Bioenergy Technologies

State Energy Advisory Board Meeting

October 18, 2007

ORNL

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& Bioconversion Science and Technology

President's State of the Union Address January 2006

Keeping America competitive requires affordable energy. And here we have a serious problem: America is addicted to oil, which is often imported from unstable parts of the world.

The best way to break this addiction is through technology…. and we are on the threshold of incredible advances…

So tonight I announce…push for breakthroughs in two vital areas…change how we power our homes and offices,…change how we power our automobiles.

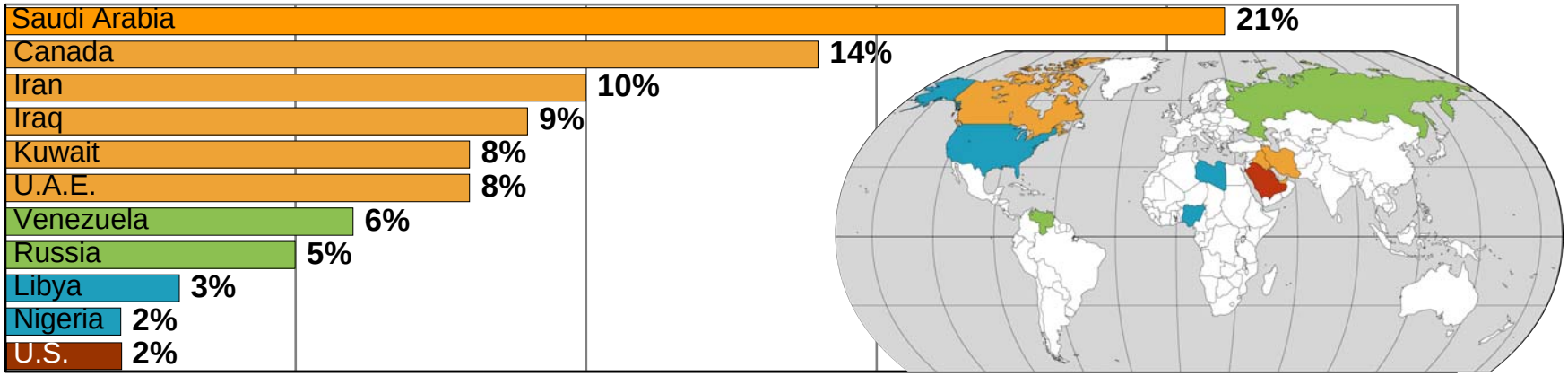
President's Biofuels Initiative

Replace more than 75 percent of our oil imports from the Middle East by 2025

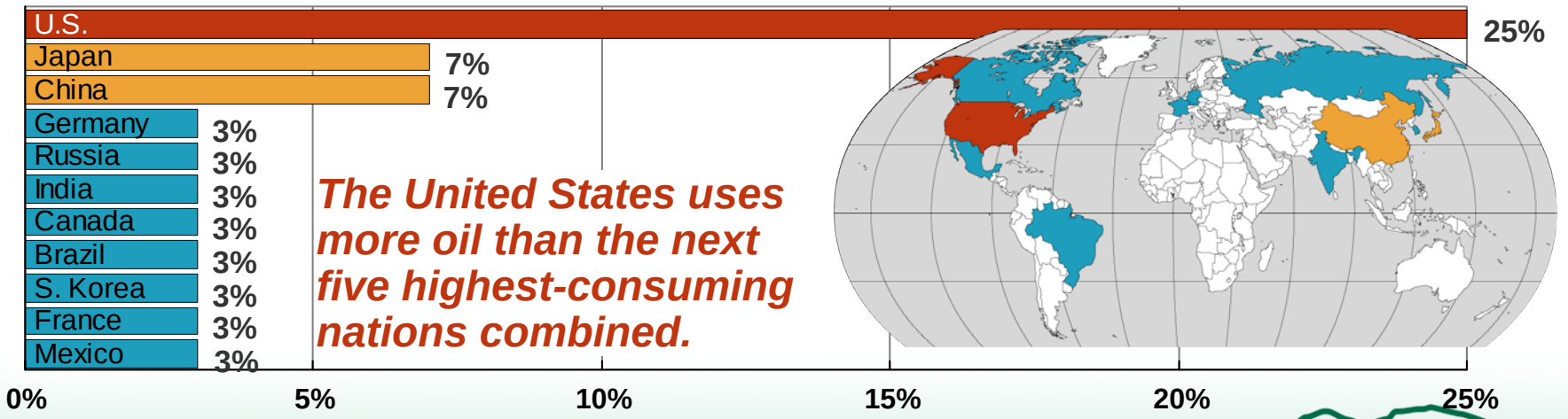
2012 Goal: Fund additional research in cutting-edge methods of producing ethanol, not just from corn, but from wood chips and stalks, or switch grass. Our goal is to make this new kind of ethanol practical and competitive within six years

