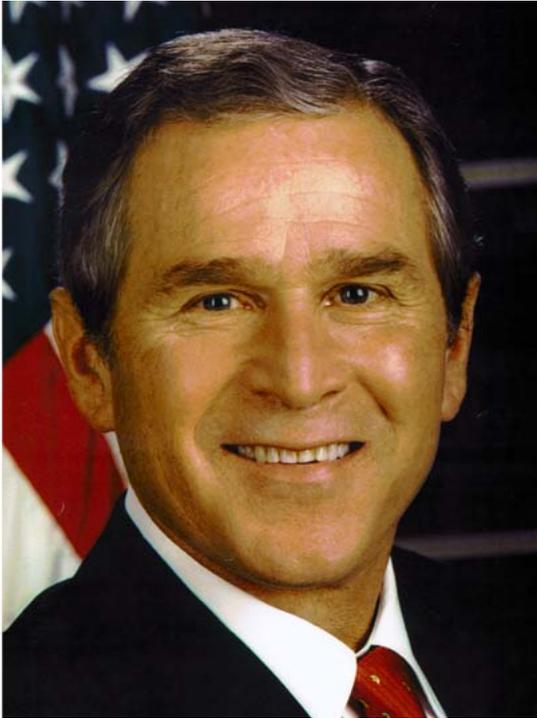


The Role of Cellulosic Conversion

**Professor Bruce E. Dale
Dept. of Chemical Engineering & Materials
Science
Michigan State University
www.everythingbiomass.org**

**Agricultural Outlook Forum
Arlington, Virginia
March 1, 2007**

Thank You Mr. President



Ethanol Production from Enzymatic Hydrolysates of AFEX-Treated Coastal Bermudagrass and Switchgrass

SULTAN RESHAMWALA,¹
BAHAA T. SHAWKY,² AND BRUCE E. DALE*¹

¹Department of Chemical Engineering, Texas A&M University, College Station, TX 77843-3122; and ²Microbial Chemistry Department, National Research Center, Cairo, Egypt

“...We'll also fund additional research in cutting-edge methods of **producing ethanol...from** wood chips and stalks, or **switch grass...**”

State of the Union Address, **2006**

Applied Biochemistry and Biotechnology, Vol. 51/52

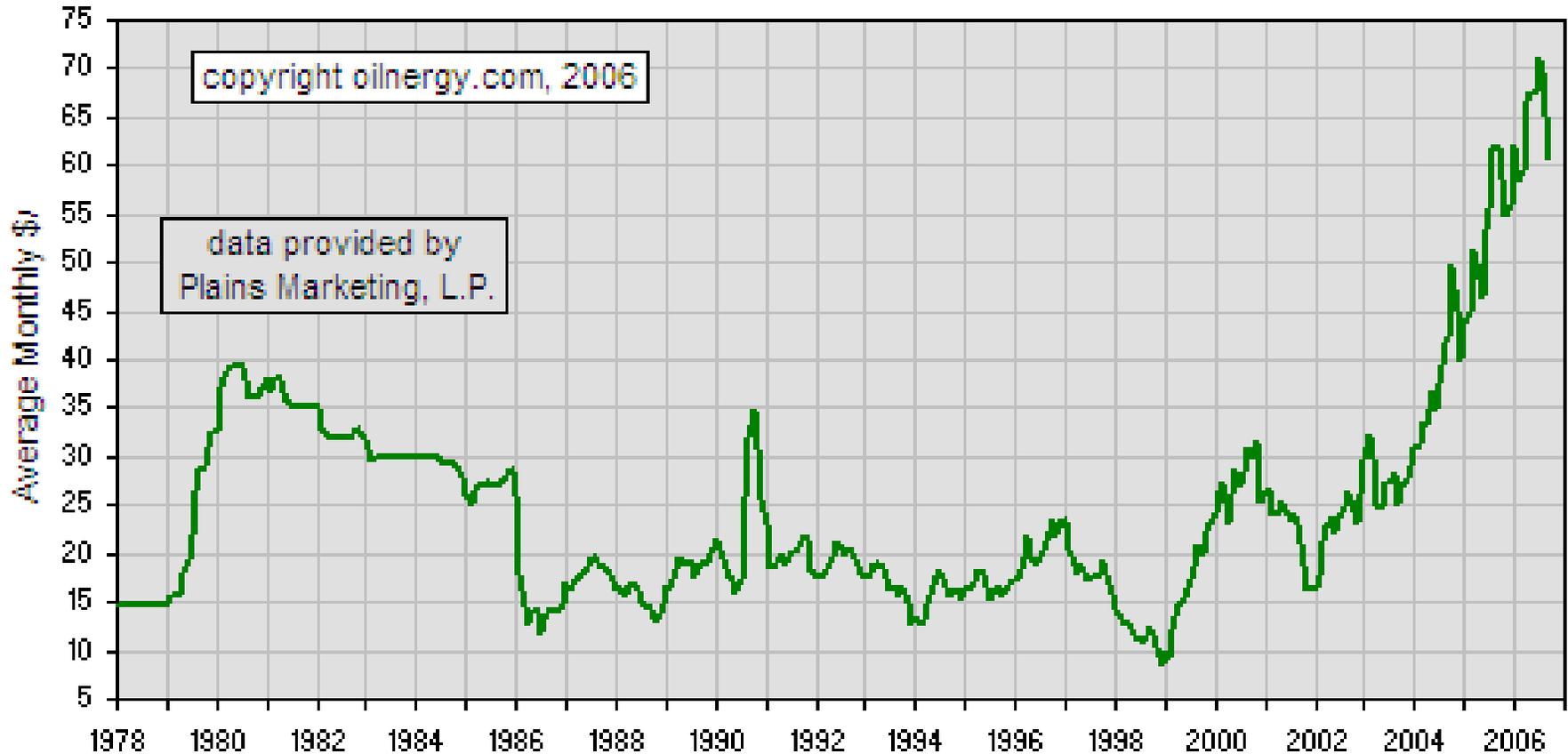
1995

So It's Not Just About "Politics"

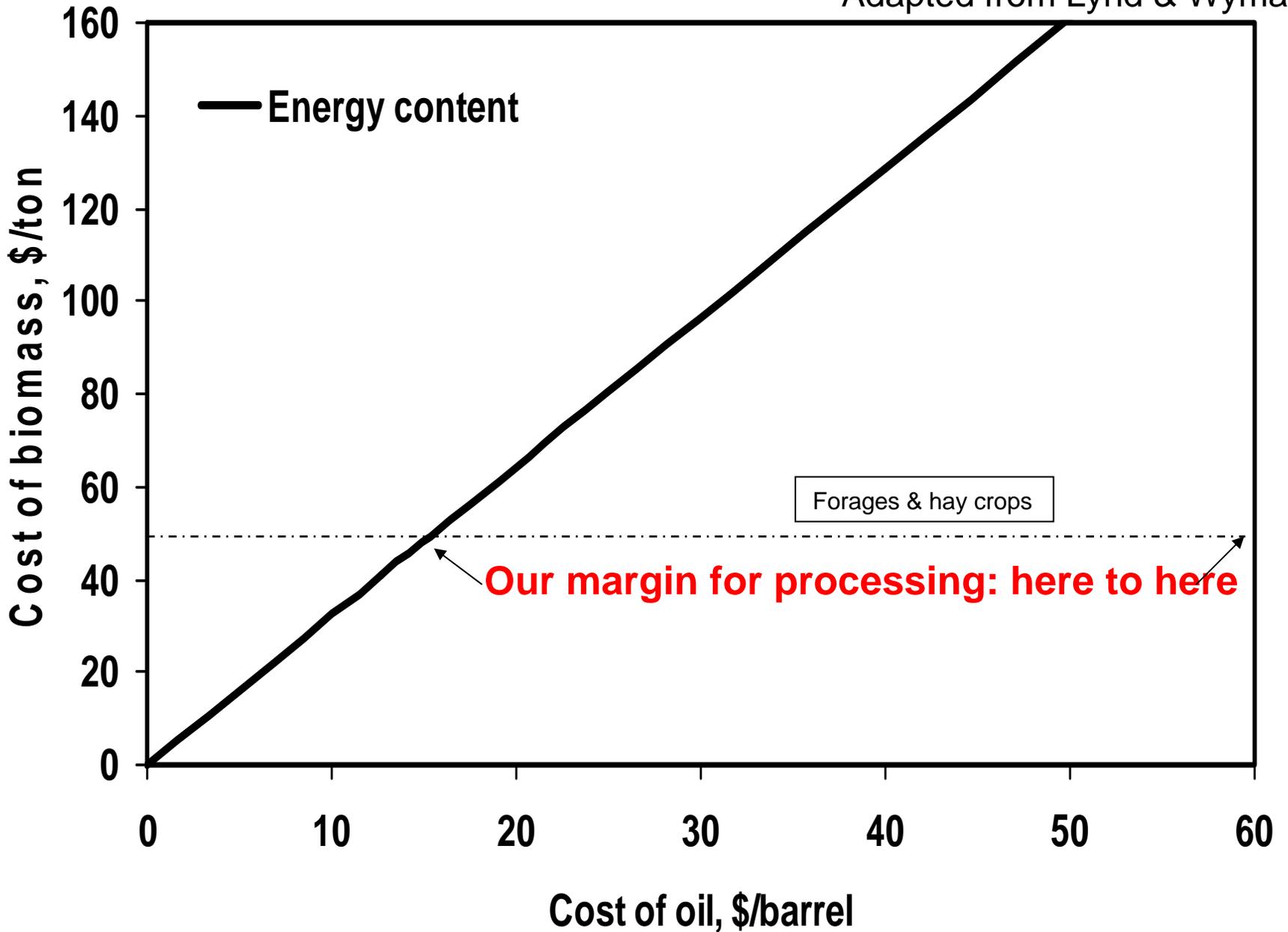
- Better Technologies
 - Better & cheaper pretreatments-AFEX for example
 - Better & cheaper enzymes
 - Better fermentation organisms
 - Consolidated bioprocessing (CBP) is progressing
 - Better integration of these technologies
- Venture capital & (we hope) more research funding
- Heightened awareness of oil "externalities"
 - Potential for climate change
 - Economic development/balance of payments
 - 9/11 & terrorism
- RFS & other help from our "big brother": ethanol from corn
- Testing platforms: pulp mills & corn mills
- \$60 per barrel oil (or thereabouts)

