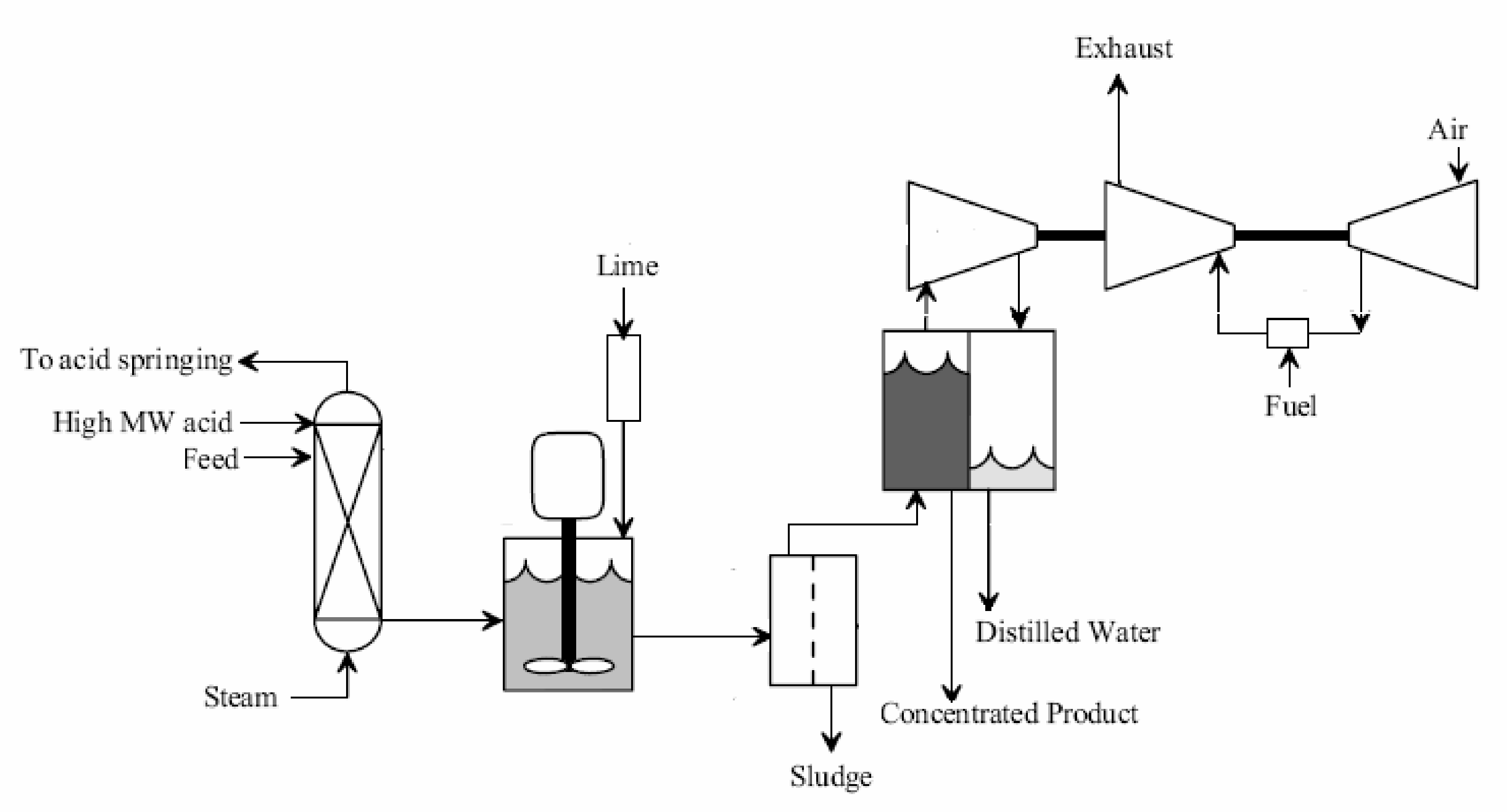


From Holtzapple p.5

Dewatering

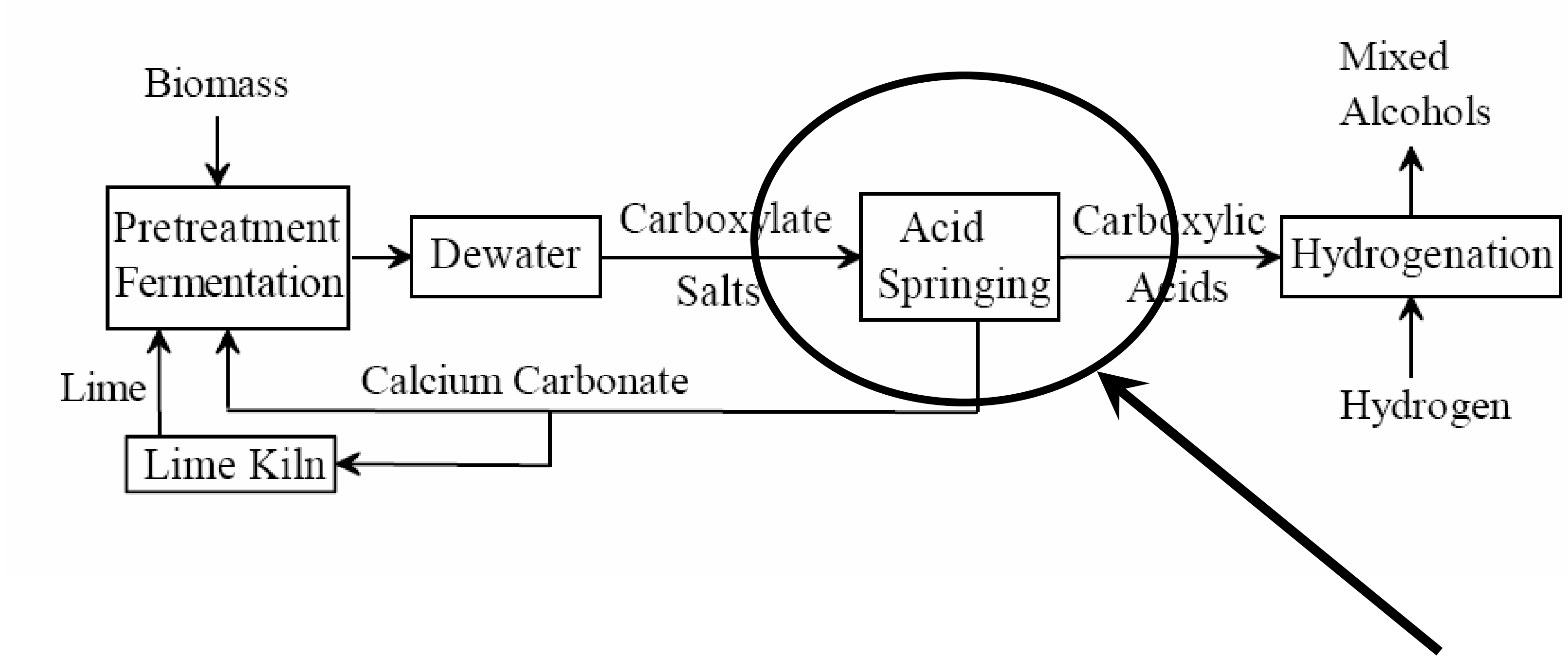
- Vapor compression evaporation
- Introduce long chain acid to acidify broth
- Steam and lime used to remove non-condensable gases and calcium carbonate
- Water is evaporated to concentrate salt solution