U.S. Dependence on Foreign Oil

Oil Reserves



Rate of Use

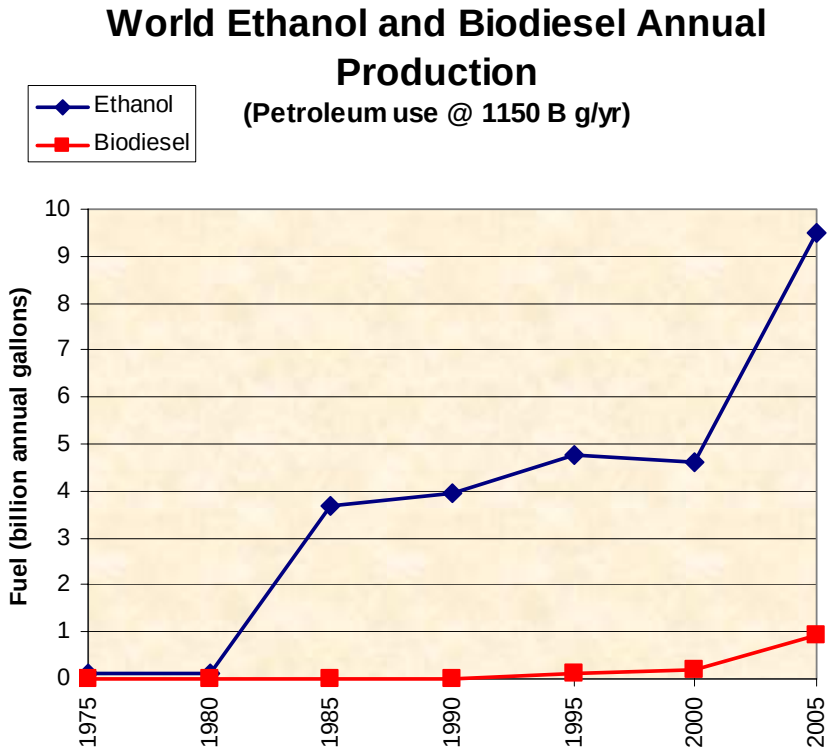


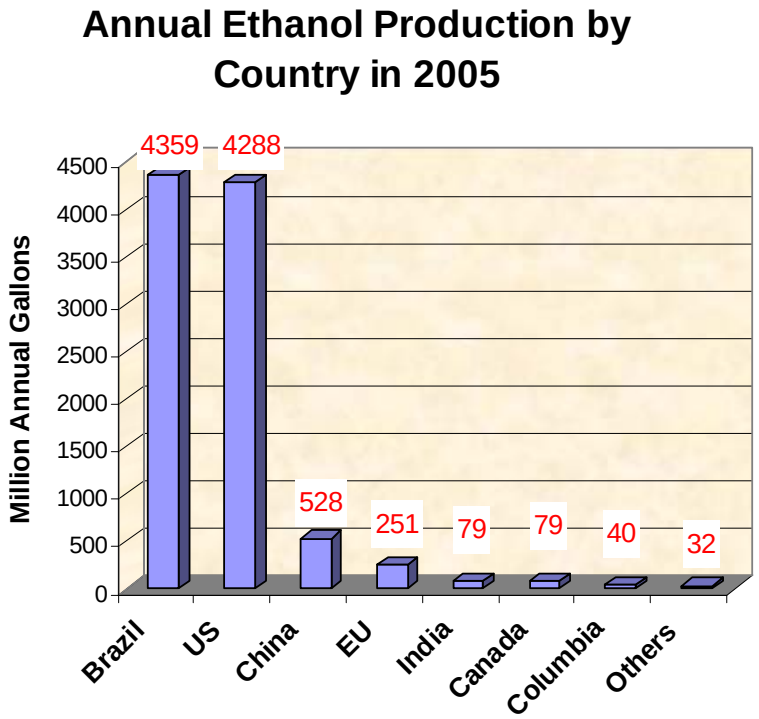
The United States uses more oil than the next five highest-consuming nations combined.

Updated July 2005. Source: International Energy Annual 2003 (EIA), Tables 1.2 and 8.1-O&GJ. Canada's reserves include tar sands.

