The Case for Biorefining

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U.S. Dependence on Foreign Oil

Have Oil		Use Oil	
Saudi Arabia	26%	U.S.	26%
Iraq	11%	Japan	7%
Kuwait	10%	China	6%
Iran	9%	Germany	4%
UAE	8%	Canada	4%
Venezuela	6%	Russia	3%
Russia	5%	Brazil	3%
Libya	3%	S. Korea	3%
Mexico	3%	France	3%
China	3%	India	3%
Nigeria	2%	Mexico	3%
U.S.	2%	Italy	2%

The U.S. uses more than the next 5 highest consuming nations combined.

Updated March 2003. Source: International Energy Annual 2001 (EIA), Tables 11.4 and 11.10.

Why Bioenergy?

- **National security**
  - **60% of our petroleum is imported**
- **Greenhouse warming**
  - **Natural CO_2 cycle is 10X fossil fuels**
- **Sustainability**
  - **Potential to replace petroleum-derived fuels and chemicals**
- **Rural economic benefit**

The Unique Role of Biomass

While the growing need for sustainable electric power can be met by other renewables…








Biomass is our only renewable source of carbon-based fuels and chemicals

National Bioenergy Center

Announced by Dept of Energy Secretary Bill Richardson at the Kansas City Board of Trade on October 31, 2000

NREL Role: *Coordinate research at DOE labs*

NETL

Pacific Northwest National Laboratory
Operated by Battelle for the U.S. Department of Energy

INEEL
Idaho National Engineering and Environmental Laboratory

Argonne National Laboratory
Operated by the University of Chicago

Oak Ridge National Laboratory

NREL

Bioenergy Strategic Goals

U.S Dept of Energy

Protect national and economic security by promoting a diverse supply of reliable, affordable, and environmentally sound energy

