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# Assessment of Technology Advancements in the Manufacturing of Lignocellulosic Biofuels

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# Why Forest Bioenergy in the US?

- Reduce dependence on Imported Oil
- Reduce green house gas emissions
- Rural or local economic development
- Improve the competitiveness of the Forest Products industry
- Improve forest health and/or reduce risk and impacts of fire

***Current approaches can not achieve all 5***

# A Partial List of Current Biofuels Projects in the US

More than $2.5 billion in real projects have been announced, but NONE are actually making fuels from lignocellulosic biomass.

- DOE and Private Companies– $1.2 billion for six ethanol demo. projects at the 700 tpd scale
- DOE - $375 million for 3 Genomes to Life Centers to "Break the Barriers to Cellulosic Ethanol"
- BP - $500 million to look at fundamentals barriers, to UC Berkeley and Univ. of Illinois
- DOE - $200 million in 4 small scale (70 tpd) demo projects
- Individual States – 10-15 states working on initiatives, research, pilot plants, that range between $5 and 60 million

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# YES, everyone is working on Biofuels!

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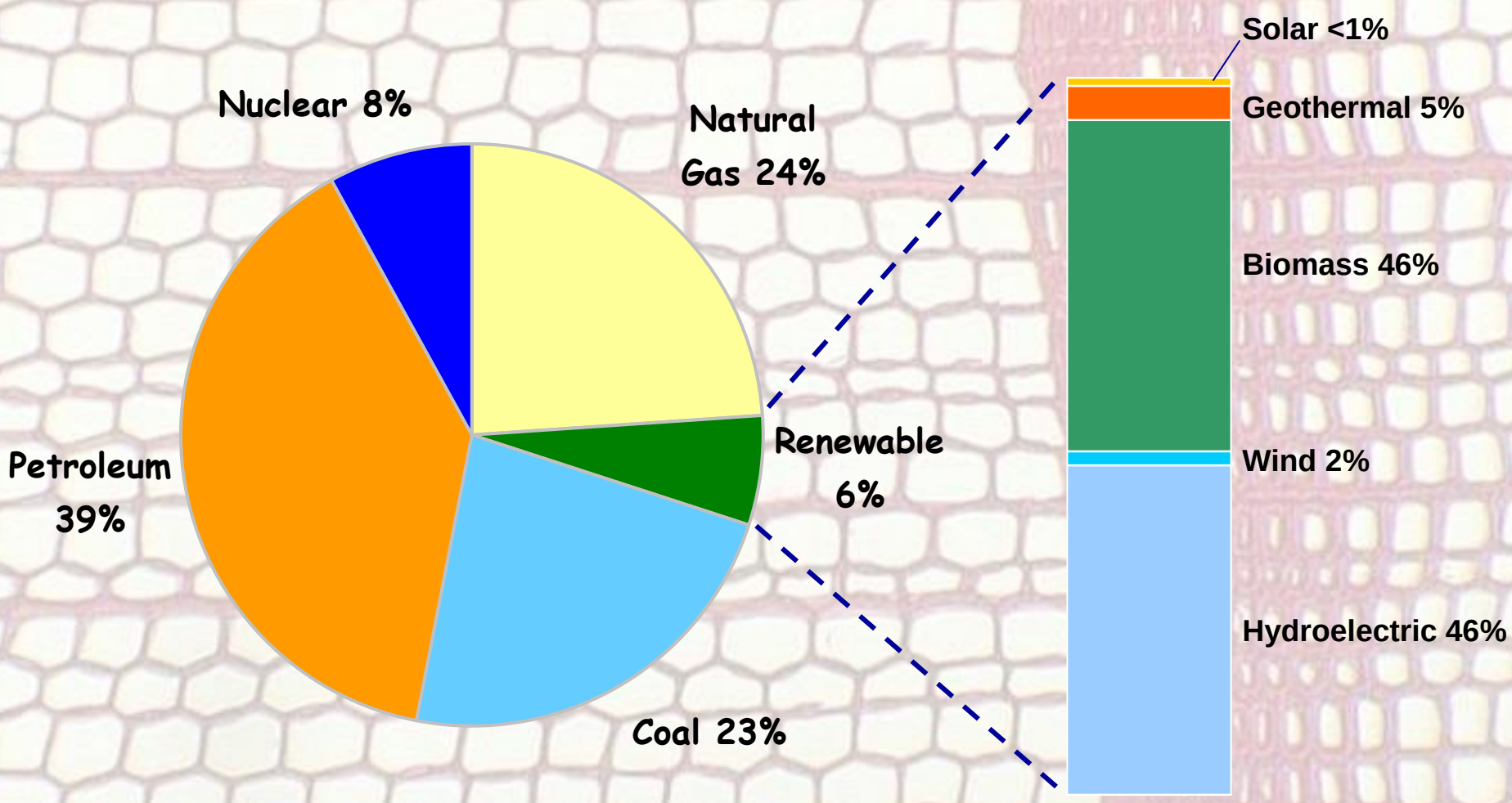
# Biomass Share of U.S. Energy Supply
## (data for 2005)