Bioenergy from the World Perspective

- Bioenergy use worldwide is growing but…

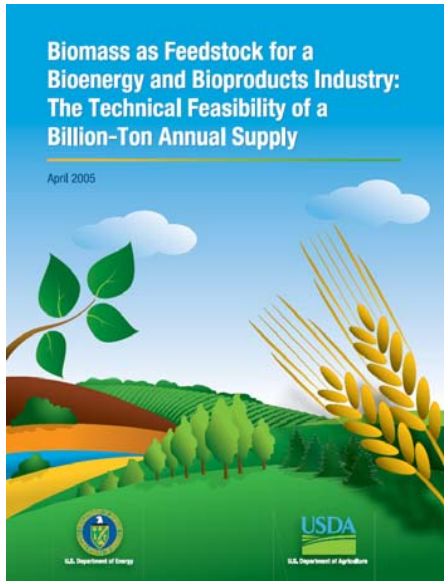


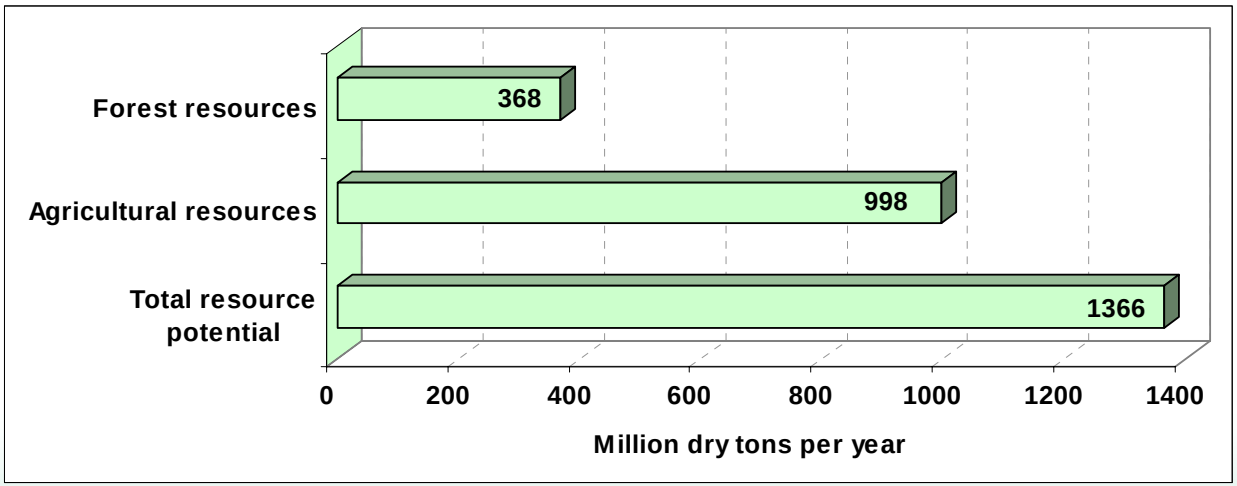


- We have a long way to go!

Are there sufficient biomass resources to replace up to 50% of the USA's petroleum requirements?

- Yes, land resources of the U.S. can sustainably supply more than 1.3 billion dry tons annually and still continue to meet food, feed, and export demands
- Required changes are not unreasonable given current trends and time-frame for bio-industry scale-up and deployment

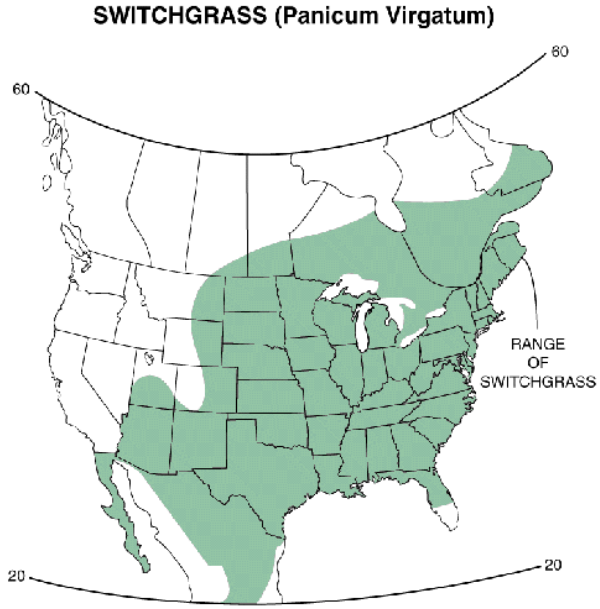




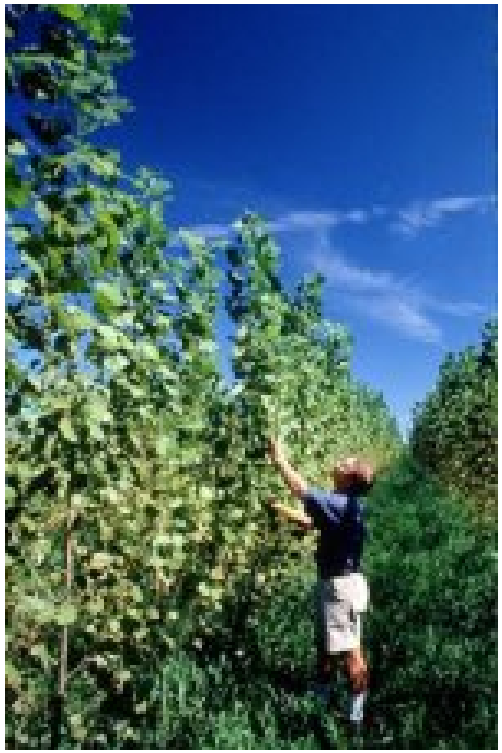
The GOAL is Low Cost & Environmentally Sustainable Systems For Producing Biomass

- Crop residues
- Perennial crops – switchgrass, poplar, willow
- Forest residues
- Urban wood residues

Switchgrass Produced in 10 Year Rotations with Annual Harvest, Using Conventional Agricultural Equipment



