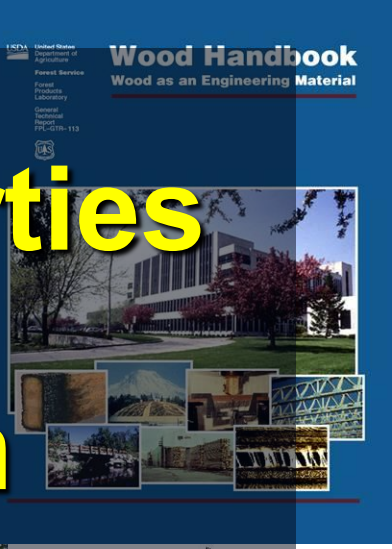
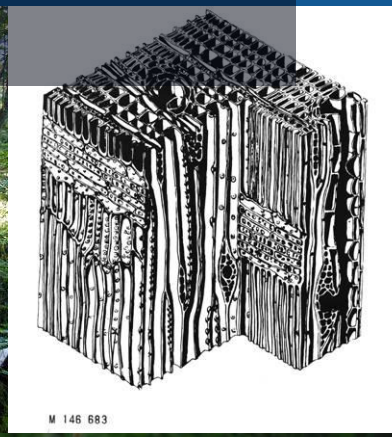
Desirable Wood Properties for Biofuels Production

Theodore H. Wegner
Peter J. Ince
Charles H. Michler
Kenneth E. Skog
USDA Forest Service

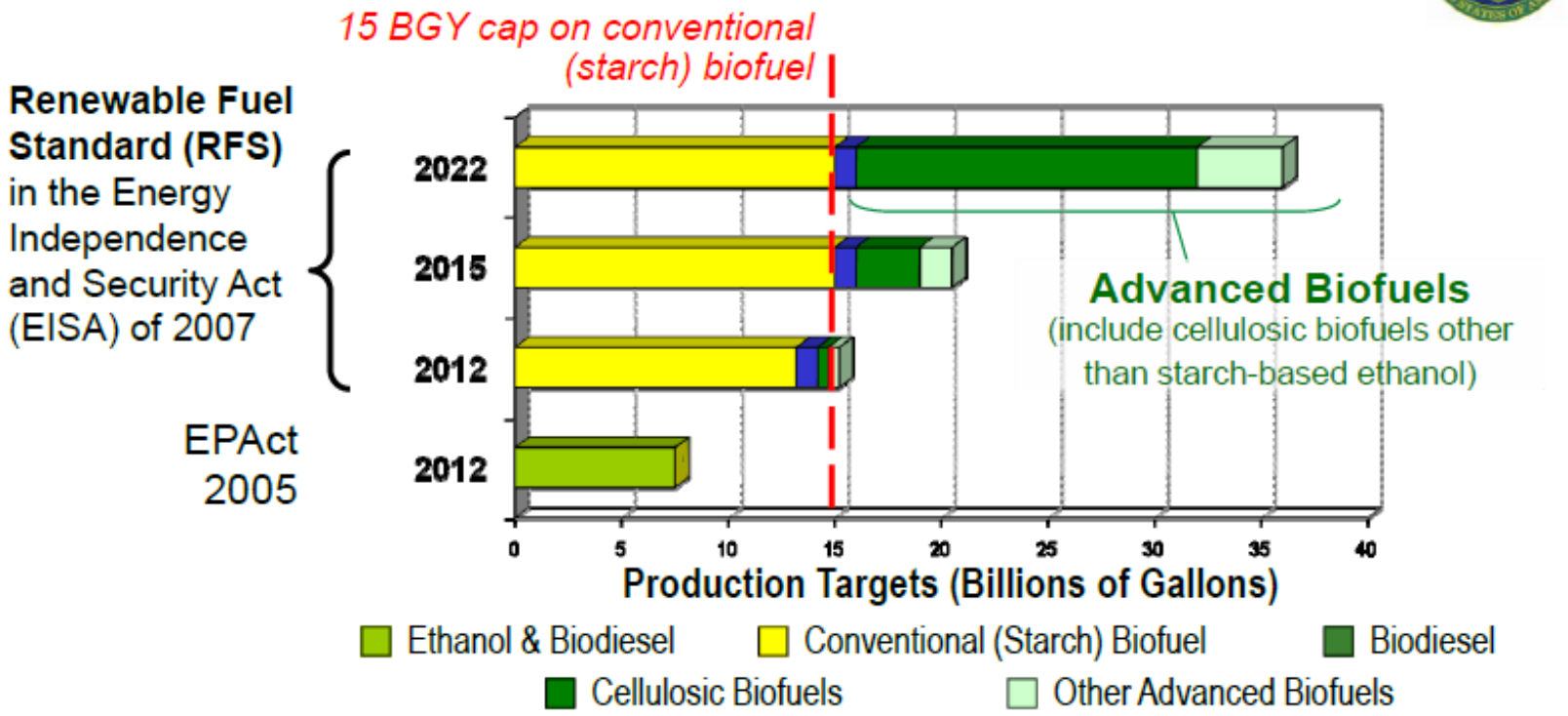
March 31, 2010





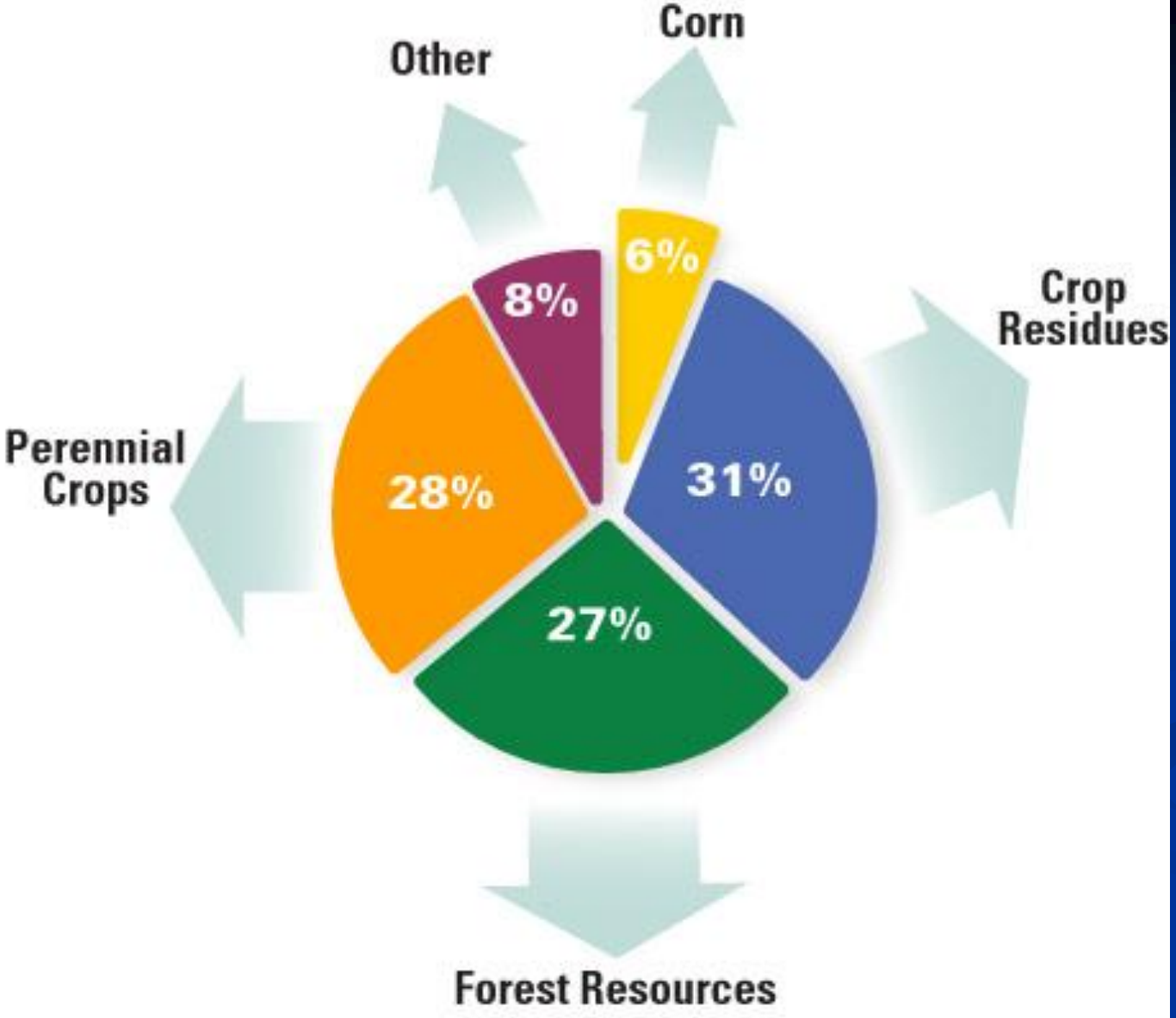
BIOMASS 2010

EISA Mandated Production Targets



EISA defines ***Cellulosic Biofuel*** as "renewable fuel derived from any cellulose, hemicellulose, or lignin that is derived from renewable biomass and that has lifecycle greenhouse gas emissions…that are *at least 60 percent less* than baseline lifecycle greenhouse gas emissions."

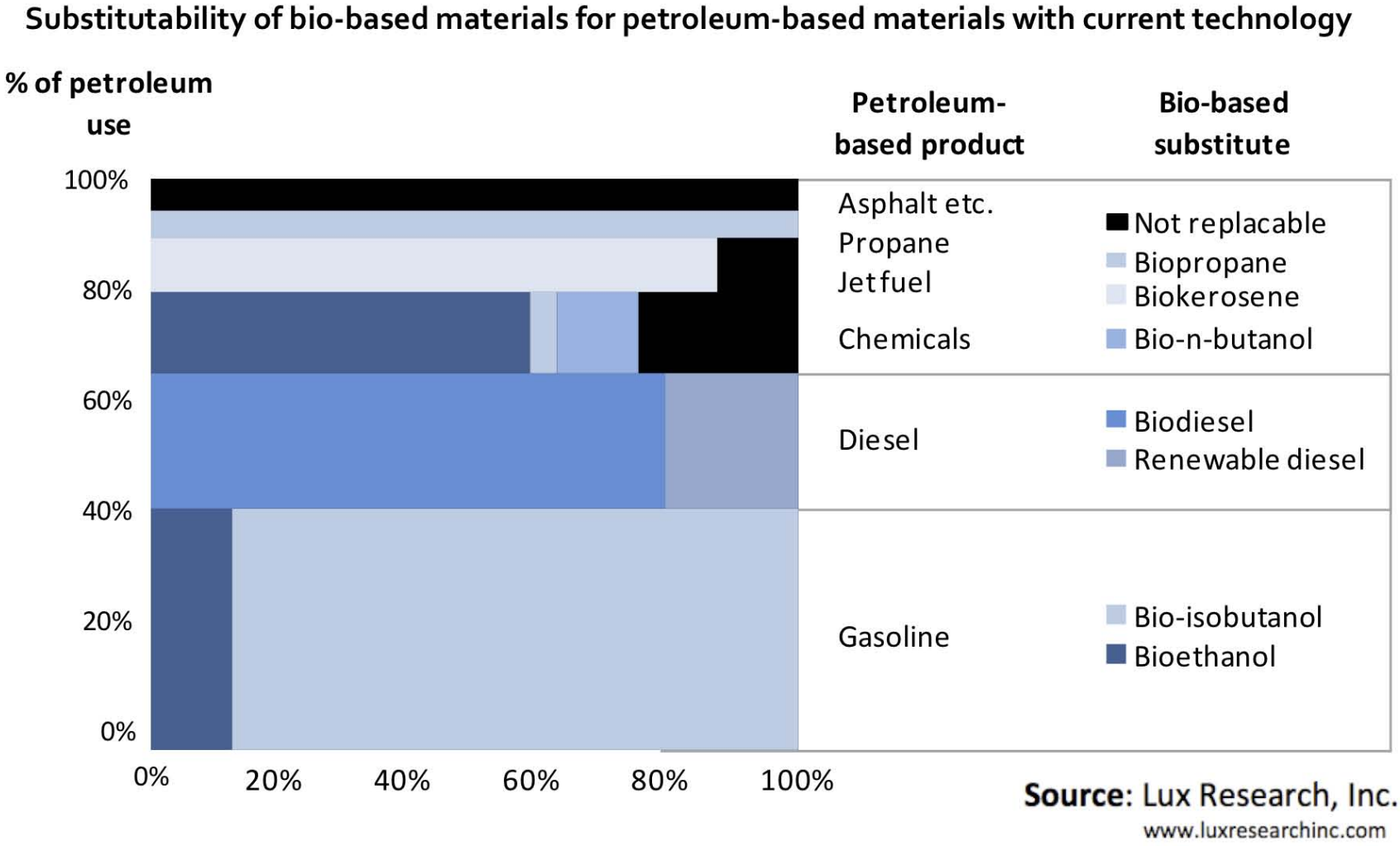
EISA defines ***Advanced Biofuel*** as "renewable fuel, other than ethanol derived from corn starch, that has lifecycle greenhouse gas emissions…that are *at least 50 percent less* than baseline lifecycle greenhouse gas emissions."



