UNIVERSITY OF MINNESOTA
EXTENSION

Biomass Energy Potential in Minnesota

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Fueling the Future: The Role of Woody Biomass for Energy Workshop

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St. Cloud

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Biomass Energy Potential in Minnesota

- National picture and progress of technology
- Put in context of current industry and new technology
- Do opportunities exist?
- Where and to what extent?

Natural Resources Research Institute

To *foster economic development of Minnesota's natural resources in an environmentally sound manner to promote private sector employment*

- Two Centers
  - Center for Applied Research and Technology Development
  - Center for Water and the Environment

- CARTD
  - Mining and Economic Geology
  - Peat/Environmental Processing
  - Forestry and Forest Products

Drivers

- Energy security
- CO2 concerns
- Economics
- Legislative Actions

Legislative Action in Minnesota

- NSP then Xcel Energy Mandate
- Renewable energy targets in lieu of dry cask storage at the Prairie Island Nuclear Facility
- Forced to solicit RFPs for renewable power
- 2007 MN Legislature – 25 X 25 passed with bipartisan support
- Target of 25% of electrical generation by 2025, higher for Xcel Energy – 30%
- Most being met by wind although biomass torrefaction may have potential

Current Energy Prices

Fuel	$/unit	unit	$/mmbtu	efficiency	net cost
Natural Gas	$6.00	mmbtu	$6.00	0.9	$6.66
Heating Oil	$2.15	gallon	$15.50	0.85	$18.19
Propane	$1.90	gallon	$20.87	0.9	$23.20
Round Wood	$75.00	cord	$3.83	0.6	$6.38
Round Wood	$100.00	cord	$5.11	0.6	$8.52
Wood Chips	$20.00	gr. ton	$2.35	0.6	$3.92
Wood Chips	$30.00	gr. ton	$3.52	0.6	$5.88
Wood Pellets	$225.00	dry ton	$13.23	0.8	$16.54
PRB Coal	$30.00	ton	$1.5	0.6	$2.50

- Note value added in pellets:~$60.00/dry ton feedstock = some margin
- Potential for economic development – get loggers back to work

Potential Demand for Pellets

- Replacing propane with wood pellets the most attractive near-term option

- $23 versus $16.50 per Mmbtu

- Typical home payback – 6 years if propane and $3,000 for pellet burner

- European markets for pellets

Gasification to Replace Natural Gas Frontline/CVEC at Benson, MN

Natural Gas

- Current price is $5.00/MMBTU
- Summer of 2008 - $10.00 per MMBTU
- Can be used in fleet transportation immediately – Picken's Plan
- @ $5.00/MMBTU = $0.62 per gallon gasoline-equivalent
- Haber Process – all N fertilizer comes from natural gas
- $75.00 roundwood = $3.67/MMBTU / 0.75 efficiency conversion to gas = $4.90 + $3.00 gasification OM+capital = ~$8.00 per MMBTU breakeven for gasification using wood

Development of the Ethanol Industry

- The industry has grown rapidly in response to RFS requirements and MTBE replacement
- Currently 6.5 billion gallons corn ethanol going to 8 billion by 2012
- State of the Union Target – 35 billion gallons by 2017
- Lofty goal – only cellulosic could fill the need

How Much Starch-Based Ethanol?

- 8 billion gallons of ethanol = 24% of U.S. corn crop
- $3.30/bushel local price (~ $3.63 CBOT)
- $1.22 in feedstock alone @ $2.90/bushel
- Gasoline @ $1.60 (taxes out) X 85% = $1.36
- 8 billion gallons X 85% = <5% of our gasoline needs
- MN - Currently 16 plants producing roughly 500 million gallons/year, 18% of corn crop
- Without subsidy, very difficult for corn ethanol

DOE/USDA "Billion Ton Study" Cellulosic Feedstocks

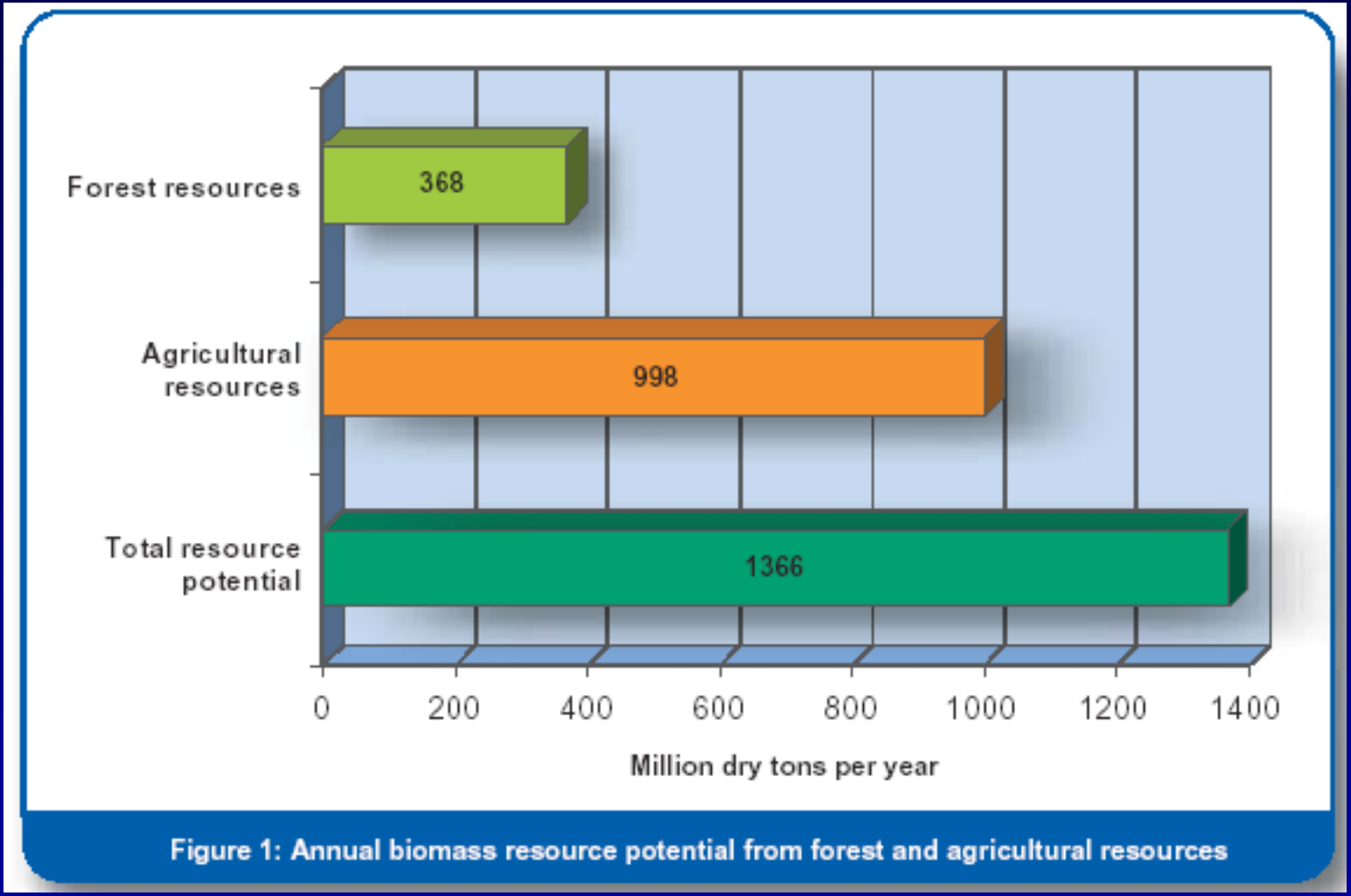


Figure 1: Annual biomass resource potential from forest and agricultural resources