Hybrid Poplars Produced Grown on Cropland in 6-10 Yr Rotations, Harvested with Forestry Equipment



Early 2nd yr poplar growth

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

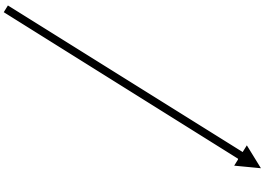
Input: Corn

Products: Corn starch

Corn gluten feed

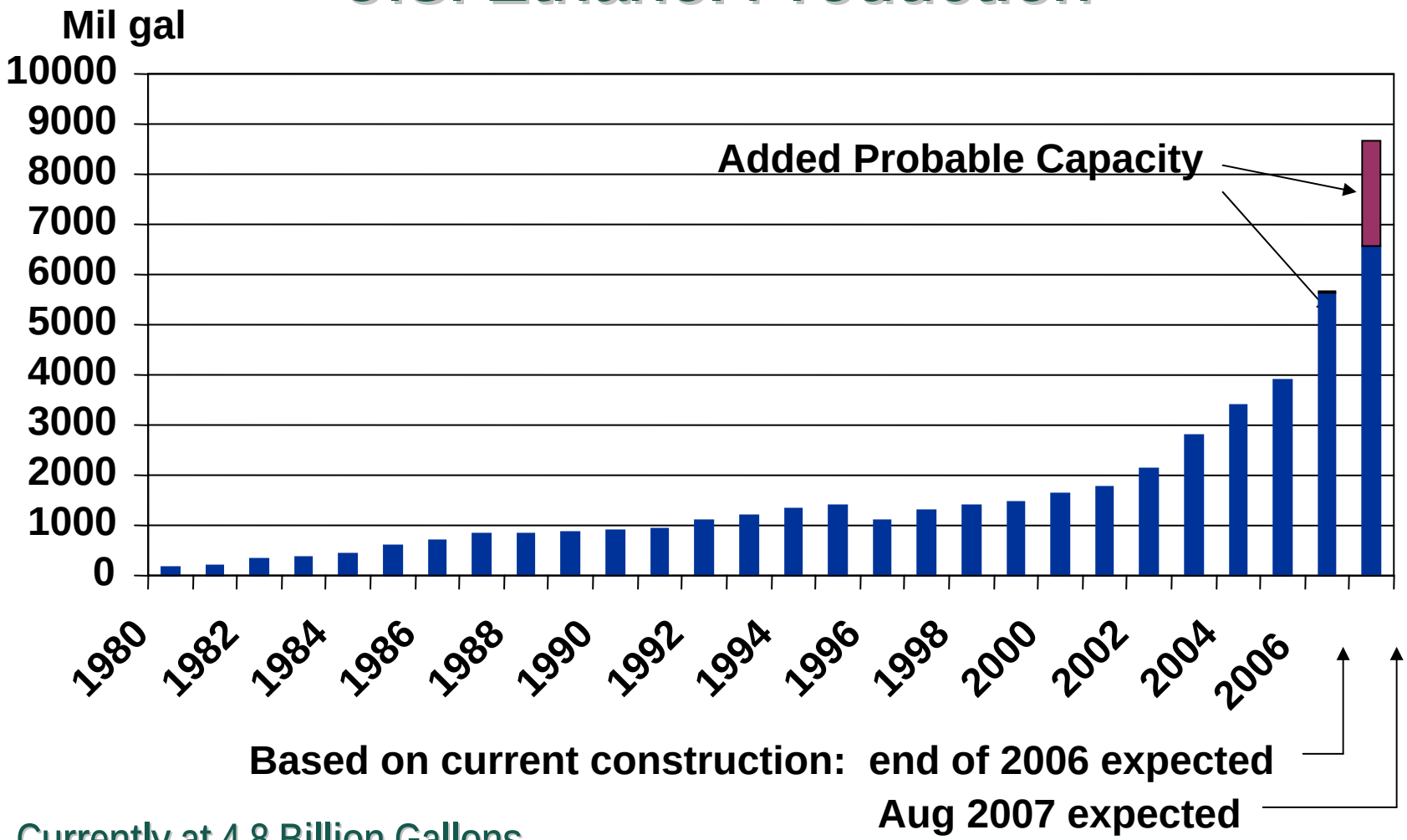
Corn oil

Corn steep liquor



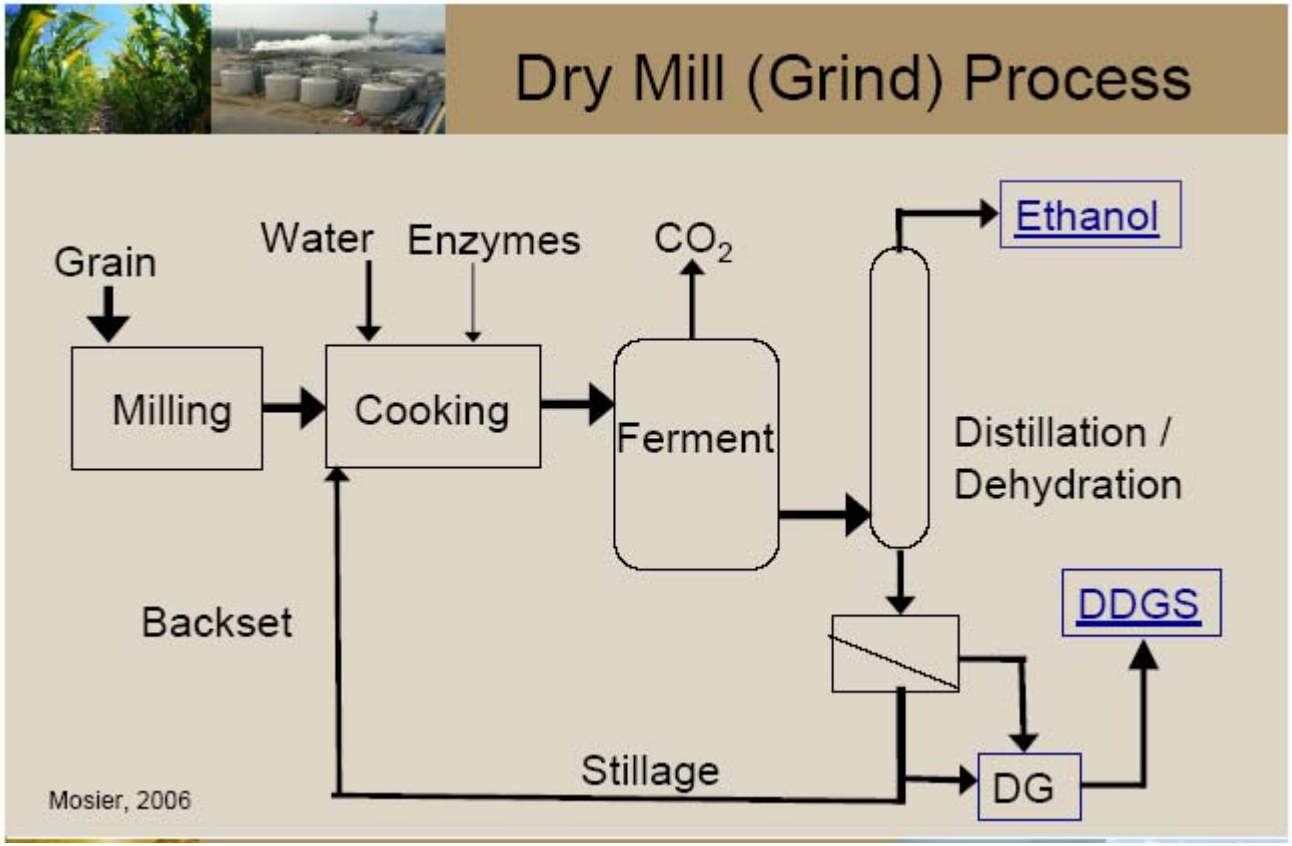
- Starch
- Corn sweeteners
- Glucose
- Ethanol
- Lactic acid/PLA
- 3PDO
- Amino acids
- Pharmaceuticals
- Industrial chemicals

