Biomass Feedstocks

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NASULGC

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Outline

- Biomass – Bioenergy Cycle
- Global Estimates
  - USA situation
- Resource Assessment
  - Supply Curve 500 Mt 2020
  - Definitions
  - Type and Quality
  - Biomass supply in context
  - Is a Gigatonne feasible?
- Quality Matters
  - Influence on product yields
  - Using advanced rapid analysis to choose and develop feedstocks

Bioenergy Cycle

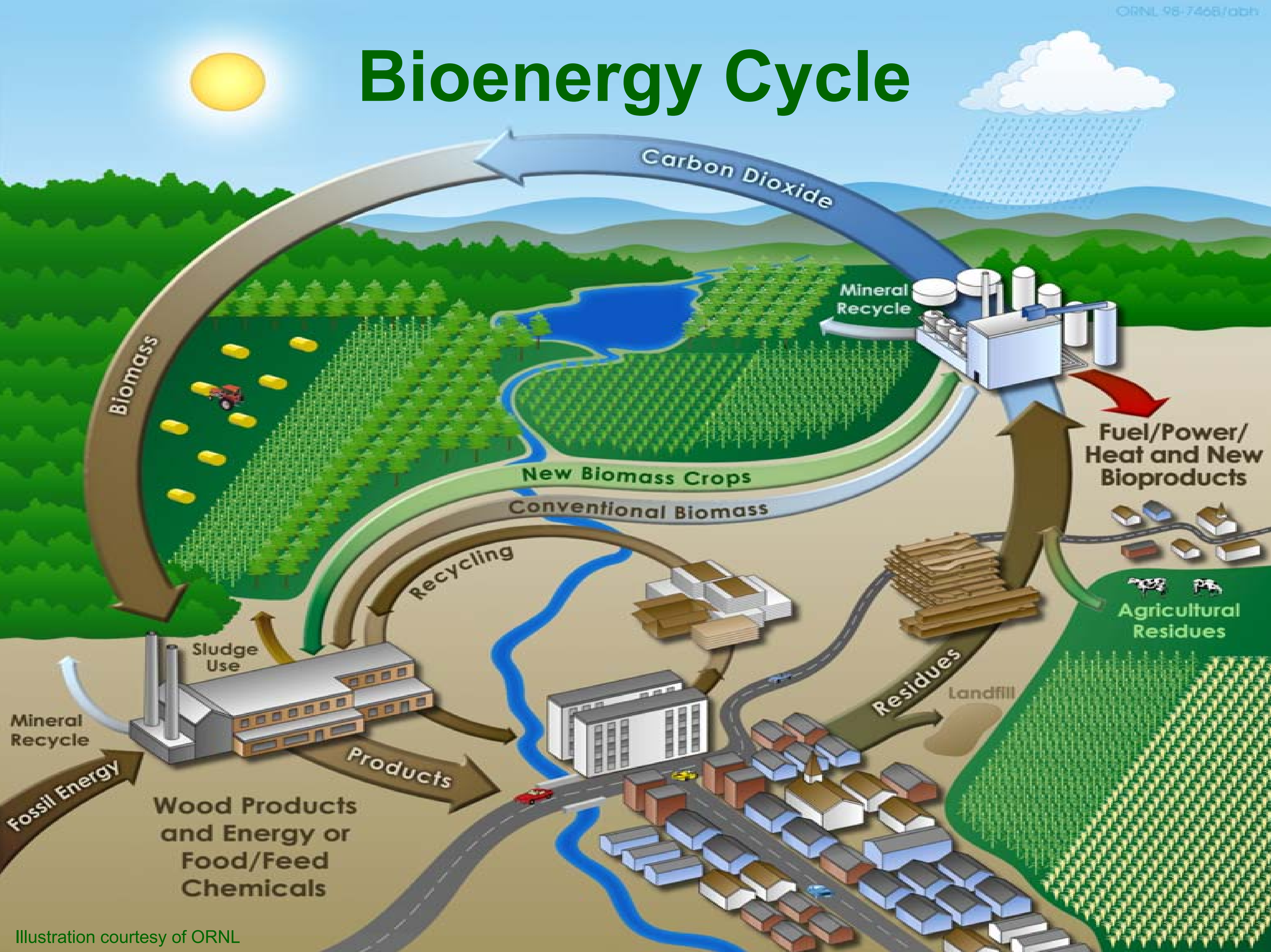
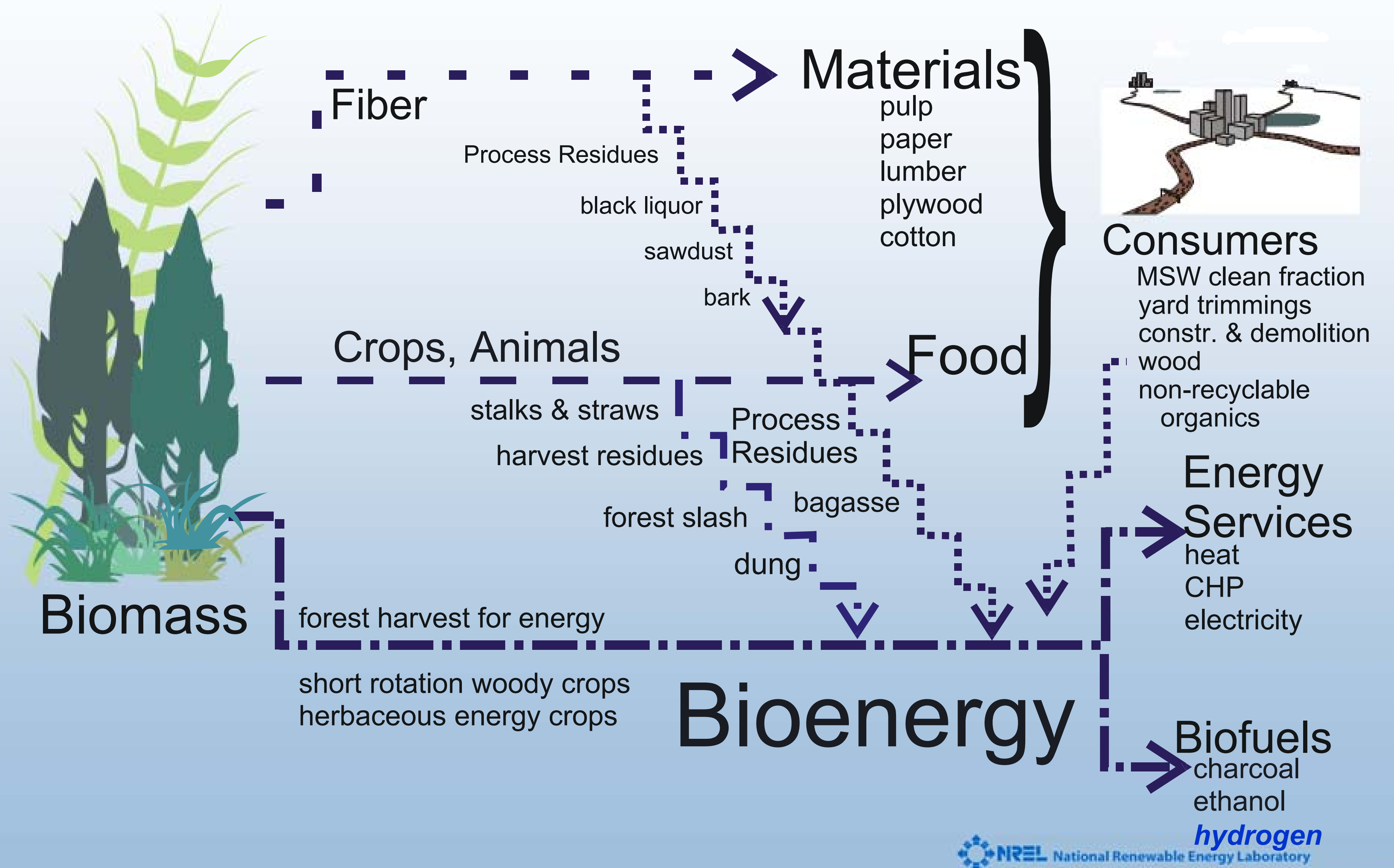
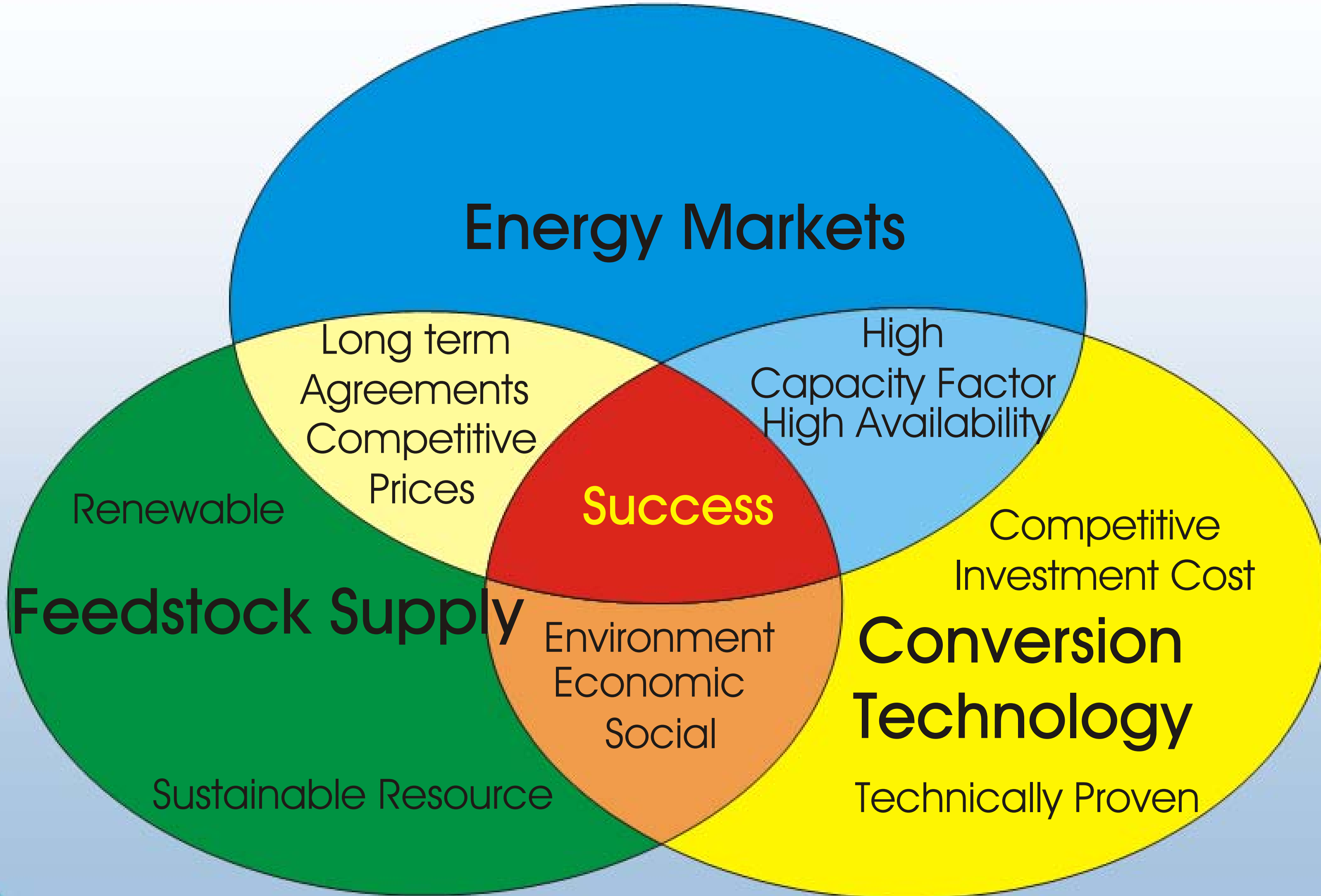


Illustration courtesy of ORNL

Biomass Flows in the U.S. Economy



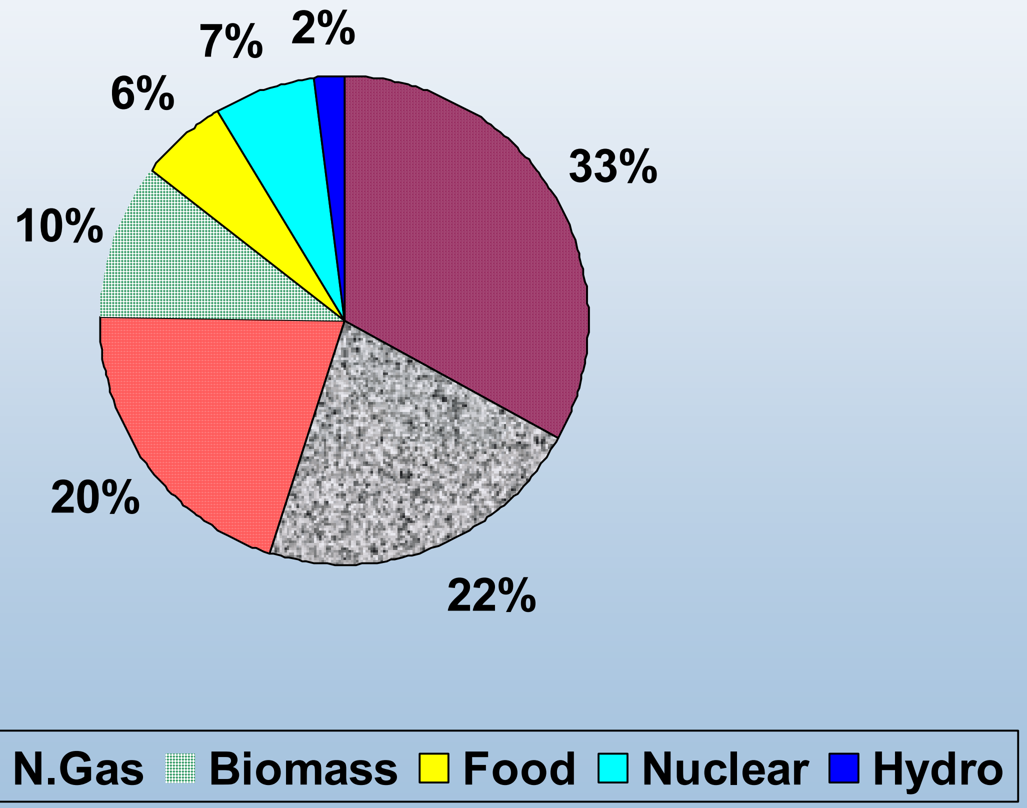
Biomass and Bioenergy Project Requirements



World TPES 2001

(Total Primary Energy Supply = 446 EJ)