Of the agricultural resources: 428 million tons are crop residues, 377 million tons from perennial energy crops on 55 million acres of land

Scale of Energy Issues

Some context:

- **U.S. demand for gasoline is approximately 150 billion gallons/year**
- **President's State of the Union speech**
- **U.S. target of 35 billion gallons of cellulosic ethanol**
- **300 million dry tons just to hit that target**
- **20% of national demand**

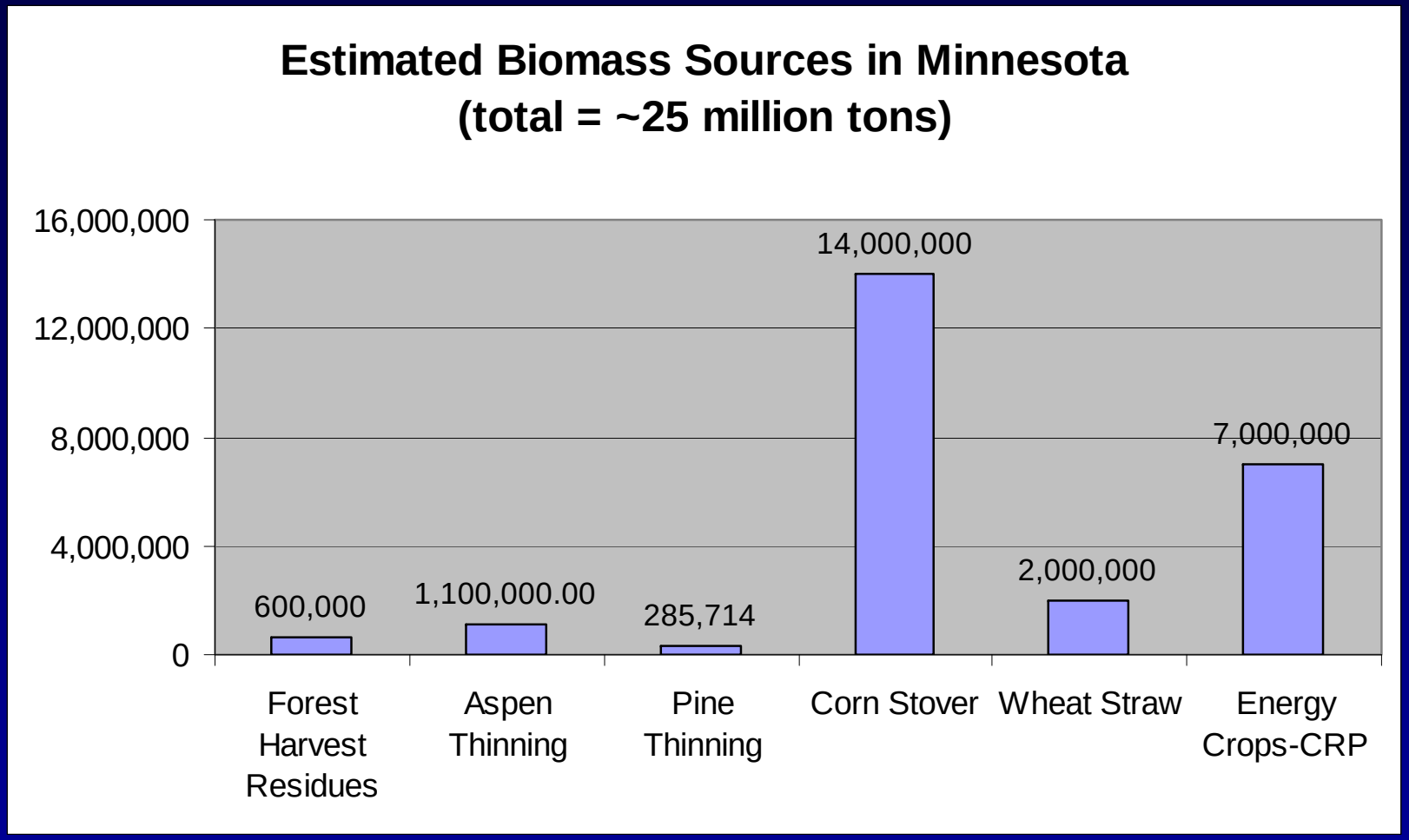
Implications of Cellulosic Ethanol

- 1.4 billion tons X 90 gallons/ton = 86% of current U.S. gasoline demand
- Rapidly becoming cost-competitive
- Could change geopolitical landscape/energy security
- Create jobs and retain income in the U.S.
- Carbon neutral
- Revive rural America

Infrastructure Needs

- To process one billion tons in U.S. = 1,000 plants
- $300 million each X 1,000 = $300 billion
- Are oil companies correct in assessment of reserves?
- If they are incorrect, what will it cost us?
- Certainly hit peak of domestic production (at least peak of low-cost fuel)

Potential Biomass Sources in Minnesota



- ~ 25 million tons X 90 gallons/ton = 2.2 billion gals
- MN is 1.7% of U.S. population = 2.4 billion gals/yr

Minnesota Energy Needs

- Estimated 30 million tons needed to move people
- 30 million tons needed to replace coal
- Numbers are staggering, not happening anytime soon
- Depending on analysis, 25 - 30 million available, all sources
- Aggressive use of all forms of biomass
- Economics will drive the process forward

Minnesota's Forest Resource GEIS and Sustainable Harvest

- 5.5 million cords sustainable
- 3.0 million cords harvested currently
- Uncertainty regarding imports and net impact on in-state harvest
- 2.0 to 2.5 million cords potentially available
- Particular niches in low-value hardwood (ash, maple, tamarack, birch)
- Obviously harvest levels affect harvest residues

Other Sources - Red Pine Thinning

- Periodic thinning to increase diameter and value
- Typical first thinning at age 25, 8 to 10 years thereafter

