



Cellulosic Technology

MICHIGAN AGRI-ENERGY CONFERENCE
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MBI International
www.mbi.org

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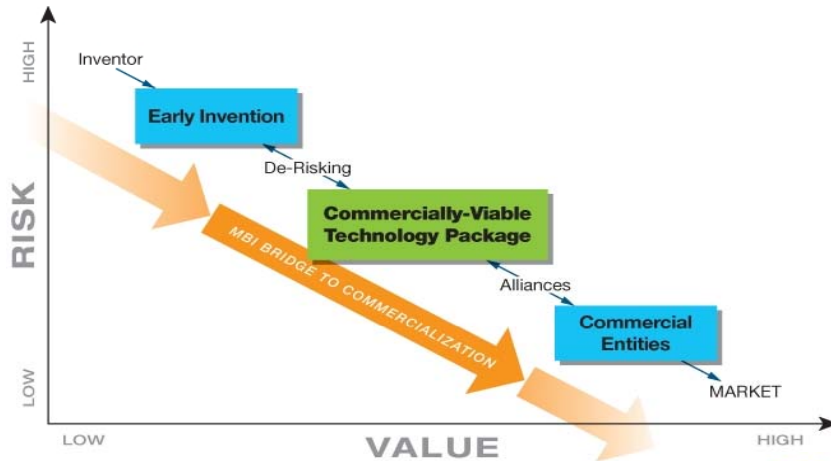
MBI Background

- **MBI is a Michigan not-for-profit company and a wholly owned subsidiary of the MSU Foundation**
- **Mission is to accelerate development of bio-based technologies for commercial application**
- **MBI is forging partnerships with Michigan State University and others for bio-based product commercialization**
- **25 years of experience, track record and networks**

2



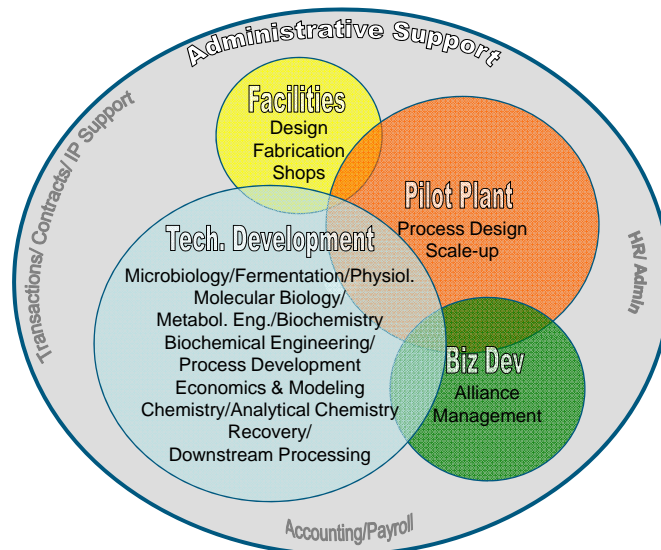
MBI - Bridging the gap between early invention and commercial applications



3



MBI Organization



4



Portfolio

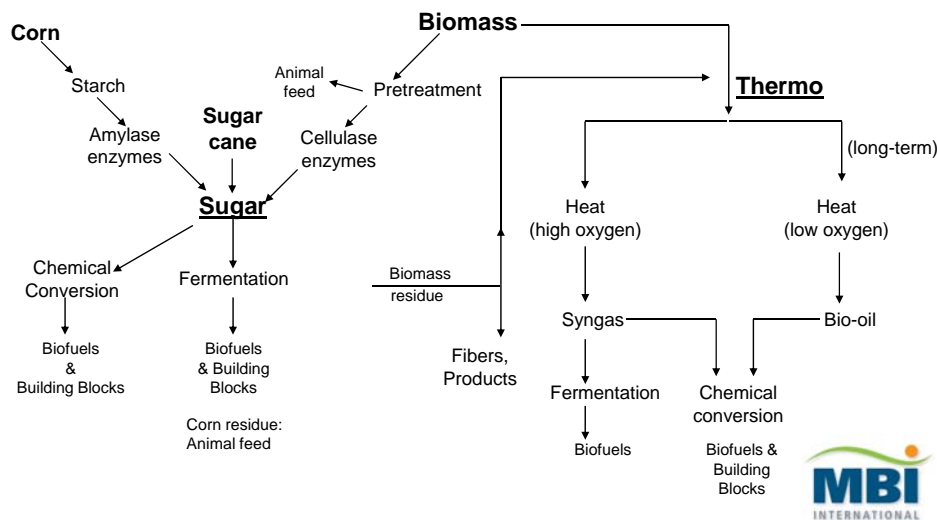
Current Portfolio:

- Cellulosics bio-fuels and products platform: AFEX Pretreatment
- Succinic acid and other organic acids
- Bio-butanol
- De-Risking Services for Corporate Clients

5



Refining of Bio-based Raw Materials to Building Blocks



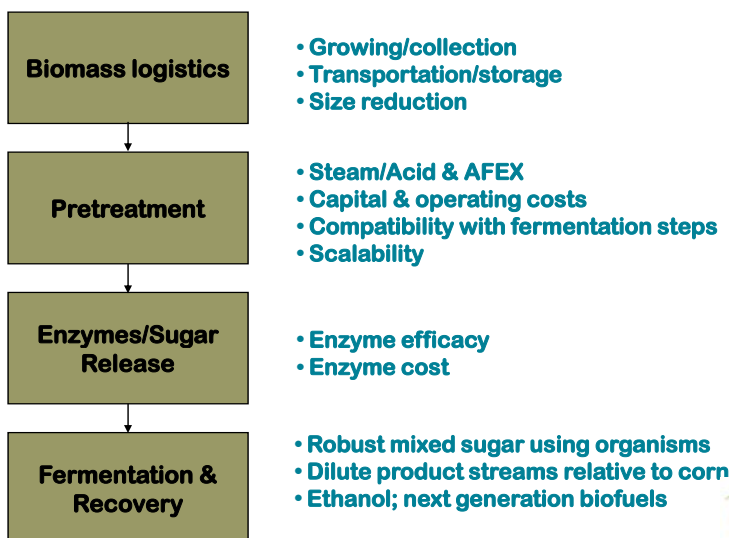
Biomass Feedstocks

- **Why biomass for fuels?**
 - Range of available feedstocks
 - Low carbon footprint, 85% less than HC Fuels
 - High potential yield: 85% of corn grain on a dry wt basis
 - Sustainability
- **Issues with Biomass feedstocks**
 - Sugars structures are complex
 - Both cellulose and hemicellulose sugars must be utilized

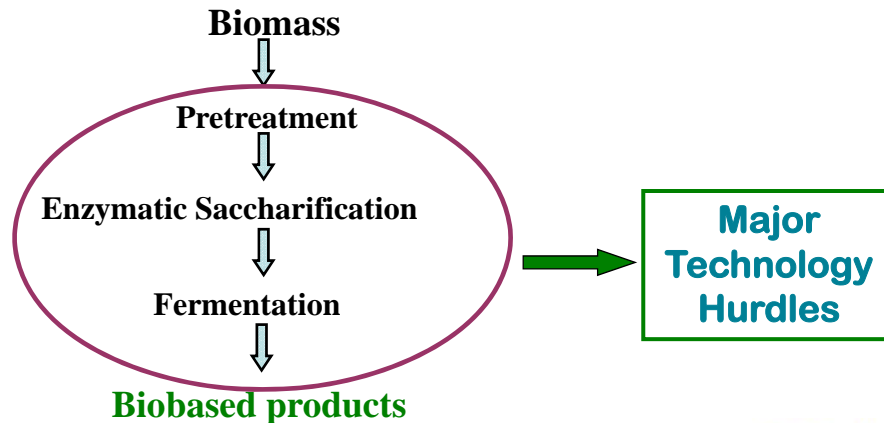
7



Cellulosic biofuels face multifaceted challenges



Biomass Conversion



9



Pretreatment: Preparing biomass for deconstruction into subcomponent sugars

Features:

- Thermo-chemical, not biological, process
- Typically use an acid or alkaline chemical agent
- Efficacy of a given treatment is feedstock dependent

Methods:

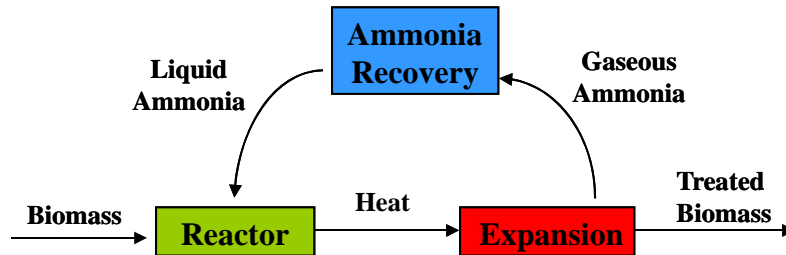
- Dilute acid
- Steam combined with acid
- AFEX (concentrated ammonia)
- Dilute alkali (e.g., dilute ammonia)
- Others

Key metrics:

- Amount of enzymes needed during hydrolysis
- Sugar yields following enzyme hydrolysis
- Fermentability of sugar stream during fermentation step



What is AFEX?



Invented by Dr. Bruce Dale at MSU

11



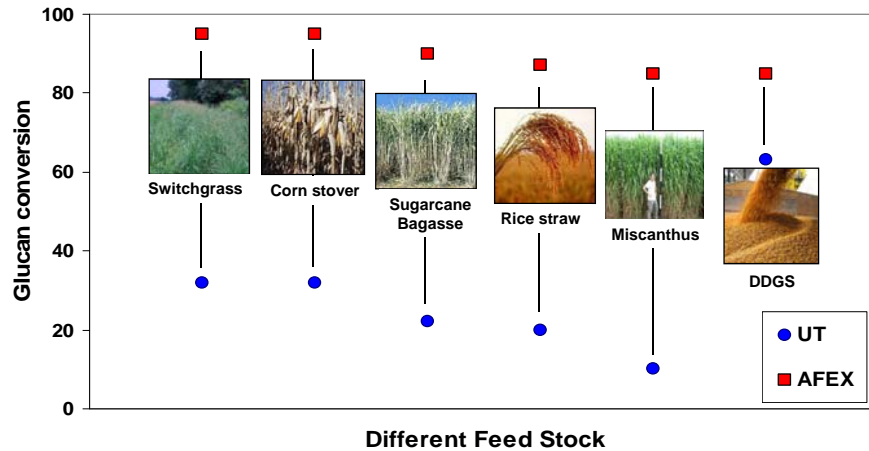
AFEX Advantages

- Suitable for many types of biomass
- No degradation of hemicellulose or cellulose
- Low enzyme loading
- Hydrolyzed material is soluble
- No neutralization requirements
- No inhibitory compounds – fermentation
- Potential uses for other applications
- Recycle of ammonia – low chemical costs
- Low waste handling cost – No wash streams
- Treated Material is stable, can be stored and used later

12



Biomass Conversion for Different Feedstocks: Before and after AFEX Treatment



Enzymatic hydrolysis: 25 mg of Cellulase and 2.5 mg of xylanase/g of glucan, 50 °C, for 168h. About 70% xylan conversion achieved for most feedstocks.

13

13

Issues with AFEX Pretreatment

- High capital cost of continuous plant
- Ammonia recapture and reuse is essential to keep chemical costs low
- Scalability of process

14

Status of the Work – Technology Hurdles

US Dept of Energy – Call for proposals

- The DOE has called for proposals for \$220million of new grants for Integrated Biorefineries making fuels
- Both for pilot plants operating at 1 ton of biomass per day and demonstration plants operating at 50 tons per day
- MBI is preparing a proposal for a pilot plant with technical partners MSU and The National Energy Laboratories at Golden, CO
 - The application is for a \$20million grant requiring 20% cost share

15



Status of the Work – DOE Proposal (con't)