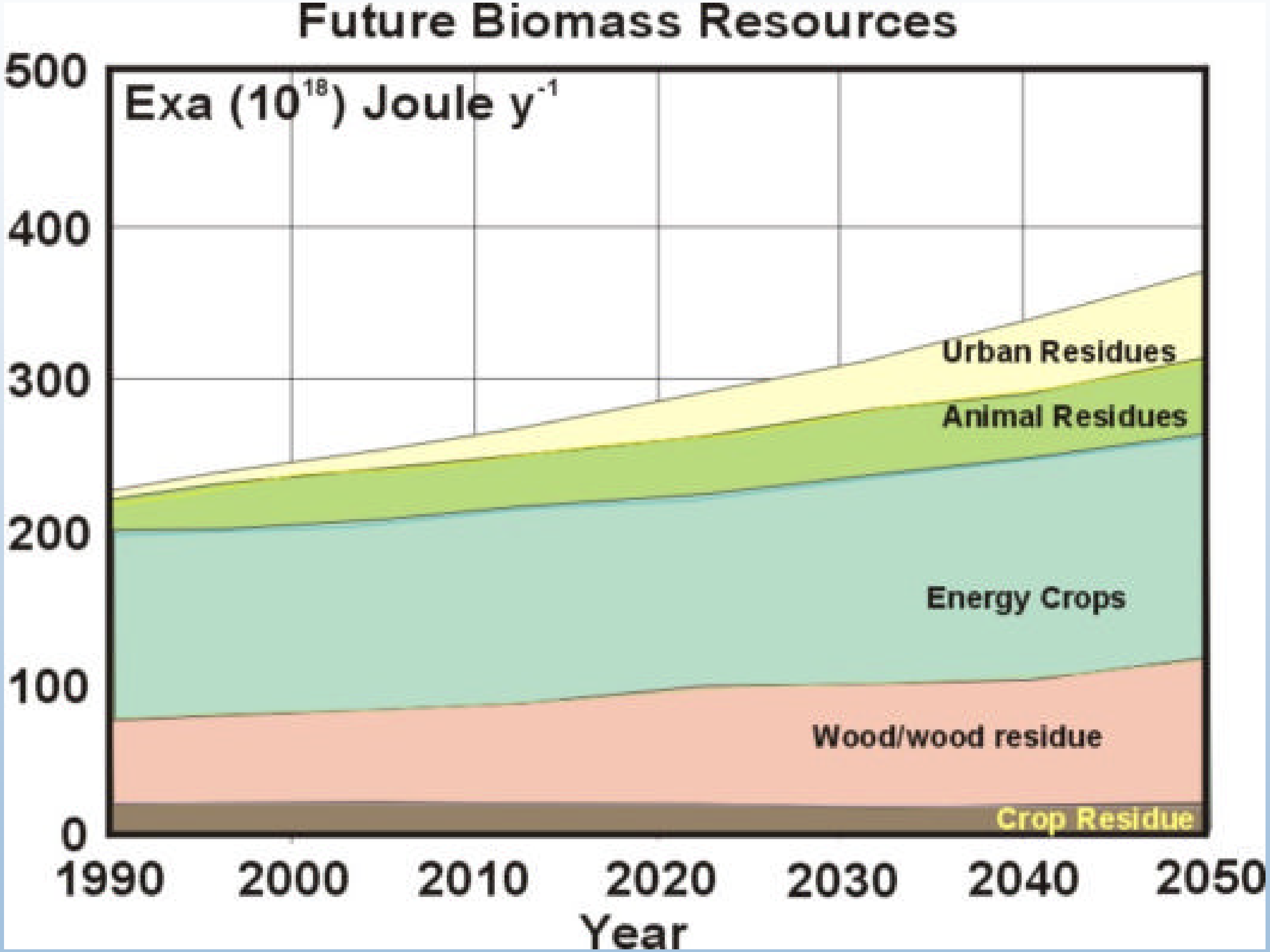
- Food TPES
  - 2806 Cal/person/day
  - Popn. 6.15 Billion
- Source for Food TPES
  - FAO.org
- Nuclear conversion
  - kWh = 10.8 MJ
- Hydro conversion
  - kWh = 3.6 MJ
- source for fuel TPES (10029 Mtoe)
  - IEA.org



Status of 2050 Global Estimates

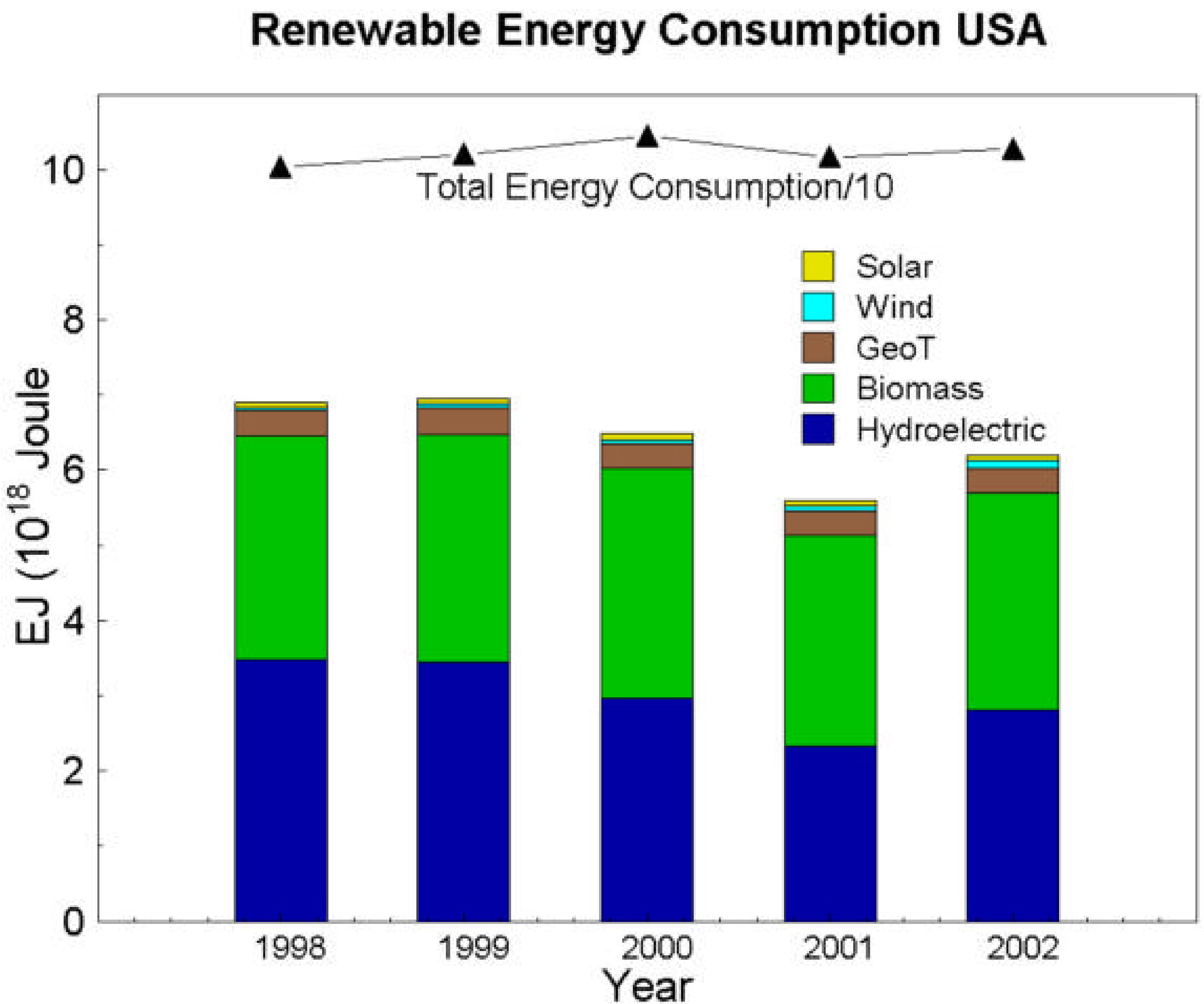
- 17 studies analyzed
  - Highest – 675 EJ/y (EPA – v-high yields assumed)
  - Lowest – 45 EJ/y (less than today – land competition)
- Biomass resources (central estimates)
  - Energy crops range from 45 – 250 EJ/y
  - Ag residues < 20 EJ/y
  - Animal excreta < 50 EJ/y
  - Wood residues (primary + traditional reuse)
  - Urban residues
- IIASA projection on next slide

IIASA Estimate
(resource based technical potential)



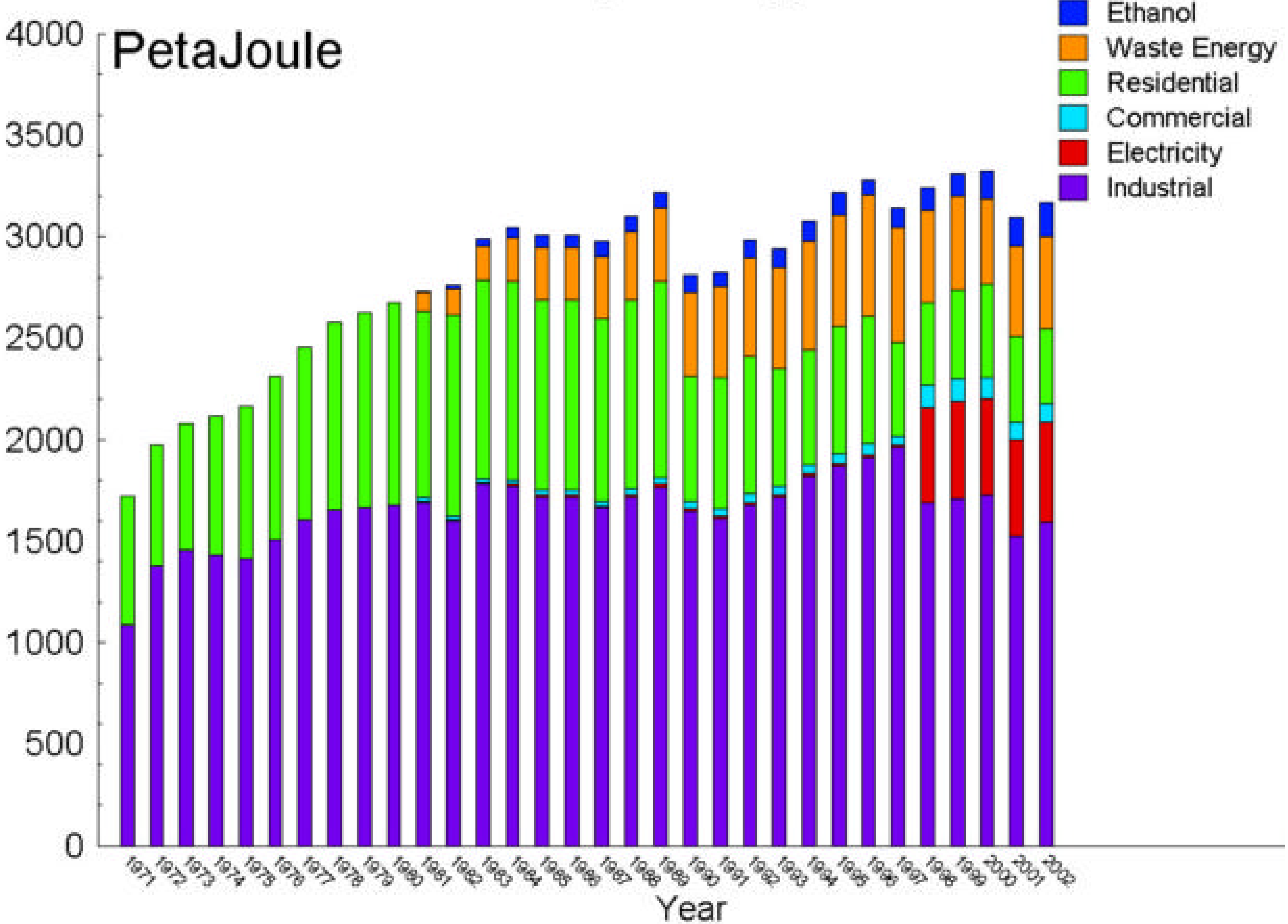
Uncertainties in Global Estimate

- Food – land competition
  - Population forecast and *per capita* income estimates
  - Calories not a problem
    - High animal vs. low animal protein future is significant issue
  - Only Sub-Sahara Africa is food – fuel issue likely, SE Asia a possibility
- Fiber – Wood demand for population
- Effects of Climate Change and Emissions
  - Brown cloud, ground level ozone – growth inhibition
  - Water availability and variability
  - Weather extremes, and plant pathogens

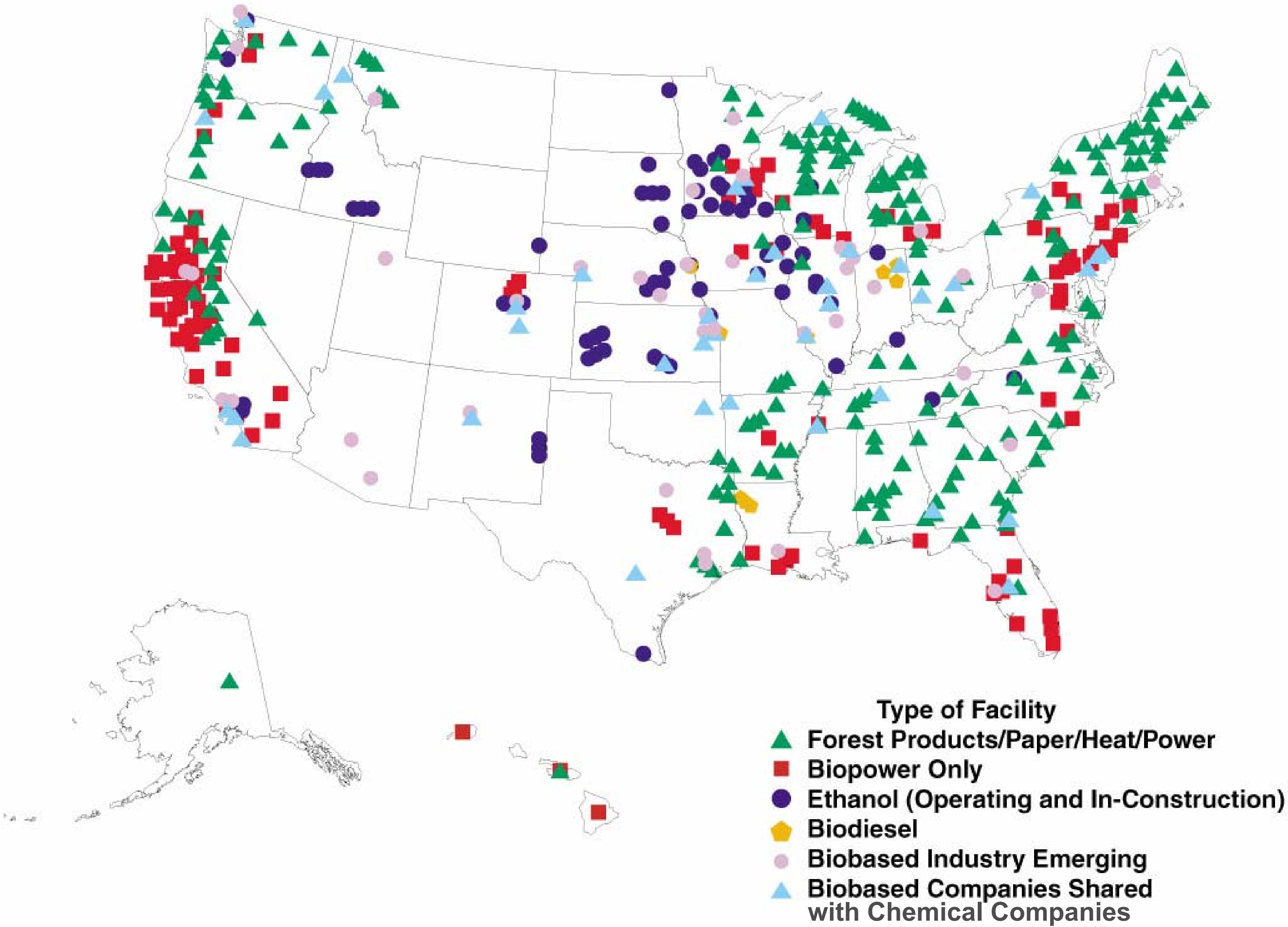


Renewable Energy Consumption USA
Total Energy Consumption/10
Solar
Wind
GeoT
Biomass
Hydroelectric
EJ (10^18 Joule)
0
2
4
6
8
10
1998
1999
2000
2001
2002
Year