Aspen Strip Thinning

Strip Thinning of Aspen – Blandin Site

- Strip thinning trials began by NRRI on industry lands in 1989
- After 16 years, no difference in total volume, larger tree size in thinned
- Strip thinning could produce 10 dry tons/acre if feasible
- 100,000 acres/year X 10 tons = 1,000,000 cords
- How to collect? – not a trivial problem

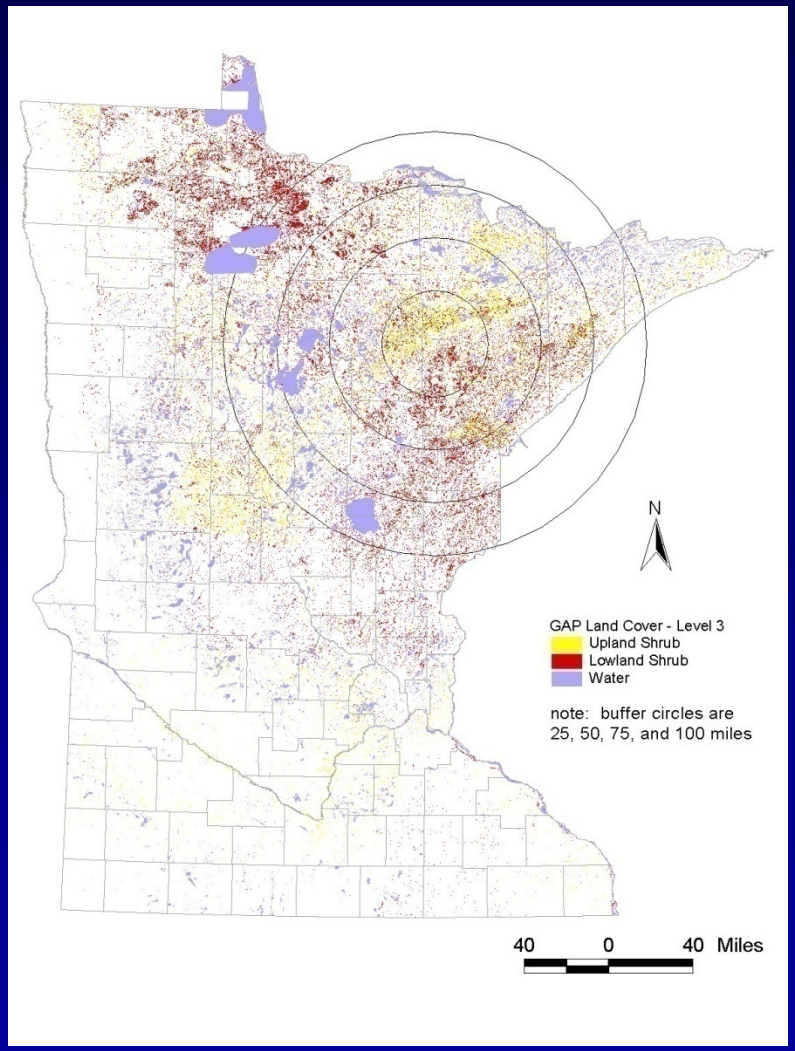
Mid-Rotation Aspen Thinning

Age 25 Aspen Stand

- Interest in evaluation of feasibility of thinning at mid-rotation
  - Economic feasibility – equipment needed, efficiency
  - Equipment manufacturers willing to test new “energy heads”
  - Biological feasibility – what effect on future harvest?
- Planning setting up test sites in 2008 for biological information
- Assist with landowners to evaluate economic feasibility

Brushland Resource and Harvesting

- Potential source of biomass
- Highly variable
- Amount and costs
- Important to identify high-biomass sites to defray expenses over greater volume



Brushland Biomass

- Study done in 1995 of brushland density and biomass
- Estimated biomass of 400,000 dry tons/year
- Efficient forwarding of windrowed material the issue
- DOE-supported project through LEA to develop and test equipment

Forest Harvest Residues

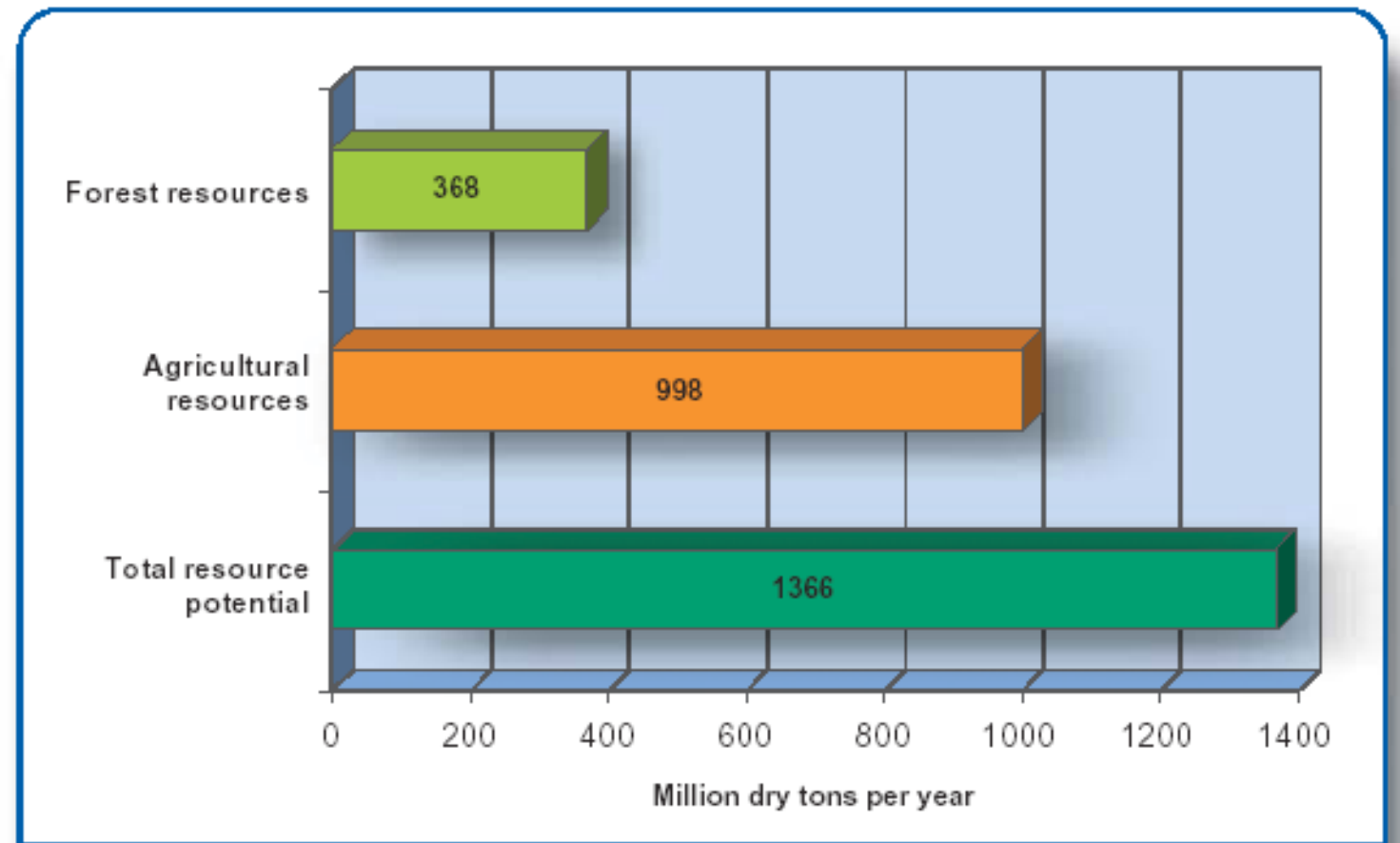
- Top and limb material, not easily debarked
- Easily integrated into current harvesting systems
- Largest, most immediate source of biomass
- Use has increased recently

