Overview of Emerging bioenergy technologies

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Energy and Agriculture—Managing Risks
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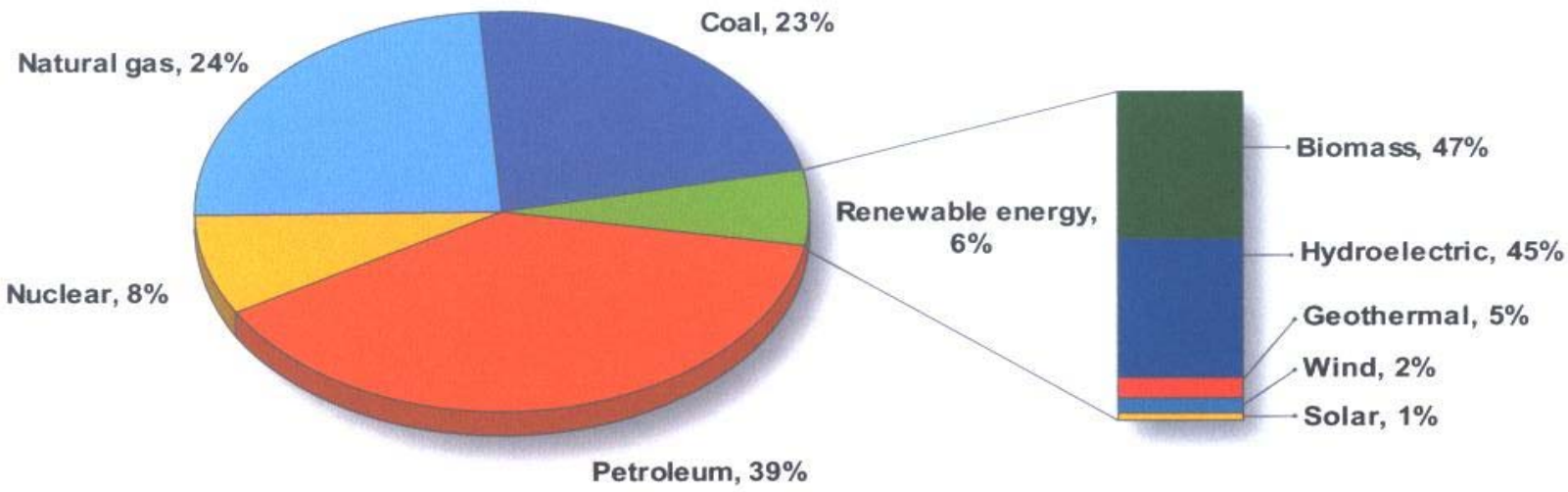
Presentation Overview

- Background
- The current situation
- The future
  - Biological processes
  - Thermochemical processes
  - Other

Biomass Definition

- Definitions of biomass vary widely
- Biomass definition: Any organic material that is available on a renewable or reoccurring basis.
- Includes agricultural crops, trees grown for energy production, wood waste and wood residues, plants (including aquatic plants), residues, fibers, animal wastes and other waste materials, and fats, oils, and greases.



Biomass Consumption	Million dry tons/year
Forest products industry	
Wood residues	44
Pulping liquors	52
Urban wood and food & other process residues	35
Fuelwood (residential/commercial & electric utilities)	35
Biofuels	18
Bioproducts	6
Total	**190**

- Forestlands and agricultural lands contribute 190 million dry tons of biomass - 3% of America's current energy consumption.

Source: EIA, 2004a & b

Figure 2: Summary of biomass resource consumption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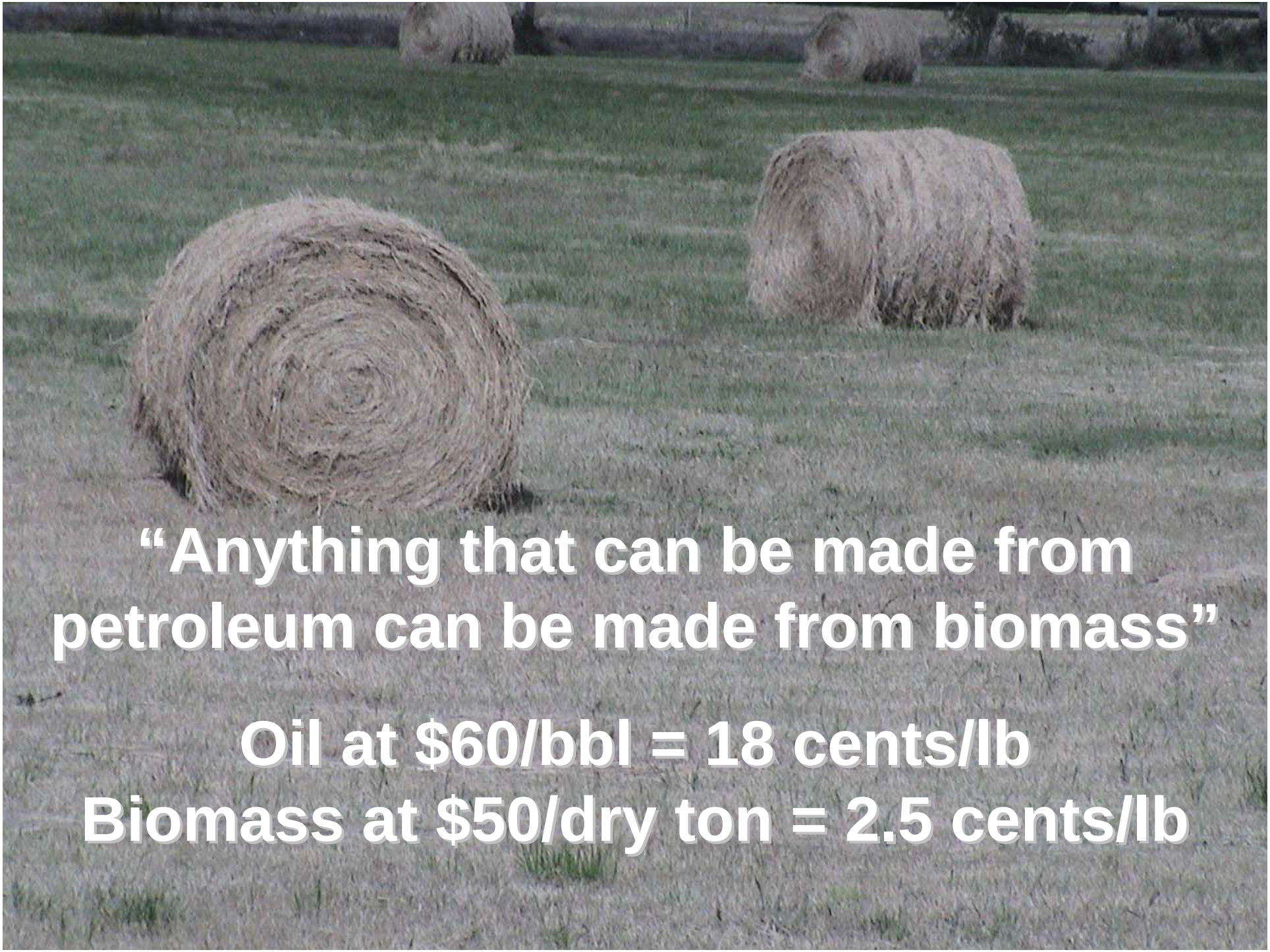
MIDEAST
GAS-N-GO
I FEEL SO VULNERABLE OUT HERE...
...BUT I HAVE TO HAVE GAS!