Source: AEO 2005 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).

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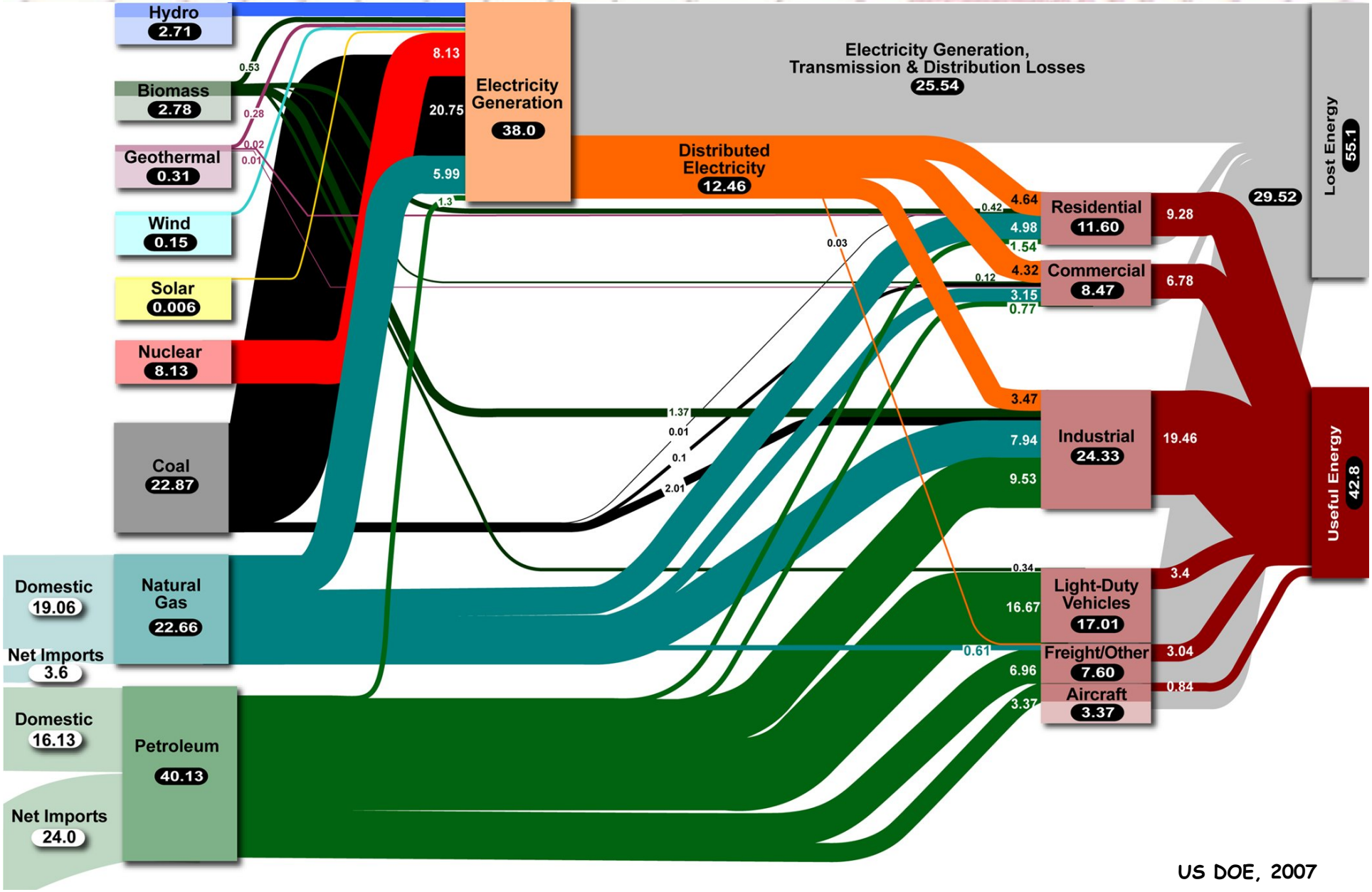
# US Energy Flows