Projected U.S. Biofuel Sources

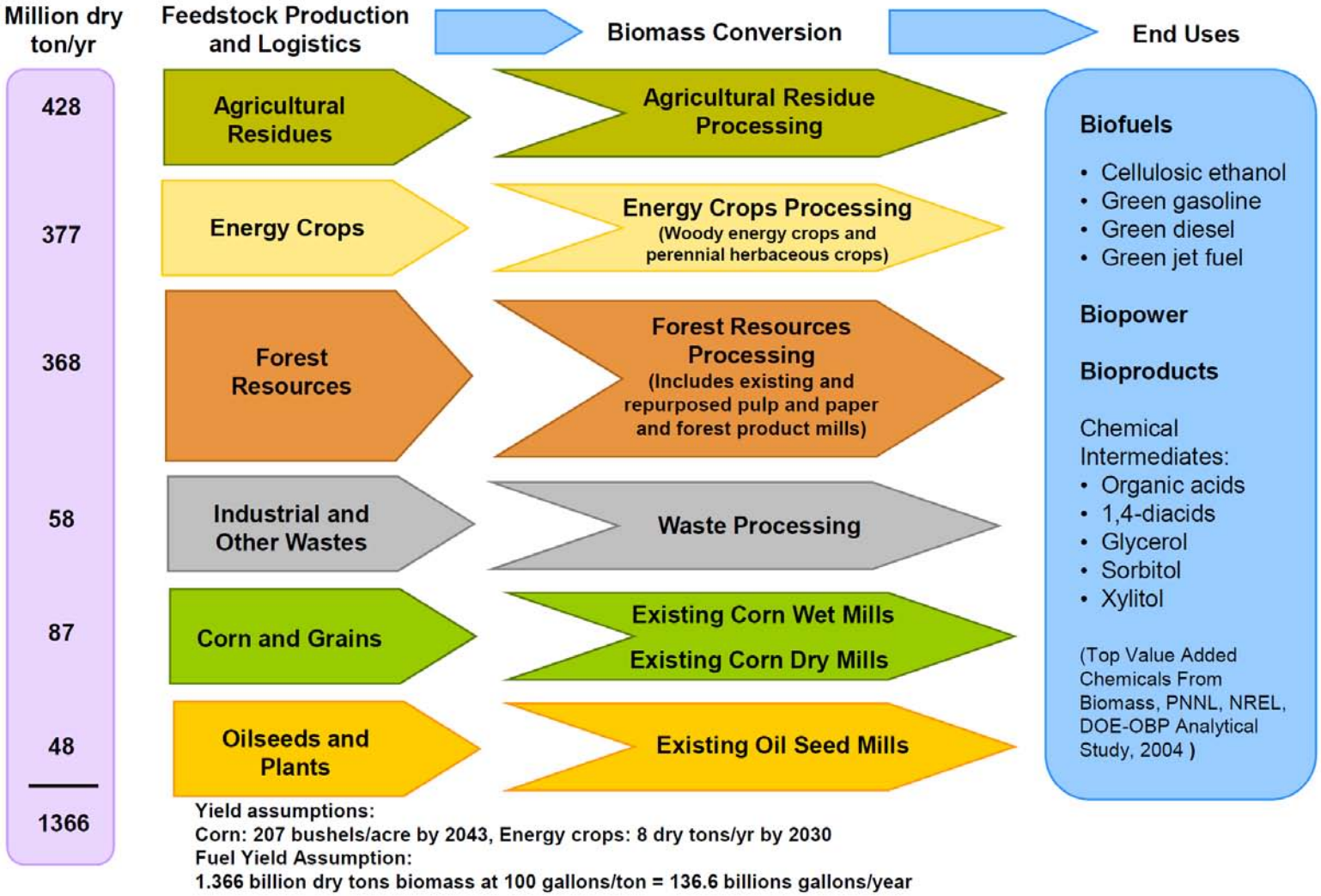
Source: Biomass as Feedstock for a Bioenergy and Bioproducts Industry: Technical Feasibility of a Billion Ton Annual Supply. 2005. DOE and USDA.

Biomass Can Substitute for Petroleum in Many Applications



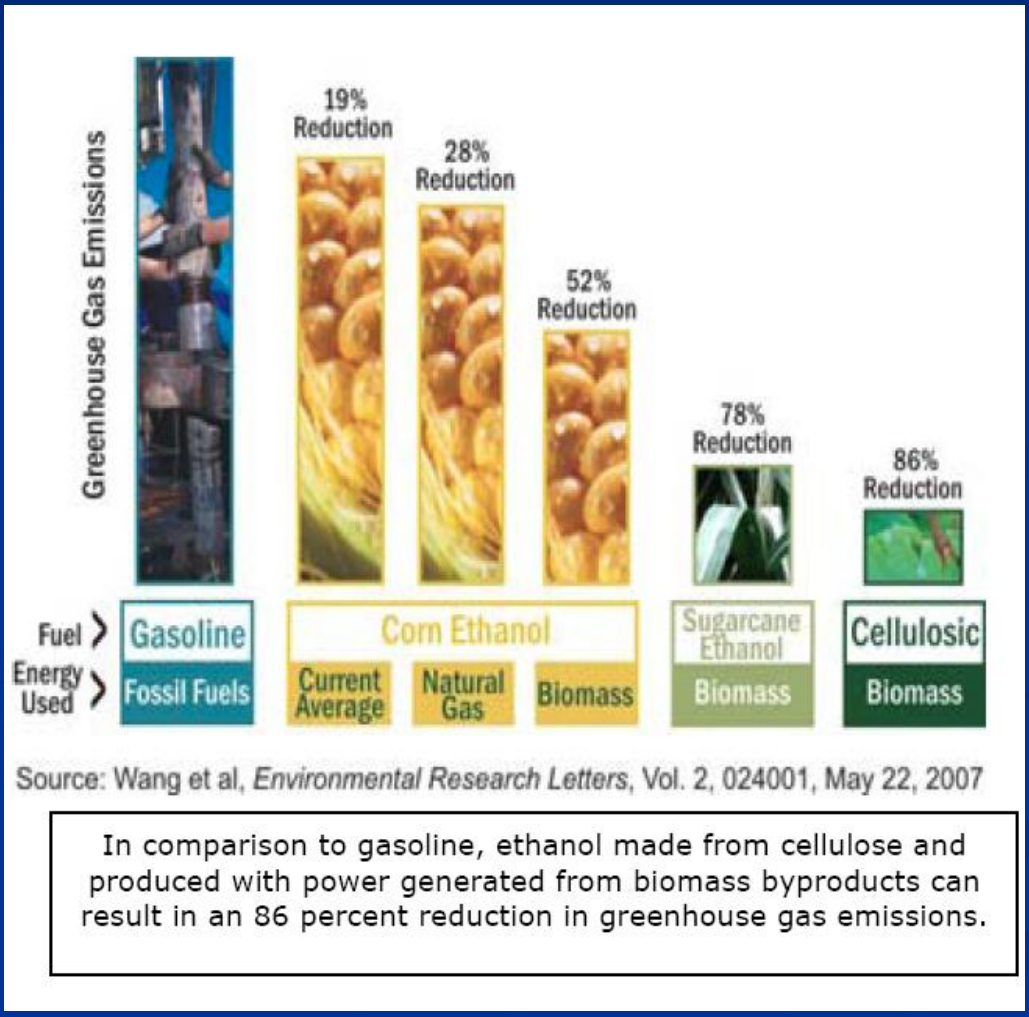
Biofuels' and Biomaterials' Path to Petroleum Parity, December 2009

Major Biomass Pathways



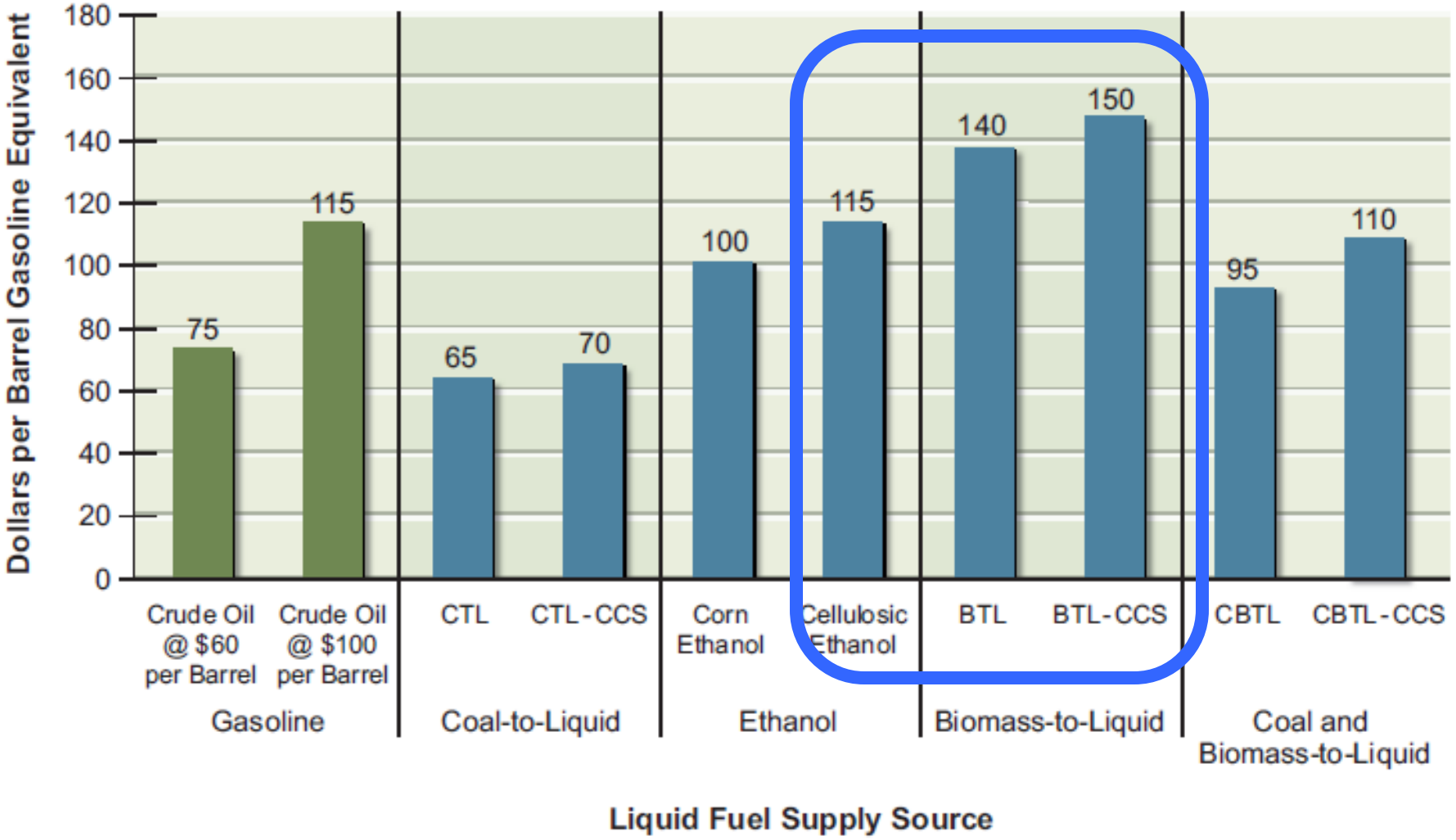
Yield assumptions:
Corn: 207 bushels/acre by 2043, Energy crops: 8 dry tons/yr by 2030
Fuel Yield Assumption:
1.366 billion dry tons biomass at 100 gallons/ton = 136.6 billions gallons/year