Homeland Security

- Indigenous resource
- Only renewable source of liquid fuels
- Stored solar energy in many plant forms
- Widely dispersed geographically
  - Reduces fuel transportation costs
  - Increases rural economic development


“Anything that can be made from petroleum can be made from biomass”
Oil at $60/bbl = 18 cents/lb
Biomass at $50/dry ton = 2.5 cents/lb

Types of Feedstocks

- Sugar
- Starch
- Cellulosic
- Oil seeds and fats

Sugar Feedstock Examples

Sugarcane, sugar beets, sweet sorghum, fruit, melons, candies and other food wastes, beverage wastes

Starch Feedstock Examples

Cereal grains, Irish (white) potatoes, sweet potatoes, cassava, Kudzu (tubers), sweet corn

Cellulose Feedstock Examples

Trees, grasses, aquatic vegetation, cardboard, paper, animal manures, urban wood wastes

Ethanol Capacity from Starch and Sugar in US

- 84 % of capacity from corn grain
- 11% of capacity other grains, including blends with corn grains
- 5% of capacity from beverage waste or not reported

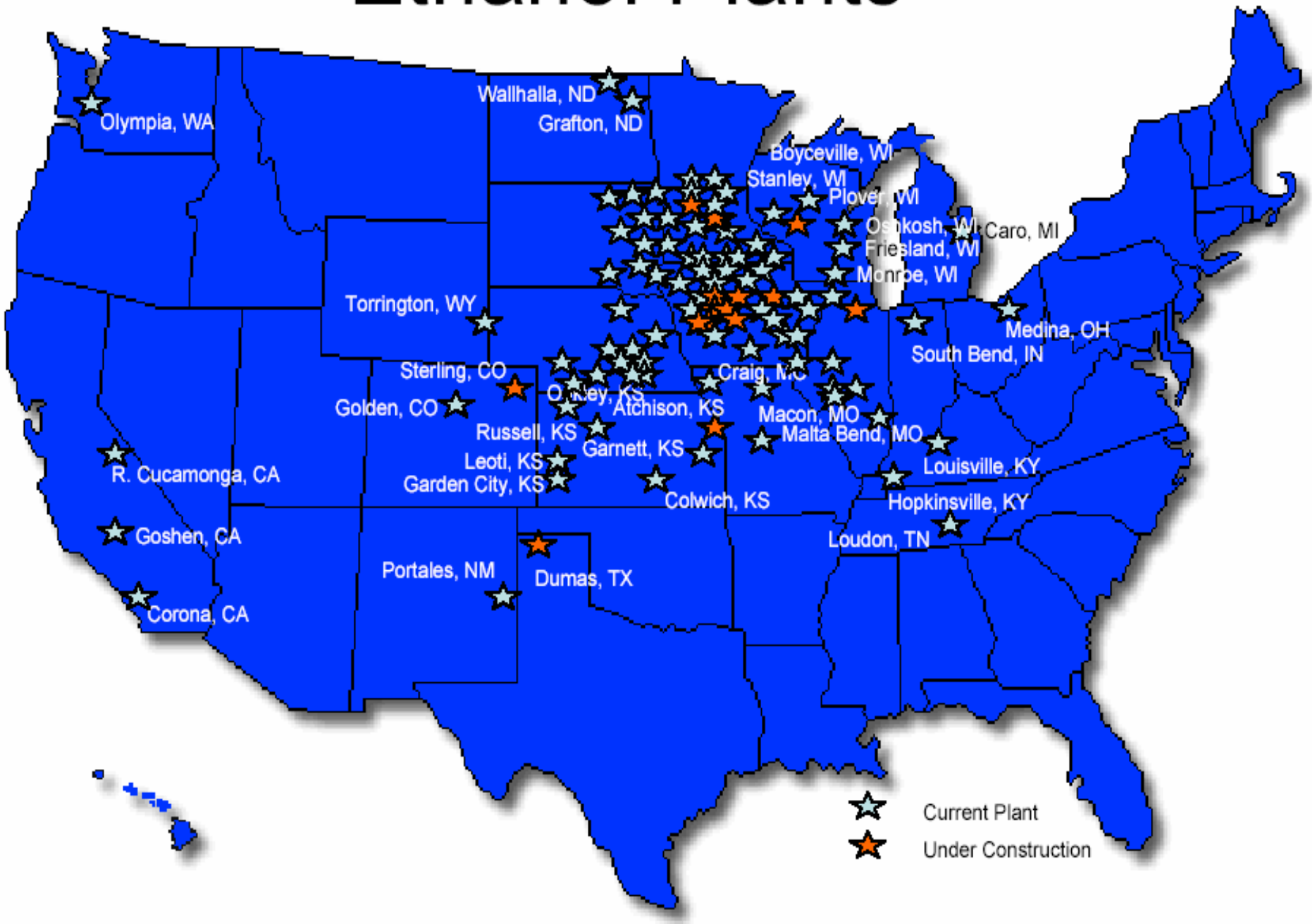
Ethanol Production

- 134 plants currently
- Total industry capacity = 4.4 Billion gal/yr
- Plant capacity range = 400,000 to 100 million gal/yr
- Average plant size = 52 million gal/yr

Ethanol Potential

- Current US gasoline use = 120 billion gal/yr
- Current US capacity = 4.8 billion gal/yr with 2.1 Billion gal/yr UC (2005)
- Potential production before food prices significantly impacted = 15 -17 billion gal/yr

Ethanol Plants



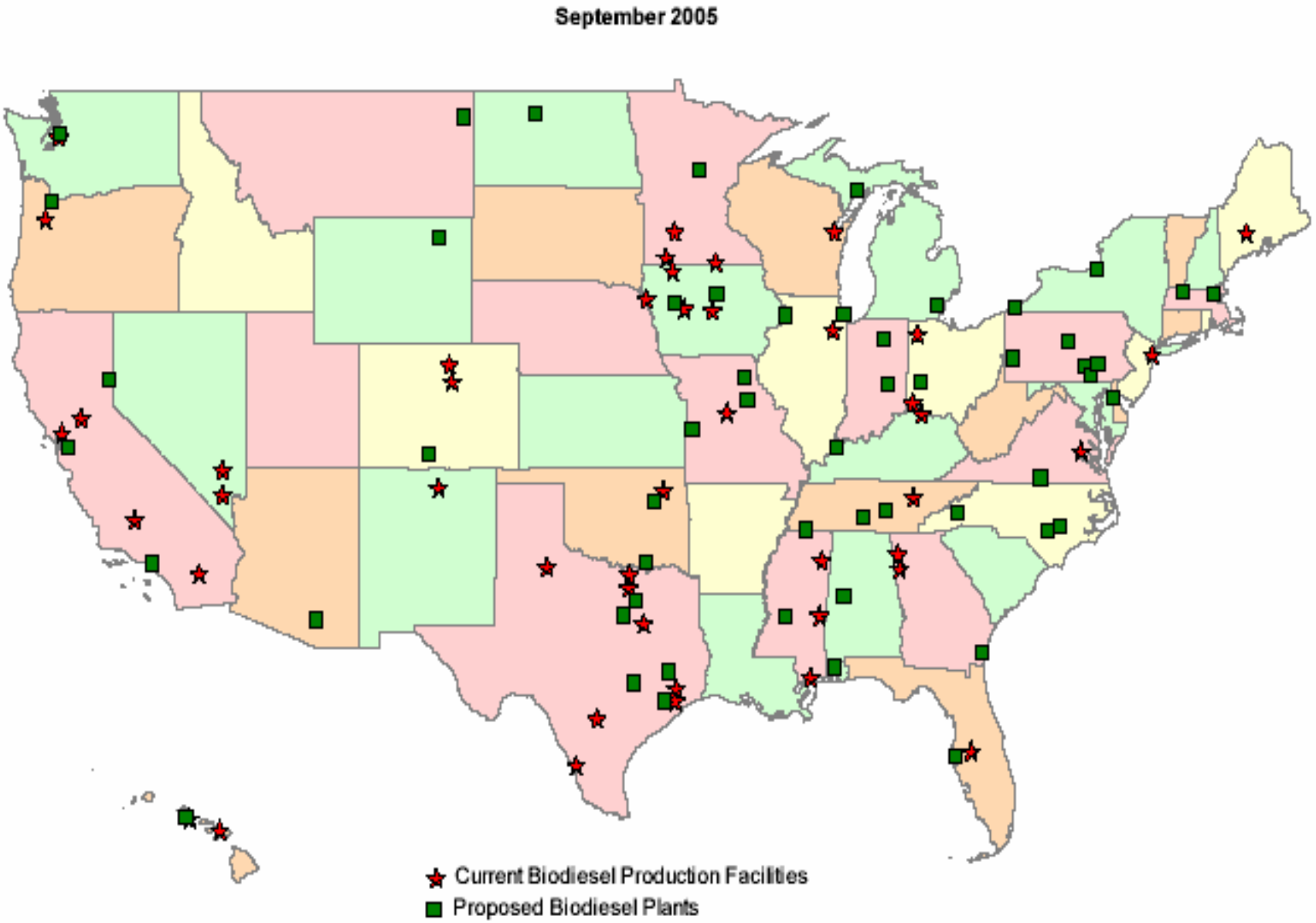
Biodiesel Production

- 54% of capacity from soybean oil
- 32% of capacity from blends of feedstocks
- 8% of capacity from recycled cooking oil
- 6% feedstock not reported
- 2% of capacity from tallow