US DOE, 2007

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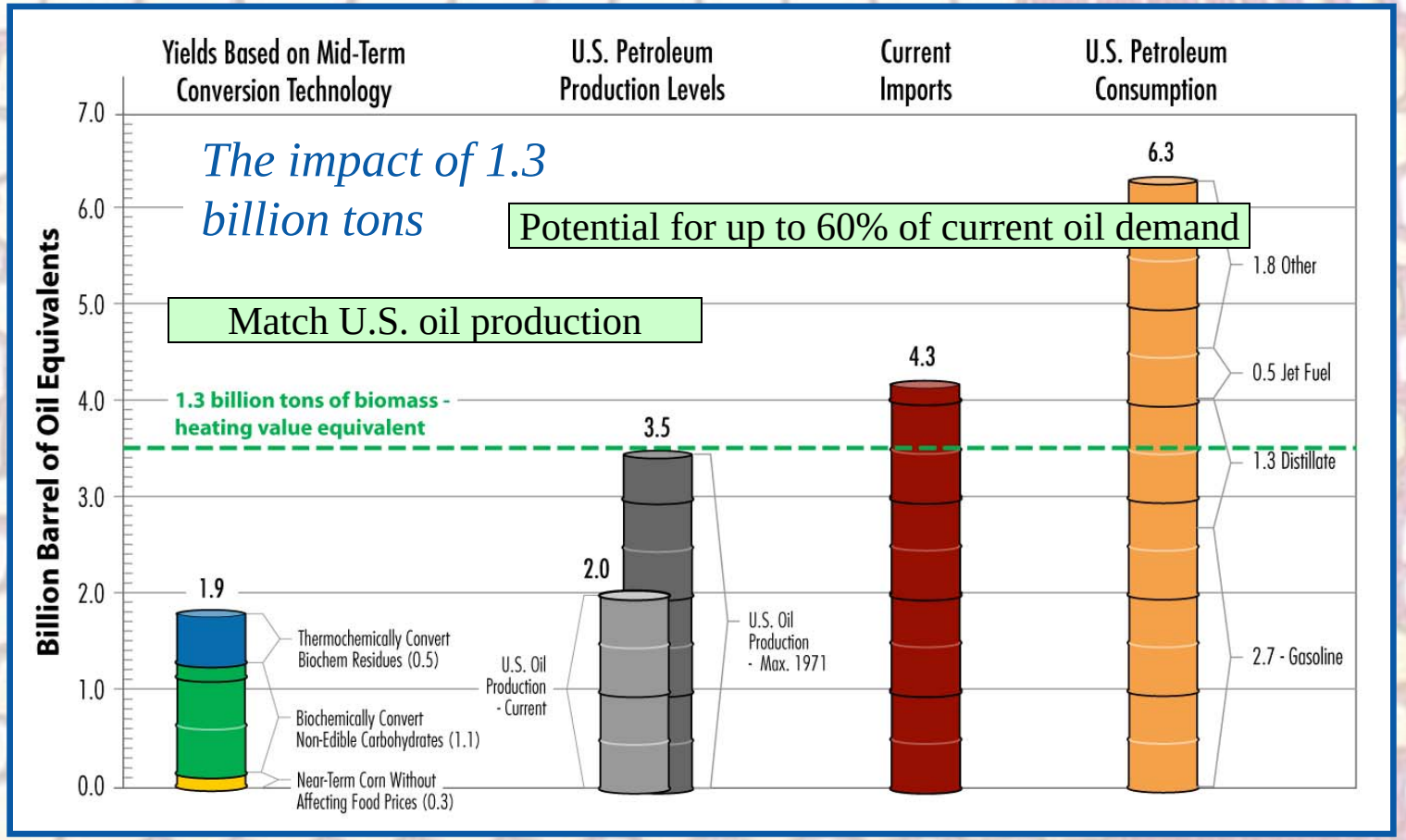
# Can Biomass have an Impact on U.S. Energy Supply?