Green House Gas Considerations
Carbon Footprint

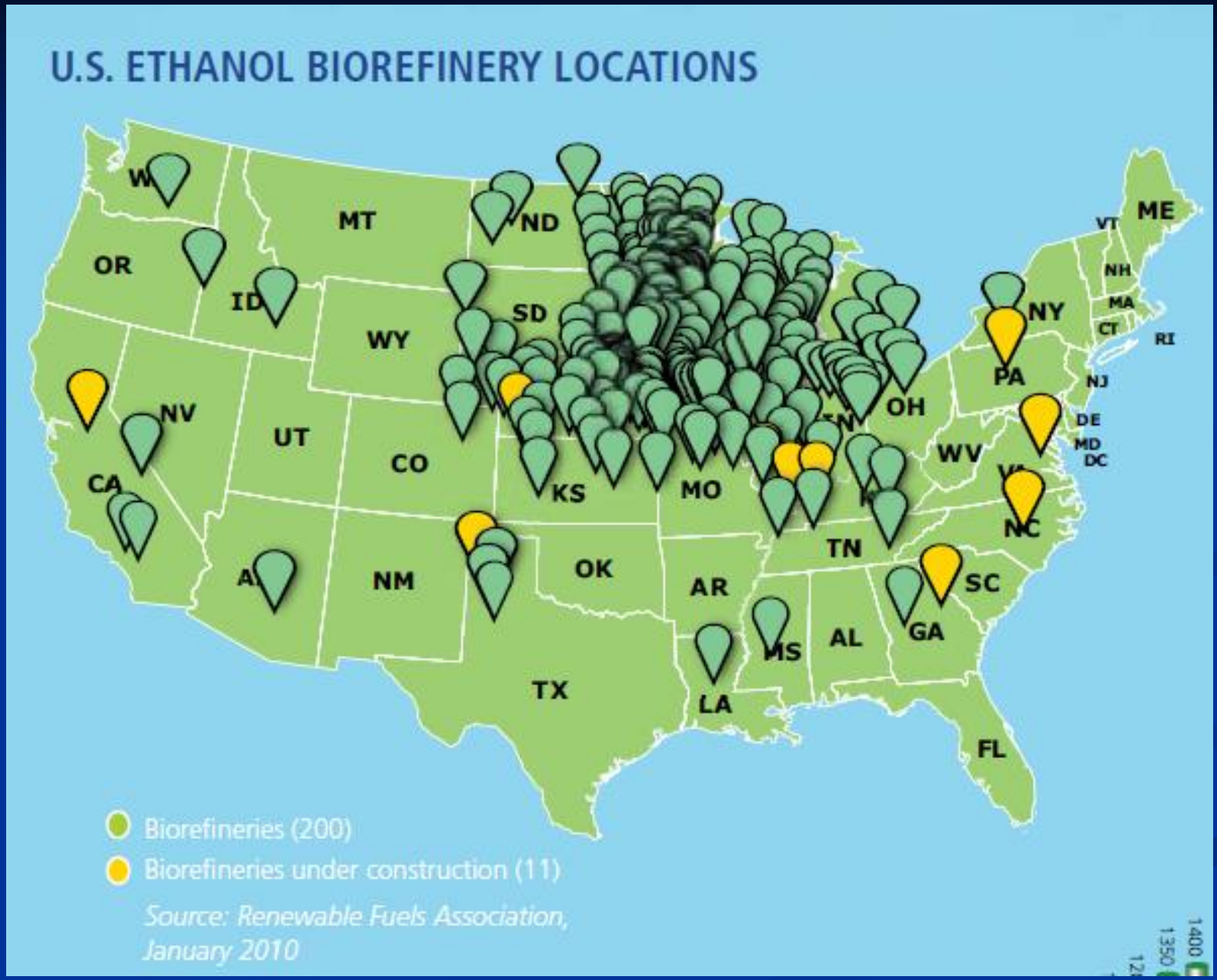


Source: Wang et al, *Environmental Research Letters*, Vol. 2, 024001, May 22, 2007

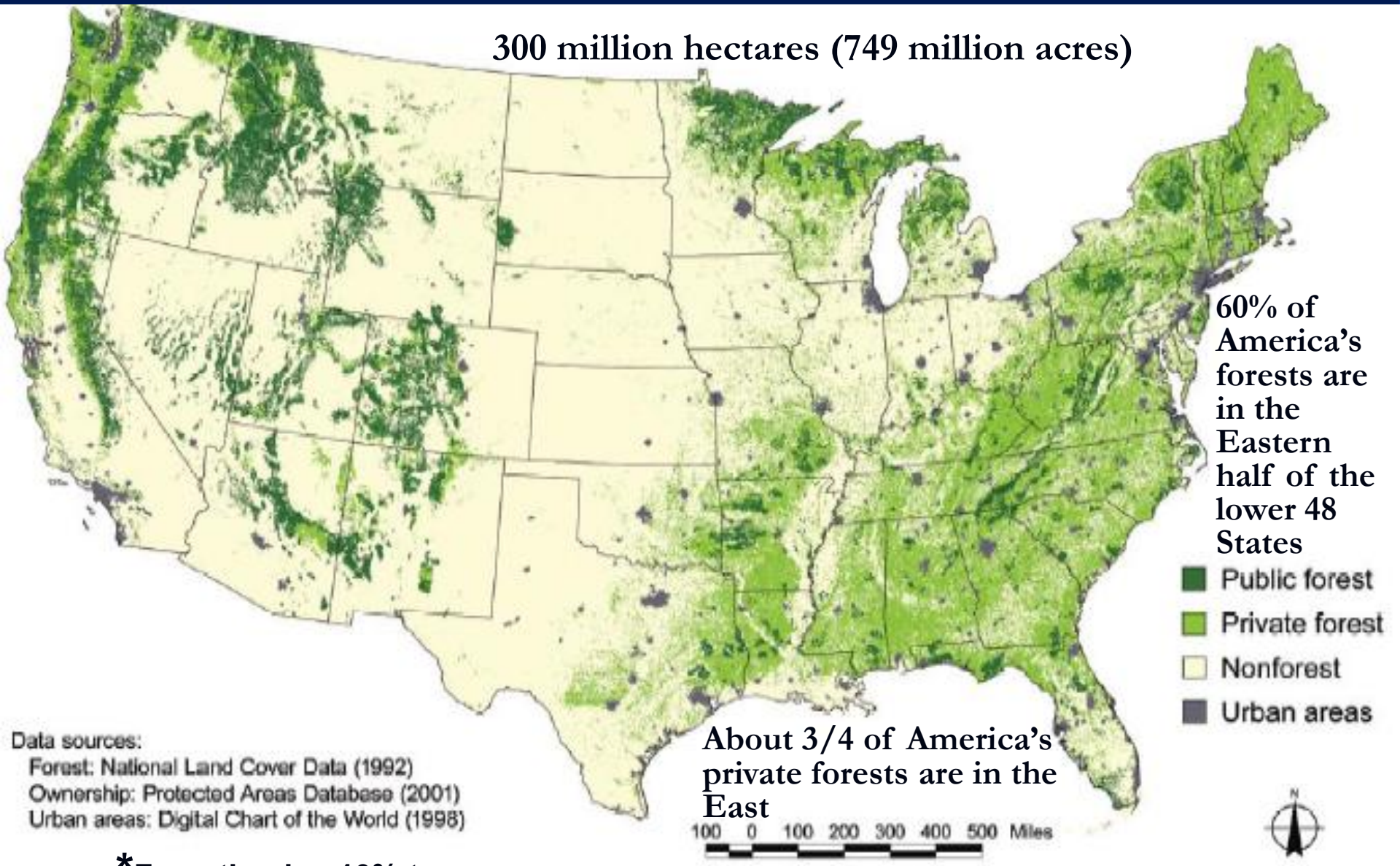
In comparison to gasoline, ethanol made from cellulose and produced with power generated from biomass byproducts can result in an 86 percent reduction in greenhouse gas emissions.



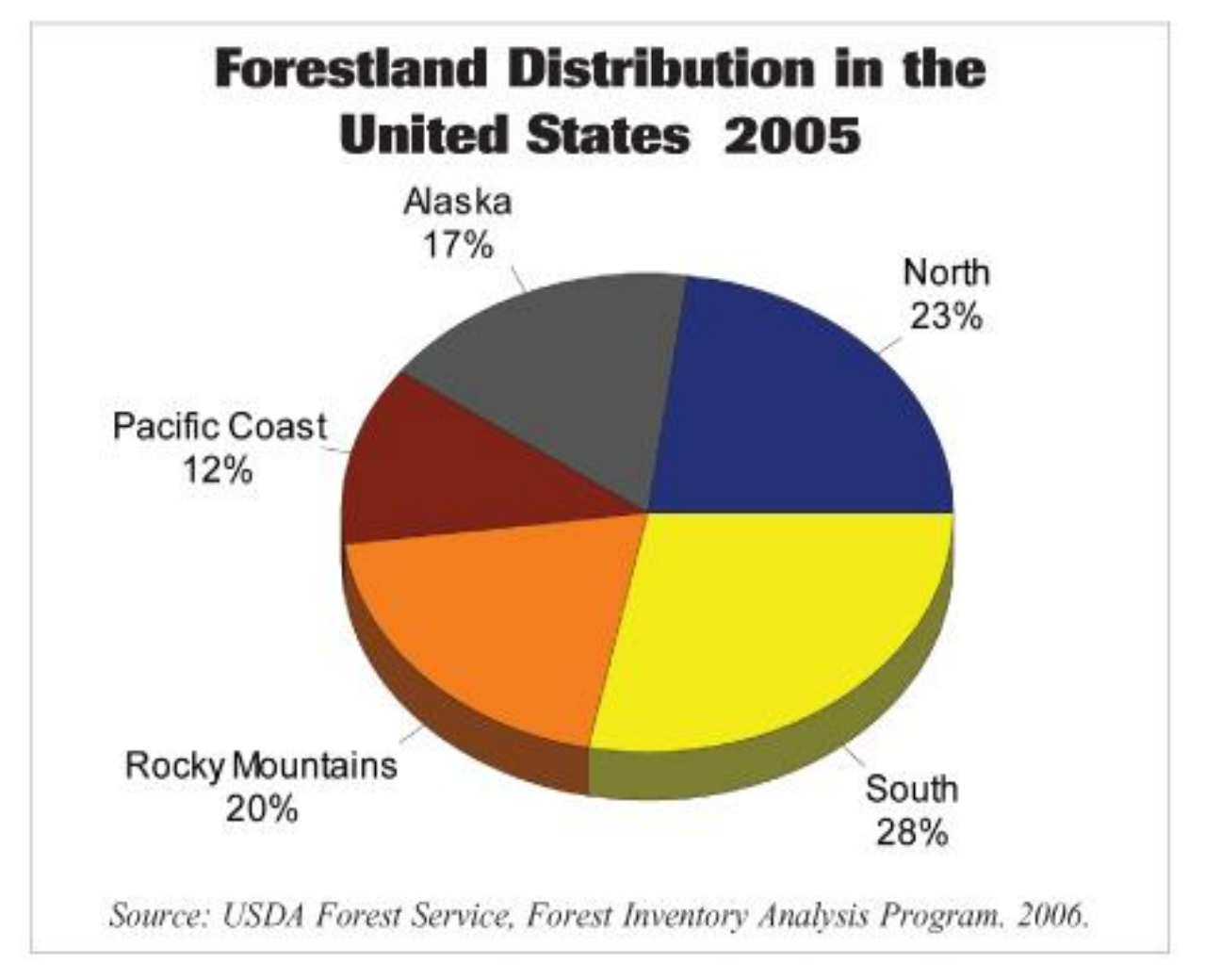
Source: America's Energy Future: Technology and Transformation, National Academy of Sciences, 2009


U.S. ETHANOL BIOREFINERY LOCATIONS
MT
ND
OR
ID
SD
WY
NV
UT
CO
KS
MO
CA
NM
OK
AR
TX
LA
MS
AL
GA
FL
SC
NC
TN
WV
OH
PA
NY
ME
VT
NH
MA
CT
RI
NJ
DE
MD
DC
Biorefineries (200)
Biorefineries under construction (11)
Source: Renewable Fuels Association, January 2010