Biodiesel Production

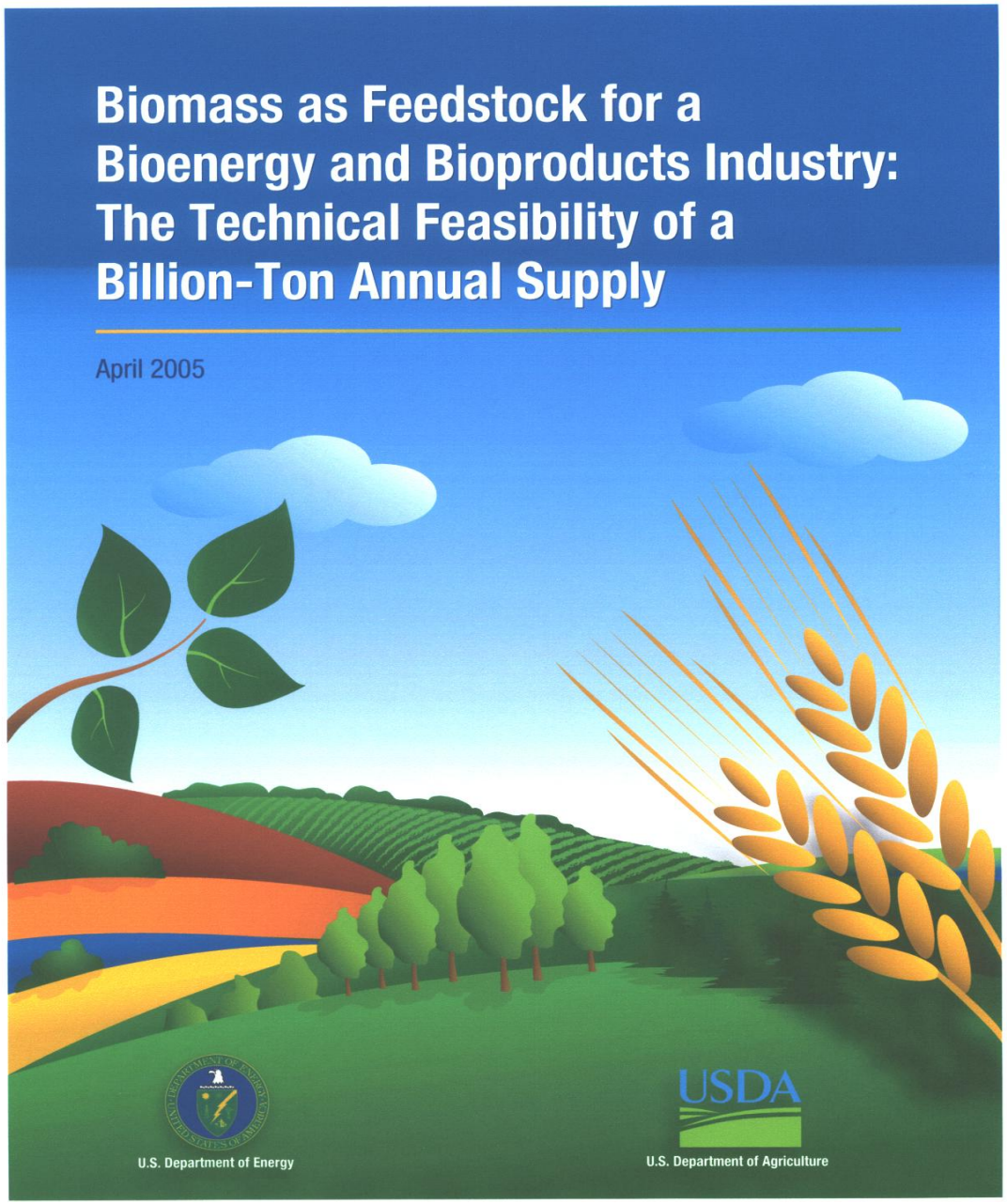
- 65 plants currently
- 377 million gallons/yr total industry annual capacity
- Plant capacity range = 200,000 to 30 million gal/yr
- Average plant size = 6.5 million

Current and Proposed Biodiesel Production Plants

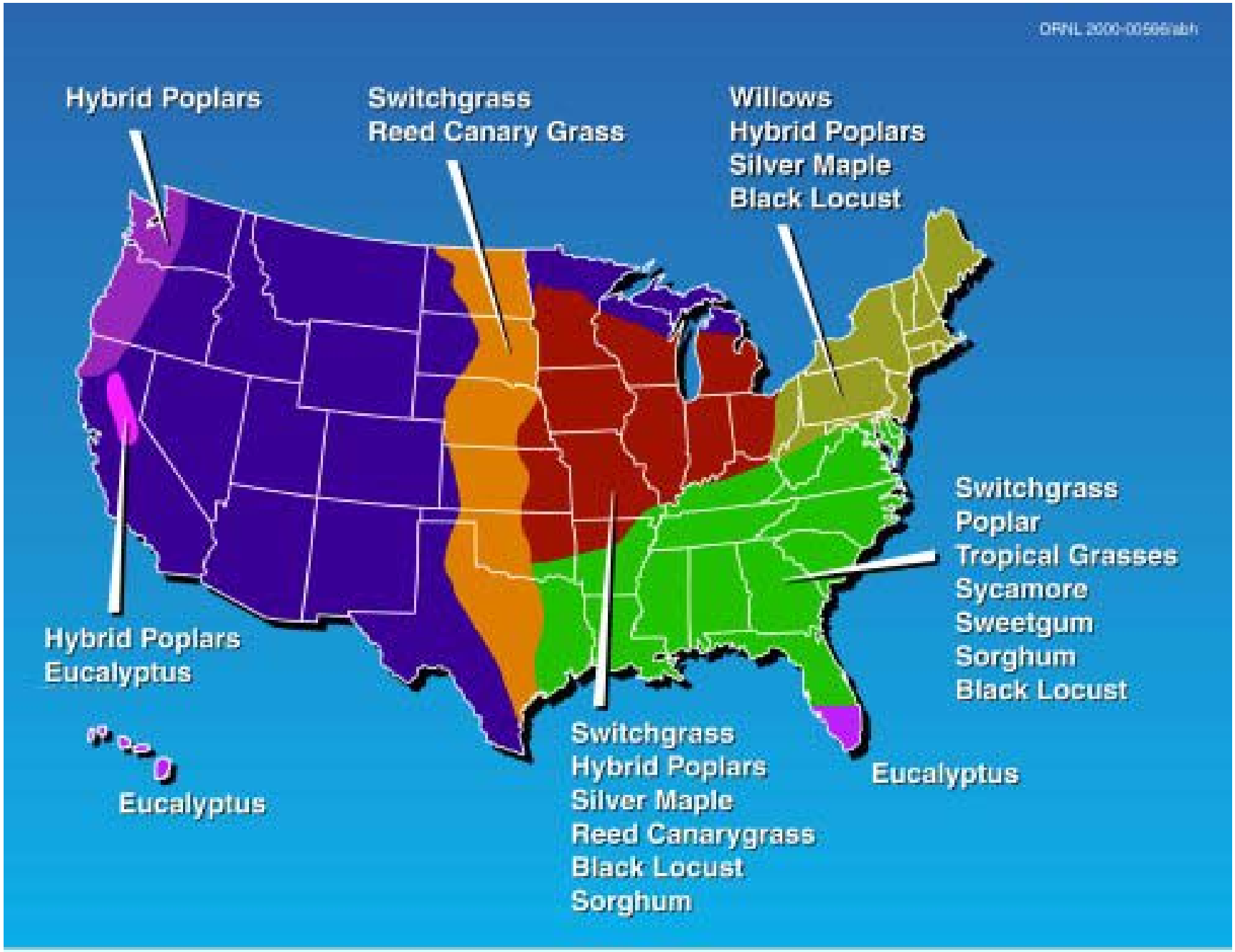


Diesel Fuel

- US diesel consumption = 56 billion gal/yr
- 20% of US transportation fuel
- 95% of power to move US freight
- 95% of US buses and heavy machinery use diesel
- Current Biodiesel production = 377 million gal/yr
- Biodiesel production under construction = 30+ million gal/yr