- Reduce our dependence on foreign oil
- Create the new domestic bioindustry

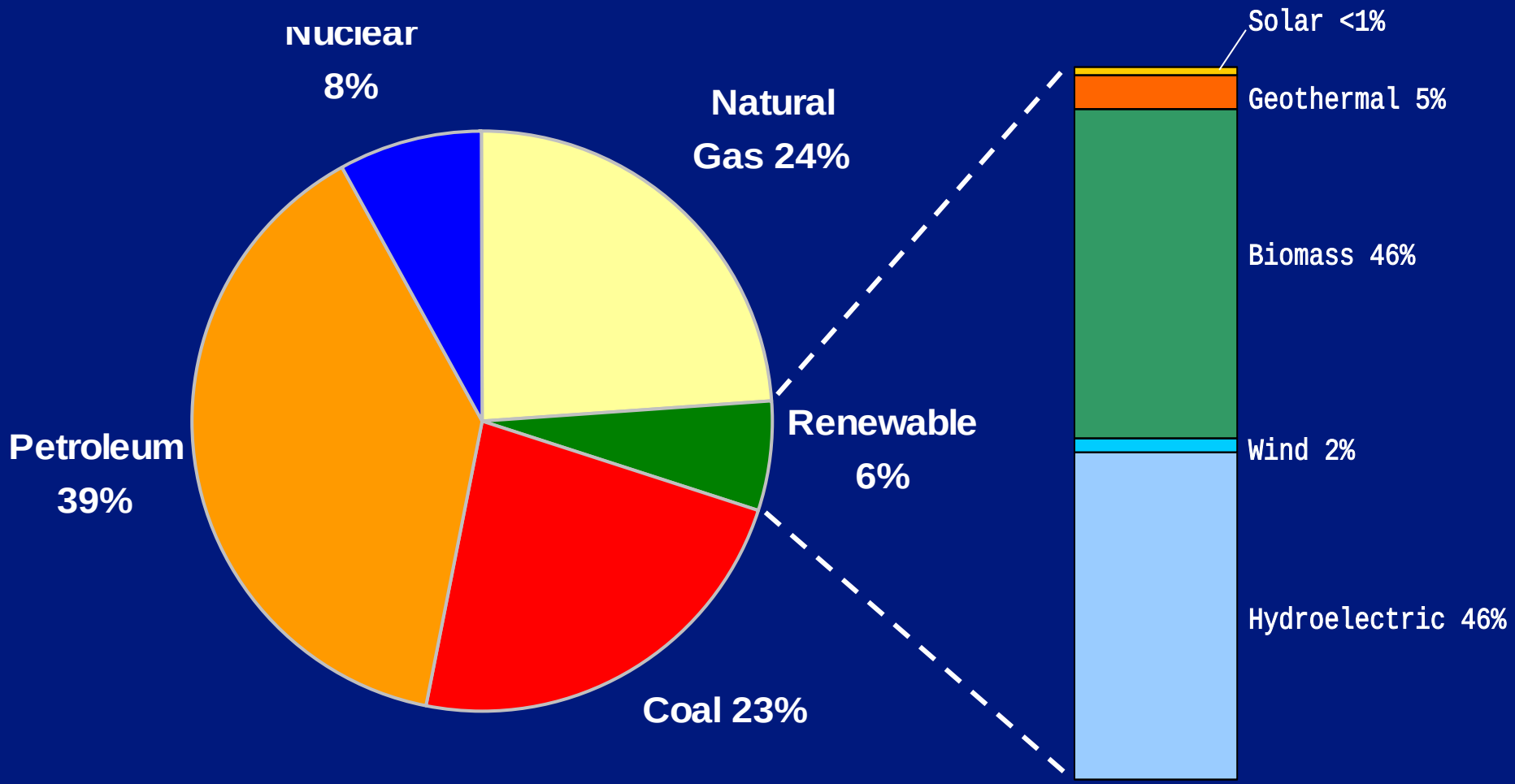
National Bioenergy Center

Develop biomass-based technologies that will be used by the