America's Forest Resource*

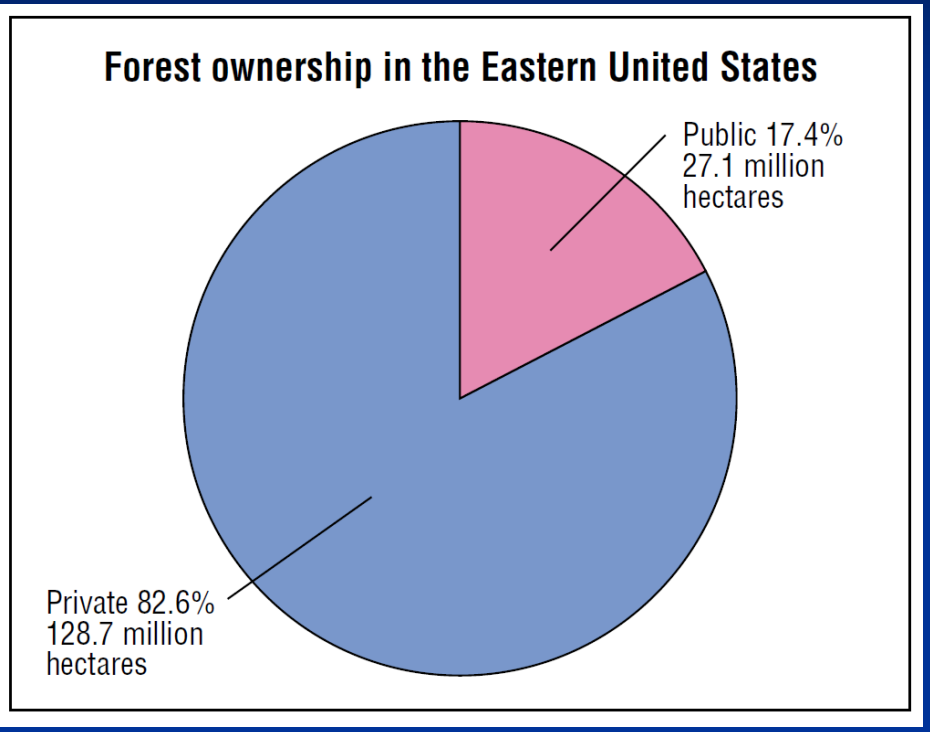


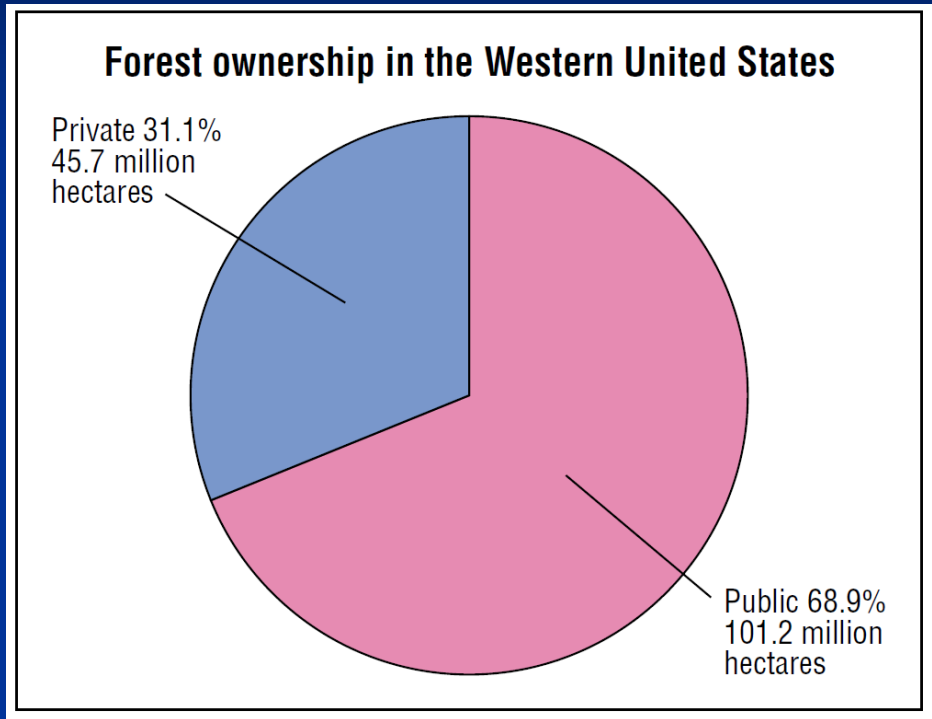
*Forestland > 10% tree cover



www.palletenterprise.com/articledatabase/view.asp?articleID=3049

Forestland Ownership in the US‡





‡Renewable Fuel Standard

- Woody biomass from federal land is not allowed--except from certain wildfire areas
- Non-slash/non pre-commercial thinnings is not allowed from most natural forested landscapes
- Agricultural land must have been cleared or cultivated prior to Dec 19, 2007 and actively managed or fallow, and non-forested

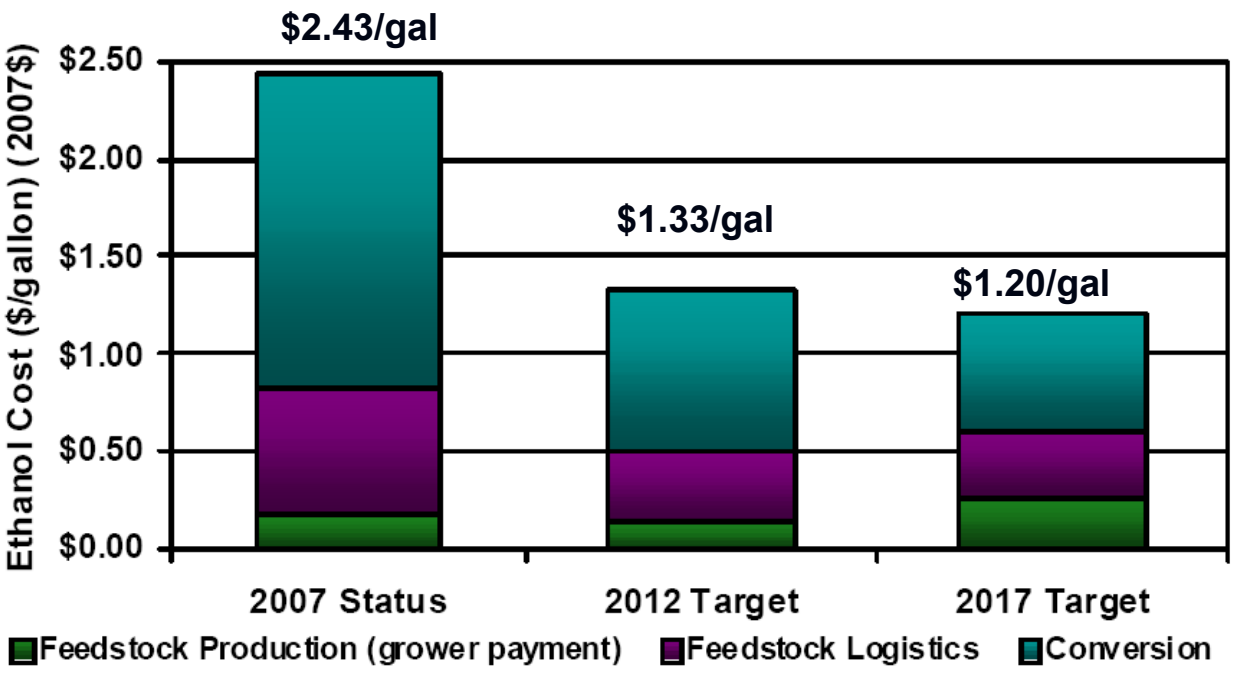
Timberland*, Contiguous US

Region	Standing Biomass	Net Annual Timber Growth	Annual Timber Removals	Annual Timber Mortality
	million dry tons			
NE	4082	49	18	14
NC	3376	50	25	16
SE	3745	92	65	18
SC	4928	107	81	25
Great Plains	157	1	1	1
Intermountain	2857	25	8	20
OR & WA	3122	50	29	14
CA	1381	23	7	5
Total	**23648**	**397**	**232**	**114**
			(~1%)	

http://nrs.fs.fed.us/pubs/gtr/gtr_wo78.pdf

* Growing >20 cubic feet of timber/acre/year (data exclude Alaska & Hawaii)

Feedstock & Logistics Cost Reductions Contribute to Cellulosic Liquid Biofuels Cost Targets*



Biomass Program Feedstock and Conversion Cost Targets

(via Biochemical Conversion)

The 2008 Farm Bill offers a $1.01 subsidy/gallon for cellulosic ethanol and $45/ton to producers/entities that deliver eligible biomass to biomass/biofuels conversion facilities

*Biomass Multi-Year Program Plan (March 2008) DOE Office of the Biomass Program, EE&RE

Forest Biomass for Biofuels Production

- Longer storage life and lower storage costs
- Higher bulk density (lower transportation costs)
- Less intensive use of water and fertilizers
- Established collection system
- Can be left to grow for longer periods of time
- Can be used for a variety of value-added products
- Compared to many agricultural materials
  - Higher lignin content
  - Lower ash content

Forest Biomass to Biofuels Issues

- Challenging goal to economically make biofuels from wood
- Huge amounts of wood exist (as standing timber), *but not all is available* (economically, socially, politically
- EISA restrictions on forest biomass sources make plantation and short rotation woody crops important
- Several types of technologies exist to make biofuels from forest biomass -- with varying raw material input requirements
- When will biofuels from forest biomass become economical without subsidy?
- Impacts on existing wood use markets
- Forest managers and land owners have just begun to contemplate biofuel wood supply issues