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# Lignocellulosic Constituents

## Lignin: 15-25%

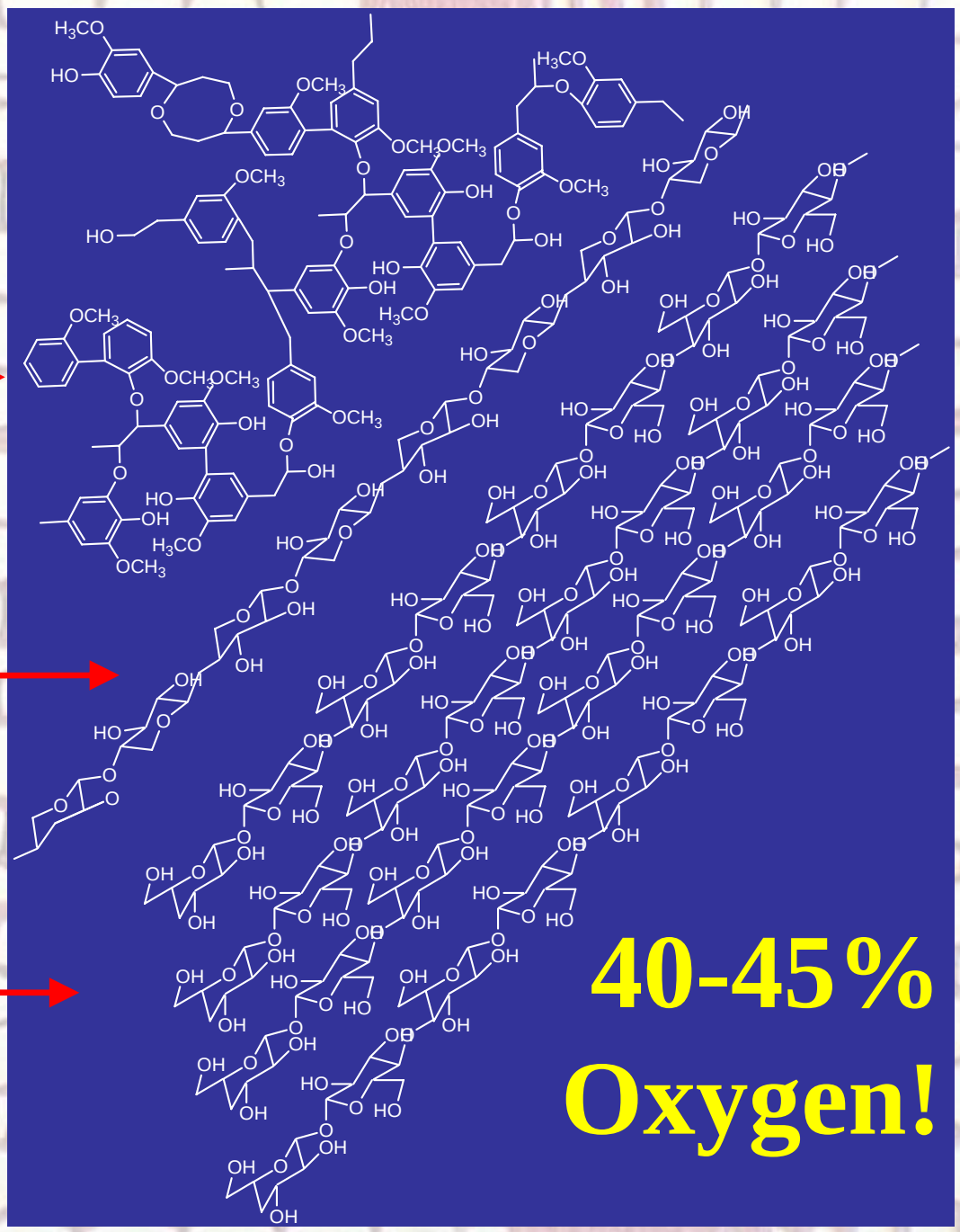
- Complex aromatic structure
- Very high energy content
- Resists biochemical conversion