1978 – 2007 CRUDE OIL PRICES

Plains Marketing, L.P.'s WTI Crude - Posted Price

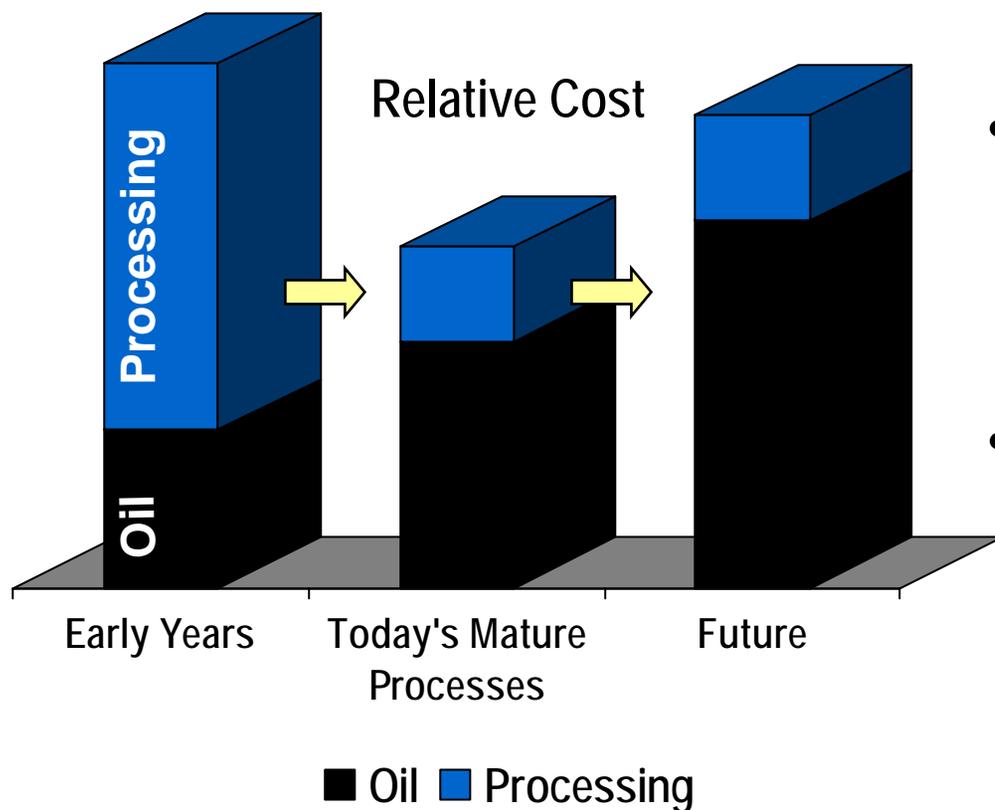


Average monthly data from January 1978 through September 2006



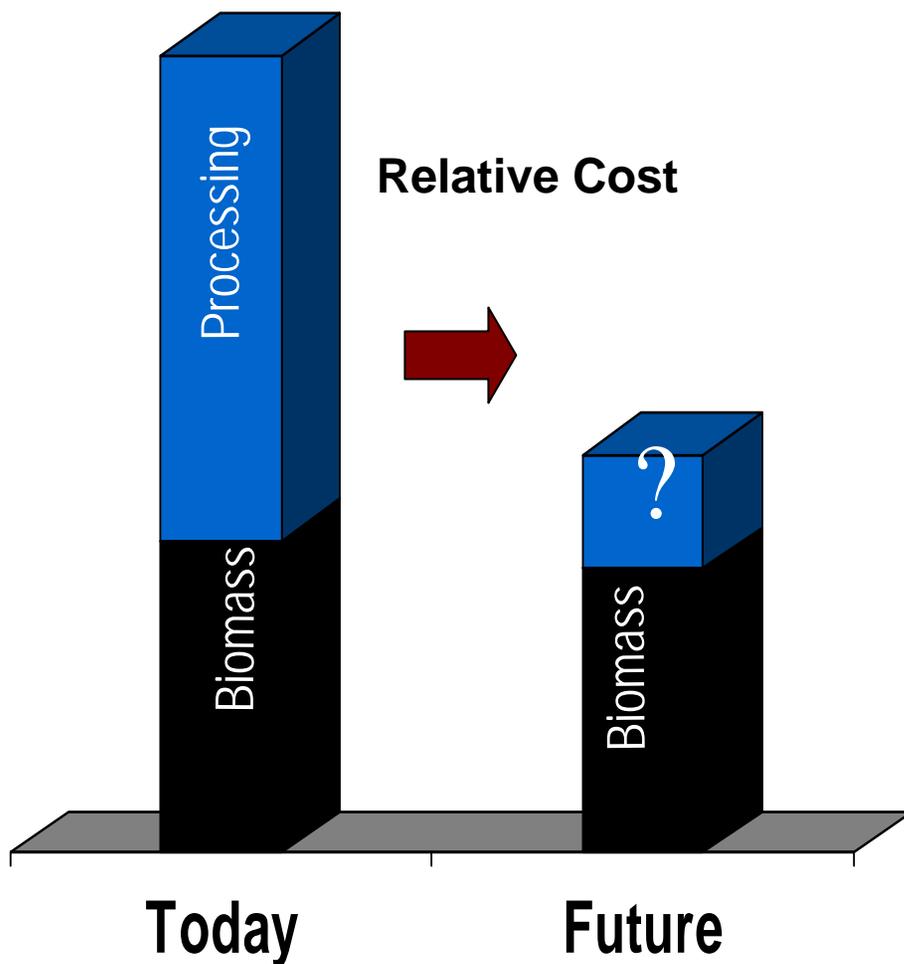
Plant material is much, much cheaper than oil on both energy & mass basis

Impact of Processing Improvements: Oil's Past & Future



- Historically, petrochemical processing costs exceeded feedstock costs
- Petroleum processing efficiencies have increased and costs have decreased dramatically but reaching point of diminishing returns
- Petroleum raw materials have long-term issues
 - Costs will continue to increase as supplies tighten
 - High price variability
 - Impacts national security
 - Climate security concerns
 - Not renewable
- **Not a pretty picture for our petroleum dependent society**

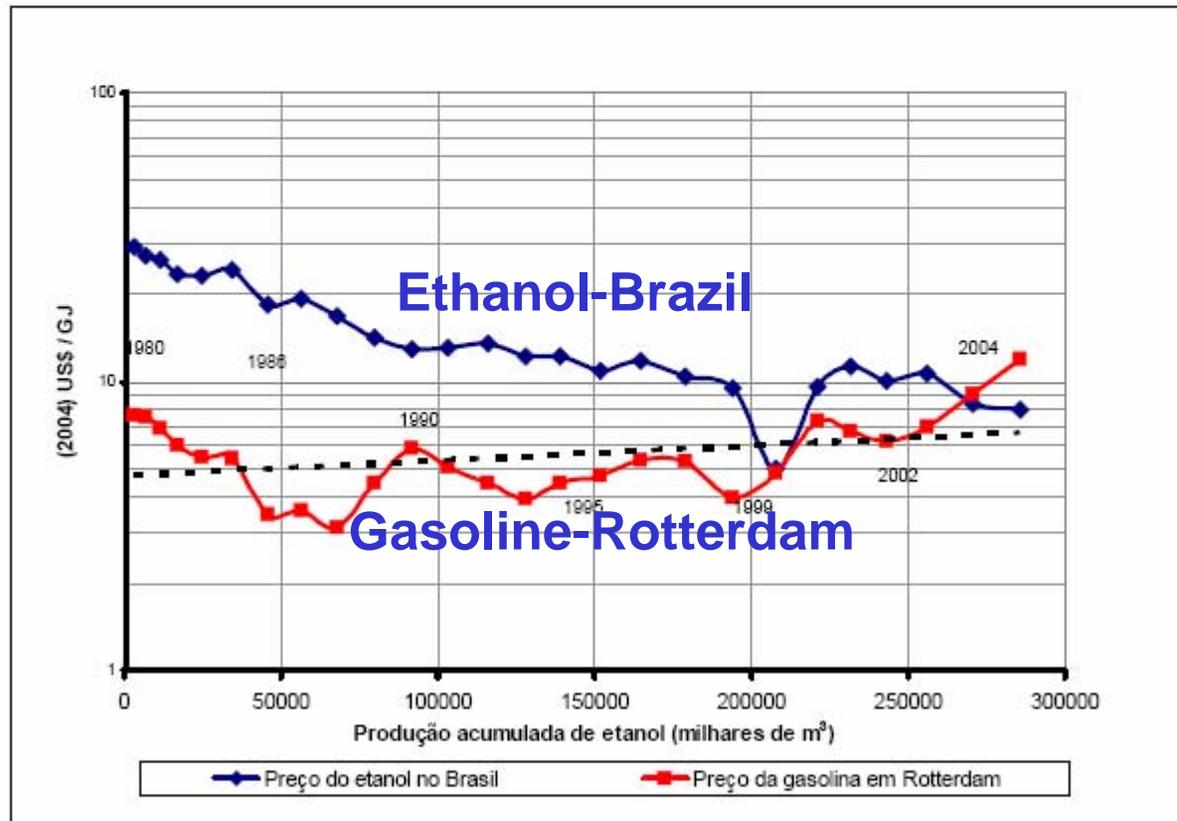
Impact of Processing Improvements: The Future of Biomass Conversion