U.S. transportation fuel, chemical and power industry

Specific Goal

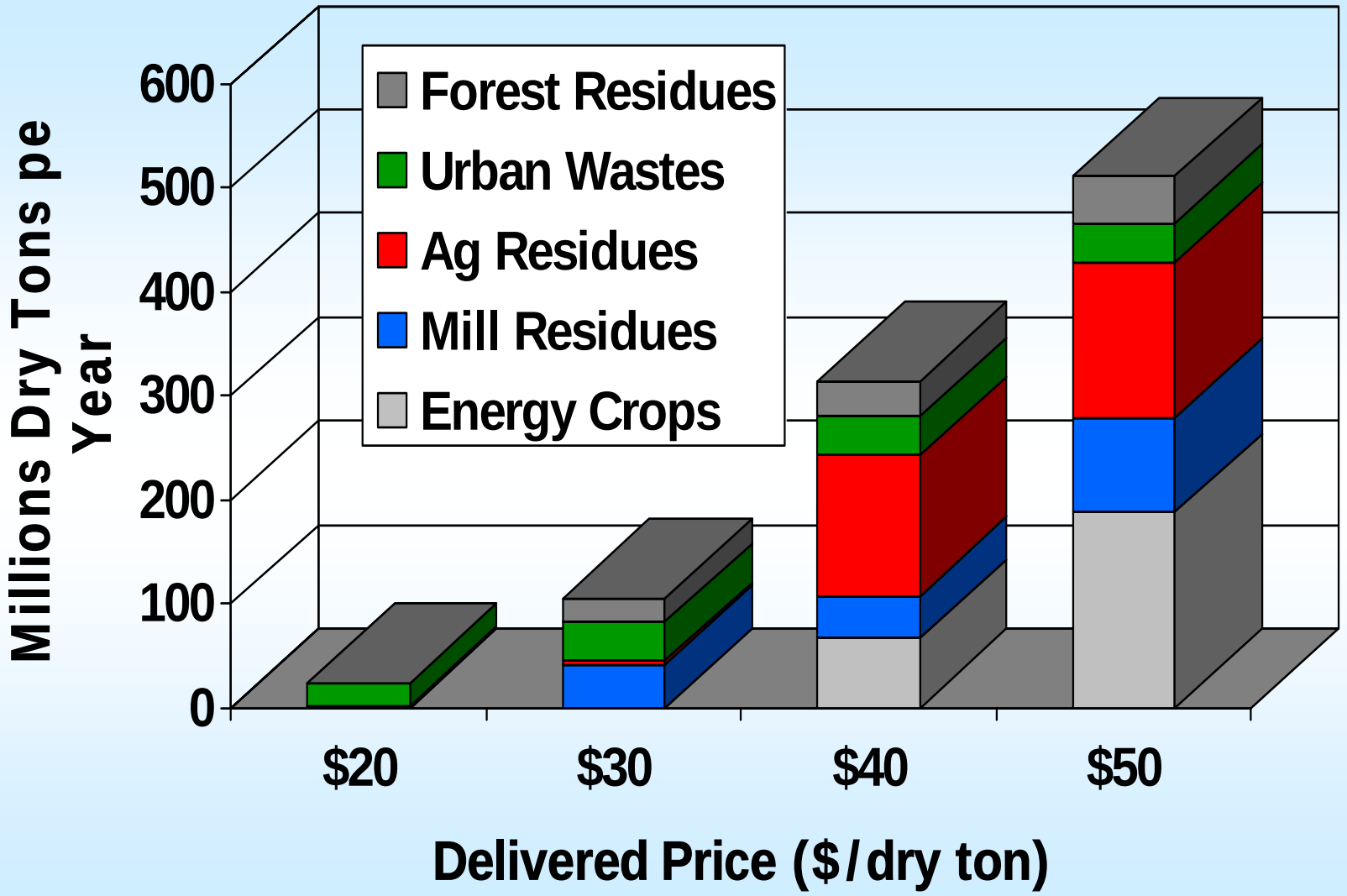
Help establish technology for large-scale biorefineries based on agricultural residues by 2010