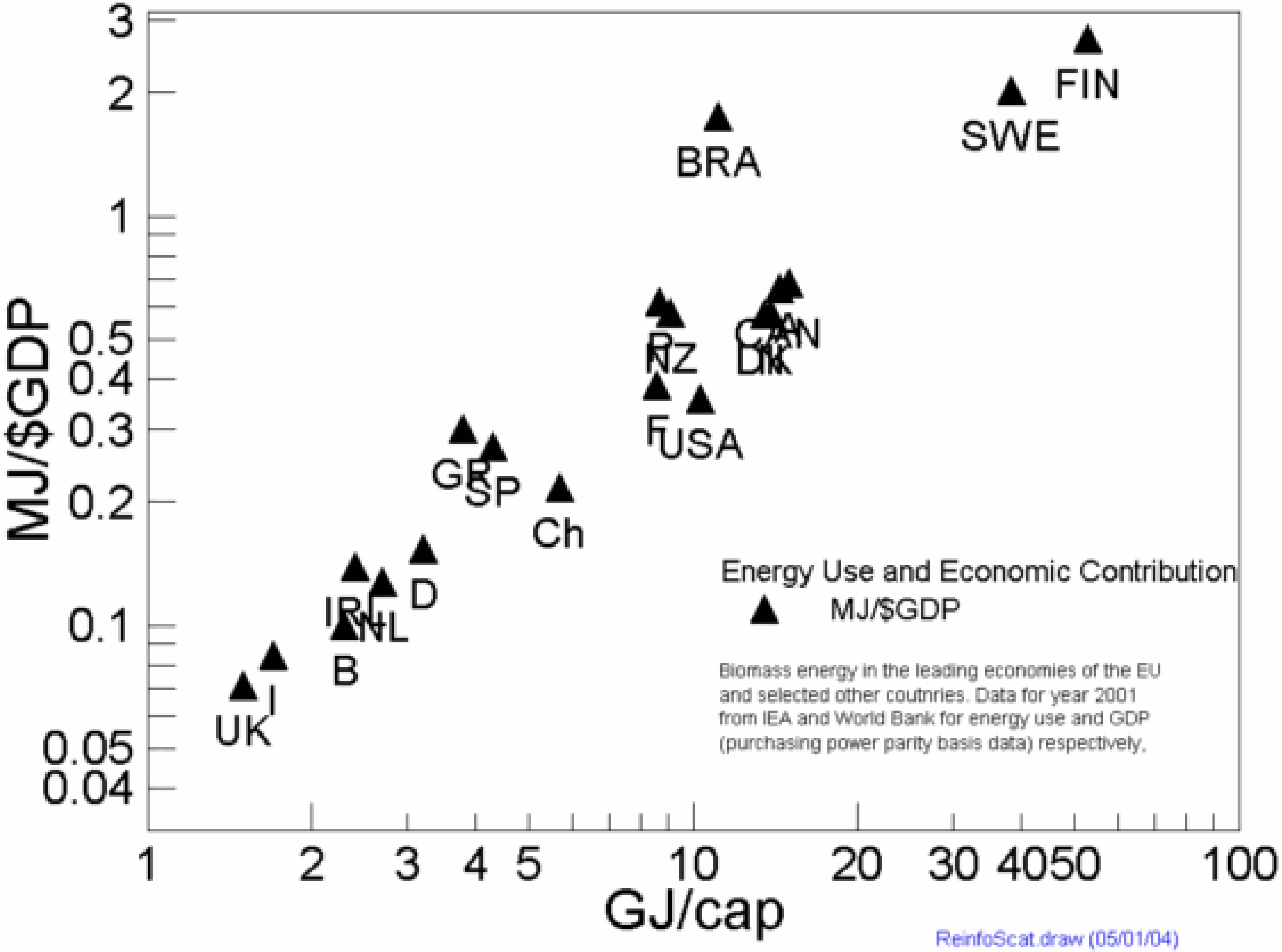
Biomass Primary Energy Trend USA



Examples of Bioenergy and Biobased Products Facilities



Biomass in EU economies (mainly)



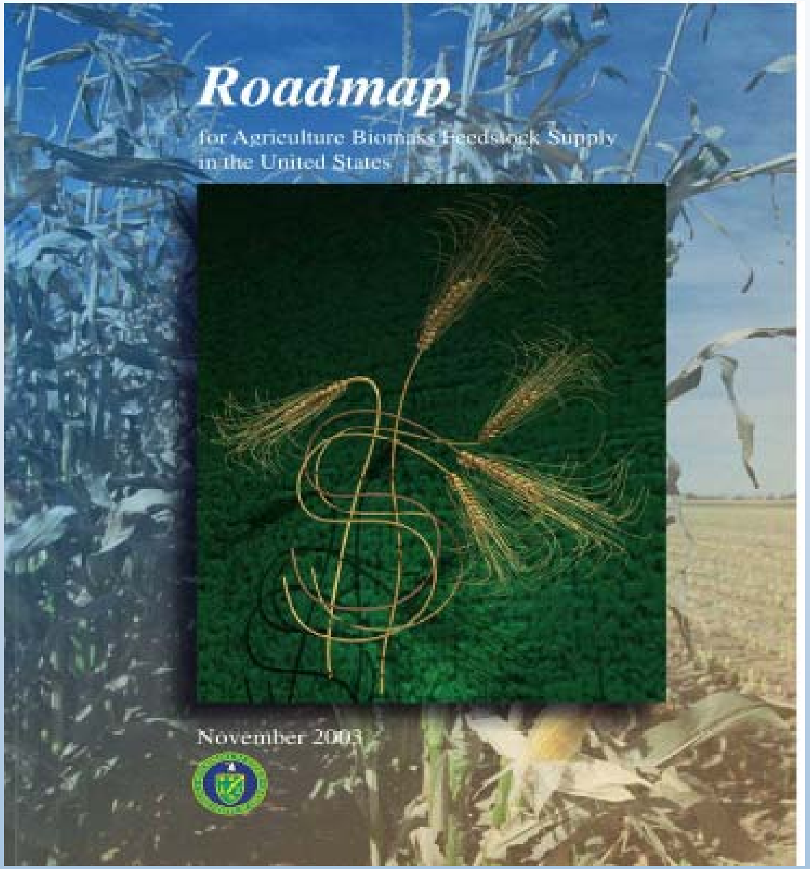
Resource Assessment in General

Key to developing sustainable biomass resources

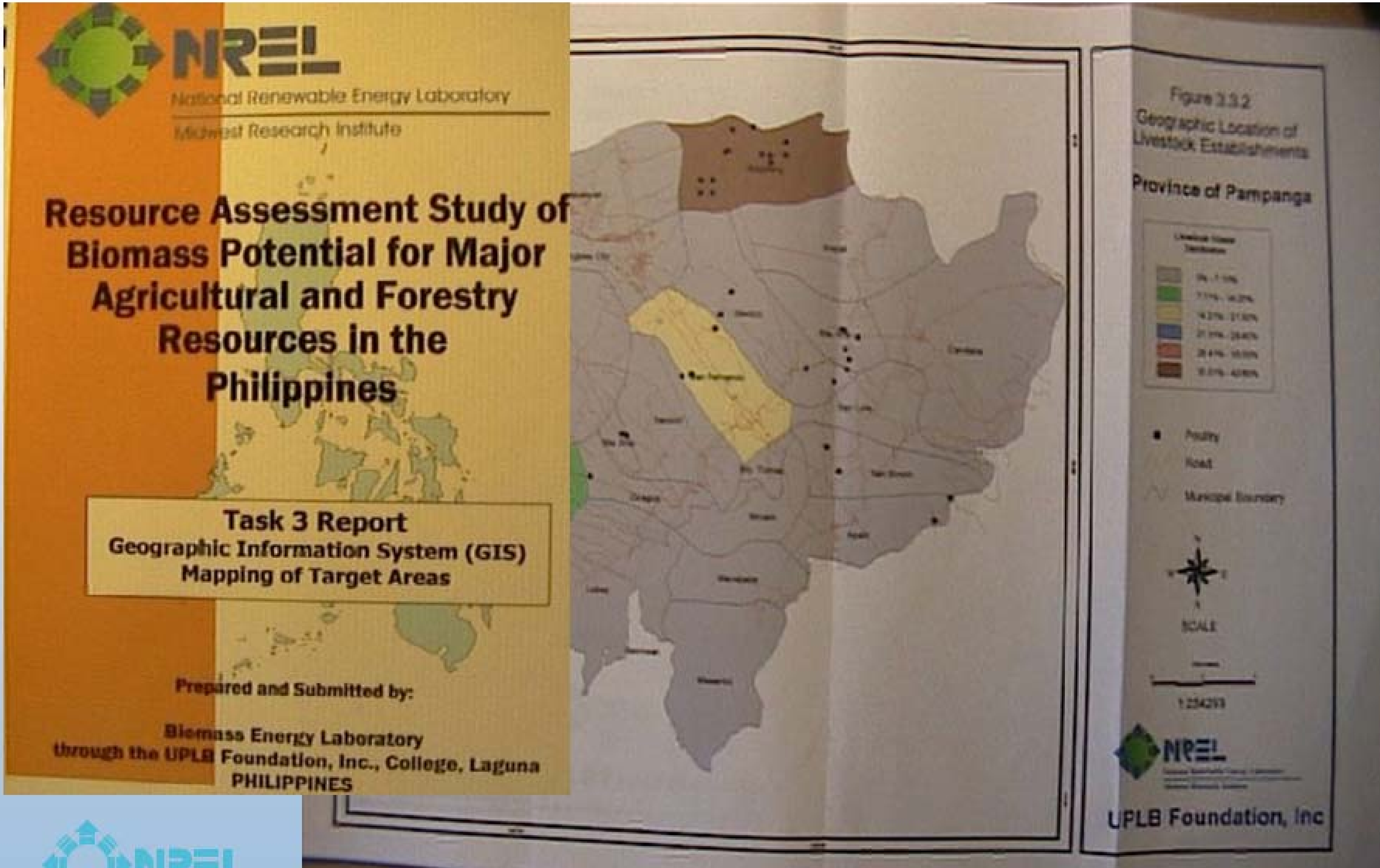
- 4 levels of survey and assessment
  - **Snapshot** - usually local and involves sampling of current use e.g. Developing Country fuel wood surveys
  - **Continuous survey and data base** - normally works from Agriculture and Forestry annual data series - only provides potential by using crop residue factors unless survey is altered (e.g. China, USA, and EU)
  - **Integrated Data Base - GIS and field based** to incorporate Data from both (1) and (2) with GPS geolocators for key industries and centres
  - **AgroEcological Zones (AEZ)** is a GIS crop forecast and incorporates soil, insolation and rainfall along with crop data. Will be needed for climate change predictions

The Harvest and Logistics Chain

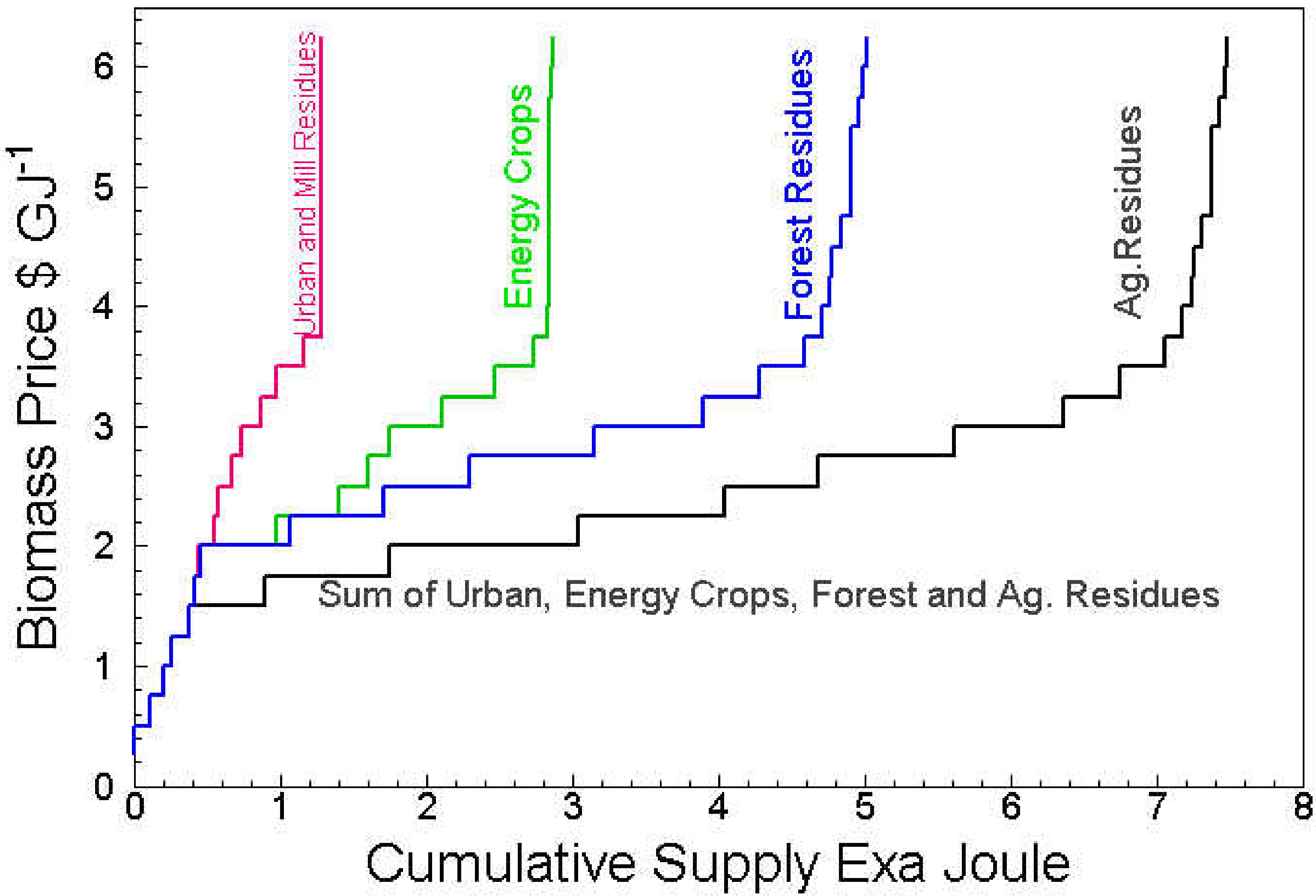
- Very important
- Feedstock Specific
  - Roadmap is strictly for straw and stover
- Area of major investment by the industry itself
- Scope for cost reduction is not great
- Better to produce
  - Multipurpose Plants - To defray Harvest costs?



Resource Assessment



USA Biomass Supply Curve 2020



Biomass Resources for Bioenergy

- Primary = energy/food/forest crops
- Primary residues
  - Agricultural crop – straw, and stover
  - Forest – tops, branches, stumps, stand improvement, thinnings
- Secondary residues
  - Food processing residues e.g. bagasse, stillage
  - Fiber processing residues e.g. black liquor, sawdust, hog fuel
  - Animal excreta – dung, chicken litter
- Tertiary residues
  - Urban residues (MSW) landfill avoidance
- Traditional biomass - *transform to modern biomass*

USA (500 Mt) Residue Access

- Supply curve derived estimate for 2020
  - Due to reliance on ag residues, forestry residues and energy crops - infrastructure investment is required
- Secondary Residues
  - Forest industry mill residues
    - are fully utilized – efficiency gains possible in black liquor
  - Urban residues
    - Generation rate is about 22 MJ/person/day
    - socio-political arena - intersection of EPA policy :
      - Reduce/re-use/recycle/composting/combustion/landfill
  - Concentrated Animal Feed Operations (CAFO)
    - Almost all residues are high moisture
    - Environmental issues include pathogens, nitrogen and phosphorous management