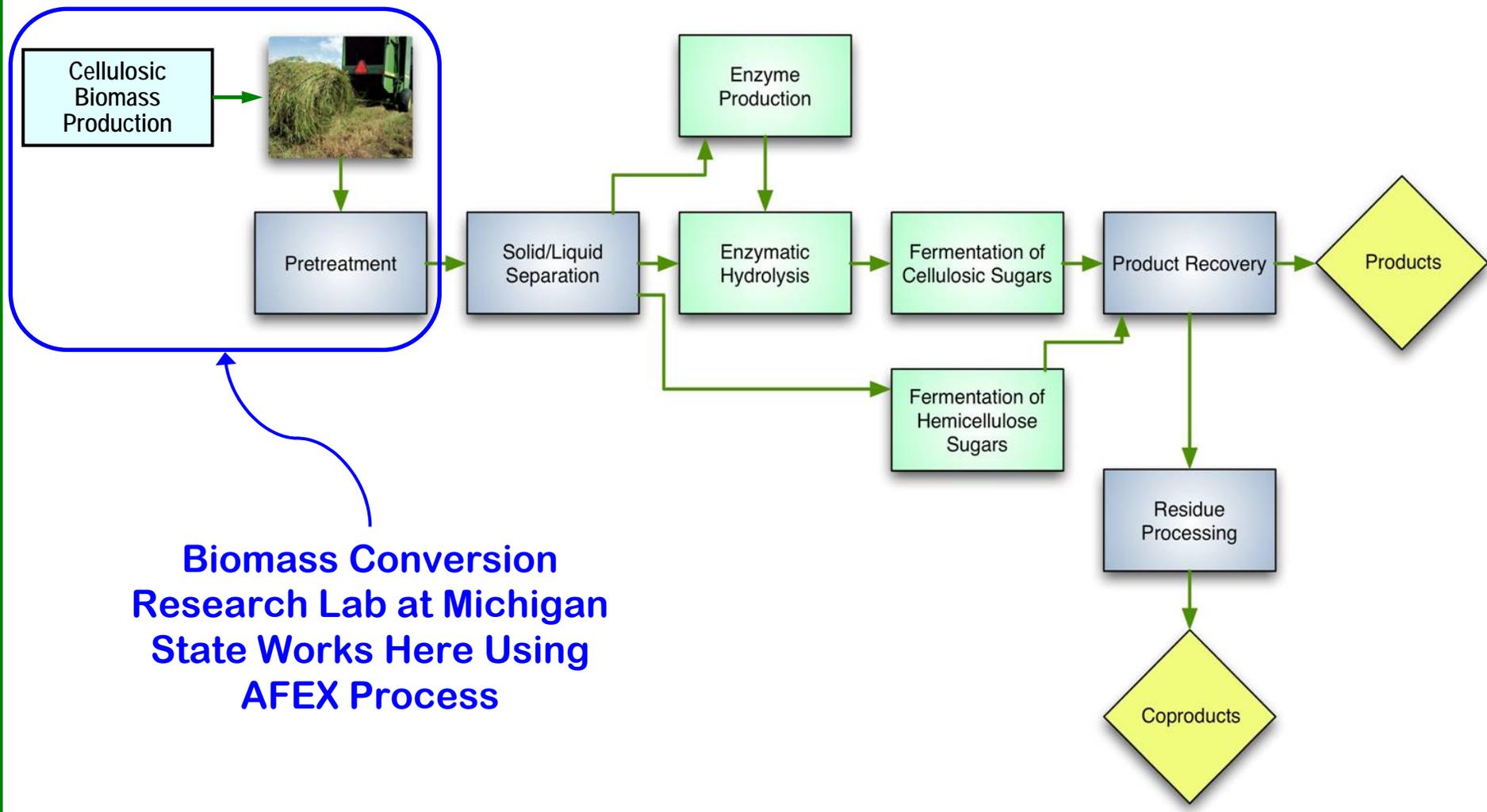
- Processing is dominant cost of cellulosic biofuels today
- Cellulosic raw material costs should be stable or decrease
- Processing costs dominated by pretreatment, enzymes & fermentation
- Biomass processing costs will decrease: deserves high priority to make it happen sooner rather than later
- **Much more attractive future**
 - Domestically produced fuels
 - Environmental improvements
 - Rural/regional economic development

Get on the Biomass Ethanol Learning Curve-Now!

.....WHILE THE COST HAS BEEN REDUCED THREE FOLD AND IS NOW LOWER THAN THE COST OF GASOLINE

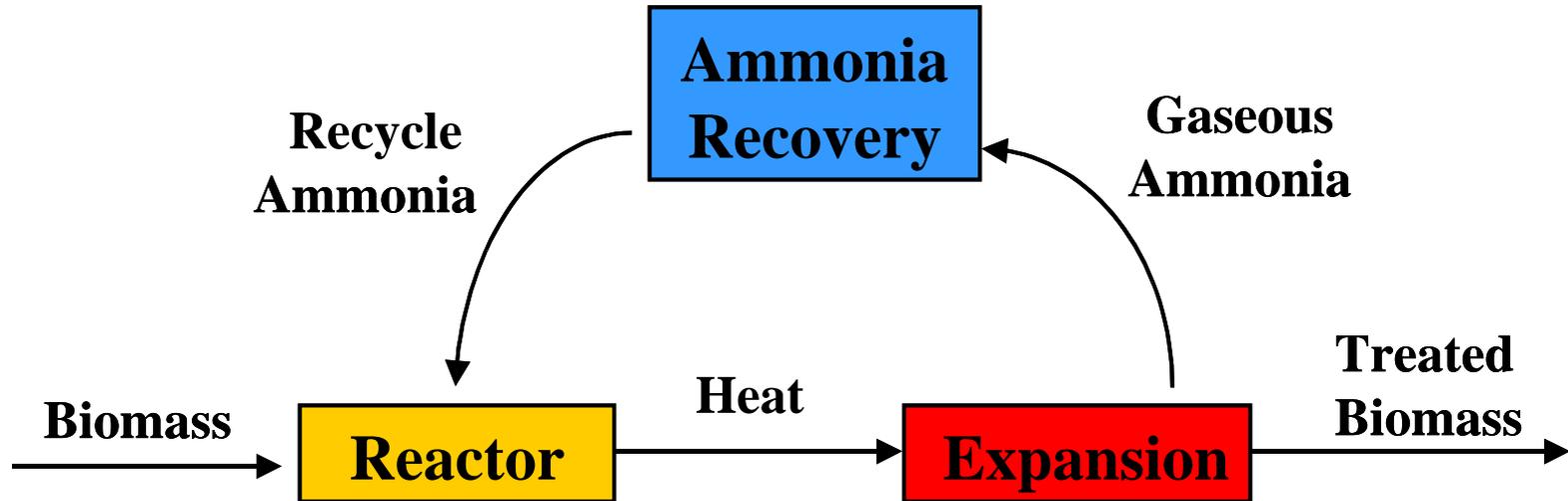


Source: Goldenberg, 2005



**Biomass Conversion
Research Lab at Michigan
State Works Here Using
AFEX Process**

How does AFEX work?

