Status of Potential Industrial Biorefinery Development

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SE Regional Biomass Energy Feedstock Partnership Workshop

A biorefinery is a facility that aims to use all components of biomass to make a range of foods, fuels, chemicals, feeds, materials, heat and power in proportions that maximizes economic return.

Example: Corn wet mill

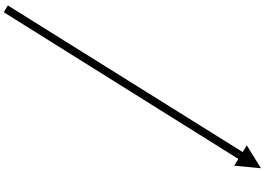
Input: Corn

Products: Corn starch

Corn gluten feed

Corn oil

Corn steep liquor



- Starch
- Corn sweeteners
- Glucose
- Ethanol
- Lactic acid/PLA
- 3PDO
- Amino acids
- Pharmaceuticals
- Industrial chemicals

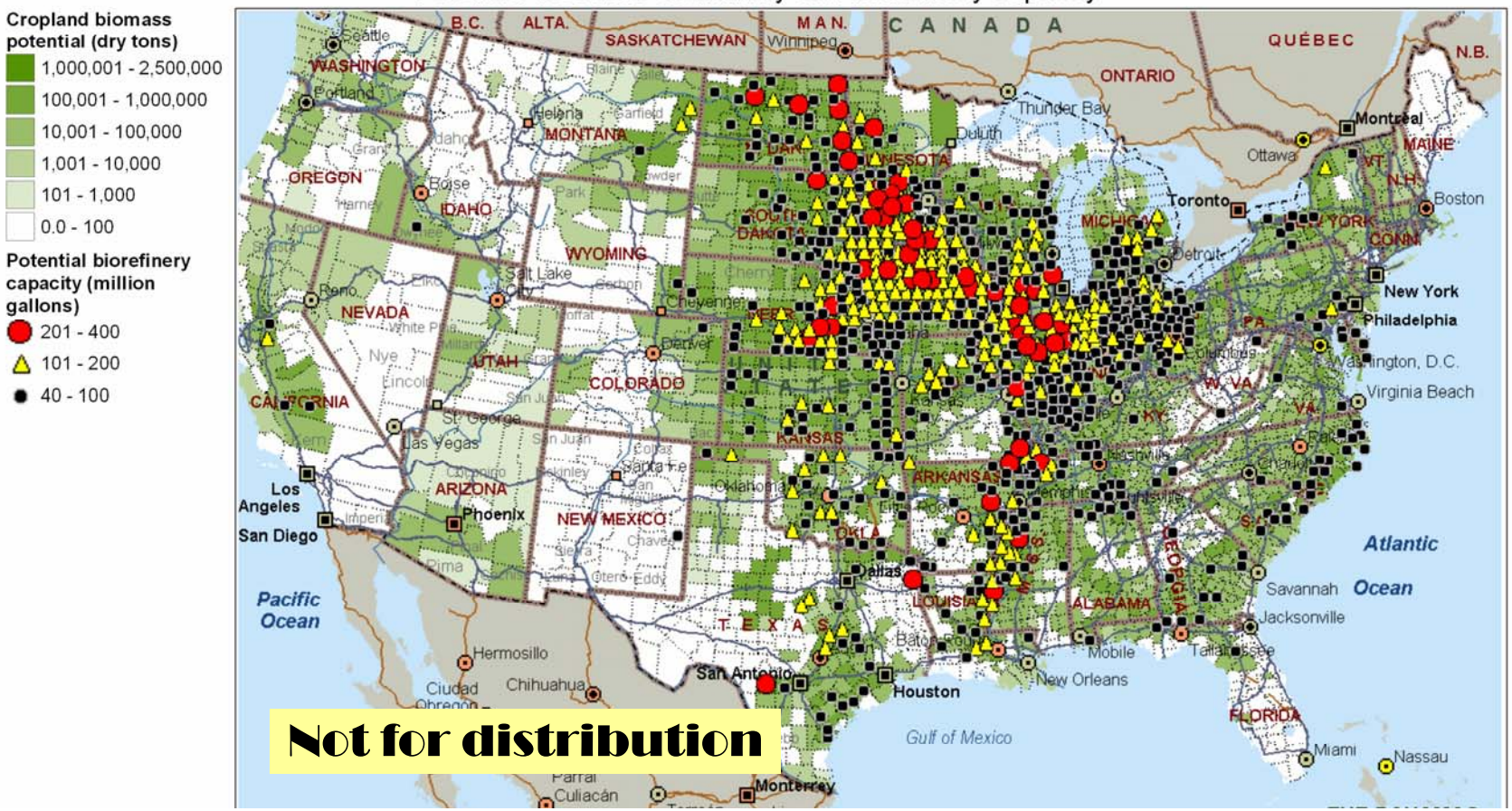
Current and Projected US Ethanol Production