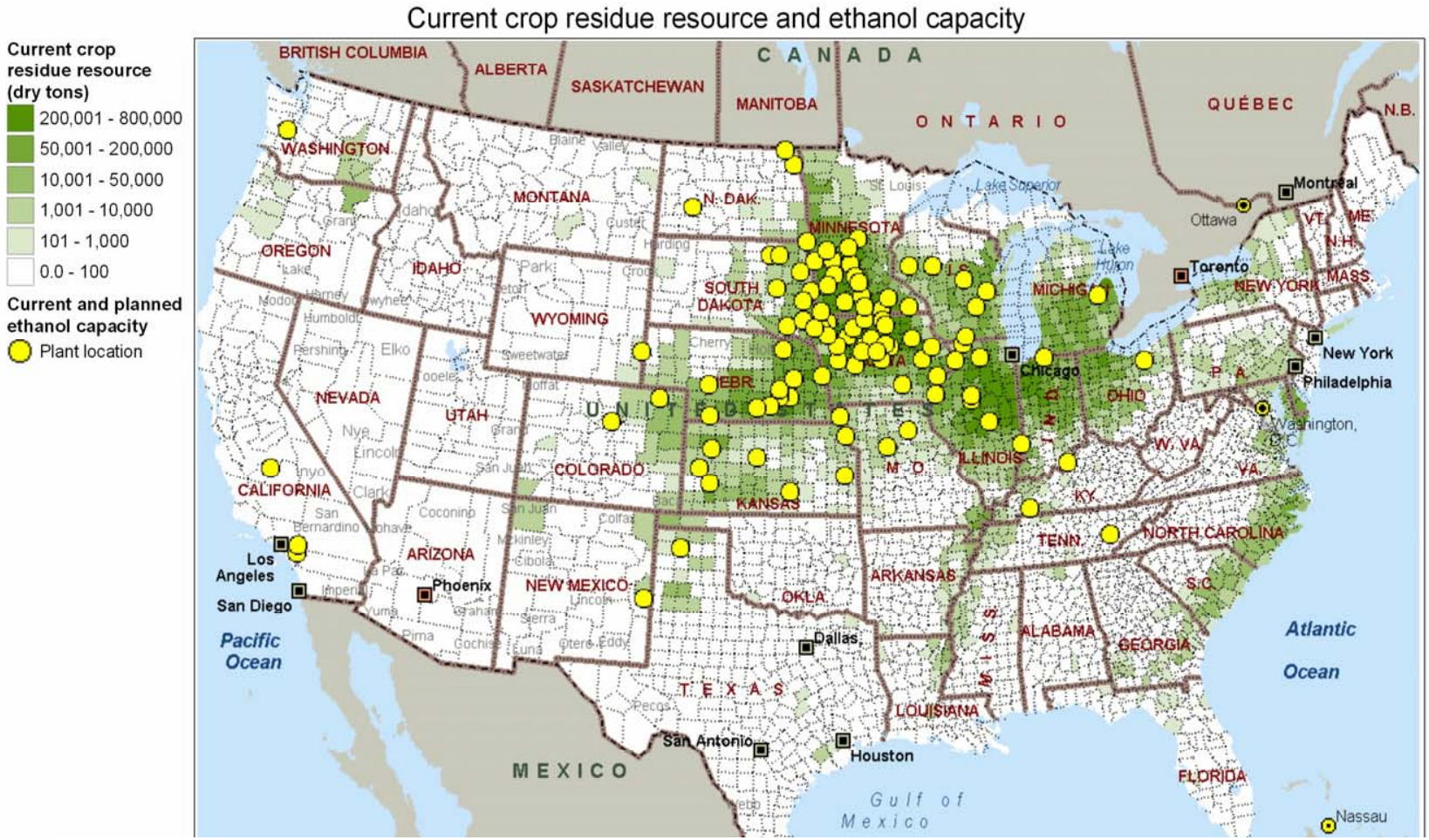
U.S. Ethanol Production



Currently at 4.8 Billion Gallons

Corn Ethanol from a Dry Mill Process





Current biomass resources and ethanol capacity are concentrated in the corn belt and upper Midwest

New Domestic Bio-industry

Biomass Feedstock

- Grasses
- Trees