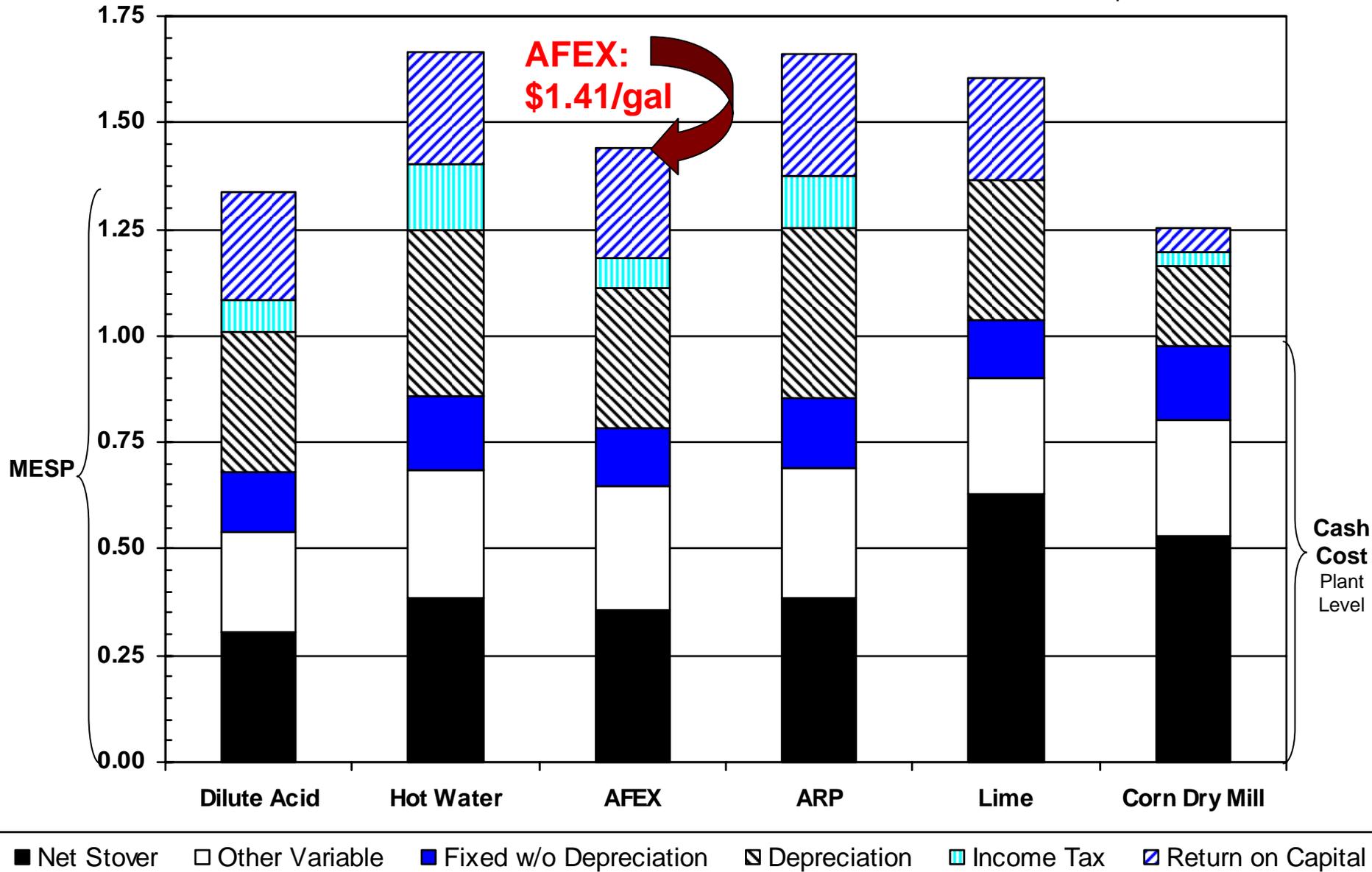


- Biomass heated (~100 C) with concentrated ammonia
- Rapid pressure release ends treatment
- 99% of ammonia is recovered & reused, remainder serves as N source downstream for fermentation
- Minimize sugar degradation, relatively mild conditions

Pretreatment Economic Analysis: CAFI Team

\$/gal EtOH

Proof Year: 4th Year of Operation



Results of Economic Analysis for AFEX*

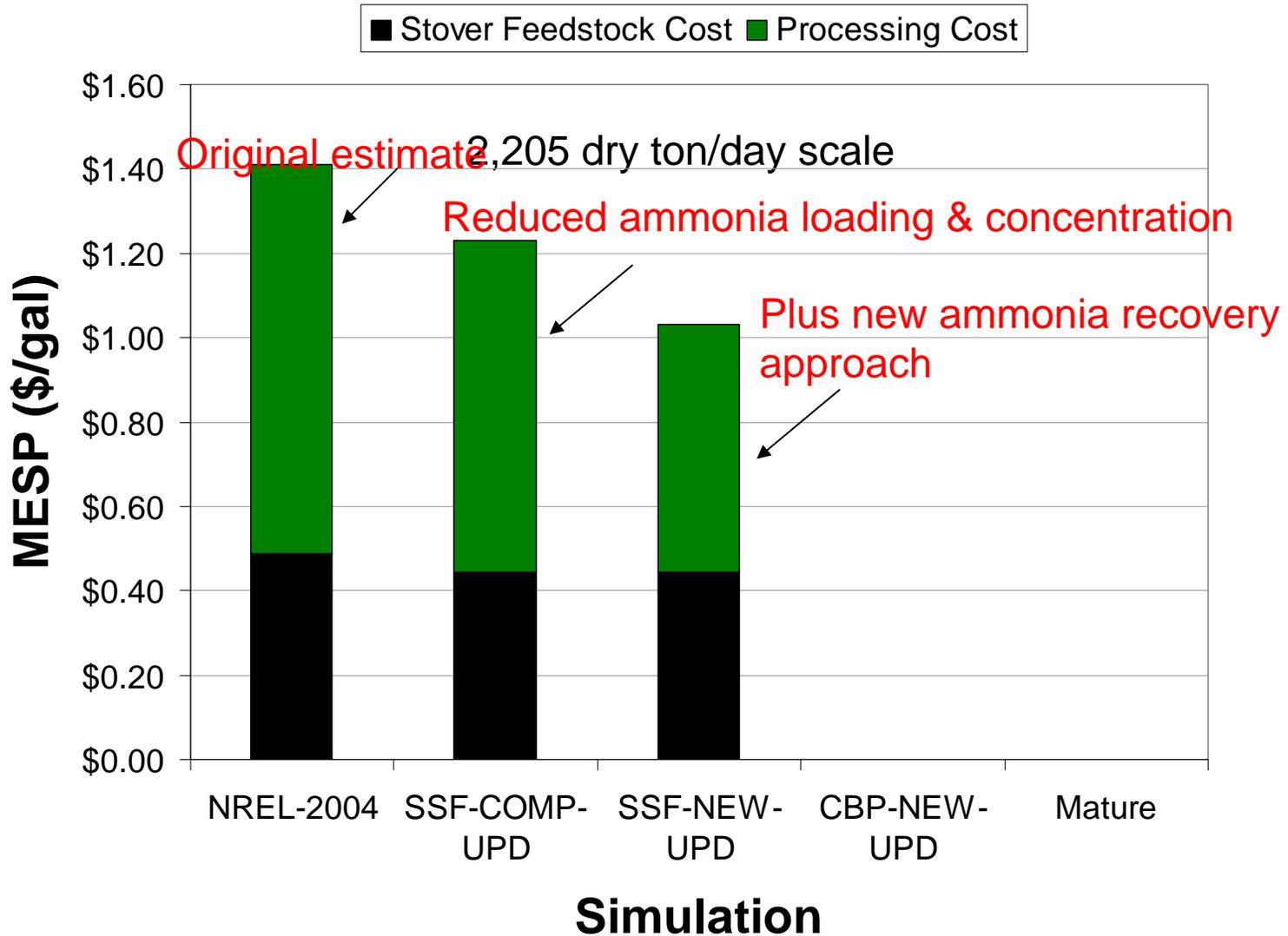
- Reduce ammonia loadings
- Reduce required ammonia recycle concentrations (manage system water)
- Reduce capital cost of AFEX
- Reduce enzyme loadings for >90% conversion of glucan plus xylan

* *Our sincere thanks to Dr. Tim Eggeman:
NREL & Neoterics*

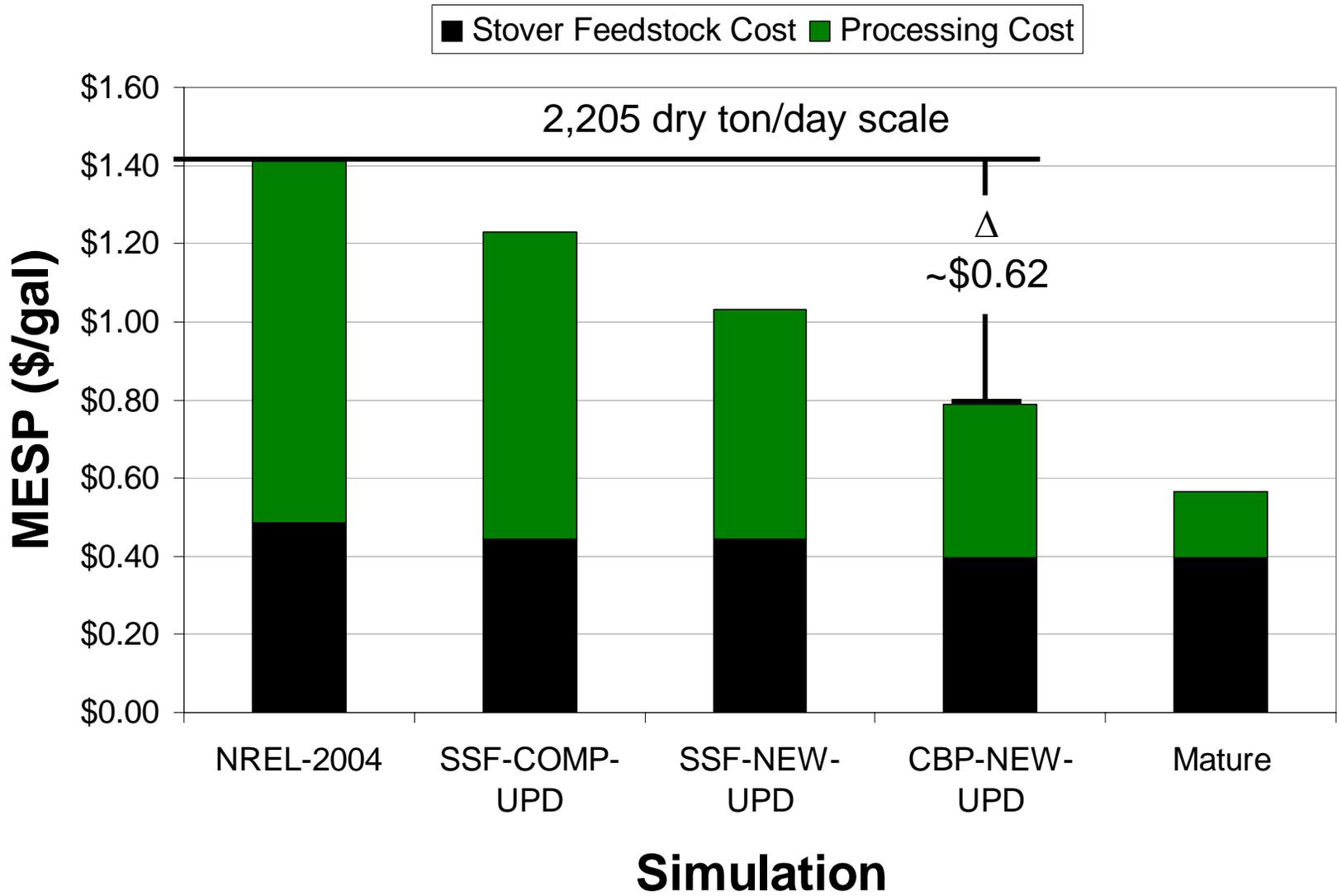
Effects of AFEX Process Improvements: New Cost Estimates (w/out Reduced Enzyme)