- Currently 4.5 billion gallons are produced from corn
  - 67% produced by corn dry mills and misc.
  - 33% produced by corn wet mills
- Projections for 2025 vary but possibly 25 billion gallons will be produced in line with the 25 by 25 program
  - 12.5 Billion gallons produced from corn
    - Assume 75% dry mill, 25% wet mills
  - 12.5 Billion gallons from biomass
    - Requires rapid growth of the biomass ethanol industry

Potential Crop Resources and Biorefineries in 2025

- Analysis based upon “Billion Ton Report” data
  - Snapshot view lacking the depth of the billion ton study
- Examined United States for:
  - Primary crop resources
  - Included corn stover, straws, and grasses
  - Included perennial switchgrass
  - *Excludes* forest resources
- Examined on a county by county basis
  - In reality, future plants will use multi-county feedstock source
- Mapped sites capable of producing 40 million gal / yr

Potential resource availability and biorefinery capacity



2025 modeled location of ethanol plants in counties with sufficient available crop residues and switchgrass (only plants greater than 40×10^6 gallons <u>within one county</u> are shown)

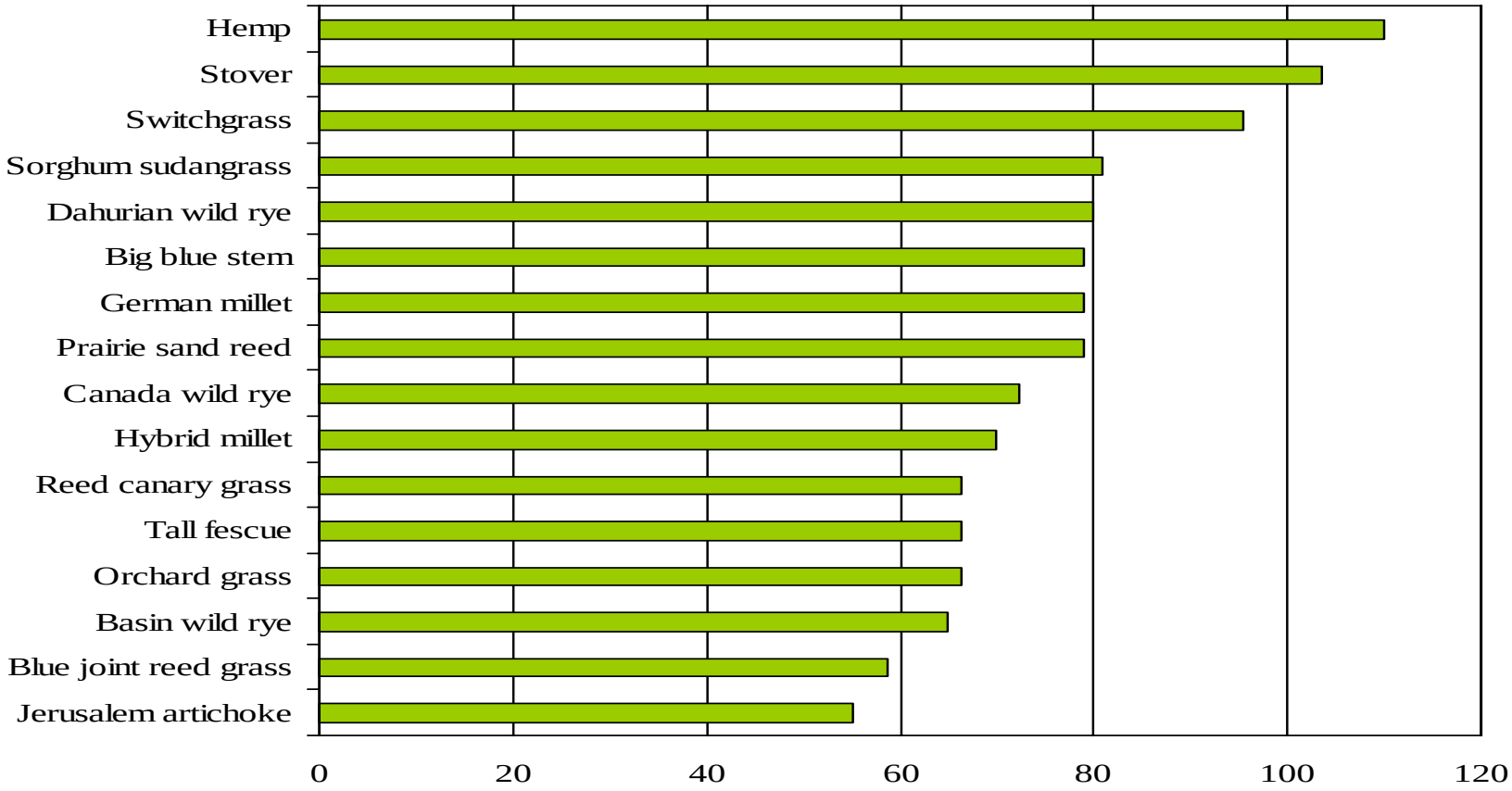
Next Era: Biomass Improvement Strategies