Achieve 1 billion Tons per year of Biomass by 2030


ORNL 2000-00566/ab/h
Hybrid Poplars
Switchgrass
Reed Canary Grass
Willows
Hybrid Poplars
Silver Maple
Black Locust
Switchgrass
Poplar
Tropical Grasses
Sycamore
Sweetgum
Sorghum
Black Locust
Hybrid Poplars
Eucalyptus
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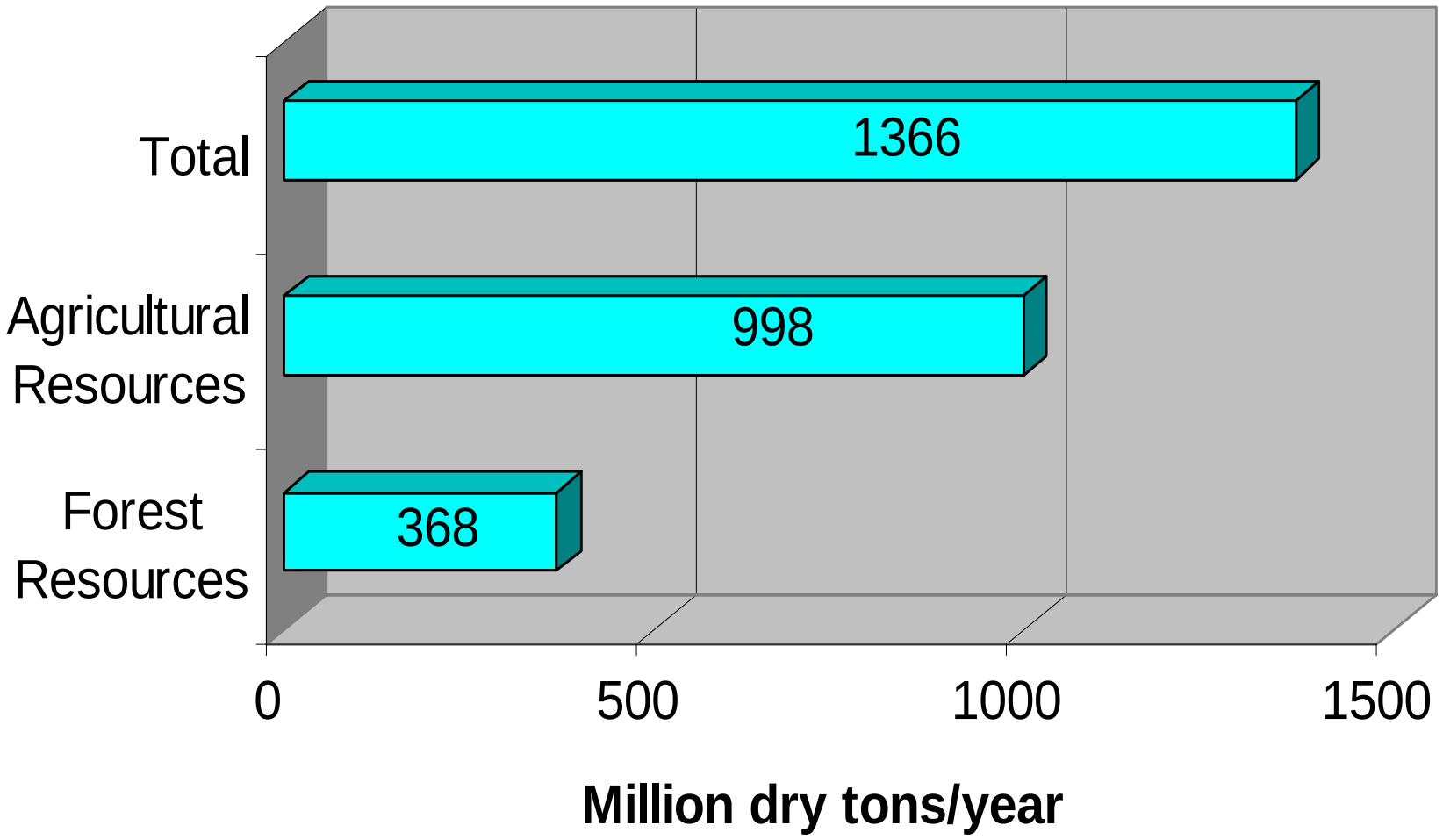
Annual U.S. Biomass Potential



US Biofuels Potential

- 1.3 billion tons biomass/yr available in 2030
- Could displace 1/3 of current US petroleum demand by 2030

Source: *Biomass as a Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a 1 Billion Ton Annual Supply,* ORNL/TM-2005/66