Forest Products Industry Biorefinery Value Map

VALUE

SAW LOGS

LUMBER

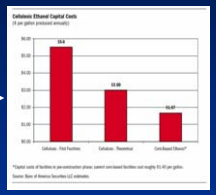
SLAB WOOD

PULP WOOD

BIOMASS

BARK

EXTRACTOR



CHEMICALS

DIGESTER

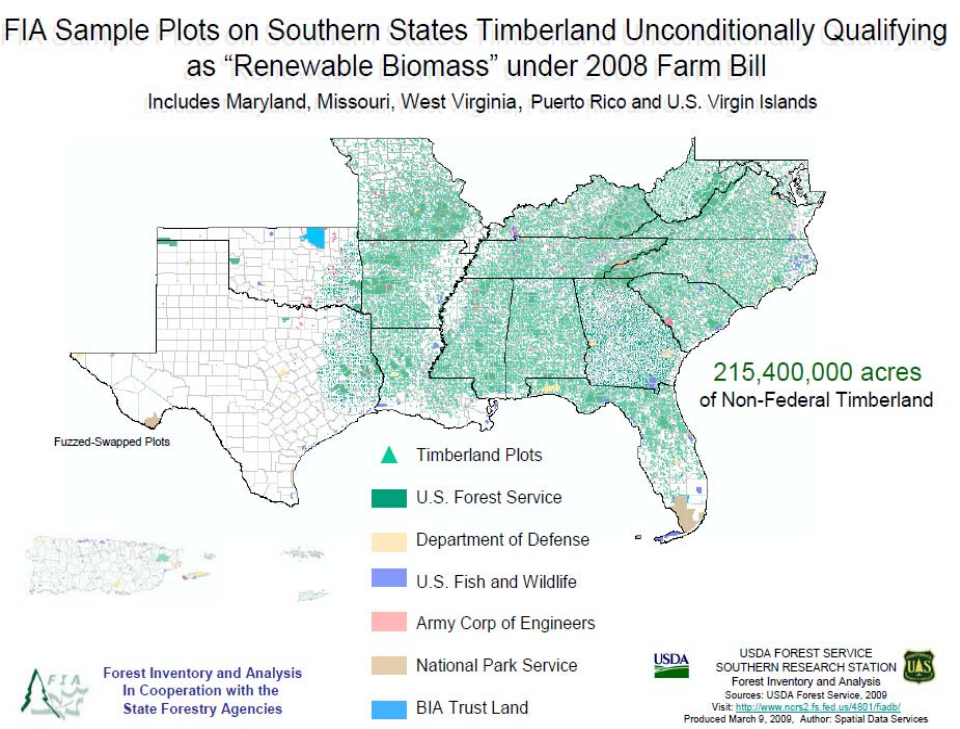
PULP & PAPER

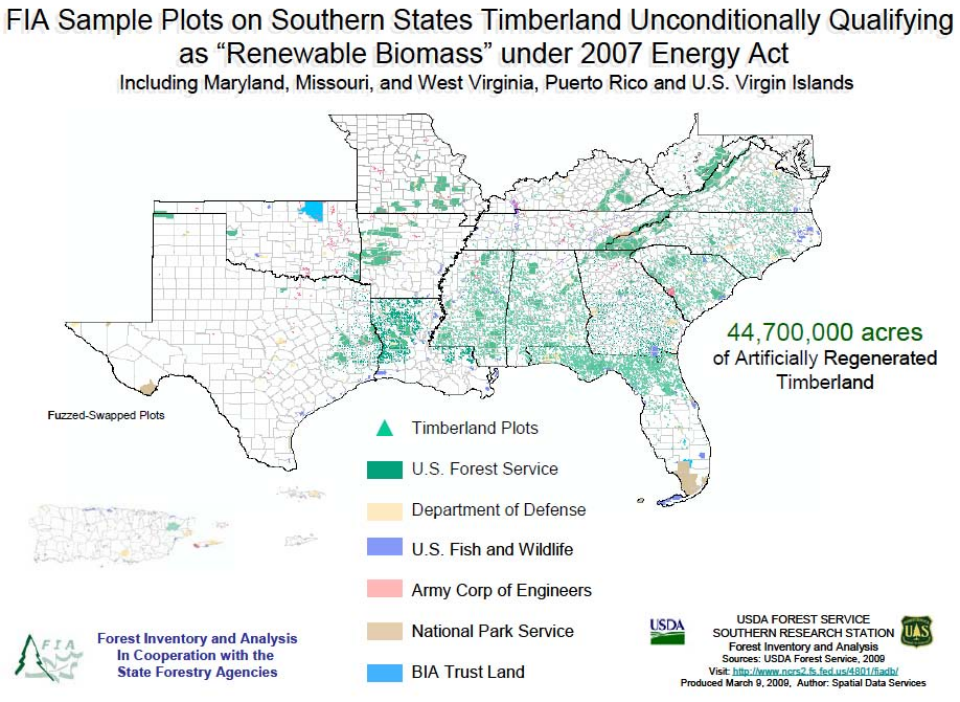
Black Liquor Gasifier

Liquid Fuels

EXTRACTOR/HOG BOILER/ GASIFIER/F-T

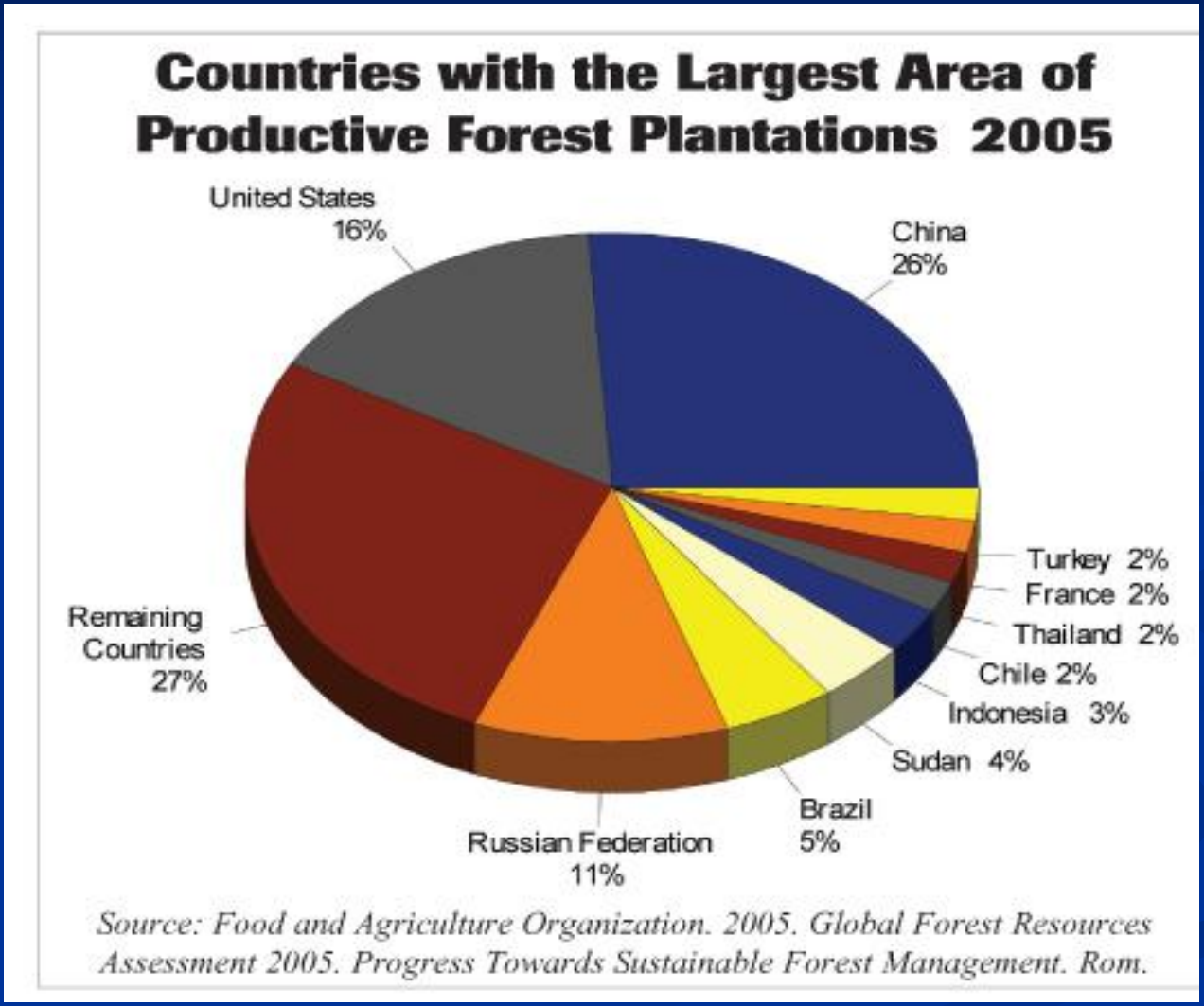
POWER





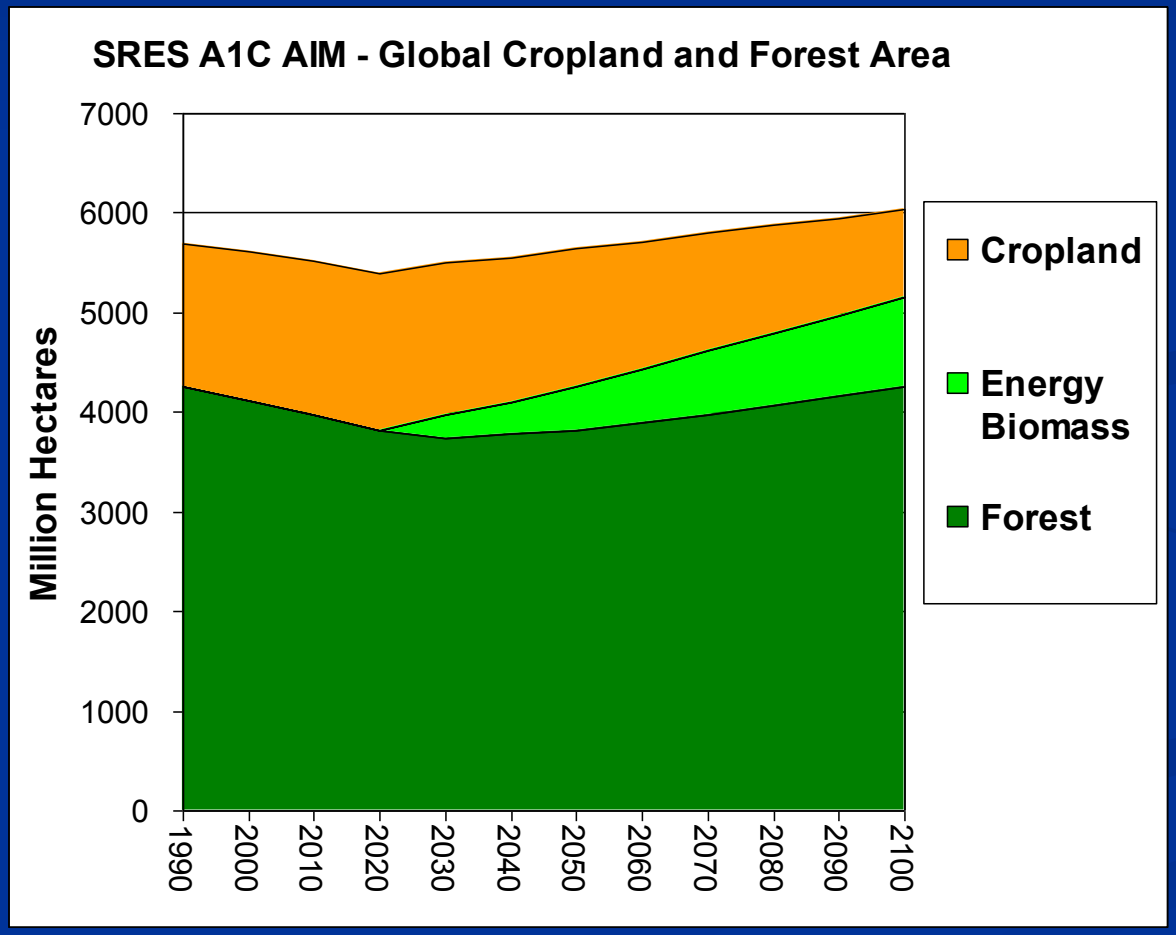
Impacts of Eligible Forestland Criteria Under EISA are Great

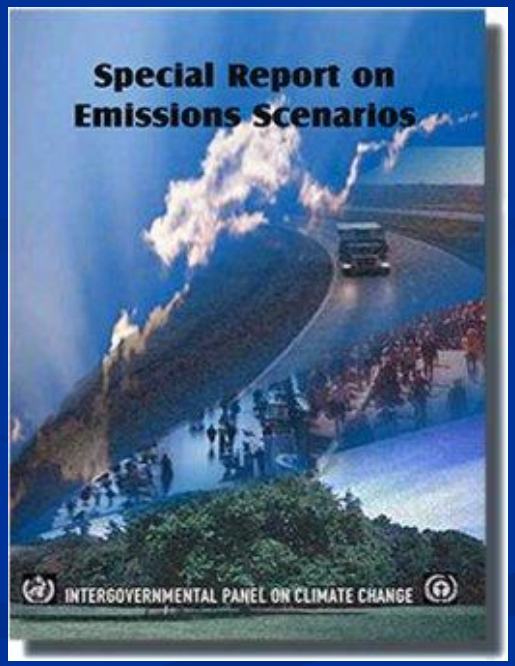
US has Significant Plantations



www.palletenterprise.com/articledatabase/view.asp?articleID=3049

According to IPCC, the land area dedicated to energy biomass (such as SRWC) will expand to hundreds of millions of hectares in the decades ahead as global oil production peaks by 2020 to 2030 and biomass energy production expands . . .