## Hemicelluloses: 23-32%

- Xylose is the 2nd most abundant sugar in biosphere
- Polymer of 5- and 6-carbon sugars, marginal biochemical feed

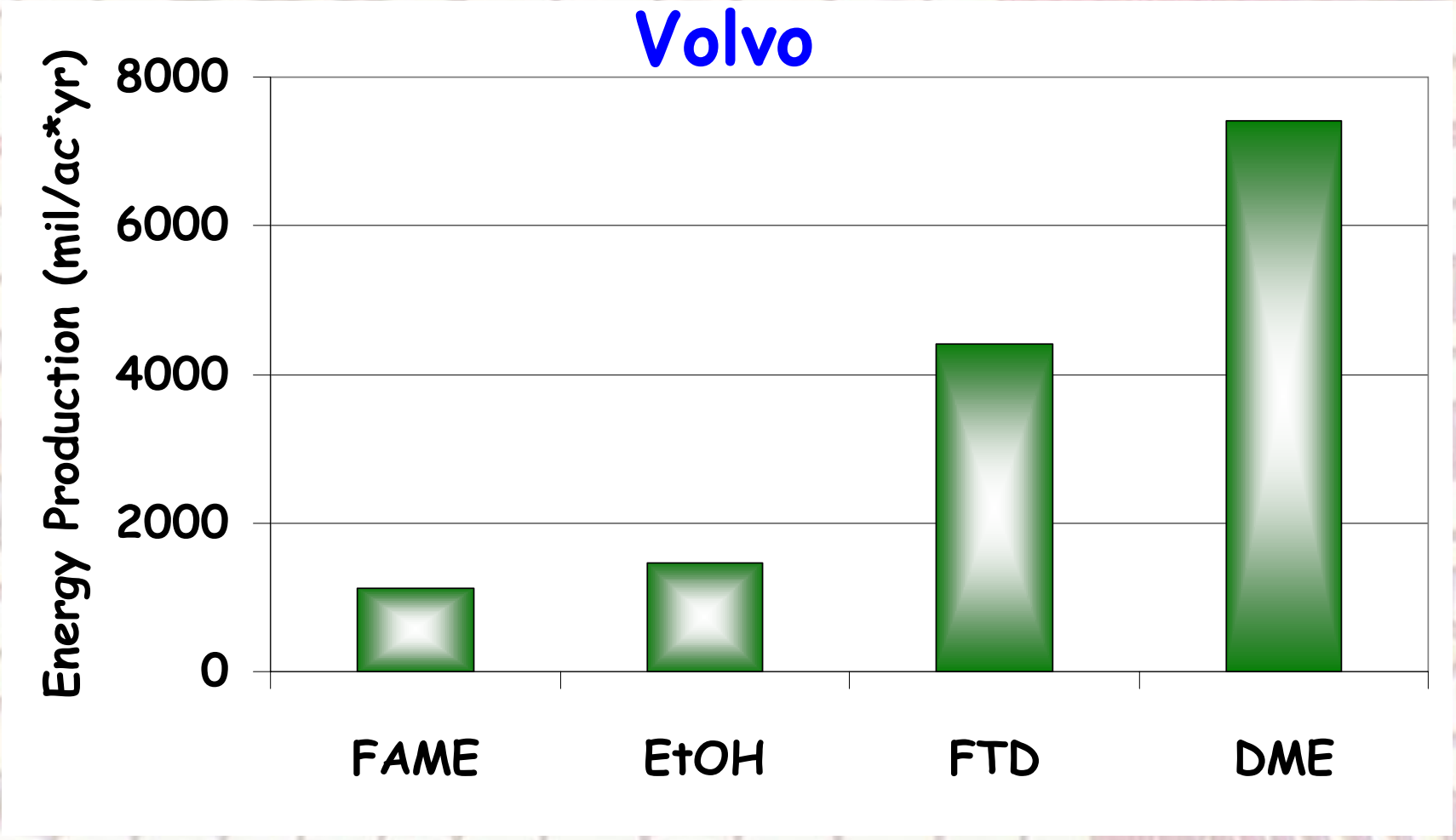
## Cellulose: 38-50%

- Most abundant form of carbon in biosphere
- Polymer of glucose, good biochemical feedstock



**40-45% Oxygen!**

# Energy Production – Process/Land Impacts




Volvo, 2005

# Mixed Waste Focus

**BlueFire Ethanol, Inc. investors/participants include: Waste Management, Inc.; JGC Corporation; MECS Inc.; NAES; and PetroDiamond.**

**DOE - $40 million; Private - $60 million**

The proposed plant will be in Southern California. The plant will use **strong acid hydrolysis and fermentation**, and will be sited on an existing landfill and produce about 90 million gallons of ethanol a year. It will use sorted green waste and wood waste from landfills.

**Target - 63 gal/ton**

# Agricultural Waste Focus

**Broin Companies (now POET) participants include: E. I. du Pont de Nemours and Company; Novozymes North America, Inc.; and DOE's National Renewable Energy Laboratory.**

**DOE - $80 million; Private – $120 million**

The plant is in Emmetsburg, Iowa. The plant will use **enzyme hydrolysis and fermentation** to 35 million gallons of ethanol per year. For feedstock in the production of cellulosic ethanol, the plant expects to use 842 tons per day of corn fiber, cobs, and stalks.

**Target – 83 gal/ton**

# Agricultural Waste Focus

**Iogen Biorefinery Partners, LLC investors/partners include: Iogen Corporation; Goldman Sachs; and The Royal Dutch/Shell Group.**

**DOE - $80 million; Private – $120 million**

The proposed plant will be built in Shelley, Idaho, near Idaho Falls. The plant will use **enzyme hydrolysis and fermentation** to produce 250 million annual gallons. The plant will use 700 tons per day of agricultural residues including wheat straw, barley straw, corn stover, or switchgrassas feedstocks.