Thanks to Chuck Baxter for photo

Forest Harvest Residues

- Cost-effective bundler development needed
- Trailer mounted system
- Allow storage and drying

Dedicated Energy Crops
DOE/USDA "Billion Ton Study"



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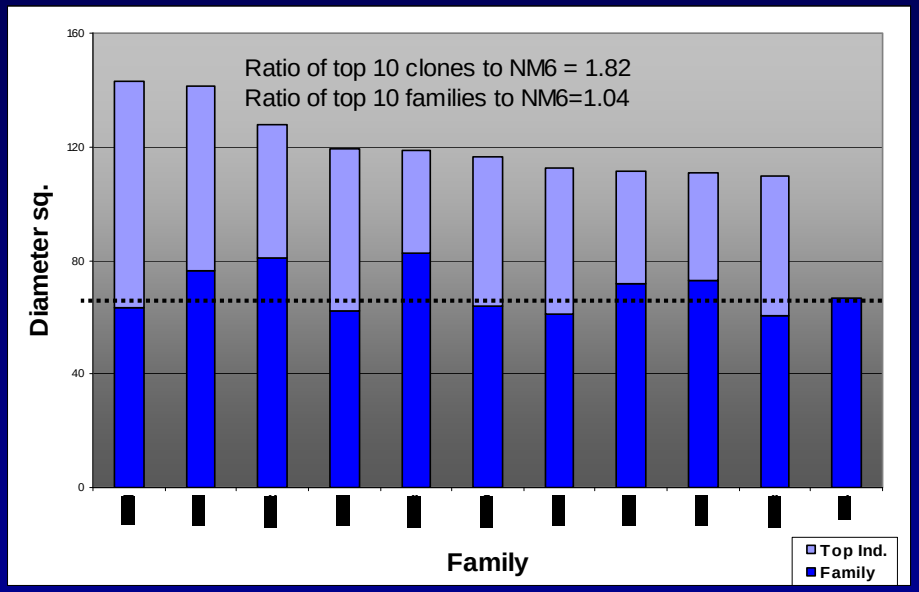
Hybrid Poplar Plantations/Energy Crops

- 20,000 acre program in central MN to support Sartell mill
- CRP program had 15 year provision for trees
- Approximately 1.6 million acres of CRP acreage
- Demonstrated yield floor of 3.5 tons/acre/year
- 5.6 million dry tons annual potential – lots to do

Verso Poplar Plantation Program

- Began in 1995, harvest starting this year
- Worked with the project since the beginning – genetics + fertilization
- Will meet all of the mill's hardwood needs

MFPRC – Genetic Improvement of Poplar

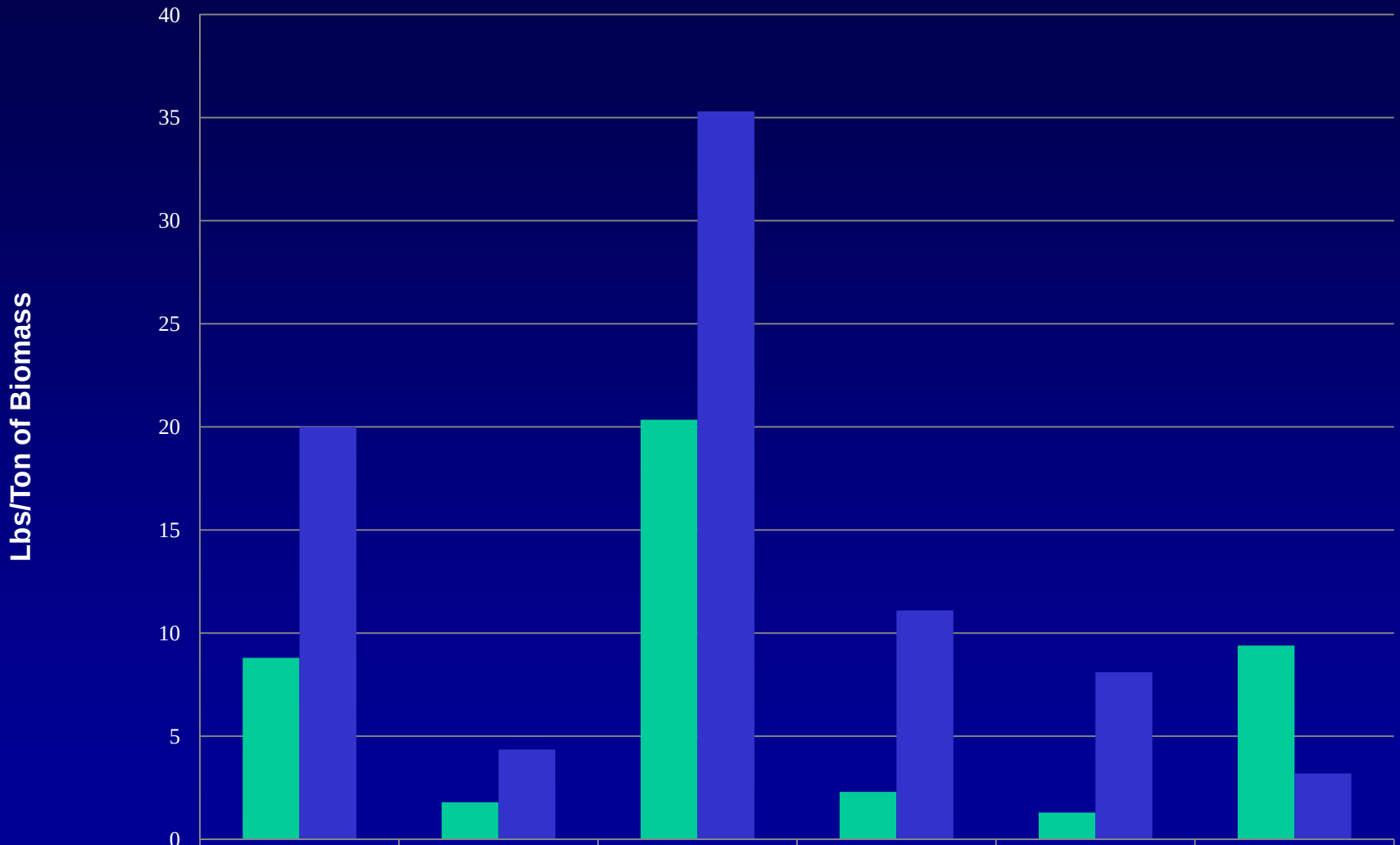


- **One of the largest programs in the world**
- **Significant yield gains and cost reductions (80% yield increase in some cases)**