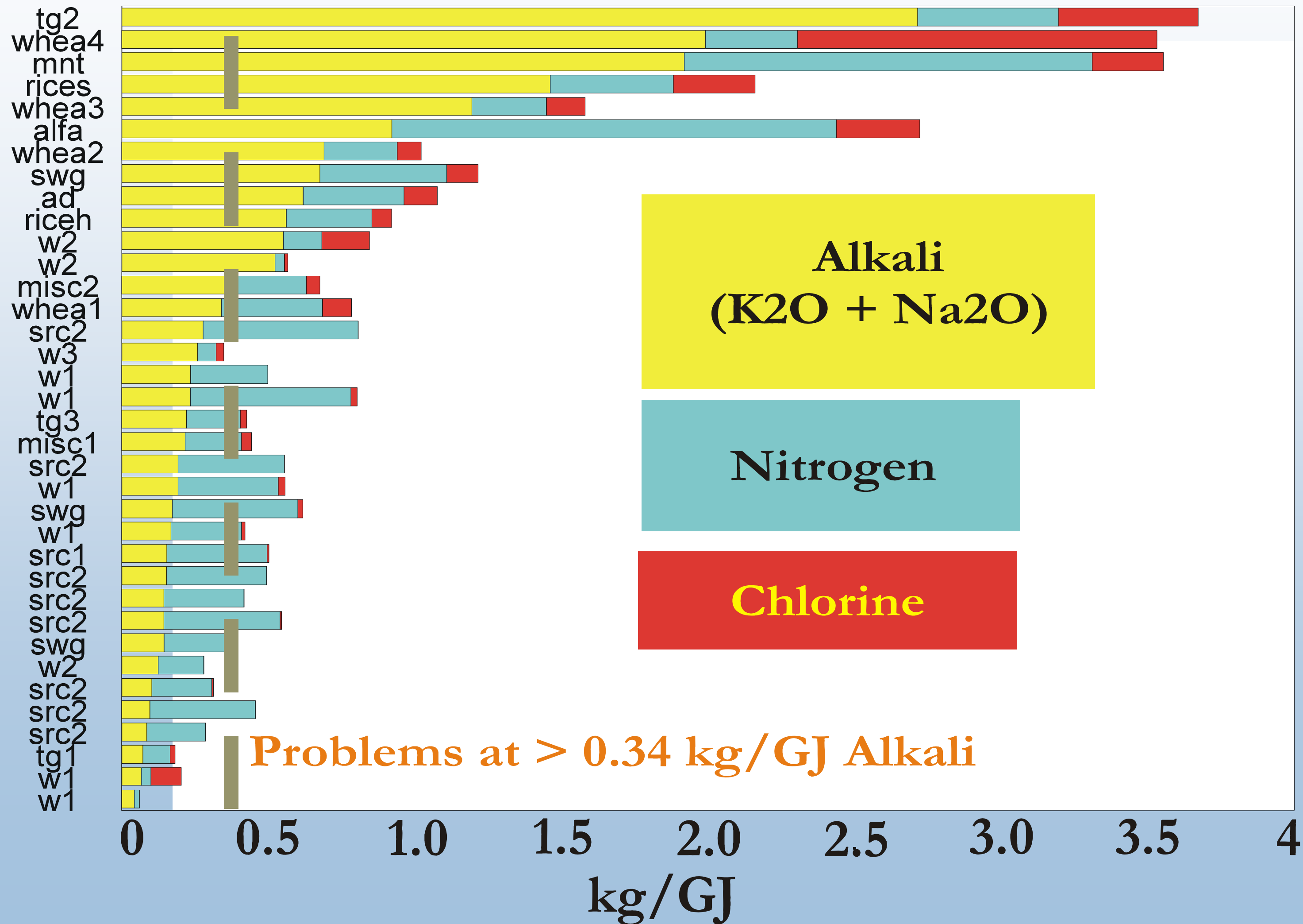
USA (500 Mt) Primary Biomass

- Primary Residues
  - Forestry <2 EJ y^{-1}
    - Technology base exists in Scandinavia
    - Environmental issues re nutrient and carbon depletion
    - Fire management strategy
  - Agriculture
    - Corn stover major opportunity 2 – 3 EJ y^{-1}
      - Collection, transport and storage technology
      - Environmental issues
        - » Diversity
        - » *Leave soybean/other cereal/Corn rotation*
        - » Erosion
        - » *No-till cultivation*

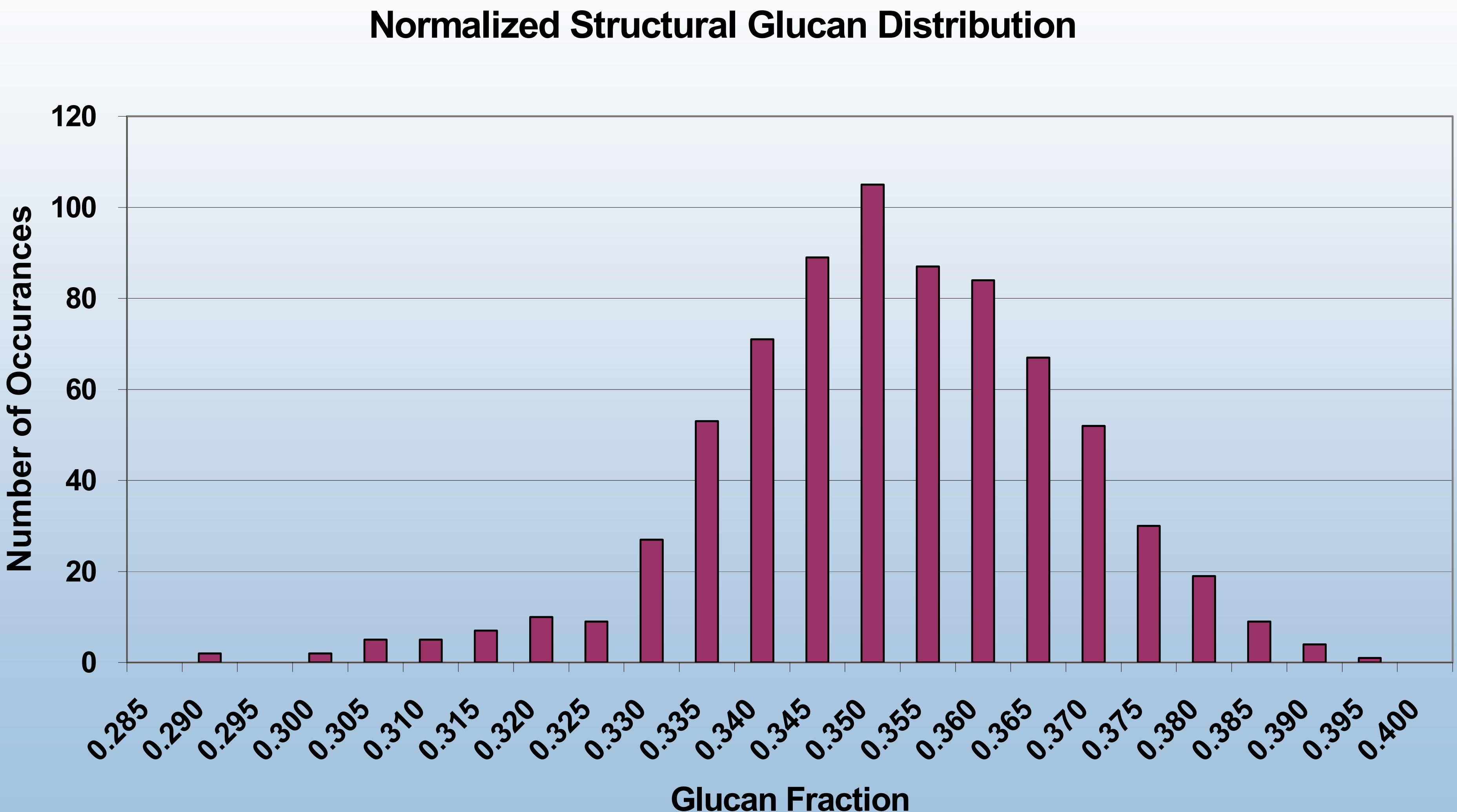
USA (500 Mt) Energy Crops

- Energy crops 1 – 2 EJ y^{-1}
  - Supply curve derived from agriculture economics - crop competition with current farmer options
    - Does not assume extensive use of set-aside as in CRP
- Energy Crops
  - Switchgrass – C-4 plant with extensive CRP plantings
  - SRWC – poplar and willow
  - Maize – present day ethanol industry
    - Could grow 2 – 3x from 10 Mm^3 /y (2.6 Billion gals) {2003}
    - Export of grain vs energy consumption
    - Capped by impacts on animal feed and soybean markets
- Land Areas
  - Consensus is for 17 Mha (about 42 Million Acres) easily accessible
    - What is the impact of changing agricultural subsidies in the WTO and Doha discussion?
    - Biotrade?

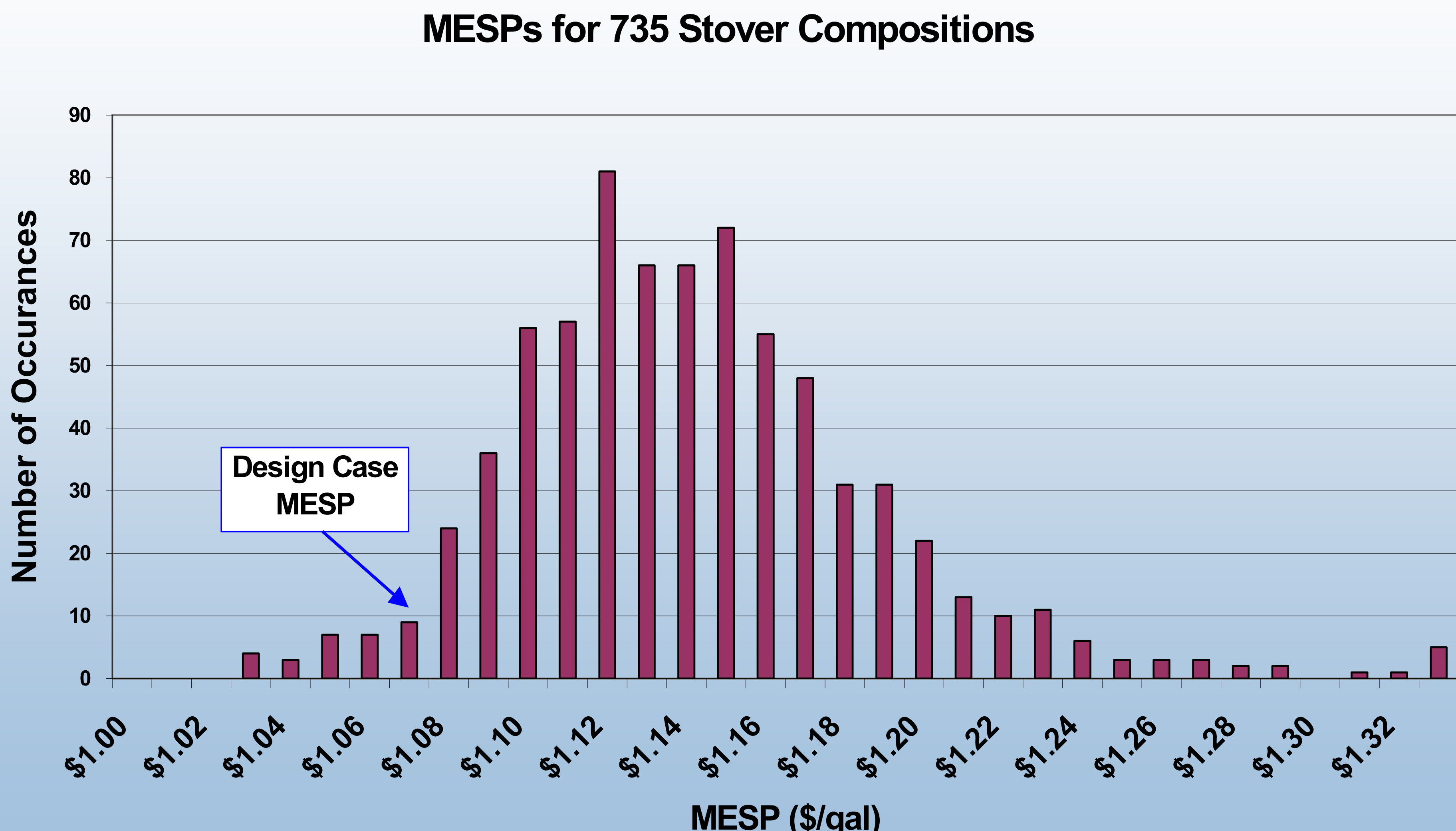
Feedstock Issues: Combustion with Alkali Metals In Biomass