**Target - 71 gal/ton**

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# Agricultural Waste Focus

**Abengoa Bioenergy Biomass investors/participants include: Abengoa Bioenergy R&D, Inc.; Abengoa Engineering and Construction, LLC; Antares Corp.; and Taylor Engineering**

**(DOE - $76 million; Private – $110 million.**

The proposed plant will be located in the state of Kansas. The plant will use **gasification** to produce 11.4 million gallons of ethanol annually and enough energy to power the facility, with any excess energy being used to power the adjacent corn dry grind mill. The plant will use 700 tons per day of corn stover, wheat straw, milo stubble, switchgrass, and other feedstocks.

**Target – 79 gal/ton**

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# Wood Feedstocks Focus

**ALICO, Inc. investors/participants include: Bioengineering Resources, Inc. of Fayetteville, Arkansas; Washington Group International of Boise, Idaho; GeoSyntec Consultants of Boca Raton, Florida; BG Katz Companies/JAKS, LLC of Parkland, Florida; and Emmaus Foundation, Inc.**

**DOE - $76 million; Private – $114 million**

The proposed plant will be in LaBelle, Florida. Using **gasification and catalysts** technology the plant will produce 20.9 million gallons of ethanol a year and 6,255 kilowatts of electric power, as well as 8.8 tons of hydrogen and 50 tons of ammonia per day. For feedstock, the plant will use 770 tons per day of yard, wood, and vegetative wastes and eventually energy cane.