Abbreviation	Meaning
NREL-2004	SSCF, NH3 Recompression, Old AFEX parameters
SSF-COMP-UPD	SSCF, NH3 Recompression, Updated AFEX parameters
SSF-NEW-UPD	SSCF, New NH3 Recovery approach, Updated AFEX parameters
CBP-NEW-UPD	CBP, New NH3 Recovery approach, Updated AFEX parameters
Mature	Cost 70% Feedstock, 30% Processing

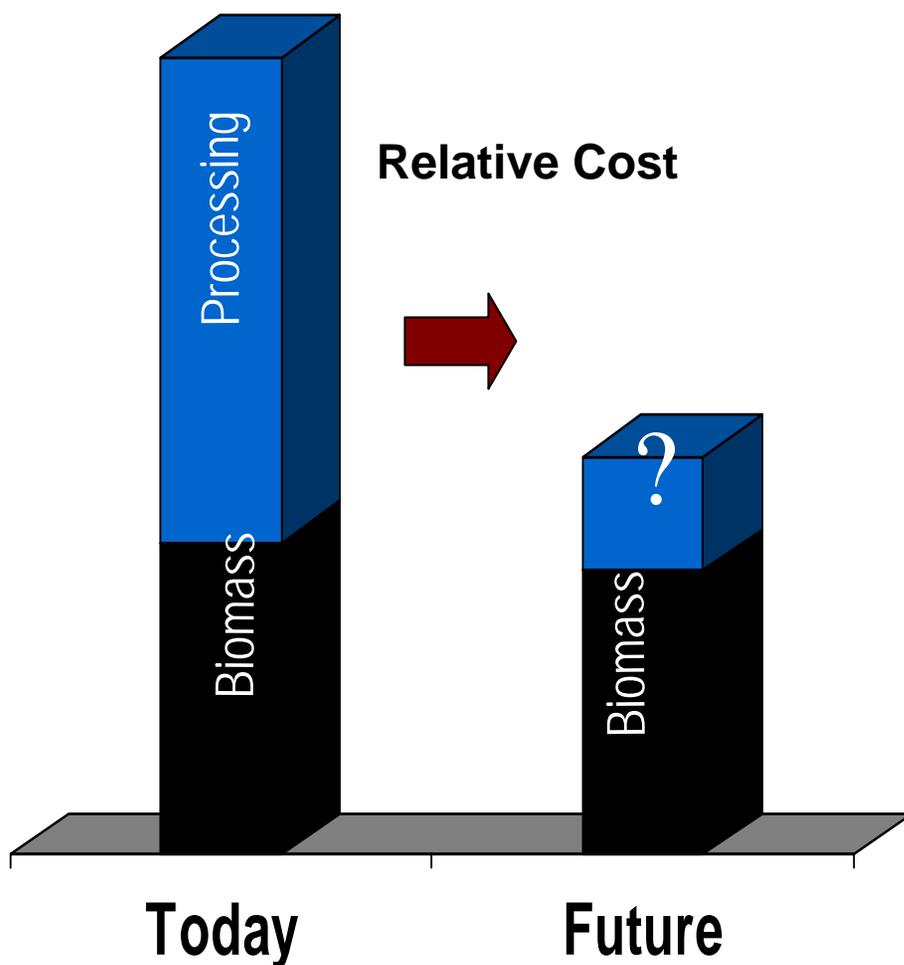
Improvements in AFEX Give Improved Ethanol MESP



Final Results



Impact of Processing Improvements: The Future of Biomass Conversion



Adapted from J. Stoppert, 2005

- Processing dominates cost of cellulosic biofuels: pretreatment, enzymes, fermentation
- Cellulosic raw material costs should be stable or decrease
- Biomass processing costs will decrease: high priority will accelerate progress
- Get cellulosic ethanol into operating plants: **now!**
- **Much more attractive future**
 - Domestically produced fuels
 - Environmental improvements
 - Rural/regional economic development

Ethanol from Cellulosics: Look for Fast Growth!



courtesy Dr. Steve Long UICU

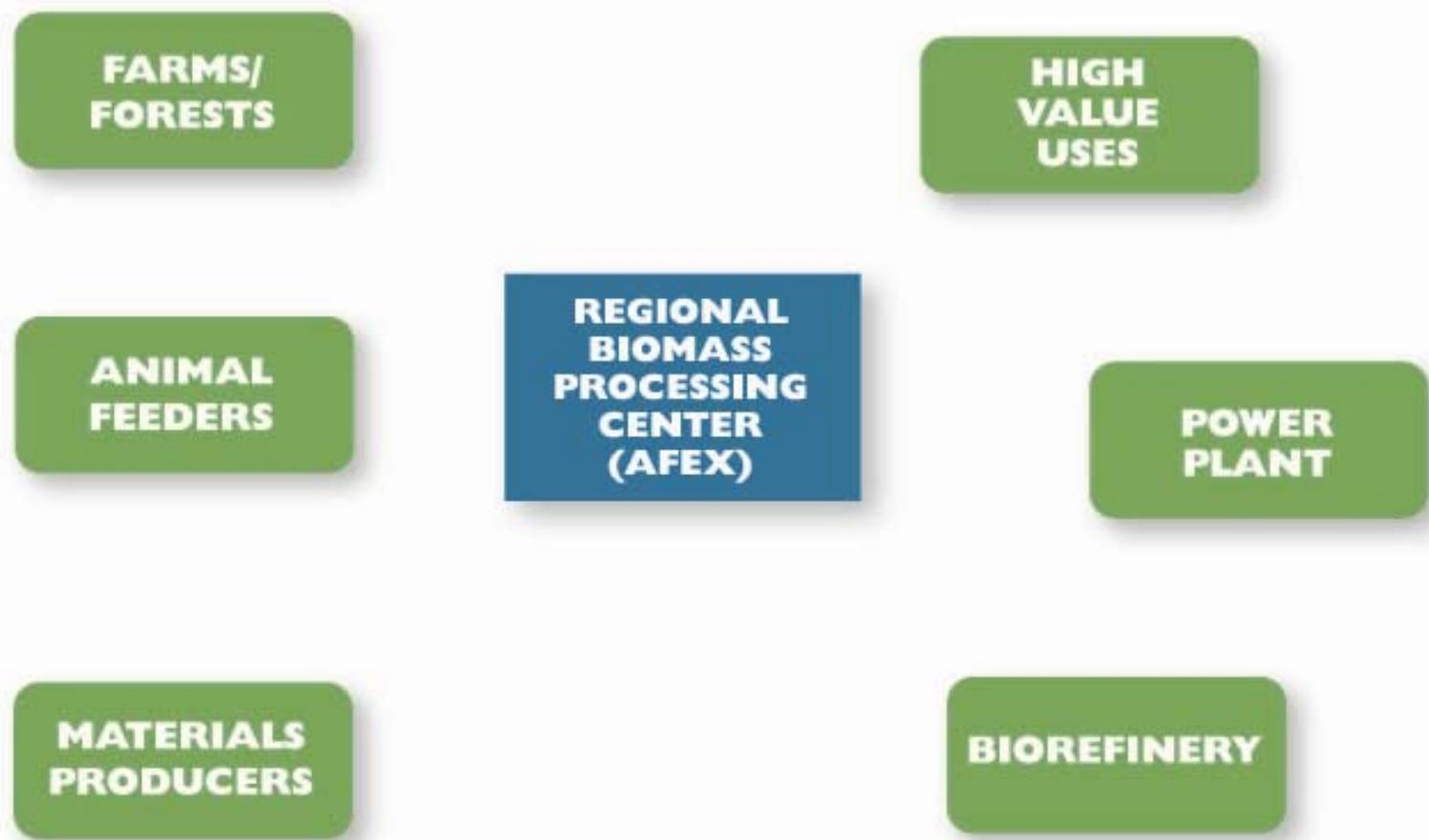
Anticipating the Biofuels Future

- Premise: *the cellulosic biofuels industry will grow rapidly in coming years.*
- Inference: Processing costs will decline & raw material costs will grow in relative importance
- Some resulting implications/questions:
 - Will USDA aggressively fund energy crops research?
 - Will traditional commodity groups simply react (perhaps negatively) or be proactive?
 - How will biofuels environmental issues (carbon sequestration, water, soil quality, etc.) be addressed?
 - What will the implications be for food/feed/fiber markets? Can we coproduce fuels (& foods/feeds)
 - **How can farmers & local communities benefit?**