- Agricultural Crops
- Agricultural Residues
- Forest Residues
- Animal Wastes
- Municipal Solid Waste

Conversion Processes

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

PRODUCTS

Fuels:
- Ethanol
- Renewable Diesel
- Hydrogen

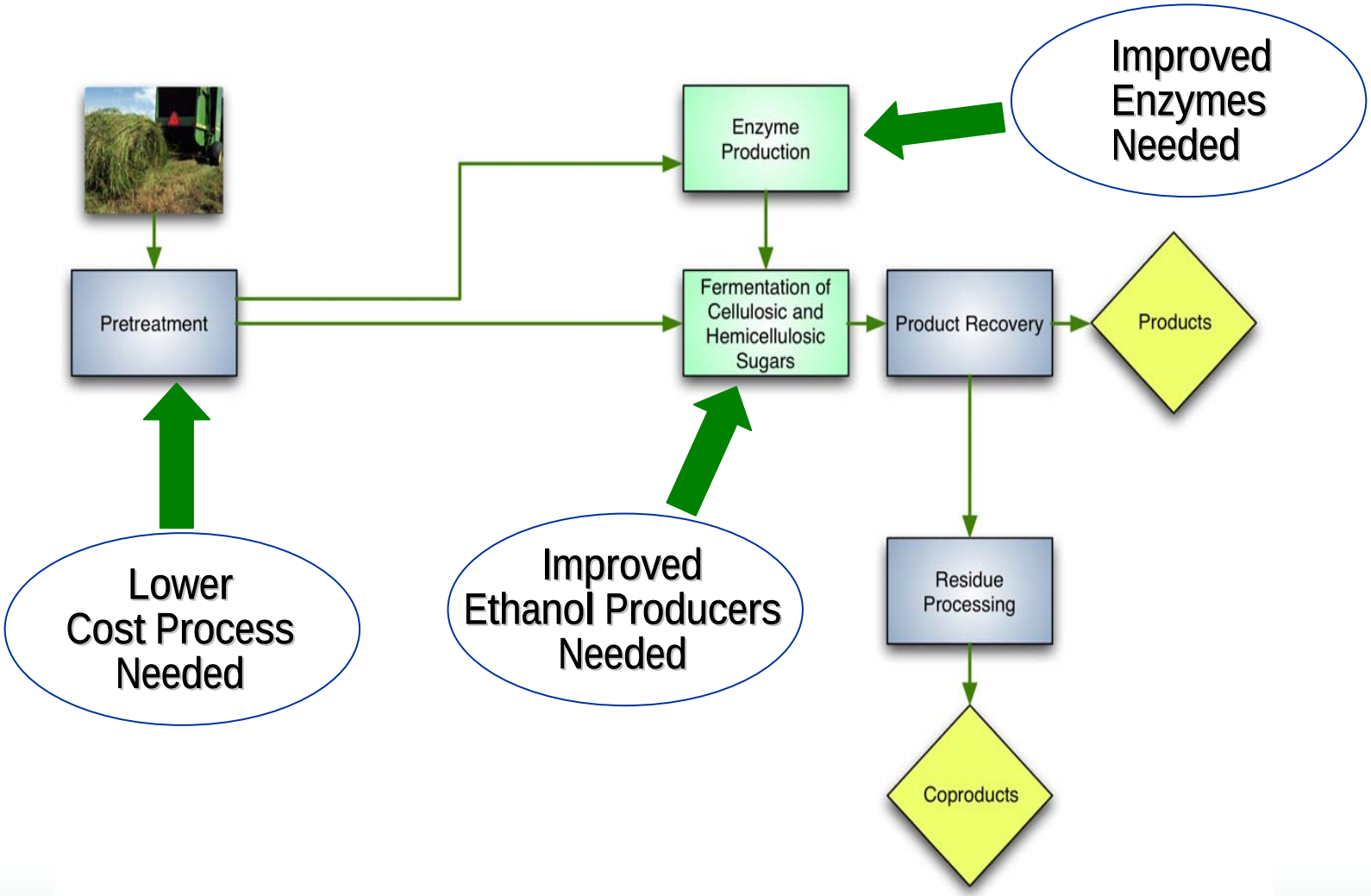
Power:
- Electricity
- Heat (co-generation)