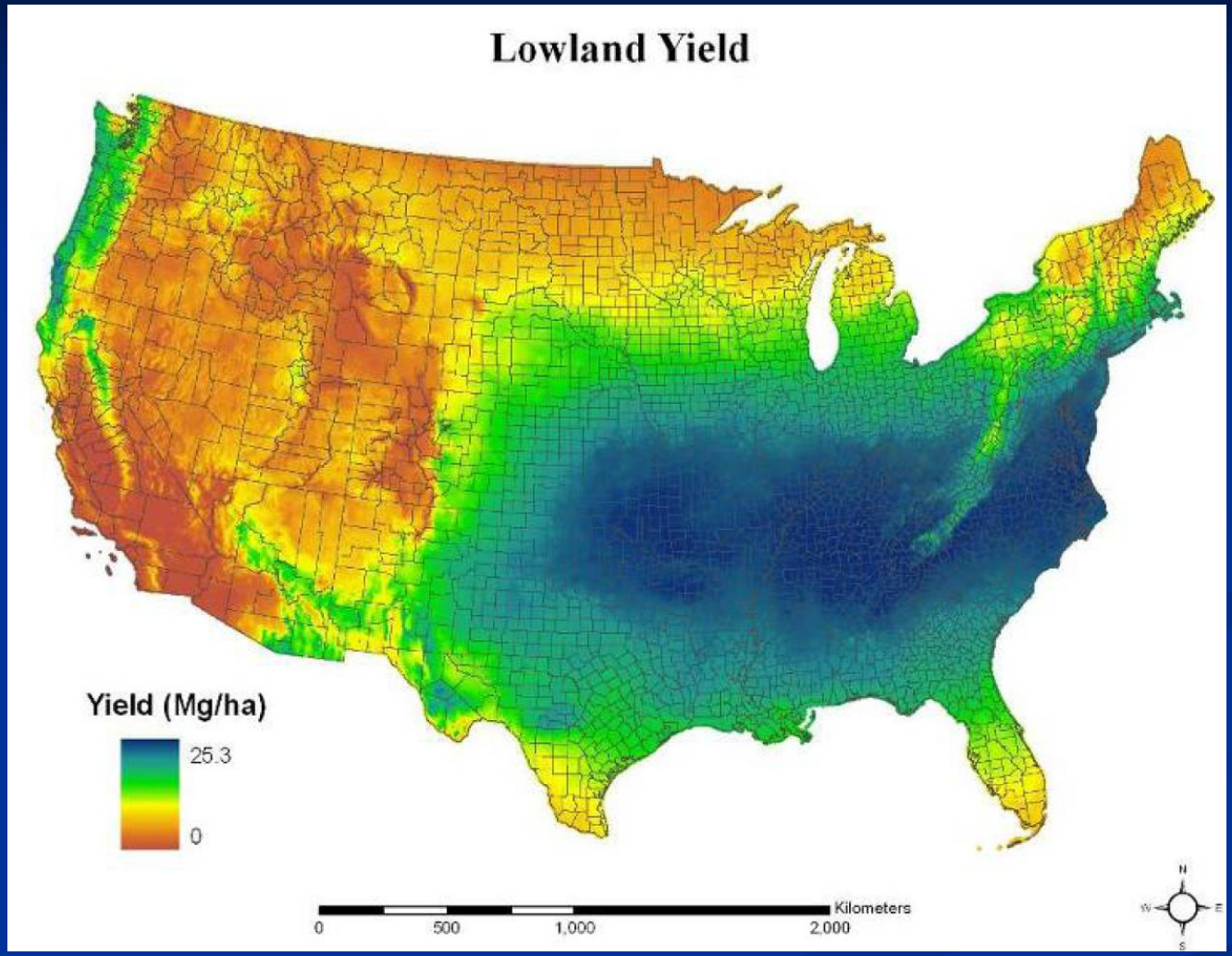




IPCC Special Report on Emissions Scenarios

IPCC – Intergovernmental Panel on Climate Change

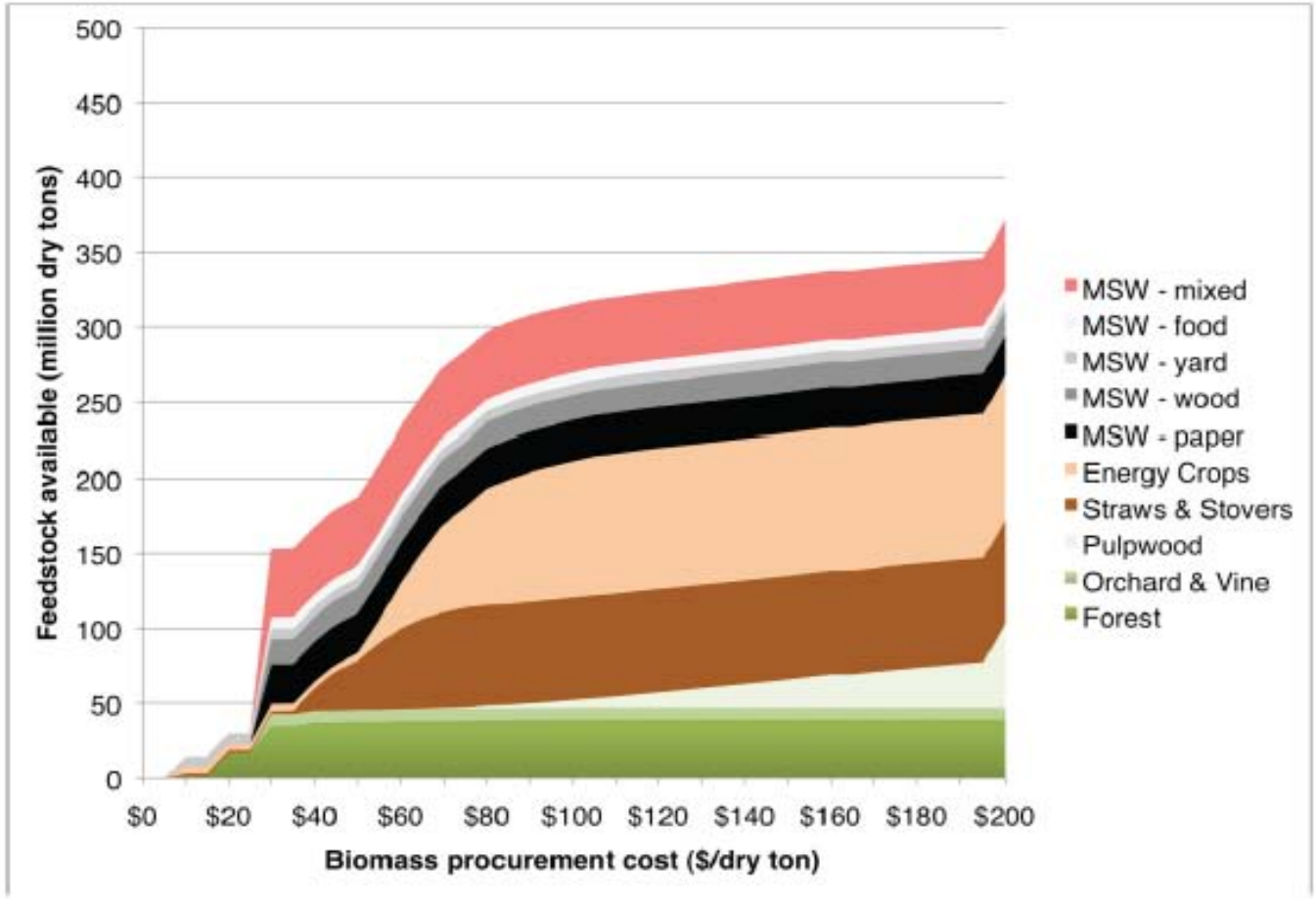
Projected Dedicated Energy Crop Yields



POLYSYS model (Agricultural Analysis Policy Center, University of Tennessee

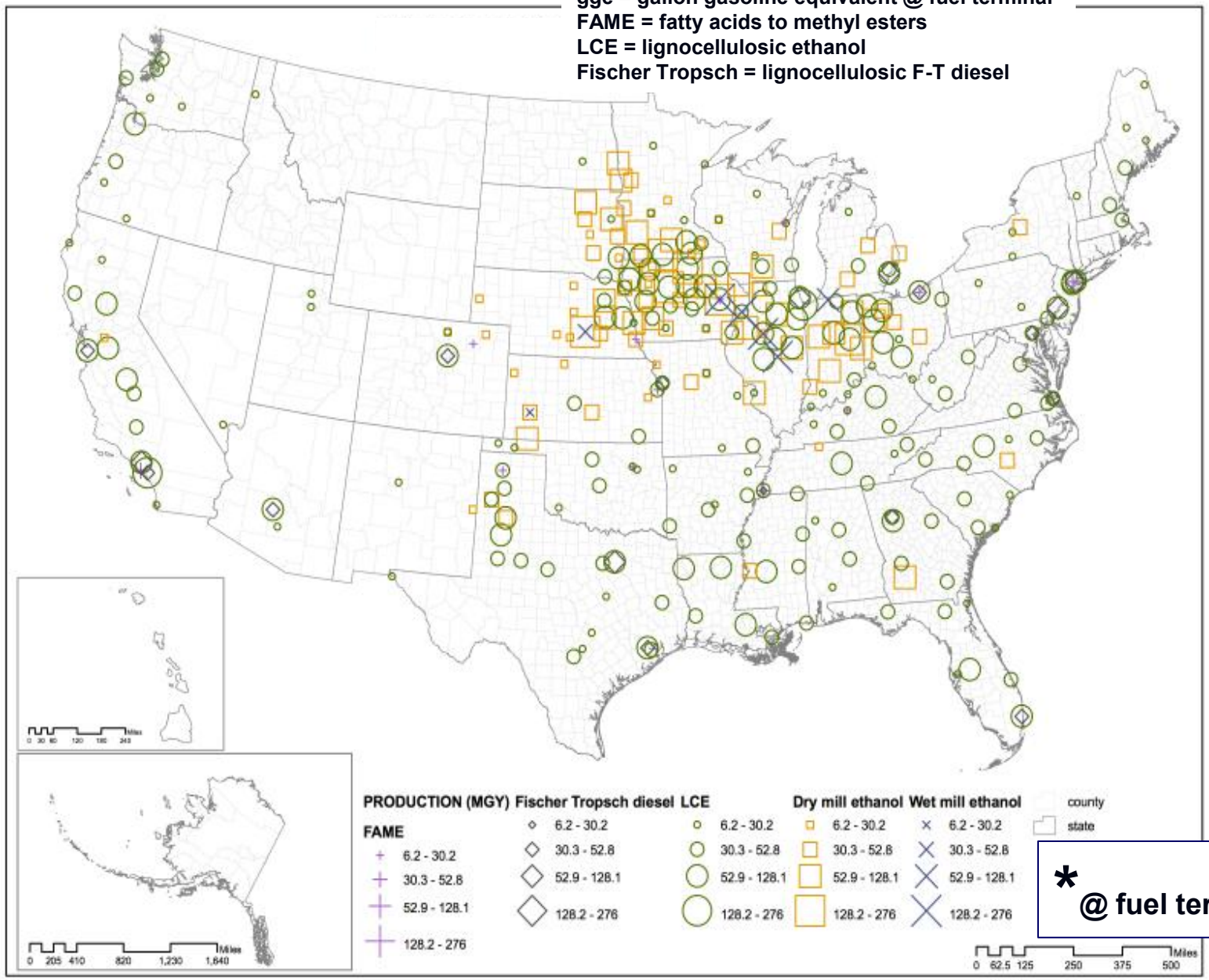
Credit: Robert Perlack ORNL & Robert Rummer USFS 2009

National Biorefinery Siting Model



Procurement (at roadside) cost of modeled cellulosic biomass resources

Locations of Biorefineries at $2.50*/gge



* @ fuel terminal

National Biorefinery Siting Model

Next Steps

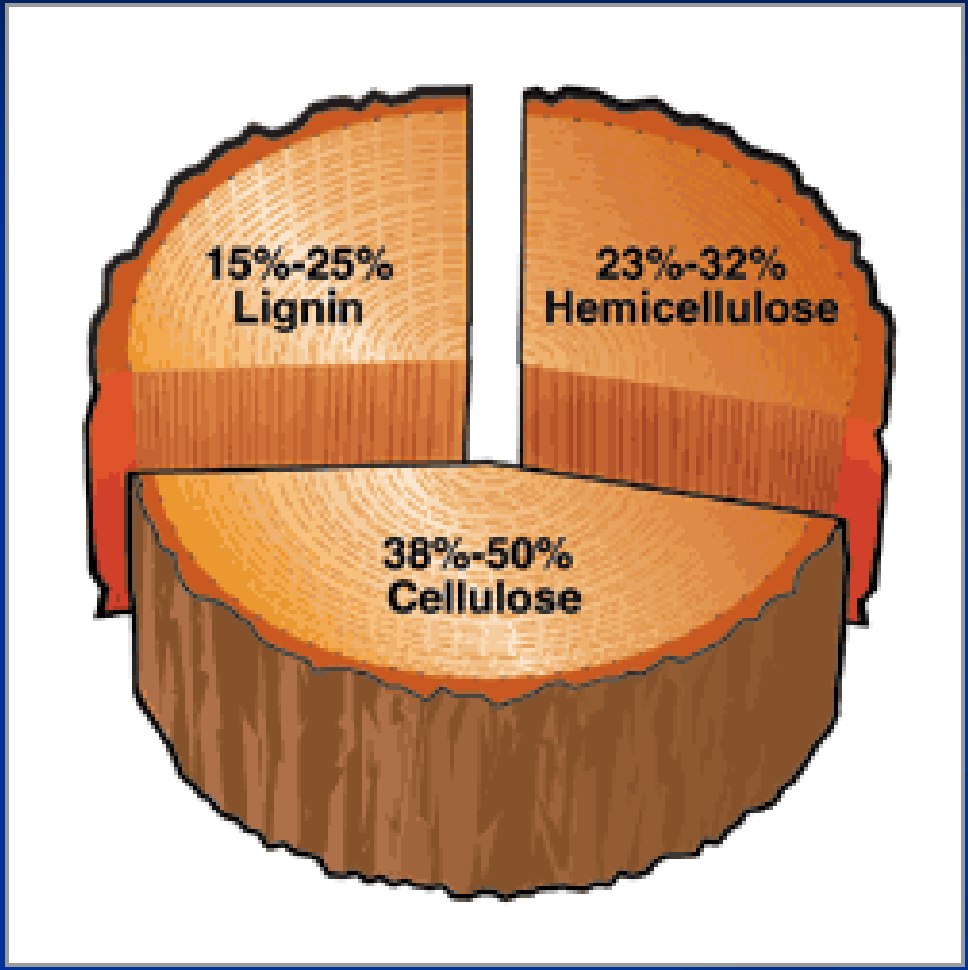
- Expand Siting model
  - Include potential sites for electric power plants using biomass
  - Evaluate competition between biofuels and biopower for biomass
  - Identify sites for biofuels and biopower production

Biofuels Knowledge Gaps

- Biomass harvesting and transportation to conversion facilities are underdeveloped
  - The ability to economically harvest and transport feedstock needs to be developed and understood
- Metrics to compare the performance of various feedstocks and conversion technologies are not available.
  - Key metrics of raw materials like physical/chemical composition and conversion efficiency are not sufficiently available