Biomass Removal – Agricultural Residues

- Work being done by ARS – Jane Johnson/John Baker
- Corn Stover roughly 2X nutrient content of corn cobs
- 14 million dry tons potentially available in leaf/stalk
  - 2 tons – every other year on 14 million acre corn/soybean acreage
  - represents ½ of the corn stover, no soybean residue
- Corn cobs – 0.75 t/yr X 7 million acres = ~ 5 million tons
- Economics?
  - Corn crop: 150 bushels X 3 = $450/acre
  - Corn cob: 0.75 X $40 = $30/acre, will than be enough?
  - Stover: 2 tons X $50 = $100/acre

Nutrient Content of Corn Stover and Cobs
IA State Extension



	N	P2O5	K2O	Ca	Mg	S
Corn Cobs	8.8	1.8	20.35	2.3	1.3	9.4
Corn Stover	20	4.35	35.3	11.1	8.1	3.2

Possible Technologies

Cellulosic Ethanol
- Biochemical
- Thermochemical

Pyrolysis
- Synthetic Oil
- Further refining to other products

Biodiesel – Choren in Germany
EERC gasifier, truck mounted

ORC CHP systems – high efficiency, distributed

Biochemical Cellulosic Ethanol Technology

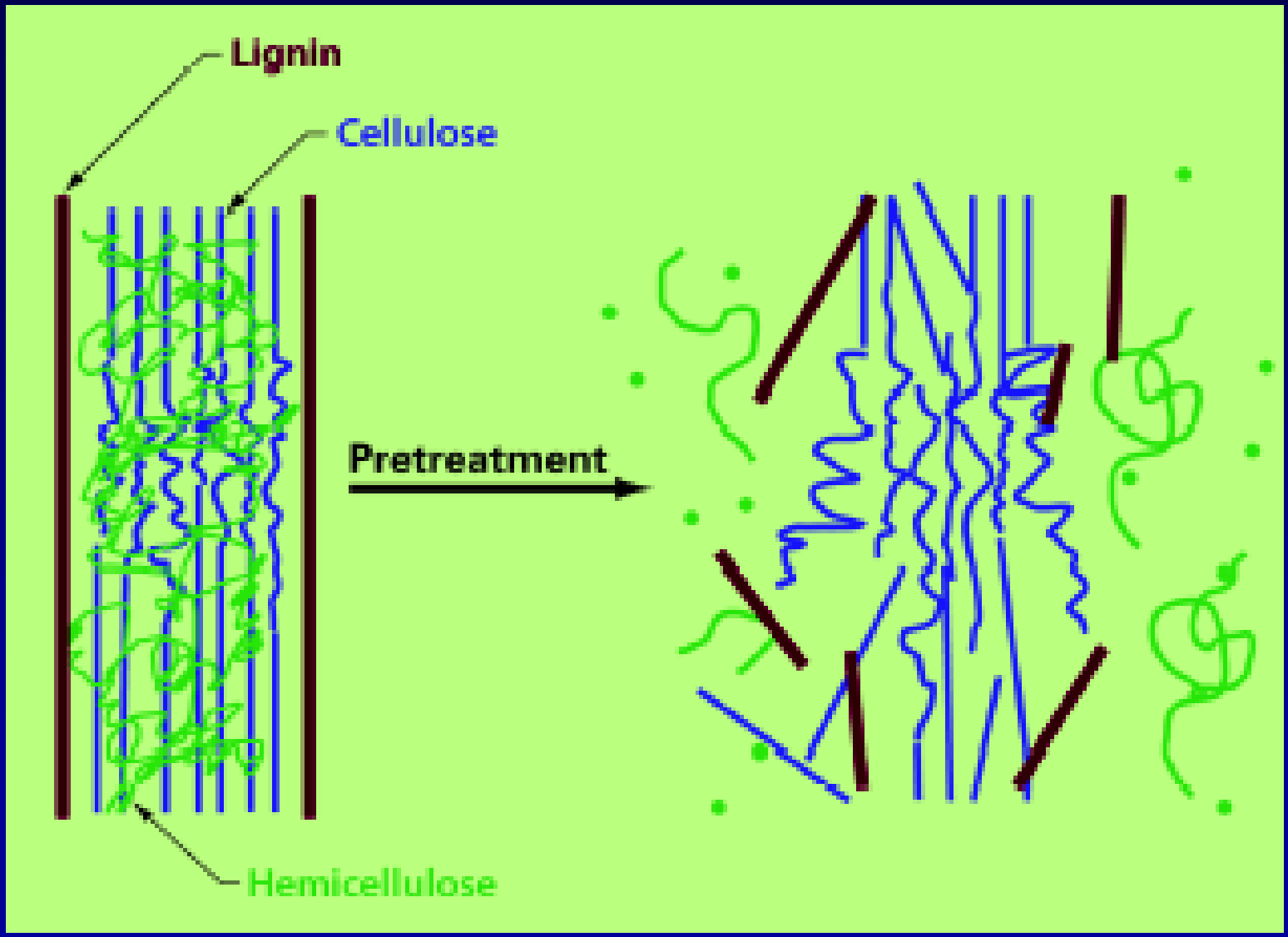
- Driven by acid separation of lignin and breakdown of cellulose and hemicellulose sugars

- Use the unfermentable lignin to meet the thermal needs of the process (10:1 vs. 1.4:1 with starch)