Dewatering



From Holtzapple p.14

MixAlco™ Process

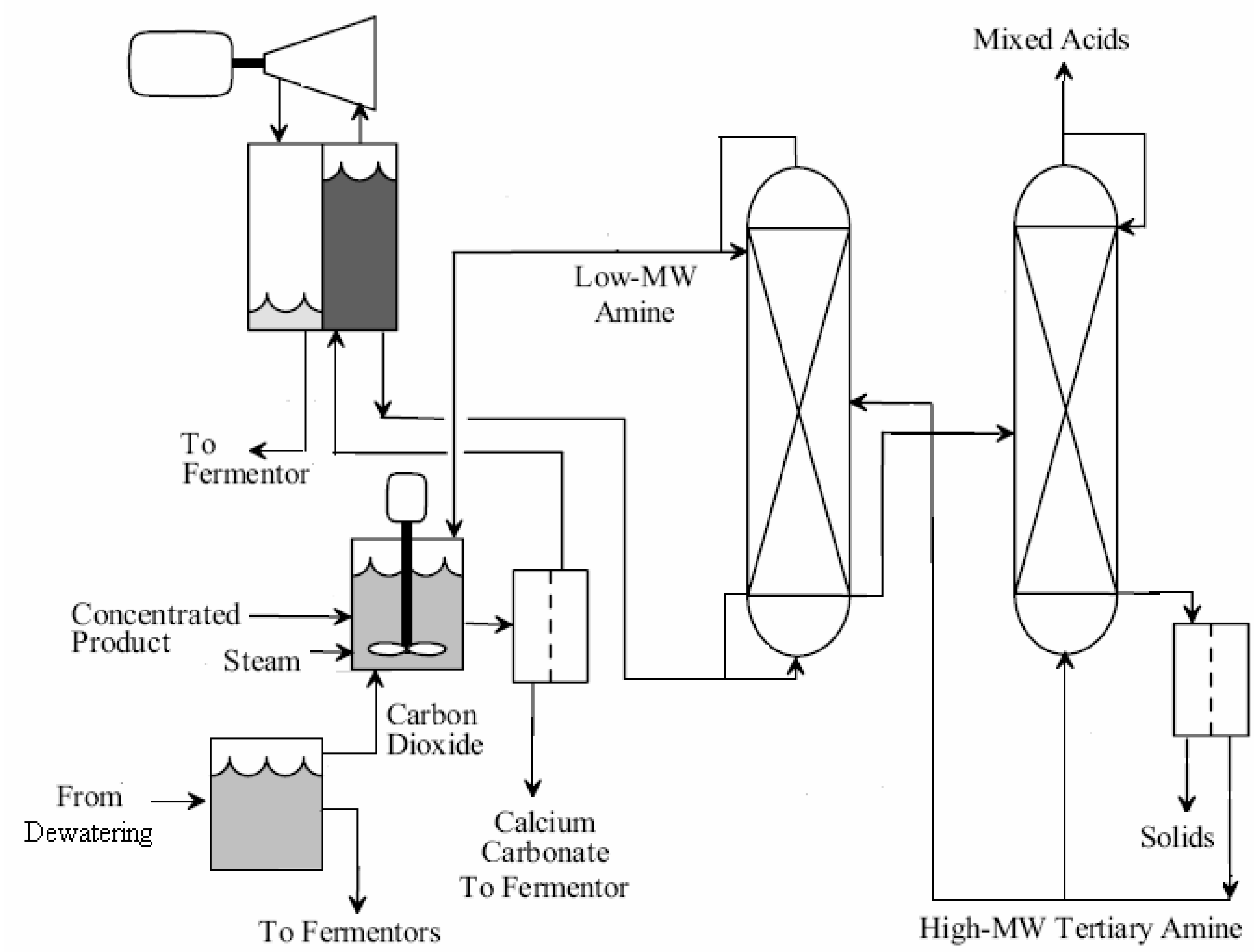


From Holtzapple p.5

Acid Springing

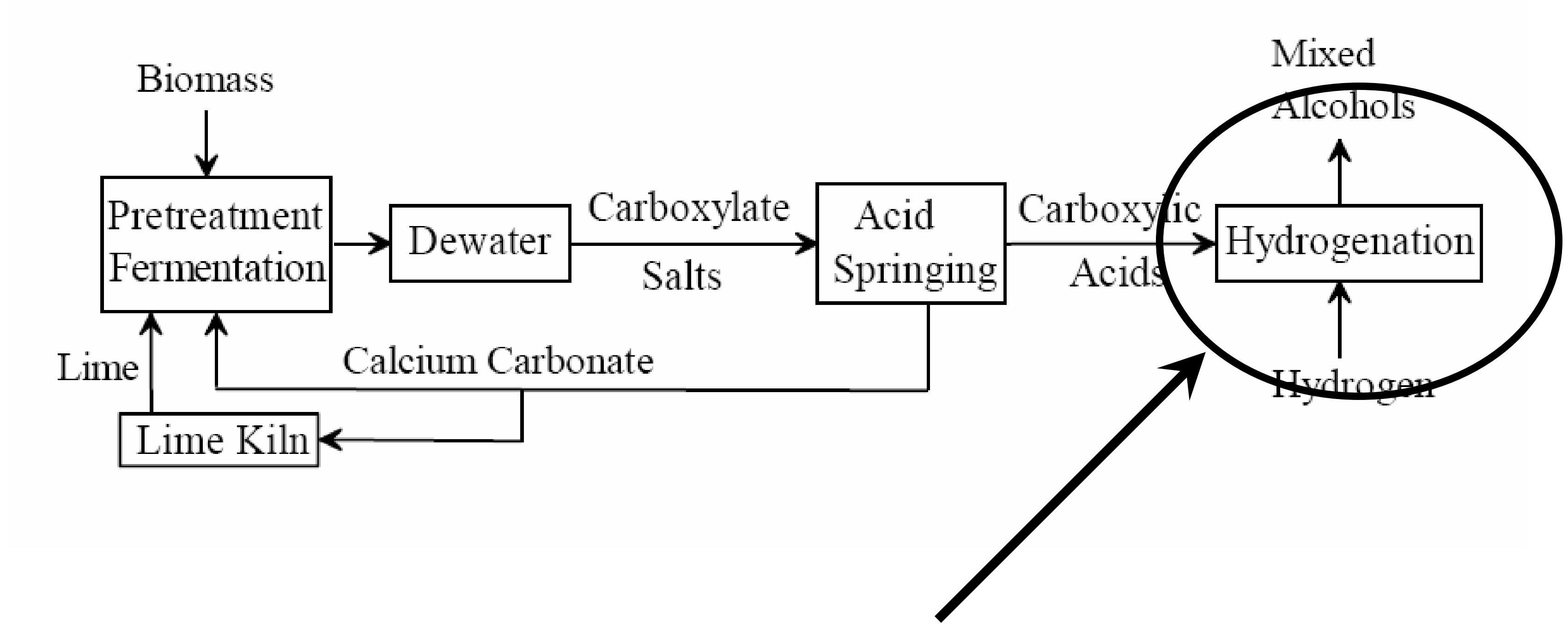
- Converts salts into acids
- Concentrated acids are blended with CO_2 and low molecular weight amines
- Removes calcium carbonate
- Calcium carbonate is recycled into pretreatment