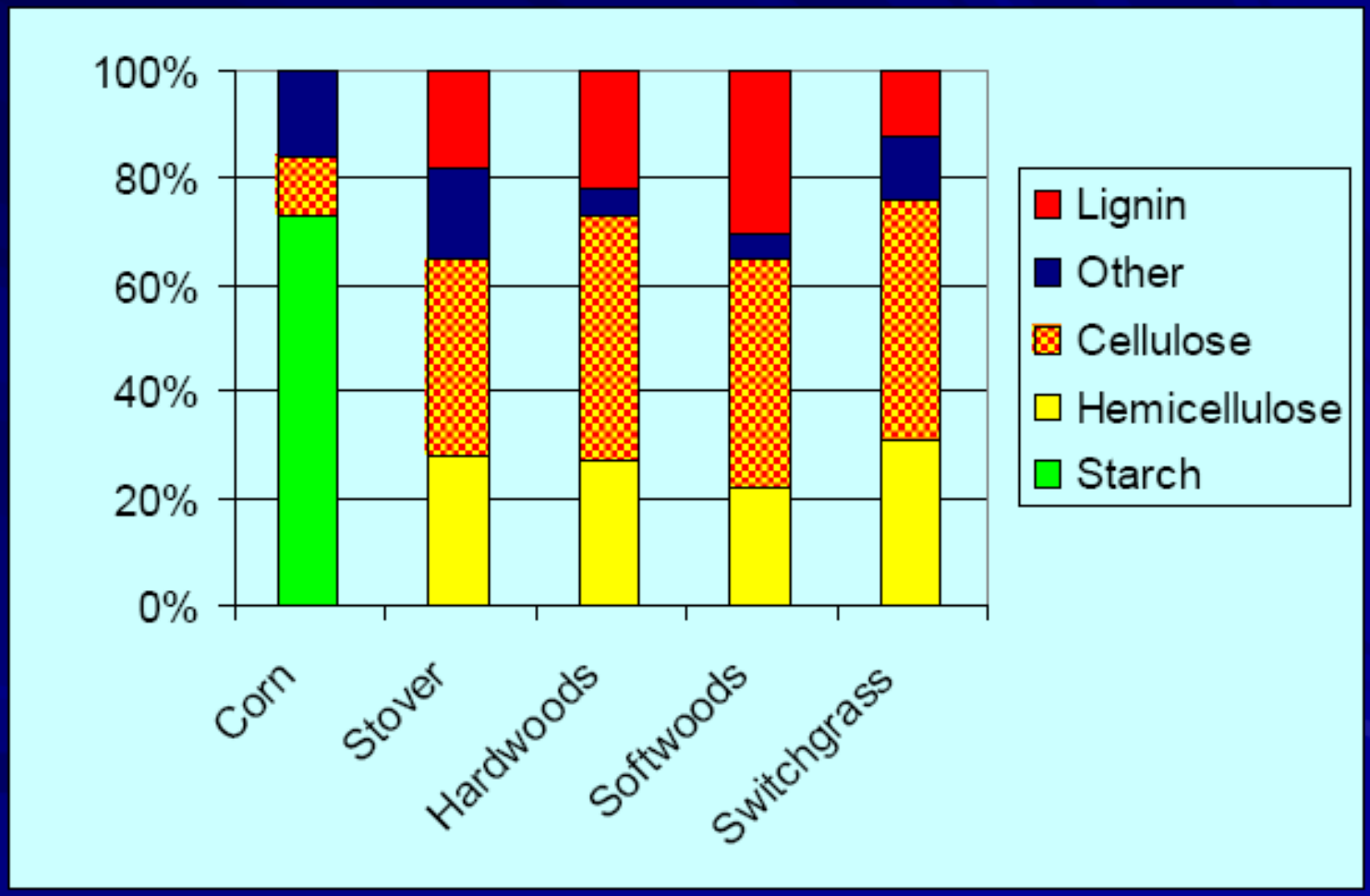
BDC
Biorefinery Deployment Collaborative

Wood Composition*



* Plus ash content (low)

Composition of Various Forms of Biomass



Starch & Cellulose Yield Six Carbon Sugars
Hemicellulose Yields Five & Six Carbon Sugars

Lignin is a cross-linked aromatic compound
Other includes ash content

Lignocellulosic Constituents

Lignin: 15-25%

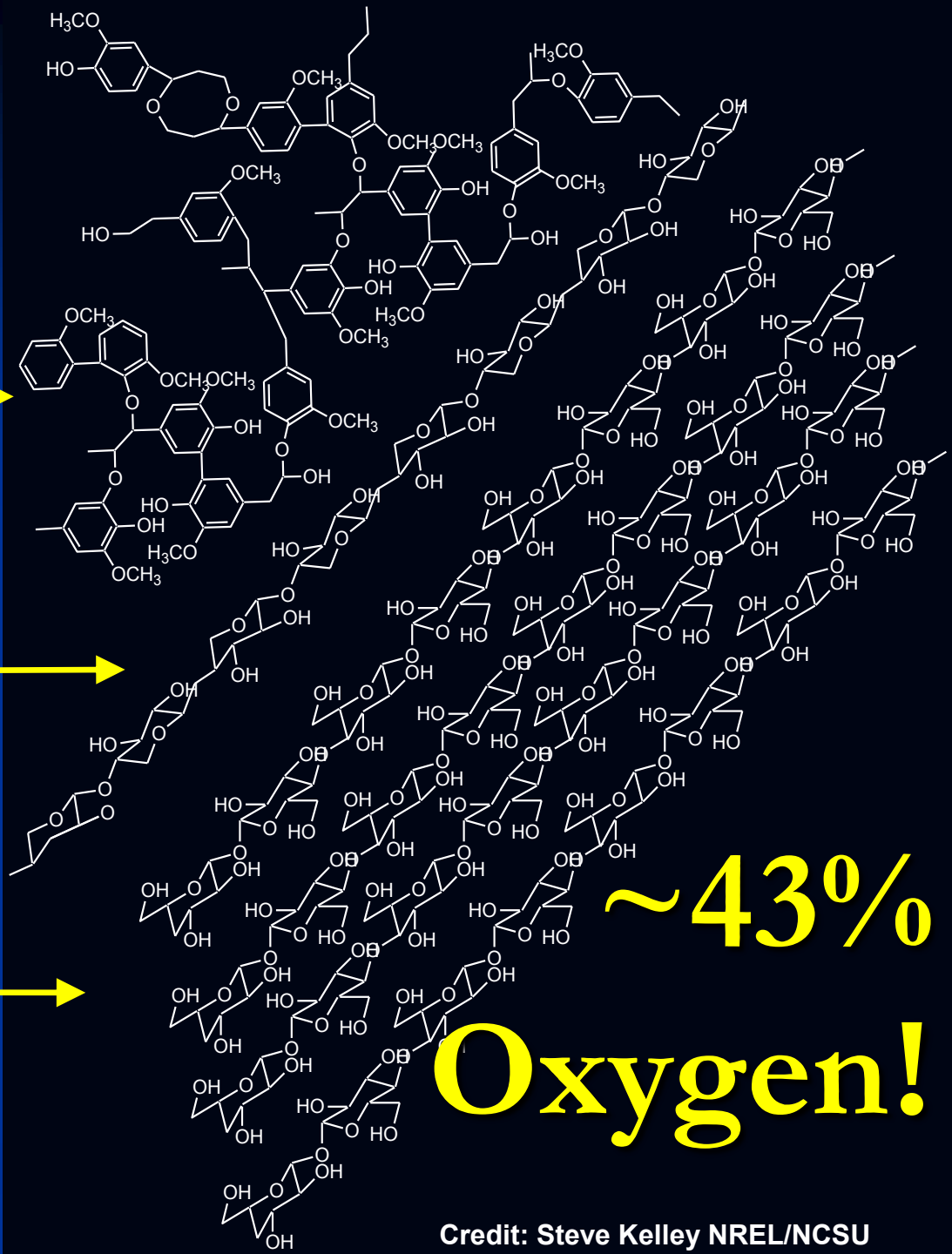
- Complex aromatic structure
- Very high energy content
- Resists biochemical conversion

Hemicellulose: 23-32%

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

Cellulose: 38-50%

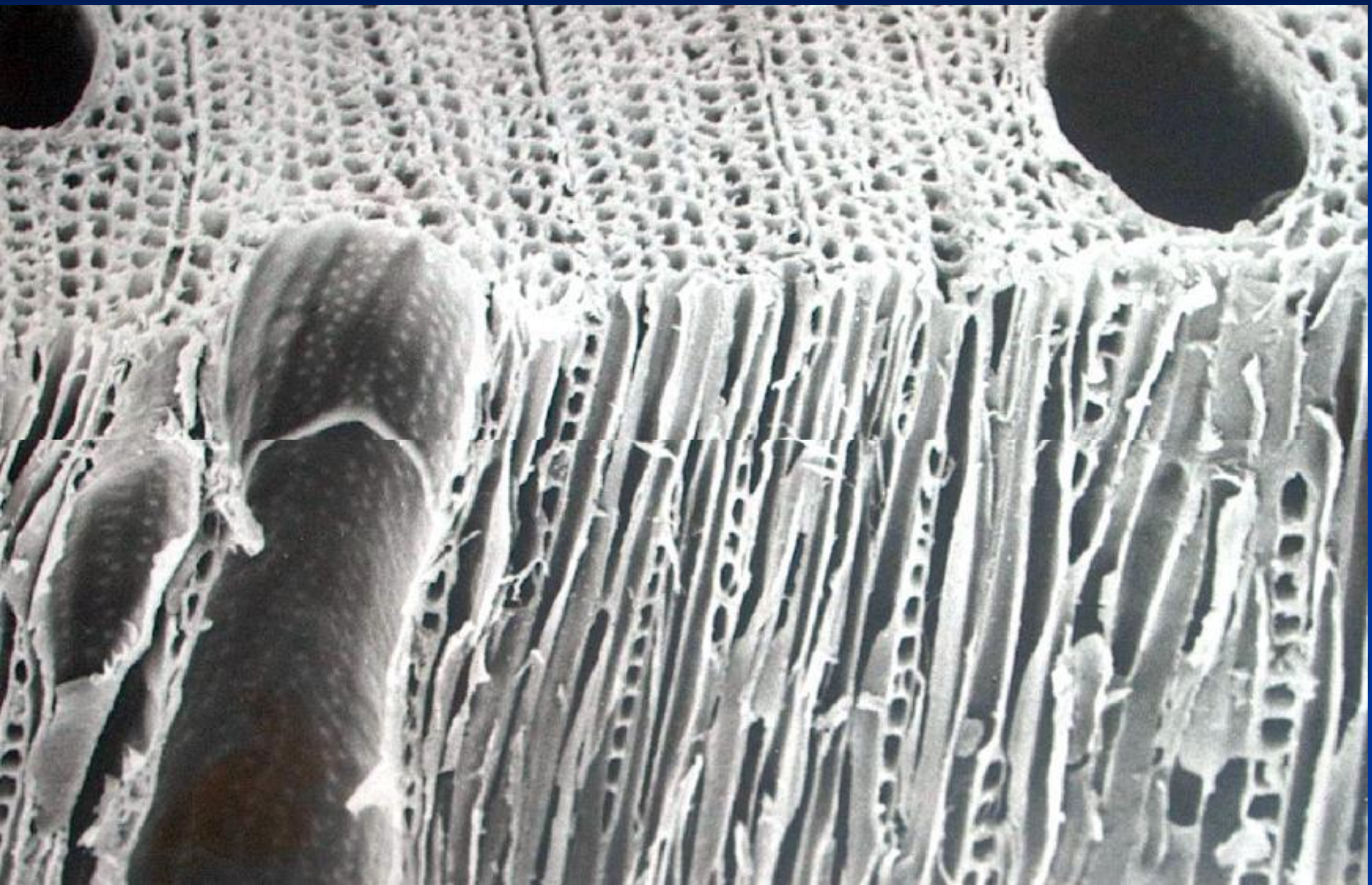
- Most abundant form of carbon in biosphere
- Polymer of glucose, good biochemical feedstock



~43% Oxygen!