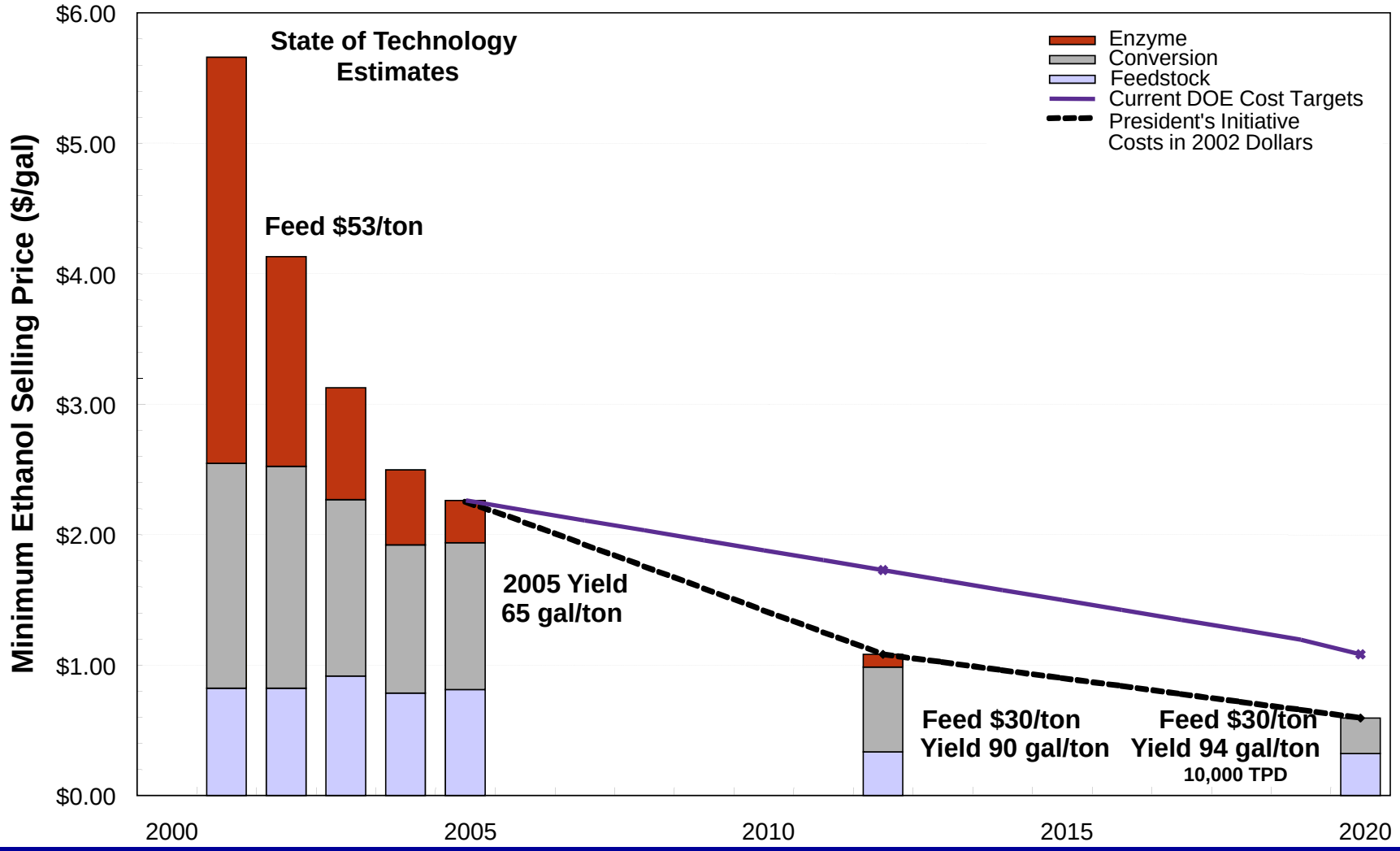
- Enzyme costs were too high to justify expense, resulting in $5.00/gallon ethanol

- Recombinant DNA technology has led to precipitous drop in enzyme costs (white rot fungi, termite guts)

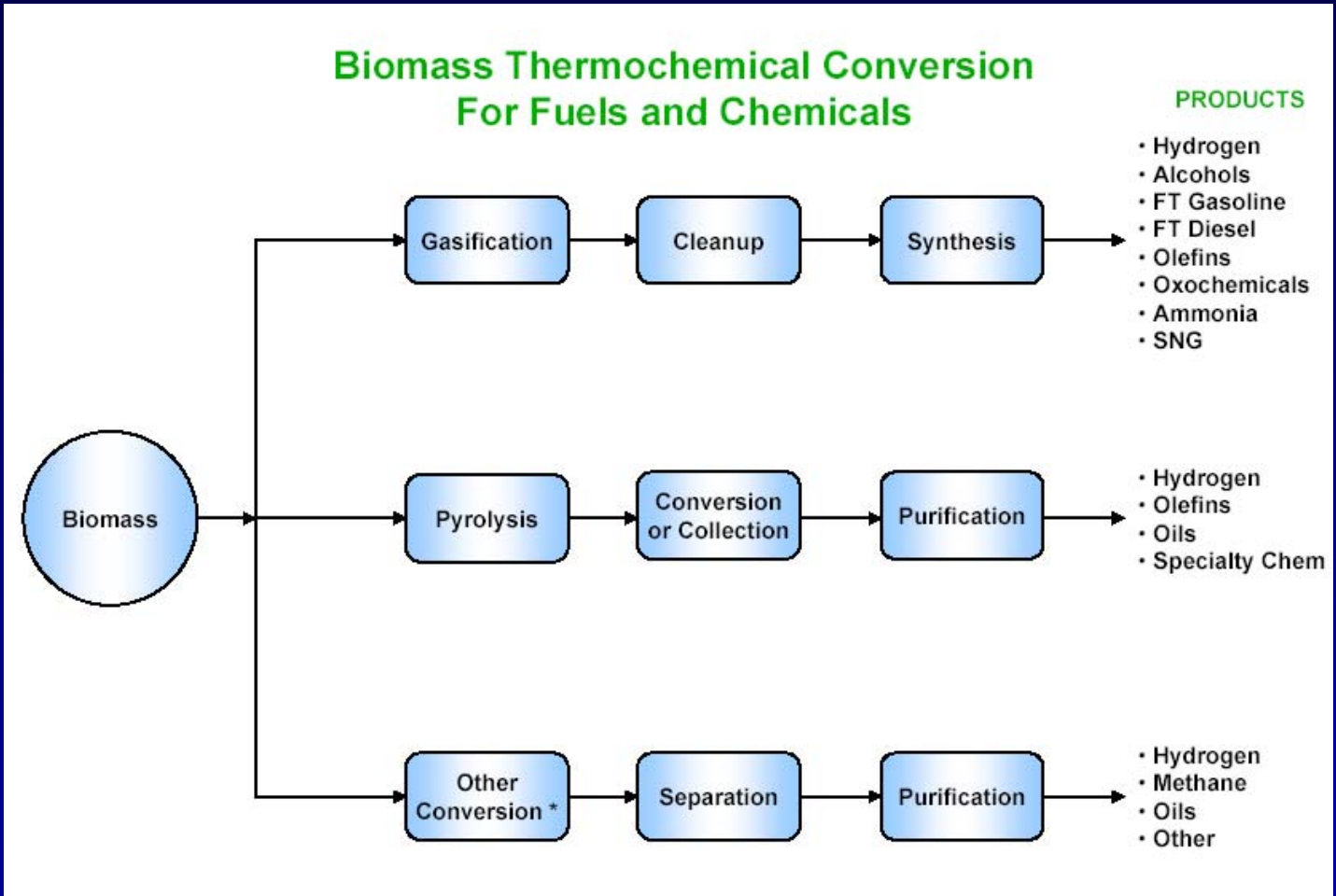
Cellulosic Ethanol Technology



Cellulosic Ethanol Cost Progression
(note: corn stover in this case, source Andy Aden, NREL)