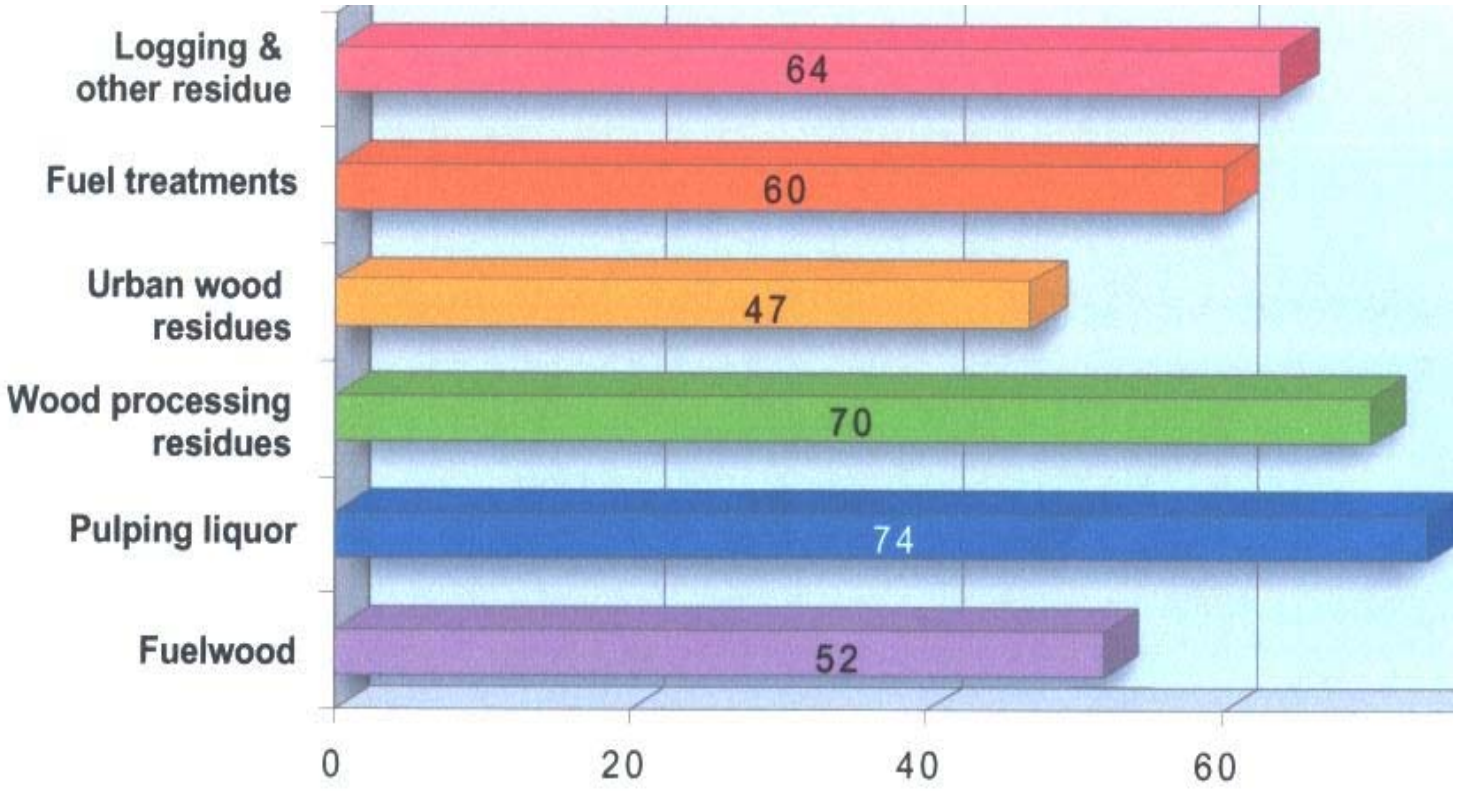


Table A. Summary of potential forest and agricultural resources

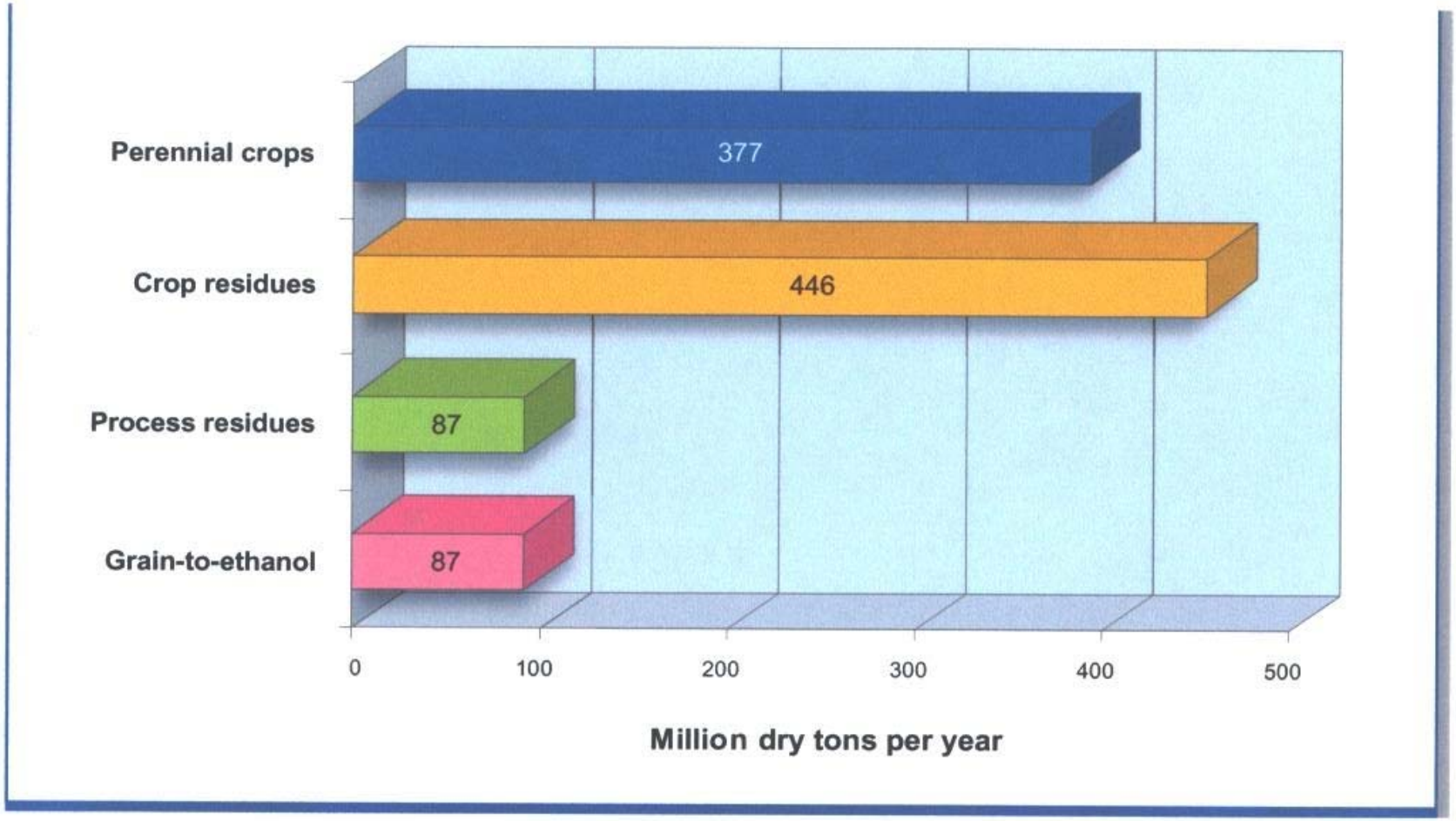
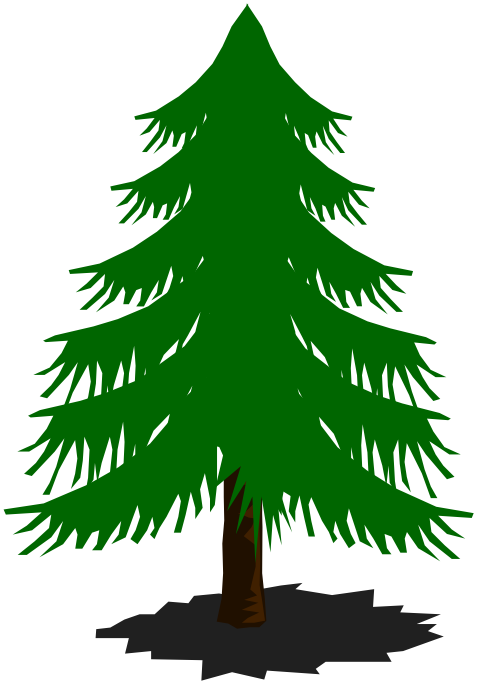


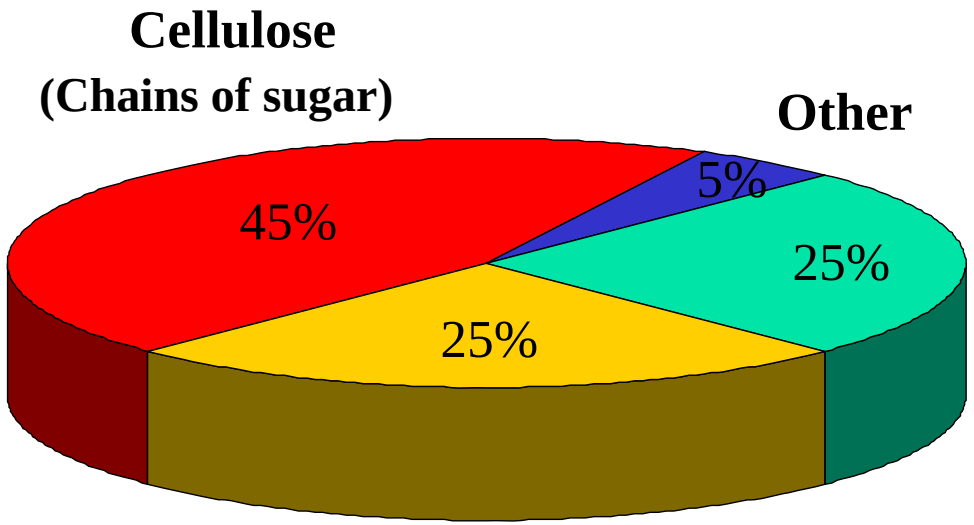
Table B. Summary of potential forest and agricultural resources

Cellulose vs Starch & Sugar

- 1.3 billion tons biomass/yr available
- Only 76 million tons/yr from grains = 6% of total
- Thus limited potential for starch/sugar ethanol and Biodiesel
- The real potential is from cellulose!