**Target – 75 gal/ton; plus ammonia, hydrogen and power**

# Wood Feedstocks Focus

**Range Fuels investors/participants include: Merrick and Company; PRAJ Industries Ltd.; Western Research Institute; Georgia Forestry Commission; Yeomans Wood and Timber; Truetlen County Development Authority; BioConversion Technology; Khosla Ventures; CH2MHill; Gillis Ag and Timber.**

**DOE - $76 million; private - $150 million**

The proposed plant will be constructed in Soperton, Georgia. The plant will use **gasification and catalysts** to produce about 40 million gallons of ethanol per year and 9 million gallons per year of methanol. As feedstock, the plant will use 1,200 tons per day of wood residues and wood based energy crops.

**Target – 113 gal/ton**

# EU Projects

## Chemrec and Volvo

- High pressure gasification of spent liquor from pulp mill to produce dimethyl ether (DME).
- DME requires a specific diesel engine; Volvo heavy trucks is building.
- Pulp mills can produce 30% of Finland's and 50% of Sweden's liquid fuels.
- Gasifier has more than 3,000 hours on stream at 500 ton/day.
- Gas to liquids plant under construction

## CHOREN and Daimler Chrysler

- Gasification and GTL to make FTL, refined into standard diesel fuel
- The ultra-low sulfur diesel can be used by any current diesel engine.
- Beta plant including gasification and GTL completed this month (200 tpd)
- Full scale plant under design (3,000 tpd)

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# Needs for Sustainable Wood Production in US

- Need detailed information on location and costs
- Need improved harvesting systems
- Need more regional field experience; interaction between site, silvaculture, harvesting and environmental impacts (water, carbon)
- Need improved hybrids or trangenics; tons per acre, BTU per acre, tons of sugars, tons of ethanol per acre

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# High Efficiency Conversion Technology (Scale is key)

- Large pulp mill – 2,500 tpd
- Wood combustion – 500 tpd

- Corn ethanol plant – 4,000 tpd wood; (100 MM gal/yr)
- Coal power plant – 15-20,000 tpd wood
- Coal gasification and GTL – 70-100,000 tpd wood

No creditable studies to suggest small scale fuel production will lower production costs

# Needs for Biochemical Conversion

- Improved pretreatment to increase reactivity of cellulose
- Improved enzymes for hydrolysis of sugar polymers (celluose and hemicellulose)
- Improved fermentation systems for C5 sugars and for mixed sugars
- Improved process models for integrated plant operations

# Needs for BioOil to Hydrocarbons

- Improved processes/models for production BioOil, heat integration
- Improved BioOil hydrogenation catalysts
- Improved catalysts for cracking of BioOil/petroleum mixtures
- Improved models for integration into refineries

# Needs for Gasification and Gas to Liquids

- Improved processes for high efficiency gasification/CHP
- Improved catalyst for tar cracking
- Improved systems for biomass scale gas clean-up, and for GTL synthesis
- Improved models for process integration
- If focused on spent pulping liquor, improved gasifier materials

# Bioenergy Policy Issues

- Bioenergy is complex and needs very broad stakeholder input
- There is a need for better data (water, energy balance, soils and ecosystem impacts) for LCA, economics and policy
- Training and work force development is important

# Summary

- There is enough biomass to make a national impact in the US

- Biomass fuels and products can be made sustainable; wood is more consistent, harder to convert with Biochem, easier with Thermochem

- There are still technical hurdles but also significant progress, capital risk is still the largest element of risk

- Total conversion of lignocelluloses biomass to ethanol will be demonstrated in the 6 DOE co-funded projects; more than $1 billion total investment with $365 million from DOE

# Summary

- Large scale deployment will require higher productivity, and biotechnology can help with both productivity and processing

- Very limited, if any, competition for feedstocks at the national scale for the next 5-10 years

- Low risk options for redeploying current assets "repurposing pulp mills" for demonstration of technology is very promising

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# Thanks for your Attention