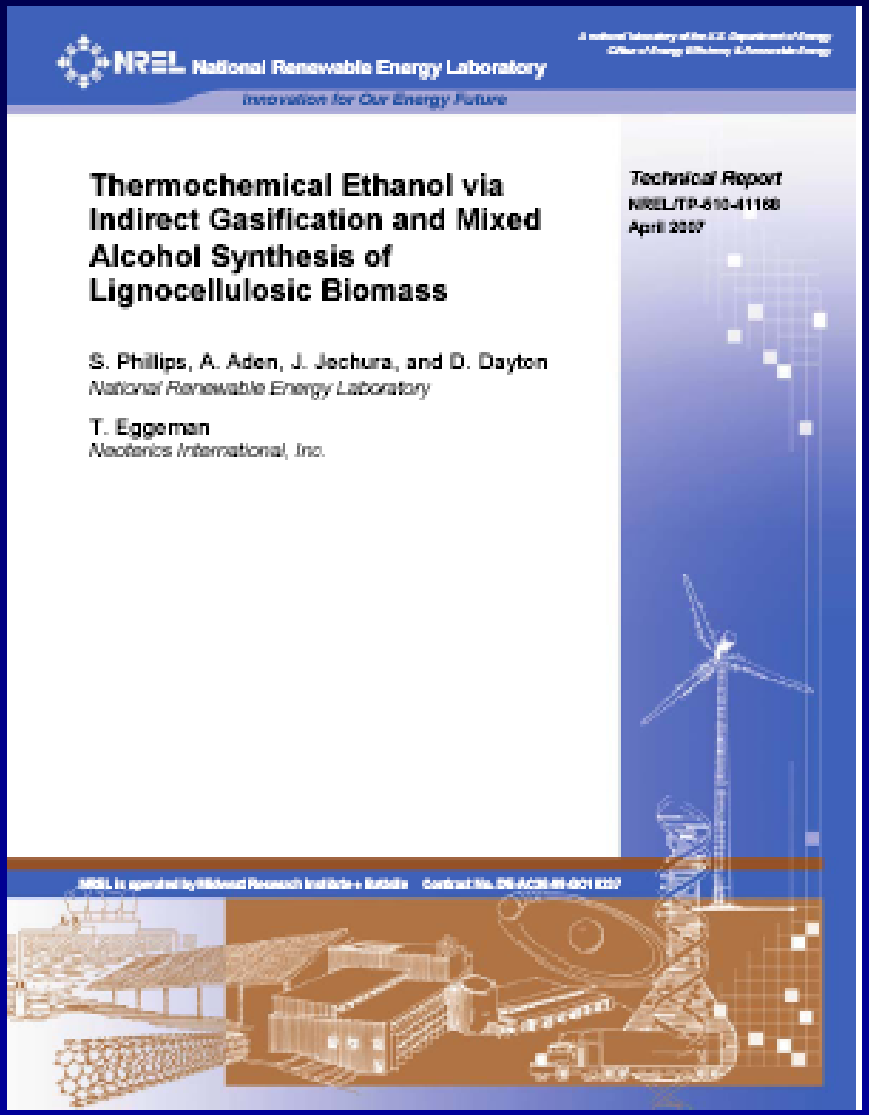
Thermochemical Processes



- Gasification more robust than biochemical
- Terpenes in pine can be a problem in biochemical
- Gasifier can use bark
- Potential to scale technology down for distributed employment

Cellulosic Ethanol Economics

- Phillips, et.al. - NREL Study
- Process flow diagrams
- Economic analysis



Assumptions in NREL Analysis

- Etoh yield of 80.1 gallons/dry ton
- Higher-chain alcohols – 14 gallons/ton
- 61.8 million gallon/year plant
- 770,000 dry tons of biomass needed
- Delivered feedstock $35.00 per dry ton
- $1.01 per gallon ethanol breakeven price with 10% return

Adjusted Price for Feedstock Cost

- $35.00 feedstock (?) – needs adjustment

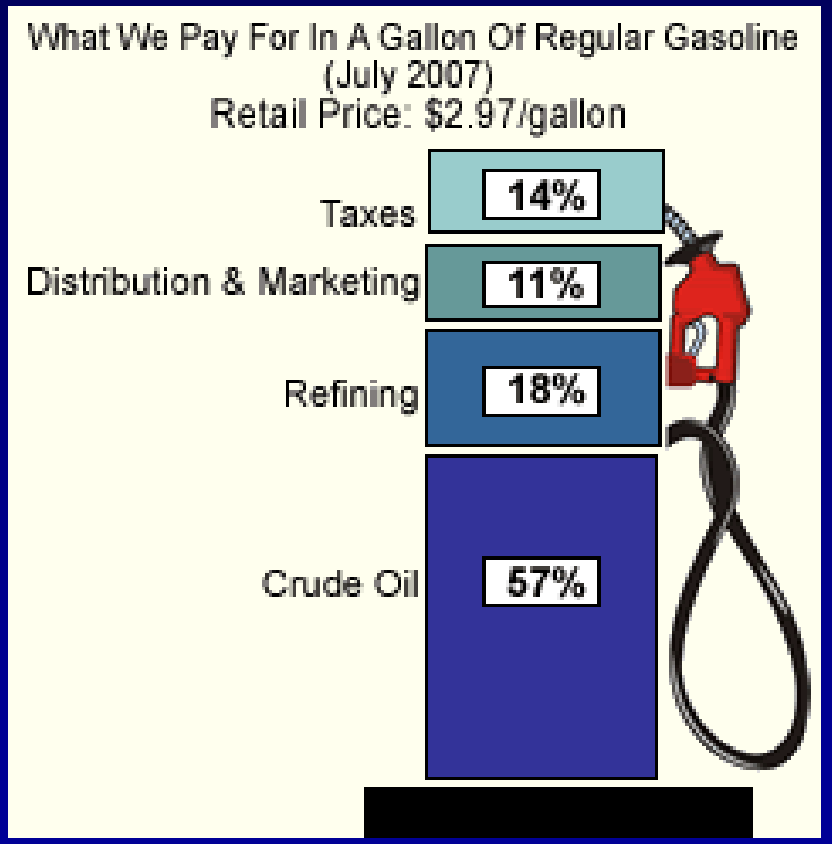
- 80.1 gallons/ton
- $0.012 per gallon / $ of feedstock cost

- If wood chips are $48.00/dry ton ($24.00/green ton), then adjusted price is $1.17 per gallon
- Using $80.00/cord roundwood = $1.44 per gallon
- Average of $1.30 per gallon

- Yield not yet to 80.1 level, however … Range Fuels expects 100 gallons of etoh and 20 gallons of higher-chain alcohols

Can $1.30 Ethanol compete with gasoline?