Acid Springing



From Holtzapple p.16

MixAlco™ Process

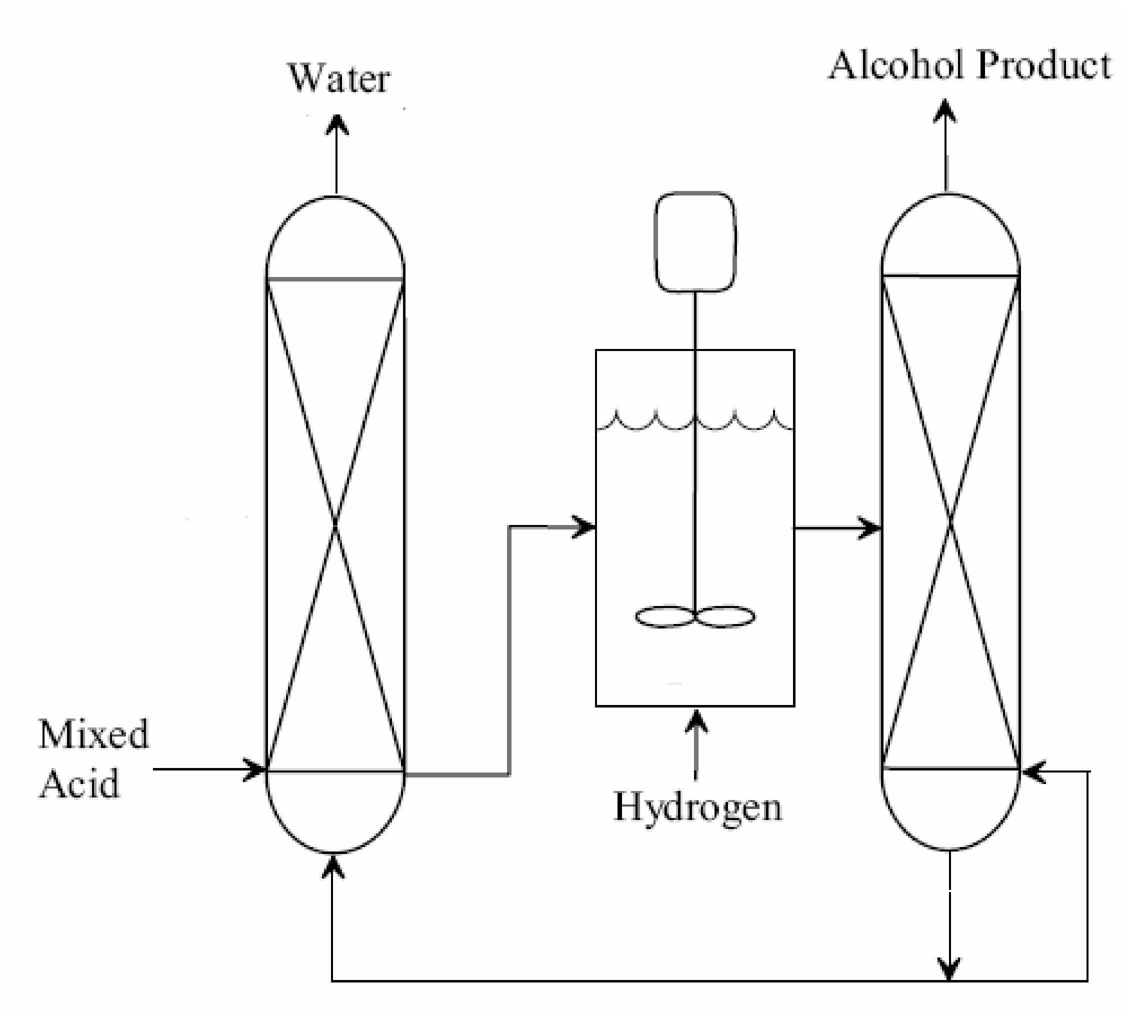


From Holtzapple p.5

Hydrogenation

- Converts acids to alcohols
- Concentrated acids are mixed with high molecular weight alcohols to form esters
- Esters are hydrogenated to form alcohol product

Hydrogenation



From Holtzapple p.18

Summary

- Can be blended or used as a “neat” fuel
- Further study of biofuel industry impact on agriculture is needed
- Further study on yield of bacteria when digesting different biomass is needed

References

1. Agbogbo, Frank K., & Holtzapple, Mark T. (2006). Fixed-bed fermentation of rice straw and chicken manure using a mixed culture of marine mesophilic microorganisms. *Bioresource Technology*, *98*, Retrieved February 16, 2007, from http://www.sciencedirect.com.
2. Holtzapple, Mark T. (2004). MixAlco Process: Biomass to Carboxylic Acids and Alcohols. Unpublished Manuscript. Viewed January 2007