Targeted Goal	Traits & Technologies
Broaden Planting Range	• Tolerance to chronic and acute drought • High salt tolerance • Tolerance to heat shock • improvement in seedling growth under cold conditions • Improve tolerance to (heavy) soil types
Increase tons per acre	• Increase in biomass (in arabidopsis in the greenhouse 5X) • Increase in rice in the field (3X) • Increase in CO2 uptake (30%)
More dollars per acre	• Significant reduction in required nitrogen • Improvement in photosyn efficiency on low nitrogen (20%) • increase in root biomass • Decrease herbicide/ pesticide requirements
More gallons per ton	• Decreased lignin • Increased cellulose/ hemicellulose

Source: Modified from Ceres Corp.

Increasing Gallons per Ton…

Composition
(How much carbohydrate is there?)



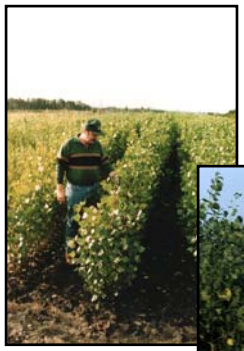
Gallons of ethanol per dry ton of feedstock*

*Data represents theoretical yields as reported by Iogen

Plant Genetic Engineering for Improved Bioenergy Utilization

- Active research in four areas that support of bioenergy:
- introduction of hydrolytic enzymes into plants
- regulation of lignin levels in plants
- increases in plant polysaccharide levels in feedstock
- fundamental genomic research on dedicated bioenergy crops ie: poplar
- Others underway as well