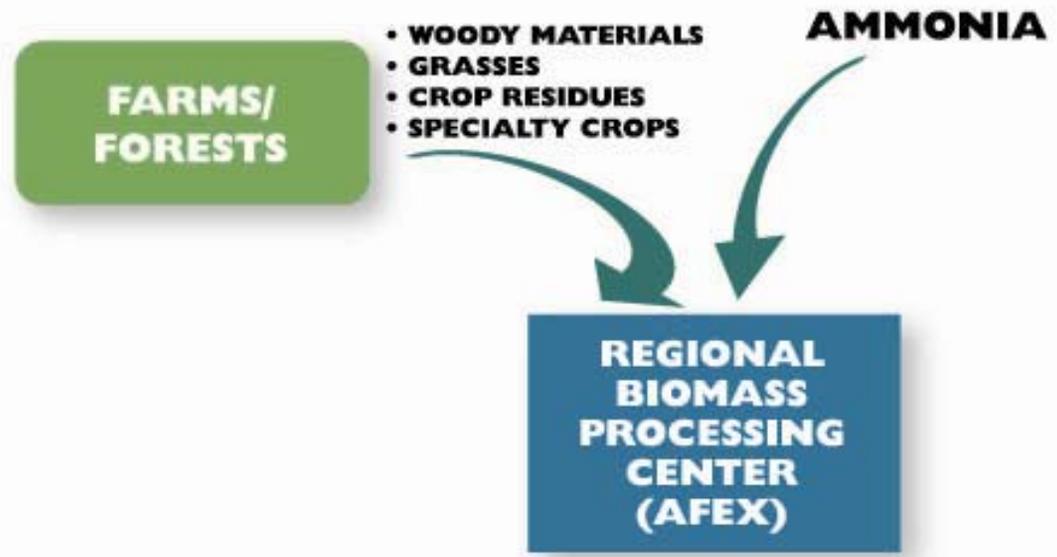
Capturing Local Benefits from Biofuels

- Some problems/issues:
 - Environmental benefits depend largely on local factors—requires local control & optimization
 - Cellulosic biomass is bulky, difficult to transport
 - Investment required for cellulosic ethanol biorefinery is huge ~ \$250 million and up—difficult for farmers to participate
 - Supply chain issues are also huge—need 5,000 ton/day from ~1,000 farmers: chemicals/fuels industries have **zero** experience with such large agricultural systems
 - Supply chains established for grains, not so much for grasses
 - Need to resolve “food vs. fuel”: actually “**feed** vs. fuel”
- Is there a common solution?
 - **Regional Biomass Processing Center— concept worthy of further study and development**
 - Pretreat biomass for biorefinery & ruminant animal feeding
 - Much lower capital requirements—accessible to rural interests
 - Potential to also accommodate high value uses: materials, nutraceuticals, enzymes, etc.

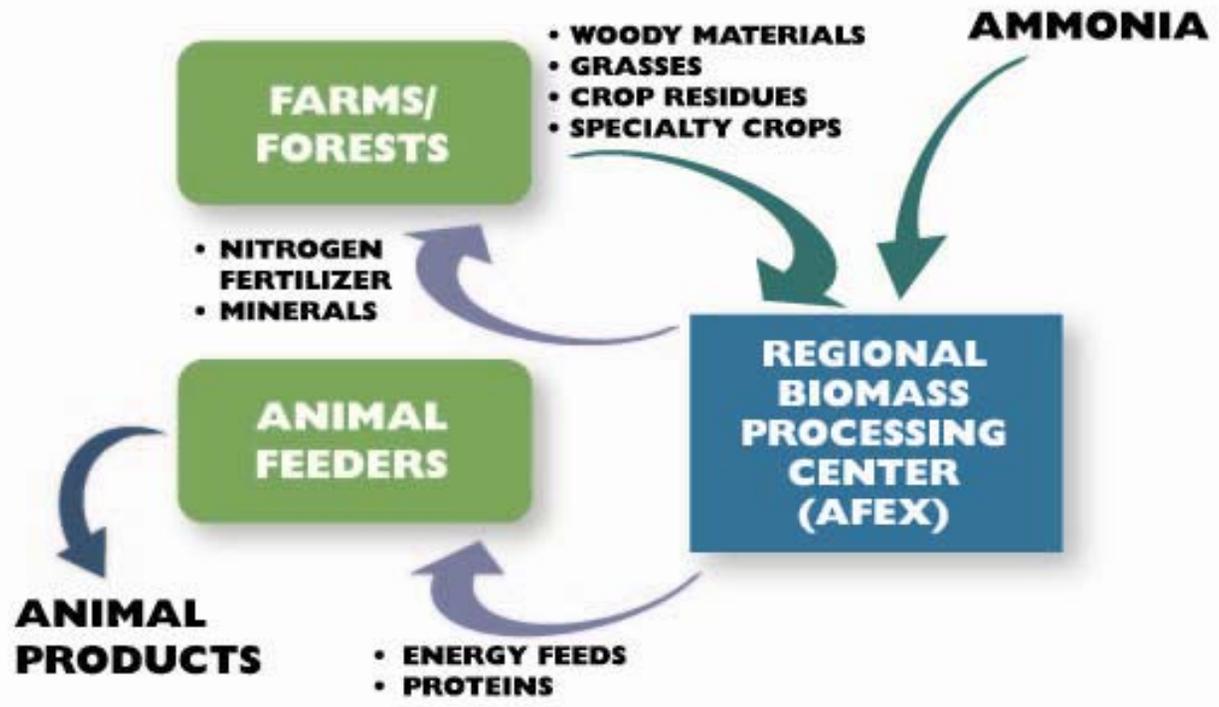
REGIONAL BIOMASS PROCESSING: SUPPLY CHAINS



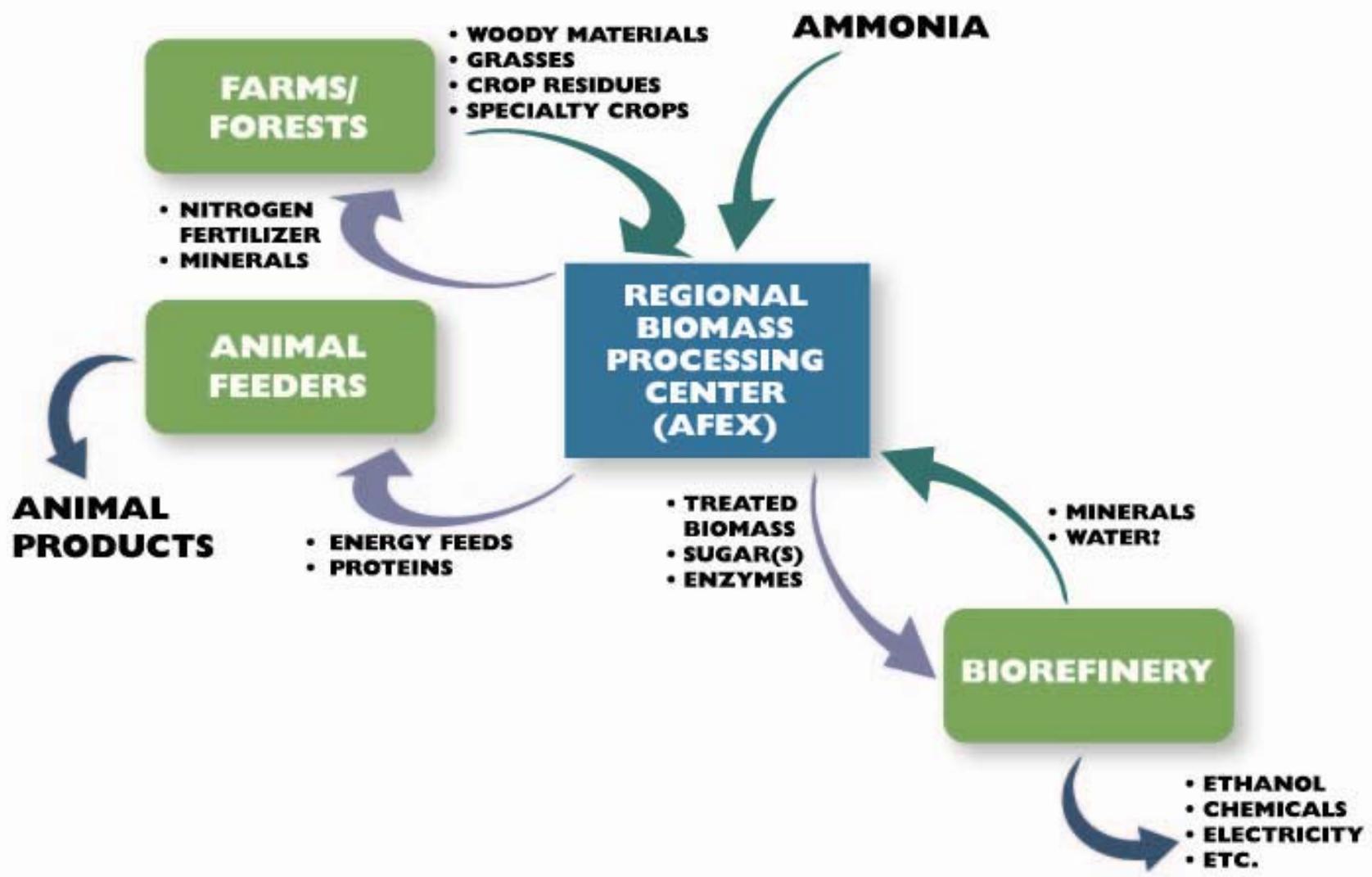
REGIONAL BIOMASS PROCESSING: SUPPLY CHAINS