Cellulose Biomass Composition





Cellulose Feedstocks

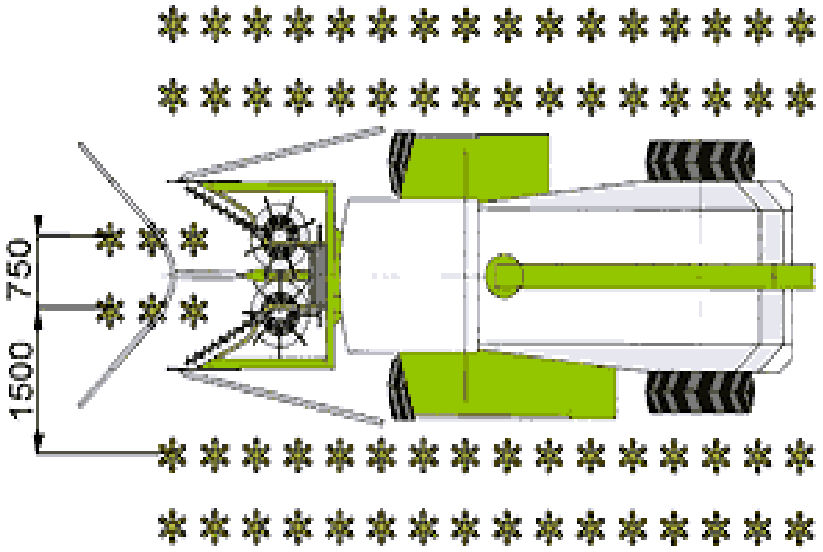
- Very long chain molecules
- Different chemical bonding
- Encased in lignin
- Contain a variety of sugars
  - Different sugars require different microbes for fermentation

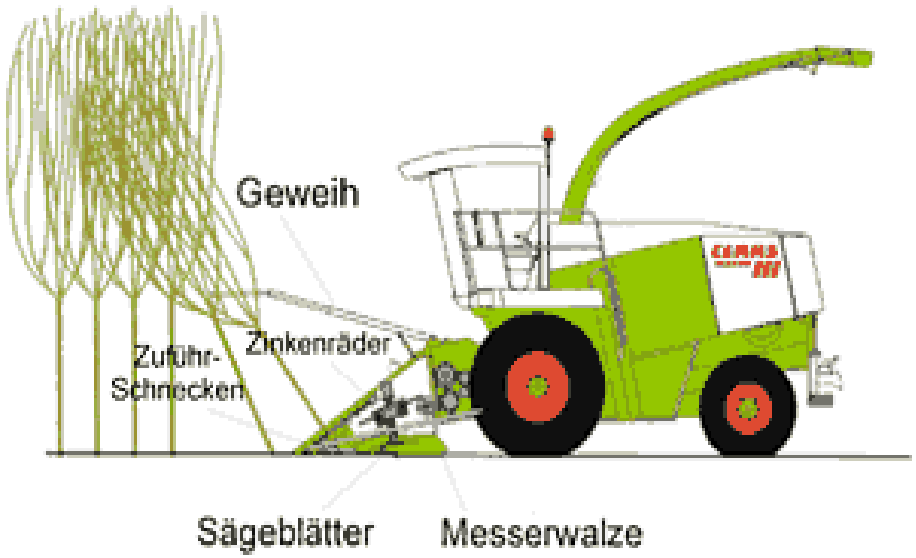

5-year old
Super Tree

Advantages of Annual Crops

- Lower production costs
- Drought resistance
- Flood resistance
- Can take advantage of CRP

Harvesting Head for Claas of America Forage Equipment



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Feedstock Cost Comparisons
Ethanol Production

Corn Grain @ $2.50 bu = $105/dry ton

$$\frac{\$2.50/\text{bu}}{2.9\ \text{gal/bu}} = \$0.86/\text{gal}$$

Wood at $35/dry ton = $17.50/green ton

$$\frac{\$35.00/\text{dry ton}}{90\ \text{gal/dry ton}} = \$0.39/\text{gal}$$

Biorefineries

- Can accept multiple feedstocks
- Produces multiple products
- Optimizes value-added products
- Minimizes residue production
- Maximizes revenues

BioFuels of the Future

- Ethanol-from-cellulose
- Gasification and Fisher Tropsch
- Thermal Depolymerization-Fast Pyrolysis

Ethanol from Cellulose Technologies

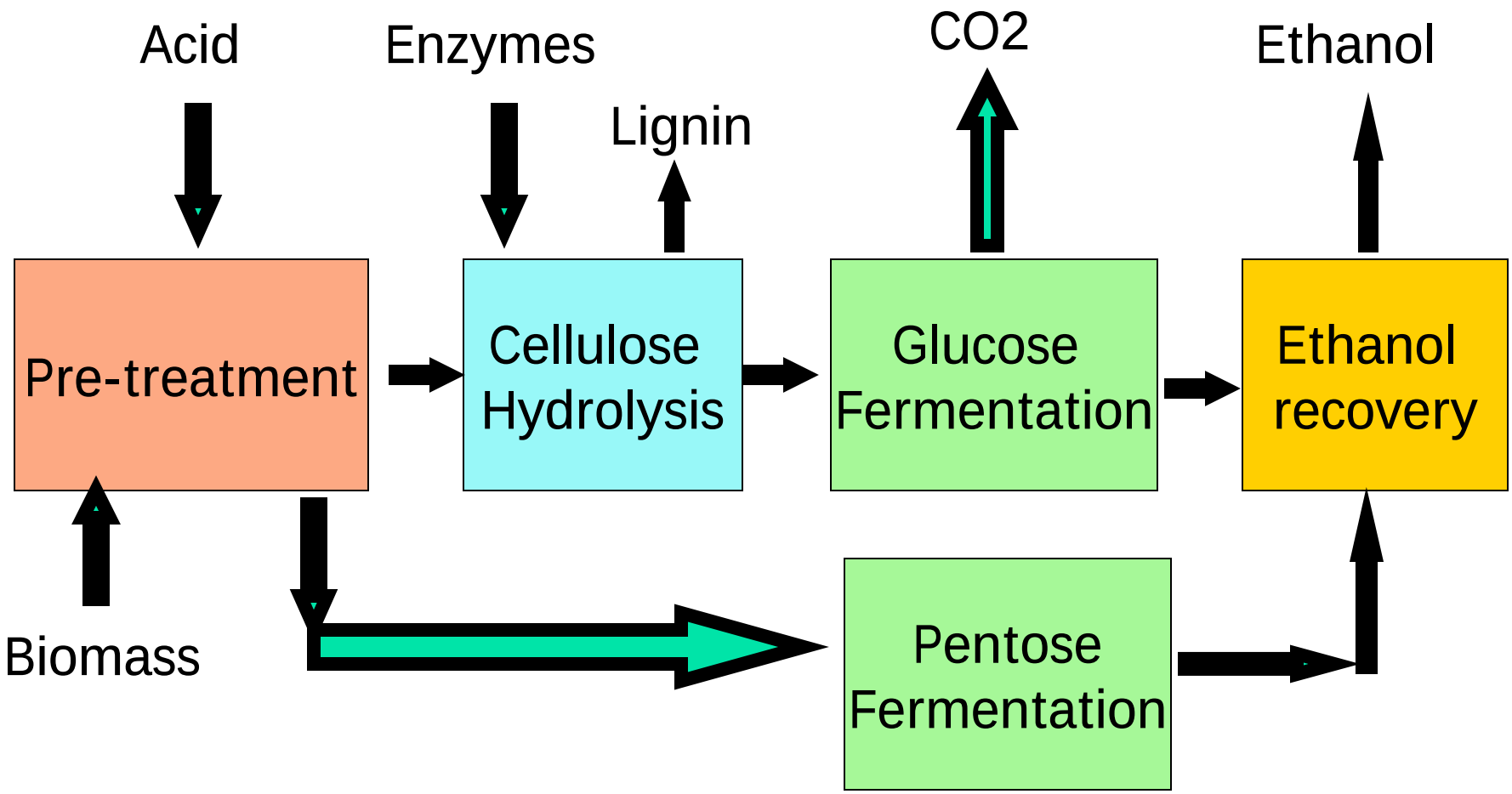
- Biological (Fermentation)
  - Concentrated acid
  - Dilute acid
  - Enzymatic with dilute acid pretreatment
- Thermochemical gasification
  - With catalytic conversion of gas to Etoh
- Hybrid
  - Thermochemical gasification with fermentation of gas to Etoh