Bioenergy and Plant Genomics: Expanding the nation's renewable energy resources

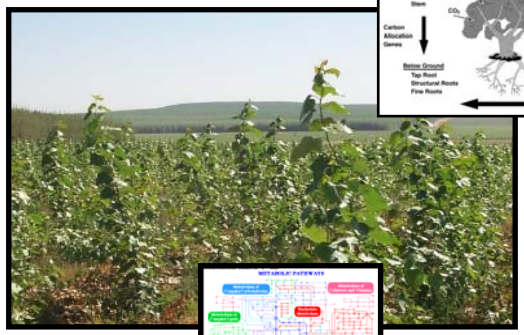


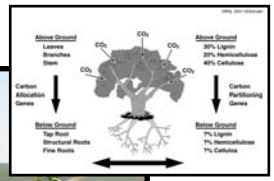
Conventional Forestry

Yesterday

Short rotation hardwoods

Today





Carbon allocation

Metabolic Profiling

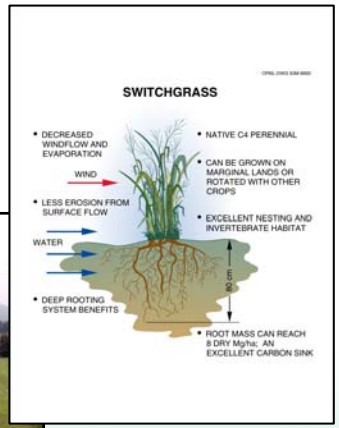
Whole Genome Microarrays

Accelerated Domestication

Tomorrow

High yield wood crops

Putting Genomes to work For Energy Security



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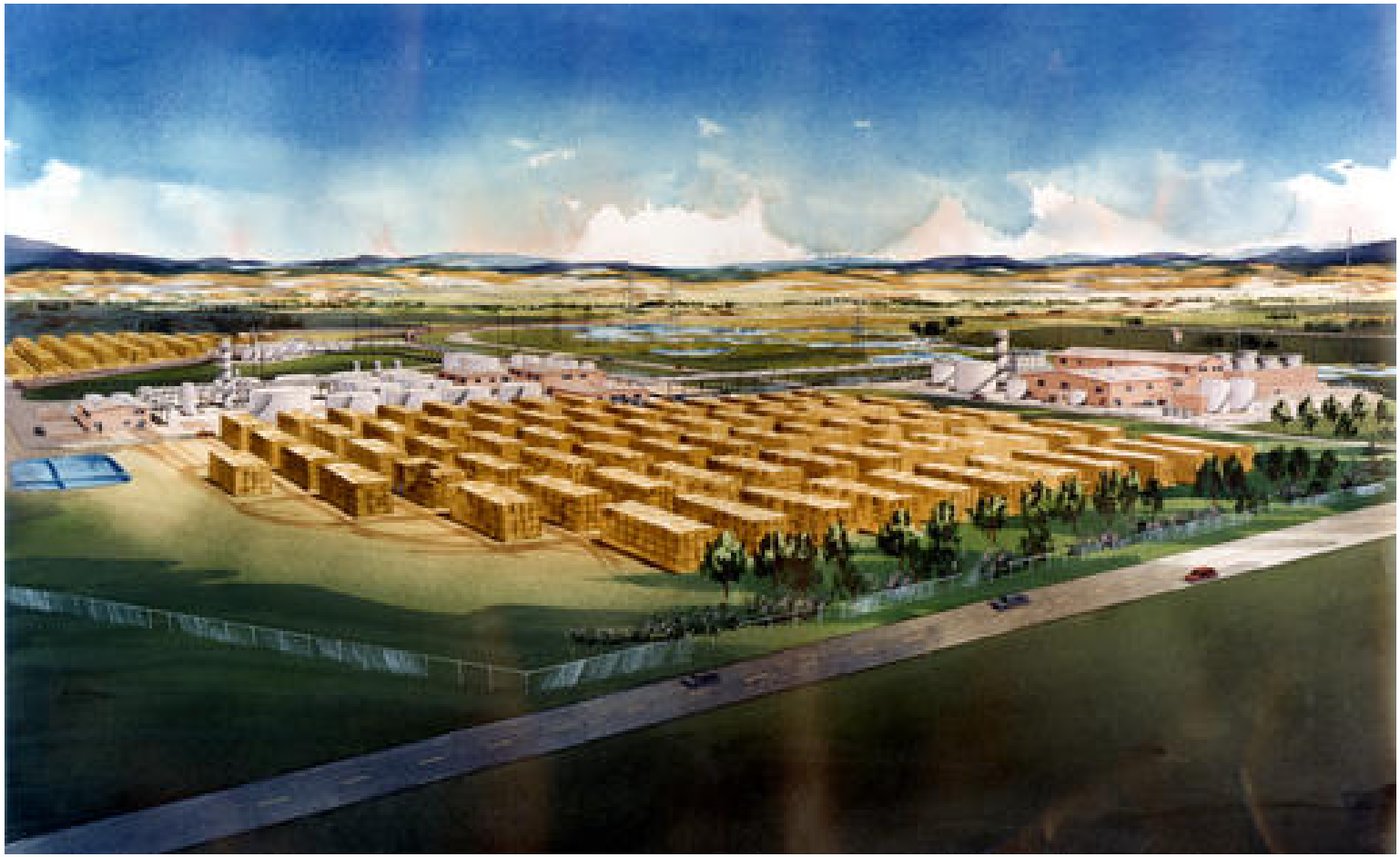
Artist Vision of a Biorefinery with Biomass Storage Adjacent