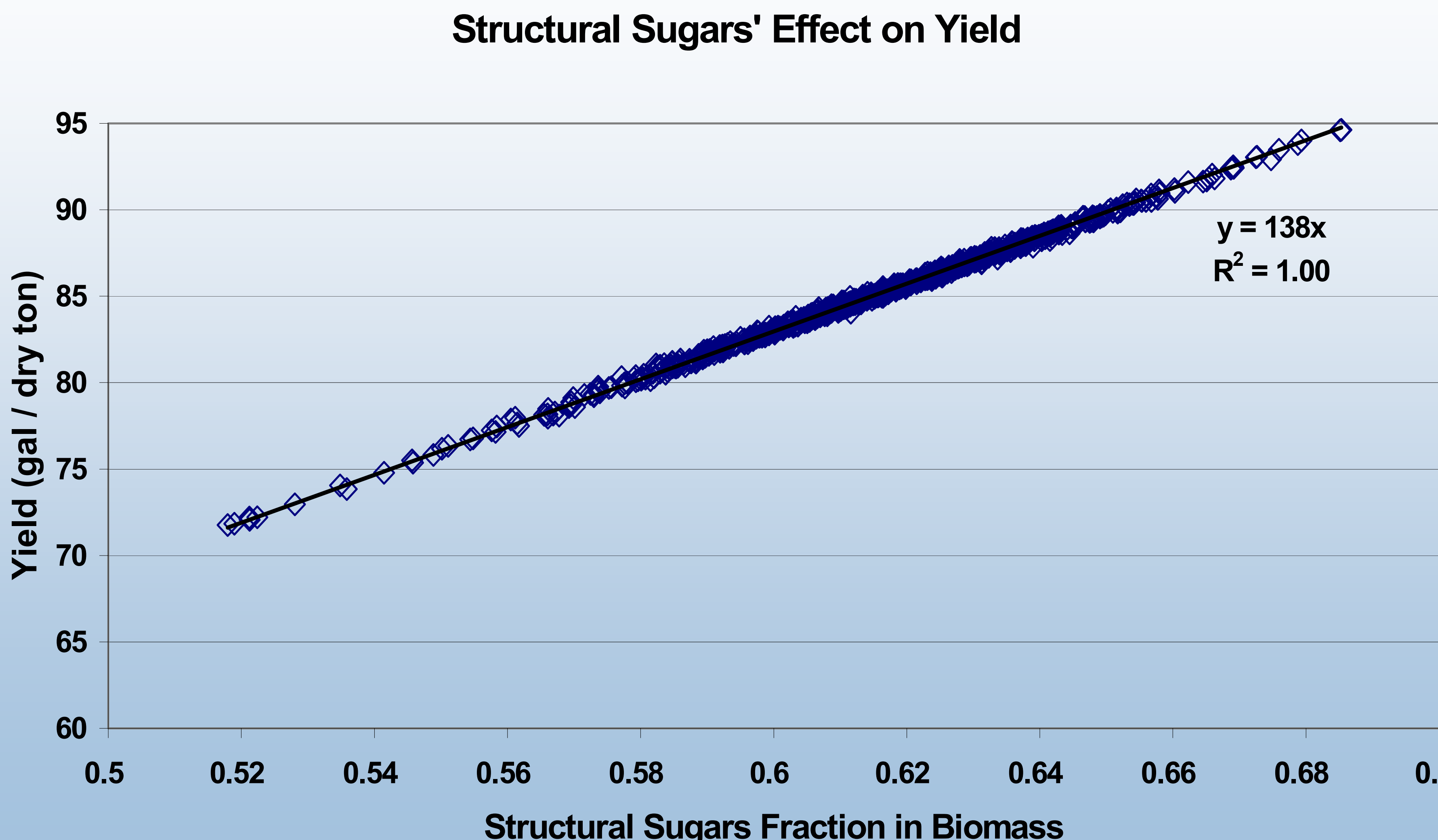
Composition Distribution



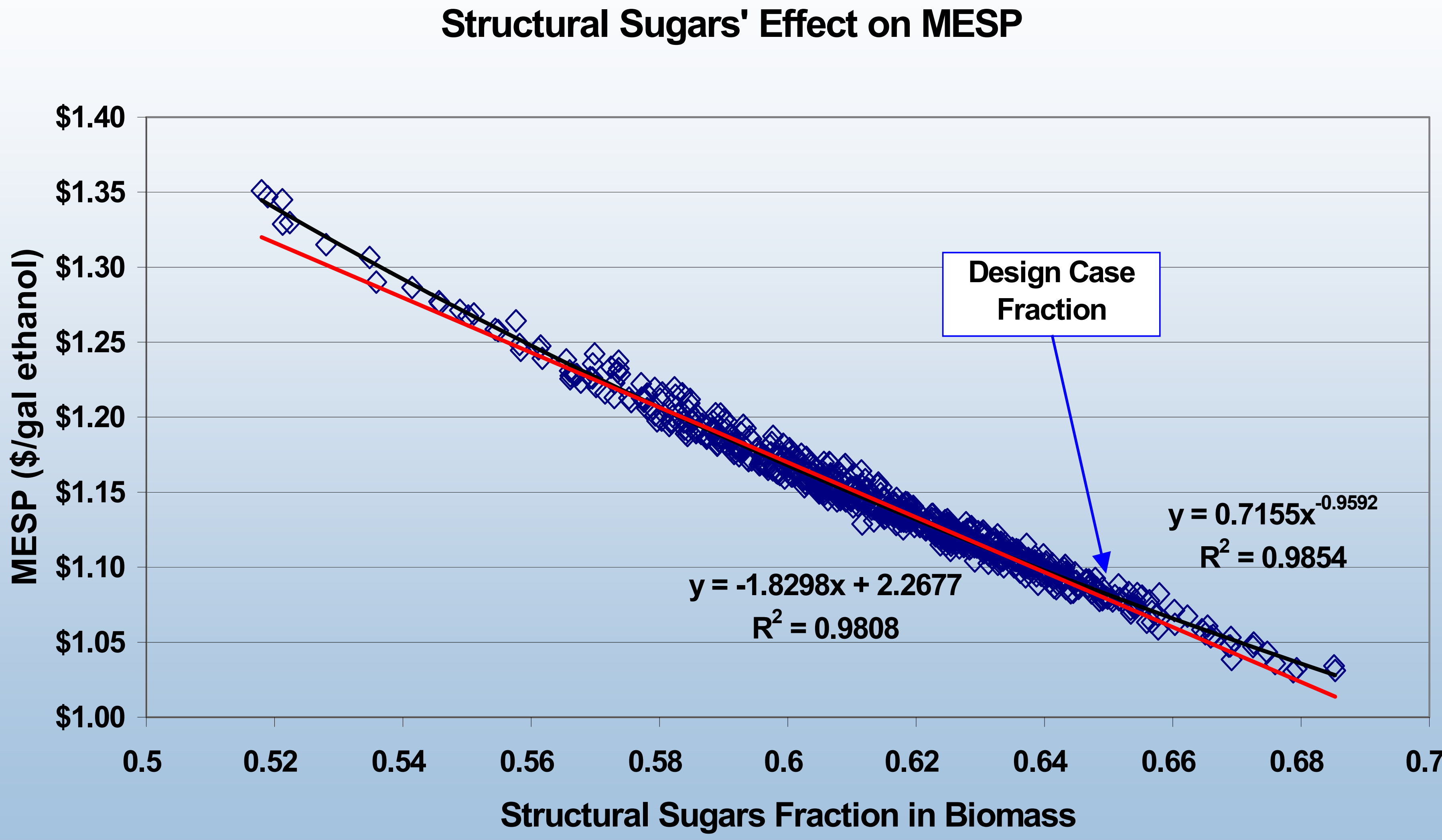
Minimum Ethanol Selling Price



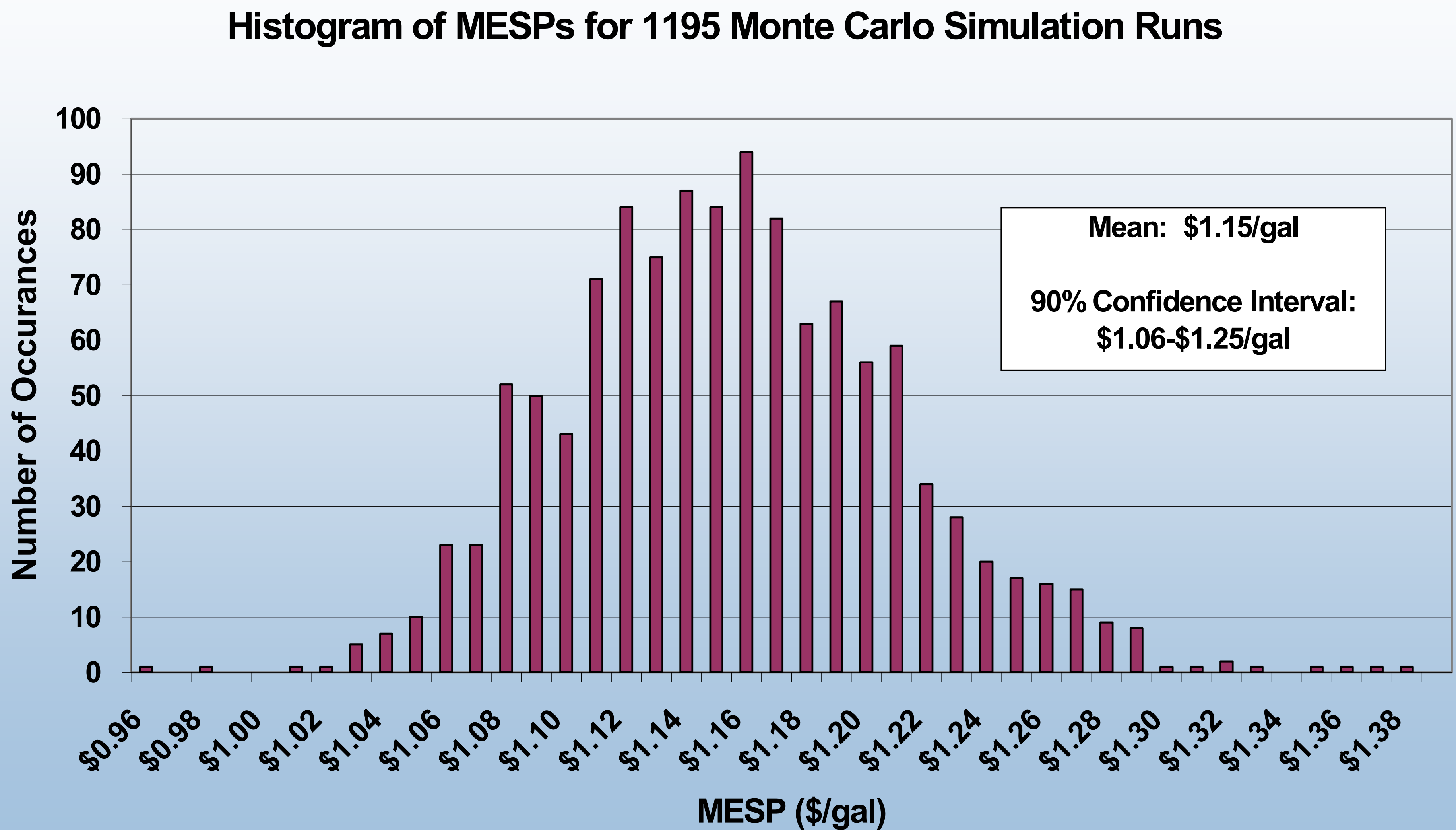
Yield is the Primary Driver



But Not the Only One



Monte Carlo Analysis Results



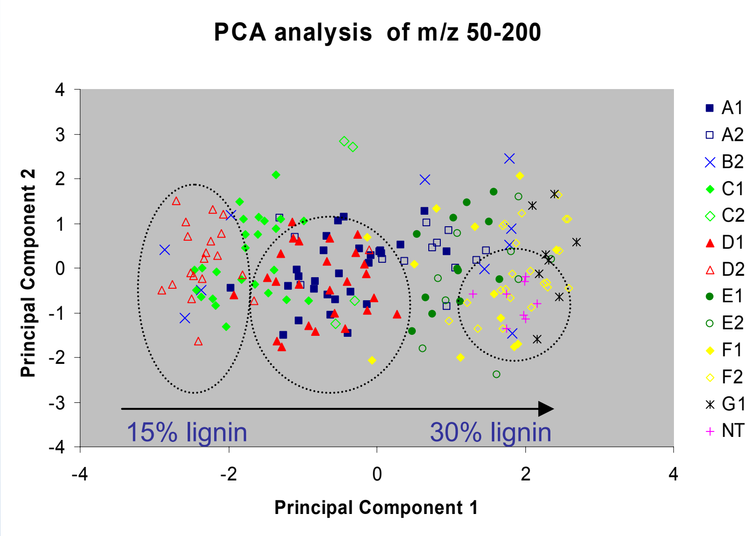
Objectives:

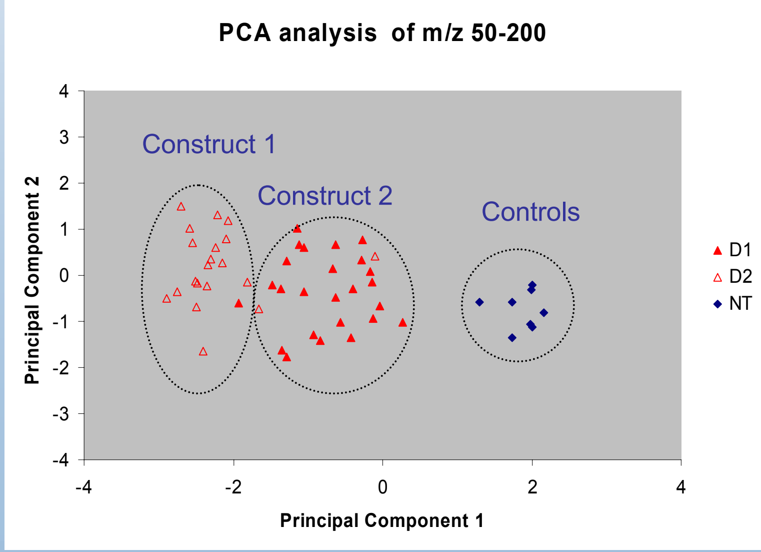
- To develop rapid, reliable and cost-effective methods for evaluation of cell wall components
    1. Pyrolysis Molecular Beam Mass Spectrometry (pyMBMS)
    2. Solid state ^{13}C-NMR
    3. NIR spectroscopy
- Use these methods to rapidly assess changes in chemical properties due to transgenic modification

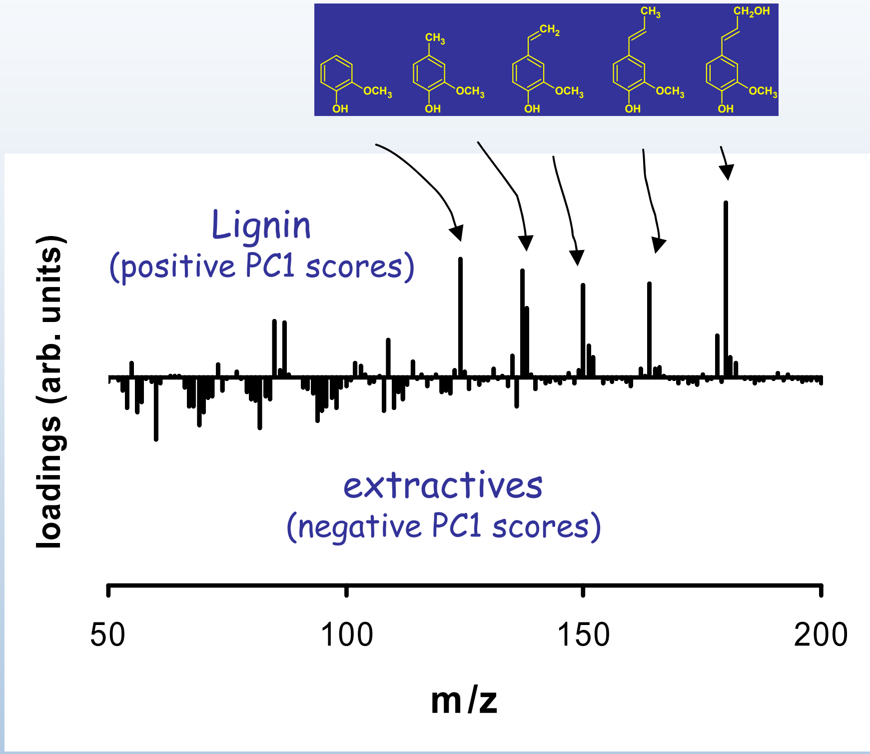
Our goal is to relate ultimately be genomic and metabolic information to unknown gene function

Genomes of plants (rice, maize, poplar) are complete –now we need to understand gene function

Rapid Evaluation of Wood Chemical Properties
Lignin Content of genetically-modified loblolly pines