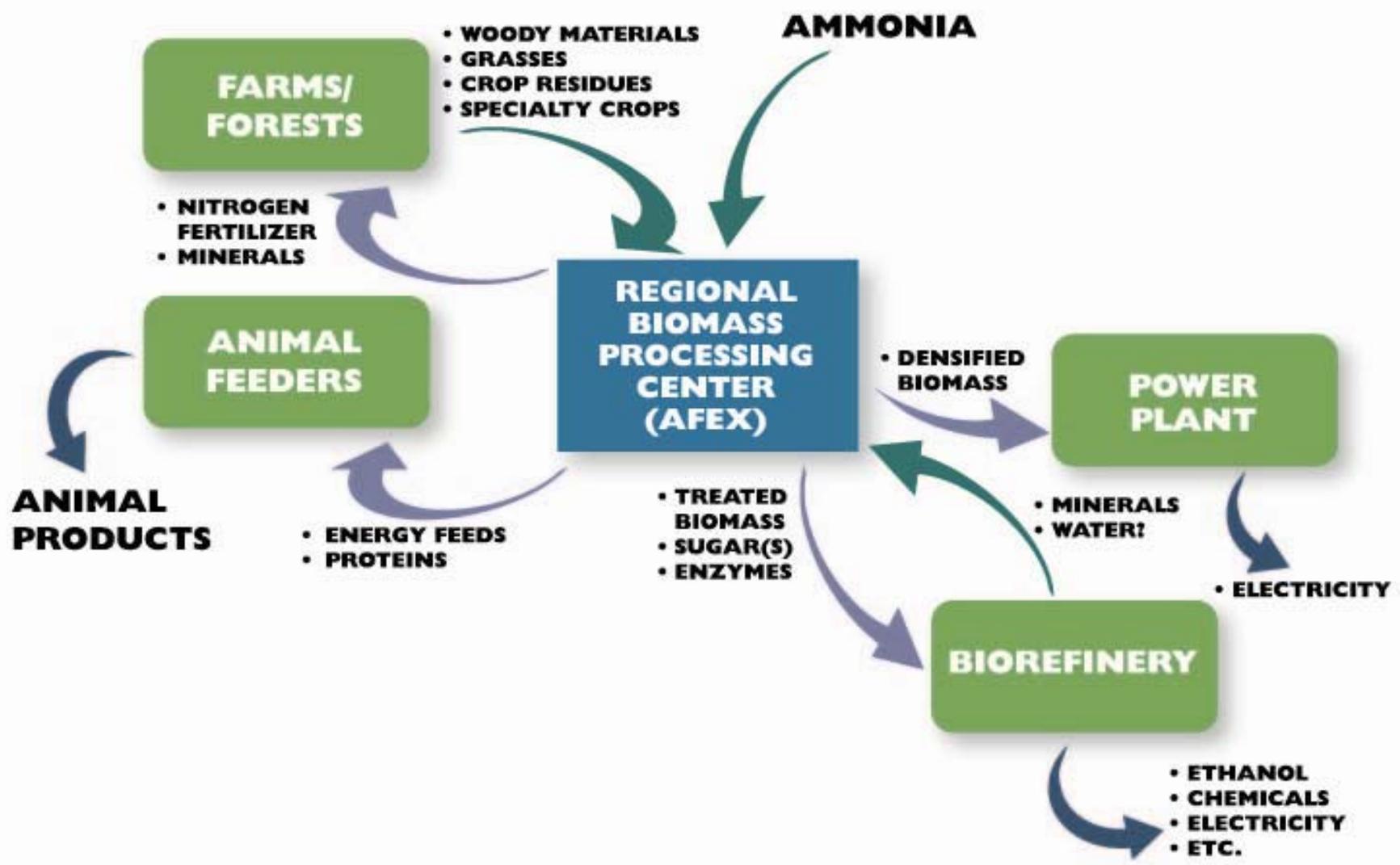
REGIONAL BIOMASS PROCESSING: SUPPLY CHAINS



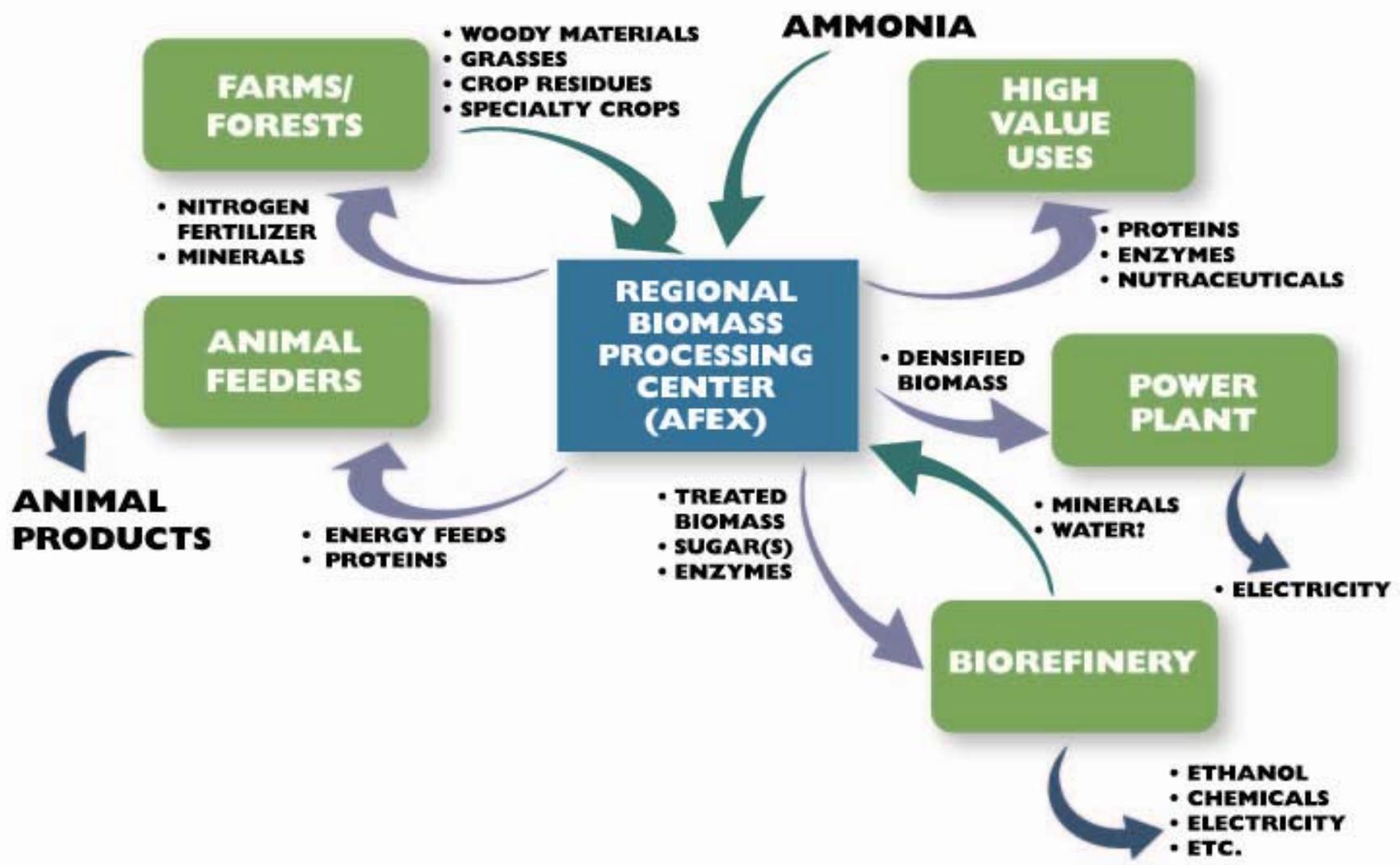
REGIONAL BIOMASS PROCESSING: SUPPLY CHAINS



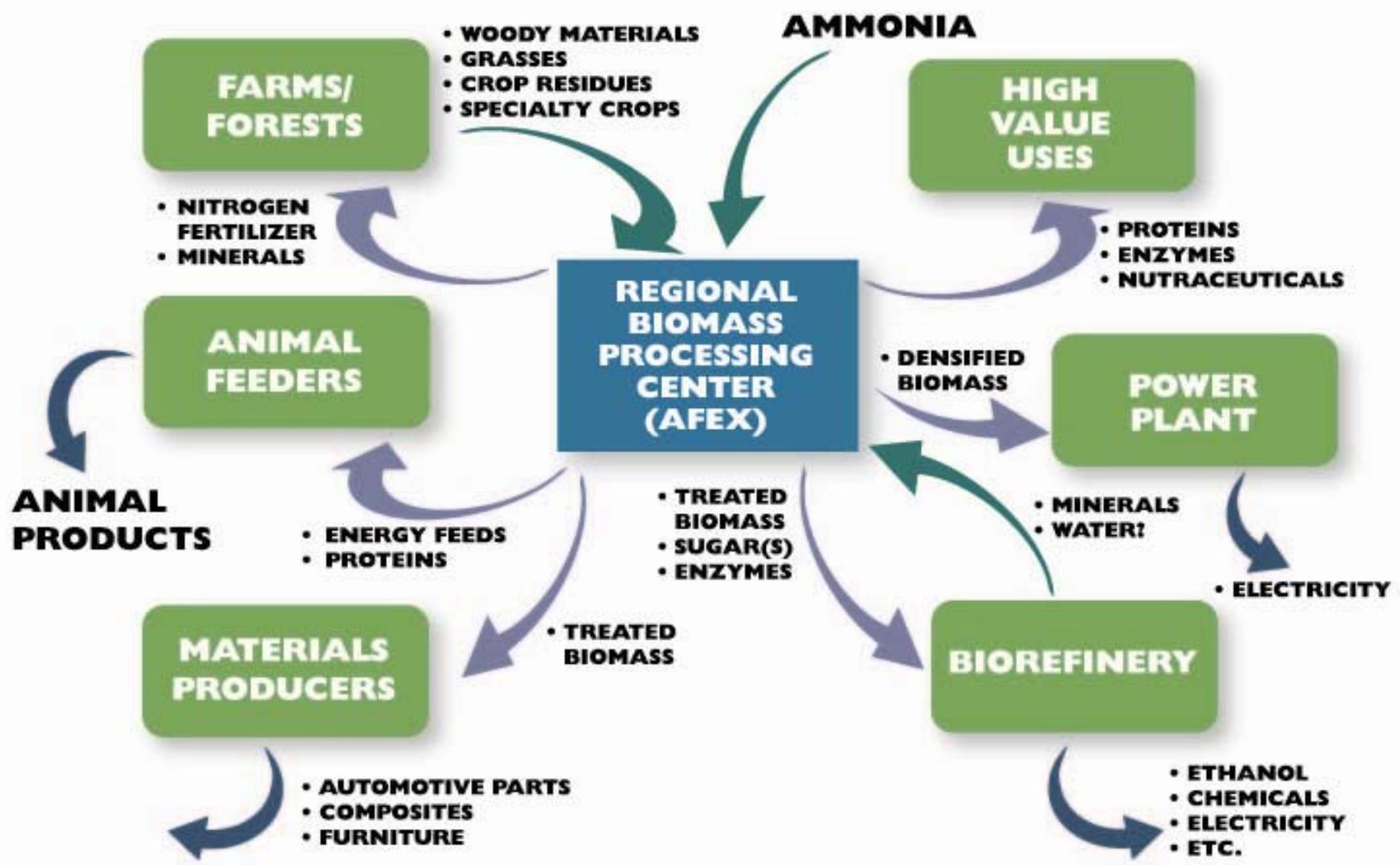
REGIONAL BIOMASS PROCESSING: SUPPLY CHAINS