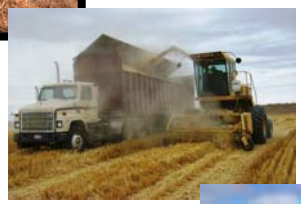


Source: NREL Pix

Biomass Handling: Logistical Considerations for Year Round Supply

Grow

Harvest



Load
In field

Field
Storage

Field Side Grind
& Load

Transport Biomass
To Biorefinery

Conversion
Biorefinery

New Domestic Bio-industry

Biomass Feedstock

- Grasses
- Agricultural Residues
- Hardwood Trees
- Softwood Trees
- Forest Residues
- Animal Wastes
- Municipal Solid Waste
- Demolition/Urban Waste

Conversion Processes

- Enzymatic Fermentation
- Gas/liquid Fermentation
- Acid Hydrolysis/Fermentation
- Gasification
- Pyrolysis
- Combustion
- Co-firing

PRODUCTS

Fuels:
- Ethanol
- Renewable Diesel
- Hydrogen

Power:
- Electricity
- Heat (co-generation)

Chemicals
- Plastics
- Solvents
- Chemical Intermediates
- Phenolics
- Adhesives
- Furfural
- Fatty acids
- Acetic Acid
- Carbon black
- Paints
- Dyes, Pigments, and Ink
- Detergents
- Etc.

Food and Feed

Source: L. Russo, US DOE Office of the Biomass Program
http://www.bioproducts-bioenergy.gov/1201.html