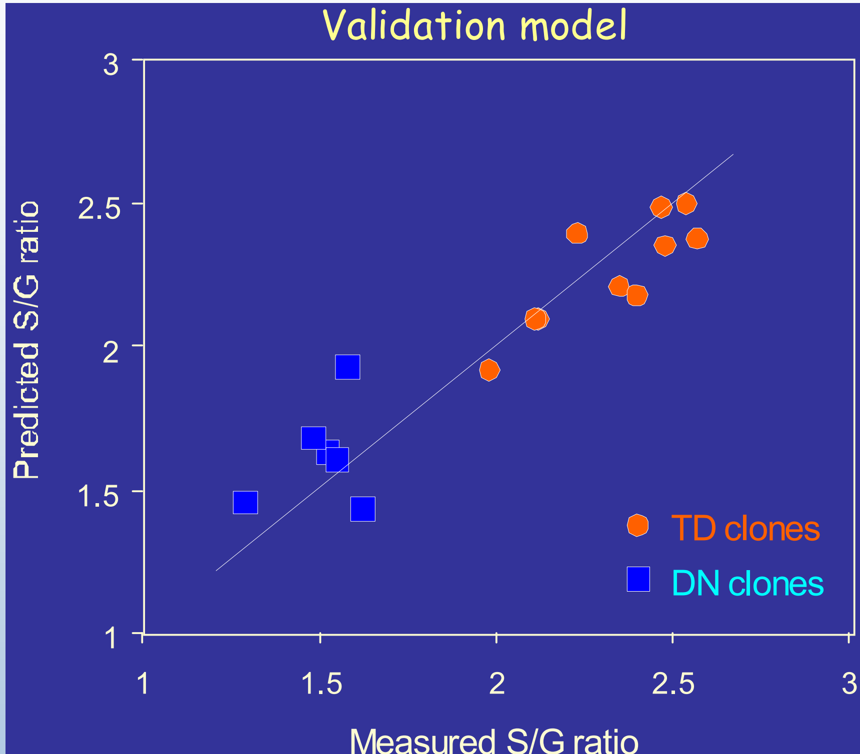


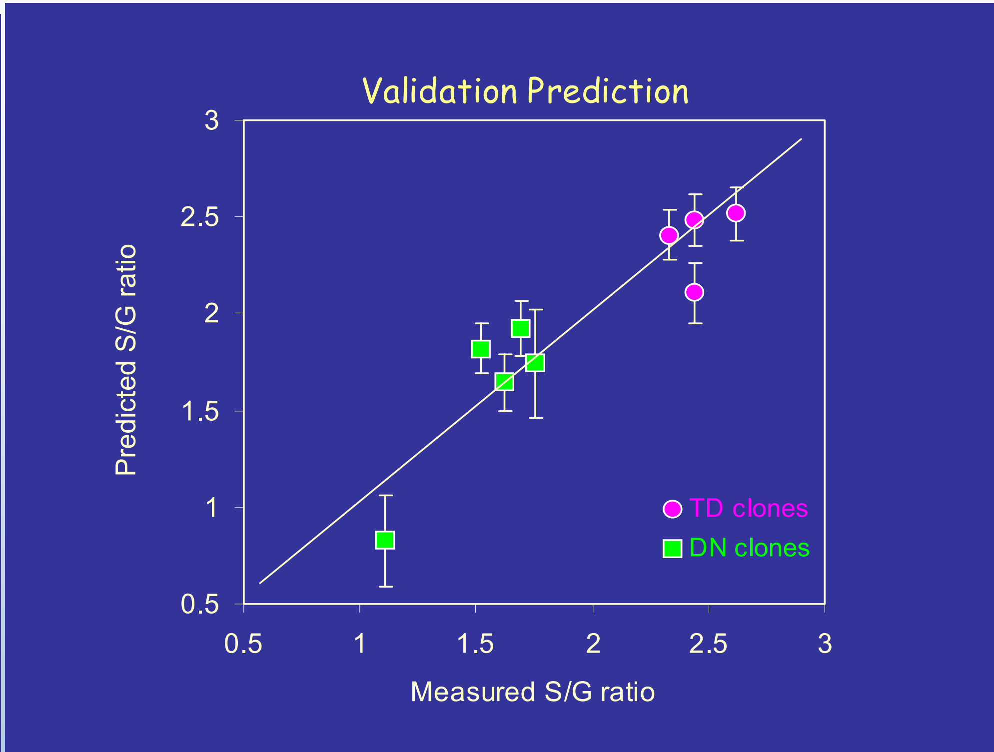




Rapid Evaluation of Wood Chemical Properties

pyMBMS Estimated S/G Ratios from PLS Modeling



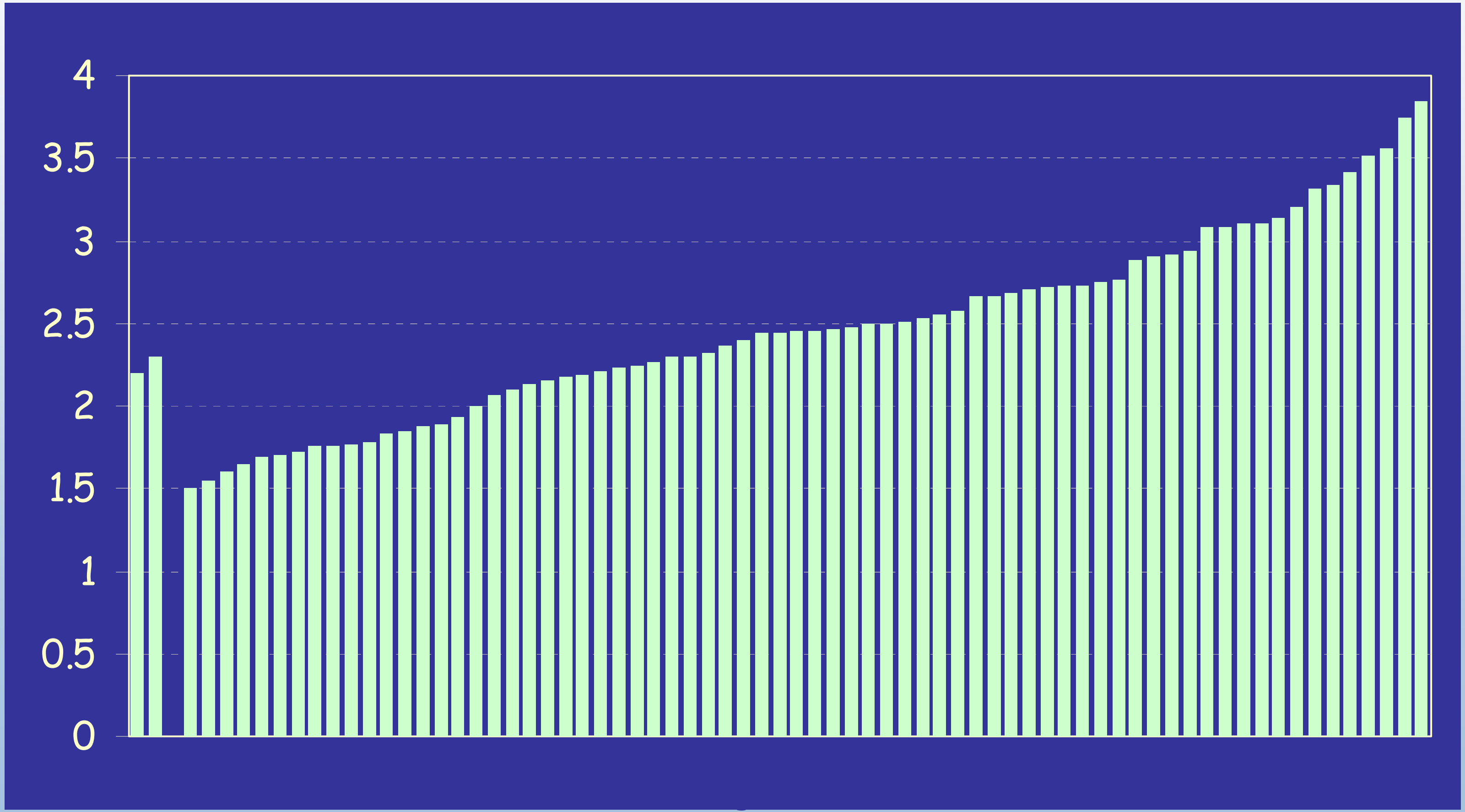


	# samples	RMSEP	RMSED	Correlation (r)
Validation model	17	0.17	-	0.93
Validation prediction	9	-	0.20	0.92
Full calibration model	26	0.16	-	0.94

Tsai, Chaing, Davis, 2004

Characterization of Transgenic *XP::CAld5H* Aspen

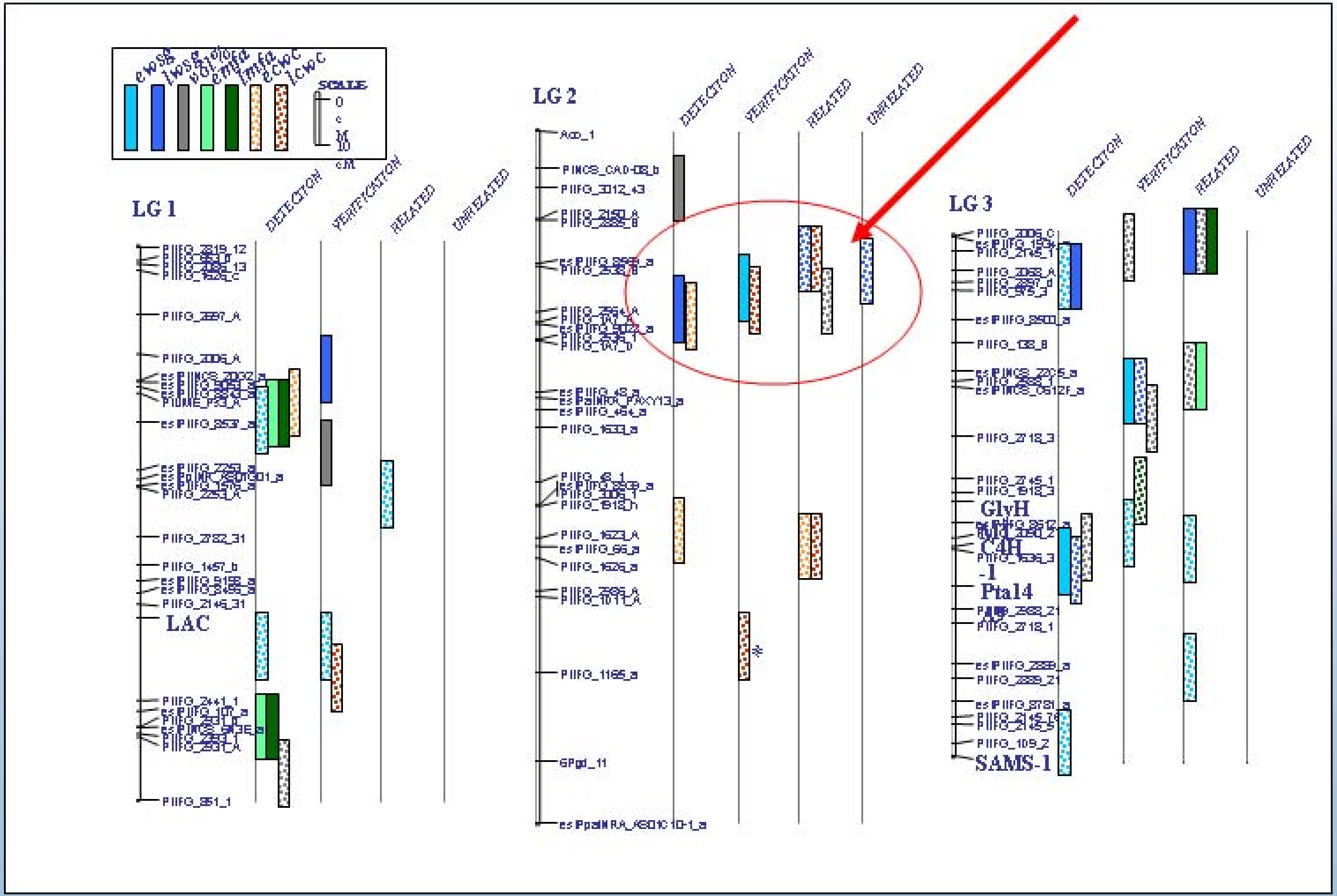
High throughput pyMBMS screening of transgenic wood samples



Tsai, Chaing, Davis, 2004

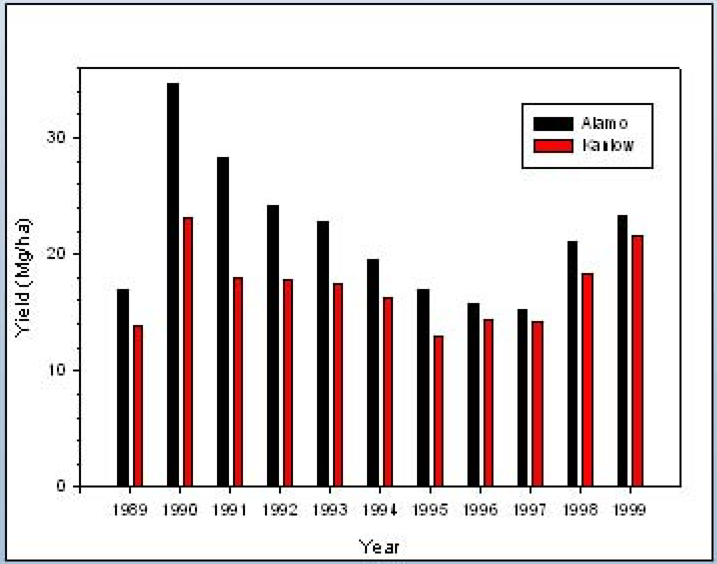
Correlations of Cell Wall Chemistry and Genetic Markers

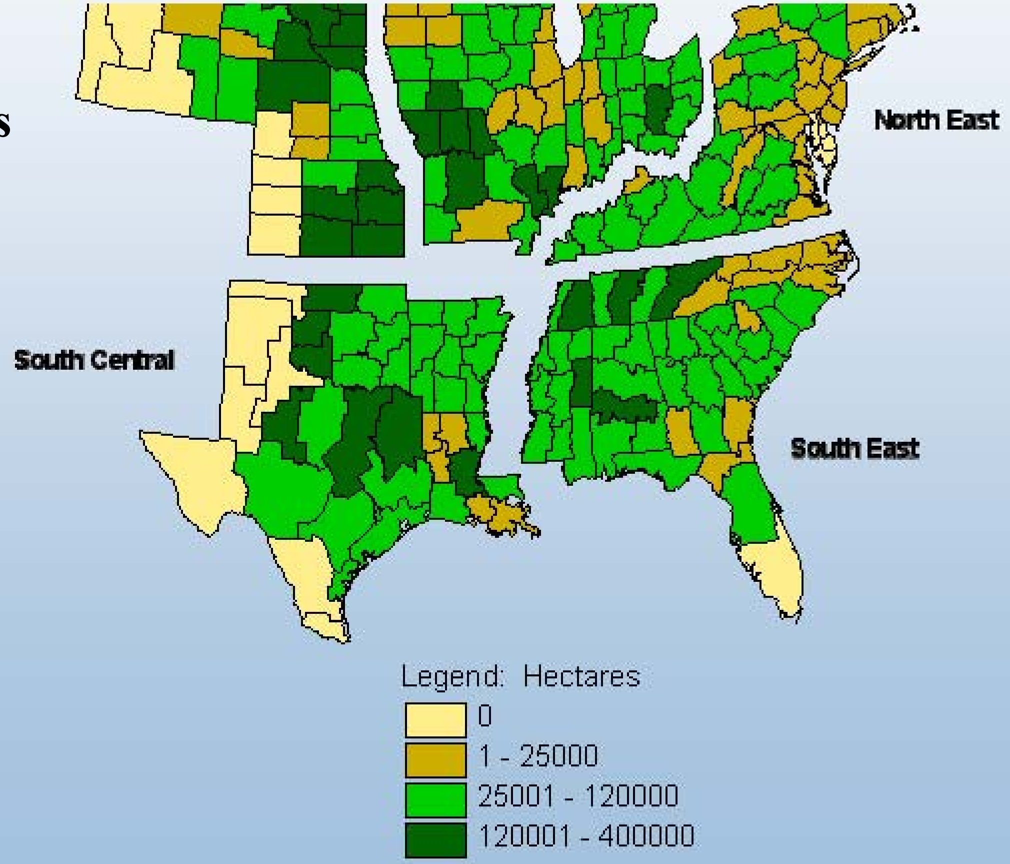
Quantitative trait loci for cell wall chemistry
In loblolly pine



Potential switchgrass production density within the U.S. by agricultural supply cells.

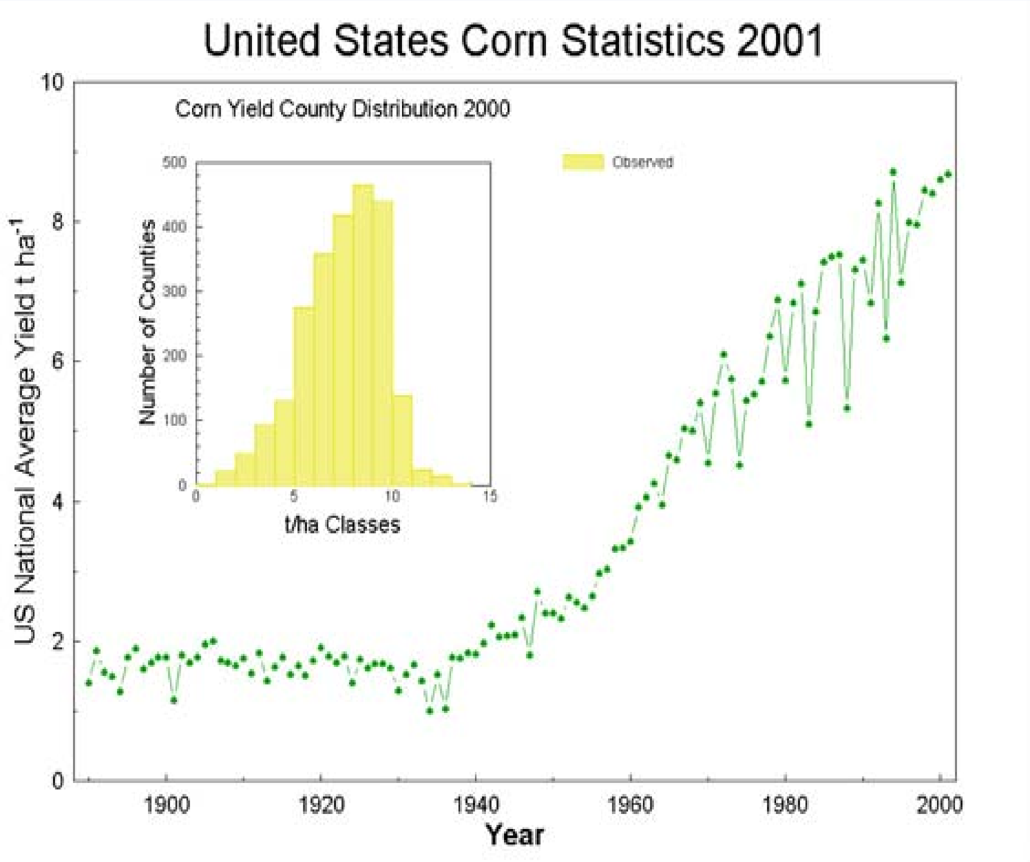
production density is based on
the distribution of counties
That convert from orginal
Agricultural crop to Switchgrass
At a price level of 44 $ Mg^{-1} .