Starch/Cellulose Comparison

Ethanol Production

	Feedstock Costs	Conversion Costs	Typical yield, gal/dry ton
Starch	High	Low	105-122
Cellulose	Low	High	50-100
starch equivalent to 2.5 to 2.9 gal/bushel of corn			

Ethanol-from-cellulose by enzymatic/biological processes



Iogen 1 million gallon per year
Cellulose-to-Ethanol Pilot Plant, Ottawa, Canada

Enzymatic Process Requirements

- 3,000 dry tons per day minimum
- Would require 30 square miles (200,000 acres @ 30% land use) yielding 5 dry tons/acre within 60 miles of plant
- Prefers hardwoods, ag residues, and grasses due to chemical content
- Assumed yield 90 gal/dry ton by 2012

Bioethanol plant in Galicia, Spain

Owner: Abengoa Bioenergy
Scheduled Startup: end of 2006
Resource: Agricultural residues
Capacity: 5 million liters/year

Ethanol-from-cellulose
Biological vs.Thermochemical

- Cleaner byproducts
- Slower processes => larger plants
- Less feedstock flexibility (chemical interference with biological process)
- Lower yields => more residue

Ethanol-from-cellulose
Biological vs. Thermochemical

- Economics requires large scale facilities
  - Increases logistics issues
  - Increases capital costs
  - Increases risks
  - Makes financing and permitting more difficult

Ethanol-from-cellulose Biological vs.Thermochemical

- Small and large scale plants feasible
- Smaller plants => mitigates logistics
- Greater feedstock flexibility => reduces feedstock costs
- Modular plants => decreases capital costs

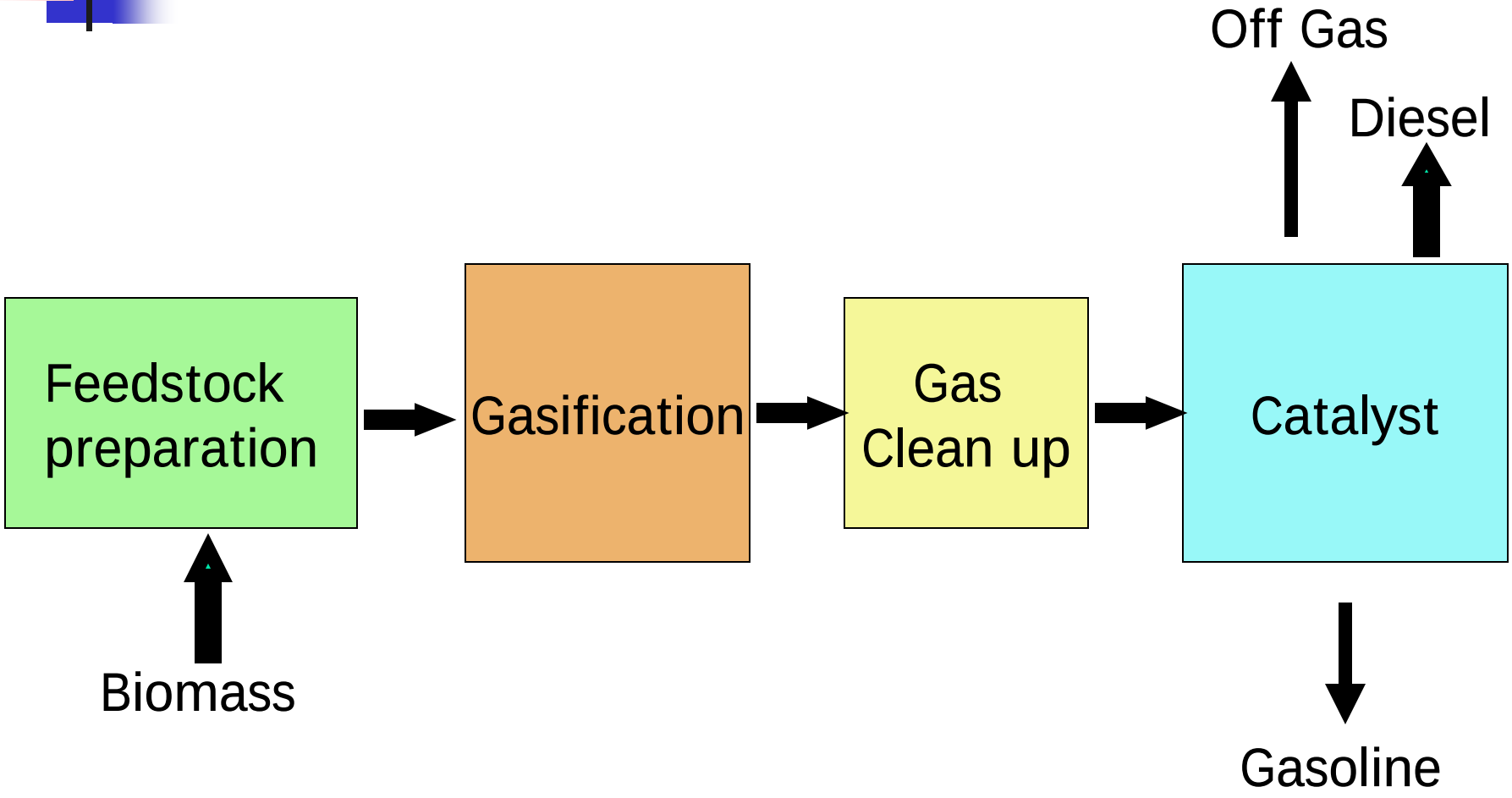
Ethanol-from-cellulose Biological vs.Thermochemical

- Decreases financial risk
  - Lower investment requirements
  - Ability to switch feedstocks
  - Ability to move plants

Thermochemical Processes

- Processes
  - Fast Pyrolysis
  - Liquefaction
  - Gasification/FT
- Common Pretreatment
  - Particle size reduction
  - Drying

Diesel/Gasoline from Biomass Gasification & Fisher Tropsch



FT Process Conditions

- FT Reactor
  - Temperature 400-600 F
  - Pressure 15-40 bars
- Catalyst: Iron and Cobalt
- Exothermic reaction
- 80% of H2 and CO converted to gasoline and/or diesel