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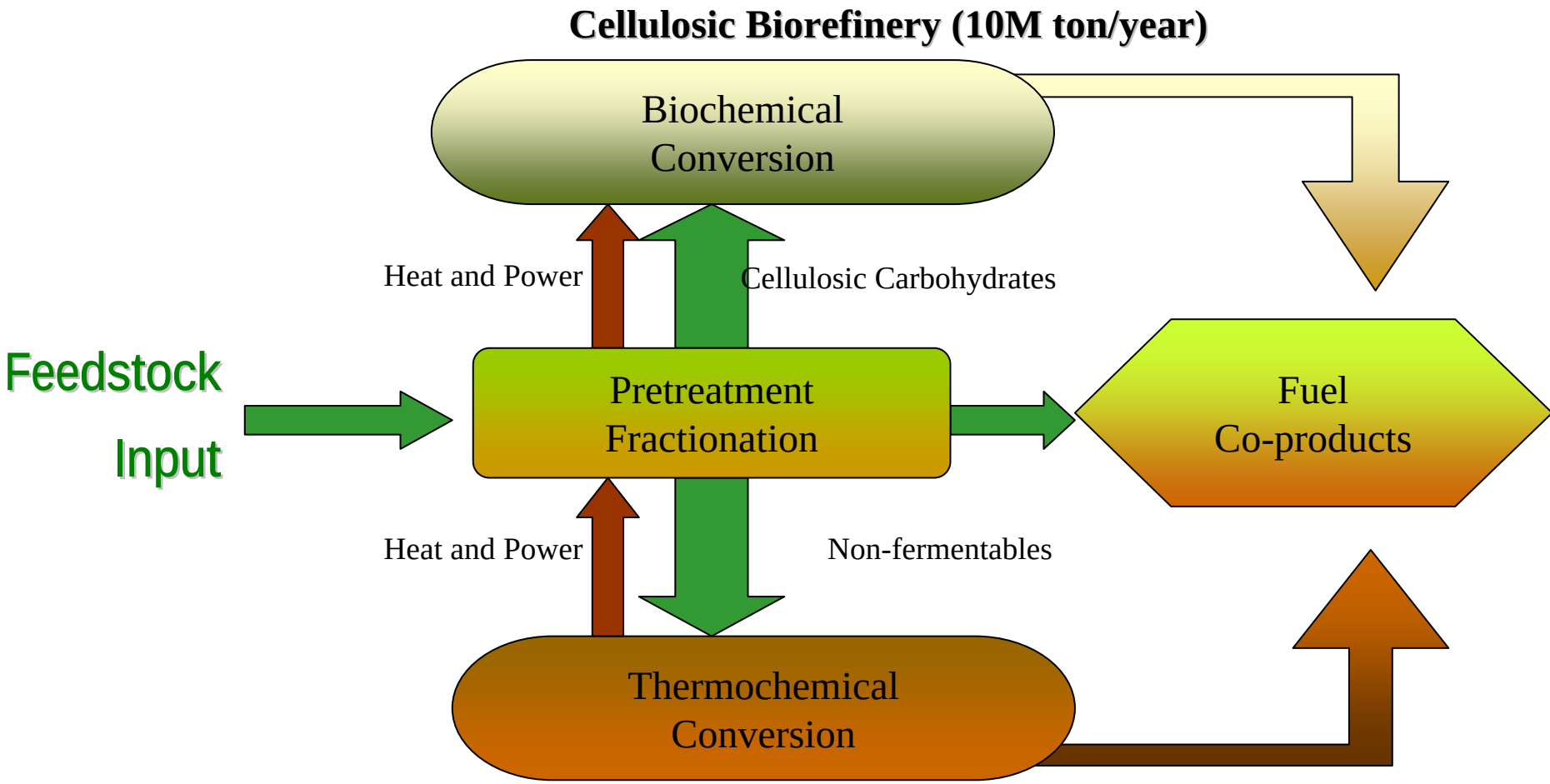
Integrated Biorefining Industry



Source: INL

Can Nitrogen Residues be a Vital Biorefinery Co-product?

- In 2025 corn wet and dry milling industry could produce about 38 million tons of gluten and DDGS feed.
- Corn contains 8% protein by weight, while corn stover has 4% and switchgrass 10%.
- By 2025 many new biorefinery will be built specifically to produce ONLY transportation fuels from biomass, but:
- Current biomass pretreatment processes severely destroy the protein and feed value in biomass
  - Many biomass ethanol plants designs ignore protein co-products

Potential Protein Available at 25 Billion Gallons Ethanol Production in 2025

	Billion Gal Ethanol	Million Tons DDGS or Gluten	% Protein for Feed or Residue	Million Tons Protein	% Total Protein Avail.
Corn Dry Mill	9.4	31.2	30	9.4	51%
Corn Wet Mill*	3.1	7.2	22	1.6	9%
Biomass Refinery**	12.5		5.2***	7.3***	40%
total	25			18.3	

*20% increase from present, **50% corn stover, 50% switchgrass, ***@ 25% N loss from process

Conclusions

- In 2025 using primary crop residues and dedicated energy grasses, biorefineries may displace ~18% petroleum use: ~80% from ethanol and ~20% from biomaterials.
- While potential plant sites are predominantly in the Eastern US, use of other biomass sources will support biorefineries in all 50 States.
- Plant engineering/breeding is underway to improve biomass for bioenergy based upon lower cost and higher return to the producer and the biorefinery
- As world population continues to increase, production of feed and food will provide ample economic justification to develop biomass processes that preserve its protein and/or nitrogen values.