Credit: Steve Kelley NREL/NCSU

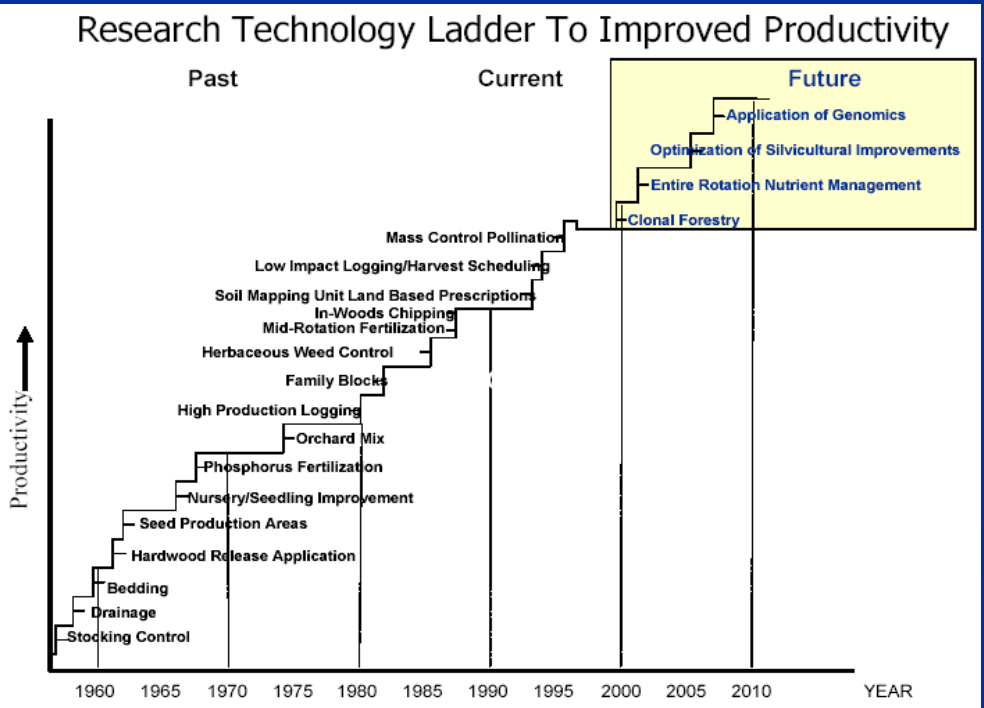
Wood Structure

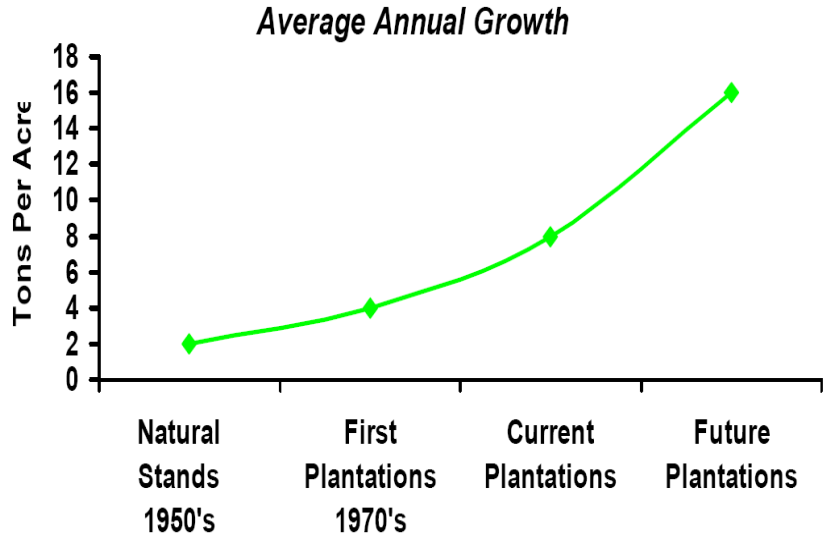


Precision Forestry applications throughout the forest cycle:

setting optimal silvicultural prescriptions for each stand

Genetics, Silviculture and forest management used to increase productivity & manipulate wood properties





Forms of Forest Biomass

Forest Biomass for Current Products

- Source
  - Plantation
  - Natural Stands
- Form - Roundwood
  - Sawlogs
  - Veneer Logs
  - Pulpwood
- Species Used
  - Spruce-Pine-Fir
  - Aspen/Red Alder
  - Mixed Hardwoods (Northern & Southern)
  - Southern Pines (e.g. Loblolly)

Forest Biomass For Biofuels

- **Source**
  - Natural Stands
  - Plantation
  - SRWC
- **Form***
  - Pulpwood
  - Slash (with bark & foliage)
  - Thinnings (with bark and foliage)
  - Whole tree chips (with bark and foliage)
- **Species Used**
  - Hardwoods & Softwoods
  - Purpose Grown Biofuel Trees (e.g. poplar, willow, eucalyptus, loblolly pine)

*Biochemical Conversion processes require bark and foliage free wood

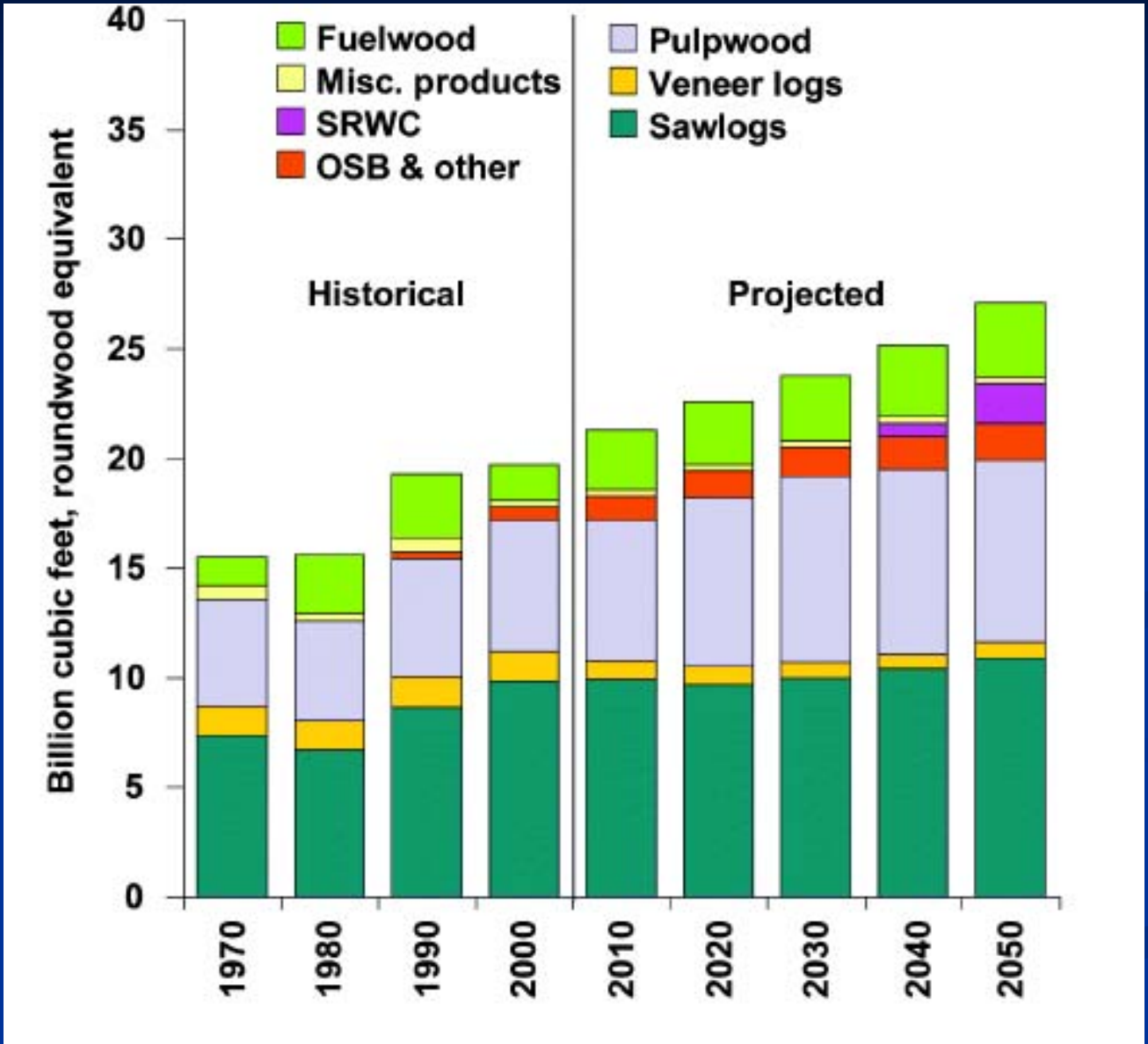
AF&PA®

AMERICAN FOREST & PAPER ASSOCIATION

GROWING WITH AMERICA SINCE 1861

- **AF&PA believes market forces should be the primary stimulant for the use of wood and wood waste as a renewable fuel source and for determining the optimum fuel choices for energy generation.**
- **Where the state or federal governments are instituting incentives or mandates for renewable energy, those policies should maintain regional agricultural and silvicultural capability and consider impacts to existing regional fiber markets.**
- **The industry strongly supports federal research, development, and demonstration efforts for breakthrough technologies in the areas of biomass production, manufacturing, and production of value added products such as biofuels.**
- **Where the government has allowed tax credits for renewable energy, we support the development of transparent systems and mechanisms to ensure the credits are accurately employed.**

RPA* Wood Uses Projections



* Haynes, et. al. -- US Forest Service 2007 Resources Planning Act Timber Assessment Update

Market Forces Affecting Wood Supply & Property Issues

- Current wood uses will continue driving wood property and species use/considerations
- RPA projections show that:
  - Fuelwood use will grow from 2000 levels
  - SRWC production will become more evident after 2030

Current Products Desired Wood Properties

Product category	Forest wood sources	Desired wood properties
Current wood products • Structural lumber (softwoods) • Appearance lumber (softwoods) • Hardwood lumber • Plywood • Composite panels (e.g., OSB, MDF, particleboard) • Paper, paperboard, and other pulp fiber-based products	Commercially important hardwood and softwood species from plantations and natural stands • Sawlogs • Veneer logs • Pulpwood	• Higher uniformity of chemical and physical properties • Higher specific gravity (density) • Lower microfibril angle • Higher cellulose content • Higher growth and yield (lower cost per ton delivered or per ton carbon) • Decreased/modified lignin content • Improved stem form (for sawlogs, veneer logs) • More desirable wood color • Longer and more flexible tracheids (fibers) • Less juvenile wood • Lower moisture content (reducing transport costs)

Forest Biomass to Energy

Forest Biomass Feedstock

- Pulpwood
- Slash
- Short rotation woody crops
- Thinnings

Conversion Processes

- Co-firing/ Combustion
- Gasification/Pyrolysis
  - F-T Liquids
  - Gas/liquid fermentation
- Bioconversion
  - Hydrolysis/fermentation
- Catalytic Conversion

USES

Fuels

- Ethanol
- Advanced biofuels
- Renewable diesel

Electricity and Heat

Biobased Products

- Composites
- Specialty products
- New products
- Chemicals
- Traditional products

Biofuels Desired Wood Properties

Product category	Forest wood sources	Desired wood properties
Biofuels/electric power/heat—Gasification/ pyrolysis/direct combustion	Hardwood and softwood species from plantations and natural stands • Pulpwood • Short-rotation woody crops • Biomass—slash/ thinnings (with bark)	• Higher growth and yield (lower cost per ton delivered or per ton carbon) * • Higher specific gravity (i.e., higher energy density) * • Low ash content • Lower moisture content (reducing transport costs) * • Low degrade in storage
Biofuels—Biochemical conversion	Hardwood and softwood species from plantations and natural stands • Pulpwood • Short-rotation woody crops • Biomass—slash/ thinnings (with bark removed)	• Higher growth and yield (lower cost per ton delivered or per ton carbon) * • Higher cellulose content (six-carbon sugars) * • Higher specific gravity (density) * • Lower recalcitrant cellulose (i.e., crystalline cellulose) • Higher six-carbon sugars in hemicelluloses • Higher syringyl lignin ratio (S/G ratio) • Lower moisture content (reducing transport costs) *

* **Commonality with Current Products Desired Properties**

Summary

- The US has a large & distributed inventory of forest biomass
- Genetic improvements and forest management enable manipulation of wood properties to meet end use and conversion process needs
- Successful supply chain investments can significantly improve economics in the areas of forest productivity, harvesting, transportation, and conversion
- Plantation and short-rotation hardwood & softwood crops are very important for biofuel feedstock production

Summary- *Continued*

- Biochemical conversion requires pulpwood quality wood
- Thermochemical conversion can use a wider variety of wood sources including slash, thinnings and short rotation woody crops
- Commercialization of wood biofuel production is in its infancy and may require several decades to mature
- Strategies for Forestland owners
  - Grow ‘generalist’ trees that have a wide number of uses and applications
  - Grow ‘specialist’ trees with very specific properties for specific markets (e.g. biofuels) where a performance premium could be obtained


BIOMASS
2010
Questions
100 Years of Service
FOREST SERVICE
DEPARTMENT OF AGRICULTURE
Forest Products
Laboratory
1910 – 2010
USDA Forest Service
Research and Development
USDA

Renewable Biomass Under the Farm Bill

The term renewable biomass means:

(A) materials, pre-commercial thinnings, or invasive species from National Forest System land and public lands (as defined in section 1702 of title 43) that

(i) are byproducts of preventive treatments that are removed

(I) to reduce hazardous fuels;

(II) to reduce or contain disease or insect infestation; or

(III) to restore ecosystem health;

(ii) would not otherwise be used for higher-value products; and

(iii) are harvested in accordance with

(I) applicable law and land management plans; and

(II) the requirements for

(aa) old-growth maintenance, restoration, and management direction of paragraphs (2), (3), and (4) of subsection (e) of section 6512 of title 16; and

(bb) large-tree retention of subsection (f) of that section; or

(B) any organic matter that is available on a renewable or recurring basis from non-Federal land or land belonging to an Indian or Indian tribe that is held in trust by the United States or subject to a restriction against alienation imposed by the United States