Share of U.S. Energy Supply
(data for 2002)



Source: AEO 2004 tables (released in December 2003) based on US energy consumption. Overall breakdown Table A1 (Total Energy Supply and Disposition), and Renewable breakdown Table A18 (Renewable Energy, Consumption by Section and Source).

2020 U.S. Biomass Supply Potential



Developing 1 billion ton case for 2050

Life Cycle Assessment

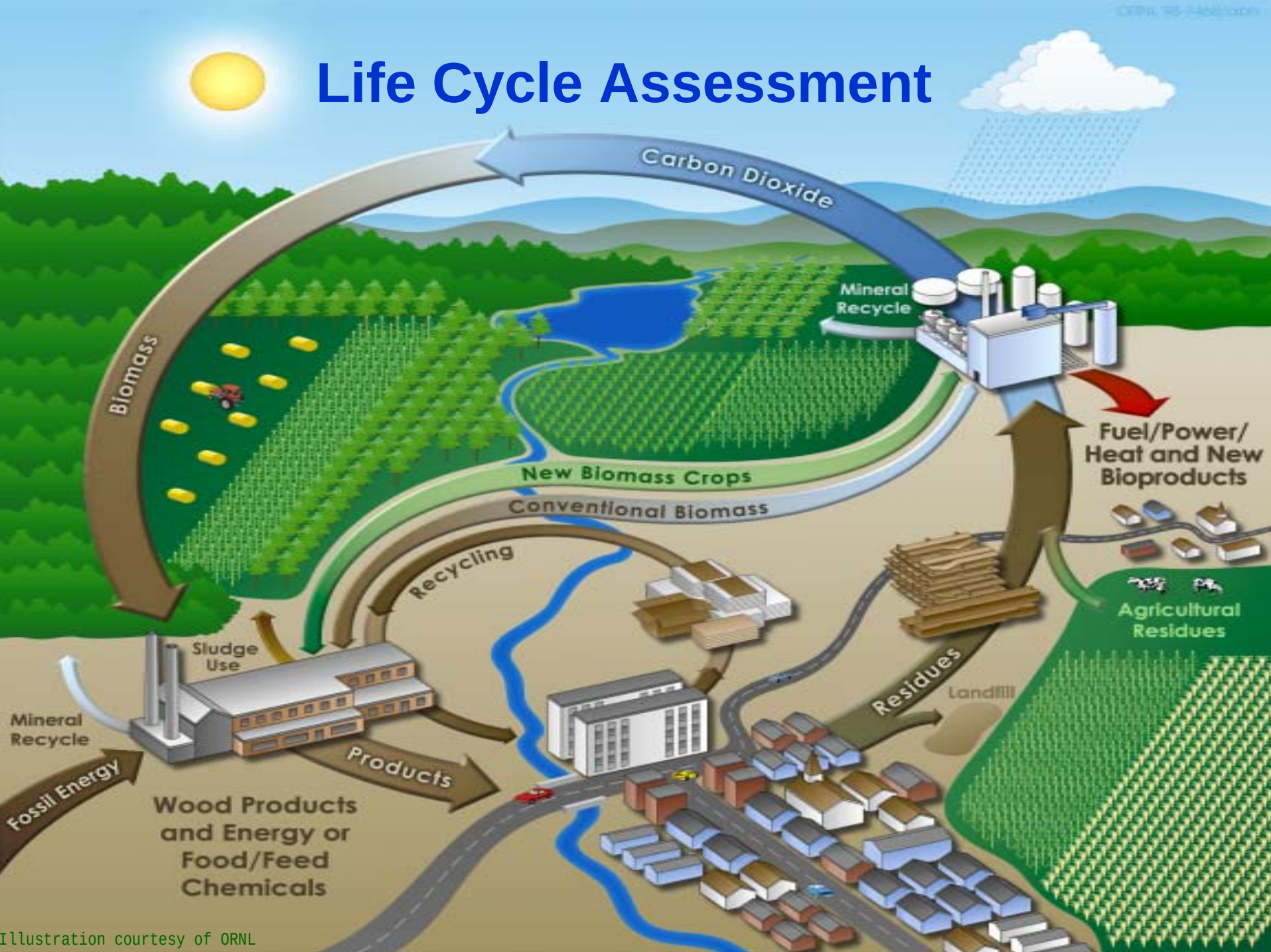
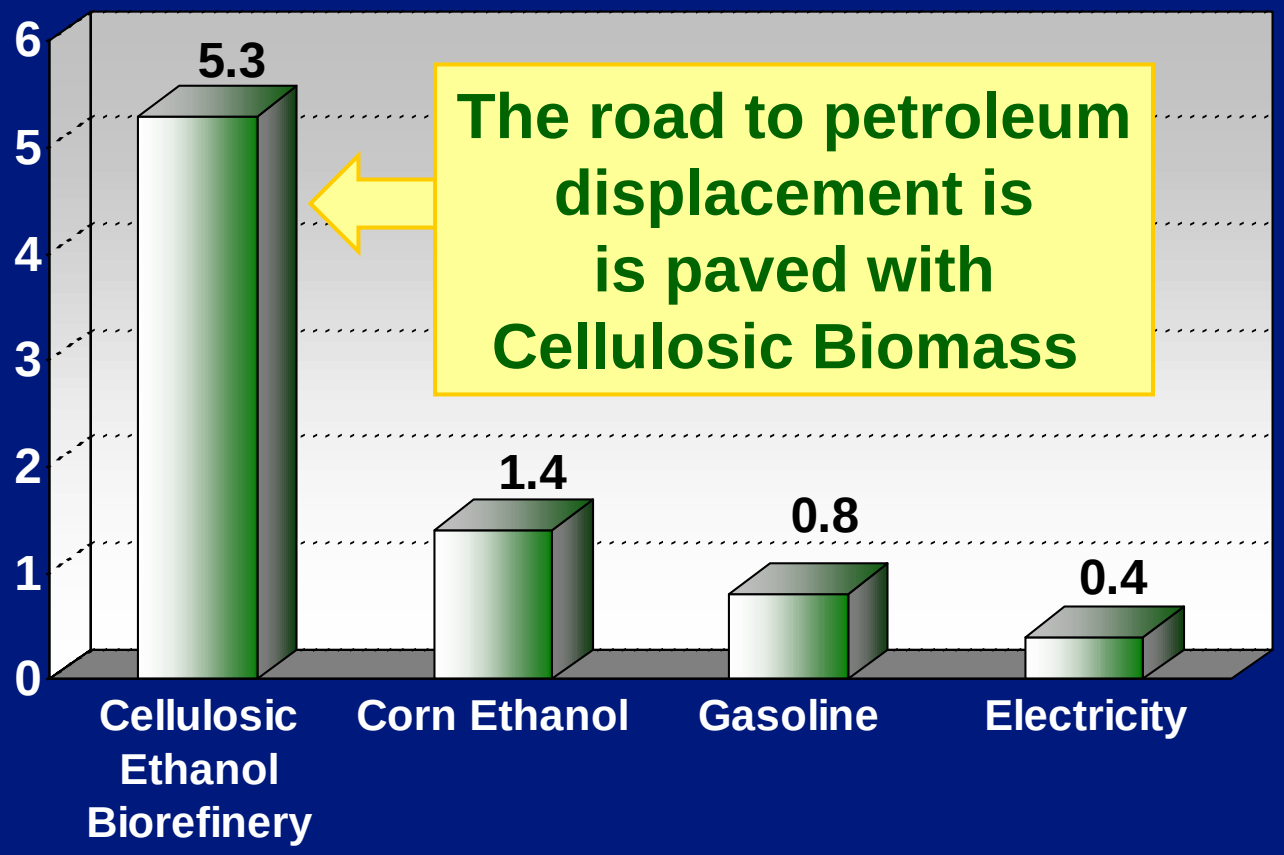