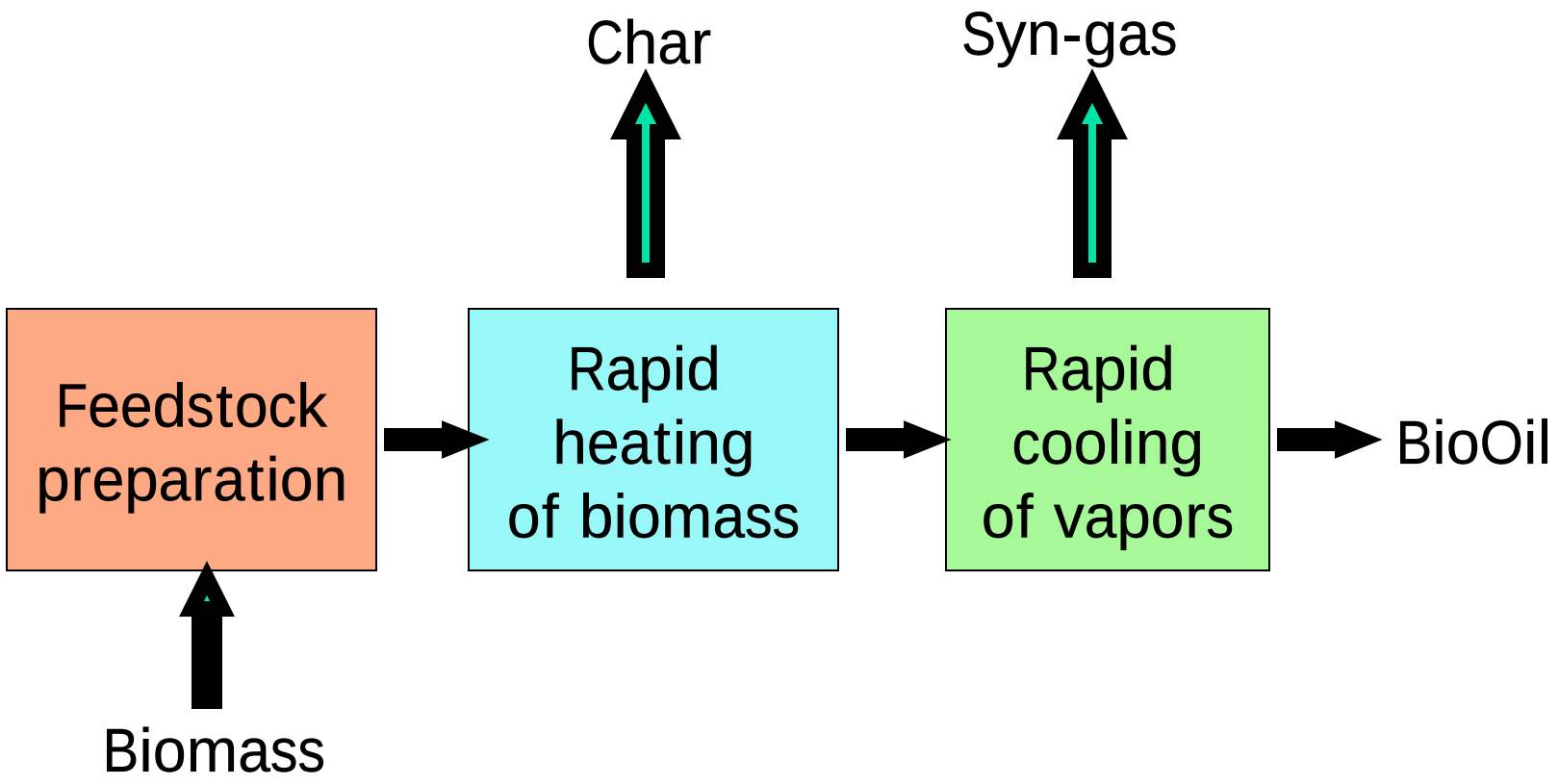
Catalyst Activity Decline

- Conversion of active sites to inactive oxide sites
- Sintering
- Loss of active area by coke deposition
- Chemical poisoning by sulfur, halides, and nitrogen compounds

Gasification / FT Vendors

- Power Energy Fuels
- Choren Industries
- Bioconversion Technology
- Pearson Technologies

Fast Pyrolysis



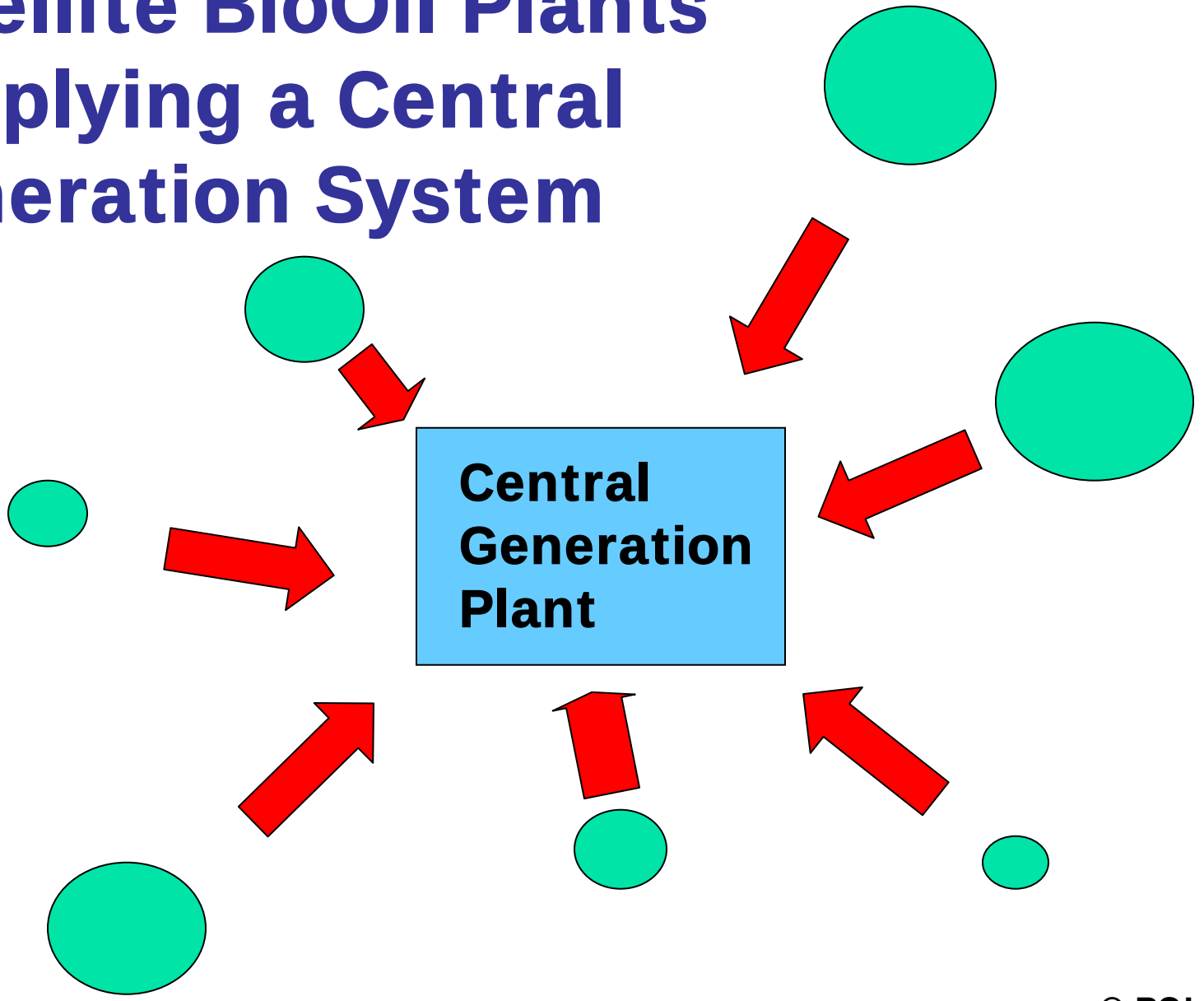
Fast Pyrolysis Process Conditions

- Reactor temperatures 400-550 C
- Reactor pressure atmospheric
- No water required
- Yield from wood
  - 60-75% liquid (120 – 150 gal/dry ton)
  - 25% char
  - 15% gas

BioOil from Fast Pyrolysis

- Commercial plants in Canada
- “Raw” BioOil can be used to fuel boilers and certain engines and turbines
- Excellent source of chemicals
- Current plants focus on chemical production

Satellite BioOil Plants Supplying a Central Generation System



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Fast Pyrolysis Vendors

- Ensyn
- Dynamotive
- Renewable Oil International

Summary

- Biomass is a resource whose diversity and local availability helps increase national security
- There is potential to offset up to 30% of US petroleum imports by 2030
- There are many different processes in various stages of development to convert biomass into liquid fuels