Energy Crops Will Follow Agricultural Crop Developments

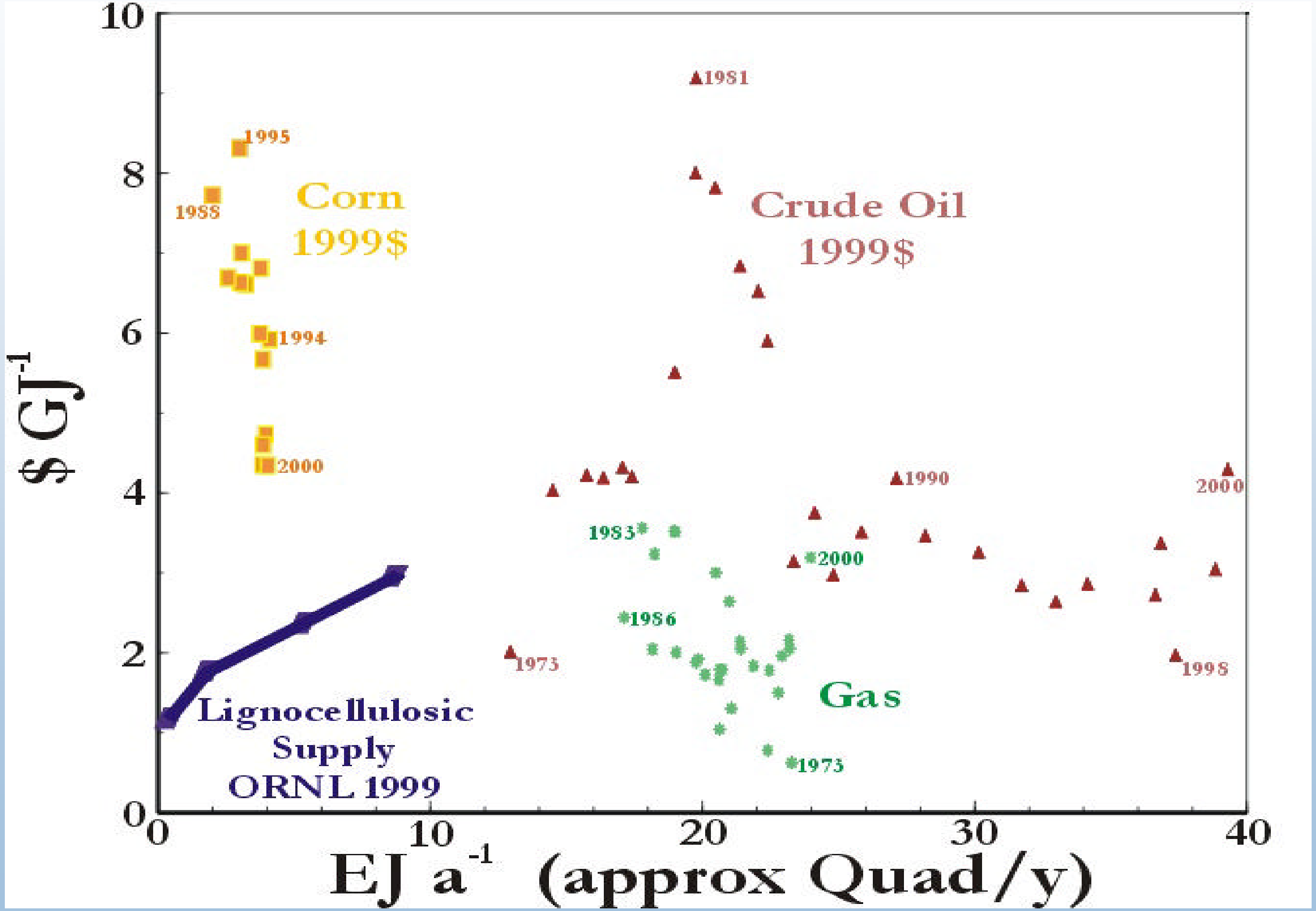
- Yield gains in Corn
  - Domestication of food crops
- Energy crops at an early stage
  - Plant selection
    - Herbaceous crops
    - Tree crops
  - Breeding with genomics assistance
  - Management (cultivation, nutrients, pests etc) needs large field trials
  - Domestication
    - Stumpy?



Yield Impact on an 80 km radius + representative outputs of fuels and electricity

Yield t/ha/y	500 t/d		2000 t/d		10,000 t/d	
3.3 [kha, %A]	44.5	2.2	178	8.8	891	44.3
9.0	16.3	0.8	65.3	3.3	327	16.3
18.0	8.2	0.3	32.7	1.6	163	8.13
Conversion	**Low**	**High**	**Low**	**High**	**Low**	**High**
Elect. MW	30.4	45.6	121	182	607	911
EtOH kL/d	166	187	663	746	3317	3732
FTL Bbl/d	453	538	1814	2154	9069	10770
H_2 t/d	6.5	7.7	25.9	30.8	130	154

Biomass Supplies in Context

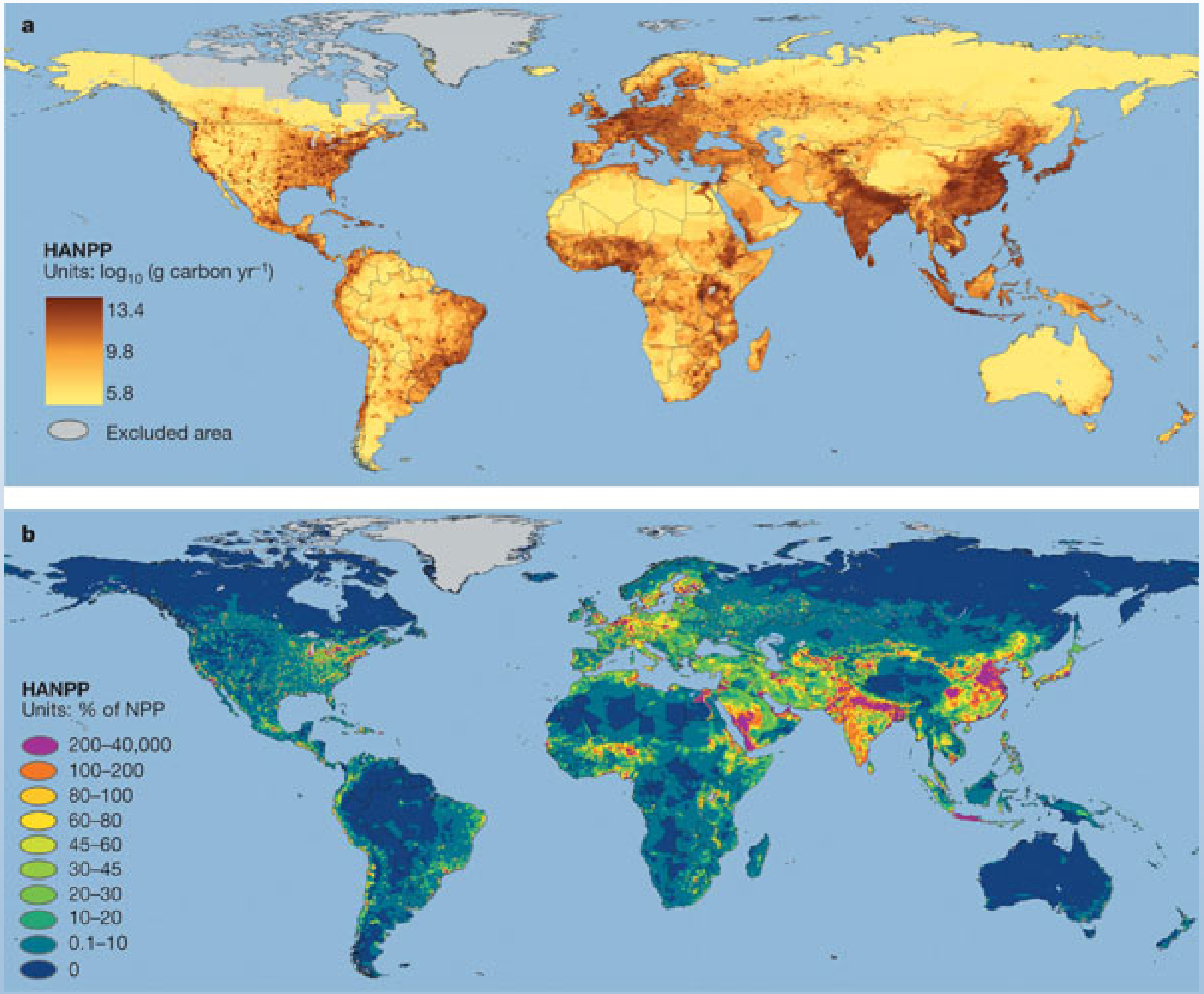


Nearly a Gigatonne

	Mtonnes	EJ
Base primary Energy from Biomass	194	3.30
Virtual primary energy from base at higher efficiency	94	1.60
ORNL 2020 Consensus less than 50$/t (42 Mio Acre Energy	450	7.60
Replacement of all feed corn by DDGS	140	2.38
Displaced Corn Exports (releases 16 Mio Acres)	100	1.70
Forest fire reduction strategy lower bound	40	0.68
Take half remaining Forest Annual Allowable Cut into Energ	49	0.83
Animal excreta (at 25% of all commercial feed) ignore forag	61	1.04
	1128	19.13

Global patterns in human consumption of net primary production

Marc L. Imhoff et Al.



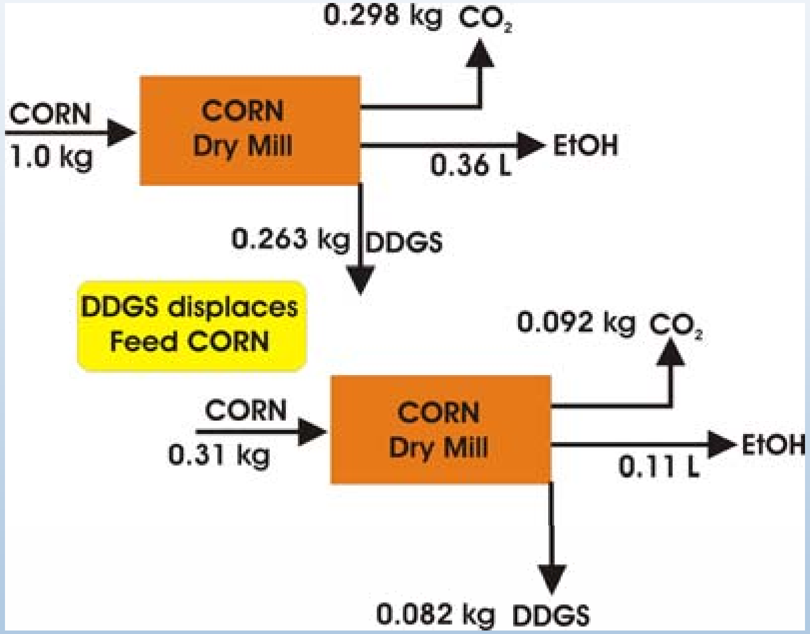
Nature 429, 870 - 873 (24 June 2004

Status Quo + Efficiency Gain

- **Current usage is about 3.3 EJ or 194 Mt**
  - **(EIA data)**
  - **Mainly lignocellulosics**
  - **low efficiency e.g. electricity @ <25%**
- Virtual tonnes to be gained through process change
  - cofiring to get effective 33 - 35% electricity
  - Retrofit kraft pulp mills and of the existing biopower facilities with gasification – near term technology
    - leading to combined cycle CHP
    - mixed F-T liquid fuels production
    - Raises efficiency to 35 - 45%
  - Net gain a factor of 1.4 leading to an effective 5.6 EJ
- **“virtual” resource increment 1.6 EJ or 94 Mt.**

Change Animal Feed to DDGS +fodder

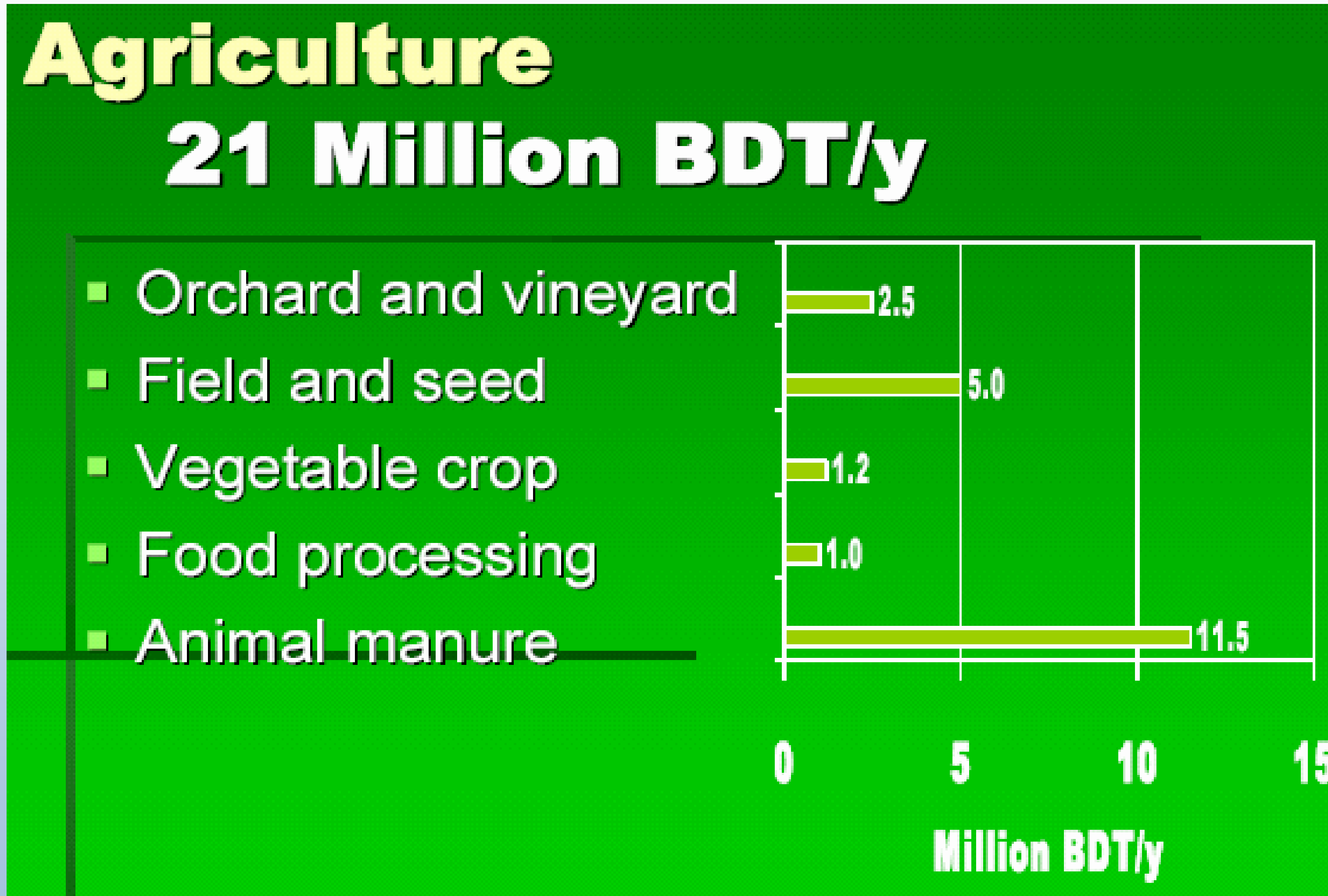
- 2001 Corn 9+ billion bu
- 5.85 billion bu to feed
- 0.74 billion bu to EtOH
  - 1.77 billion gal EtOH
- Swap DDGS for Corn
  - 0.33 billion bu corn added
  - 0.8 billion gal EtOH
- Adjust agriculure to take all corn feed for animals
  - 140 Mt equivalent addition
  - 2.38 EJ



Issue Animal Feed Efficiency Major missing component.

- 56% of corn harvest of 250 Mt is animal feed.
- Animal feed use ratios range from 6 for beef, to 1.5 Poultry, to 0.7 Milk
  - Afur = mass of feed/mass of animal
  - Further losses in preparing final “cuts”
  - Energy efficiency goes from 5% to 21% (milk)
- All input not metabolized becomes animal waste and results in the CAFO issues of BOD, N, P, and K as well as biodiversity, pesticide, and other issues.