Illustration courtesy of ORNL

Fossil Energy Replacement Ratio

$$\text{Fossil Energy Ratio (FER)} = \frac{\text{Energy Delivered to Customer}}{\text{Fossil Energy Used}}$$



Source: J. Sheehan & M. Wang (2003)

Lab-Industry Partnerships Focus on Viable Biorefinery Concepts

Biomass Feedstock

– Trees
– Grasses
– Agricultural Crops
– Agricultural Residues
– Animal Wastes
– Municipal Solid Waste

Conversion Processes

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

USES

Fuels:
– **Ethanol**
– **Renewable Diesel**

Power:
– **Electricity**
– **Heat**

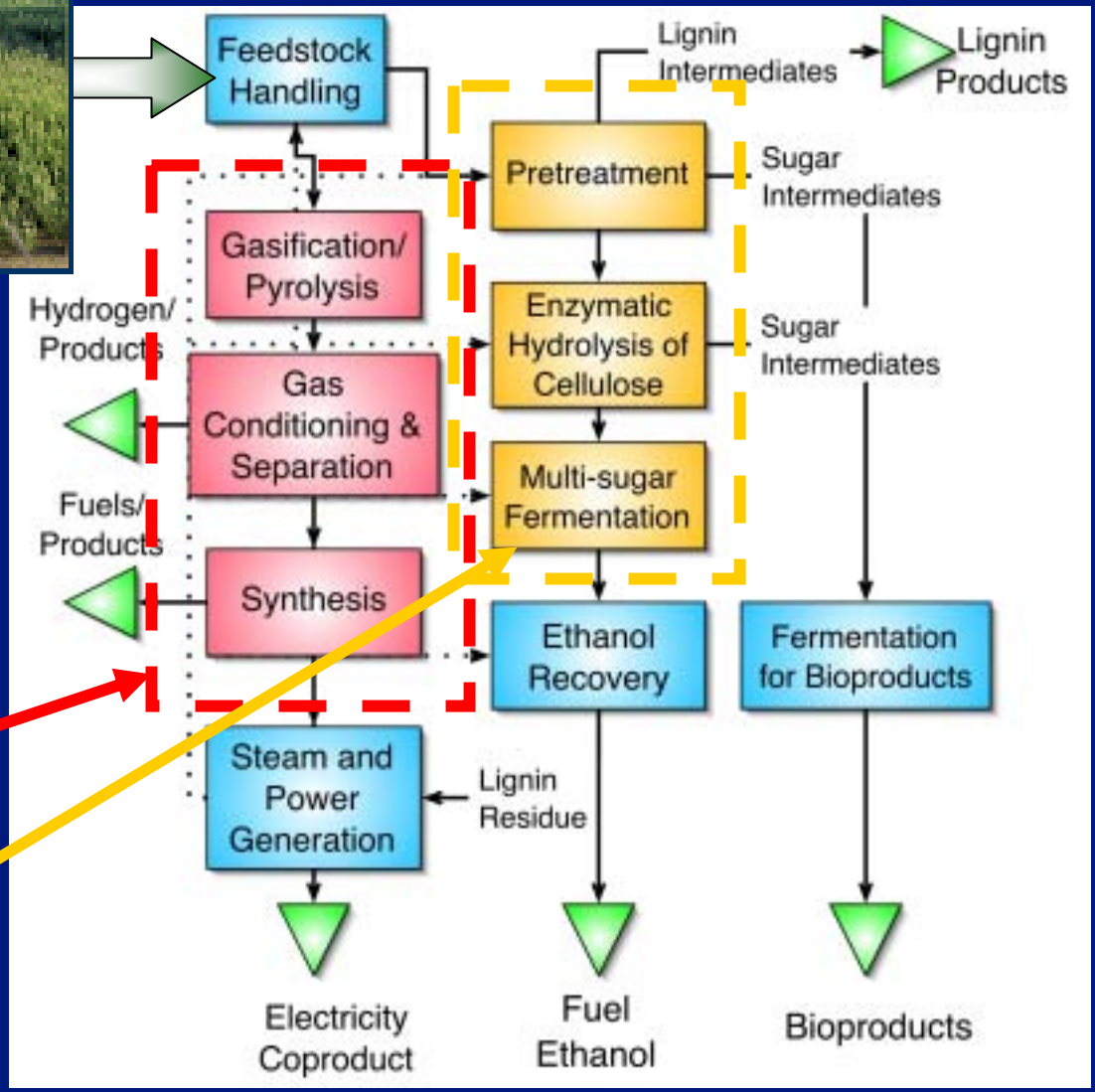
Chemicals
– **Plastics**
– **Solvents**
– **Chemical Intermediates**
– **Phenolics**
– **Adhesives**
– **Furfural**
– **Fatty acids**
– **Acetic Acid**
– **Carbon black**
– **Paints**
– **Dyes, Pigments, and Ink**
– **Detergents**
– **Etc.**

Food and Feed

Vision of Future Biorefineries

An integrated biorefinery will make use of:

- Thermochemical conversion technology
- Biochemical conversion technology
- Existing technology
  Available today