- Starting with $2.00 gasoline and removing taxes and distribution = $1.40/gal
- Reduction of 15% for reduced mileage using etoh
- Value of etoh = $1.19/gallon
- Cellulosic etoh with realistic feedstock = ~ $1.30 / gallon



Torrefaction of Biomass

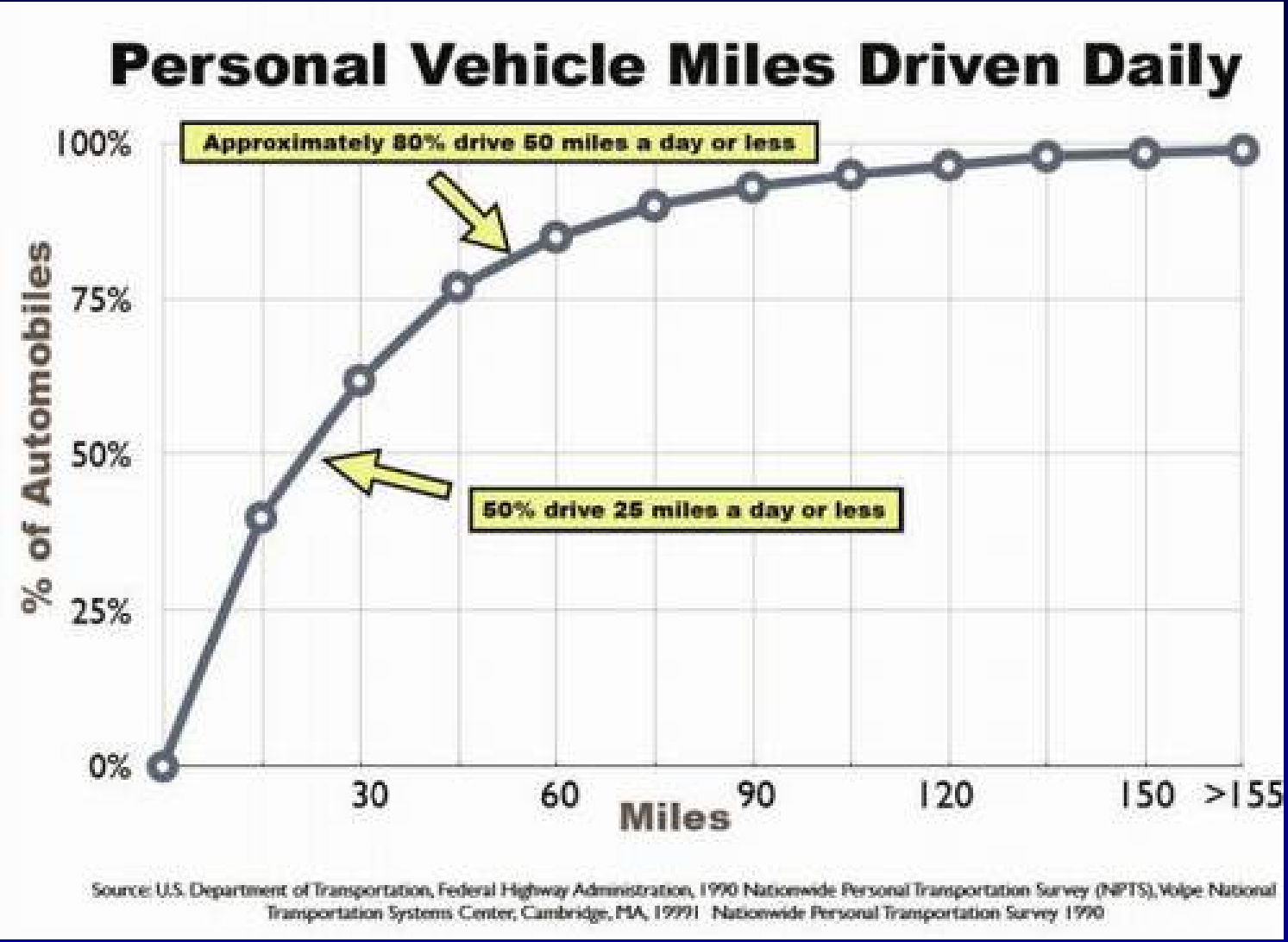
- Partial carbonization in the absence of oxygen
- Produces friable (pulverizable) dried product
- First plants being constructed in the Netherlands
- Economics in MN under investigation

- NRRI-Coleraine conducting tests of torrefaction using TGA/calorimetry to evaluate weight and energy loss
- Gathering information on commercial units – Topell
- May have potential but economics and energy budgets still need work

Game Changer - Electric Vehicles

- Toyota RAV4-EV, GM EV, Chevy Volt, BYD-China
- 30 mpg @ $3.00/gallon = $0.10/mile driven IC engine
- 4 mpkwh @ $0.08/kwh = $0.02/mile driven
- Putting taxes back in = $0.033/mile driven electric
- Technology under development but not far away
- Final purchase cost uncertain

America's Driving Habits



- Approximately 75% drive less than 45 miles per day

Conversion Comparison

Cellulosic Ethanol-Fueled Vehicle		
Biomass Input (ton)	1	oven dry ton of biomass
Conversion Efficiency	100	gallons ethanol per oven dry ton (future)
Vehicle Mileage (gasoline)	30	mpg-vehicle using gasoline
Ethanol Mileage	25.5	15% deduction for reduced energy
Miles Driven	2550	miles driven per oven dry ton
Plug-In Electric Vehicle		
Biomass Input (ton)	1	oven dry ton of biomass
Conversion Efficiency	0.33	conversion efficiency biomass-to-electricity
Electricity Produced	1,643	kwh produced per ton of biomass
Vehicle Mileage	4	miles per kwh
Miles Driven	6572	miles driven per oven dry ton
	2.58	ratio of electric vehicle to etoh-powered vehicle

Plug-Ins (cont.)

Based on 3 million cars in MN and 40 miles/day:

- Need 1.2 to 1.5 GW of additional power (slightly larger than MP-Cohasset)
- Could be new biomass/wind generation
- If all biomass fueled = about 7 million ovendry tons of biomass

Integrates well with existing infrastructure

Even if double the generation cost for renewable electricity:

- Add slightly over $0.01 to the average cost per kwh due to blending in with existing generation

Conclusions

- Economy will rebound! The U.S. needs to be ready
- Pellets and CHP systems to replace propane are likely feasible currently
- $2.50 to $3.00 gasoline: breakpoint for cellulosic ethanol
- Electric transportation is very efficient and cost effective assuming battery technology advances
- Torrefaction may hold promise
- Continued research needed in:
  - Energy crop development – woody and herbaceous
  - Forest Management – aspen/pine thinning
  - Agricultural residues – impacts of removal

- Picking winners is difficult – technology will affect the energy mix