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

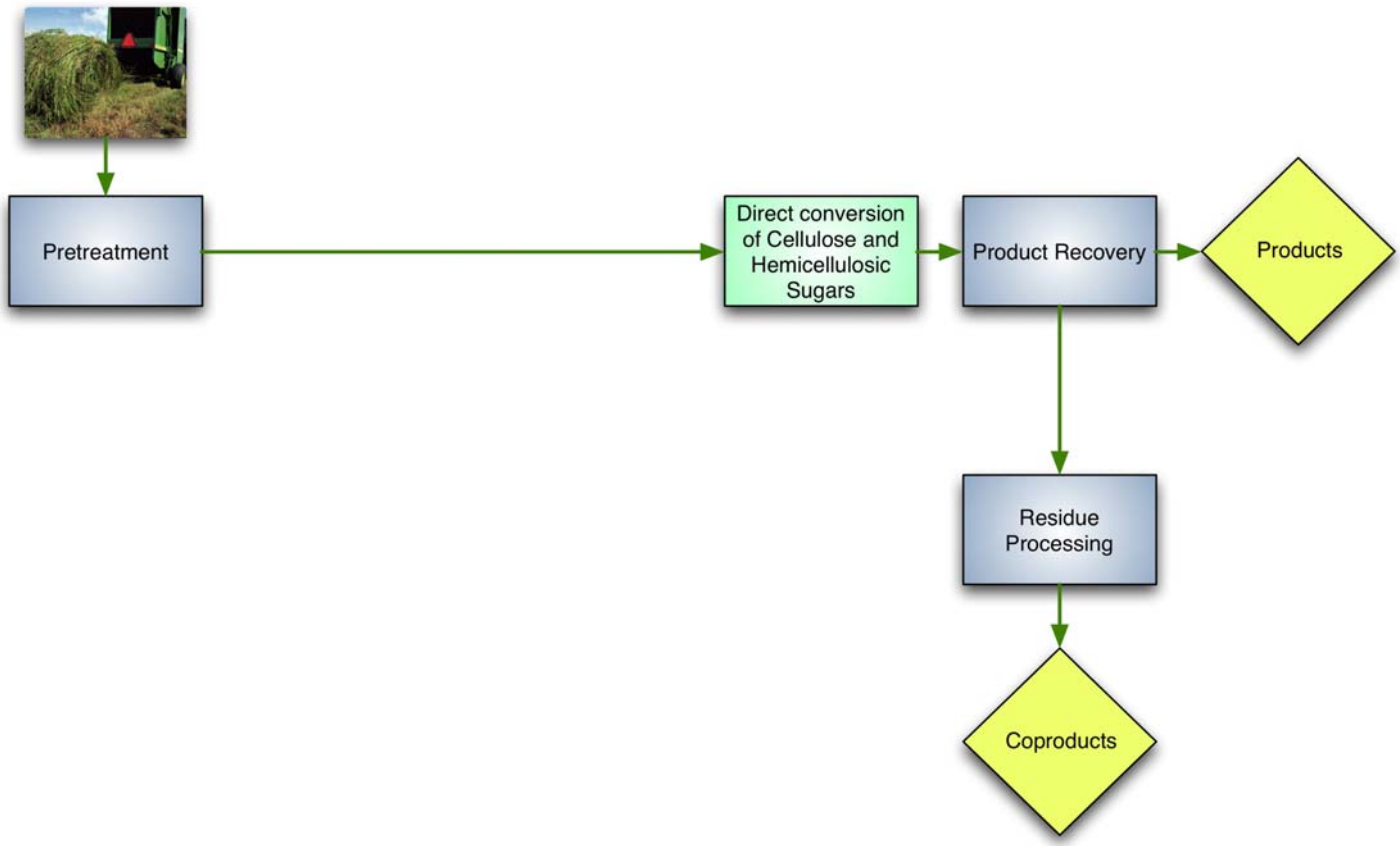
Food and Feed

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

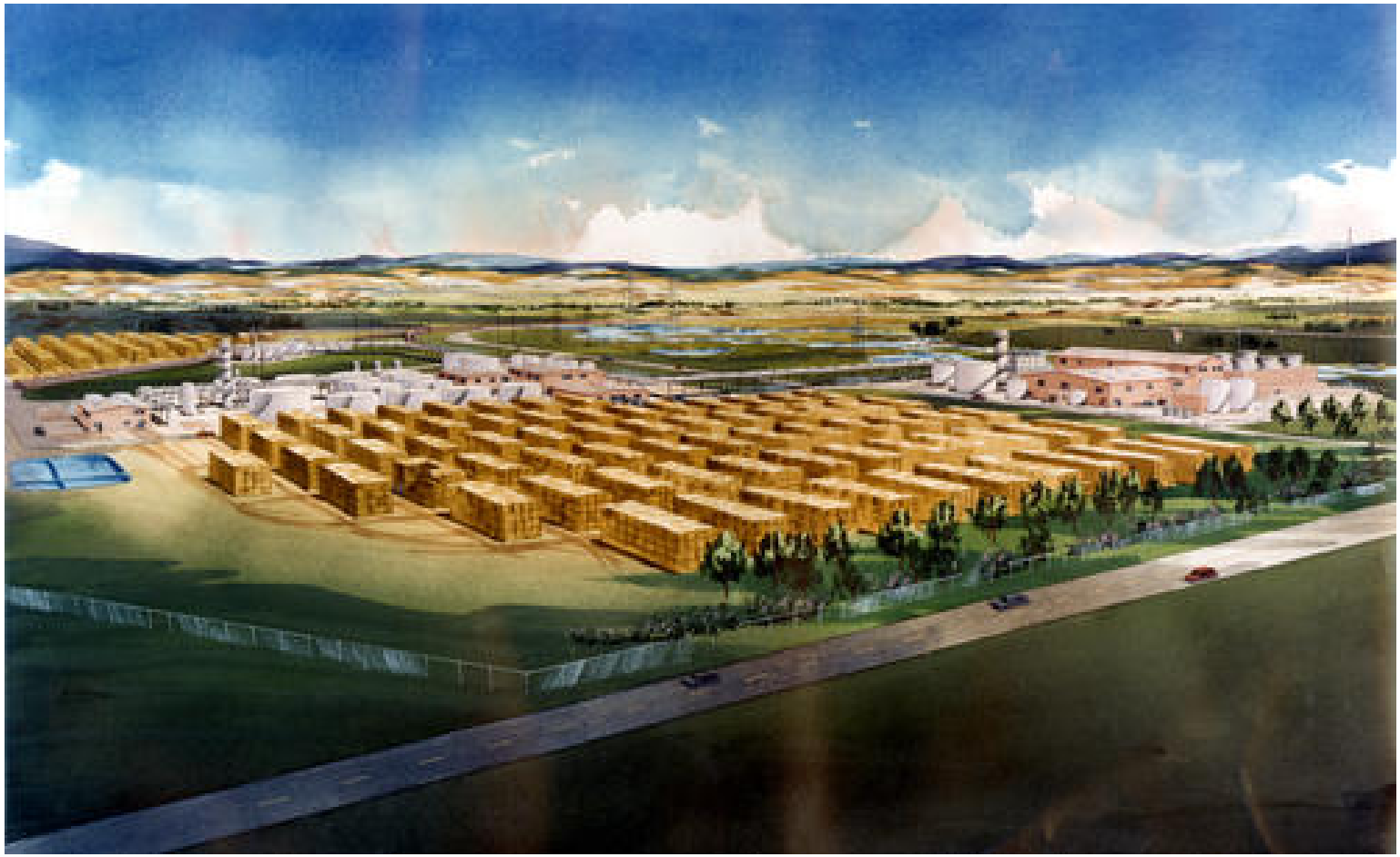
Current Process for Biomass Ethanol Production



Natural Progression of Process Simplification



Artist Vision of a Biorefinery with Biomass Storage Adjacent



Source: NREL Pix

Conclusions

- Using primary crop residues and dedicated energy switchgrass, sufficient biomass could be available to support significant replacement of current *gasoline* use in the US by 2025.
- Technology is available now to produce ethanol from biomass to REALLY impact our 140 Billion gallon appetite
- Cost of the process for biomass ethanol must drop by half to support large expansion.
- ORNL and other National Labs are working on supplying lower cost biomass feedstock and a biomass ethanol processes to meet this Nations transportation fuel needs.