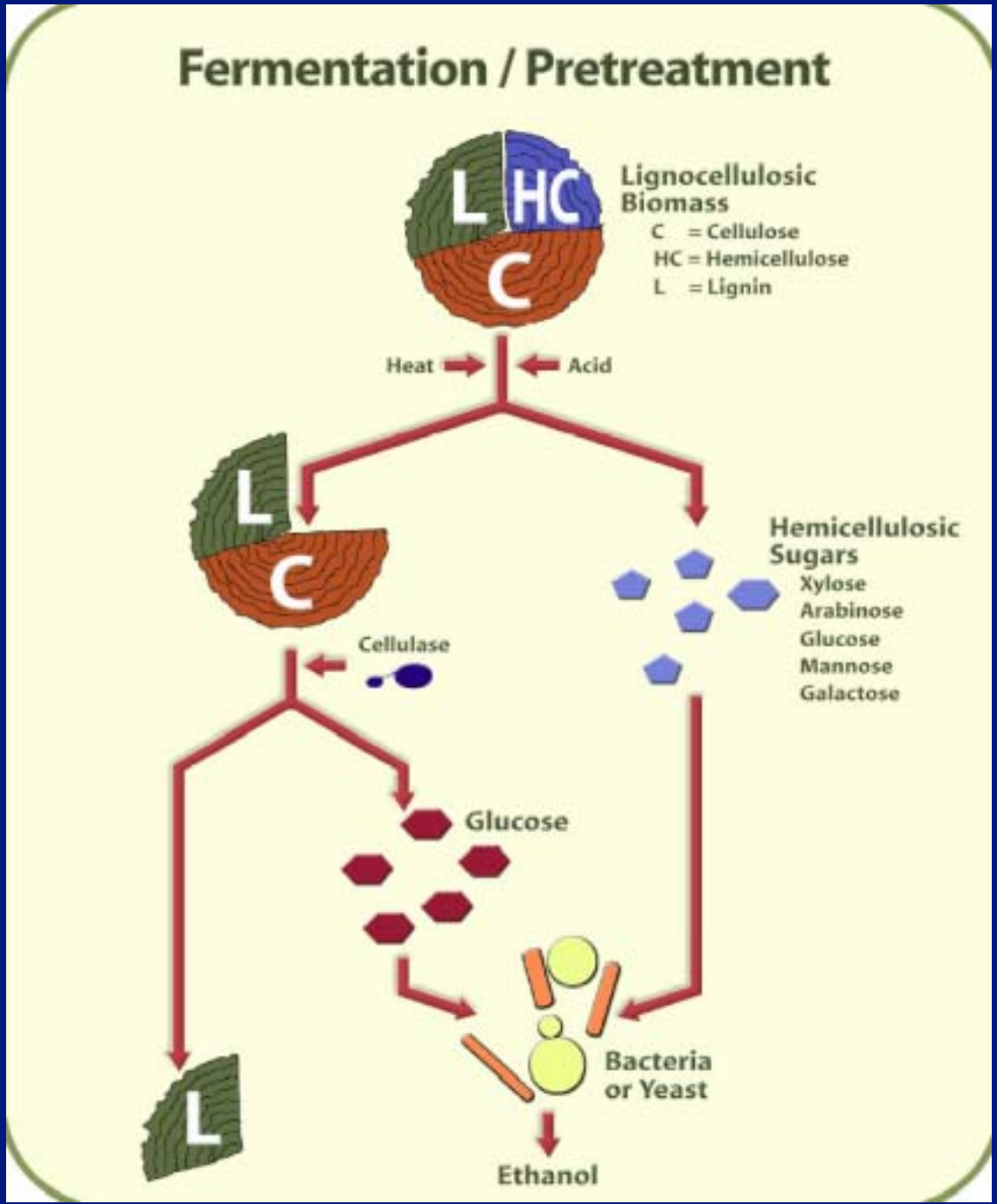
Why 2 Platforms?

Bio-Chemical Technology

effective for cellulose and hemicellulose

Thermochemical Technology

needed to convert the lignin fraction, or the whole biomass



Opportunities other than Ethanol

- Sugar-derived chemicals
- Lignin derivatives (BTX, phenols, etc.)
- Biodiesel & chemicals from vegetable oils
- Pyrolysis oils from biomass
  - Oxygen rich *"cracked stocks"*
  - Exploring options for refining/upgrading
- Gasification of biomass
  - Fischer-Tropsch liquids
  - Hydrogen
  - Chemicals

The Biomass Value Proposition

- Only sustainable source of hydrocarbon-based fuels, petrochemicals, and plastics
- Huge U.S. and worldwide potential biomass resource base
  - potential to displace over 50% of U.S. gasoline and diesel consumption with domestic resources
- Reduction of greenhouse gas emissions
- Reinvigorate and diversify rural economy

Summary

- Biomass is key to displacing petroleum
  - Improve energy balance – *full use of resource*
- Reduce green house gases
  - Improve rural economy
- Major advances in technology needed
  - Biomass supply and harvesting
  - Improvements in conversion technology
  - Co-products to enhance value creation

Summary, con't.

- USDOE's vision of a biorefinery incorporates multiple conversion technologies to produce fuel, chemicals, & power
- NREL's Renewable Diesel R&D addresses barriers to commercialization
  - Ensuring Fuel Quality
  - Ensuring Fuel Stability
  - Ensuring Reliability
  - Maximizing Environmental Benefit
  - Demonstrating Performance