Animal manure in the new CA resource assessment (see CBC forum



http://biomass.ucdavis.edu/pages/forum/forum.html

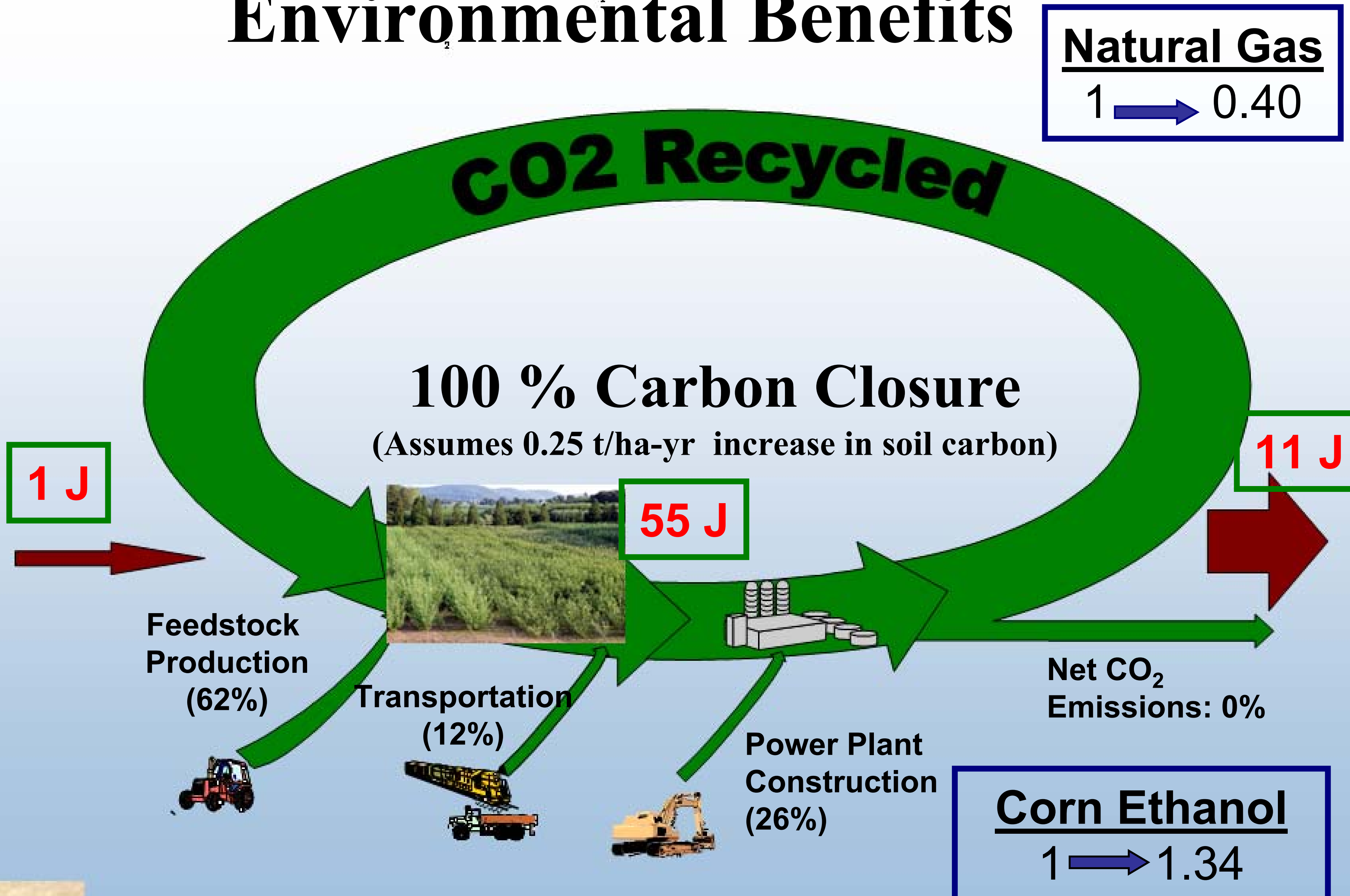
Additional Land for Energy Crops

- Conjecture – all corn exports terminated
  - Could be a function of WTO – Doha round
  - Corn harvest is 8.5 – 10.5 billion bu (1990s)
    - Exports around 2 billion bu – say 10%
      - 16 Mha released at 6.3 t/acre corn crop productivity
      - 51 Mt of kernel, 51 Mt of Stover
      - 1.7 EJ
  - Alternate scenarios would be
    - Oil self-sufficiency
    - Climate change – carbon offset strategy

Western Forest Fire Mitigation Strategy

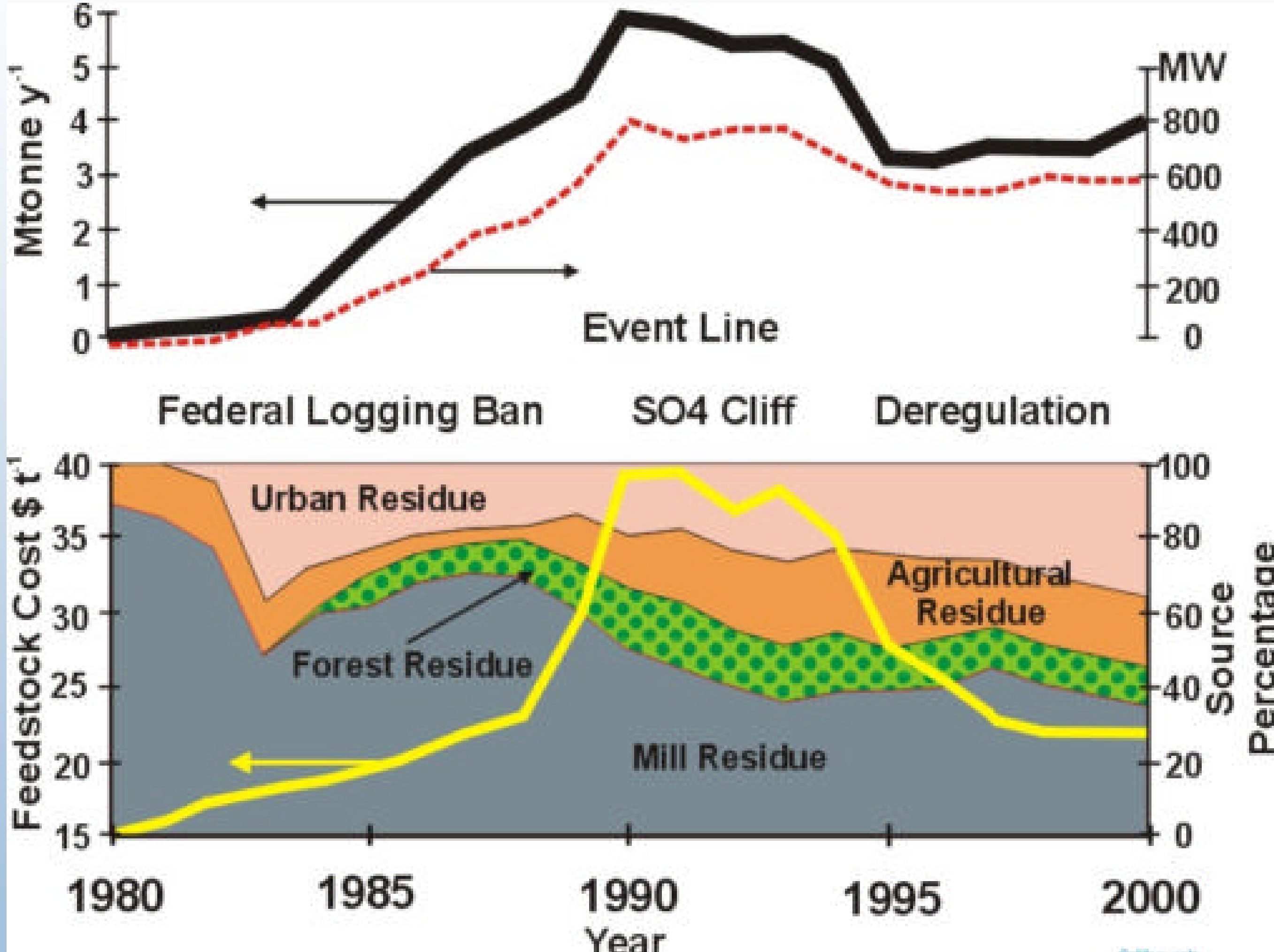
- Area needing treatment
  - 40 Mio acres - 160 Mio acres
  - Geometric mean = 80 Mio Acres
  - 20 year cycle
  - Biomass loading
    - range from 5 - 10 tonne per acre
    - additional fuels from previous fire damage and insect/pathogen kills having loadings between 50 and 100 t/acre.
    - Assume 10 t/acre.
- This is 40 Mt of biomass per year or 680 PJ.

Environmental Benefits

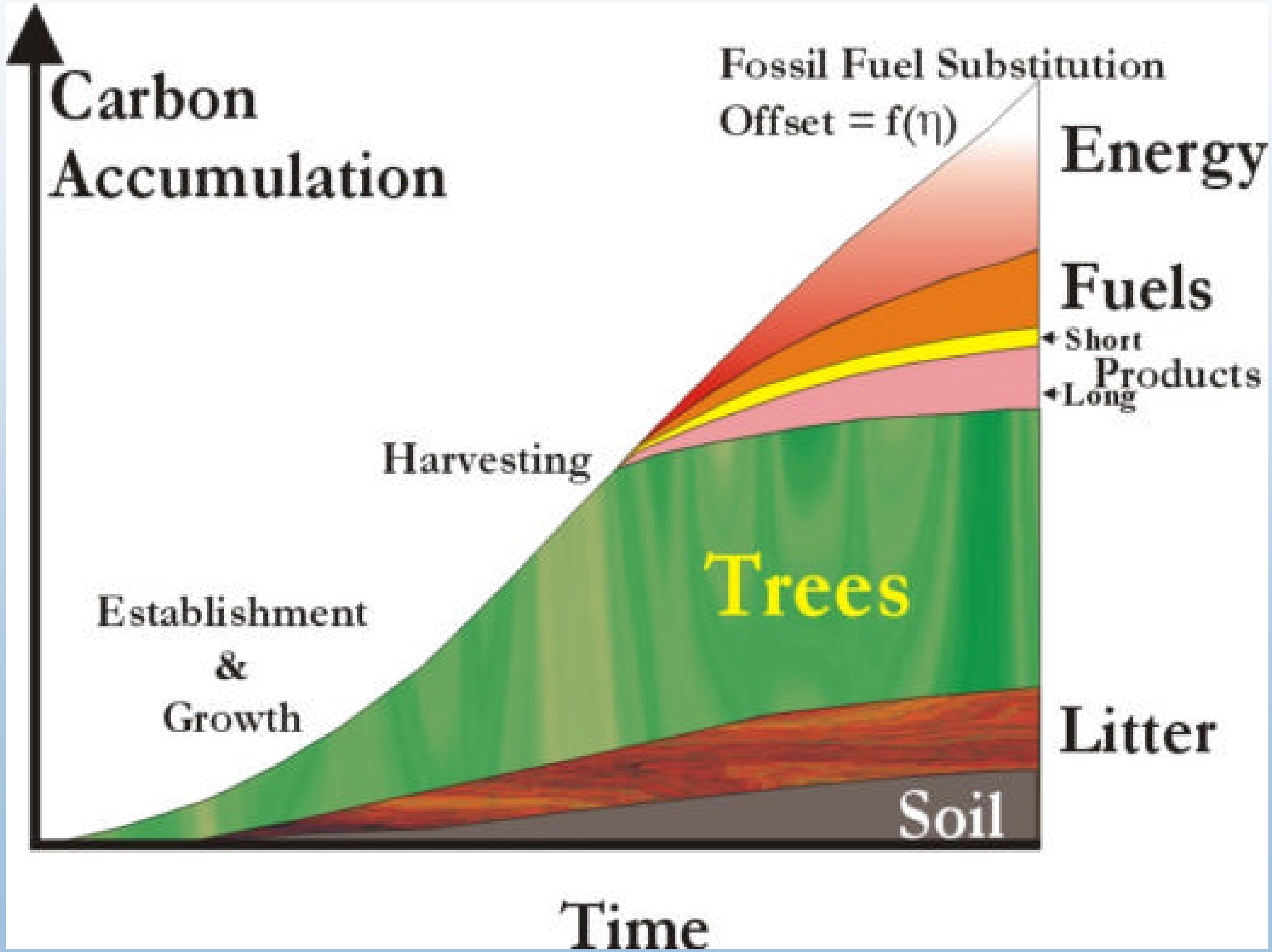


(Mann and Spath 1997, Heller et al. 2003)

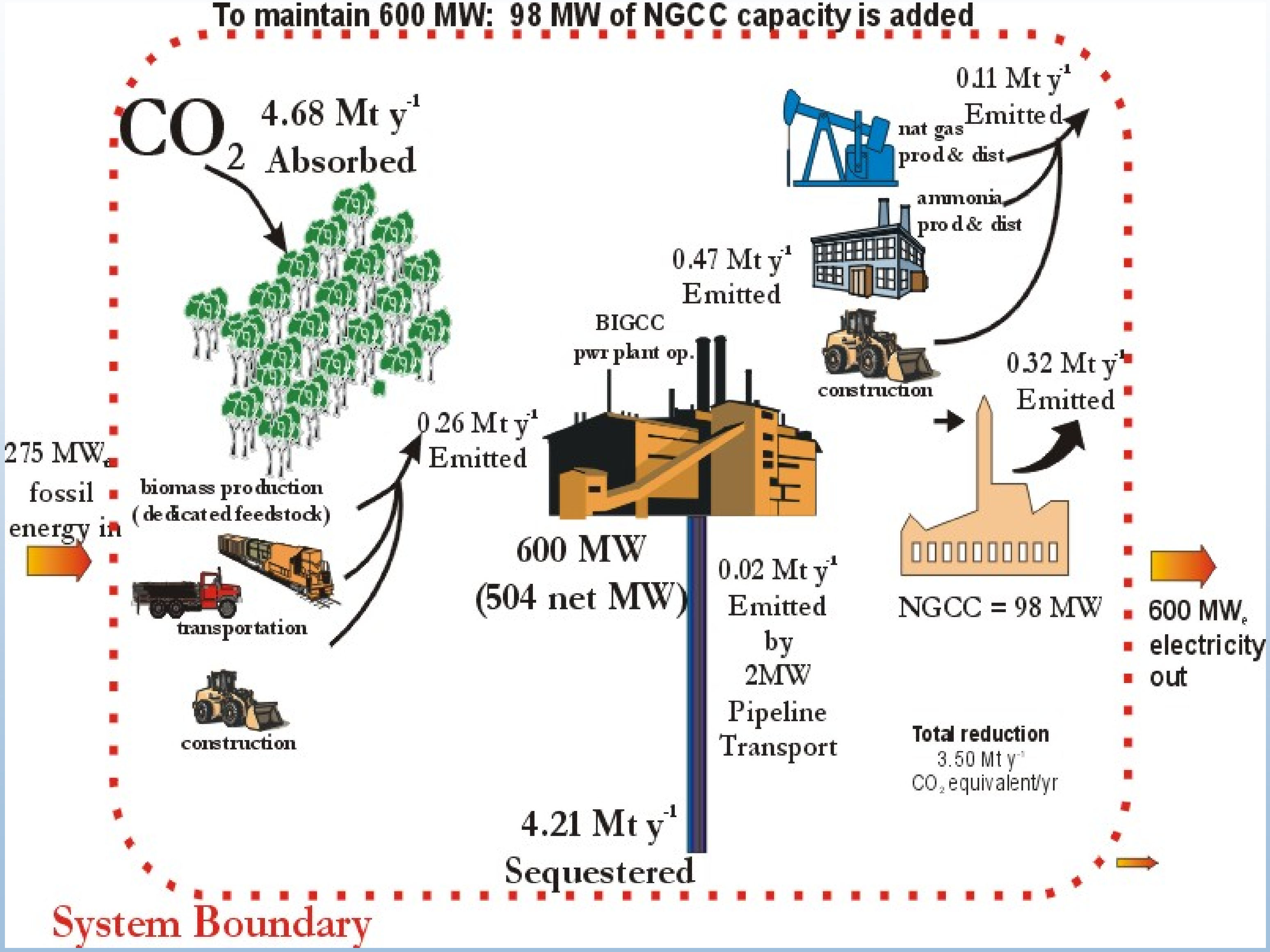
California's 20 years of BioPower



Beneficial Use of Carbon in Climate Mitigation



Biomass as a CO_2 Pump



Power Investment and GWP Effect of Sequestration vs Biomass