- Commercial support partners include: The Andersons, Vermeer Corporation, Airgas, ICM, Novozymes and Poet
- The proposal is due in May 2009 and awards are expected to be made in September 2009
- Collaborators at MSU include: The GLBRC, Bruce Dale's Laboratory and others in energy crops and livestock feeding

16



Status of the Work – Technology Hurdles

- **Enzyme Development for 5 & 6 carbon sugars**
 - Corn hemicellulose sugars are recalcitrant to current enzymes
 - Cellulase enzymes are inhibited in low ethanol concentrations
 - Continued work is on going at Novozymes
- **Robust Organisms for simultaneous utilization of both 5 and 6 carbon sugars**
 - Current show stopper for all in cellulosic ethanol from the sugar platform
 - New organism available from NREL

17



Ethanol & The US Government

Renewable Fuel Standards (2005 Energy Bill)

2006 4.0 billion gals 2.78% of fuel use

2012 7.5 billion gals 5.21% of fuel use

250 million gallons of cellulosic derived ethanol by 2013

A more likely scenario:

2008 10.1 billion gals(9/08) 7.23% of fuel use

2008 3.6 billion gals(9/08) new capacity under construction)

13.7 billion gals 9.52 % of fuel use

Essentially all from corn

(Renewable Fuels Association 9-11-08)



The Energy Independence and Security Act of 2007

RENEWABLE FUEL STANDARD (Sec. 202)

Directs EPA to promulgate regulations ensuring that applicable volumes of renewable fuel are sold or introduced into commerce in the United States annually.

Sets forth Cellulosic fuel volumes beginning with .1 b gals in 2010 and ending at 16 b gals in 2022.

Year	Renewable	Advanced	Cellulosic	Bio-Diesel	Undiff	Total RFS
2009	10.5	0.6		0.5	0.1	11.1
2010	12	0.95	0.1	0.65	0.2	12.95
2011	12.6	1.35	0.25	0.8	0.3	13.95
2012	13.2	2	0.5	1	0.5	15.2
2013	13.8	2.75	1		1.75	16.55
2014	14.4	3.75	1.75		2	18.15
2015	15	5.5	3		2.5	20.5
2016	15	7.25	4.25		3	22.25
2017	15	9	5.5		3.5	24
2018	15	11	7		4	26
2019	15	13	8.5		4.5	28
2020	15	15	10.5		4.5	30
2021	15	18	13.5		4.5	33
2022	15	21	16		5	36
14 yr Total	205.5	111.15	71.85	2.95	36.35	316.65

US DOE Grants for Cellulosic Ethanol plants

- 2/07 - \$385 million for 6 commercial plants, 102.3 million gallons annual production
- 1/08 - \$114 million for 4 “pilot” plants, 12.2 million gallons annual capacity
- 4/08 - \$85 million for 3 pilot plants, 5.5 million gallons annual capacity
- 2009 - \$200 million for pilot plants and demonstration plants

Status of Government Projects

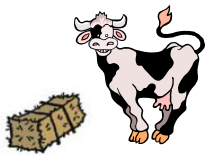
- Prospects for producing cellulosic ethanol are uncertain for the 250,000 million gallons by 2012 and 71 billion gallons by 2022
- Technologies need to be developed, de-risked and made available to commercial operators
- Only the Verenium Plant in LA is listed by the RFA as operative.