REGIONAL BIOMASS PROCESSING: SUPPLY CHAINS



REGIONAL BIOMASS PROCESSING: SUPPLY CHAINS



Why We Should Explore Regional Biomass Processing Centers

- Rising corn prices negatively affect animal feeding operations— provide feed alternatives
- Ruminant animals are well-suited to high digestibility grasses (by pretreatment)
- Develop prototype supply chains & pretreatment systems for cellulosic ethanol (and butanol and...)
- Many more states/locations can grow grass than can grow corn—more widespread benefits
- Provides processing locus for high value products (biobased composites, nutraceuticals, etc.)
- Position ourselves to export these technologies

“Absolutely!”

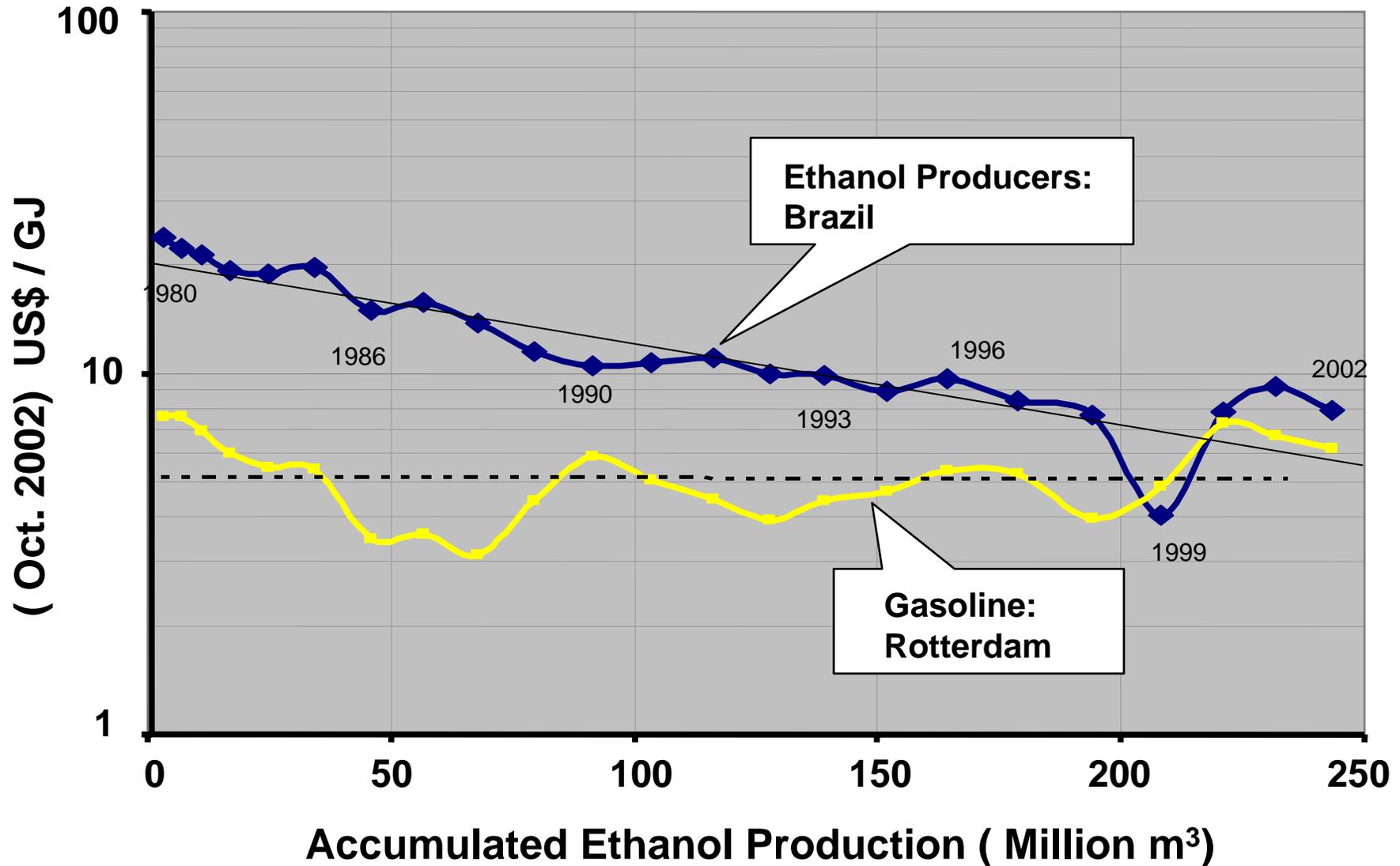


Questions ??

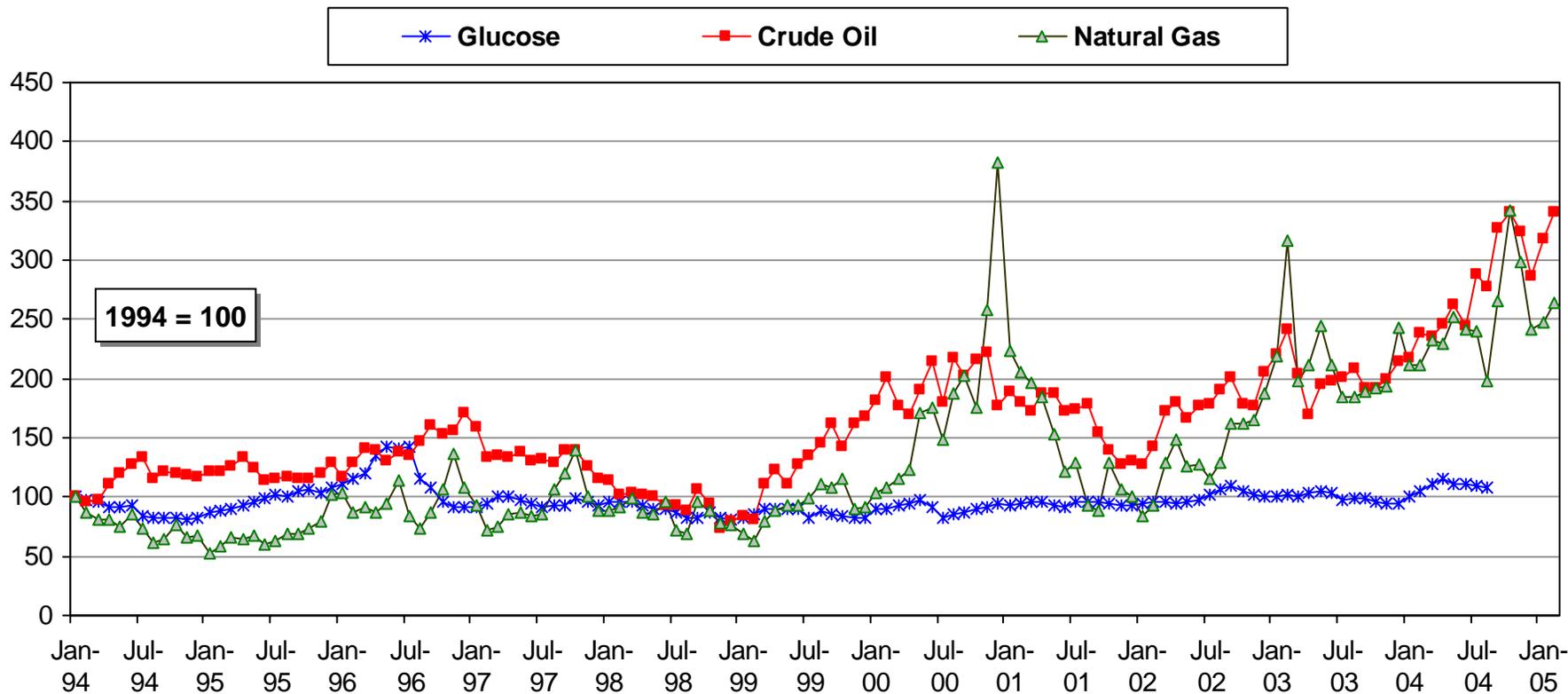


Learning Curve: Sugar Ethanol Production Cost

(J. Goldemberg, 2003)



Glucose, Crude Oil & Natural Gas Price Index



Actual Jan 94

SBO (cents/lb)	28.93
Crude (\$/barrel)	15.19
Nat gas (\$/mm btu)	2.55
Propylene (¢/lb)	11.25

Actual Feb 05

SBO (cents/lb)	21.50
Crude (\$/barrel)	51.76
Nat gas (\$/mm btu)	8.73
Propylene (¢/lb)	43.00

From J. Stoppert, 2005