21



Food vs. Fuel -Two Bioreactors

**Mobile Cellulose
Biorefinery (a.k.a. Cow)**



=

**Stationary Cellulose
Biorefinery**

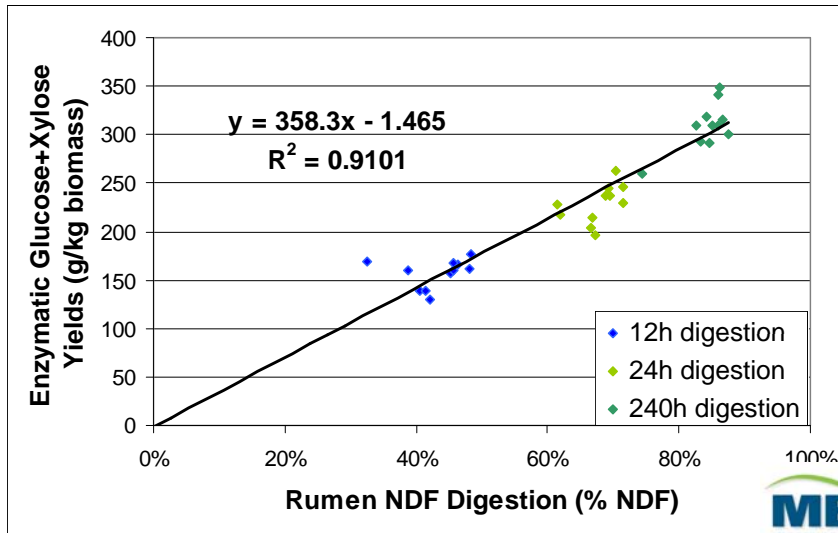


*Improve Cellulose Conversion for Biorefinery
= Improve Cellulose Digestibility for Cows*

22



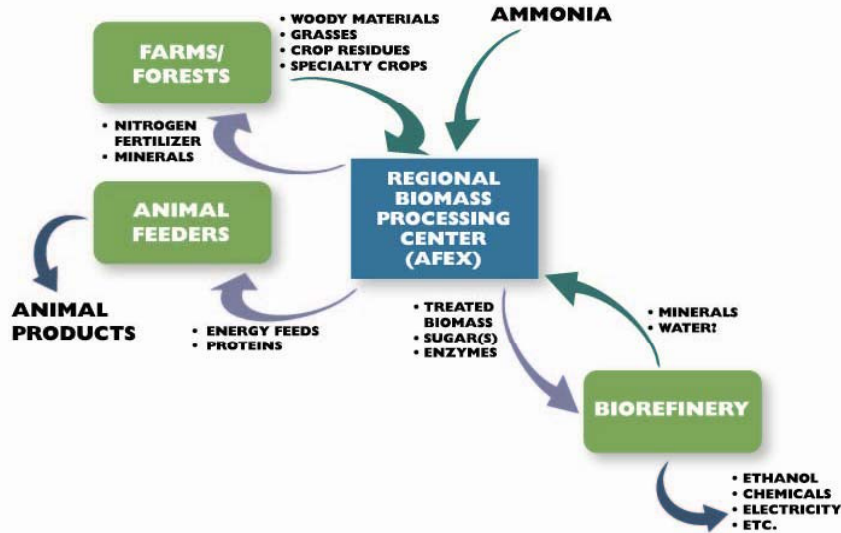
AFEX Treated Grass as Animal Feed



AFEX Treated Grass as Animal Feed

- Laboratory testing results indicate AFEX treated biomass could replace corn in cattle performance rations
- Digestibility does not necessarily equal to energy in rations
- Feeding trials needed to determine actual value
- It's a high priority at MBI to produce enough of this material to complete these trials
- Allows for a novel business plan

REGIONAL BIOMASS PROCESSING: SUPPLY CHAINS



Strategic Opportunities for Regional Processing Centers

- **Flexibility to use AFEX-treated materials as animal energy feed**
 - Addresses “Feed vs. Fuel” issue
- **Flexibility to decouple pretreatment from biorefinery**
 - Addresses supply chain issue
 - Not necessary to have pretreatment step at the refinery
- **Economic benefits**
 - Transportation and storage reduced
 - Animal feeding opportunities
 - Rural benefits; locally owned and operated

Integrated Pilot Plant for Biofuels

- **An MBI-MSU/OBT Incentive**
- **An integrated center where wherein:**
 - Emphasis on corn stover
 - Various biomass feedstocks could be used
 - Pretreatments will be compared with NREL data
 - Various schemes for hydrolysis and fermentation could be utilized
- **Would provide treated materials for animal feeding as well as fuel production**

27



Acknowledgements

- **Bobby Bringi, President and CEO at MBI**
- **Co-workers and colleagues at MBI**
- **Professor Bruce Dale at MSU**
- **The MSU Office of Biobased Technologies**

Thank You!

28

